INFORMATION RETRIEVAL *I*NTERACTION

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PREFACE

> Books are not made to be believed, but to be subjected to inquiry.
> When we consider a book, we mustn't ask ourselves what it says but what it means...
>
> Umberto Eco: *The Name of the Rose, 1984, p. 316.*

Information retrieval covers the problems relating to the effective storage, access, and searching of information required by individuals. Currently, information is continuing to grow exponentially, diversifying into many forms and media. In this complex retrieval labyrinth there is a definite need for increased effort aimed at tailoring IR performance to user demands.

As Umberto Eco makes the learned Brother William point out in a moment of reflection visiting the library, the fundamental problem in information retrieval is how to bridge text and its potentiality for providing information to the individual reader.

As a contribution to these continuing efforts of harmony between information and user, the objective of this publication is to exhibit and enhance the theoretical and operative requirements necessary for effective performance, in particular of intermediaries, in information retrieval interaction.

For me this book represents a turning point. It covers more than ten years of progressive research and development work, inspired and supported by colleagues and friends in an international environment.

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During my work on this book I have received encouragement and crititicism from many colleagues. This has been extremely advantageous in forming and cultivating my concepts and ideas.

At this moment in particular my thoughts go to the late Professor Povl Timmermann whose visionary and innovative ideas about information retrieval research originally made me initiate this interesting exploration. Throughout the years they have often been my guide. Moreover, I want to express my appreciation of the adaptive way Professor Niels Bjørn-Andersen has provided me with his constructive support, which has been extremely beneficial during this period of creativity.

Finally, but most important, I want to thank my wife Irene Wormell, for her intellectual sustenance as well as for all the necessary logistics.

Peter Ingwersen, Ph.D., FLA

Copenhagen, 1992.

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INTRODUCTION

During recent years the author has evaluated several international projects, mainly originating from outside the core information retrieval (IR) environment. They have been concerned with the design and management of a variety of information systems ranging from knowledge-based applications to office automation configurations incorporating hypermedia and hypertext.

In common to such projects one may notice that the chosen retrieval components rather often constitute the weak elements in otherwise solid proposals. The suggested IR techniques and the indexing methods adhere to decade-old traditions, and the proposed interface functionalities may demonstrate a certain lack of functionality.

The IR field itself actually has produced sound and inspiring monographs and articles on IR theory, research and applications. However, the monographs are often not recently published, and for this reason alone difficult to obtain, or they demonstrate stand-alone approaches to IR research. Similarly, the journal articles and thematic reviews, indeed the IR research itself, seem to demonstrate a diversity of smaller communities, each one viewing IR from their own position.

In the author's view this somewhat blurred state of affairs in IR research, not really demonstrating a unifying framework for the field, is rather unfortunate. It results in a much smaller export ratio to related fields than deserved. The actual moment is ripe for a change: the technological advance has opened up for further *integration* of very different information sources and processes on a larger scale than hitherto observed in the entire information sector; also IT itself is not seen any more as *the* solution to the organisation, provision and use of information, not even in a multimedia context. The focus of attention has moved into the *qualitative* aspects of such processes. Intellectual access and use of information – structured as well as unstructured, administrative as well as textual and image-based – are the requirements asked for today.

This situation creates an optimal opportunity for IR, provided that the field overcomes its present state of theory fragmentation. Viewed as a variety of technical, intellectual and conceptual elements that actually should be fitting together, IR holds a strong potential for successful contributions to integrated systems design in future.

One of the reasons for the diversification into smaller self-contained IR research communities may be that information science as a discipline until recently has suffered from similar fragmentation problems. As an educator and developer of curriculum programs in library and information science (LIS) one is very often asked questions from colleagues, such as: 'What is information science really – what is its substance?' – or 'IR, that's simply a technique, isn't it?' Again, the fragmentation of the information landscape makes it rather cumbersome to provide simple and exhaustive answers, for instance to fellow colleagues or to researchers in other fields.

To illustrate the colourful cocktail of IR research and its findings one picks the basic ingredients, Salton and Sparck Jones, mixing them with van Rijsbergen, whereby mathematical-linguistic-logico positions in IR theory from the past and present are covered. Then, this can be mixed with some Belkin & Vickery and Ellis to provide a user-orientation in a socio-psychological context, and the cocktail is almost ready by adding pragmatic aspects from Croft or E. Fox. To give it a final touch one adds some drops of Blair (Wittgenstein) and the mandatory Winograd & Flores (Heidegger). This blend or other similar ones can be expected to be created in genuine LIS departments all over the world – not easily achieved outside our field, however.

In the attempt to compensate for the situation outlined above it is hoped that this publication will be of value to the IR community and in addition can be used in related fields, providing an integrated understanding of solutions to IR problems and contributing to the progress of the field.

Hence, the aims of the book are to establish a unifying scientific approach to IR – a synthesis based on the concept of IR interaction and the cognitive viewpoint; to present research and developments in the field of information retrieval based on a new categorisation; and to generate a consolidated framework of functional requirements for intermediary analysis and design – the Mediator Model. The introduction describes the aims and the organisation of the contents, including an outline of the original contributions to the field of IR presented in this book.

IR interaction is defined as the interactive communication processes that occur during the retrieval of information by involving *all* the major participants in IR, i.e. the user, the intermediary, and the IR system – the latter consisting of potential information mainly in the form of text and text representation as well as the IR system setting, e.g. database structures and retrieval techniques.

By applying the *cognitive viewpoint* as an epistemological foundation for IR research it becomes evident that one must take into account the variety of states of knowledge associated with these major participants in information retrieval interaction. Hence, IR interaction implies a cognitive holistic turn in IR research.

The book is organised with an initiating chapter describing the author's view of the emergence, scope and current state of information science as a scientific discipline. In order to correct the misunderstanding often observed in recent papers on the philosophical basis for AI and IR, namely that cognitivism (or 'hard AI') is identical to the cognitive viewpoint advocated by Brookes, Belkin and the author during a decade, Chapter 2 provides an original epistemological analysis of the matter.

The discussion leads to a necessary re-conception of the understanding of the *concept of information* for information science. This understanding of information is a further development of N. Belkin's concept based on his ASK hypothesis (1977, 1978) as well as G. Wersig's earlier work on the issue (1971, 1973). It incorporates cognitive analyses of B.C. Brookes' Fundamental Equation for Information Science. The innovation of the concept lies in its explicit emphasis of conditions for both the sender *and* the recipient as to when we may talk of information associated with conveyed messages.

Based on a tri-partite *categorisation of IR research*, originally developed by the author (1988), Chapters 3–7 explore the R&D discussions and major results hitherto presented in the field. This framework is established according to the foci of research in IR: the system components and processes (the *traditional* approach, Chapter 4); the human participants and their information requirements (the *user-oriented* approach, Chapter 5); the integration of all the interaction processes taking place in IR (the *cognitive* approach, Chapters 6–7).

Chapter 6 discusses selected cognitive IR models and the user and intermediary knowledge characteristics and categories fundamental to the understanding of IR interaction. These models and typologies are based on empirical investigations and incorporate a fundamental distinction between various forms of IR knowledge and conceptual knowledge. In addition, the chapter provides an analysis of problems related to evaluation and relevance assessment, incorporating cognitive task modelling and information quality issues. Chapter 7 exhibits the characteristics of cognitive IR research, in particular by discussing its integrative properties and the role of knowledge-based IR. The approach is seen as an attempt to produce a synthesis concerning IR theory and application.

A central point for discussion is the degree to which an intermediary mechanism ought to carry out intensive user modelling, followed up by knowledge-based inference of relevant search strategies and retrieval of information, or alternatively, ought to make user modelling and inference instruments for supporting the user and the development of his information need and underlying problem, interest or goal. This supportive role of the intermediary in knowledge-based IR interaction implies the deliberate use of the user's own intelligence and associative capability, integrated with a high degree of transparency and structured feedback from IR systems as well as adaptive functionalities in the mechanism. In particular, the notion of *structured feedback* from (remote) IR systems plays a significant role. The feedback supports the user *and* the intermediary in their definition and understanding of the actual requirement for information, the underlying purpose as well as the entire performance in IR interaction. In short, the philosophy underlying this latter approach is to allow the participants to adapt to one another during IR interaction by means of supportive user modelling, integrated with modelling of, and adaption to, (remote) IR systems and information sources.

The author's position on this issue is the adaptive and supportive approach.

Drawing upon the results presented earlier in the book, Chapter 8 presents and discusses the consolidated framework of functional requirements for intermediary mechanisms in multi-domain and IR environments – the *MEDIATOR Model*.

This model is a further development and extension of the Monstrat Model's 10 functions and 23 tasks (Belkin, Seeger and Wersig, 1983; Daniels, Brooks and Belkin, 1985; Belkin et al., 1987) into 13 functional requirements and 54 sub-functions. It integrates the Monstrat Model's profound user-orientation with generalised domain and task knowledge as well as IR system adaption.

The Mediator Model displays three levels of functionality: a cognitive task modelling level; a cognitive adaption level; an IR effectiveness level.

At the first level, Mediator stresses the importance of long-term domain, user and IR system models, intended to be generated via field study analysis. At the second level, two functions are active and adaptive short-term model builders, geared toward the actual user and his goal and information need *as well as* the exploration of the potentialities in the IR environment. At the third level, the remaining eight functions are viewed as integrated structures concerned with request model building, the mapping of user profiles, the matching of retrieval strategies, and structured conceptual feedback generation, as well as their processes internal to the mechanism. In particular, its three-level distinction between pre-structured models, actual model building and functional performance, as well as the introduction of the Feedback, the IR System Adaptor, and the Domain Model functions, are seen as improvements of intermediary mechanism design in an adaptive and supportive knowledge-based IR environment.

1. INFORMATION SCIENCE in CONTEXT

The aims of this chapter are to outline the scientific landscape in which information science operates and to analyse its core substance.

Since the seventies, a new generation of information professionals and scientists has emerged, including the congregation of interested colleagues in the East European countries. This generation has not been trained by the pioneers of the field and thus demonstrates a keen interest in its foundation and development. In addition, R&D work in the field during the eighties seems to indicate a profound shift from focussing on the technological aspects only to viewing the human sphere in *interaction* with information technology as the main focus in information transfer.

This has implications for the interpretation of the historical dimensions leading to the present state of art in information science as well as our understanding of the function of information in society. In particular, the IR area becomes affected.

The chapter demonstrates the development of information science through three stages: its emergence prior to the Second World War, its search for identity and alliances during the sixties and seventies, and its establishment as a discipline during the period 1977–80. The scope and present state of the discipline is discussed, pointing to five major areas of concern for information science as well as a number of fundamental sub-disciplines.

1.1 The emergence of information science

Information science is a young discipline. The earliest formal use of the term information science dates back to 1958 when the Institute of Information Scientists (IIS) was formed in the UK. The use of the term information scientist may have been intended to differentiate *information* scientists from *laboratory* scientists, since the main concern of the members was with management of scientific and technological information (Farradane, 1970). The members were scientists from various disciplines, often highly distinguished, who devoted themselves to organizing and providing scientific information to their fellow researchers in R&D institutes and industry. This fact provides us with important clues as to the understanding of the emergence and development of the discipline.

By naming themselves information scientists the members of IIS obviously wanted to stress the importance of the study of (scientific) information and the *processes* involved in *scientific communication*. Hereby their work was a continuation of previous scientific attempts to deal with problems of organisation, growth and dissemination of *recorded* knowledge, carried out before the Second World War. First H.E. Bliss (1929) published his studies in the organization of knowledge, preparatory to developing his bibliographic classification, carrying an introduction by the philosopher John Dewey.

A second area of intellectual investigation in documentation was opened up with the quantitative study of bibliographic production. S.C. Bradford (1934) first drew attention to a *bibliometric* distribution that has since been widely studied. Slightly earlier, other statistical means were applied to measure productivity in the form of publication ratios among scientists, by A.J. Lotka (1926), as well as to word frequencies in texts, by G.K. Zipf (1932).

Third, during the thirties, *social survey methods* were first applied to studying the use of books and libraries (Waples, 1932). The Indian mathematician S.R. Ranganathan initiated the formulation of his 'five laws of library science' at the same time. He himself stressed that the laws were not scientific generalizations but norms, principles, guides to good *practice:* 'every reader his book'; 'books are for use'; 'every book its reader'; 'save the time of the reader, and of the staff'; 'a library is a growing organism' (Ranganathan, 1957). The latter principles predict information management as an important aspect of information science. Recently, the original texts have been published in a collection edited by A.J. Meadows (1987).

However, the notions 'book' and 'practice' demonstrate the influence of the *current information technology* on the actual handling and accessing processes of recorded knowledge; the fact that all methods and theories applied to these processes, during approximately five millenia of clay-tablets and paper techniques, encouraged the development of principles and skills of a practical nature. Traditionally, the agents of these processes are librarians and documentalists. Their trade is librarianship (library science) and documentation. Exactly at a point where information technology went through a fundamental change with the application of computer technology, information science was born. Librarians typically organize, analyse and provide access for all kinds of users to the contents of documents. Documentalists do the same thing, but tend to exploit a wider variety of media and formats and traditionally limit their work to scientific-technical documents and users.

Information scientists emerge mainly from the ranks of documentalists, being aware of the wider aspects of scientific investigation of the processes of generation, representation, management, retrieval and use of information.

It is the increasing problems of both physical and intellectual access to a very fast growing body of (scientific) knowledge in the form of the 'document explosion' since 1945, coupled with the increase in the complexity of problem-solving at all levels throughout the world and the upportunities offered by the new information technology, that gave birth to the discipline. Ranganathan's principle 'every reader his book' is forced to change, carrying more qualitative and specific dimensions to it: 'the most *relevant* piece of text to each reader'. The problem of relevance will never cease to be under investigation.

During two decades, 1958–1977, information scientists as well as researchers from other fields attempted to establish the core areas of research in information science and to define its boundaries to other disciplines. They were helped by the fact that other related fields, such as information theory, the systems sciences, and computer science, emerged a short while earlier or at the same time. This may seem a paradox since these post-war disciplines all have in common the handling of data in various ways by the same new technologies. Do they leave space for information science? At a first glance independence seemed difficult. By evolving from something apparently so trivial and hence not a science, i.e. the practice of documents and the skills involved, information science gave (and still gives) cause for discussion. In contrast to the other new fields, information science did *not* emerge from a well-established major scientific domain, such as electrical engineering, mathematics or physics. This lack of an independent theoretical foundation is outlined by B.C. Brookes in his introduction to the Popperian ontology and its relevance to information science. He states (Brookes, 1980, p. 125):

> Theoretical information science hardly yet exists. I discern scattered bits of theory, some neat in themselves but which resist integration into coherence. So there are no common assumptions, implicit or explicit, which can be regarded as its theoretical foundations. Information science operates busily on an ocean of commonsense practical applications, which increasingly involve the computer... and on commonsense views of language, of communication, of knowledge and information. Computer science is in little better state.

On the other hand, in most of the new computer dependent fields debates concerning the nature of 'information', 'knowledge' and epistemological issues, as well as the intermingling of theories and between fields, took place during the same period (Machlup, 1983). These discussions support an *interdisciplinary approach* to all the fields, which again provide a framework for an understanding of the theoretical and applied objectives and limits. The situation from 1958 and onwards can be illustrated by Figure 1.1.

The problems for information science with respect to its borderlines with other disciplines are mainly found at interdisciplinary level, less often at the disciplinary level. A core dimension noticed by other fields, is that information science actually is the one which studies large *text* entities containing preserved knowledge – with more interest in solving theoretical and practical problems of its organisation and representation in systems for later retrieval and use on demand, than in the technology itself; the latter being the means to the former. Consequently, important areas of common interest between information science and other disciplines may develop. One may state that its *applied level* contributes to its recognition.

More important, during this period information science starts producing research results and theories of its own. These are often of high relevance to other disciplines, for example to computer technology applications in medicine, engineering and chemistry, in relation to text indexing, retrieval and transfer. The research efforts are carried out by applying, some may argue by leaning heavily on, a number of established theories from various fields.

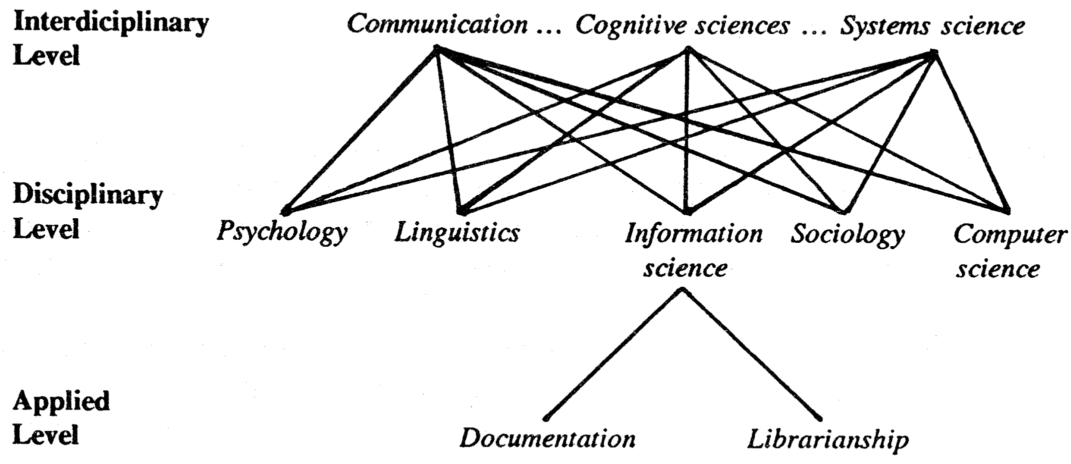


Fig. 1.1. Information science viewed as one of several sciences of information (Ingwersen, 1991, p. 3).

For instance, the behavioural sciences contribute on the methodological side, and provide a framework for understanding the use of information in the context of society (Wersig and Neveling, 1975). Slightly earlier, G. Wersig applies communication theory to model knowledge transfer (Wersig, 1971). Partly based on communication, partly on statistics, E. Garfield explores and develops his quite unique theories and techniques of citation analysis in science (1979). Linguistic theories concerning syntactics and semantics provide the bases for theories and developments of text representation and retrieval (Spark Jones and Key, 1973). C.E. Shannon and W. Weaver's quantitative formulation for the coding and transmission of signals in a message (1949) have a recognized influence on theory construction. R. Fairthorne applies it, as well as communication theory, to producing his classical Notification Hexagon consisting of the interacting elements in an information system (1967), later further developed by C.N. Mooers (1974). Its mathematical possibilities and relevance to information transfer are analysed by M.F. Lynch (1976) and reviewed by P. Zunde and J. Gehl, who concentrate on problems of aggregation of information, information decay, information measures and performance criteria, and extension of information theory (Zunde and Gehl, 1979).

These approaches to theory generation, although rather scattered and not providing one coherent foundation, support the recognition on a disciplinary level of the nature of information science and its relations to the interdisciplinary fields mentioned.

This analysis leads to the observation that *library science* is a special R&D activity within information science. Library science, in the author's opinion, is concerned with the information processes that takes place *in libraries*. As such, library science becomes a special case where for instance information retrieval is called reference work and information management is named library management. A similar special case is 'documentation theory', which mainly is concerned with generation, transfer and use of scientific information.

1.1.1 Alliances, identity or exaggeration?

As can be expected, the flow of theories and viewpoints between the disciplines, horizontally on the disciplinary level and vertically from the interdisciplinary level downwards, Figure 1.1, creates various attempts during the period for information science to merge with other fields – or to be merged – in order to manifest a stronger scientific position.

Two major trends are visible: a vertical move towards *communication,* and an attempt horizontally to merge with *computer science* into *informatics.*

Communication theory, which concerns itself with the role of language, the nature of movement and other means for conveying meaning, is perceived by some scientists not only to contribute to, but to be the meta theory for information science. This has been suggested and discussed by T. Saracevic (1970b) and W. Goffman (1970a).

This trend does seem logical in the sense that transfer of recorded knowledge involves transactions and communication of meaning between humans, and between humans and systems containing conceptual structures. Fairthorne's notation scheme, Wersig's socio-communicative views, research on scientific communication and several approaches to information retrieval and indexing demonstrate this allegiance to communication. The relation seems reinforced during the eighties under the influences of a more user-oriented research view and the cognitive sciences (see Chapters 5–7). As a consequence, some US faculties of communication and library and information science did merge from the mid-eighties. Basically, the allegiance mainly suits the researchers studying the behaviour and interaction of the human elements of transfer of recorded knowledge.

In contrast, some information scientists, mainly focussing on systems and information technology applications in relation to knowledge organisation and transfer, demonstrate a drive towards *computer science*. H. Wellisch analyses this possibility (1972) and S. Gorn actually advocates a merger between the two fields into *informatics* (1983). This notion is close but not identical to the French 'informatique' which in general designates a wider range of information technology applications, with emphasis on their technological aspects. Very recently, Zhang Yuexiao discusses the definitions of information science*s* (1988). In his analysis he states that there is "not any real justification to replace computer science by information science or informatics", although he allows for a renaming into 'computer and information science'(p. 483–485). In fact, it might have been logical to join the information retrieval, representation and management elements from information science with the software and AI sides of computer science – from a computer science point of view. Certain computer departments in universities in the

UK and USA do incorporate the information retrieval elements in their curriculum and R&D activities, e.g. Amherst, Massachusetts and Glasgow.

The problems for information science would in such a case consist of maintaining its behavioural aspects and links to practice in librarianship and documentation. However, the subfields mentioned from the two disciplines increasingly cross and cooperate, e.g. as shown by Wormell (1988) and in several ESPRIT projects. For example, the KIRA (Esprit 1117) and the SIMPR projects (Esprit 2083), involving AI theories for knowledge-based systems design. The KIRA project (Knowledge-based Information Retrieval Assistant) builds on theories for intermediary performance as well as thesaurus theory; SIMPR (Structured Information Management: Processing and Retrieval) takes advantage of classification and indexing theories originating from information retrieval. The close ties between computer science and information science are mainly demonstrated by the Informatics conferences starting in 1973, and the initiation in 1978 of the yearly ACM-SIGIR conferences.

'Informatics' unfortunately also carries another meaning to it. Since 1968 the Russian key-figure in documentation, A.I. Mikhailov designates 'informatics' to the study of scientific communication and knowledge transfer, i.e. to contain the theoretical level of documentation alone (Mikhailov, Chernyi & Giliarevskii, 1968). The effect on East European information science research is notorious.

The most coherent proposal for a merger with computer science, as well as other interdisciplinary fields, originates from the Swedish systems scientist K. Samuelson, who created a department based on these principles. Cybernetics, including communication and control, and the systems sciences are seen as closely related metadisciplines to informatics, which incorporates the information and computer sciences as well as information technology. The well argued suggestion is called SCI, Systems, Cybernetics, Informatics (1976).

In parallel to the described trend to relate closer to various fields or theories, the major part of the information science community attempts to solve the identity problem on its own. Several research conference proceedings as well as individually published studies contain titles that mirror the striving for consensus in information science, for instance: *Information science: discipline or disappearance?* (Goffman, 1970b); *Information Science: Search for Identity* (Debons, 1974); *Perspectives of Information Science* (Debons and Cameron, 1975); *The fundamental problem of information science* (Brookes, 1975); *Information: one label, several bottles* (Fairthorne, 1975); *Towards a true information science* (Farradane, 1976).

Aside from demonstrating a struggle and a wish for coherence, the cited titles cover a great number of valuable research works and contributions to the understanding of specific elements of the generation, organisation, retrieval, transfer and use of information.

In retrospective, however, this fragmentation and specificity of research interests and scientific background knowledge among scientists in reality produced effective obstacles for the achievement of an independent consensus at a disciplinary level. Debons, a leading US information scientist during the entire period may have sensed this problem very accurately when in 1977 at the 2nd IRFIS Conference in

Copenhagen he analyses the situation. In a critical essay he proposes *informatology* as a metascience (Debons, 1980), based on suggestions put forward already (Otten & Debons, 1970).

He operates within two frames of reference concerned with issues of the foundation for information science. The first frame regards information science as that body of understanding which concerns, for instance, scientific flow of knowledge or the organisation of information for better retrieval. To Debons this formulation looks for practical (applied) solutions, mostly through the establishment of new procedures and technologies.

The second frame of reference regards information science as directed towards an understanding of the 'phenomenon of information' – discovering fundamental laws governing the experience. He calls this the 'science of information' – *informatology*. He defines it "as a process leading to a 'state of the information system'". In practice, these two frames are intermingled although their respective foundations may not be the same. Debons continues to propose a step toward resolving the confusion, also stated by Brookes previously, by viewing information science as based on three primary factors concerned with the functioning of organisms: "the creation or generation of states (*generation*); the ability to use states in the accomplishment of tasks (*utilization*); the capacity to convey to other organisms indications of our states (transfer or *communication*)".

To Debons the human organism is a model information system, and he strongly advocates that it is the *interrelationship and interaction* of the three functional factors that constitutes the system, not the three separately conceived.

In the author's opinion, he *exaggerates* the goals and value of information science. When he attempts to lift it up above the disciplinary level, Figure 1.1, he encompasses other established disciplines. Debons' first frame of reference refers clearly to the applied level. His second reference frame, however, places the 'phenomenon of information', i.e. the object of information science, at a level already occupied by other disciplines and theories that are concerned with "information as a process leading to a state of the information system". For example, the cognitive sciences, the systems sciences, and epistemology. There does not seem to be any space nor any justification for 'informatology' (or science of information) at this level. The author finds it more fruitful to apply Debons' proposal to information science at a *disciplinary level* only. The condition for a disciplinary level is to accept an understanding of the phenomenon of information, as well as the interaction of the three functional factors constituting the system, in the context of *recorded and demanded knowledge* or experience.

The reason for analysing Debons' view rather carefully is that, with this minor modification or reinterpretation, it does point towards a common understanding and provides an identity for the field. It makes visible what information science ought to study concerning the generation, communication, and utilization of information (see Figure 1.3). Also, it justifies from which other disciplines (dealing *separately* with the three fundamental factors) the field may receive or provide valuable contributions: psychology, linguistics, communication, computer science, etc. (see Figure 1.2).

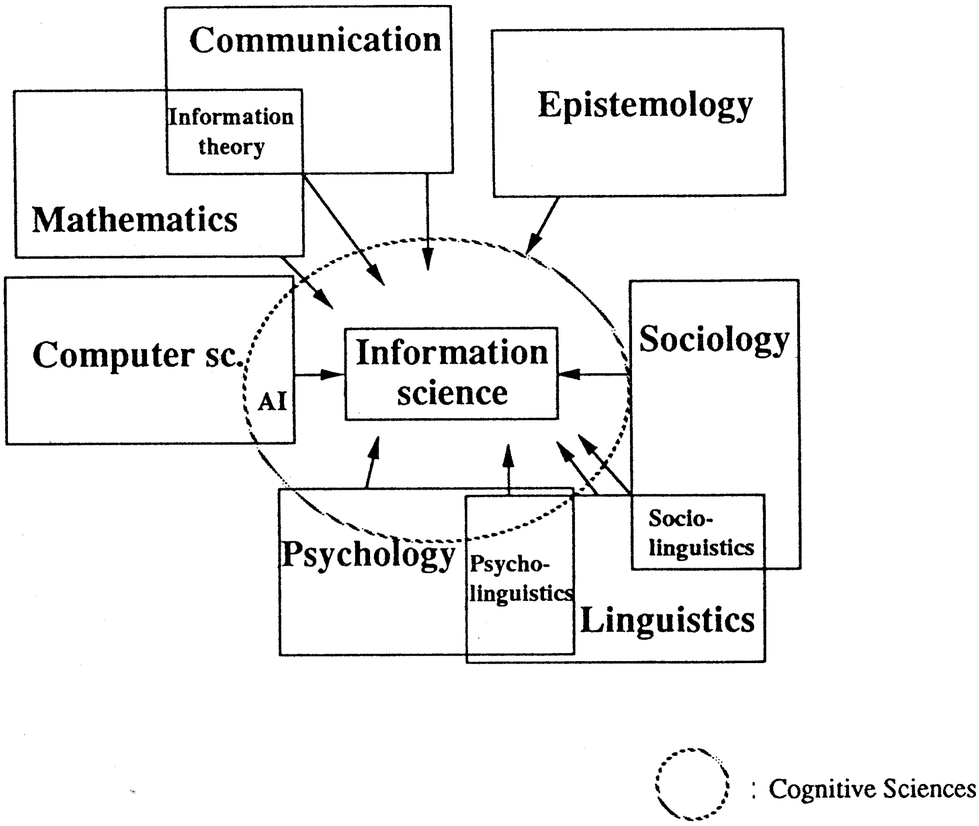


Figure 1.2. Scientific disciplines influencing (->) information science (Ingwersen, 1991, p. 7).

This tendency to *exaggeration* has made information science more vulnerable than the fragmented and incoherent theory developments mentioned earlier – and it still is. For example, it makes little sense when B.C. and A. Vickery very recently widen the scope of information science to be "the scientific study of the communication of information in society" (Vickery and Vickery, 1987, p. 11), thereby postulating an umbrella-role, for example covering mass-communication, which it cannot fulfil.

Previously, Figure 1.2 has been published in slightly different versions (Ingwersen, 1984c, p. 84; 1986, p. 208). The arrows designate from where information science mainly obtains inspiration and theoretical input as discussed above. Disciplines like AI, becoming influential in the eighties, are included. The reason for exhibiting the cognitive sciences, understood as the intersection of linguistics, artificial intelligence (AI) and psychology, as stated by Shank and Abelson (1977), is to stress a direct influence of these fields mainly in relation to information retrieval (IR). In this respect information science can be seen basically as a cognitive science, as outlined in Chapter 2.3.

1.1.2 The turning-point 1977–1980

What seems to emerge between 1977 and 1980 is an identity, and the scope which was searched for during previous decades. Several significant publications on the matter provide profound analyses that indicate the turning-point for information science as a discipline. It becomes more mature and well-defined.

The first to appear was an analysis of the understanding and use of the concept of information as seen from an information science point of view, by Belkin (1978). As can be expected, the interpretation and different use of the concept is rather scattered, depending on the scientific viewpoint and the research area in which the concept is applied. The paper suggests a scheme for the requirements of an information concept for information science. In addition, it outlines a framework for information science which is discussed and elaborated in greater detail in Chapter 1.2.

A second publication is the introduction of Karl Popper's ontology as well as the cognitive view, by B.C. Brookes (1977, 1980). Brookes argues that Popper's 'Three-world model' provides a framework for understanding the nature of information science. In the Three-world model World 1 consists of nature and human, physical artefacts, such as buildings, books or computers. World 2 is 'subjective knowledge' within the mind of individuals, and World 3 consists of 'objective knowledge', i.e. recorded knowledge, mainly generated by humans (Popper, 1973). The difference between World 1 and World 3 can be illustrated by the sentence "this was really a heavy book". Brookes claims that the world of 'Objective knowledge' in particular, World 3, consists of characteristics of major interest to information science. He relates the cognitive view to the Popperian model in order to admit the concept of information and its relation to subjective and objective knowledge. Brookes' contribution – his Fundamental Equation – is discussed in Chapter 2.2.1.

In his view, the "theoretical task [for information scientists] is to study the interactions between Worlds 2 and 3, to describe and explain them if they can and so to help in organizing knowledge rather than documents for more effective use" (Brookes, 1980, p. 128). This observation is obviously correct and useful in the sense that it may explain what information science and librarianship *should do*, but have not yet achieved. It is with respect to knowledge accessibility, acquisition and representation that Popper's ideas seem most relevant. Concerning these aspects Ingwersen points out (1984c, p. 89–90):

> ... that hitherto we have seldom succeeded in allowing for *direct intellectual access* to the potential information or objective knowledge. Most information retrieval systems point to documents or parts of documents, giving *physical access*, or at maximum *bibliographic access* via representations, to World 1 objects, i.e. to artefacts like articles, books, reports, etc. placed in remote archives.

This so-called 'tri-partite conception of accessibility' and the serious problems involved are further discussed by Wormell (1985).

Brookes goes further in using the Popperian ontology and rather exaggerates the potentiality of information science, by claiming World 3 forms "a territory which no other discipline has already claimed" (1980, p. 128). For many decades, however, both in psychology, history, history of science, and literature, researchers have analysed World 3 and the specific phenomena of interaction with World 2. Its uniqueness for information science lies in the theoretical way of *organizing* the world of objective knowledge *for intellectual use* by World 2 – well aware that World 3 almost totally originates from individual, subjective knowledge. Brookes' interpretation of Popper's ontology gave rise to discussions among information scientists for several years (Neil, 1982, 1987).

Another valuable and well known interdisciplinary contribution, mainly from information scientists themselves, is the proceedings, edited by A. Debons, of the Third NATO Advanced Study Institute held at Crete 1978. The title: *Information Science in Action: System Design* (Debons, 1983) indicated the progress achieved to that date in the field. The conference viewed information systems and their design in a context of information science. There were essentially four major focal points: 1. examination of the understanding of the meaning when talking about the design of information systems; 2. ideas about the knowledge about information systems and their effectiveness; 3. examination of the systems' impact on people and institutions, e.g. regarding issues of privacy, copyright, censorship; 4. problems concerned with the human resources that are critical to the design of information systems. The collection of papers includes reports of empirical investigations pointing to future developments up through the eighties. At the same time, but with a wider scope, C. B. Griffith edited a collection of key-papers in information science (1980).

Finally, the author wishes to point to a significant publication, edited by F. Machlup and U. Mansfield (1983): *The Study of Information*. It provides in-depth interdisciplinary analyses of approaches to information, as well as foci and scopes with respect to various disciplines, such as cognitive science, computer science, library and information science, linguistics, cybernetics, information theory and systems theory. Further, each discipline attempts to relate to information science. This highly communicatively designed publication, produced from 1980–83, put information science into perspective.

The publication includes two contributions on what information science should do and should not do, by J.H. Shera and M. Kochen, both highly distinguished scholars. Shera's analyses focus on information science from a librarian's point of view, whilst Kochen discusses the field from an information science approach. Shera advocates the establishment of a scientific discipline mainly dealing with 'symbolic interaction', also called social interaction. He outlines a scenario in which information science operates at theory-level, seen as the theoretical foundation to librarianship (Shera, 1983). He looks upon the field with the *social role* of the library profession clearly in mind, denouncing both the "marking and parking" syndrome typical of document retrieval in libraries, and the computer and data-driven nature of information science in that period. However, Shera does not talk about 'information'. His idealistic view, or hope for the survival of the profession, is hardly operational – more associated with library science than information science.

Kochen, from his point of view, is more straightforward. He finds it fruitless to engage in semantic disputes over when the discipline of information is not epistemology, psychology, biopsychology, and so forth. "What matters is that investigators who identify with the information disciplines, formulate researchable problems and make discoveries, and contribute insights that clarify the nature and dynamics of information and knowledge" (Kochen, 1983, p. 371). Like Shera, he disapproves of librarianship, library science, documentation, and information science understood in a narrow sense, i.e. focussing solely on written records and the physical documents and processes. From a more psychological view he defines information science in a broader sense, concerned with information, knowledge, and understanding, i.e. essentially with *meaning* as perceived by a receiving mind and embedded in such physical entities. This definition by Kochen leads directly to the present conception of information science.

1.2 The scope of information science

The formulation of the problem and the phenomena which information science hopes to solve is of basic significance. It is through the establishment of this problem that the precise area of systematic, scientific investigation can be specified, and the assumptions governing that activity developed. Drawing upon previous statements by Wersig and Neveling (1975) and Belkin and Robertson (1976), N. Belkin formulates that problem to be (1977, p. 22; 1978, p. 58):

> Facilitating the effective communication of desired information between human generator and human user.

In the author's opinion, the crucial notion is *desired information*. We are here explicitly speaking of a purposeful wish for information. The emphasis is on the quality of the interaction between generators and users of recorded information.

The statement implies the study of the users' *reasons* for acquiring information, recorded in systems of various kinds, the processes of *providing* desired information to users *qualitatively*, and the processes of *use* and *further generation* of information. We are dealing with *all kinds* of users as well as knowledge levels in these processes which basically involve all types of means of recording. Hence, information science is limited to studying specific phenomena of communication, not all communicative processes, as suggested by Debons and Vickery. Neither should it concentrate solely on the means of recording and communication, e.g. IT applications.

Belkin outlines five areas of concern for information science, based on the problem statement formulated above (Belkin, 1978, p. 58):

1. [transfer of] information in human, cognitive communication systems;
2. the idea of desired information;
3. the effectiveness of information [systems] and information transfer;
4. the relationship between information and generator;
5. the relationship between information and user.

Ingwersen (1986) points to these five major areas of study, and develops their substantial impact on information science (Ingwersen and Wormell, 1990b):

The first area deals mainly with formal and informal transfer of information, for instance scientific communication or information flow within institutions. The second area seeks to understand the generation and development of needs for information, within society, among specific groupings of people or individually. It is the nature of and reasons for desired information which is the focus of attention, *those reasons being problem solving or fulfilment of cultural, affective* or *factual goals*.

The third area studies methods and technologies that may improve the performance and quality of information in information systems. Further, this area is concerned with the development of theories and ways to ease the transfer processes of information between generators and users. The area is closely linked to the fourth area of concern, which deals with generated knowledge and forms of its analysis and representation in (text) information systems. Here we find theoretical and empirical approaches to indexing and classification, as well as theories concerned with measurements and distribution of R&D production. The fifth major area of study has its focus on the relevance, use and value of information.

Belkin's problem formulation and areas for study are attractive, exactly because of the explicit statement of foci for present and future research, demonstrating both sociological and individual psychological dimensions. Debon's suggestions of interactivity between generation, communication and use of 'states', Kochen's psychological dimensions, as well as Shera's much more social approach to information interaction and transfer, are made operational.

The five major areas, illustrated in the two-dimensional Figure 1.3, may be studied separately or in combinations. In the author's opinion they form a framework within which information science develops important sub-disciplines:

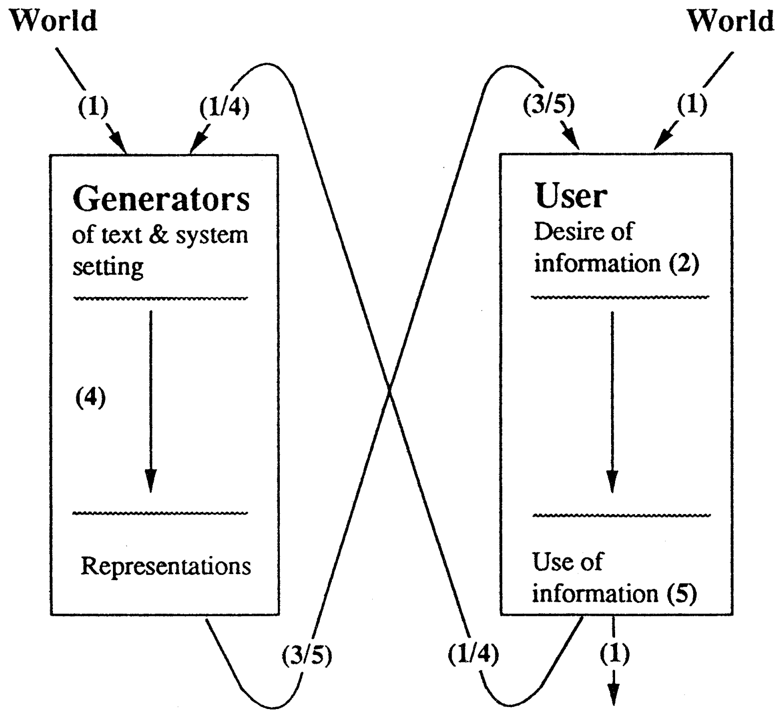
Informetrics, i.e. the quantitative study of the processes of communication of information, such as co-citation, is mainly concerned with the areas 1 and 4.

Information management, incl. evaluation and quality of textual and other media-based IR systems, is basically concerned with the areas 3 and 4.

Information (retrieval) systems design which belongs to areas 3, 4 and 5.

Information retrieval interaction is fundamentally concerned with the study of information processes in areas 2 through 5.

In Figure 1.3 the arrows refer to relations between or within generators and user associated with the processing and transfer of information. Numbers in brackets refer to the study areas described above. To the left there are the generators of texts, graphics, etc. as well as system features and their forms of representation in (text) information systems (4), e.g. in the form of database structures and indexing terms. To the right the user may transform his desire for information (2) into a solution and use (5) by obtaining relevant information from a system (3/5). Below to the right the user may decide to become generator and communicate something to the world (1), for example as author of text or as painter (1/4). The user and generators may communicate with, and be influenced by, the world around them (1).



text = text, graphics, pictures, sound

Fig. 1.3. Major areas of study in information science. Numbers in () refer to Belkin's (1978) five areas (Ingwersen, 1991, p. 10).

In the author's opinion, research and development work carried out since the end of the seventies in information science demonstrates the validity and actuality of these major study areas as well as the outlined sub-disciplines.

1.2.1 Current and future trends

To summarize what seems to form the kernel around which information science currently is developing and to demonstrate its new challenges one may point to certain trends, made visible during the very recent CoLIS Conference on Conceptions of Library and Information Science (Vakkari and Cronin, 1992). They are all in strong connection to a more *human-driven approach* to information transfer, i.e. the transfer processes associated with the right hand side, Figure 1.3. A strong overall trend seems characterised by a move of research interest from access-orientation towards accessibility *and* use of stored knowledge or knowledge representations (Ingwersen, 1992a). This may reinforce a rather *holistic* approach to all the areas (Figure 1.3), in particular the areas 1, 3 and 5, i.e. communication, management, and evaluation as well as the use of information.

The scope of information science expands at present into society, and the discipline is reaching a critical junction in its evolution, in line with related fields such as computer science, informatics and the cognitive sciences (Saracevic, 1992). This move thus entails far more interest in the use and transformation of information into knowledge on both individual and societal level, i.e. the areas 1 and 5. A similar trend concerns the quatitative study of the communication of information, *informetrics*, recently defined as the meta-concept for bibliometrics and scientometrics (Tague-Sutcliffe, 1992). A central challenge ahead is to develop and make operational new *qualitative evaluation criteria*. This implies the replacement, or at least the extension, of relevance and utility measures by functional use, quality and value, selectivity and strategic importance assessments, i.e. the areas 3 and 5.

The following specific trends are demonstrated in the information science R&D literature as well as during recent conferences and workshops, pointing to the future:

1. a strong requirement for making the technology fit the human;
2. a shift from focussing on 'documents' and 'text' to aiming at 'information' transformed into 'knowledge' by means of all conceivable media;
3. a shift from understanding information as purely scientific towards 'information' understood in a broad sense, as a critical and strategic asset to individuals and society;

The background for these changes is recently argued by Wersig, by introducing the concept of *knowledge for action* by actors (Wersig, 1992). Knowledge for action followes up Saracevic' historical views (1992) and signifies an extension of Wersig's earlier work on the reasons for desire for information (1971, 1973), further discussed in Chapter 2.2.

By placing the focus on the human sphere (trend 1) as well as on transformations of information into knowledge via a multitude of media (trend 2), and dealing with a wide range of information types (trend 3), the *intentionality* behind and use of such transformations becomes increasingly important to information science. Evidently, reasons for a desire for information cannot be confined to problem solving issues alone, but must eventually also involve cultural and emotional goals or interests.

These trends walk hand in hand with the focus on 'accessibility *and* use'. This issue clearly involves research areas that are under rapid development at present: the problems related to technology applications; and the modelling of information processing and retrieval. The challenge is that one now has to deal with such rational matters in a holistic fashion, achieving a realistic balance between techonology and man. Hence, the recent expression *information ecology* (Capurro, 1992).

This highly complex scenario introduces a certain degree of *uncertainty*. It becomes profoundly uncertain which elements of various types of information inherent in a both highly structured and virtually unstructured world of stored potential information may be of most strategic importance to often vaguely defined intentionality underlying often ill-defined requests for information – information that finally is supposed to become usable knowledge in a given situation. Hence, present and future theory building in information science will have to introduce and consider ways that allow for *cognitive dynamics of information* in order to meet the demands from a rapidly changing world of actors.

2. The COGNITIVE VIEW and INFORMATION

In the previous chapter we have demonstrated that the goal of information science is to facilitate the effective communication of desired information between human generator and human user. As such, information science is one of the disciplines dealing with aspects of human *cognition* and cognitive processes. There are, however, several epistemological and philosopical ways to approach such processes. To name the most important ones, the processes may be viewed from a standpoint of pragmatism, rationalism, hermeneutics and phenomenology, materialism, or approached with a language-philosophical, cognitivistic or cognitive point of view in mind.

This chapter will consider and analyse the *cognitive viewpoint*, separating it in a epistemological sense from cognitivism and relating it briefly to hermeneutics.

Probably, the viewpoint was coined for the first time by M. De Mey in his epistemological framework presented at the multidisciplinary Workshop on the Cognitive Viewpoint, in Ghent (1977). There are several reasons for examining this in greater detail in relation to information science.

First, it provides a much deeper insight into the nature of the interactive IR processes than hitherto obtained by means of pragmatic or other views. With the view in mind one is capable of explaining the benefits as well as the limitations of R&D in IR up to its present state and beyond. Thus, it may serve as a framework for future research, leading to improvements, refinements and re-definitions in the field.

Secondly, the view leads to a profound understanding of the concept of information for information science, further discussed in Chapter 2.2.

Third, it underlies a substantial portion of several authors' contributions to R&D in information science and IR in particular. B.C. Brookes (1977) is the first to refer explicitly to the viewpoint. N. Belkin also applies the view (1978), recently reviewing its impact on several authors' work in IR (1990). However, none of these scholars actually discusses its objectives, scope and relation to other epistemological approaches. Influenced by the results of the Workshop, Ingwersen explicitly explores the viewpoint in several contributions to IR (1982, 1984a, 1986), but fails to provide a sufficiently detailed discussion of its perspectives and limitations.

De Mey formulates its central point to be:

> *that any processing of information, whether perceptual or symbolic, is mediated by a system of categories or concepts which, for the information processing device, are a model of his [its] world* (De Mey, 1977, p. xvi–xvii; 1980, p. 48)

– whether the device is a human being or a machine. The viewpoint's epistemological and paradigmatic nature is further discussed by De Mey (1982), in which he outlines the pioneering work in cognitive science by J. Piaget on the development of cognitive structures since 1929. In 1984 De Mey stresses that there might be "a greater variety of such structures than expected by Piaget, and they might be more connected to domains of knowledge than to psychological development or age [of the individual]" (1984, p. 108).

According to the view, the 'world model', often also named 'world knowledge', 'schemata' (Bartlett, 1932), or 'image' (Boulding, 1971) consists of *knowledge structures*, or *cognitive structures*, which are "determined by the individual *and* its social/collective experiences, education, etc." (Ingwersen, 1982, p. 168). The connections and influences between individual and social/organisational knowledge, goals and purpose, preferences, as well as expectations and experiences, are thus reflected in this cognitive view of information science and IR.

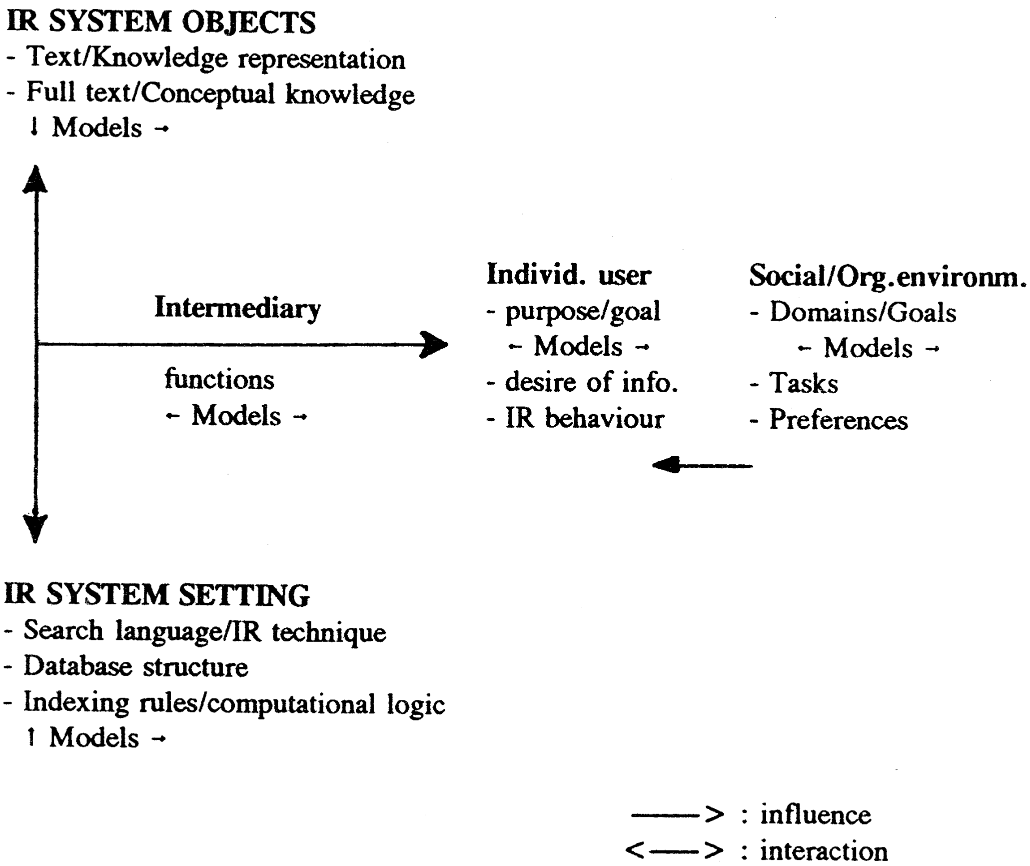


Fig. 2.1. Simplified cognitive model of IR interaction. From Ingwersen (1991, p. 62).

A selection of these individual mental factors and models influencing IR interaction is shown in the model, Figure 2.1 which incorporates certain environmental variables as well. An elaborated version of the model is considered and analysed in Chapter 6.3 in association with the design and evaluation of IR systems. In addition, Figure 2.1 can be seen as a transformation of Figure 1.3, dedicated IR interaction.

In Figure 2.1 the 'IR System Setting' consists of implemented structures, e.g. IR technique and indexing rules, representing the designers' conceptions of how to process the objects in the system. The 'System Objects' contain for instance interpretations of contents of text or pictures by means of indexing (representative structures) as well as the texts or pictures themselves. Naturally, these representations are generated through application of relevant rules or algorithms in the System Setting. Other knowledge structures are incorporated into the Intermediary (mechanism), e.g. by training or direct implementation. To the right, the Individual User possesses certain knowledge structures, goals and a desire for information at the event of instigating retrieval. Up to the point of IR interaction the user's system of categories and concepts is constantly influenced by his social environment which may possess social conventions, preferences and collective cognitive structures adhering to domains. Inherent in each variable that forms part of the interaction specific (world) models guide the expectations of that variable or participant. For example, a specific search language structure in the System Setting is designed with the purpose of serving (containing a model of) particular group(s) of searchers, e.g. CCL, expected to be applied by information specialists only. Another example is that a user does not wish to approach a particular service or person for reason of previous experiences that have altered the user's previous model of the service or person. Emotional factors are thus taking part in the process.

In short, the cognitive viewpoint displays the following characteristics:

1. it treats computers and alike processing devices *as if* they are humans, whereby the *limitations* of the former in relation to information processing and cognition are estimated;
2. it is an *individual view* in that it regards each processing device as independent, consisting of its own 'system of categories and concepts' – i.e. his/its model of him/itself and his/its world.
3. at the *actual event* of information processing this activity is mediated by the *actual state of knowledge* of the device, i.e. his/its actual knowledge structures, expectations, goals, etc.
4. the 'system of categories and concepts', the world model, is generated and determined by *individual cognition* in a *social context.*

The four characteristics demonstrate a *subjective* and profoundly *dynamic style* of information processing – ideally resulting in continuous changes of models and actual state of knowledge for each device. Point 3 leads to the interesting assumption that any transformation of the current system of categories and concepts – the actual state of knowledge of the individual – must be associated with his/its present world model, that is, what he/it knows, expects or aims at right now. To a recipient this means that at least some elements of a communicated message must be perceived or recognized, in order to allow the message to transform the present state into a new state of knowledge. This transformation does not necessarily produce a simple accumulation of categories and concepts, but can be seen as a reconfiguration, a restructuring or a compression in part of the recipient's knowledge structures. Hence, for the same human recipient receiving even identical messages over a period of time the assumption creates a degree of *unpredictability* as to the exact nature of the transformations. In the perspective of the cognitive view, machines do not eventually become affected in the same unpredictable way under identical conditions.

For *information science*, and IR research in particular, this understanding and application of De Mey's central point of the cognitive view may be summarized in the following way (Ingwersen, 1982, p. 168–169):

> A consequence of this view is a variety of individual differences in knowledge structures – a variety which recent research in learning has also suggested (Dahlgren and Marton, 1978). Thus, the task of IR is to bring cognitive structures of authors, systems designers and indexers into accord with those of the information worker [intermediary mechanism] and the user, in order to cope with the actual information need (Harbo, Ingwersen, Timmermann, 1977). *Collective cognitive mechanisms,* often described in paradigm theories (Kuhn, 1970), also influence the structure of classification and indexing systems, and thus have implications for the relations of topics and concepts treated in the body of literature *and information needs.*

Hence, the cognitive viewpoint suggests that we investigate the variety of individual world models and knowledge structures that underly the surface structures of the variables of interaction with one another, Figure 2.1. Further, it proposes the study of their quality and limitations, in order to produce IR theories and applications that may optimize IR interaction, make us understand the nature of individual users' actual desire for information and support its fulfilment.

Since IR handles *stored* intellectual structures placed as System Settings, Objects and Intermediary mechanisms which are dynamically generated by humans up to the point of storage and implementation where they 'freeze', the view seems purposefully applied in guiding such qualitative studies.

The understanding of the cognitive viewpoint cited above has been familiar for quite some time, for instance in K. Craik (1943), but rather recently the so-called 'cognitive movement' or 'cognitive turn' has come to attention, such as in the fields of AI (Hayes, 1975), sociology (Cicourel, 1973) and rather preeminently in psychology, e.g. E. Hollnagel (1979). The cognitive movement is strongly opposed to the classic behaviouristic viewpoint and seems to have swept away such strongholds as the stimulus-response concepts.

Since the mid-seventies, notwithstanding, a certain confusion and misunderstanding has emerged, associating the 'cognitive viewpoint' with so-called 'cognitivism'. Both views have been considered under the umbrella of the 'cognitive movement'. Let the author emphasize most strongly: *the cognitive view should not be equaled with 'cognitivism',* in particular not in information science and IR.

Hence, to clarify the distinction between the cognitive viewpoint and the ideas behind cognitivism, one is referred to the argumentation against 'cognitivism' (and 'Strong AI') put forward by, among others, J. Searle (1984) and T. Winograd and F. Flores (1986). The arguments are discussed in Chapter 2.1.

An outspoken line of opposition, aimed at the cognitive view within IR as well as cognitivism, is concerned with the economic, environmental, socio-behavioural relations to individual cognition and mental states. From a materialistic standpoint both B. Hjørland (1991, 1992) and B. Frohmann (1990, 1992) have opposed the viewpoint, which to a great extent they get mixed up with cognitivism.

From a social science point of view D. Ellis regards the cognitive view as too limited in a behavioural sense (1989). L. Schambers et al. (1990) see affective, historical and cultural factors, and the role of background context, as an alternative framework for IR research. They base their argumentation on Winograd and Flores' notion of meaning from hermeneutics, seen as something "fundamentally social [which] cannot be reduced to meaning-giving activity of individual subjects" (1986, p.33). The notion of 'meaning', also fundamental to the cognitive view, has been recognized as of importance to IR for several decades. One may here refer to the problems of aboutness, inherent in the process of handling recorded knowledge, discussed in Chapter 3. As will be demonstrated below, the point is that to IR the essential goal does not imply simply to retrieve meaning(s), but something beyond, that is, information.

Faced with the previous argumentation, one may state that no *theoretical* limitation exists for exploding the system environment variables – only operational and methodological limits (see the right-hand side, Figure 2.1).

From the citation referred to above (Ingwersen, 1982, p. 168), the models of information science and IR interaction shown in Figure 1.3 and 2.1, as well as the empirical findings outlined in Chapter 5.3 on human intermediary and user behaviour, it is clear that the author's application of the cognitive viewpoint – up to a point – respects such social and phenomological factors.

Chapter 2.2 discusses the understanding of information in information science based on the cognitive viewpoint, leading to specific conditions as to when we may talk of information and information processing. Chapter 2.3 follows up the discussion of the appertainance of information science, classifying the discipline as belonging to the family of cognitive sciences. This is followed by a brief outline of the relevance of hermeneutics to IR, in Chapter 2.4.

The tri-partite distinction between IR research approaches outlined in Chapters 4 to 7 is basically framed with the cognitive viewpoint in mind. In particular, Chapter 6 and 7 pursues the characteristics of the emerging cognitive research approach to IR. A brief overview of the three approaches is given in Chapter 3.2.

2.1 The cognitive viewpoint versus cognitivism

The author acknowledges Searle's argumentation and conclusions concerning the 'Strong AI' attitude and underlying assumption. According to Searle, this attitude is based on an assumption about strong analogies between the functioning of the human brain and the functioning of digital computers. Searle states: "according to the most extreme version of this view, the brain is just a digital computer and the mind is just a computer program" (1984 p. 28). References to the 'Strong AI' attitude are, for instance, Turing (1950), Newell and Simon (1972) and Johnson-Laird (1988) to name a few. Searle's argumentation and conclusions very elegantly attack the fundamental premises of 'Strong AI'. His premises for his conclusions are: 1) brains cause minds; 2) syntax is not sufficient for semantics; 3) computer programs are entirely defined by their formal, syntactical structure; 4) minds have mental contents, specifically, they have semantic contents (1984, p. 39).

To keep Searle's terminology straight, he names the view that all there is to having in mind is 'having a program', 'Strong AI' – and the view that the brain is a digital computer, 'Cognitivism'. The view that brain processes (and mental processes) can only be simulated computationally is called 'Weak AI'. In relation to Weak AI he acknowledges that certain human mental processes, e.g. of a formal nature, can be *simulated* by a computer, in fact also representations of consciousness, thoughts, feelings, and emotions. However, since these features involve more than syntax, the computer is unable, by definition, to *duplicate* them, however powerful its ability to simulate. "The key distinction here is between duplication and simulation. No simulation by itself ever constitutes duplication" (1984, p. 37).

Weak AI (or Soft AI) may therefore be regarded as closely related to the position of the cognitive viewpoint. It can be seen as an example of an application area, which is under constant development during the eighties – in opposition to the positions of Strong AI and cognitivistic theory.

To the author, the fundamental difference between Strong AI and 'cognitivism' on the one hand and the cognitive view on the other hand lies in the way the three positions view machines and human mental activities. According to the four characteristics as well as its historical foundation outlined above, the *cognitive viewpoint* is born out of investigations of *human* mental behaviour. Computers and their behaviour are non-semantic manifestations or simulations of certain human mental processes, but not all. In contrast, both Strong AI and cognitivism are basically demonstrating the completely *opposite attitude*: (all) human mental activities are carried out as if they are processed in computers.

Searle sees cognitivism as forming the mainstream of a new discipline of 'cognitive science'. "Like Strong AI, it sees the computer as the right picture of the mind, and not just as a metaphor. But unlike strong AI, it does not, or at least it doesn't have to, claim that computers literally have thoughts and feelings" (1984, p. 43). He continues:

> If one has to summarize the research program of cognitivism it would look like this: Thinking is processing information, but *information processing is just symbol manipulation.* Computers do symbol manipulation. So the best way to study thinking (or as they prefer to call it, 'cognition') is to study computational symbol-manipulation programs, whether they are in computers or in brains. On this view, then, the task of cognitive science is to characterize the brain, not at the level of nerve cells, nor at the level of conscious mental states, but *rather at the level of its functioning as an information processing system*. (Emphases by this author).

It is exactly on this point that cognitivism (and strong AI), and the cognitive viewpoint are *on 180° diverse course.*

In contrast to cognitivism, the cognitive view attempts to model information processing in terms of 'categories and concepts' at the level of mainly conscious mental states, implying the property of *meaning* – *not* simply as symbol manipulation. As an obvious consequence, machines are not capable of understanding meaning, concept manipulation, thinking, cognition, creativity, etc. *except* when told or supported by humans. This qualitative discrimination between low-level processing made by computers (and in particular made in books and clay-tablets) and high-level semantic manipulation made by man constitute exactly the man-machine interaction problems.

The confusions or misunderstandings arise because cognitivism may tend to mix what goes on in computers with what is *thought to go on* in minds or brains. One must stress that because *man* is *capable* of implementing programs which process strings of symbols or signs following some formal rules, then this fact does *not mean* that man only processes information (and knowledge) in such formal ways. The notion 'what is thought to go on' refers to the problem of obtrusiveness in experimental techniques and reality interpretation problems, as touched upon by Weizenbaum (1984) and analysed further in Chapter 5.2.

An example may demonstrate this phenomenon. It is possible experimentally, by thinking-aloud methods or open-ended interviews, to extract from users *representations* of mental states like: 'I don't know about X, so I want to look-up in Y first, concerning X'. Naturally, a researcher may then make the following simulation: 'X is a TopicObject'; 'Y is a Material-Object (BookObject)'; 'If user does not know X, then Find Y'. The point is that, although this formal rule may be valid with a high probability for most users of a domain-specific interface design, the objects and the rule only *syntactically mimic* the mental state. All *causal contexts* behind the original statement (I don't know X, so I want to look up..) have been lost. Yet more 'subtle' would be to ask the subjects under investigation to represent their considerations in terms of formal if-then rules. They are then obliged, and obviously capable of, simulating or even duplicating, computer processing rules. However, to state from this ability that man can master only such functional rules and logic, must be regarded as an illogical generalization in itself.

Simply because computers process symbols faster, store and remember what has been entered into them better than man in general, and often are capable of smart performances simulating man's communicative behaviour, these facts ought not lead to the belief that studying computer processes may replace the study of human mental activities and behaviour. This would be a trap similar to that of seriously examining books and indexes in order to understand the human memory – prior to the computer age.

The cognitive viewpoint does not adhere to this reductionistic misconception, which essentially is a reduction of meaning (and pragmatics) into syntax, of possibly observed human rules into formal rules only, and of information into data.

The confusions and misunderstandings may also be caused by the use of *metaphors*, often originating from information theory and communication, as argued by Machlup (1983, p. 657), e.g. in relation to the use of 'information' (Chapter 2.2).

The "maps-in-the-classroom-ceiling" example (Chapter 6.1), (originating from Ingwersen, 1986, p. 209, 213), in which individual knowledge structures with semantic properties are *illustrated* by extensive multidimensional maps that can be manipulated, e.g. during communication, does *not* show what happens mentally in reality in the human head. However, if an IR systems designer finds this illustration attractive and actually implements it in a computerized IR system, this does not mean that humans therefore think or process information, actually pulling maps down and up. Thesaurus structures, association maps, 'semantic road-maps' as suggested by Doyle (1961), and term cluster displays, made by a human or by a man-made computer program, have all been implemented in IR systems *exactly because* they seem to *support* humans to a certain degree in *their* known way of IR behaviour and information processing.

The cognitive viewpoint, as well as its application in relation to the information concept for information science, attempts to provide *conditions* as to how and when to talk about 'information processing' and 'information' vs data processing, potential information and data.

In association with the viewpoint, De Mey has established a valuable evolutionary view consisting of four stages through which thinking on information processing has developed (1977. p. xvii; 1980, p. 49):

1. *A monadic* stage during which information units are handled separately and independently of each other as if they were simple self-contained entities.
2. *A structural* stage where the information is seen as a more complex entity consisting of several information units arranged in some specific way.
3. *A contextual* stage where in addition to an anlysis of its structural organisation of the information-bearing units, there is required information on context to disambiguate the meaning of the message.
4. *A cognitive* or epistemic stage in which information is seen as supplementary or complementary to a conceptual system that represents the information-processing system's knowledge of its world.

He exemplifies the evolutionary stages in the development of, for example, pattern recognition and language understanding. Each new stage contains the features of the preceding one.

In machine perception, stage 1) implies template matching, 2) feature analysis, 3) contextual analysis, 4) analysis by synthesis. In language understanding the examples are the well-known 'time flies like an arrow' and Winograd's 'Sam and Bill wanted to take the girls to the movies but *they* didn't have any money'. Stage 1) is word-to-word translation, 2) syntactic analysis, 3) presuppositions, 4) ubiquitous knowledge.

In IR (e.g. text representation) one might suggest: 1) one book = one assigned class or index term, or single term extraction from the text, 2) keyword phrases, morpho-syntactic term extraction, clustering, 3) semantic values combined with request modelling, 4) really adaptive, knowledge-based systems, pragmatic systems. The stages 1) and 2) represent the present level of traditional, system-driven IR research which, in conjunction with more user-oriented IR, attempts to catch at stage 3).

With these four stages in mind, the cognitive view hence explains the limited position of cognitivism. So far, stage 3) has *not* been reached completely and stage

4) cannot be reached in computerized systems, except by direct support from humans.

In machine translation, for instance, semantic text analysis (disambiguation of syntactically defined 'meanings') is able to construct translations in domains with limited (and stable) vocabularies, because the prevailing presuppositions to a great extent are known. The sentence 'time flies like an arrow' is still valid as a test-bed, since its meanings are multiple. It could be that 'time runs fast' or indeed 'time goes slowly' – depending on the reader of the sentence. Also, the meaning might be 'time flies like (to eat/love) arrows', so perhaps 'arrows' then signifies another animal or a plant? The sentence might have something to do with 'Time Magazine' – and how fast/easy it is to read. A complex and abundant number of presuppositions must be present in the machine to deduce the 'meaning' from the surrounding textual context or to ask somebody the right questions. Very recently M. Kay (1991) has illustrated the problems met by machine translation in relation to understanding pictorial/textual signs and symbols that are simple to understand by humans, providing that they share common socio-cultural contexts and conventions.

For humans, all four stages are available at any given moment. In fact the fourth stage constitute the platform on which most human information processing takes place.

The important characteristic to address is that we are moving gradually from the object and sign in a message toward the knowing subject or recipient; as stated by De Mey: "From clearly delineated units handled in isolation toward handling information processing in terms of world models" (1980, p. 54–55).

The *meaning* of a message is synthesized by the recipient out of his own knowledge, in interaction with the message. This is exactly what the human indexer does when assigning keywords and concepts to a text. It is *his* meaning that is assigned, which immediately results in loss of potential information, inherent in the process of representation (Wormell, 1985). The carefully assigned meaning 'drops' into syntactic or even to separate and unconnected entities. So called 'objective indexing' put forward by for example Hjørland (1992), based on a (scientific) domain's established and therefore 'objective' conceptual pattern, generates thus one variation of meaning, additional to other forms of document representation.

In the *contextual stage*, man (or the machine for that matter) requires additional information, obtained internally or externally, in order to perceive meaning, e.g. of a sentence or an entire text entity. It may require a great amount of (cultural) context to infer the referent of 'they' actually to be 'Sam and Bill', and not all four teenagers(?), or 'the girls' – in Winograd's example above. It is not the amount of context that poses problems, it is the *presuppositions* that must be present to think or to ask questions. Essentially, the problem in designing interactive IR systems and intermediaries is to provide each individual user with that context which satisfies him by yielding desired information – but still with a design simplistically based on syntactic and formal features. In IR one may refer to Chapter 4 for explanations of the various methods of representation up to include the structural stage. IR on a contextual level is dealt with in Chapter 7.5.

Therefore, a design at a contextual level should incorporate such presuppositions, embedded in the processing mechanisms. These can be arrived at by modelling a domain, its users' application of language and other means of communication in action, e.g. when performing working tasks. Presuppositions can be seen as conventions and preferences which, naturally, may change over time. The presupposed stability of meaning in the form of representations is then out of order and may only be re-established by somebody altering the embedded conventions in the system. For humans this activity takes place in the cognitive stage.

The *cognitive stage* implies that the context, or the requirement for external information, be produced by the processing device itself, and thus requires "self-generated expectations" (De Mey, 1980, p. 51). These self-generated expectations or presuppositions will assure that the person may change his interpretation of a representation of meaning into new representations, or find the means to ask questions about a meaning during conversation. Only in this stage *information* enters the scene. It becomes that supplement which makes it possible for the actual mental state to cope with a new situation, to transform into some slightly different configuration. The use of language and other communicative means become here the *key instrument* in this process. The daily use of language – or as Vigotsky puts it "daily-life language as opposed to scientific-abstract language" (1962) – may serve as the platform for exchange of world models, representations, meaning and information. Socio-linguistic conventions, and collective cognitive structures, play a significant role. Interestingly enough, this attitude of the psychologically based cognitive viewpoint coincides with Blair's use of Wittgenstein's later language philosophy, as opposed to 'mentalistic' theory of meaning (Blair, 1990). A notable example provided by Blair is the "Mark Twain Painting Case" (Blair, 1990, p. 133).

> [Mark Twain is visiting a house giving the reader an account of what he sees and how he interpretes the situation]:
>
> In this building we saw .. a fine oil painting representing Stonewall Jackson's last interview with General Lee. Both men are on horseback. Jackson has just ridden up, and is accosting Lee. The picture is very valuable, on account of the portraits, which are authentic. But, like many other historical pictures, it means nothing without its label. And one label will fit as well as another:
>
>> First Interview Between Lee and Jackson. Last Interview Between Lee and Jackson.
>> Jackson Introducing Himself to Lee. Jackson Accepting Lee's Invitation to Dinner.
>> Jackson Declining Lee's Invitation to Dinner -- with Thanks. Jackson Apologizing for a Heavy Defeat. Jackson Reporting a Great Victory. Jackson Asking Lee for a Match.
>
> .. a good legible label is usually worth, *for information*, a ton of significant attitude and expression in a historical picture (Twain, 1965, p. 216), [Emphasis by the author].

This case demonstrates what is meant by 'representation', 'meaning' and 'information'. The entire citation exhibits a representation of representations of representations of.. It may convey a message supposedly containing at least one meaning, e.g. that labelling paintings is worth while (for the benefit of the spectator) or that one label put on paintings will fit as well as another. To obtain any meaning the reader must at least know what a '(historical) painting' means. This condition fulfilled, people not knowing this particular painting may know other historical paintings of similar nature, i.e. they may recognize some of the contents of the painting from the description and for example recall "Wellington meeting Blücher at Waterloo". Here, they will apply a representation by association, guided by the conventions applied in the language Mark Twain has used. If, for instance, the term 'General' had been ommitted in the description, and the reader is unfamiliar with US history, a completely different type of painting might have been associated by that reader, e.g. one of the many versions of "David confronts Goliath".

The contents of the painting, which the reader actually may never have seen, is represented by at least the nine labels suggested by Twain. With imagination a few others could easily be added. These labels constitute nine interpretations, some even contradictory, of what he thinks the painter might wish to communicate. Depending of the presuppositions in the reader's mind each label may convey a meaning, particular to every reader. Each of the nine meanings plus the description of the painting may first of all provide information to Twain himself, and now to us. For example, that there might be a matchbox in the hand of Lee, that Jackson is a smoker, that he looks exhausted and lost, or that a battle has occured which may not be in the painting at all. These are your author's representations of the *information* which your author got from the labels, and just now conveyed to you the reader of this book. They are themselves messages with a certain meaning carrying information attached to them.

One might go on like this. However, one should also notice that the *painting itself,* hanging on the museum wall, in principle also is a representation of one or all the labels plus the description generated by Twain. Such iconic representations are often used on the front covers of museum catalogs because they are thought to project the content or other dimensions of the collection. Iconic representations are used in the Bookhouse by Mark Pejtersen (1989) because of their multidimensional and informative power.

An important aspect of the Mark Twain Painting Case is its capability of demonstrating that *information goes beyond meaning.* IR, regardless at which level it is performed, is not and is *not* intended to be satisfied with semantically correct 'translations' of any text or picture. Retrieving meanings is not sufficient, or indeed perhaps not necessary in information retrieval. IR is preoccupied with providing information which may act as a supplement to human conscious or unconscious mental conditions in a given situation.

For computerized 'information processing' we may state that as long as the cognitive stage has *not* been achieved, the categories, concepts, and presuppositions guiding the processing are originally generated and implemented by humans, but during this process become reduced into *data*. The machine performes data processing. Or information processing, metaphorically speaking. Thus, the cognitivistic view mirrors very simplistic human mental activities. If ever reached, a cognitive stage requires self-generation, i.e. learning, adaption, semantics and beyond into a pragmatics that does not follow *any* pre-establishment generated by humans.

2.2 Understanding information in information science

The major areas of study (Chapter 1.2) demonstrate that *information* must be the central phenomenon of interest to information science. Therefore, there should be some generally agreed-upon *concept of information* appropriate to that problem.

Prerequisites for such a concept for information science are that it is relevant to the five core areas of study, must be related to knowledge, is definable, and operational, that is, generalizable, i.e. not situation specific, and offers a means for the prediction of effects of information. The latter implies that we are able to compare information, whether it is generated or received. Hence, we are not looking for a definition of information but an understanding and use of such a concept which may serve information science and does not contradict other information-related disciplines. The major study areas and the problem statement show that communication processes play a fundamental role, involving sender, message, channel, and recipient. The special case for information science lies in the notion of *desired information* and that the messages mainly, but not always, have the form of text, somehow organized in a system. A relevant information concept should consequently be associated with all components in the communication process.

Often, however, understanding of information is associated with one or two, but not all of the components, thereby reducing their relevance to information science.

G. Salton (1983), for example, identifies information with *text contents*, represented by the words or index terms. Although a user may be allowed to provide relevance feedback, stating whether a document or text is relevant or not, this fact does not indicate any notion of effect on the user, only on the system. Neither does it provide any social communicative context. Salton's interest lies in isolating generated messages (texts) conveyed by signs (words and other attributes) in organized channels (text information systems), in order to establish mathematical theories in relation to (text retrieval) systems' performance.

Yet more limited in scope but underlying Salton's view is Shannon's information concept, which, to be more accurate, originally was a measure of probability, forming part of his mathematical theory of communication (Shannon and Weaver, 1949). The measure is concerned with the probability of the reception of messages through a channel, explicitely *not with the semantic aspects* of messages. Shannon's information measure concept is not possible to apply to the entire context of information science where meaning in general is related to information.

Notwithstanding, S. Artandi (1973) and M.F. Lynch (1976) have attempted to make use of Shannon's information measure. Artandi assumes the measure to form the basis for two other understandings of information, each related to different components in the communication process.

One approach adheres to semiotics, i.e. essentially to meaning, the other views information as a means to *reduction of uncertainty.* In these three understandings of information Shannon's information measure plays its original role, being restricted to the functions of non-semantic encoding, transmission, and decoding of messages or texts. Although the three approaches to information are all concerned with communication, they seem only applicable to information science by viewing its research areas isolated from each other, using different understandings of information for each purpose. For instance, while it is clear that reduction of uncertainty is a relevant concept in the study of recipients (users) and their reasons to desire information, it becomes unclear how this understanding of information may be related to generation processes.

With Salton, Shannon and Artandi the focus for a concept of information has moved from the areas of generated messages (contents of texts), over the message itself (not its meaning), to its meaning (e.g. to recipient or sender), and ending in the form of reduction of uncertainty in the mind of the recipient. This drift in focus corresponds to the cognitive viewpoint's stages 1 $\rightarrow$ 3 outlined previously.

Also G. Wersig devotes attention to a concept associated with the *reduction of uncertainty* or doubt and the *effect* of a message on a recipient. In a very careful and profound examination of the communication process he categorizes various information concepts and develops his own (Wersig, 1971). His analysis suggests that it is difficult to see information only as a change of an individual recipient's state of knowledge, since it may be impossible to characterize or determine a state of knowledge as such. Instead Wersig narrows his concept of information to associate with a reduction of uncertainty which for information science implies reduction of uncertainty by means of the communication processes. Uncertainty (or doubt) is the end product of a problem situation, in which knowledge and experience may not be sufficient in order to solve the doubt. It is important to note that information is associated with knowledge through the event of reducing the uncertainty, but also, just as for Artandi, this concept of information only vaguely may deal with the senders' states of knowledge. Slightly later, but relatively unnoticed by Belkin, Wersig extends his information concept and his communication model to include the *meaning* of the communicated message in order to explain the effect on the recipient, reducing uncertainty (Wersig, 1973). In this concept a message 'has meaning', and may 'give meaning' to the recipient.

However, Wersig's extended information concept does not explicitly incorporate the sender's situation. Belkin's argument (1978) against Wersig's information concept from 1971 as to its concentration exclusively upon the recipient still holds, but is less powerful. Similarly, Belkin's argument, that Wersig's original concept is situation specific and not generalizable loses some weight.

This problem of exclusivity can only be dealt with by extending the concept to include the entire communication process. This has been attempted by Brookes (1975/77/80), Belkin (1978), Machlup (1983) and Ingwersen (1984a) and will be discussed below.

The author wishes to emphasize the importance of Wersig's analysis, because it points to *reasons* for requiring information through communication with external sources, the 'state of uncertainty' or doubt being this reason, in the context of a problematic situation.

Secondly, the 'problematic situation', i.e what is known by the recipient to be a *choice between possibilities* of action, of solutions to problems, or fulfilment of factual or emotional goals (author's interpretation), is re-defined to be the *problem* *space* which may be transformed into a state of uncertainty. This latter state can then be seen to be identical to the notion of the 'anomalous state of knowledge' (ASK), defined by Belkin (1977/78) to be "the recognition of an anomaly by the recipient in his/her state of knowledge" which can only be solved by communication, for example by interrogating an information system. In 1978 however, Belkin does not operate with a 'problematic situation' or 'problem space' functioning as the trigger for his ASK. To the author, the transformation in problem space into a state of uncertainty is fundamental and eventually takes place when a person cannot solve a problematic situation or fulfil a goal by himself by thinking.

In his critical essay on the semantics of information, published as an epilogue to his book referred to earlier, Machlup follows similar lines of principle as does Belkin concerning the importance of the sender in the communication processes. In addition he provides a definition of the concept of information in comunication, broader than Wersig's but useful in its distinction between information proper and 'metaphoric information'. He states (Machlup, 1983, p.657):

> Real information can come only from an informant. Information without an informant – without a person who tells something – is information in an only metaphoric sense....information is a sign conveying to some mind or minds a meaningful message that may influence the recipients in their considerations, decisions, and actions.

He points to C. Cherry who states that "all communication proceeds by means of signs, with which one organism affects the 'state' of another" (Cherry, 1957). Cherry also considered the question of how to distinguish between communication proper, by the use of spoken language or similar empirical signs, e.g. text, and other forms of causation, e.g. electrical effectors. It is in the latter sense that Machlup recommends the notion of information as a metaphor.

This understanding of information clearly distinguishes between the linguistic level (signs) and the sematic level of a message and relates information to the recipient's knowledge state providing clues as to the possible effects or use of information: considerations, decisions and/or actions taken by the recipient. In addition, we are allowed to use 'information' (metaphorically) when speaking of causations within machines.

Like Wersig's extended concept, Machlup's definition does not inform about what information really is, perceived from the generator's point of view, except that it is 'something', e.g. signs conveying a meaningful message. Obviously meaningful to the recipient and supposedly meaningful to the informant.

With Wersig and Machlup we have a rather profound understanding of the *reasons* for the desire for information, the eventual *effects* of information on the recipients' knowledge state and a *distinction* between the *linguistic* and the *semantic levels* in the communicated messages. Machlup does not seem influenced by either Belkin, Wersig or Brookes, although the latter is referred to, but on different issues.

N. J. Belkin makes a similar distinction between levels of communication to that of Machlup. In his critical review article from 1978 he suggests and argues an information concept "explicitly based on a *cognitive view* of the situation with which information science is concerned" (p. 80). His model of the communication system of information science derives from (Belkin, 1977, p.111) and displays two levels of *interactivity:*

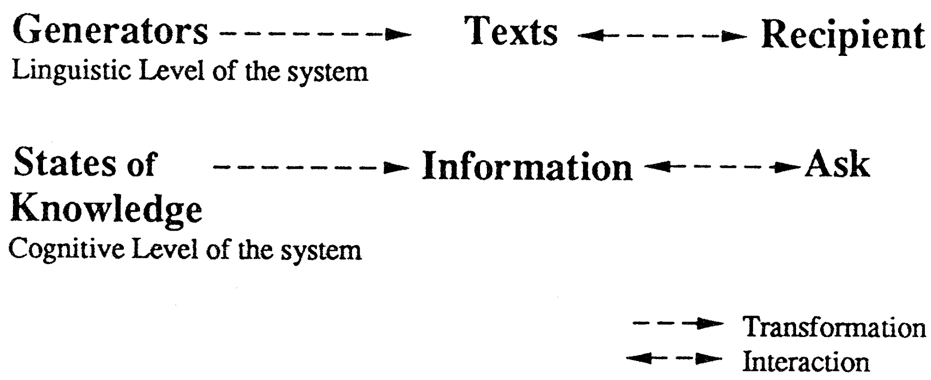


Fig. 2.2. The communication system of information science (Belkin, 1978, p. 81).

Information is here seen as a *structure* and Belkin proposes that (1978, p. 81):

> the *information* associated with a text is the generator's modified (by purpose, intent, knowledge of recipient's state of knowledge) conceptual structure which underlies the surface structure (e.g. language) of that text.

He argues that this information concept satisfies all the prerequisites outlined above by linking it to the idea of structure within an analysis of the communication system that is of interest to information science. He takes "that system to be a recipient-controlled communication system, instigated by the recipient's anomalous state of knowledge (ASK) concerning some topic" (p. 80).

The 'recipient-control' serves to include the important notion of desire for information, and Belkin is right in claiming his concept to be satisfying. It is related to states of knowledge of both generators and recipients in terms of structural representation and it takes into account an effect, by solving the anomaly in the recipient's ASK.

However, it is somewhat unsatisfying that the concept in its verbal description emphasizes the generation and then relies on the context of the communication model. Belkin's own arguments in relation for example to Wersig's original information concept are merely based on its verbal part and does not take the model into account. Likewise, we must assume that the effect on the recipient's state of knowledge exists. The effect is neither expressed in the model nor in the concept statement. In addition, one may doubt that generated texts always are structured according to specific 'knowledge of (one) recipient's state of knowledge'. Instead, a generator may be said to have a model or general idea of a group of *potential recipients' states of knowledge* in mind. The concept 'anomalous state of knowledge' is, as stated above, very identical to 'state of uncertainty', and similar to D.M. Mackay's notion 'a certain incompleteness in his (the user's) picture of the world, an inadequacy..' (1960). 'Uncertainty', 'incompleteness' or 'inadequacy' seem to have more accurate connotations as to the user's situation than the vague term 'anomalous'. However, the acronym 'ASK' is of course of a more powerful nature than USK or ISK.

In relation to prediction Belkin himself argues that "because both the information and the recipient's state of knowledge are considered as structures, and because the information structure is derived from a knowledge structure, the effect of the information associated with any particular text can be predicted, *given some idea* of the recipient's state of knowledge, and *some means for representing state of knowledge*" (1978, p. 82)(emphasis by the author).

This argument relies, quite rightly, on the *notion of structure* related to all components participating in the communication process. However, is it possible to have an idea of a state of knowledge and representative means? Wersig doubts it. In the author's opinion it is possible to have a (general) idea of a group of recipients' state of knowledge, or better, deliberately to induce a specific and controlled 'problem space' or a problematic situation, creating a 'state of uncertainty'. In such experimental cases the resulting effects on the recipients (considerations, actions taken, etc.) represent parts of the state of knowledge which can be analysed. Controlled empirical investigations have been carried out by C.W. Cleverdon et al. in relation to (human) indexer consistency (1966) and by Ingwersen in relation to librarians' search procedures and use of search concepts (1982) (see Chapter 5.2.2).

What is not possible is to have an exact idea of several states of knowledge, nor to predict individual effects. This is a problem of *uncertainty* inherent in the cognitive approach to information.

2.2.1 Consolidation of the information concept

The author's proposal for a concept of information for information science is based on the the cognitive view, as defined by M. De Mey (1977, p. XVI), Chapter 2.1:

> any processing of information, whether perceptual or symbolic, is *mediated* by a system of categories or concepts which, for the information-processing device, are a model of its world.

The viewpoint stresses the role of the *actual state of knowledge* (categories or concepts = world model) in the information processing device, it being human or machine. Concepts are defined by Gowin as "perceived regularities in events or objects as designated by a sign or symbol" (1970). For a recipient in a communication process this view implies that if a message cannot be mediated by his state of knowledge, no information processing takes place. Consequently, if the recipient cannot *perceive* the message, although he wishes to do so, information is reduced to the surface structure (Figure 2.2), i.e. to data (text or signs). This approach is reflected by P.H. Lindsay and D.A. Norman (1977) and P. Johnson-Laird and P.C. Wasow (1977) among others.

Ingwersen has analysed the implications of the cognitive viewpoint for information processing and retrieval, discussing B.C. Brookes 'Fundamental Equation' for information science (Ingwersen, 1984a, p. 465–471). Actually, this 'equation' has been displayed in several forms during the period in which Brookes developed it (Brookes, 1975, 1977, 1980). Belkin (1978) refers briefly to it, and Zunde and Gehl (1979) reject it completely as being non-operational.

The equation for information science has normally had this form (1980):

$$\mathbf{K(S) + \delta I = K(S + \delta S)} \qquad (1)$$

which states in its very general way that the knowledge structures K(S) are changed into a new modified state of knowledge $K(S{+}\delta S)$ by the information δI, the δS indicating the effect of the modification. Brookes states (1977 and 1980) that its expression is in pseudo-mathematical form because this is the most compact way in which his idea of information can be expressed. We may therefore see it as a model. He stresses that although his terms and symbols are not defined, the equation implies, that if its entities were measurable, they would have to be measured in the same units, i e. that information and knowledge are of the same kind and have the same dimensions. In (Brookes, 1977) the equation has a more dynamic form:

$$\mathbf{\delta I + K(S) \rightarrow K(S{+}\delta S)} \qquad (2)$$

Approximately at the same time as Belkin (1977) and slightly before (Belkin, 1978) Brookes stated (1977, p. 197):

1) Implicitely it (the equation) offers a definition of *information as that which modifies what is denoted by K(S),* which is a *knowledge* structure.
2) It implies that the information [δI] is also structured.
3) Knowledge structures can be either subjective or objective (recorded).

He regards knowledge as a structure of concepts linked by their relations and information as a small part of such a structure. The reason for statement 3) is that he regards recorded K(S) as Popper's World 3 (objective knowledge). By deliberately not substituting δS for δI in model (1) and (2) the notation emphasizes that the same δI may have *different effects on different knowledge structures*, i.e. implying subjectivity (Brookes, 1980).

Consequently, one may understand model (2) and the points 1) – 3) to *include generation* and reception of information in such a way that a state of knowledge is *transformed.* Unfortunately, Brookes does not follow up this line of interpretation of his own model.

The important notions for information science in this understanding of communication and information processing are: 1) viewed from the recipient the information is a *potential* for cognition; 2) viewed from the generator the recipients are likewise potential; 3) when in a 'state of uncertainty' a recipient accesses the potential information (one opens a book) it becomes (drops to) *data* which may become information if perceived. Data is communicated designations, i.e. signs, symbols, words, text... that contain a potentiality of what R.C. Shank calls meaning and inference (Shank, 1975); 4) if not perceived the potential information *remains data* for that particular recipient and potential information for other recipients and generators; 5) the perception is controlled by the actual knowledge structures (K(S)) in the recipient's actual state of knowledge and problem space; 6) the information (δI) may infer (support) the uncertainty state by transforming the problem space and the state of knowledge, causing considerations, decisions, actions, intentions, change of values...(effect); 7) information is a transformation of a recipient's knowledge structures.

Brookes' model (2) may be displayed in a modified form which includes generation (variation of Ingwersen, 1984a, p. 468), given that generated and accessed potential information (pI) is perceived by a recipient:

$$\mathbf{pI \rightarrow \delta I + K(S) \rightarrow K(S + \delta S) \rightarrow pI'} \qquad (3)$$

In (3), of potential information pI is perceived the information δI, which is *mediated* by the actual knowledge state (including the 'problem space' and 'state of uncertainty') K(S), transforming the state of knowledge into a new state K(S+δS) with the effect (δS). The modified state of knowledge may *generate*, e.g. answer back or later create, new information (pI'), potential to other recipients.

Similarly when accessed, *information systems* receive *data* from the searcher. The system's information processing in model (3), however, follows a slightly different pattern. δI is reduced to designations, that is, when perceived they remain data. Recognized designations may be manipulated by the system's K(S) and non-recognized designations can be analysed up to a cognitive contextual level by means of embedded presuppositions. Their conceptual meaning will remain uncertain to the K(S) implying that the system's K(S) remain the same. Therefore, any effect (δS) of the perception on the system's K(S) happens on the surface level of the communication and no transformation of state of knowledge takes place, as illustrated in model (4). In this model the notation D stands for 'data' or 'designations'.

$$\mathbf{pI \rightarrow D + K(S) \rightarrow K(S) + \delta S \rightarrow pI'} \qquad (4)$$

One may notice that the system's components, Figure 2.1 center and left hand side, will neither possess a problem space nor be capable of being in a state of uncertainty. The components do not semantically understand what they do not know. For instance, the designer has programmed a threshold as to the number of times users *intuitively* relate 'whales' to 'fish' and this threshold is exceeded, whereby a 'conceptual map' get this (generically false) relation added automatically. However, this new fact (effect) does not imply a change in knowledge state of the IR system. The underlying threshold rule is a man-made, syntactic rule, transforming a man-made conceptual structure into a slightly different one, as foreseen by the designer.

(IR) systems may hence *look* intelligent and perceptive, exactly because their K(S) may contain ideas of searcher behaviour which are applied when the systems display structured answers (pI') of potential cognitive value to recipients.

In view of the arguments stated above, Belkin's model, Figure 2.2, may be extended to incorporate the 'problem space' and the 'state of knowledge' of the recipient. In Figure 2.3 the recipient's actual state of knowledge may be transformed into a situation-specific state of mind – a problem space – in which the individual recognizes its lack of knowledge, e.g. in order to choose between possibilities for action, between solutions to problems, or in relation to the fulfilment of factual or emotional goals. If not capable of filling this problem space by thinking, the individual's state of mind may end up in a state of uncertainty, which may be reduced by information through interaction with the world around it, e.g. by accessing an information retrieval system. A further discussion of the properties of the various mental states in relation to IR is carried out in Chapter 6.1.

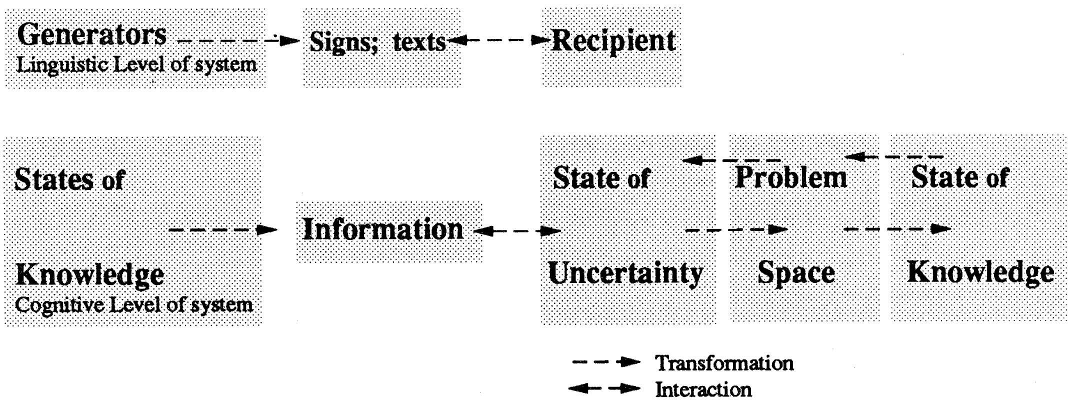


Figure 2.3. The cognitive communication system for information science (extension of Belkin, 1978, p. 81). From Ingwersen (1991, p. 18)

The concept of information, from a perspective of information science, has to satisfy dual requirements:

on the one hand information being

the result of a transformation of generator's knowledge structures (by intentionality, model of recipients' states of knowledge, and in the form of signs);

and on the other hand being something which

when perceived, affects and transforms the recipient's state of knowledge.

Inherent in the notion 'perceived' is intentional causation, expectation and thus *desire* in relation to accessing the (recorded) world around the recipient. Signs will mainly take the form of text, including graphics and other linguistic means of communication in a multi-media environment. Intentionality is understood as stated and argued by J.R. Searle (1984a, p. 15), i.e. that "all valid teleological explanations are species of explanation in terms of intentional causation".

This concept of information satisfies all the requirements stated previously. It draws on a wide range of sources, does not contradict more broad understandings of information at the interdisciplinary level, and it is related to other information concepts, including in information science, state-change concepts such as those of Debons (1980), Wersig (1971, 1973), Farradane (1976), and Kochen (1983), and structure-based concepts such as Brookes' (1975, 1977, 1980) and Belkin's (1977, 1978). It takes into account and repudiates the rather dubious criticism by C.J. Fox of Wersig's recipient-oriented information concept (Fox, C.J., 1983, p. 41–61).

From outside information science, Machlup's (and Cherry's) concept is very similar in many respects, being based on the representation of meaning, change of state, and effects (1983). The concept is associated with N. Bjørn-Andersen's information concept, developed in relation to decision-making processes (1974). By introducing the concept of *premiss* – defined as *that* information, in relation to an actual decision, which is received, perceived, influencing the decision-making process, and affecting the recipient's state of knowledge – he also emphasizes a cognitive and pragmatic approach to information processing and transfer.

2.2.2 Implications of the information concept

This understanding of the concept of information in information science is fundamentally associated with *human* communication of *recorded* potential information, processed by generators as well as recipients.

Only when the dual requirements are satisfied in a space/time continuum may we talk of *information* – in a real sense. Real information can only materialise when all the conditions embedded in the *second requirement* are satisfied, that is, at the moment when the generated potential information is received and perceived, affecting *and* transforming the recipient's state of knowledge.

Hence, in information science and in particular in IR one is constantly constrained to the Linguistic Level of communication (Figure 2.3), operating with potential information or data in the form of signs, text, image, etc. both ways during interaction. Solely at the moment of transformation of a human recipient's state of knowledge the communication and interaction takes place at the cognitive level. Only at this instant is an 'information' system a real information system.

The *operationality of the concept* exactly relies on the fulfilment of these three conditions. In order to *measure* any kind of perception and the further steps in the cognitive development process the recipient must be turned into a generator's role, producing a response, as demonstrated in the extended and dynamic version of Brookes' equation, model (3).

Research into how and why this transformation occurs may hence only take place during *interaction*, for example between a system and a person who turns into being a generator who creates a response by communicating potential information back to the system or to another person. The response forms the basis for the measurement of perception, effects and transformations into knowledge. The previously mentioned investigations of indexer consistency (Cleverdon et al., 1966) and studies of librarians' retrieval procedures (Ingwersen, 1982) actually applied this type of research setting. For example, in the latter experiments all the public librarians were given the same question which deliberately should induce a conceivable problem space and *uncertainty state* in the state of mind of each librarian. It is assumed that the researcher possesses a (general) idea of frail knowledge structures as to the librarians in question. Another method is to induce potential information which does *not* contain concepts that may lead directly to an adequate system response. By means of the 'thinking aloud method' applied during their search activities, i.e. their interaction with documents and system features, one is able to measure their ways of perception of information space as well as effects and conceivable transformations of their knowledge states. Certain patterns may then emerge. For instance, all librarians are 'persuaded' by the question (pIx) to look up and read (perceive) one and the same reference tool (pIy); some librarians overlook particularly potential information (no effect and no transformation), others grasp a potential segment of information (δI) and change their search behaviour according to their subjectively modified knowledge state K(S+δS).

At this point we may talk of *information* because a transformation of knowledge structures clearly takes place. The transformation is measured by the conceivable *linguistic manifestations* of new search paths and/or new search terms, generated by each librarian (pI'). The outcome of the experiments depends on the quality of the method applied (Chapter 5.2).

Two distinct limitations of measurement exist:

First, certain behavioural, but no (or only vague) linguistic manifestations are observed of the transformation. Thus, it is not possible to make a distinct assessment of the transformation. Hence, we are only measuring the effect on the state of knowledge – not the full impact of information.

Another case is that linguistic manifestations do occur (e.g. "this book makes me remember Z, so I'll look again..") but no behavioural changes occur (e.g. the recipient performs a loop). In such cases, the contents of the manifestation decide whether the perceived text produced a mental transformation (e.g. as in "makes me remember *Z*") in addition to an effect (e.g. verification of the already known). At any rate the possible measure of information is definitively loose and unreliable.

Hence it is evident that the cognitive viewpoint and the information concept have implications for R&D work performed in the areas of interest of information science outlined above (Chapter 1.2). The significance is to view both System Setting features – such as dbs-structures, indexing rules and retrieval techniques – as well as the Intermediary Mechanism's functional processes, *and* the System Object's conceptual structures in form of text or images, *as potential information* to human recipients. All these structures and features satisfy the concept's first requirement, being transformations of a variety of human generators' knowledge structures.

As demonstrated in Figure 2.1 the information concept based on the cognitive viewpoint makes it easy to *distinguish* between three completely different types of potential information in IR interaction:

- *Passive system structures* embedded in the System Setting, e.g. as indexing rules or database structures, or in Intermediary Mechanisms, e.g. as a user model;
- *Active system structures* in the System Setting, e.g. as IR technique(s), or in the Intermediary Mechanism, e.g. as model building or user interviewing capacities, or as IR system interrogation devices;
- *Conceptual structures*, embedded in the System Object, e.g as texts, pictures or representations, or in Intermediary Mechanisms, e.g. as a thesaurus.

The person communicating with the information system may to a certain extent also possess these three basic types of information, of potential value to the intermediary and IR system. For a further discussion, see Chapter 6.1/2 on individual cognitive structures relevant to IR.

During interaction the information concept applies to both searcher, intermediary mechanism and system.

In *informetrics* this understanding of information implies more qualitatively based analysis methods than hitherto applied. The qualitative *cognitive impact* and nature of, for example, citations – their transformative power – ought to be measured, not the common co-existence or cluster of citations in isolation. At least bibliometric analyses ought to incorporate the *weight of influence and direction* of the citation impact, e.g. the frequency and nature of specific citations and their role within a text.

In *information management*, in particular concerning evaluation criteria, the concept means to involve *functional cognitive impact and use* analyses, for instance to assess how the functionalities of a user interface are perceived by users and transform their states of knowledge. Further, qualitative assessment methods with respect to informativeness and use should be developed. This is a common and crucial issue in all information and systems science fields. However, its solution is supposedly more difficult to achieve in information science, because of the rather unstructured nature of the objects in the field. A further discussion of design and evaluation is carried out in Chapter 6.3.

In order to improve *IR interaction* the cognitive viewpoint clearly suggest the appreciation of *poly-representative means* during the communication between searcher and IR system(s). Due to the individuality of each user's knowledge structures the three basic types of potential information embedded in an IR system (and an intermediary) should be represented in several ways by the application of several different representative methods. Intuitively and by logic this poly-representation has taken place since the sixties in the online environment, however, only with respect to the conceptual structures in IR systems: the application of controlled terms, uncontrolled terms and natural language representations (NLR) in titles and abstracts. The active system structures have remained the one and only: the Boolean exact match logic. Only because of the mediation via a human intermediary has a certain processing flexibility come into light. Hence, IR interaction, including intermediary mechanisms, requires a variation of knowledge representations which, in the one and same system configuration, should be combined with a multiplicity of IR techniques and interrogation methods. The question in IR is *neither* to discuss which method of representation or IR technique, etc. is the 'best one' to apply – *nor* simply to apply all of them 'to be sure'. In view of the cognitive approach such solutions are rather futile. What counts is to gain knowledge of the characteristics and implications of each method. The question is rather: *which combination* of active, passive and conceptual system structures is the most suitable one to apply in a given retrieval situation.

In line with this approach are heading hierarchies and other formal or structured document characteristics as well as hypertext, multimedia and other applications that reinforce the possibilities of access to and *navigation* between conceptually related text entities, tables, figures, pictures, etc. Also for the purpose of defining adequate combinations, modern text analysis methods, and the recently suggested plausible inference networking technique by Turtle and Croft (1990), as well as Rijsbergen's logical uncertainty principle (1986a, 1990) are research achievements important to future research and development in IR.

Similarly, it is evident that *each desire for information* should be represented in a variety of appropriately related ways that can be perceived by an intermediary mechanism and applied to the information space. This requirement calls for interactive navigation and/or system interrogation which is structured according to knowledge of the actual user, or at least to the potential groups of users that may instigate the system.

In *information (retrieval) systems design* the information concept thus forces designers to make systems transparent and to create highly *adaptive and supportive* systems in order to improve their *informativeness* and their potentiality for use.

What IR research should do is to try to establish more systematic knowledge of what users in general and individually do, how and why they think or react mentally to combinations of techniques, procedures and conceptual structures in IR systems during IR interaction. This acquired knowledge may be said to be representations of what we, with a degree of uncertainty, know that they think, feel, or behave. We then implement this knowledge in IR systems and intermediaries, *not basically to simulate* librarians, but to improve the *interaction with* human users.

2.3 Information science seen as a cognitive science

Cognitive science has been defined as an intersection of linguistics, artificial intelligence (AI) and psychology (Schank and Abelson, 1977) – see Figure 1.2, Chapter 1.1.1. Key research foci are phenomena such as perception, cognition, conceptualisation, understanding, thinking and the role of language, and a fundamental concept is *representation*, as pointed out by, for example D. Bobrow and A. M. Collins (1975) and T. Winograd and F. Flores (1986). Its boundaries are rather vague. In a 'cognitivistic' sense, discussed in the previous chapter, cognitive science is *limited* to emphasize the (Strong) AI aspects which then ought to provide psychology and linguistics with formal insights into how the mind works.

H. Gardner outlines the fundamentals of the 'cognitivistic' approach to *cognitive science* by stating (1985, p. 6–7): "First of all, there is the belief that ... it is necessary to speak about mental representations and to posit a level of analysis wholly separate from .. the sociological or cultural. Second, there is the faith that central to any understanding of the human mind is the electronic computer [which] also serves as the most viable model of how the human mind functions. The third feature is the deliberate decison to de-emphasize factors [that] include the influence of affective factors or emotions, the contribution of historical and cultural factors, and the role of background context in which particular actions or thoughts occur".

By application of the contrasting *cognitive view*, cognitive science in turn displays sociological and socio-psychological dimensions (Cicourel, 1977) and views AI as one of *several* platforms for cognitive research. M. Boden explicitly stresses the importance of studying *man* (1977, p. 225):

> To study knowledge is to study man, for knowledge enters intimately into all human life. The classic threefold distinction between 'cognitive', 'conative', and 'affective' aspects of the mind is more a matter of emphasis than a reflection of autonomous mental realities. Not only thought and belief, but also action, intention, purpose, value, and emotion are generated by way of cognitive representations within the mind. Some of these representations are accessible to consciousness, while others are not. They include models of the person himself and of his cultural milieu, as well as of the environment shared by all members of the human species.
>
> Cognitive science is the study of the content, structure, function, and development of these mental representations.

The only core issue in common between the cognitive view and 'cognitivism' in relation to cognitive science is the notion of 'representation'. However, as argued previously, the cognitive view acknowledges a much wider interpretation of this concept, incorporating meaning. Since the concept of representation also is fundamental to information science, and IR in particular, one must *stress the cognitive view*, when talking of information science as a cognitive science.

Figure 1.2 in Chapter 1.1.1 places information science within the area of cognitive science. As shown, its borderline touches upon sociology in order to demonstrate the *complementarity* and interrelationship between individual mental behaviour and social impact.

Individual world models, i.e. knowledge structures consisting of categories, concepts and concept relations, somehow intermingled with emotional experiences, are paramount in information science and its subdisciplines, as well as in cognitive science. This science may specify what the relevant phenomena of study might be, providing a rather strong framework for research in information science. This typically means considering its scope as being concerned with a human communication system, in which texts play a key-role, and individuals within that system in their interactions with potential information, and with one another in relation to such texts. Such a cognitive communication system implies, as argued by Belkin (1990, p. 12), “that at both ends of the communication channel certain cognitive processes occur”. In the author’s opinion, cognitive science introduces ways of explaining and treating such cognitive processes dealing with expectations, intentionality, perception, understanding, etc. for each individual recipient of potential information, recorded in systems of various kinds. However, each individual world model, which mediates the processing of information, evolves from interaction with the surrounding world (see Figure 1.3). When therefore studying a user’s cognitive processes for acquiring information, *his socio-behavioural and emotional context* must be taken into account. Identical conditions apply to individual generators of knowledge, to their affective experiences and to IR systems. Thus, cognitive science provides the basis for understanding important aspects of individual knowledge communication and acquisition. Information science studies similar individual phenomena in relation to *recorded* knowledge.

It is worth noting that the *emotional phenomena* associated with information science may take two different forms. One is the role of emotional factors intermingled with cognitive processes associated with perception, e.g. *disliking* a person may prevent effective communication; or, from IR situations: librarians’ *fear* of using certain reference tools or databases may turn retrieval by a human intermediary into a cumbersome affair, or completely disrupt it. The other form is typical in information retrieval, namely the large amount of representations of *potential affective information*, stored in IR systems, e.g. fiction, music, films, etc. Desire for, methods of representation, communication, and retrieval of such types of information require special prerequisites. These are definitively more difficult to pursue than in non-affective areas. Interestingly enough, several scientific fields purposely produce potential information containing affective facets, such as historical and literary biographies.

In the sub-discipline IR, the association with cognitive science is very obvious. Essential problems, such as for instance representation, aboutness, relevance and informativeness (Chapter 3–6), can be approached from a cognitive point of view. This provides a more profound understanding of these phenomena than more traditional approaches to IR. Although the individual user’s world model becomes created in a social-organisational context, it is the *individual alone* who retrieves information. It is the individual retrieval situation in IR interaction that IR research is basically concerned with.

As stated above, the task of IR and IR systems design is to bring cognitive structures of authors, systems designers and indexers into accord with those of the information worker, and the user – at the *event of searching*. By attacking the problems associated with this and other tasks in information transfer, the discipline may in turn contribute to the addressing of pertinent research questions in cognitive science.

The complementary *social dimension* to the cognitive aspects of transfer of information has been recognized for decades in information science, mainly within disciplines such as informetrics and information management. Co-citation, coupling and citation cluster analyses are based on the assumption that individual, cognitive reasons make scientific authors cite one another. Citations may therefore mirror or map social as well as cognitive and topical links and concentrations within a field. Figure 1.3 demonstrates this impact of both formal and informal communication by the notations (1/4) and (1). As pointed out by Cronin (1984), bibliometrics alone does not assure a solid picture of such cognitive patterns. Without additional information the analyses only provide indications.

On the boundary between information management and bibliometrics one may find studies of the *diffusion of information* in society. For instance, Lancaster and Lee (1985) applied bibliometric techniques to trace possible patterns of information diffusion. They called this kind of analysis 'Issues Management'. It is based on the general, well-known pattern of scientific transfer of knowledge from one document type to another. For example, a R&D investigation may initially be published in a report and/or conference paper, followed-up later in a journal article. This may take place along the lines of basic and applied research. Some issues may be taken up, perhaps immediately, by more popular, scientific magazines, newspapers or TV. This may happen in 'hot' areas, e.g. the issues of 'cold fusion', 1987, or 'the ozone gap', 1992. Nowadays environmental issues may often, indeed rather quickly, enter into Parliament, provoking political debate and decision. From all these levels, spreading in new directions may be initiated. All the document types mentioned are tracable via public databases. In a sense, investigations of such transfer processes survey the continuous chains of retrieval (2) through IR systems (3/5), use of information (5), and generation (1/4) (Figure 1.3). Under certain circumstances, individual persons as well as institutions play key-roles in the information production and diffusion pattern.

With the more human approach to information transfer as well as a broader understanding of the role of information in mind – outlined in Chapter 1.2.1 – one may clearly envisage an important trend in future information science research: the emphasis on the complementarity of cognitive-linguistic *and* socio-behavioural scientific aspects of information transfer. Where IR research as well as systems design may show a stronger affiliation to the cognitive fields, but not excluding the social dimension, information management and economics as well as informetrics and issues management may demonstrate an increasing reliance on the socio-behavioural elements. The concept of 'accessibility and use' underlines this complementarity. A common platform might be studies of the influence of collective cognitive structures on information behaviour in various domains, such as the humanities, the social sciences as well as the science and technology fields. Only the latter domains and fields have been investigated, whereas the social sciences (Ellis, 1989) and the humanities seem to display a rather different information seeking and usage behaviour. Evidently, more than ninety percent of the world's information transfer takes place outside the academic fields. The research task of information science is consequently immense and complex, and when it succeeds – illustrious.

The *complementarity* between cognitive and social research approaches to the study of information phenomena suggests a fruitful merger of qualitative, psycho-linguistic methods with more quantitative ones. 'Why' and 'How/What' can be viewed jointly.

2.4 Hermeneutics in IR interaction

The reasons for drawing attention to hermeneutics in relation to information science, and IR interaction in particular, are two-fold. First of all, the unsatisfactory results or direct failure of the cognitivistic and rationalistic approaches to information systems design have forced information researchers to look for alternative philosophical platforms underlying their work. Winograd and Flores' interpretation of Heidegger's hermeneutic philosophy seems to constitute a really influential alternative (1986). Secondly, the holistic trends in information science research point to similar approaches. As argued by Hoel (1992), one may regard information science as a historical science in that it deals with communication of already recorded knowledge, e.g. in form of text. Hermeneutics originates as a philosophical approach to text understanding. Hence, it seems valid to apply hermeneutic views to the study of information transfer.

We will briefly examine selected hermeneutic concepts that seem significant to information retrieval and IR systems design, and relate them to similar concepts adhering to the cognitive viewpoint. In addition, we will draw attention to the differences between the two approaches. The discussion, which is of a non-inclusive nature, is based on Heidegger's views (1962), Gadamer's approach to hermeneutics (1975, 1976) as well as Winograd and Flores' independent understanding (1986).

Because the cognitive viewpoint is rooted in the sphere of human cognition it adheres to the hermeneutic position, rather than to rationalism. The relationship between the epistemological viewpoint and the hermeneutic philosophy is constituted by a certain overlap of understanding or interpretations of mental processes. One may point to hermeneutic concepts such as *interpretation, meaning, pre-understanding, horizon, the hermeneutic circle, thrownness,* and *breakdown*. A more problematic similarity can be observed in relation to the understanding of *representation.*

The major differences are grounded in the *individual-centered* and *subjective* position concerning cognition taken by the cognitive viewpoint in opposition to the fundamentally social approach in hermeneutics. Further, the viewpoint insists on its ability to understand information processing by machines as if this activity is carried out by human beings. Hermenutics concentrates solely on man and his way of existence in and interpretation of the world. This limitation in scope may not, however, inhibit the value of hermeneutics to IR interection. Underlying each implanted structure in a system one may find knowledge structures generated and transformed by man, structures which originally may be seen as interpretations.

It is quite interesting that the application of the cognitive viewpoint to information science, analysed in the previous chapters, underlines the *complementarity* between the social dimension of cognition and individual-centered cognitive processes. It is impossible to isolate the former from the latter. A closer examination of the variety of concepts outlined above reveals that this complementarity very well may offer novel insights into information retrieval interaction and transfer of information.

Interpretation is a fundamental concept in modern hermeneutics in strong connection to *meaning*. Originally, texts were viewed as self-contained entities carrying meaning which exists independently of the act of interpretation. Thus, meaning was seen as something objective inherent of the text. In the author's opinion the traditional theories and methods applied to text representation and indexing in IR can be seen as attempts to optimize these indexing processes of 'objective meaning extraction' and, to a certain extent, of 'meaning assignment'.

The act of interpretation of text is profoundly stressed by Gadamer (1975) who opposes the former classic hermeneutic view of objectivity. In order to explain interpretation in general the concepts of *horizon*, *pre-understanding* and the *hermeneutic circle* are introduced. Meaning is *given* to a text through interpretation by the reader. The reader's *horizon interacts* with the *horizon* provided by the text. Following Gadamer, any understanding of the surrounding world by an individual is constituted by a continuous involvement of interpretation activity. These acts of interpretation rely on *pre-understanding* which includes assumptions implicit in the language that the person uses. Since language is a social phenomenon, pre-understanding can only be seen in a social context, born out of interactions individuals in between. Language is learned through individual activities of interpretation and may therefore change through its use by individuals and in turn change the individual's pre-understanding. These processes constitute the *hermeneutic circle*. With the cognitive viewpoint in mind one may regard the circle rather as a *spiral of cognition*. Winograd and Flores interprete these conceptualisations of Gadamer as (1986, p. 30):

> The meaning of an individual text is contextual, depending on the moment of interpretation and the horizon brought to it by the interpreter. But that horizon is itself the product of a history of interactions in language, interactions which themselves represent texts that had to be understood in the light of pre-understanding. *What we understand is based on what we already know, and what we already know comes from being able to understand* (emphasis by the author).

With reference to the author's application of the cognitive view and his holistic understanding of information, a close similarity exists between Gadamer's views and the position of the cognitive viewpoint in information science. For example, one may observe strong similarities between the sender-oriented information concepts by Salton (1983) or Artandi (1973) and classic hermeneutic positions, as opposed to Wersig's (1971, 1973) and Belkin's (1978) recipient-oriented views leading to Ingwersen's consolidated concept (1991) which, as for Gadamer, relies on recipient-related conditions.

Hence, individual 'world models' consisting of 'knowledge structures', are similar to individual 'horizons', and are "determined by the individual and his social-collective experiences, education, etc." (Ingwersen, 1982, p. 168). 'Pre-understanding' is almost identical to the concepts of 'pre-supposition' and 'self-generated expectations' at a cognitive level of information processing. The change of individual horizons and pre-understanding via interaction and communication is like the transformation of knowledge structures during such processes. The 'state of knowledge' of the individual refers to "what we [the individual] already know".

Essentially, the citation above from Winograd and Flores (1986, p. 30) provides an understanding of cognition virtually identical to the comprehension of this issue demonstrated in model (3), Chapter 2.2.1: the nature of the actual K(S) is responsible for perception of information which may transform K(S) into a new state of knowledge, K(S+δS), ready for new interpretations of the world.

In a cognitive sense one may regard the act of interpretation as a *premiss* for producing mental representations of the surrounding world. In order to produce or transform intrinsic representations of objects and situations, perception and understanding of the event must take place, implying interpretation and intent. From a cognitive point of view machines cannot transform their knowledge structures, because they are unable *themselves* to deal with 'meaning', i.e. with understanding. In a hermeneutic sense this fact might be explained by their lack of the interpretation premiss.

However, it is important to stress that in information science, and essentially in IR interaction, 'meaning interpretation' does not consitute the ultimate goal. As stated previously, IR is concerned with the provision of *information*, carried by and going beyond 'meaning'. Consequently, Gadamer's hermeneutic views may add conceptually to our understanding of the *transitional processes* in information provision, for instance, our perception of the 'aboutness' problems in indexing. A question to be answered might be: which (kind of) concepts should be extracted and/or assigned to given documents in order to meet specific desires for information based on specific 'pre-understandings' underlying potential users' 'horizons'? The Mark Twain Painting Case, discussed in Chapter 2.1, demonstrates these problems as well as the differences between interpretation, representation, meaning, and information.

We have here touched upon major similarities and certain conceivable variations between hermeneutics and the cognitive viewpoint, essentially with respect to IR interaction.

The major obstacles *seem* constituted by the the roles played by *consciousness* and *subjectivity* in cognitive science in relation to cognition and the concept of 'mental representations'.

Regarding the role of sub-consciousness – or the self-evident – Gadamer suggests (1975, p. 245): "..long before we understand ourselves through the process of self-examination, we understand ourselves *in a self-evident way* in the family, society and state in which we live." This 'self-evident' understanding or, as Heidegger puts it: "implicit beliefs and assumptions that cannot be made explicit" (1962), are fundamental pre-requisites for Gadamer's and Heidegger's philosophies concerning man's whole existense and being. From a cognitive point of view M. Boden states (1977, p. 225): ".. not only thought and belief, but also action, intention, purpose, value, and emotion are generated by way of cognitive representations within the mind. Some of these representations are accessible to consciousness, *while others are not.*" This citation does not carry any social connotations with it, but it emphasizes that cognitive models and representations very well may be used in a non-conscious way during cognition. This position is closely related to the concept of *deep knowledge* in cognitive psychology. 'Deep' knowledge implies that execution of mental activities becomes less conscious than if the individual possesses 'surface' or 'shallow' knowledge of a situation or practice (Hollnagel, 1987, p. 40). In addition, Hollnagel stresses (1979) the impossibility of communicating models of one-self to other partners during interaction, since these models are implicit representations.

The divergence between hermeneutic approaches and the cognitive view thus boils down to the issues of *subjectivity* and *mental representations* versus social practice which relate to Heidegger's fundamental concepts of *thrownness* and *breakdown*. Gadamer states that "the focus on subjectivity is a distorting mirror. The self-awareness of the individual is only a flickering in the closed circuits of historical life. That is why the prejudices [pre-understanding] of the individual, far more than his judgments, constitute the historical reality of his being." (Gadamer, 1975, p. 245). Like Gadamer, Heidegger puts emphasis on the social dimension of interaction but he goes further by generalizing the importance of *cognition as concernful acting* in the world (praxis). To the author, as well as to Winograd and Flores (1986, p. 32–33) this position implies that ".. *Detached contemplation* can be illuminating, but it also obscures the phenomena themselves by isolating and categorizing them. Much of current study of logic, language, and thought gives primacy to activities of detached contemplation. Heidegger does not disregard this kind of thinking, but puts it into a context of cognition as *praxis*."

This agreement between a cognitive view of categorisation and a hermeneutic idea of praxis-related cognition is easily reached since a vast number of *empirical evidence* exactly demonstrates this fact. One may here refer to Piaget (1929), Vigotsky (1962) and foremost to Bartlett's (1932) and Luria's experiments (1976), originally dating back to the thirties – more than a decade before Heidegger puts thought to the matter. The latter study will be analysed in detail in Chapter 6.1. In common to all the studies are the findings of *situational categorisation*, i.e. daily-life oriented and event dependent *intuitive* cognition which, during mental activities, in the first place overshadows abstract or generic (objective) classifications of objects.

Consequently, the cognitive viewpoint's 'categories and concepts' are mental representations identified as a variety of situational ways and forms. Only one of these forms can be characterised as a direct result of 'detached contemplation'. As a matter of fact, this multi-dimensionality of mental representations has been *self-evident in information science* and IR for quite some time. Ranganathan's faceted principles (1952) can be seen as a first serious attempt to overcome some of the basic problems constituted by hierarchical and abstract classification of texts. Still, his 'idea-level' does not conform to hermeneutics. In a well-argued analysis Boyd Rayward very recently points to why attempts at knowledge classification based on 'detached contemplation', for example made by philosophers, for several centuries continiously fall apart or are in vain (1992).

One may therefore state that the rejection of cognitive or mental representations by Winograd and Flores, i.e. Heidegger, loses weight. Their rejective position seems rather related to an anti-cognitivistic attitude.

The disagreement between hermeneutics and the cognitive viewpoint adheres to when individual and subjective factors take over from socially induced pre-understanding. In the author's opinion, the individual's subjectivity takes over at the point of *breakdown* – or 'breakoff' – in Heidegger's sense.

'Breakdown' situations are closely related to Heidegger's concept of *thrownness*. The latter implies the former. In short, 'thrownness' means that a person is in a situation or activity (praxis) familiar to him. He is for instance driving his car the usual way home from work. His wife is the passenger and they talk together. We may all have experienced this situation. The driver does not think explicitly about the car, the other cars on the road, the road itself, the traffic lights, etc. He simply is *in the act of driving*. Often, if asked, he may not remember whether the previous traffic light showed green or yellow when he just passed it. Here we have the 'implicit assumptions' and the pre-understanding which, in an unreflective way, guide the mental and physical activity. He can make an intelligible conversation with his wife concerning dinner. This is also a situation of 'thrownness'. In contrast, his wife may reflect over her husband's driving which as usual is too fast (when in thrownness) for her taste. She makes explicit perception and reflections of the other cars and traffic lights, i.e. detached contemplation. She is an observer and may be said to have 'broken off' from thrownness concerning the driving. As to the dinner conversation she is in thrownness.

From a cognitive point of view the driver possesses 'deep' knowledge of the car, the road, etc. and his mental representations of the entire driving act are auto-matically evolving from his sub-consciousness, i.e. they form part of his tacit knowledge. The wife is carrying out deductions based on her previous experiences with her husband's driving mode in a reflective manner based on conscious mental representations.

This daily-life situation continues until the wife asks the driver to go to X-Street in order to buy some new stockings she needs since the Smiths are joining the dinner. The husband immediately 'breaks off', trying to establish where X-Street is in relation to where he and his car are now. Actually, he does not really remember the exact position of X-Street. He is now not only in trouble – but in a *breakdown* situation. The other cars become present, as do the road and the traffic lights. His car engine is not any more "a part of himself". He can sense its drawl. It becomes a problem where in fact to turn to get to X-Street. When his wife informs him that X-Street is close to Z-Avenue, he reflects a moment and turns to the right. Exhausted, he is back in 'thrownness', until his wife asks him why he did not take the Y-Street they just passed a second ago. This new interruption may give rise to a second 'breakdown'.

Cognitively speaking the driver for a moment lacked proper mental representations of X-Street's position, i.e. he possessed none or only 'surface' knowledge. Informed of the position of the known Z-Avenue, his mental picture of the area – perhaps in form of a zoomed airmap – taught him the whereabouts of X-Street. From that moment on he follows the direction he usually would take to reach Z-Avenu, i.e. he gets back into 'thrownness' relying on 'deep' knowledge.

This example demonstrates that breakdown situations play an important role during a learning process because of their reflectiveness. *Breakdown situations may imply the obtaining and processing of information*.

Winograd and Flores (and Heidegger) mainly base their philosophy and positions regarding systems design on a "deep awareness of everyday life". Basically, the situation of 'thrownness' plays the major and most important role in their work.

However, in relation to information science, and *IR interaction* in particular, the '*breakdown*' *situations consitute the crucial events!* A 'breakdown' is the typical situation *giving cause to IR*. From a cognitive viewpoint, a breakdown in the actual state of knowledge leads to a state of 'problem space' which, if not solved by thinking or reflection, may lead to a 'state of uncertainty', e.g. where *is* X-Street. The driver above might ask his wife about its position, e.g. non-verbally by use of a conventional gestus, or he might turn to a city-map, i.e. perform information retrieval.

Generally speaking, from a cognitive point of view, breakdown events may happen to users, intermediary mechanisms *and* IR systems during IR interaction. To users the breakdown situation initiating IR takes place in their 'conceptual knowledge', implying that they are unable to solve problems or fulfil emotional or interest-related goals. *The take-over* by the individual's subjectivity from his social/collective and historical reality, grounded in his previous experiences, happens exactly when he begins to read a book or instigates the IR system, interpreting the screen contents. As indirectly demonstrated by Winograd and Flores in their 'text processing example' (1986, p. 36–37) it is important to *distinguish* between "the network of equipment that includes my arms and hands, a keyboard, and many complex devices that mediate between it and the screen [i.e. the IR processes in our case]" *and* the potential information in the book or on the screen. In their example the mental position of the writer regarding text creation itself is very vaguely analysed. The writer is – supposedly – "in existence via interpretation .. being a manifestation of 'Dasein' within a space of possibilities, situated within a world and within a tradition" (p. 33) with respect mentally to transforming his actual state into for example a letter. But his position as to the computer interaction is distinct in their example. He is definitively in 'thrownness': "None of this equipment is present for me *except when there is a break down* [in the use of or in the equipment]" (p. 37). Their concern is to find means to make this man-machine interactive thrownness to last.

At an IR event, however, the person starts from a 'breakdown' position in his conceptual knowledge. When he looks up in a book's index or states (writes) his desire for information to an intermediary mechanism he is, in general, still in a 'breakdown' situation with respect to his information problem – but not necessarily regarding the search process itself. He may, for instance, grasp the city-map and automatically open the back of the volume because that is where indexes regularly are placed in books. His individual state of knowledge, feelings, etc. during this situation determine the further outcome – naturally under the influence of previous experiences, that is, his prevailing models of the world.

Hence, the task of IR is to bring the individual user out of his uncertainty state and close to thrownness, with respect to his *desire for information* by making him obtain information that transforms his knowledge state. Naturally, inherent in this activity are potential new breakdown situations or new states of uncertainty. Therefore, IR systems and intermediary mechanisms should be designed in such a way that this primary goal can be met. Secondly, IR systems design should assure that the *retrieval process itself* does not hamper the primary goal of information seeking. This means that the use of these processes by the searcher for information should exclude or minimize 'unforseen breakdowns' in that person's mental state. Following the nature of breakdown, such events can be applied positively to train persons about IR and the functionality of intermediary mechanisms – in a controlled manner.

In addition, such breakdowns in a user's mental state can be caused by a 'breakdown' within the retrieval mechanism's own state of knowledge, i.e. the 'Syntax Error Syndrome'. For instance, the implanted knowledge structures of the system do not recognize and 'understand' the input from the person in front of the screen. During IR interaction such situations may happen in relation to one or several of the three System Structures (Chapter 2.2.2), i.e. the

- 'active structures', e.g. IR technique or user model building devices;
- 'passive structures', such as dbs-structures or user models;
- 'conceptual structures', e.g. thesaurii, knowledge representations or texts/images in full.

From a cognitive view such 'within-machine breakdowns' are impossible to solve in 'self-generative' ways – without the involvement of humans – because computer structures *do not* contain their own 'problem spaces' and 'states of uncertainty', only 'states of knowledge' stored once.

The remaining chapters of this book are dedicated the quests and considerations concerning the support required to solve breakdown-generated information retrieval situations.

2.5 Summary statements

The cognitive point of view is seen as a highly valuable epistemological approach to information science, and IR interaction in particular, in strong opposition to cognitivism. While cognitivism provides very reductionistic views on information processing and demonstrates a limited capacity with respect to explaining mental states, the cognitive view illuminates research issues of importance to IR interaction. A consequence of this view is a variety of individual differences in the knowledge structures that are embedded in IR systems and intermediaries as well as in the user population. The cognitive view suggests we investigate combinations of such structures, their nature and properties, in order to produce adequate solutions to IR situations.

In contrast to cognitivistic positions the cognitive point of view makes the study of man its starting point and attempts to model information processing in terms of categories and concepts at a level of mental states implying the property of meaning, not simply symbol manipulation. The viewpoint may therefore establish a four-stage evolutionary approach to the development of thinking and research on information processing. These are the 'monadic', the 'structural', the 'contextual', and the 'cognitive' stages. Each new stage contains the features of the preceding one and may demonstrate the characteristics of today's level of processing in relation to, for instance, machine perception, language understanding, and IR. So far, IR research has only reached the structural level but attempts to arive at the contextual one.

The important notion is that we are moving gradually from focussing on the object and sign in a message toward the knowing subject or recipient. The meaning of a message is synthesized by the recipient out of his own knowledge. Pre-suppositions and self-generation of preferences in the mental states of individuals mediates the perception and understanding of information which is seen as a supplement to the actual state of knowledge of a person. At the cognitive level information is that which transforms actual state of knowledge into a new state. Language and social contexts are the key instruments in this process.

The concepts of representation, meaning, understanding, and information are fundamental to the cognitive viewpoint. Of importance to information science and IR
is the conception of 'information' which is seen as a manifestation that goes beyond 'meaning'. As a consequence, the information concept for information science is consolidated in terms of conditions as to when one may speak of information, and not simply of data or signs on a surface level of communication. Information is a transformation of generators' knowledge structures in form of signs which, when perceived, may affect and transform a recipient's state of knowledge. Since IR interaction deals with stored knowledge structures originating from a variety of generators, information systems only contain information potential to persons instigating the systems – not real information. Only at the event of transformation of a recipient's state of knowledge are such systems real information systems.

This conception has implications for the various sub-disciplines of information science. Basically, the qualitative aspects of information transfer and use become reinforced. In IR this understanding of information suggests we apply poly-representative means at all levels of interaction between searcher and IR system(s). Evidently, the conception leads to design philosophies that promote transparency and highly adaptive and supportive IR systems in order to improve their potentiality for use. Information science may thus be regarded as a cognitive science viewed episte-mologically from a cognitive point of view. However, the complementarity between socio-behavioural dimensions and individual cognitive aspects of information transfer is of importance, with IR research and systems design showing a stronger affiliation to the cognitive-linguistic fields – but not excluding the social dimension. Informetrics and information management demonstrate the opposite reliance.

The growing interest in human issues in relation to design of information systems as well as an increasingly holistic approach to IR interaction makes it relevant to analyse the similarity of hermeneutic and cognitive concepts. The major difference is grounded in the individual-centered and subjective position taken by the cognitive viewpoint. Notwithstanding, the conclusion is that strong similarities exist between the hermeneutic concepts of meaning, pre-understanding, horizon, the hermeneutic circle, and cognitive notions of meaning, pre-supposition, actual state of knowledge, and transformation of mental states by state of knowledge. The hermeneutic concept of interpretation can be regarded as a premiss for mental representation in a cognitive sense, including situation or event-based, practice-related representations, not being limited to results of 'detached contemplation' only. 'Thrownness' is regarded as an ideal situation. But conceptual and individual 'breakdown' situations are seen as the crucial event in IR interaction, providing the fundamental cause for IR instigation.

3. INFORMATION RETRIEVAL

Information retrieval is concerned with the processes involved in the representation, storage, searching and finding of information which is relevant to a requirement for information desired by a human user. Information is understood to be as formulated in the previous chapter.

In Chapters 4 to 7 three basic R&D viewpoints to IR are discussed. An introductory summary of their characteristics is given in Chapter 3.2. The subsequent concepts and problem areas of general importance to IR and it evolution across these research viewpoints are: *aboutness*, types of *representation, relevance*, and *evaluation.* These areas are introduced in the sub-sections below and further discussed in detail in the relevant chapters in relation to the various research approaches.

3.1 Essential issues in IR

As such, IR is the core research field in information science (Järvelin and Vakkari, 1992). The objective is to study and understand IR processes in order to design, build and test retrieval systems that may facilitate the effective communication of desired information between human generator and human user.

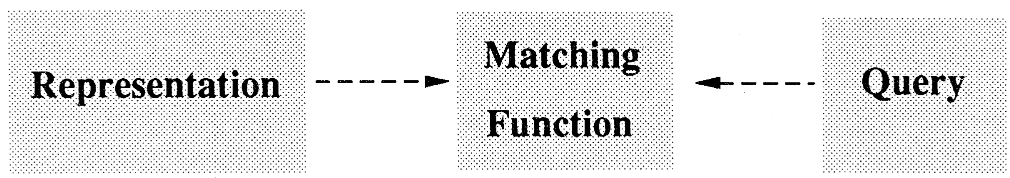


Fig. 3.1. Simplest model for information retrieval.

Traditionally, information takes the form of text, implying that IR is synonymous with document or text retrieval, regardless of whether we are talking about full-text, administrative, directory, numeric or bibliographic information. In recent years the

IR landscape has been extended to multi-media environments concerned with storage and retrieval of images, graphics, sound, software components, office documents, etc.

The most simple model for IR is shown in Figure 3.1 To the left potential information is represented, for example by itself, index terms, graphical structures or category codes as well as formal data. To the right a requirement for information is represented by a query, in natural language or in an artificial query language. In the centre a matching function compares representations with query and retrieves text entities, e.g. documents or parts of documents, that provide the information that the user seeks.

Essentially, the problem is to find *that information* in the form of text(s) and other media which optimally satisfies the user's state of uncertainty and problem space. Hence, some texts are more relevant to a specific requirement for information than other texts, and a specific text may have different significance to several information requirements.

Although IR is mainly concerned with information in the form of document text, i.e. bibliographic or full-text IR systems, three basic and inter-related problem areas are of importance to *all* IR processes, including multi-media retrieval, IR theories, and R&D approaches:

- Aboutness
- Representation, the types involved
- Relevance and evaluation

3.1.1 Aboutness and representation

Fundamentally, *aboutness* refers to the question: 'What is this document, text or image about?' Gradually moving from the left to the right in Figure 3.1, different understandings of this concept evolve.

Inherent in Salton's and similar researchers' information concept, aboutness is associated with content bearing units in the text, generated by the author (Salton, 1968; Salton and McGill, 1983). Consequently, one may represent information by single terms derived directly from the document itself. This is called *author aboutness* and forms the basis for theories concerning automatic indexing and matching techniques, providing simple representations of authors' modified states of knowledge. One may notice that the logic, algorithm or rule itself, which determines this automatic *extraction*, introduces an element of distortion and reduction of the author's original intentionality and knowledge state: that of the knowledge state underlying the logic or rule. This is the common method of natural language representation (NLR). From a cognitive viewpoint this single-term mode of representation is placed at a monadic level. By means of additional automatic support from a domain dependent thesaurus the resulting representation may form a semantic structure at a structural level. We are here clearly combining two kinds of transformed states of knowledge: that of authors and that of the thesaurus designer, e.g. a domain expert. The author aboutness has been extracted and conceivably *modified* into a controlled vocabulary structure. A similar way of approaching aboutness, but of a slightly different scope, is to focus on the process of representation. In this case, the question of what a document is about may be answered by an indexer who, by means of classification or indexing of documents, attempts to *summarize or surrogate the contents of the message* in each document or piece of text. The opinions or *meaning*, not necessarily the informativeness of the original text or picture, are analysed and mixed with interpretations by a human indexer's state of knowledge. This implies the *assignment* of representative terms which, as above, may be translated into a controlled vocabulary and extended by means of a thesaurus structure.

This *indexer aboutness* has theoretically an advantage over the 'author aboutness', because the role of the indexer is to create *unified* interpretations and representations of the meanings of contents. The indexer is in general supposed to possess knowledge of the domain in question and the body of literature, applying classification and indexing rules that mirror the issues and terminological structures of the field. Faceted classification systems, traditional thesauri, and controlled indexing vocabularies are typical instruments in this process of representation in IR. Note that classification implies to *arrange together* texts with similar 'indexer aboutness', while indexing means to *separate* texts by pointing to their specific aboutness. A typical problem for this kind of representation is *indexer inconsistency* or 'inter-indexer consistency', i.e. the same text is classified or indexed in various ways by different indexers (Cleverdon, Mills & Keen, 1966)(Jones, 1983).

In modern, commercial IR systems 'indexer aboutness' is the dominant approach to the retrieval of information. This is then combined with natural language extraction from titles and abstracts, i.e. author aboutness, in form of inverted files. The assumption behind the former is that indexers and users share similar vocabularies and that science, society and needs develops slowly or ought to be of a rather static nature. The assumption behind the latter is that authors and users share similar conceptual representations of a domain which may evolve more dynamically. It is in this sense that we may talk about 'document' or 'text retrieval' – not really 'information' retrieval. A detailed review of the relationships between aboutness and indexing theory in IR is given by Wormell (1984). Here, Wormell also touches upon the problem of loss of information, inherent in all present IR models of representation. Kemp (1988) refers to the correlation in a knowledge retrieval framework.

A typical epistemological approach to indexer aboutness in scientific domains is to introduce so called 'objective representation' (Hjørland, 1992). The underlying assumption is that an 'objective conceptual truth' must exist and can be found within every field or scientific domain. A well-skilled indexer (or intermediary) *knows* per se this 'truth'. Apart from knowledge of evident scientific truth, e.g. the melting point of ice, the problem is simply to find this god-like domain supervisor who, from a cognitive viewpoint, cannot be completely objective but constantly subjective as conceptual interpreter. However, at a structural meta-level one may naturally possess definitive ideas about scientific views, conceptual aspects and evident situation-related facets of a domain which may prove useful during the assignment of representative concepts.

In relation to IR theory development, however, in 1979 K. Sparck Jones already states that the whole idea of representation of meaning seems dubiously relevant to IR in anything like its present form. "Therefore it seems right to think in terms of 'aboutness' rather than the representation of meaning".

This demonstrates an understanding of information similar to the author's information concept, discussed in Chapter 2.2. Sparck Jones' 'aboutness' clearly refers to a 'user-related aboutness', as originally proposed by Hutchins (1978). His concept incorporates the user's context which is variable and often ill-defined. '*User-related aboutness*' implies a more realistic and changed general attitude towards representation. Hutchins suggests that the purpose of indexing should be to indicate the 'aboutness' of documents in terms of *what knowledge they presuppose* in order to be used. The idea is that the user can express what he knows, but cannot define the state of uncertainty and problem space in terms of information, the nature of which the user does not yet know. In short, the user can produce a nut-shell, not the nut sought for.

Hutchins' and Sparck Jones' views of IR are reflecting a more comprehensive approach to IR theory development in which generators' (author, designer, and indexer) as well as individual users' state of knowledge plays significant roles. In association with Hutchins' aboutness concept, Wormell argues that inherent in this concept a conflict exists between what readers regard as the aboutness of a document and what indexers define as its aboutness (Wormell, 1984). In order to minimize this conflict and to obtain *general ideas* of which kinds of knowledge a particular IR system should presuppose to accomodate its users, one may suggest carrying out *empirical investigations* of potential users' preferences, as suggested by Ingwersen and Mark Pejtersen (1986). In addition, knowledge of such preferences may guide the functionality of an intermediary mechanism which models and serves *the individual* needs. Chapter 6.3 outlines a variety of field study and evaluative methods. A final concept of aboutness, not associated with documents, might be called *request aboutness*, i.e. what the request is about. In relation to the aboutness problems we have moved from the left to the right, and beyond the query, Figure 3.1, and into the problem space of the user – from document or text retrieval into information retrieval.

In relation to this tri-partite differentiation between author, indexer, and user aboutness, Soergel has presented a more simplistic distinction concerning aboutness and indexing (1985). He operates with two concepts: document-oriented and request-oriented indexing. Soergel does not seem influenced by either Sparck Jones' or Hutchins' ideas and well-argued theories. The document-oriented mode of representation implies extraction from texts as well as assignment of indexing terms, e.g. from controlled vocabularies or by means of 'objective indexing'. The request-orientation means to employ a *user-generated*, preferred vocabulary, e.g. obtained via empirical analyses. This user-driven approach to representation has actually been applied in a large-scale experiment carried out by Mark Pejtersen 1979–1986. The research was based on term associations generated by users and applied as indexing terms representing fiction in a larger database (1987). The real-life test results of these experiments are reported recently by Mark Pejtersen (1991). As emphasized in the previous chapters, these test results also demonstrate that the question of method of representation is not answered by an 'either – or', e.g. by elucidating the user-oriented mode as *the* method to apply. The answer is 'poly-representativity', i.e. a combination of methods – and the problem is to define the adequate one in the given IR situations.

Representation of potential textual information may take two fundamental forms: 1) a '*formal' type* which in document retrieval is called ''bibliographic data'; 2) a '*topical' type* concerned with what a document is about. The first type contains facts in relation to the generation of the text and the media carrying it. For example, author names, date of publication, number of pages, publisher, journal name, document type, etc. Under other names, such exclusive and formal attributes are also found in multi-media and office environments and are characterized by having only a vague or no relation to what the text is about. Instead, such attributes are concerned with *isness*, i.e. what the objects in a system is or has of physical or other values.

The 'topical' or conceptual type of representation and its problems, e.g. of aboutness or of relationship to adequate matching functions or techniques, is in general the core area of study in IR (see Chapter 4). Traditionally, topical representations of documents combine their text, titles, abstracts, and assigned indexing terms or phrases to form the so-called inverted basic index. In both commercial and experimental text IR systems topical searching can be carried out either in the basic index or in the individually inverted topical fields. Each bibliographic data type forms its own exclusive and inverted index. In total, document or text-based IR systems operate with a linear text file and an *inverted file structure.* The advantage is very high retrieval efficiency when using Boolean matching functions. Common Command Language (CCL) is the standard commercial search language. In contrast, most fact and administrative retrieval systems apply *relational file structures*, developed as database management systems (DBMS) for reasons of efficient retrieval of formal and exclusive data structures, and using Sequential Query Language (SQL) – also involving Boolean logic. The reason for stressing the difference between formal and topical representation and the two retrieval architectures is the fact that the somewhat archaic nature of inversion is only vaguely known to advanced computer engineers. They are mainly trained in formal data structures and their retrieval problems. Although *aboutness* is fundamentally *different from isness*, and retrieval from the same basic index of several individual terms logically combined is highly efficient in large-scale inverted bibliographic databases on mainframes, it is only with the introduction of integrated full-text office information systems that IR theory and techniques, methods for topical representation, (and the advantages of inverted files), are becoming obvious to a wider audience. As long as a text retrieval system may retrieve and display the texts, e.g. letters or memos, only by means of exclusive, formal representations like author name, date, recipient, address, etc., DBMS structures are sufficient and the retrieval problems involved exhibit characteristics only to a degree overlapping issues dealt with in IR research. One of these commonly shared issues is the nature of users' needs for information.

3.1.2 Relevance – the Dark Matter problem in IR

In a very recent article, C.J. van Rijsbergen touches upon the relationships between *aboutness* and *relevance in IR,* relevance being defined as "the measure or degree of a correspondence or utility existing between a text or document and a query or information requirement as determined by a person". The person being the inquirer of information. Rijsbergen emphasizes:

> If a document contains information about X then it is likely to be relevant to X ... The process of locating relevant documents (however), is inherently uncertain, it is also highly context dependent. The uncertainty enters in a number of ways, firstly through the aboutness, (where) it is only possible to determine that a document is about something to a degree, hence our probabilistic models, secondly, whether a document is relevant to an expressed need is also a matter of degree. Finally, a document is about X with the probability α, it may or may not contain the information X (1990, p. 24).

The latter relevance problem refers to a text (or an image, as in the Mark Twain Painting Case, Chapter 2.1) with author aboutness X, e.g. General Lee sit on a horse. It may contain information X, e.g. that Lee likes horse riding, but this fact may only be established by inference through a context, for instance as provided by a dynamic thesaurus, added semantic values, knowledge by the author of the user, or by the user himself. Hence, relevance is ultimately a value of pragmatic nature, linked to the individual user's problem space and state of knowledge. This gives rise to methodological problems in relation to *evaluation* of models for IR as a whole, of representation and IR techniques as well as across systems. Chapters 4.5 and 6.3 will discuss these issues further.

A fundamental and intriguing characteristic of IR is that its effectiveness – within the limits of present theories and IR models – is far from 100 %. One must here keep in mind that patent retrieval requires either zero or 100 % recall of information. The searcher, the IR system, and the IR researcher, 'does not know what he does not retrieve' – and will never know it. This absolute *retrieval uncertainty*, stressed by van Rijsbergen above and inherent in the cognitive viewpoint, may constitute the only original universal principle in information science.

Essentially, this is the *Dark Matter problem* in IR. This metaphor originates from Astronomy. The expression signifies that matter in the Universe which cannot be directly observed by today's instruments, but which can be detected indirectly because of the deflection of light from very remote galaxies passing intermediate galaxies. The deflection is caused by the mass of the intermediate galaxy, but is found to be larger than expected. This discovery indicates that an additional portion of matter exists which influences the deflection but cannot be observed, i.e. the 'Dark Matter'. Similarly, in IR we may observe what we retrieve, but all experiments and observations inform us that some potential information of relevance to a given request resides out there in our information systems, information we cannot get at. Recall ratios tell us about the size of Dark Matter, but not its nature. From a cognitive point of view Dark Matter in IR may take at least two forms: first, as that potential information which *explicitly* holds subject matter of relevance at a given moment, but which is not retrieved because of lack of, for instance, a proper thesaurus; secondly, as that potential information which is *implicitly* present in documents, that is, that information X which is not directly contained in a document, but via perception might be 'read into it' by interpretation of a recipient, e.g. 'the General is a smoker'. The latter form of Dark Matter is by its individually-based nature the most difficult to retrieve and evaluate. Chapter 7.5, on contextual IR, will discuss this problem in more detail.

3.1.3 Simplistic IR interaction

In the light of the information concept for information science outlined in Chapter 2.2, this general discussion of the problems of aboutness, representation, relevance, and evaluation makes it obvious that IR and IR research are much more complex than demonstrated by the model in Figure 3.1. For example, 'user aboutness' is associated with processes leading up to generation of a query occuring *outside* the model, and interactions between the major components taking part in retrieval are only implicitly expressed.

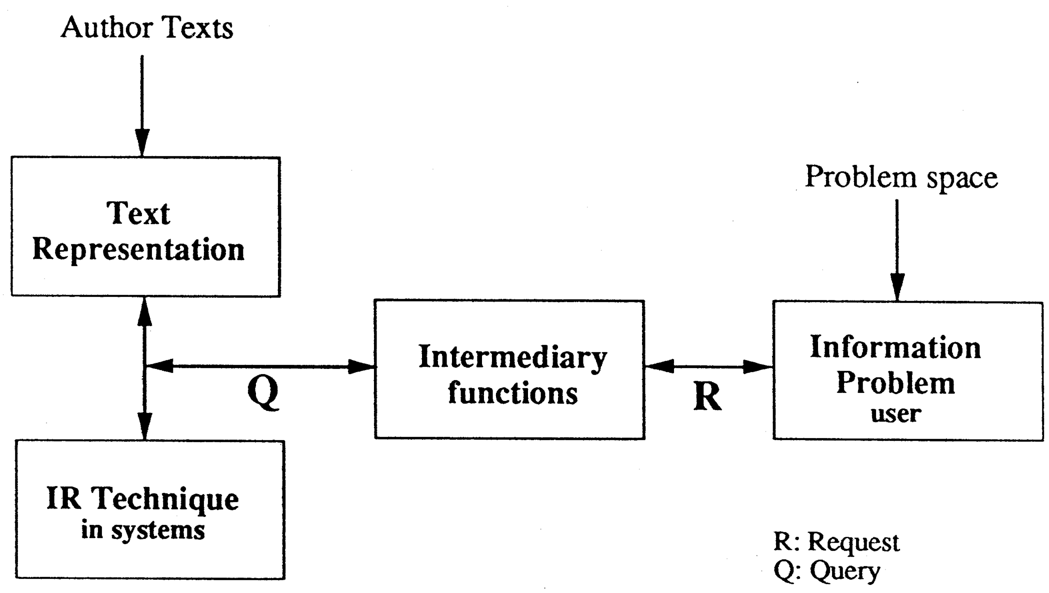


Fig. 3.2. The information retrieval system and simplistic IR interaction. (From Ingwersen and Wormell, 1989, p. 80).

The more encompassing model in Figure 3.2 (Ingwersen & Wormell, 1989, p.80) derives from Ingwersen & Mark Pejtersen (1986, p. 113) and displays these components and the interactive IR processes involved – in line with the understanding of IR and information science demonstrated in the Figures 2.1 and 2.3.

In the upper left-hand corner of the figure we have the *author texts,* i.e. transformations of authors' states of knowledge. Through analysis by a human indexer (or by automatic text analysis) these texts are represented in some particular form, for instance by some bibliographic data, e.g. author name and date, as well as by topical attributes like title, abstract and index terms. The form of *text representation* is dependent on the rules for representation and the IR technique(s) that are built into the system by its producer.

In the lower left-hand corner we have the *IR technique(s)* that determines the search logic for the system. As mentioned, in the commercial IR systems this technique is Boolean, incorporating the use of proximity operators that make it possible to search applying composite concepts. More advanced techniques, directly influencing representation and searching, are still under investigation and development (see Chapters 4.4 and 7). For each entity of potential information generated by an author, representation implies processes of *IR interaction* between the indexing rule structures, the impact of a particular IR technique, and the entity of information interpreted by the state of knowledge of the indexer (mechanism).

In the middle the *intermediary functions* consist of the entire system's capacity to understand and support the information problem or need of the actual user as well as the search possibilities and logic of the source system. These functions are outlined and discussed in detail in Chapter 8. They form part of the professional knowledge of the human intermediary (librarian/information specialist), or may be skillfully adapted to a front-end to the system as a user interface, in order to support retrieval.

At the right-hand side we have the user's *problem space*, e.g. as part of a process of interest fulfilment of problem solving. If not solved by the user himself, this 'problem space' may lead to an *information problem*, i.e. a state of uncertainty (see Figure 2.3), that results in a *request* for information, often formulated to an IR system.

Interactions may take place between intermediary and user in relation to the desire for information, i.e. its isness and aboutness, whereby request reformulations may occur. The *query* denotes reformulations (transformations) of the request(s) for information, according to the logic of the actual IR technique and the representations, processed by the system or the user at search time. Also at search time, interaction takes place between IR technique and representation in association with user request variations and query reformulations.

The model demonstrates a complex system that is undergoing constant development and change. It also serves as a framework for the discussion of the development of the two major approaches characterizing R&D in IR since the fifties, summarized in Chapters 4–5: the *traditional* (or classic) *approach* and the *user-oriented approach*. In addition, the model puts into perspective the changes taking place in the mid-eighties where the two prevailing research approaches tend to merge, turning into a *cognitive* one (Chapters 6–7).

3.2 Major IR research approaches – an overview

T. Saracevic, chief-editor of one of the core IR research journals *Information Processing and Management*, has described the change from the classic, traditional approach to a more cognitive one by stating (1987, p. i–ii):

> [The work] by a whole group of scholars is not only a description and a suggestion of a particular model – but even more so – a statement of a paradigm of an emerging and desired direction for research on information systems. It incorporates and merges into one context the research approaches in information retrieval (IR) within information science, on the one hand, with the research approaches on expert systems (ES) within artificial intelligence on the other. This IR-ES paradigm, although related to both areas, is also quite different from the ones found in 'classic' information retrieval and 'classic' experts systems research. This is an significant change particularly for the community of scholars in information science. Of course, time will show if this new paradigm will lead to a success. However, what this already demonstrates is that there exists a core group of scholars challenging the established problem definition and approaches in a research area covered for close to a quarter century by this journal. This is how it should be in the ways of science.

Already in 1983, however, Belkin states that IR research in general "appears to be moving from ad-hoc, technical, mechanism and document oriented views of problems to principled, integrated, interactive and human views of problems". This is the overall pattern displayed from 1950 to date for theories in IR.

In short, the focus of the 'traditional' IR research approach is on developments only associated with the left-hand side of Figure 3.2 – or the entire Figure 3.1. The more recent 'user-oriented' approach concentrates its R&D efforts on the centre and right-hand side of the figure, i.e. the human components in IR. The 'cognitive' approach develops around a unifying holistic understanding of the interactions and inferences of *all components*, that is, all states of knowledge, involved in the total model.

In order to track down the changing attitudes applied, the research goals and results obtained in these three major approaches to IR, Figure 3.3 elucidates their major attributes in relation to the following four core issues, i.e. their

- *Research aims and foci;*
- *Types of results and consequences;*
- *Understanding of information;*
- *Use of supporting disciplines;*

Aim and foci:

The fundamental aim for research in IR shifts from maximisation of retrieval performance by means of refinements of IR techniques and methods of text representation *within IR systems* to maximisation via understanding of user behaviour and information need representation during retrieval.

The traditional view stresses the importance of the capability for evaluation of the various techniques and means to representation in a controlled, scientific manner, i.e. in the form of laboratory tests. This research community reaches for a unifying mathematical-linguistically based theory for IR. This desire seems constantly to be ineffective.

The user-oriented group of researchers, in contrast, do not consider the IR matching techniques, but rather knowledge of user behaviour, to be the key solution to successful retrieval. One may here notice that while the classic research already by the seventies quits the exact match technique as a possible solution, the user-driven researchers from this time on base their research on this matching environment only. They are forced by their user investigations in 'real-life' (online and library) environments. However, these researchers rarely take into account the matching functions invented by the classic approach.

	Traditional	User-oriented	Cognitive
Aim & Foci	Refinements of IR techniques Methods of representation Controlled scientific tests Problems of relevance Request equals Query	Understanding user behaviour & information needs Real-life investigations User modelling	IR as a process involving cognitive states Complex interaction Cognitive domain & task modelling Knowledge-based IR
Results, Consequences	Ad hoc solutions Partial match techniques Automatic classification fails Parsing algorithms in text analysis Multi & Hyper-medie appl.	User models, types User-intermediary interaction Simplistic interface design Search interviewing models ASK hypothesis Monstrat Model	Intermediary design Intelligent IR Support-adaptive IR Unifying IR theory Semantic values, plausible inference Mediator Model
Understanding info.	Scientific information only Scientific users	Information regarded vital in society, incl. fiction Users from all societal levels	Info. supplement to user's understanding of the world Individual variety
Support	Mathematics, linguistics computer science, AI	Cognitive psychology, psycho-lingustics Sociology	Cognitive sciences, Sociology AI <-> IR

Fig. 3.3. Condensed overview of IR research approach characteristics.

This contradiction is in recent years beginning to be overcome by merging traditional IR models with user-oriented research results into more complex and interactive solutions, building up to an improved understanding of IR as a process involving cognitive states.

The aim is to model and design knowledge-based interactive IR systems. So far, one may visualize one design approach leading towards 'intelligent IR' models using expert system architectures, and another trend moving toward supportive and adaptive intermediary design.

The danger is to stay satisfied with an 'intelligent IR' approach solely concentrating on limited expert system-like solutions. The challenge is to face the paramount complexity in 'real' IR situations, with heterogeneous domains, users, and commercial IR systems, the latter still exclusively applying exact match techniques.

Results and consequences:

In the early eighties the classic approach has achieved its maximum point as to defining and testing a variety of *ad hoc* solutions in the form of partial match techniques and hence also methods of representation. The techniques, for instance probability, clustering and vector-space, remain on a monadic and structural level – seen from a cognitive point of view. On the other hand, the user-oriented community actually produces certain models which, although rather monolithic and mainly anchored in the exact match environment, display a degree of complexity and understanding of users as well as information need and problem development that make them useful for advanced design purposes. See for instance the Monstrat Model, Chapter 5.4.1.

One may here state that exactly at the same time, the mid-eighties, AI research turns to interesting application fields. One of these is IR, mainly because knowledge-base building and structuring, e.g. in expert systems, may require retrieval technology, and because searching for information in textual form is an intriguing affair. From now on, a mutual interest exists between AI and IR researchers to cooperate. By doing so, AI research does not have to re-invent thesaurii, faceted classification, various indexing methods, etc. These are exported from the IR community. The import from AI consists of models for design architectures and NLP methods used in text analysis. The cognitive aspects of interface design and retrieval become a meeting point. As such, the Mediator Model, Chapter 8, can be seen as a result of mutual exchange of knowledge IR and AI in between. A fruitful example of AI-IR bridging and cooperation has recently been published (Wormell, ed., 1988). Basically, the Weak AI solutions are the preferred models for development, in general because the Strong AI cards seem already played and used up by the classic IR approach during the preceding period.

One may argue that in certain aspects the benefit from the AI-IR cooperation is more on the AI side than given to IR, since several advanced and sound IR projects, at least in Europe, are headed and carried out by AI companies and university departments. Very crudely, one may say, with a paraphrase of B. Cronin, that most of the IR research in particular, and in information science in general, has been and is carried out by *interested visitors* from other fields. Only time may show whether IR research under a cognitive umbrella will be totally taken over by computer science as one of many application areas.

Understanding of information:

In view of the last statement, this problem of information may turn out to be the more challenging to present and future IR research, regardless of which discipline it is performed in.

In the traditional or classic sense information was (and is) scientific, domain-specific information – or better – knowledge. This view made text representation more controllable, less problematic. With the user-oriented attitude the information concept was opened up to include all kinds of generated potential information, ranging from scientific texts to newspaper articles. Information comes to play a vital role, not only in the scientific community, but in society (see Chapter 1.2.1). Evidently, this wider context for information influences simultaneously the view on users. They become diversified, in knowledge as well as in relation to their information needs and underlying interests or problems. IR may therefore be seen as one of several tools for problem solving. In addition, the IR process itself is seen as a problem solving and goal oriented activity. This issue refers back to the 'breakdown-thrownness' states during IR (Chapter 2.5). The cognitive view emphasizes the importance of information as a supplement to users' understanding of the surrounding world when in a state of uncertainty. Knowledge-based IR is consequently an interactive and adaptive process, supporting the actual user's cognitive states.

Supportive disciplines:

From being dependent on lingustic and logico-statistical theories, IR takes advantage of psychological and sociological methods in the user-driven approach. With the emerging AI-IR relationship cognitive science disciplines come into use. The new aspect is the transfer of models and methods to other fields, e.g. in relation to software reuse (faceted systems → case frames), expert knowledge acquisition (online IR models), office automation (text retrieval methods), etc. In parallel with the emerging AI-IR developments in a cognitive direction, epistemological issues begin to occur in IR research attitudes. In the classic approach the rather rationalistic and positivistic position never became (and still is not) an issue. However, in particular from the mid-eighties, both the user-oriented and the more AI-related research work have come under pressure from various angles. The rather individualistic user-orientated view comes under attack from a more behavioural and socio-logical oriented part of the research community. This seems at present to go hand in hand with anti-cognitivistic trends, mainly based on hermeneutic arguments.

Hence, it is important to emphasize 'the middle road' position of the cognitive viewpoint in relation to IR, in forceful opposition to Strong AI and cognitivism. The cognitive viewpoint attempts to unify the results produced by the rationalistic and traditional approach on the one hand, with the advantages offered by socio-behavioural positions on the other hand being without, however, confined to a totally hermeneutic research style. The existing complementarity between the epistemological cognitive viewpoint and the more sociological attitudes may in future contribute to further understanding of IR.

4. The TRADITIONAL IR RESEARCH APPROACH

This classic approach to IR reaches far back into the history of library and information science. It has its roots in the first keepers of registers in early human history and is heavily influenced by the current type of recording and information processing technology: from parchment and paper to electronic disks, and from manual copying over printing into computerization. Already in Roman times it was familiar to separate the storage order of manuscripts on shelves from the order of author and subject entries in catalogues. In the Middle Ages simple classification and indexing of manuscripts took place (Witty, 1973) and, as pointed out by Umberto Ecco (1980), such classification systems mirror the socio-philosophical understanding of the world, its ideas and knowledge – like today. The mysticism associated with the work of 'keepers of books' originates mainly from such coding schemes and subject 'labyrinths', which only an alphabetical key makes accessible for others than librarians.

With a changed attitude in society towards the use of information and the access to scientific knowledge, mainly in North-Western Europe and in USA, the role of librarians and documentalists shifted towards the end of the last century. Libraries opened up their shelves and the core abstract journals in physics, chemistry, medicine and engineering begin to emerge. The overall goal of IR – to ease the users' access to and the availability of information in documents – is established.

Up to the mid-seventies in this century, however, all researchers concerned with IR focused on (scientific) documents, their content, and how to relate them in a proper way – not on their users. Simple or advanced, 'marking and parking' of documents or their surrogates became the objective in IR. Consequently one may state that this approach, which also could be called the 'system-driven' or the 'document-driven' approach (Ingwersen, 1988), forms a dominant tradition of *paradigmatic* force in IR research.

In retrospect it is interesting to observe that this tradition produces its best results concerning theories of representation, when still linked to the paper tools but under pressure from the emerging computer and online media after the fifties. It is in this period – the fifties into the seventies – that indexing comes of age and develops into practice based on theory. First, with the computer age, advanced retrieval techniques come into focus. However, it is also the computer technology itself, aided by the demand for information in society – not documents – that shakes the approach in the eighties. Modern information technology makes transparent the 'garbage in – garbage out' syndrome in IR.

Notwithstanding, one must keep in mind the outstanding results which the traditional approach has achieved – and still does on a minor scale. Under the influence of progress in linguistic text analysis and AI techniques some traditional IR researchers keep up their spirits. As A. Smeaton optimistically put it at an ESPRIT II research meeting (1990): "Super indexing makes perfect retrieval!".

In contrast, B. Croft describes the theoretical situation (1987, p.249):

> ..there have been many advances in the field of IR (in the last 30 years), but some fundamental issues remain unsolved. To put it simply, we do not know the best way of representing the content of text documents and the users' information needs so that they can be compared and the relevant documents retrieved. We cannot even agree on a definition of relevance. Statistical approaches to the analysis of text and retrieval of documents have significant advantages in terms of efficiency and performance relative to other techniques (Belkin and Croft, 1987), but one need only look at the absolute performance levels measured in terms of recall and precision to see their limitations. Dissatisfaction with the current state of affairs is one of the two major factors in the recent upsurge of interest in intelligent IR. The other factor is the increasing awareness of the importance of IR as an application area, brought about by the proliferation of systems that handle text and multimedia documents (van Rijsbergen, 1986).

In the traditional approach the following characteristics can be demonstrated:

1. *Aim and foci:*

   Study of text representation (classification, indexing, natural language processing) theory, retrieval techniques, and mechanical components of sources and systems in laboratory settings.
   Emphasis on maximisation of retrieval performance by means of comparisons of techniques, theory and experimental design in a controlled manner in database test collections.

2. *Type of results and consequences:*

   Ad hoc-based refinement of methods and models for text analysis, representation and IR technique.
   IR is understood as a paradigmatic process, i.e. that systems designers, indexers and authors, as well as searchers (i.e. human intermediary and end-user) *per se* do share similar scientific views, terminology, etc.

3. *Understanding of information:*

   Information understood as scientific information (and associated with meaning of text).

4. *Use of supporting disciplines:*

   Linguistics, mathematics, logic, and computer science as basic supporting disciplines.
   Text linguistic (syntactic) methods applied to problems of representation; mathematics and computer science, including AI in recent years, are related to (theory and) design of components and IR techniques.

Associated with the traditional R&D approach one may easily observe the influence of a variety of underlying research traditions. Theory building in relation to classification of document contents has constantly been attempted based on an *ontological* tradition (Vickery, 1975; Boyd Rayward, 1992). Theoretical and applied issues concerning indexing and IR technique development have basically been founded in *linguistic* traditions or approached from a *logico-statistical* perspective.

Very recently, Blair has put forward strong arguments, from a philosophy of language standpoint, against the traditional way of thinking on information retrieval, and representation in particular (1990). In addition, he warns against the assumptions underlying the development of the variety of IR techniques discussed below in Chapter 4.4. Essentially, he suggests avoiding assumptions guided by questions like "what does an expression *mean*/signify?". Instead he advocates asking: "how is an expression *used?*" (1990, p. 136). One may observe certain similarities to the problems addressed concerning aboutness, in particular the problem of user-aboutness (Chapter 3.1.1). A further discussion of Blair's context-based position in relation to IR, but essentially limited to representative issues, is carried out in Chapter 7.5.

In order to understand the basic problems faced by the traditional mainstream tradition in relation to *representation*, we may briefly look at theories and developments in classification, indexing and natural language processing. This is followed by an outline of the major *IR techniques* and a brief discussion of relevance adhering to this tradition, in Chapters 4.4 and 4.5. A summary is provided in Chapter 4.6.

4.1 Classification theories

The great universal classification systems, e.g. Dewey's designed in 1876 for shelf ordering purpose in libraries, and UDC constructed by Otlet and La Fontaine in the nineties, attempt to categorize all (scientific) knowledge stored in documents. These and other derived systems are still in use and under constant development. In relation to aboutness it is interesting to note that several universal classification systems applied to public libraries are in fact either off-springs of the pure scientific ones, or, as in the Danish case (DK5), is a hybrid between Dewey's original system, UDC and the organisation of scientific disciplines at Copenhagen University before World War II.

Major characteristics of any classification system are that classes must be mutually exclusive and the system must be exhaustive within its domain, so that any document can be placed in one distinct category. As the world changes around the system it becomes more and more difficult to classify new topics and concept relations.

In the fifties and sixties faceted classification theories appear, initiated by the Classification Research Group, UK. These are based on the subject categories in the body of literature concerning a domain, e.g. in engineering or the natural sciences (Foskett, 1962) (Vickery, 1975), and more universal in the Broad System of Ordering (BSO) (Coates, 1983). They all adhere to the famous universal facets – PMEST (Personality, Matter, Energy, Space, Time) – by Ranganathan (1952). Faceted classification, also incorporated in UDC, implies a specific order (e.g. decreasing complexity) of facets in a string.

With the introduction of the computer, several attempts at automatic classification have been made without profound success (Sparck Jones, 1976), and classification expert systems are currently under development (Sharif, 1988).

In terms of aboutness the advantage of faceted classification is that several aspects (instead of one) of the contents of a document can be made searchable. We are here close to actually indexing the document.

Following these lines of IR research, a comparison between for example Ranganathan's or Vickery's facet schemes, and Fillmore's (1968) linguistically-based case grammar, or Lindsay and Norman's LSD scheme (1977), demonstrates intriguing similarities which in the eighties are explored in order to design retrieval systems, e.g. based on morpho-syntactic text analysis and probability (Smeaton, Voutilainen and Sheridan, 1990).

4.2 Indexing theory, controlled vocabulary issues

Indexing theory has in general developed around two concepts: use of a controlled vocabulary, or use of natural language inherent in the document text, or a mixture of both.

With respect to *controlled vocabulary,* A.J. Foskett's work on subject indexing provides a review of theories and methods at the edge of automation and commercial online retrieval (1971). This is followed up by F.W. Lancaster (1986b). The theories (and the technology) suggest a string of predefined terms or keyword phrases that typically represent the indexer aboutness of a document. A document with the title 'Danish exportation to India', mainly on butter export, might be indexed: *Denmark; Export; Butter export; India.* Today's commercial online bibliographic databases run on this type of representation, invented in the sixties to be applied to printed reference tools. In the online databases we may talk of post-coordinate searching for documents, since the term coordination, i.e. the query structure, is made at search time. In printed tools, this structure is pre-coordinate, i.e. the four keywords exemplified above, possibly only in form of single terms, together with other sets of four keywords representing other documents, form a permuted index always headed by one of the four terms. The remaining three terms create a *context* in the printed index which serves to disambiguate the meaning of the entry for the searcher. As may be observed, the example demonstrates that disambiguation is difficult: Who exports to whom? Albeit, most commercial systems have gone no further – for economic reasons.

From a theoretical viewpoint, H. Spang-Hanssen argued the concepts of 'roles and links' (1976), based on linguistic cases and other linguistic means. Commercially, this theory has only been made available in certain chemical databases for chemical compounds.

The only commercial general-domain retrieval system actually attempting to solve this problem is the British National Bibliography (BNB). Based on intensive research, Austin developed the PRECIS system for the printed version of BNB (1974), containing a large controlled vocabulary and applying syntactic roles (prepositions) which, in the *human indexing* process, are used to form the string(s) automatically, representing monographic documents. For example: *Denmark; Butter export to India.* However, in an online situation the roles are lost, except in the record display.

The advantage of representation using controlled vocabularies should be that (the content of) new documents can be linked to old ones by consistent use of terms. It is the combination of terms at search time which separates documents or sets of documents. However, the theory presupposes that searchers as well as indexers share the same vocabulary, also with respect to any new concepts that become translated into old ones. This assumption may be dubious. For instance, the query posed to our example above should not be expressed by the terms 'exportation' or 'Danish export', but by 'export' or 'butter export' and 'Denmark'. From a cognitive viewpoint this assumption of vocabulary concordance may only be justified for a limited period of time in confined domains among smaller groupings of collective cognitive structures.

As a proof, also stated in Chapter 3, *indexer inconsistency* occurs, i.e. that only from 10 to approx. 80 % of the index terms added to the same document by different human indexers are similar or identical, mainly attributable to the presence, completeness and stringency of decision rules for applying index terms (Cleverdon, Mills and Keen, 1966), (Jones, 1983) and depending on the source field in the document the indexers rely upon (Tell, 1969).

If *user-aboutness*, including simple weighting of major aspects, as well as roles and links, at least to some extent, should have been introduced in the example above, it might look like Figure 4.1.

As one may observe (Figure 4.1), this solution provides several additional access points for potential users, e.g. 'import' or 'Danish butter', and improved understanding of the content in the full-text document on the display. Given that user's query contains roles and links, non-relevant documents on 'Indian export to

Denmark' are avoided. In addition, this solution is also extremely expensive (time-consuming) to carry out by human indexing – and hence, with the exception of simple weighting, never applied commercially.

Denmark(a)(l')(x); Danish export(ac)(x); Export(ac)(x); Butter(o); Butter export*(ac)(x); Danish butter export*(ac)(x); Import(ac)(z); India(a)(l)(z); Danish butter(o); Indian import(ac)(z);
...

Roles:	(a)= agent; (ac)= activity
	(l)= location (to); (o)=object
	(l')= location (from)
Links:	(x),(z)= agent-activity
Weight:	* = major terms

Fig. 4.1. Indexing example based on simple user-aboutness with controlled vocabulary.

Further, there is a problem of context exhaustivity: how many combinations of terms are relevant and required. The number of index terms in this solution might be reduced or constrained by means of an elaborated domain-dependent search thesaurus which (automatically) might lead the searcher to adequate index terms. Then, of course, the time consumption and introduction of new conceptual relations has moved to the maintenance of the thesaurus.

Surprisingly enough, *automatic indexing techniques* based on the *single words* that occur in document texts are rather effective. Reducing words to stems, excluding stopwords and the incorporation of a simple thesaurus with only synonym relations is the only vocabulary control that has been shown to have definite advantages (Croft, 1987). Indexer inconsistency is avoided, as in natural language representation. This is an example of mainly author aboutness, further demonstrated in Chapter 4.3.

However, the constant theoretical problem is, as pointed out by Rijsbergen (1990), that the indexer (mechanism) does not really know which user-aboutness or semantic value to apply in order to meet a potential user. Perhaps 'butter transport' or 'Indian butter import' might have been an adequate index term? – seen from some users' viewpoints.

Thesaurus theory is associated with vocabulary control. Its focus is on concept relations and it displays general relations between terms like generic relations, i.e. broader and narrow terms, part-whole relations, i.e. top and part terms, as well as synonyms and homographs. It serves as a tool for indexers and searchers in a domain, e.g. leading from non-used terms to preferred index terms. A thesaurus can be used for automatic validation of terms generated by human or automatic text analysis. In addition to the general relations, a thesaurus would traditionally operate with so-called 'related terms' which actually contain concepts with the properties of the linguistic cases or facets mentioned above. Often, the related terms mirror the *situational relations* between concepts. Although the semantic relations between such terms are unspecified the concepts themselves may be of great value to users who, in a cognitive and hermeneutic sense, are more familiar with processes than with the more abstract hierarchies of the objects involved in such events or processes. See Chapter 2.4 for a discussion of cognition seen as a 'concernful acting' in a hermeneutic (Heidegger) sense, as well as Chapter 6.1.1 on situational categorisation seen from the cognitive point of view.

Therefore, thesaurus theory is an adequate means for designing knowledge bases in specific domains, e.g. in the form of semantic networks or case frames.

It is intriguing – but quite unsatisfactory – that the indexing theories and their applications do not demonstrate a high effectiveness in terms of IR performance, and do not solve the IR problems mentioned, although a rather *intelligent, knowledge-based component* guided by elaborated rules is involved in the processes: the human indexer. Obviously, the lack of consistency is one reason. Another seems to be the absence of the user's influence in relation to the IR models, theory, and solutions. Although semantics is introduced by human indexing, a third cause is that the analysed, extracted and translated concepts fall out of context and *immediately drop* from a cognitive to a structural level in a cognitive sense, see Chapter 2.1.

4.3 Natural language representation

Natural language representation (NLR) demonstrates a rather different attitude towards retrieval processes by deliberately omitting the human indexer and replacing him with simple or more advanced algorithms. We may here talk only of 'author aboutness' at a monadic or structural level of information processing. The sources for representation are document titles, author generated abstracts or full-texts, including citations of other documents.

By avoiding the problems of indexer inconsistency and moving it to a 'natural' author inconsistency, the general theory behind is to place the user and his information need closer to the source in the communication process. The theory presupposes a similarity in use of terminology, concept relations, etc. between generators (i.e. authors) and potential searchers. In contrast to vocabulary control, by which users either retrieve nothing or a great deal, depending on the concordance between search and index terms, NLR normally retrieves something because of the variety of author and user generated terms. From a cognitive viewpoint the vast variety of individual knowledge structures, also within the one and same domain, makes this presupposition doubtful, and at the same time inadequate in IR.

A fundamental problem in NLR is an inherently simplistic conception of 'meaning' and the absence of an original conception of information. Information is seen as identical to meaning which is identified as author generated expressions.

The classic NLR is in general based on documents in machine readable form and may therefore be carried out automatically and with low costs. Four different approaches towards NLR are discussed:

1. structured
2. single term
3. single term in context
4. single term with weighting

4.3.1 Structured natural language representation

Structured NLR implies making use of a) the term structures in document texts, e.g. in abstracts or full-text; b) the citation structure related to a (scientific) document. Method a) relies on clustering theory which is discussed in relation to IR techniques (Chapter 4.4.2). Method b) is based on the idea that a citation in document A of document B relates A and B; a document C, also citing B, must hence be related to A. Further, if one document cites A and B, then A and B must be related.

These coupling and co-citation methods, explored by E. Garfield (1979), can be used to generate 'citation clusters' for browsing and searching purposes. The theory follows the relations 1/4 and 3/5 (Figure 1.3, Chapter 1.2). In relation to bibliometric analysis of citations within scientific domains, certain limitations have been expressed as to its completeness (Cronin, 1984), whereas there is no doubt about its validity as science indicator (De Solla Price, 1976). In terms of representation the most severe problem in citation clustering is the weight or representativeness as well as the direction, i.e. the *qualitative cognitive impact*, of each citation in a document.

4.3.2 Single term natural language representation

Single term NLR is the most used indexing method in commercial online systems. In combination with added controlled index terms, single words from document titles, and from abstracts (since the end of the seventies), form an inverted basic index as well as individual inverted fields. The Boolean exact match technique extended with proximity operators makes it possible to search for concepts in all these fields – called free-text searching. In full-text systems the vocabulary control combination rarely occurs.

By combining vocabulary control, which could be supported by a thesaurus, and NLR it is theoretically possible to obtain good retrieval performance – providing that the searcher is very good at manipulating the query language and conceptual structures interactively. One may say that this combination creates an *author+indexer aboutness,* superior to each of the two forms of representation individually, in terms of number of entry points and performance. However, their disadvantages also accompany this solution: lack of indexer consistency, and for NLR: *all* the single terms have *equal weight.* When searching on, for instance, 'Danish butter' and

'India' in our example, therefore, we may retrieve more documents (e.g. via abstract words and titles), but we have no control of the degree of relevance. The best way to keep high relevance in this free-text mode is to search on title terms combined with added index terms, i.e. in general avoiding the abstract field, or only searching within sentences.

In addition, it is important to note that several investigations have shown that "in general 34–86% of the index terms, assigned by human indexers, can be derived from *title words* only. Depending on the discipline, titles of articles usually describe or at least imply the contents of the document more or less sufficiently; more in the fields of science and engineering; less in the social sciences and humanities" (Borko and Bernier, 1978, p. 163–164). In our first indexing example on 'Danish exportation to India' at the beginning of Chapter 4.2, 75% of the index terms added are similar to those in the title.

4.3.3 Single term in context NLR

NLR based on single term in context has therefore been explored in two directions: a) automatic use of title words from journal articles in printed indexing tools; b) (semi)automatic use of title and chapter heading words from monographs in online databases.

KWOC or KWAC (KeyWord Out of Context; KeyWord And Context) are methods following direction (a). In scientific domains their performance is high, and the cost low. Article titles are scanned and significant words, i.e. the keywords, are extracted, forming a permuted, alphabetic index with the complete title 'hanging' as a tail in each entry, providing a context (Stevens, 1965). This solution is similar in principle to the PRECIS solution in the previous chapter. The difference is that all keywords are NLR, and that the context displays natural linguistic syntax. In an online search situation we have no means to control these linguistic cases or roles – as for PRECIS.

It is necessary to point out that KWOC and alike title-based NLR has less value concerning monographs, since their title terms usually are too broad as subject terms. The rich and nuanced content of a book may hardly be described by the few words of the title.

In direct competition with the PRECIS system, direction (b) attempts to apply the *features inherent* in monographic publications. Originally suggested by P. Atherton-Cochrane, the SAP (Subject Access Project) theory makes use of titles and chapter headings in order to improve the subject accessibility in library catalogues (1978).

Wormell extends the SAP method to incorporate captions of tables and figures, as well as back-of-the-book index terms, all referring to specific pages in the publication. This deep-indexing theory, practiced at moderate costs, is well argued (1985) and demonstrates an advantage to most other NLR approaches by pointing *directly* at the portions of text in documents containing the combinations of terms searched for in their headings. SAP does not have to be limited to monographs like books or reports. It may also be applied to journal articles, their captions and sub-section titles, as suggested by Ingwersen and Wormell (1986). The theory presupposes that captions and chapter headings possess higher representativity than full-text single terms combined.

From a relevance viewpoint this theory is interesting, since relevance must be extended from the usual 'document relevance' concept, which in this case merely is without interest, to part-of-document relevance. Another interesting feature is the possibility of searching *graphics* (figures, graphs, etc. by their headings) which makes it applicable to office information systems and other multimedia environments. Due to the contextual and the deep-indexing characteristics, the SAP principles for NLR come closer to providing 'user-aboutness' associated with a document, than most other indexing theories in use. Note also that Wormell's theory is workable in a general domain environment. If provided with a synonym thesaurus in a more specific domain, it might perform equal to or better than the automatic term extraction supported by thesaurus, as suggested by Croft (1987) in the previous section on vocabulary control. The Esprit Project 2083 (SIMPR) automatically makes use of chapter and sub-chapter headings to form a so-called 'heading hierarchy'. The hierarchy is produced by application of the SMGL standard and can be applied as a navigation tool during searching.

It must be mentioned that neither SAP nor KWAC, nor single term NLR – with or without weighting – may avoid non-relevant retrieval of documents/captions on 'Indian export to Denmark' when users enter 'Denmark', 'India' and 'Export' as search terms.

4.3.4 Single term extraction incorporating weighting

This type of NLR is based on document abstracts or full-text words, applying word frequency analysis. Along with the developments of manual indexing theories several methods and theories for automatic extraction have been put forward and tested. Originally based on Zipf's *rank-frequency law* which implies that the frequency of a given word in a text multiplied by the rank order of that term approximates to a constant for that text (1932), automatic NLR has developed around various applications of term frequency.

Intensive research during the fifties and sixties has provided IR with knowledge of the best ways of exploring the issue, leading to strong theoretical frameworks concerning advanced IR techniques in particular. Much of this research is summarized by Salton (1968), Sparck Jones (1974) and (Salton & McGill, 1983). By applying the term-frequency approach Sparck Jones carried out large-scale experiments on *term weighting* (1973). Hitherto, all of the single term NLR approaches outlined produce representations in the form of a very simple 'author aboutness' on a monadic level, where all terms (and documents) are equal. Term frequencies may provide estimates of their relative value.

The intentions behind weighting are twofold: to *rank* texts that contain single query terms, and/or to allow query terms to carry weights whereby documents can be ranked according to those term weights. Relative term weights for each text may be calculated at indexing time or at search time. The various methods of weighting lead to advances in relevance weighting (Robertson & Sparck Jones, 1976) and directly to theories for experimental IR techniques, as from the seventies.

The fundamental theory can be expressed by the *tf.idf* value which, for each term *T* multiplies its relative term-frequency in the text (tf) by the inverted document frequency (idf) in the collection for term *T*. For (idf) the relative frequency ratio *log N/n* is often used, where *N* is the number of texts in the collection and *n* the number of texts that contain the term *T*. Terms with low values are terms appearing rarely in the text and documents containing it appear often in the collection, or the term appears often in both text and in collection. Such terms are poor discriminators. An appropriate lower threshold value is determined in order to select the proper single index terms. By means of other mathematical calculations term-term relation values and term-document association values can be established. These principles are used to relate terms or documents in networks. Note however, that the same term in different IR systems will carry different tf.idf values.

In relation to term-frequencies, Salton has suggested that since medium-range frequencies of terms in a text possess higher 'resolving power' or are better discriminators than low or high frequency words, one may handle such terms differently (1975). Low-frequency words may be grouped in classes to increase their effective frequency and high-frequency terms combined as phrases to reduce theirs. This solution implies support from either a thesaurus or a human indexer as 'validator', but omits new, and hence rare terms to be searched. Still better, according to Croft (1987), is extraction of the single terms as stems and calculating statistically their resolving power, supported by a synonym thesaurus. Automatic indexing techniques based on identification of syntactic elements of the document text have been used (Salton, 1968) (Dillon and Gray, 1983), but have not demonstrated high retrieval performance (Sparck Jones & Key, 1973).

Although syntactic NL processing has not in itself proven to improve IR performance, syntactic text analysis *combined* with elaborated rules for concept relationships and *empirically based knowledge* of categories of user goals seem applicable in specific domains to represent and use domain knowledge (Cohen & Kjeldsen, 1987). Their GRANT system makes use of domain knowledge (research funding bodies) represented as a semantic network of concepts, linked by a large number of types of relations and categories. Search is carried out by constrained spreading activation.

This semantic network approach is similar to but more elaborated and constrained, than knowledge representation based on thesaurus theory or roles and links. Because of knowledge of *user preferences* this approach is an example of moving towards a cognitive research approach, discussed in Chapter 7.

4.4 IR technique developments

Mainly based on the single term NLR theories and achievements, laboratory experiments in the seventies demonstrate that *partial match techniques*, such as probability and relevance weighting, may improve the retrieval effectiveness fairly dramatically. A profound review of IR research for this period is produced by McGill and Huitfeldt (1979). A major trend in the eighties was to refine further the effectiveness of partial match and other retrieval and text representation techniques, within the confines of the source system. In connection with the various techniques, improved support of query (not the request) formulation is analysed.

In a recent review Belkin and Croft summarize the current state of R&D on IR techniques (1987). The review provides a new and appropriate classification of IR techniques by categorizing them as *exact match* and *partial match* techniques.

Also recently, in his introduction to "Document Retrieval Systems", Willett provides an excellent review of theories, models and results produced in the classic IR research environment (1988).

Exact match presupposes that information needs are identical to queries which again are equivalent to document representations and texts, that provide the information sought. One may say that this technique requires the model of the request, Figure 3.2, be contained, precisely as represented in the query formulation, within the text representation. Boolean or string searching is the common implementation of this IR technique in current operational IR environments. Belkin and Croft (p. 113) point to the most well-known and documented *disadvantages:*

> .. a variety of search aids such as thesaurii are required to achive reasonable performance. In the simple case exact match searching: 1) misses many relevant texts whose representations match the query only partially; 2) does *not rank* retrieved texts [except cronologically]; 3) cannot take into account the *relative importance of concepts* either within the query or within the text [except for weighting e.g. title terms higher than other terms, leading to a simple ranking formular]; 4) requires complicated query logic formulation, and 5) depends on the two representations being compared having been drawn from the same vocabulary.

In addition, the Boolean 'not' logic always results in the omission of relevant texts.

The reasons for not abandoning exact match in the large-scale commercial systems are several, of which the most important are given in a recent empirical survey (Smit and Kochen, 1988). Traditionally, one answer is that the vendors have invested too much in present software to change it for new, non-tested techniques, that is, not tested in large-scale systems. Another reason seems to be that users may apply other (partial match) techniques on their micros so why change policy? Vendors are also stating that results of alternative techniques are not sufficiently better even in experimental environments to justify any changes. A significant argument, actually demonstrating an *advantage*, is that *Boolean statements are structured*, representing important aspects of user requests and problem spaces. A recent review edited by Radecki demonstrates several approaches to improvements of exact match by partial match techniques in online environments (1988).

In *partial matching* the request is regarded as being the query, consisting of the significant terms from the request.

Partial match techniques are categorized into 'individual feature-based' and 'network-based' techniques. The first category contains *formal models,* e.g. the *vector-space model*, fuzzy-set theory and *the probabilistic model.* This category denotes that we are dealing with individual texts' author aboutness features, such as their terms. The second category implies that we are operating on a network of texts, such as in the *clustering* technique, browsing or spreading activation.

The formal models behind the first group of techniques are discussed by van Rijsbergen (1979) and Salton and MacGill (1983). More recent refinements and developments of the models are outlined by A. Bookstein, who compares probability and fuzzy-set theory for applications in IR (1985).

In contrast to exact match technique which *operates on* text representations in the form of manual indexing or simple single word extraction, all formal feature-based and network-based techniques may either similarly compare queries with documents represented as sets of features or index terms, or they may in addition be regarded as *indexing techniques*. They can work on all types of representation, whether controlled or NLR. Features can represent single words, stems, phrases, or concepts and can have weights associated with them. Query features are of similar nature.

Further, in common to *all* partial match techniques is their potential for *ranking* retrieved documents.

4.4.1 The vector space model

The vector space model is one of the first models to appear (Salton, 1968) and has been developed and refined up to the present. Documents and queries are vectors in an n-dimensional space, where each dimension corresponds to an index term. In general, the number of query terms defines this dimensionality. Term weights are calculated by tf.idf values, discrimination ratios found and documents are ranked in decreasing order of similarity to the query using the cosine correlation cos v to retrieve documents closest to the query in vector space: $\cos v = \Sigma di\ qi / \sqrt{\Sigma}\ di^2\ \sqrt{\Sigma}\ qi^2$, where di is the tf.idf weight and qi the weight for query term i, with $0 \leq \cos v \leq 1$. The model can be used at indexing time, but provides higher performance at search time, because of the dynamic nature of the collection. It may be supported by a thesaurus to include important relationships among words or to expand terms to classes, since it is those relationships and classes that are relevant to an individual query, that should be identified (Croft and Thompson, 1987).

An interesting performance improvement has very recently been reported by Wendlandt and Driscoll who apply query-document similarity measures that include tf.idf weights of the linguistic thematic roles, in addition to the calculated weights of the content-bearing words in texts (1991). In this way semantic values, or conceptual relationship properties of text portions can be retrieved and measured against similar values in requests on a syntactic linguistic level.

Related to and expanding the vector space model – in particular in association with operational Boolean systems – is the *extended Boolean IR technique* (Fox, 1983; Salton, Fox and Wu, 1983). The model allows for structured Boolean queries to be used, e.g. *(Denmark OR India) AND Export*. Texts containing one to all three terms are found and a similarity measure is defined that ranks the documents, e.g. in vector space. Documents that match all or parts of the Boolean query are given precedence. In an example we may have the text on 'Danish *export*ation to *India*' (1), one on '*Denmark – India*, an import & transport guide' (2), and a text on '*Export* statistics: *India*'(3). Naturally, the model cannot solve the (at least), threefold ambiguity problem of what the query really is about: Danish export to India or visa versa, or Danish export as well as Indian export. Ignoring this problem, which only to a certain degree is solvable in the techniques and models, by including 'relevance feedback' from the user, and ignoring effects of term weights, the extended Boolean model will give precedence to text (1) and (3) since they both contain two query terms and match the Boolean query specification. Text (2) also contains two query terms (Denmark, India) but they do not match the query specification (Denmark OR India). Note that text (1) and (2) would outrank text (3) if a thesaurus was used, adding the terms 'Danish' (= Denmark) and 'Import' (Export).

4.4.2 The probabilistic model

The probabilistic model generates the most researched and developed IR techniques. The version most often referred to was introduced by S.E. Robertson (1977a) and major contributions to its further development and success come from van Rijsbergen (1977), Sparck Jones and Webster (1980), van Rijsbergen, Robertson and Porter (1980) and, in the eighties, Robertson, Maron and Cooper (1982). Also Bookstein (1985) makes significant contributions, and yet more refined modifications to the theory, increasing its performance, have very recently been proposed and tested by N. Fuhr and C. Buckley (1990).

The techniques are similar to those developed from the vector space model. Belkin and Croft state (1987, p. 117–118):

> The basic aim is to retrieve documents in order of their probability of relevance to the query. If we assume that document term weights are either 1 or 0 and that *terms are independent* of each other, this can be shown to be achieved by ranking documents according to: $\Sigma\ d\mathrm{i}\ q\mathrm{i}$, where $q\mathrm{i}$ is a weight equal to: $\log p r\mathrm{i}\ (1 - pnr\mathrm{i}) / pnr\mathrm{i}\ (1 - pr\mathrm{i})$, where $pr\mathrm{i}$ is the probability that term *i* occurs in the relevant set of documents, and $pnr\mathrm{i}$ is the probability that the term *i* occurs in the non-relevant set of documents.

The problem in applying this ranking function is the estimation of the probabilities in the query term weights, at search initiation. Laboratory experiments have solved this problem as well as other estimation and weighting issues, e.g. by use of the *tf.idf* weight. van Rijsbergen has proposed to remove the term independency assumption (1977) and to allow structured Boolean queries to be applied with the probabilistic retrieval model. If term dependencies are used to modify document rankings they must be accurately identified, e.g. by the user or by NL processing methods (Croft, 1986).

It is interesting to note from an office automation viewpoint that 'formal' types of representations, e.g. addresses, dates, zip-codes, etc., may be included with weights in probability IR, as demonstrated for instance by Croft et al. (1990).

4.4.3 Clustering techniques

Clustering is that method among the network-based IR techniques to which most research effort has been devoted during the last twenty years. "A cluster is a group of texts whose contents are similar. A particular clustering method gives a more detailed definition of a cluster and provides techniques for generating them" (Belkin and Croft, 1987, p. 121).

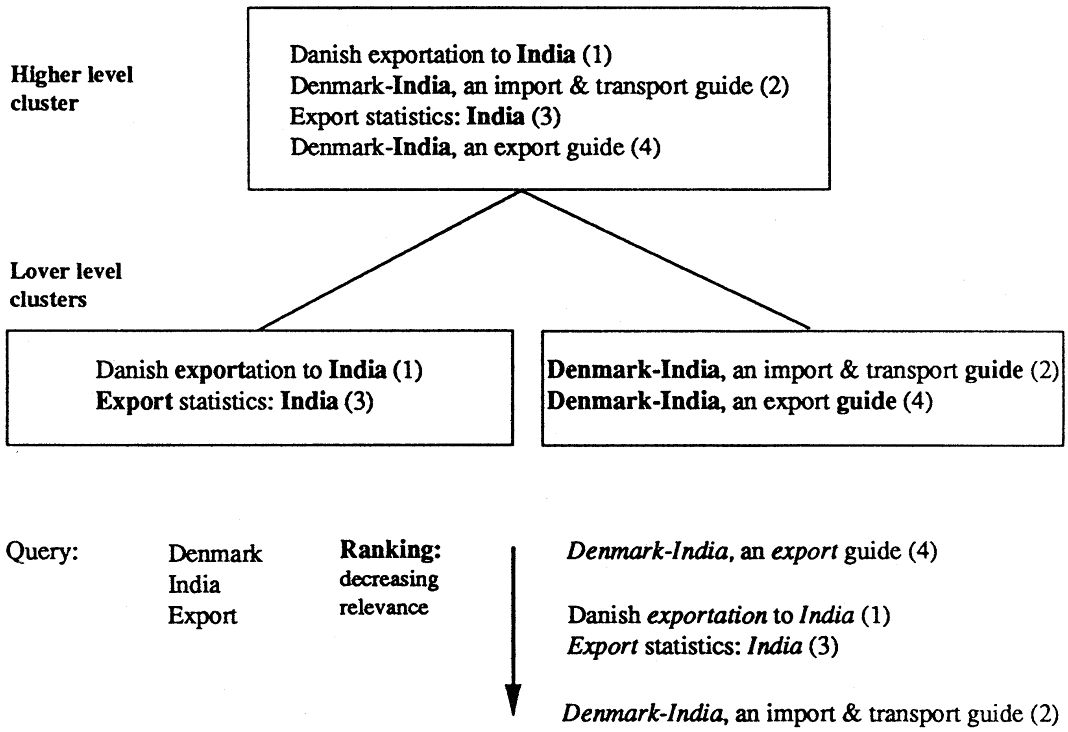


Fig. 4.2. Illustration of clustering of documents and their ranking according to a query. **Words in bold** imply example of 'cluster representatives'; *words in italics* identify query matching.

G. Salton's SMART project studied a variety of methods, mainly leading to top-down searching of cluster hierarchies (1968). Large clusters are formed automatically according to the similarity of (index) terms they contain. These are divided into smaller (and denser) clusters, etc. and a query is compared to term representatives of the large clusters by a similarity coefficient. The best cluster is chosen and comparison continues downwards in the hierarchy, resulting in a ranked list of lower-level clusters. The top-ranked clusters' documents are then ranked in relation to similarity to the query. Figure 4.2 illustrates the technique in a simple way. To the three documents on 'export, Denmark, India' mentioned above under extended Boolean logic is added a fourth: 'Denmark – India, an export guide' (4).

Also applying top-down searching Jardine and van Rijsbergen introduced a formal clustering method applying a 'single link' technique where clusters were retrieved without ranking individual documents (1971). A bottom-up method is also possible, as demonstrated by Croft (1980).

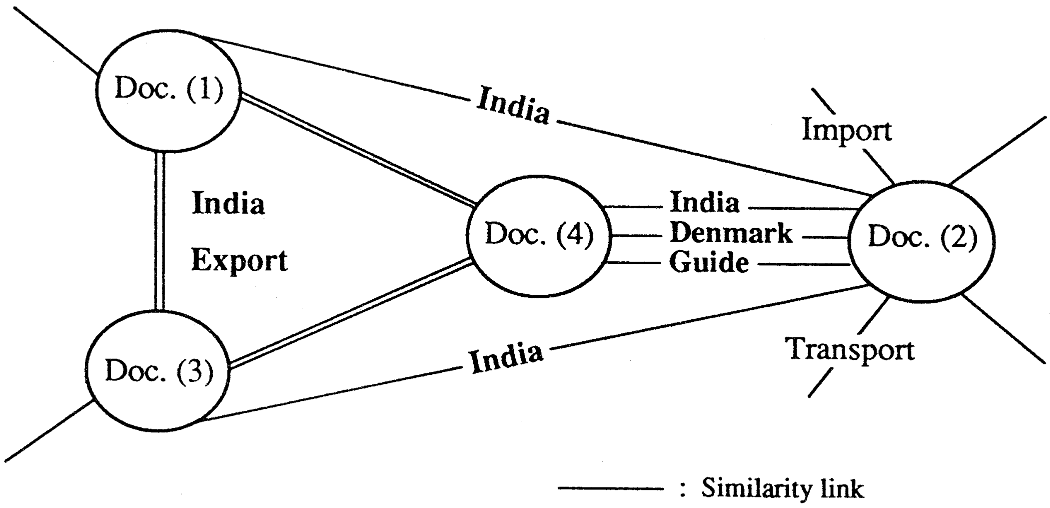


Fig. 4.3. Illustration of nearest neighbour clustering.

The query is compared to the lowest-level clusters, and documents in the highest ranked clusters are retrieved. This technique is similar to a cluster technique using the 'nearest neighbour' method (Willett, 1984). By means of term similarity measures, a document has its nearest neighbour documents linked in a network which, at search time, is used to generate clusters and their representatives. In Figure 4.2 this means for instance, that the four documents at the lower-level have their nearest neighbours linked, as shown in Figure 4.3. In the group to the right the two documents are linked very closely because of the similarity of three terms (Denmark, India, Guide). Individually they are linked to the two documents to the left, Doc. (1)

and (3), in a slightly weaker way: Document (2) is linked with a one-word similarity (India) to both, while document (4) is linked to them with a two-word similarity (India, Export). The two documents (1) and (3) are linked to one another by the same two-words.

This latter method has been explored and refined through the eighties, because it may save storage considerably (Willett and El-Hamdouchi, 1987). Perhaps more important, it can be used to demonstrate for users the conceptual *potentiality* of the IR system – its author dependent *domain space* or state of knowledge – in a structured way, serving as a feedback feature and allowing for browsing. In a recent review P. Willett analyses the present state and discusses it effectiveness (1988).

Besides the capability to retrieve documents *similar* to a known (and relevant) document, the technique may be used to create term clusters. However, the most severe problems encountered in relation to the clustering techniques, which can be seen as a form of automatic classification, are the issues of determining the *linguistic basis* for term associations and the provision of formal definitions of association between a pair of terms, and association among a class of terms. As stated by Sparck Jones and Kay (1973, p 163–164):

> Most experiments have tended to involve a great deal of grouping in the dark and theoretically unsatisfactory procedures being adopted in an ad-hoc manner on the basis of largely unjustified assumptions, and being inadequately tested.

The Figures 4.2 and 4.3 demonstrate these problems to a certain extent, as yet not solved. For instance, how do we automatically create adequate semantic connections between, say 'India' and 'Export', the left-hand side in Figure 4.3? By observing Figure 4.2 it is obvious that we require more context than simply provided by the surrounding terms in the texts. Following S.E. Robertson (1977, p. 126–127):

> ..the assumption underlying term-clustering experiments is that semantic connections between terms can be discovered by considering their co-occurences. But attempts to incorporate such semantic connections into retrieval procedures have generally been disappointing. Is this because the relation between these semantic connections and some traditional retrieval operations is purely superficial, and the one cannot usefully be substituted for the other? Or is it because we lack a vital part of the overall theory, which would make this relation explicit and show us how to use it? The experiments do not tell us.

An important aspect lies in the fact that clustering techniques applied to the same collection with the same queries as the probability technique, result in like performance effectiveness, but provide slightly different output of ranked documents. In other words, they demonstrate a kind of *indexer inconsistency,* similar to two different indexers' interpretations of indentical documents. The complementarity of the two IR techniques may hence be used to refine relevance in certain retrieval situations.

4.4.4 Feedback issues

Feedback in the IR environment is understood slightly different from the notion of Wiener (1948, 1961). By feedback is meant either: *relevance feedback*, as developed by Salton (1968) in relation to the feature-based IR techniques, or: *system feedback*, as used by the author in relation to the Zoom feature and other means in an IR system that display author/indexer aboutness to a user (Ingwersen, 1984a, 1986; Ingwersen and Wormell, 1986). The cognitive impact of elaborated system feedback on retrieval processes is discussed in Chapter 7.3.

Salton's notion refers to the process where a user's request is modified automatically *in the system*. The modification or refinement is based on 'system feedback', e.g. displayed documents, graphic representations of concepts, ranked lists of terms, thesaurus structures, etc. Documents (or concepts) identified by the user to be relevant lead to adjustments of weights in relation to the query terms. The relevant document(s) term weights are used in a repetitive search, providing retrieval of documents similar to the document judged relevant by the user (Fuhr and Buckley, 1990). Relevance feedback may therefore be applied to all IR techniques, including clustering. An example of both types of feedback can be shown by looking at Figure 4.3; stage 1: the user enters the words 'India, Export, Denmark'; stage 2: the nearest neighbour clustering technique produces the network display as in the figure, i.e. as *system feedback,* focusing on the document node (4) as most relevant; stage 3: the user observes the network and points to Doc.(4) to see its title; stage 4: Doc. (4) 'Denmark-India, an export guide' is displayed (system feedback); stage 5: the user indicates its relevance; stage 6: this *relevance feedback* modifies the query to include the term 'guide', whereby the focus of the search shifts towards the right-hand side of Figure 4.3. The nearest neighbour documents to Doc. (2) will be displayed, e.g. linked by the terms 'Import' and 'Transport', and an eventual ranking order of documents will shift accordingly. Relevance feedback is thus an attempt to reach into the information space of the system, i.e. one of several methods which have been tried to overcome the Dark Matter problem in IR.

Both types of feedback are extremely important features in IR interaction, ensuring higher performance. Note however, that the system does not know whether to keep the original query, adding it to the modified one, or to exchange it completely for the modified one. That would require an intermediary mechanism. In association with probability techniques, relevance feedback is essential to the system in order to know about query term weights and the pr value.

4.5 Relevance measurement techniques

Since the sixties, a core issue of research in IR has been performance studies. The most common method applied within the context of the traditional approach is the application of laboratory tests on databases designed for that purpose. Sparck Jones (ed.,1981) and Sparck Jones and van Rijsbergen (1976) outline the perspective of the methods and describe the test beds used.

The principle is scientific, i.e. that for each test collection a number of fixed queries are used, and the total number of 'objectively' relevant documents for each query is known to the researcher. Variables in the tests are either a specific IR technique, or a particular method of representation. Comparative studies of relative performance may hence be carried out. The test collections are small, from approximately 3,000 items to approximately 20,000 items, far from the size of large-scale operational systems which measure up to 9,000,000 document records. Relevance, defined as the measure or degree of a correspondence or utility existing between a text or document and a query or information requirement as determined by a person (van Rijsbergen, 1990), is normally measured in form of 'bibliographic relevance', i.e. that judgements of relevance are based on document representations, such as titles, abstracts, etc. 'Document relevance', i.e. judgements on full-text documents, may also be applied. Part-of-document relevance is not in use.

In the laboratory experiments human *users do not take part* in the experiments. This is the main draw-back. More recent user-oriented approaches to the design of IR systems naturally take into account the cognitive effects of a dynamic interaction and the feedback on the user's problem space, his request, and query structure. The fixed queries are then no longer constants, but become variables, with loss of knowledge of the total number of relevant texts as a consequence. The test collections and the comparative methods are consequently only operational in relation to the traditional approach.

The *standard criteria* for evaluation are *recall and precision,* and more recently *fallout* (Robertson, 1977). 'Recall' is defined as the number of relevant documents retrieved *R,* related to the total number of relevant documents in the collection *C, i.e. R/C*. Recall may therefore only be defined by exactly knowing C, normally impossible in operational systems and in real-life experiments, and thus resulting in a degree of uncertainty, in addition to the uncertainty inherent in IR itself.

'Precision' is the relationship between number of relevant retrieved documents *R* and number of retrieved documents *L, i.e. R/L.* 'Fallout' is often used as a replacement for precision, because it takes into account the total collection *N*. It involves the relationship between the number of non-relevant, retrieved documents, and all non-relevant documents: *(L–R)/(N–C).* In general, an inverse relationship exists between 'recall' and 'precision'.

By standard performance measures it has been possible to compare the various techniques mentioned in this chapter. Partial match techniques all demonstrate significantly higher performance than exact match techniques, i.e. Boolean techniques. Probability is the major feature-based technique, in particular when incorporating the tf.idf weights. Following Belkin and Croft (1987, p. 127) the use of term dependencies to modify document rankings may also improve performance, but only if the dependencies are accurately identified by the user or NL processing (Croft, 1986). Thesaurus information automatically applied to expand queries is only really effective if the terms expanded and the type of thesaurus information used is tightly controlled. Clustering techniques can achieve levels of performance similar to the feature-based IR techniques but tend to be better for high-precision results (Croft, 1980). For certain queries clustering works better.

4.6 Summary statements

The traditional or classic IR approach has its limitations, as several researchers have stated sence the end of the seventies, especially in relation to the issues concerning the user's problem space and its development into request and query formulations (Ingwersen, 1988, p. 153–154). In view of more recent R&D approaches and theoretical developments in IR, it is important, however, to emphasize the potential of the traditional approach, in particular serving as one of the basic instruments in knowledge-based IR environments. The theories underlying the techniques are at present often exported to other disciplines, such as classification theory to AI in relation to software reuse (Albrechtsen, 1990), and online IR techniques to office automation and work station research landscapes (McAlpine and Ingwersen, 1989; Croft et al., 1990; van Rijsbergen, 1986b).

It is evident, that for each method applied to text analysis, representation and IR technique, similar methods are used in relation to the *representation of requests*. This implies that indexing with vocabulary control or NLR requires queries, either consisting of identical or similar controlled terms structured properly, e.g. by Boolean logic, or consisting of similar single and independent terms with no or vague relationships between them. We may have control of the syntax in the query but not its meaning; not to speak of the *potential information* it carries with it, from the problem space of the user towards the system. One may easily uncover examples of request formulations which, notwithstanding their rather elaborated nature, demonstrate very different semantics, looked at from the side of the system.

It is symptomatic that all the various approaches within the classic IR research tradition take the *query or request expression for granted*. Relevance feedback in probability or clustering IR simply creates a new query, although rather complex, and moves the search spotlight from one place in the collection to another. Then, of course, even if the technique shows high performance test-results relatively speaking, some unknown but relevant texts fall into darkness. Exactly identical queries from two users may often result in totally distinct relevance judgements. The same query applied to different statistical or network based IR techniques produces overlapping, but not identical results. More poor retrieval techniques show high performance for certain type of queries. It is exactly in relation to these problems of IR theory that we are referred to by Sparck Jones' (1979) and van Rijsbergen's (1990) statements and arguments previously mentioned in this chapter. Essential issues are the deficiency of adequate conceptions of 'meaning' and 'information', the constantly inherent 'generator aboutness' versus application of 'user aboutness', and intentional usage of information in knowledge, not document, representation, as well as the problems of increasing retrieval uncertainty.

All the methods and principles outlined in this chapter are *ad hoc theories* but linked to one another, originating from mathematics, linguistics or philosophy. However, they provide a definitive step towards a unifying theory of IR. The importance for progress in IR research is to have an idea of when to use the different principles and techniques, to have *precise understanding of parameters* for their appropriate application. Because of the intensive research under the umbrella of this mainstream approach, and given their premises, we possess a fair portion of knowledge concerning their advantages and disadvantages. But, unfortunately, we do not know which of the principles, or their combinations, that may suit the various kinds of IR situations.

From the outcome of the classic position we have only vague ideas about what may happen when users put their cognitive efforts into the game, actually applying the refined techniques in real IR interaction. This ought to be profoundly tested.

One may in addition anticipate a 'trap' easily fallen into, namely a tendency to apply linguistic theories that are better suited to research into automatic language translation. Unambiguous semantic analysis of elaborated request statements as well as of texts will supposedly be technically feasible in the near future. Such analysis techniques may demonstrate a high retrieval performance ratio – but of what? Of sentences carrying identical, or very similar semantics, to the semantics of the request, but not necessarily carrying *information*. In other words, the searcher may thus retrieve what he already knows from various texts, rather than what he does not know. Naturally, in certain verificative subject retrieval situations this mode of IR is evidently valid – but it might be achieved with less analytic and processing effort invested.

If we wish to ask the user about his desire for information we need a *platform of knowledge about users* to ask from and to relate answers to. This platform constitutes the intermediary mechanism. In this case we leave the traditional IR approach, accepting a more user-driven or cognitive one. Belkin and Croft's profound review on IR techniques (1987) is in itself a serious step towards the latter, providing an interesting introduction in the form of research questions to be answered in the near future.

Such attempts at synthesis, made out of results from the classic tradition and the more user-oriented research position, are mandatory if IR research seriously wishes to take hold at levels of information processing and knowledge transfer above the monadic and structural levels - as suggested by the cognitive point of view.

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5. The USER-ORIENTED IR RESEARCH APPROACH

This approach to IR research and development activities focusses on the psychological and behavioural aspects of the communication of desired information between human generator and human user. In contrast to the dominant classic tradition this research approach aims at improvements of IR effectiveness within the framework of the user, his 'desire for information' and the interactive processes shown in Figure 3.2, the centre and right-hand side. By means of *empirical, real-life investigations* of individual users' and human intermediaries' searching behaviour, it is believed that a specific *understanding of common patterns* and parameters in the development from problem space over uncertainty state into requests (and backwards), and knowledge of human IR and search procedures, may contribute to such improvements. The reasons for certain researchers to follow this line of research from the mid-seventies into the eighties are threefold: the suggestion for change in the understanding of information put forward by Wersig (1971, 1973) and Belkin and Robertson (1976), pointing to communicative and interactive IR models; the wish for deeper insight into the interactive functions and tasks carried out by intermediaries, e.g. for didactic purposes (Ingwersen, Johansen, Timmermann, 1976); and the theoretical drawbacks explicitly stated (Sparck Jones, 1979) and described in the previous chapters.

During the same period user-oriented *analytical* studies of search strategies and IR improvements emerge. Their aim is to produce refined retrieval methods in relation to the large-scale operational online IR systems based on Boolean logic. Interchanges of models and results between the empirical and analytical environments begin to take place from the beginning of the eighties, mainly for the purpose of designing interface mechanisms as front-ends to the operational systems. Chapter 5.1 briefly discusses the overall role and necessity of the intermediary mechanism in IR. Chapter 5.2 describes basic qualitative methods applied to selected empirical research settings and Chapter 5.3 and 5.4 outline the core empirical investigations and discuss the results – foremost the Monstrat Model. Chapter 5.5 is devoted to analytic research.

The three latter chapters serve as a framework for the various contributions to the field made by scholars and research teams, mainly during the period 1975–1985.

It is important to stress the influence of the *cognitive view* on the empirically based, user-oriented approach from the end of the seventies (Chapter 2.1). However, although a substantial part of the investigations as well as certain analytical studies of IR processes explicitly rely on this view, as stated by Belkin (1990, p. 13–14), including contributions by the author, this fact does *not imply* that they automatically belong to a cognitive IR research approach. The reason being that the objectives for research, and the models and results published, omit all or several system components; see for instance Figure 5.1. The user-oriented approach does not, within the individual projects, concern itself with the problems of different text representation *and* IR technique issues. In the traditional IR approach the user and intermediary hardly exist. Similarly, the user-oriented approach in general takes system components *to be constants*, rarely linked to the human ones. This is presumably a natural consequence of the real-life R&D environment which either involves printed retrieval tools with poor and similar access possibilities or exact match online retrieval only.

As a consequence, the user-orientation demonstrates a similar restricted view of the total IR situation, and has difficulty in contributing to more overall IR theories. During the decade 1975–1985 user-oriented researchers, with few exceptions, do not ask questions like: 'Which retrieval technique(s) may suit which information need type?' or 'Which kinds of representation method may optimally support the understanding of user problems and system output?' Major exceptions are Oddy (1977) producing his IR system THOMAS based on browsing, and Mark Pejtersen who investigates methods of representation and search strategy in fiction retrieval (1980). Only from the mid-eighties those types of issues are discussed, e.g. by Belkin and Vickery (1985), Ingwersen and Wormell (1986), and in particular by Belkin and Croft (1987) and Ingwersen and Wormell (1988/89), incorporating a variety of system features. This can be seen as the moment when the conception of *IR interaction* actually is born, and a *cognitive turn* takes place (Chapter 6). From now on, both the empirically based and the more analytic user-oriented research activities finally attempt to encompass the total IR situation and to merge with the advanced counterparts in the traditional approach – forming a cognitive approach to IR (Chapter 7).

The user-oriented IR research approach demonstrates the following characteristics:

1. *Aim and foci:*
   Study of representation of information problems, searching behaviour, and human components of (information) systems in real-life situations.
   The emphasis is on the individual user's and intermediary's problem solving processes during IR, especially concerning the development and representation of the information need, in order to improve IR effectiveness.

2. *Type of results and consequences:*
   Dynamic and complex models of information behaviour.

IR is regarded as a problem solving and goal oriented, interactive process. The system is involved simplistically. The users may belong to several societal groups, e.g. scientists, children, laymen, often with ambiguous or ill-defined needs and requests for information.

3. *Understanding of information:*

   Information is understood in a wide context, including abridged or non-scientific material, emotional and cultural information.
   IR is understood to play an important role in information transfer and communication at all levels of society.

4. *Use of supporting disciplines:*
   Cognitive sciences (and sociology) as basic supporting disciplines. Cognitive (and experimental) psychology and psycho-linguistics are applied to user-intermediary behaviour and understanding of request formulations; in recent years, AI techniques are applied to the design of intermediary mechanisms.

The characteristics demonstrate that the problem of *representation* plays an important role. One may observe that this problem now explicitly is concerned with intermediaries' understanding of the users' need situations, and consequently the best way to mediate such knowledge to IR systems in order to extract adequate, potential information. Another issue is to understand end-users' retrieval behaviour, directly accessing (online) IR systems without the participation of mediators.

One may compare these R&D characteristics with those associated with the traditional research approach (Chapter 4). A concentrated comparison of characteristics and attributes for all three IR research approaches is demonstrated in Chapter 3.2.

Figure 5.1 outlines various types of the representative data the user-oriented research encounters in IR investigations. The figure is a result of the empirical studies carried out mainly by P. Atherton-Cochrane (1981), N.J. Belkin, R. Oddy and H. Brooks (1982) and Ingwersen and Kaae (1980). The figure differs from the original by Belkin and Vickery (1985) by the categorisation of the 10 elements (or 'microsystems') into Pre-information searching, Information searching and Post-information searching behaviour. Also the arrows are added to demonstrate the *recycling* possibilities of the elements within each category. Element 1 implies the user's 'problem space', element 2 is identical to the 'state of uncertainty', and element 3 signifies that the user, having a need for information which is expected to be solved by the system, asks an IR system. See also Figure 2.3, the right hand side.

In the category 'Information searching behaviour', 'source selection' has been added to element 5 to stress that we may operate in a multi-system environment. In element 8 'request' is introduced to underline that reformulations, not only of query, but of the information need/problem statement may take place, caused by a reformulation of the problem.

Under Data Type the figure has been adjusted accordingly, stressing that ‘knowledge’ in relation to element 2 incorporates both conceptual and system knowledge, and ‘request’ is made explicit in element 4.

MICROSYSTEMS in IR BEHAVIOUR	DATA Type
Pre-information searching behaviour	
1. User has a problem or goal which needs to be solved	User´s situation User´s goals
2. User´s information behaviour arises from recognition of inadequate (anomaleous) state of knowledge	User´s characteristics User´s (conceptual) knowledge
3. User seeks to resolve ASK by searching for information in system (info.-problem)	User´s problem statement and User´s expectations
Information searching behaviour	
4. "Pre-search" interaction with e.g. human or computer intermediary	User question/request Intermediary´s characteristics User/intermediary interaction
5. "Pre-search" formulation of search strategy/source-selection/query	User/intermediary interaction System's characteristics Query statement(s)
6. Searching activity	User/intermediary/ system interaction
7. Initial evaluation of results	User/intermediary assessment
8. Reformulation of problem/ info.problem/ request/ query/ strategy	User/intermediary interaction
Post-information searching behavior	
9. Evaluation of retrieved text(s) (if any) by user	User satisfaction
10. Use of information	User satisfaction User´s goals

Fig. 5.1. Representation of information search behaviour in the IR interaction process (Ingwersen, 1988, p. 156); modification of Belkin and Vickery (1985, p. 3).

In relation to Figure 5.1 Ingwersen states (1988, p. 158):

> At present we are provided with a fair amount of knowledge about 'Pre-information searching behaviour' and its relation to 'Information searching behaviour'. However, we do not know very much about the activities and behaviour in elements 9 and 10; and we possess scarce information about the derived knowledge structures produced by element 10 and used later, e.g. to generate new (potential) information or knowledge, stored in information sources, or to produce new problems, element 1.

5.1 The role of the intermediary and the user in IR

In relation to the traditional approach, the difference to the user-oriented approach to IR is basically concerned with the researchers' explicitly different attitudes towards the:

- concept of information;
- nature of the information need;
- research environment used for experimentation;
- the roles of intermediary, user and information retrieval systems;
- question as to where the retrieval system ends and the automatic intermediary begins.

Often in experimental and theoretical IR environments the intermediary functions implicitly form part of the 'matching function' (Figure 3.1) – or they are omitted deliberately from IR models and their description. The former is understandable but limited in scope because of its non-dynamic conception of the entire system; the latter demonstrates a misconception of the nature of IR.

The major issues to be analytically discussed are related to different attitudes towards *exact versus partial match techniques*, associated with:

- assumptions of the relationship between information need, request, and query;
- human versus (semi)automatic intermediary functions.

The following discussions and argumentation regarding the unconditional requisite for an intermediary mechanism is pursued by logic, but in addition based on empirical evidence – with the cognitive viewpoint as an underlying guideline.

5.1.1 The intermediary and user in exact match IR

With exact match, because of the Boolean syntax, requests in natural language *must* be translated into a proper query. Clearly, this requires a *Request translation function*, different from the matching technique – or this function must be carried out by the searcher. The translation requires knowledge of the Boolean syntax rules in a particular IR system, *and* of the semantics of the request, i.e. a *System model function* which relates to *Domain knowledge* is required. Connected to the request translation and the System model functions is a *Matching function* which implies carrying out the retrieval process by means of queries.

All of the investigations mentioned above in relation to Figure 5.1, and of reference work in libraries as online IR situations, are associated with exact match retrieval. The human intermediary plays a key role in those studies. Of real *performance studies*, involving recall and precision measures as well as human intermediaries, one may refer to the MEDLARS evaluation by F.W. Lancaster (1968). Medlars (now Medline) is the core operational bibliographic IR system in medicine. This evaluation is nowadays rarely cited, although it demonstrates several interesting results in relation to basic IR research.

Let δ stand for a possible *conceptual distance* between a user's desire or need for information and his actual request formulation. Lancaster reported that between 22–40 % of the requests differed from the needs. This rather large number of δ problems was measured based on the users' own relevance judgments of retrieved and added texts. Retrieved texts, and texts added from other bibliographic sources to measure recall ratios statistically, were originating from written request statements in NLR mailed to the Medlars search centre for batch-mode searching. As such, no interaction between user and system could take place at that level of information technology, and the request may consequently be regarded as an elaborated initial request formulation in present day online environments. Two major reasons for this conceptual distance were found by Lancaster: 1) the user-produced request statements did *not mirror* the underlying need for information; 2) the original user request had been *distorted* by interference from information specialists or librarians, who *interviewed* the user only supported by the MeSH thesaurus, and then wrote the final request in NLR. (MeSh stands for Medical Subject Headings). This interview sequence possesses all the characteristics of the socalled 'pre-search interview' – elements 4 and 5, Figure 5.1. The distortion yielded lower recall/precision ratios than the user-written requests, directly mailed and translated to the system in Boolean syntax.

The first reason for the conceptual distance indicates rather strongly that δ may exist – in an unpredictive way; a *Dialogue function* is obviously required in order to check or discover $\delta \geq 0$. The second reason, however, demonstrates that such a function must *not be limited* to only pre-search interviewing, but ought to be extended to include the retrieval processes and interaction with the system, performed instantly and providing system feedback. Chapters 7 and 8 develop these issues further.

5.1.2 The intermediary and user in partial match IR

In partial match IR the intermediary issue is somewhat blurred.

As stated in Chapter 4.6 the traditional approach takes the request for granted, i.e. the IR system is regarded as adaptive to *what a user asks for* – with a certain probability α – not his real desire for information. Human users and intermediaries do not participate in IR experiments for reasons of control of the test situation. In fact, the basic idea in partial match is to *avoid* a human intermediary. The argument relies on the real possibility of *inconsistencies,* similar to those partial matches avoided by omitting the human indexer. This stand is relevant, because of the distortion possibility sometimes made by pre-search interviewing, as stated previously. The researcher would state that by not at all including such mechanisms, whether human or automatic, the user himself via a matching function may explore the ranked texts and the cluster maps. Hence, if a conceptual distance δ should exist the end-user will alter the search accordingly via *relevance feedback*, and in a second or third run retrieve relevant information with probability α.

This seems a solid argument.

Notwithstanding, in the author's opinion the probability is decreased for the user to actually observe text representations relevant to his need, placed high on a ranked list produced by the partial match technique, since the ranking is determined by his *initial* request formulation. This probability is $\leq \alpha$, in proportion to the conceptual distance δ between request and need. Further arguments against the traditional views of intermediary exclusion and ideas of $\delta = 0$ are provided by Belkin et al. (1982) and by Ingwersen (1986, p. 218–220).

Thus, also in partial match, a 'Dialogue function' is required to check the distance δ, or better, to explore user aboutness, that is, the user's presuppositions. An alike 'Dialogue function' should also be used to communicate with the IR system(s), obtaining appropriately structured *system feedback*. All major automatic partial match techniques provide implicitly such a function.

In the case of complete omission of any intermediary functions from the models we must assume that we deal either with one global information retrieval system, without any redundancy, and with the one and only partial match IR technique implemented, or the *functions form part of the user.* This latter condition would imply that (all) users know of the global system and are capable of forming adequate queries to that particular system, *always with* $\delta = 0$. By possessing the functions himself, the user must encompass the centre and the righ-hand side in Figure 3.2. Since IR theory cannot avoid the reality of a multi-system environment a *System selection function* is required in order to access the most adequate system. This again requires a *System model and a Model building function*, understanding the various methods of text representation, system feedback, IR techniques, as well as the information spaces in external IR systems and/or in different, integrated (inhouse) systems, directly under control of the designer of an intermediary mechanism. This system modelling approach is in line with the suggestion by E. Hollnagel and D. Woods, originating from Hollnagel (1979), that the entire human-computer system should be considered an adaptive, cognitive system, where all parties interact with and adapt to one another (1983). One may notice that many empirical studies of user-intermediary interaction as well as design suggestions for automatic intermediary mechanisms operate on an *unitary* (stand-alone) *system concept,* i.e. that only one (domain specific) IR system plays a role in the investigation or design. This means, for instance, that the 'System model building function' as well as other interactive intermediary functions are regarded as part of or actually being the one IR system itself. In such cases the tendency is to view the centre and the left-hand side in Figure 3.2 as one integrated retrieval system. This frequently-applied type of research configuration tends to blur the entire issue of what IR fundamentally is about. See also Chapter 7.1 for samples of intermediary design models.

It is the author's opinion that, when talking about *IR interaction*, it is crucial to emphasize and view the role, functions and tasks of the intermediary *conceptually* (and physically) *separated* from other retrieval components, directed *interactively both* towards the user, *and* the retrieval system(s) holding the potential information to be retrieved. Like a Janus-figure. Hence, a unitary system concept involving an intermediary mechanism, e.g. the CODER system (Fox, 1987), should rather be seen as a distributed stand-alone information system only, the intermediary ending with the query interaction (Figure 3.2). This is not the way, however, one traditionally views such designs and systems. They are regarded as integrated systems holding distributed functions, and representing all IR areas as such. Naturally, in all types of retrieval, at the event of a request, the intermediary mechanism forms part of the entire information system, seen from the user's point of view.

5.1.3 Major intermediary functions

Based on these arguments one may summarize that at least eight intermediary functions are mandatory from an analytical point of view, also in partial match IR:

1. *Dialogue function*(s), directed towards *user and IR systems,* in order to learn about these components;
2. *Domain knowledge* or model function, to understand information need and problem space underlying the request, incl. the δ problem;
3. *Request modelling function*, to translate request into query;
4. *Systems model building function*, to understand the features of the IR systems;
5. *Systems selection function*, to choose an adequate IR system;
6. *Matching function*, to search the IR system with an IR technique, retrieving information;
7. *System feedback function*, to optain conceptual feedback from IR systems to support the user;
8. *Rule function*, to control and guide other functions' procedures.

One may note that all eight functions, with the exception of function 2, belong to the *active IR knowledge* category presented in Chapter 2.2.2. The Domain knowledge or model function forms part of the category of *conceptual knowledge*.

The requirements for these and additional intermediary (sub)functions and tasks, originating from the analysis results of the major empirical studies, are further discussed in Chapter 8.

By explicitly concentrating on the intermediary mechanism (Figure 3.2), each point of interaction and transformation can be seen to involve one or more functions, and becomes points of problem solving activity for the participating components. Although the intention in user-oriented IR research ultimately is to make functional a non-human intermediary, whereby one may avoid possible inconsistences, it seems evident that potential uncertainty problems may occur at each event of transformation.

With reference to Winograd and Flores' interpretation of Heidegger's concepts of breakdown and thrownness in systems design, and the author's suggestion of viewing a desire for information as a *result of a conceptual* (or goal-oriented) *breakdown* situation (Chapter 2.4), it is evident that the retrieval processes themselves ought not to cause additional breakdowns. The task of intermediary design is therefore to avoid such double-sided negative consequences. Thus, a basic requirement is to study how and why the outlined functions, as well as other ones not found by analysis, may actually be used (and mis-used) during IR interaction.

5.2 Major empirical user studies

The largest group of user-oriented research activities emphasizes the *behavioural dimensions* in a social context associated with information transfer, for example investigations of library use and non-use, formal and informal communication in connection to information seeking behaviour or studies of end-users' satisfaction with documentation, information and library services and reference tools.

Within this group of research, elements of information retrieval processes are often contained in the investigations, but not forming their main objective. Typically, the investigative methods are quantitative and statistically based, demonstrating applications of questionnaires, interviews, observation, and other techniques borrowed from sociology. Beginning in the thirties (Waples, 1932) these kinds of use and user-studies provide the IR research community with a variety of descriptive data concerning accessibility, search situations, (non)use, librarians' and users' behaviour, etc. – resulting in adequate, general clues to design and management of libraries and information retrieval systems.

J. Martyn and F.W. Lancaster survey this group of sociological and socio-linguistically oriented user studies and outline the methodological approaches (1981). Of major interest to IR research are those studies in library environments that concentrate on reference work and online searching. T.J. Allen (1969) and J. Martyn (1974) publish profound reviews of studies of information need situations and user behaviour. Among others, Ingwersen investigates user applications of public library subject catalogues using interviewing and observation (1974) and E.M. Keen (1977) follows up the Cranfield experiments on indexing systems' performance made by Cleverdon et al. (1966), by investigating the searching and use of printed subject index entries. Barnes applies observational methods to point to characteristics of librarians' search behaviour (1980). Continuing in the eighties, this behavioural line of studies includes online searching, e.g. H. Howard (1982) studying end-user behaviour and characteristics, L. Klasén (1982) and J. Deunette (1983) concentrating on large-scale surveys of the online user population in Sweden and UK, respectively.

The so-called 'Sheffield school', still active, initiates its studies of information behaviour from the mid-seventies. T.D. Wilson and D. Streatfield broaden the scope for user studies by incorporating *investigations of work tasks* leading to requirements for information outside the traditional library and documentation environment (1977). In contrast to the observational and interviewing methods applying predefined categories and closed-ended questions, Wilson advocates qualitative research by the use of "'structured observation' ... implying that categories are developed during the observation and after it takes place, influencing the researcher by the single event and important incidents taking place before him" (1980). Further, he emphasizes the importance of distinguishing between basic human needs in a social context and secondary needs, such as information needs (1981). This distinction is related to the view of the problematic situation leading to a state of uncertainty and information behaviour suggested by Wersig (1971,1973). It is interesting to note the comparability of the views of Wilson and his team on investigating potential users' work tasks in relation to design of dedicated information systems, and the suggestions of analysing *work domains and problem tasks,* made by Bennett (1972) and Bjørn-Andersen (1974, p. 141–146), preceding human-computer interface and decision support systems design. (See further, on this issue, Chapter 6.3.1).

Very recently, D. Ellis has carried out an extensive investigation of behavioural patterns in the work tasks and information seeking activities of academic social scientists (1989). He continues the Sheffield research approaches, but applies open-ended, taped interviews, claiming this methodology to lead to a *behavioural* IR system design approach, as an alternative to focussing on more individual phenomena of cognition in IR.

As stated previously, however, the *complementary* investigations of both the socio-behavioural and the psychological aspects of IR interaction are necessary. Depending on the data acquisition method used, the various behavioural studies give rise to important questions to be investigated further by subsequent user-studies. However, they do not provide *detailed* information about *why* information retrieval processes occur as they do – on an individual, mental scale. With the exception of the critical incident technique, common interviewing techniques provide answers of a general, retrospective nature. The intentionality behind individual considerations, questions, answers, and events during problem solving or interest fulfilment, search interviewing and retrieval, as well as mental decisions in relation to *acute* but *recursive* IR problems and use of background knowledge, are difficult to get hold of.

In order to obtain such data one must not replace with, *but in addition* apply more *qualitative*, empirical methods from psychology and psycho-linguistics, such as recording and protocol analysis (Ingwersen and Mark Pejtersen, 1986).

Using Figure 5.1 as a framework one may outline the basic real-life investigative studies, based on such qualitative methods. With respect to human intermediary performance and interviewing techniques, Atherton-Cochrane performs a large-scale experimental study of the 'presearch' interview situation in online IR (1981), (elements 3–5, Figure 5.1). Besides Mark Pejtersen (1980) and Ingwersen (1980, 1982), (both covering elements 3–8), Belkin, Oddy and Brooks study the user-intermediary interaction situation (elements 3–6) – the latter with the explicit purpose of collecting information for the design of automated intermediary functions (1982). It is important to stress that the basic results of the studies are of a very similar nature when covering identical elements, although the research mentioned applies different recording and analysis methods and focuses on different user groups and types of information.

All these qualitative empirical investigations are mainly focussed on the *user-intermediary interaction* in various IR environments. The most significant differences between the investigations lie in the elements embodied. One group of researchers attempts to cover the entire search interviewing process, including the search for and retrieval of potential information via recursive IR activities. Another group concentrates on the 'presearch interview' which, as the concept states, is limited to interview activities prior to actual searching and retrieval. Selected experimental settings are described below and the virtues and problems encountered when performing the gathering and analysis of data are discussed. Chapter 5.3 outlines the major results provided by the research encompassing the entire user-intermediary-IR system interaction with respect to factual as well as fiction retrieval. Chapter 5.4 provides an outline of the results of the 'presearch interview' investigations, and discusses the resulting Monstrat Model, which stands as the most substantial framework for intermediary functionality design established so far. The corresponding analytic user-studies are described and selected issues discussed in detail in Chapter 5.5. Chapter 5.6 provides a summary of the user-oriented contributions.

5.2.1 Qualitative methodological issues

In connection to the investigations carried out in Danish public libraries 1975–1981, Ingwersen states (1982, p. 166):

> ..it is a part of our aim to try to reinforce methods and teaching aids which may improve the quality of the information transfer processes conducted by librarians/information specialists. Most librarians constantly handle subject-related questions and concepts outside the sphere of their own formal training and knowledge. [The domain is of universal nature and thus difficult to grasp]. Users also normally cover a very broad range of learning and educational levels [in public libraries]. In addition, the documents as well as the representation of documents mirror knowledge structures, which for the most part are originally derived from scholarly domains.

Hence, the experiments attempted to bring into light the kind of cognitive problems intermediaries and users face during factual information retrieval and verbal communication, and how they are conceivably solved. The findings were primarily aimed at the improvement of training methods in library schools. Not until later did it become obvious to apply the results to developments in other areas of IR, e.g. intermediary design. This purpose is mirrored in the methodological approach used during the experiments, in particular with respect to the analysis method.

Underlying the investigations are the incoming results from the early user studies, referred to in Chapter 5.2. In addition, Ingwersen had carried out a statistically based catalogue use study (1974), applying structured, open-ended interviews and observation. This study showed that approximately 25% of the users applying the (printed) catalogue were looking for topics. However, 40% of this group attempted to locate their topical need in the alphabetical title index. These users simply mixed the conception of title words with that of subject headings. Not really finding any relevant references, they approached a librarian. Also, this catalogue use study demonstrated that only 5% of the users are capable of combining the catalogue subject index and the shelf organisation, i.e. to use the Danish Classification system (DK5). However, this behavioural study did not reveal *why* users behaved as they did.

Thus, the later qualitative investigations focussed on users' own searching and the succeding interaction with an intermediary. Also, some observational studies demonstrated that librarians in practice very often immediately rushed to the shelves to pick out materials (Barnes, 1980). Again, what was lacking in these studies was *why* intermediaries do this, i.e. their considerations and expectations.

Accordingly, the data collection methods in the investigation are *combinations* of 'thinking aloud' and tape recording of conversations, observation of simultaneous activities during IR system interaction, and a self-confrontation interview (post-recording) of the participating subjects. The resulting verbal protocols are then analysed by means of a macro and micro analysis of statements and observations.

The focus of the experimental setting was the *triangular interactivity* between user, intermediary and system. In another Danish large-scale investigation of fiction retrieval and interaction, the identical triangular setting was applied. However, the means of recording was writing down the conversation and observation of actions taken by an observer (Mark Pejtersen, 1980). No mechanical devices were used. Video cameras (with sound recording) might also have been used, as did Atherton-Cochrane (1981). In a triangular online setting, one video camera can be used to monitor the user-intermediary interaction combined with real-time logging of online retrieval. The logging can be replaced or combined with video recording of screen output. Saracevic et al. apply these latter methods of data collection. 'Pre-search' investigations have used video or tape recording of the search interview (Belkin et al., 1982, 1985).

Depending on how the analyses are carried out, certain statistical uncertainty is involved. For instance, the study of fiction IR involved 300 but short recordings. Statistically they mirror the Danish public library user population retrieving fiction. Ingwersen's and Belkin's number of recordings were smaller (7 and 6) but each one much more substantial in length. They do not mirror any population, but divided up into small consistent units they may yield trustworthy behavioural and psychological patterns across recordings.

Chapter 5.2.2 discusses briefly the obtrusiveness inherent in 'thinking aloud' and recording, and the uncertainty related to analysis of verbal protocols.

Chapter 5.2.3 describes the experimental settings for the various experiments conducted during the investigations.

5.2.2 Obtrusiveness and uncertainty

The advantages of the 'thinking aloud' method and recording of dialogues are that everything recorded is in *real-time*, and that the very complicated cognitive tasks, which take place during longer periods, can be analysed. Further, the researchers obtain rather detailed information concerned with problem solving activities. The methods seem better suited for information retrieval studies than, for instance, interviewing and introspection. Another reason for choosing recording in the Danish investigations was that no empirical evidence existed about the cognitive aspects of search interviewing and IR, prior to these experiments. Hence, there was no detailed model on which one might base, for example, interviewing.

Basically, the disadvantage is that the 'thinking aloud' method is obtrusive; in particular, as pointed out by R. Byrne (1977), P. Johnson-Laird and P. Wasow (1977), and G. Hatano et al. (1977), if the subjects are not trained in thinking aloud before real experimentation. The reason is the substantial amount of (longer) pauses that occur without training. Without training, the subjects partly wish to act purposefully, not demonstrating too many misconceptions and errors in a well-known work task to the investigators, and are partly are inhibited by the unfamiliar situation as a whole. By means of training sessions it is thus possible to reduce the pauses to a minimum – but they are inescapable. Especially, when persons are looking for documents on shelves or processing data in the books or indexes, they are not able to read, perceive and assimilate as well as talk aloud about it simultaneously. During IR work tasks, however, it is often observed that information specialists talk aloud to themselves (inner speech). Thinking aloud may therefore be a method not too alien to librarians.

This pause problem does not seem to exist during recording of conversations. The subjects are not thinking aloud. Accustomed to recording, they interact verbally in a natural way. Mark Pejtersen's studies were less obtrusive, partly because no thinking aloud took place, partly because her users were 'day-to-day' users who hardly knew they were subject to investigation. The observer writing down the dialogue simply 'shadowed' the user and the librarian. In contrast, the users taking part in Ingwersen's investigations were trained to think aloud. In all other aspects they were, however, ordinary public library users.

The inescapable *obtrusiveness* during thinking aloud produces a degree of *uncertainty with respect to the experimental results*. Three kinds of uncertainty occur: 1) the degree to which the resulting protocols mirror actual thoughts, and not 'edited' statements; 2) the degree to which the protocols contain the intentionality behind actions and considerations, crucial to the whole outcome of the experiments; 3) the degree to which the protocol analysis methods applied bring forward consistent data, from which conclusions can be drawn.

In relation to the points 1) and 2), the nature of the experimental setting is very important concerning reliability, and *ethical values* are predominant in relation to research conduct. In order to be 'honest' in their thinking aloud, the subjects must trust the researchers that, for example, bad professional conduct, mistakes or errors are not disclosed from the experimental group. Further, the subjects must understand the purpose and objectives of the investigations and agree to the major goals. This was not difficult in the present study, because of its didactic goals. Neither would it be difficult when using the method to assess functional usage of, e.g. screen layout and interface functionality. Subjects must also be constantly informed about progress in the experiments. They should be the first to get the intermediate and final results.

The third reason for uncertainty is connected to the fact that qualitative analysis, although often involving statistical methods, is basically subjective. This is unavoidable, but may be reduced by tightly controlled analysis categories combined with analysis carried out by more than one researcher, independent of one another.

One may state that if thinking aloud protocols contain few and short pauses in the stream of statements, and the statements in addition contain one or two levels of intentionality underlying, for example, activities, then the uncertainty is minimized. An example of a two-level consideration behind a search activity is shown in the protocol example, Figure 5.2, Chapter 5.2.3, statements 2 and 3 ('then I in the first place rather have to ...).

Because of the obtrusiveness, one cannot maintain that one collects data on the true reality, similar to experiments in particle physics. However, one obtains data from the experimental reality which then may be used, for instance, to design intermediary mechanisms. If such a mechanism functions *with* its intended users, we have created a new reality, and conceivably grasped something of the real one during the experiments. We are applying a 'systems evolution' without necessarily being able to explain all relationships. The results may be reinforced by non-contradictive results from other domains using the same methods, or by results from within the same domain, but using other methods.

The present studies have not been contradicted with respect to their basic results.

5.2.3 Experimental settings

The substantial part of this sub-section outlines the experimental settings connected to Danish factual retrieval interaction (Ingwersen and Kaae, 1980; Ingwersen, 1982). Other variations of settings are outlined in relation to the individual research works in Chapter 5.3.

The author may refer to Ingwersen (1982, p. 173–175) for a detailed outline of the investigative settings and analysis methods. The following three basic settings were used:

a) Thinking aloud by *librarians* in different public libraries (their own), based on two sets of *written test questions*. No users participated. The objective was to study the cognitive aspects of *search procedures* (seeking behaviour) in technical domains, in which public librarians often demonstrate lack of knowledge.
b) Thinking aloud by *users* in the identical libraries, based on their own actual information needs. The objective was to observe users' *interaction with the IR systems* (i.e. shelf organisation, reference tools, catalogue), their cognitive *considerations*, and, if they could not find adequate information, their way of *formulating their request* to the librarian.
c) Tape recording of the search interview and IR interaction which took place as a result of b). The aim was to compare the search procedures found in a), observing the *types of questions* posed by the intermediary as well as what the qustions were aiming at, and studying the influence of the IR system, the document contents and tools (conceptual feedback) on the interactive process.

Aside from recording, *visual observation* of the subject's behaviour as well as *post-interviews* were carried out, in order to obtain information on documents used and verification of garbled portions on tapes.

In Chapter 2.2.2 the author refers to setting a) when stating that the proposed concept of information is predictive. This setting's test-questions were constructed so that the researchers had control of the feasible tools and documents that could be applied to solve the information need. Both test-questions deliberately contained expressions presumably either unknown to the librarian (Marking scales used in 'technical draughtsmen' assessments) or the information could only be found in tools very difficult to use for non-specialist (Danish aquavitae's freezing-point). In other words, *breakdown situations were induced* deliberately which supposedly would cause cognitive problems that only might be solved by immediate learning processes, giving raise to specific and pre-defined changes of the state of knowledge in the subjects. Naturally, it is not possible to predict for each individual subject, only for the entire population.

The a) experiments resulted in 2 x 12 protocols, out of which 23 are analysed. The experiment b) resulted in 7 analysed protocols, while c) resulted in 4 protocols that are analysed in relation to user-librarian negotiation (Ingwersen and Kaae, 1980). The duration of protocols a) are from 3 minutes up to 25 minutes. The b) and c) protocols take up to one hour in total.

Analyses of the transcribed protocols are done on a macro-level and a micro-level. The training sessions carried out previous to the real experiments provide a foundation for the construction of analysis schemes. The macro-level analysis is done in order to observe *search activity elements*. The micro analysis spots patterns of the decision-making processes and mental considerations in relation to search tasks. The recordings themselves are used as a supplement to understanding interpersonal conversation patterns, such as filled pauses and verbal emphasis. In the micro analysis thinking aloud protocols as well as interview recordings were divided up into semantically self-contained statements, often separated by pauses. According to the goals of the analyses the statements and their patterns may be used to generate hypoteses for further analysis. For example, statements could be analysed for occurrences of terms and concepts applied, their modification through interaction, and from which sources such concepts derive. The observational remarks in the protocols were found to be of significant value, for instance, when subjects moved along the shelf arangement, looking up documents or pointing to classification indicators on top of shelves, without stating aloud the actual object or location (e.g. Libr.: 'here we are you see and this book should give you some indications ...').

OBSERVATION
REMARKS ( ):

(1): begins at the reference desk
(2): |[5]walks to doc. in reference room| (there are 2 *EK*: a: one for reference purpose b: one for lending Subj. employ first a |[6]reach *EK* and pick up the index card|
(2a): look up tech. draugh. in index
(3): look through the *EK* without finding the card
(4): look up in *EK* b
(5): look through *EK* b
(6): pick up the card concerning tech. draughtsmen
(7): Subj. scans the text

Subj: 05/1/UL/761020-rev. 1-obs.: SK
QI: WHICH MARKING SCALE IS USED IN THE ASSESSMENT OF (TECHNICAL) DRAUGHTSMEN?

|[1](1) "Which marking scale is used in the assessment of technical draughtsmen"|[2] /4/yes/3/then I in the first place rather have to find out which . training the draughtsmen get|[3]err which high school they consult I don't know that immediately|[4] . and uhmm that I think I will look up in the *E*rhvervs*k*artotek|[5+6]/12(2)/|[7]in .. Erhvervskartoteket's. index . . one can look up (2a)|[8]. technical draughtsmen |[9]/26 (3)/|[10] but that article is not in its place|[11+12]... (4)|[13] I'll try the other Erhvervs-kartotek|[14]/24 (5)/|[15] yes that was really embarrassing that . there is a mess in the Erhvervskartotek|[16]... there it was (6) ..|[17] "technical draughtsmen"|[18]/11 (7)/---

Key:
|[1]--------|[2]: a statement
. .: 2 sec. pause
/4/: 4 sec. pause
EK: Erhvervskartoteket—an archive with information on cards on different professions.

Fig. 5.2. Part of verbal protocol concerning the retrieval of information concerning 'technical draughtsmen' (setting a)), translated from Danish; observational remarks are to the left and refer to ( ) in the text to the right (from Ingwersen, 1982, p. 175).

In Figure 5.2 one may for instance observe the generation by thinking of two new concepts, namely 'training of draughtsmen' and specific 'high schools' they consult. Secondly, one may observe the intentionality behind the proceeding application of a reference tool. In the case of search dialogue the protocol will consist of three columns: one for the user statements, one for the intermediary's part of the conversation, and one for the observations taken during retrieval. If an underlying model had been used for the analysis, e.g. the Monstrat Model as in Belkin's case

(1982 →), each statement would be classified according to the model's functional categories. For instance, the statements 7–8 could be classified as 'Query' within the function 'Retrieval Strategy', and the statements 16–17 could be coded as 'Output Generation' – (see Chapter 5.4).

From a methodological point of view as well as a psycho-linguistic approach, the Danish project and the findings are reviewed by G.W. Beattie (1981) as a contribution to cognitive psychology and a conversational analysis application.

5.3 Empirical investigations of user-intermediary-system interaction

This chapter provides the major results deriving from selected empirical studies that cover both the user-librarian dialogue and the retrieval interaction in a triangular way. The chapters 5.3.1 through 5.3.3 concentrate on factual retrieval, e.g. in reference work, while Chapter 5.3.4 deals with the retrieval of fiction.

One of the first empirical studies of user-librarian interaction during information retrieval to be published was by Hitchingham (1979). Based on a behavioural approach using a socio-emotional analysis-scheme, Hitchingham recorded and analysed 18 user-intermediary interviews during searching, performed in research institutions with access to the MEDLINE online database. Users ranged from students to research faculty staff and were mainly online novices with various levels of domain knowledge as background. The objective of the study was to quantify the volume of user information-giving and intermediary-asking, and the frequencies of different types of events taking place. Previously, Saracevic had proposed theories stating that domain knowledgeability among users may be a factor leading to provision of more information, to improved assessments of relevance and to more concern for recall than less knowledgeable users (1970). Hitchingham's study demonstrates no basis for such conclusions. However, the fact that a major part of the users were inexperienced in online IR may have influenced the result.

Slightly earlier, M. Lynch reported the results from investigations of the reference interview in public libraries (1978). She recorded (by writing) and examined 309 real-life interviews (elements 3–8, Figure 5.1), mainly concentrating on the question modes applied during interviewing. The results are basically of a quantitative nature.

Also in a public library context, with no online facilities at hand, Ingwersen et al. made use of 'thinking aloud' methods, observation and tape recording of librarians' as well as users' mental procedures and use of strategies during their own searching for information (Ingwersen and Kaae, 1980; Ingwersen, 1982), as outlined in the previous chapter sections. The results of the intermediaries' retrieval performance and user-librarian interaction are given below. The resulting user characteristics are outlined in Chapter 6.1 in relation to cognitive models of individuals in IR. Results concerning the nature of the information need are provided in Chapter 5.5.2 in relation to other studies of this issue. All these results are of substantial relevance to the construction of the Mediator Model displaying functional requirements for intermediary mechanisms, discussed in detail in Chapter 8.

5.3.1 *Human intermediary IR behaviour*

With reference to Ingwersen (1982, p. 182–188) the experimental setting a) yielded 23 protocols based on two different requests. The librarians were told to act as if the requests represented inter-library loan specifications.

Aside from strong evidence about the *influence of the work task environment* on actual IR performance, motivation and selection of retrieval procedure (1982, p. 184, fig. 5), the investigations showed the following basic results on intermediary behaviour:

a) the *mode of searching is determined by* work domain, IR and actual conceptual knowledge on the topic, motives, and expectations as to documents and text representation;
b) the *mode of searching determines* the perception of potential information from the IR system, documents and text entities, i.e. it controls the learning effectiveness in unknown territory.

Three different modes of retrieval of information were found: *open, fixed,* and *semi-fixed search mode.*

'Open search' implies that the intermediary attempts to *extend* its conceptual knowledge, to find out about the subject area based in the request. The IR systems, documents and tools are used to *learn about* the conceptual characteristics surrounding the request. The IR system is used primarily as a *feedback mechanism* in this process. When the intermediary has perceived and obtained useful information about, for example, where 'technical draughtsmen' are trained, the mode shifts into 'fixed search mode' – and final searching for the information to the user is initiated.

'Fixed search' implies immediately to search for the information required by the user. This mode is effective only when the actual conceptual knowledge possessed by the intermediary is substantial. Otherwise the 'fixed mode' is very ineffective. The intermediaries begin to search in circles, i.e. returning to the same retrieval tools previously frequented. Random associative searching may take place.

'Semi-fixed search mode' implies starting as in the fixed mode. But mainly due to retrieval problems, the mode may change momentarily into 'open mode' in order to learn about the topic.

Ingwersen states (1982, p. 186):

> It is important to note that, although .. the librarians when initiating an enquiry prefer action before consideration of the problem, these *actions* .. may have *different objectives* because of the [intermediary's] attitude employed. Thus, *externally observed*, the same repeated search routine, e.g. looking up in a tool, may in fact be used in different ways; for example to gain information or find the answer.

Consequently, the expectations and the intentions behind the retrieval actions control their use, i.e. the same tool is used in two different ways. The interesting point is that intermediaries in 'open search' seem much more sensitive to perception of new information which changes their *state of knowledge,* than individuals applying 'fixed search mode'. In the same tools, looking for information related to identical requests, the latter group tends to *overlook* that piece of information, necessary for further retrieval, which is discovered by the 'open' group.

In addition, the study demonstrates the percentage of *perceived and remembered new concepts* related to search mode across the 23 protocols. The figures indicate that in 'fixed mode' the subjects only reuse (from perception of reference tools), as well as via recall from memory, 35% of their concepts applied during all search actions. The remaining 65% derives only from the initial request statement. In contrast, both 'open' and 'semi-fixed' librarians re-use, via perceived feedback from materials and via recall from memory, 60% of the employed concepts. The 'open' group mainly consisted of reference librarians while all the 'fixed searchers' had their working domain in lending departments.

In relation to *intermediary design* these results indicate that by *interrogation* of the remote information space, i.e. the IR systems underlying the intermediary, it is possible heuristically to *apply the feedback conceptually* to extend actual knowledge *and*, at the same time, to learn about rather unknown retrieval tools or IR systems.

It is consequently necessary to possess an *IR system model* and a *System modelling* or *model building* mechanism. If interrogation is not possible, the intermediary mechanism may stick only to its pre-defined tools and IR systems, not even being capable of *verifying* whether a tool or a database is adequate or not, or maybe has a changed index routine.

5.3.2 Human intermediary-user interaction during retrieval

In relation to total IR interaction, setting c), the analyses of the four protocols indicate the following results of interest for intermediary design (Ingwersen, 1982, p. 178–182):

1) use of *open questions is scarce and use of closed question types* seems to depend on the intermediary's knowledge state concerning the subject area;
2) provision of *conceptual feedback* from IR systems and documents seem crucial for the user's request development and the match of participants' knowledge structures with the IR system;
3) questions to the *underlying problem or work task* often provide highly relevant information and concepts to be used in the proceeding retrieval process.

Although these results must be regarded as indicative, the findings in 1) and 3) are confirmed by investigations by Belkin (1984) and Brooks (1986a). The results in 2) on feedback are currently under study by Saracevic, Mokros and Su (1990) and preliminary findings seem to confirm the conceptual feedback as fundamentally important.

Like in the study by Lynch (1978), the use of '*open*' *questions* (why?, when?..) was scarce throughout all negotiations, regardless of the amount of background knowledge possessed by the intermediary on the topic. Logically open questions would seem very adequate since they may provide a certain amount of *situational context* in answers from the user. However, there seems to exist a connection between lack of domain knowledge and use of '*closed*' *questions* posed by the intermediary as a replacement (is it ..?; has that to do with ..?). As for open questions, the aim of the closed ones is to obtain a context from the user – but in a much more *controlled manner*, for instance (Ingwersen, 1982, p. 180) [the initial request from the user in this case is about the 'application of Boolean logic']:

> (Librarian standing at the philosophy groups, showing a book on Boole):
> 'Is this .. is it Boole...this?
> User: 'Yes, that ... it's his *laws*, but his ... his dogma *doctrines*
> are not here ... his, they are called *identities*.
> (*laws* is new information at this point of interaction)

By showing a specific book or text item, the intermediary confines the conceptual level and space, to which the user is allowed to respond. With really open questions the answer is similarly open and rather unpredictible. When interviewing the participating intermediaries about this issue, it became clear that their previous *experiences* in situations of weak knowledge had taught them not to use open questions, since in those cases they did not fully understand the answer and its concepts. In such situations they felt they lost credibility.

On the other hand, when possessing sufficient knowledge, "open questions are not required since we (the librarians) are capable of creating a picture of the need rather fast" (citation from post-interview). This seems confirmed by the recordings of the search interviews. Closed questions are applied to confirm the picture and to refine it. In research libraries this method seems rather frequently used, because of the knowledge characteristics of the domain specialists acting as intermediaries.

An additional interesting aspect is the degree to which new concepts provided by a user actually become applied in the subsequent retrieval processes and search dialogue. This aspect touches upon point 3) above. A general trend is that non-understood concepts are *not used* by intermediaries. (In the dialogue example above the new concepts are understood as leading to mathematical aspects of the 'Boolean request' which make the intermediary take the user to these groups of materials on the shelves).

In relation to *design*, this issue of question mode and use of concepts is important. Simulations of 'closed questions' in an interface take the form of menus with confined *pre-defined options*, i.e. such as asking "Is your question (e.g. on Boolean logic) related to 'philosophy', 'mathematics' or 'computer science'?". The protocols demonstrate that the *conceptual level* is maintained in the user's contextual answer. This implies that aside from pointing to an option, similar to stating "yes – it is computer science", and implicitly answering "no" to the remaining options, one may open it up for users to enter their own answer if not satisfied with the options, as shown in the example above.

Furthermore, an 'open question' mode could as well be applied by an intermediary mechanism in IR. As stated in Chapter 7.4, requests in NL may be used without the necessity for really understanding the meaning of the request. Because humans tend to forget potential information not perceived, and consequently do not make use of the concepts later on, this ought *not be simulated* in computerized intermediaries. On the contrary, such non-recognized concepts can obviously be used to infer *conceptual feedback* from the underlying IR system(s) – point 2) above. The feedback seems useful because it allows the user to define and/or modify his request.

In relation to point 3) above, Ingwersen suggests questioning the user about his problem or interest situation in his problem space, stating (1982, p. 182):

> Frequently the answers take the form of *situational classification* of concepts, including highly relevant relations to some kind of process or *working situation*, often containing recognizable common concepts linked to more special/scientific terms.

In the case of menu or window-driven options from which the user may pick the relevant one, the options ought to mirror work tasks and processes in the actual domain.

In relation to Hitchingham's results (1979), Ingwersen found that IR-inexperienced but domain knowledgeable library users become influenced by the role and status of the intermediary which, together with their expectations, are determining factors for their information-giving activities.

The protocol analyses lead directly to studies of the importance of system feedback in relation to the knowledge involved in various user types and IR system components in operational online IR systems, discussed by Ingwersen (1984a) (Chapter 7.3), and further, to improved understanding of the intermediary role and functions (1986).

5.3.3 Online IR interaction behaviour

Online IR interaction behaviour has been studied by Fenichel (1980, 1981) in connection with end-user searching and levels of IR experience. Using decision theory for the framework of their study, Blackshaw and Fischhoff extend the investigations of online IR interaction to encompass end-users, intermediaries and the online system (1988).

The most profound empirical study of the triangular human-human-computerized IR system interaction has been in progress in the USA since 1988, performed by T. Saracevic and L. Su at Rutgers University. Their aim is to

> contribute to the formal characterization and better understanding of elements involved in information seeking and retrieving, particularly in relation to the cognitive context and human decisions and interactions in these processes. ... The objectives are to 1) observe and classify the elements in interactions between users, intermediary searchers and computer in the context of online searching in libraries and 2) observe the *effects* of different types of interactions on search results as judged by users (Saracevic and Su, 1989, p. 75–76)[emphasis by this author].

This promising real-life study makes use of video-recording, logging and observation and intends to produce both quantitative and qualitative results in detail. As can be seen, the investigative methods as well as the scope overlap and extend the studies of Mark Pejtersen and Ingwersen (who did not involve computerized IR), and those of the Belkin team (human-computer interaction practically not involved). Preliminary results are under publication (Saracevic, Mokros and Su, 1990) and show for example that the average time spent for pre-search interviewing (elements 3–5, Figure 5.1), compares roughly to 1:2 to online connection and further search interviewing including evaluation (elements 6–9). Further, the average precision ratio achieved equaled 57%, somewhat higher than found in studies without intermediary interaction, where average precision hovered around 40–50%. *Feedback from the online IR systems* searched plays a determining role for the conduct of IR interaction, as also indicated by Ingwersen (1984a, 1986). The initial results are based on 40 actual requests, providing 49 hours of vidoetaped interactions and 34 hours of online searching, including 6,200 relevance judgments by end-users.

These studies and the relative progress of the field outlined in previous sections demonstrate the value of international cooperation. During the period 1977–1983 a close international contact existed between the Danish teams and the British one headed by Belkin, resulting in exchange of models and methods (Belkin, 1990). Since 1987 research relations have been re-established across the Atlantic. The investigative results supplement one another, in particular with respect to the role of system feedback, types of knowledge structures involved in IR, user and task modelling, and intermediary functionality.

5.3.4 Fiction retrieval – strategies and dimensions

Mark Pejtersen (1980) recorded 300 user-librarian-system interactions in relation to real-life fiction retrieval in public libraries. Recordings were made by an observer writing down the often short dialogue sequences. The results display important *dimensions* around which users develop their desire for emotional experiences and information, and demonstrate *5 basic strategies* by which they attempt to retrieve information in the system, supported by the librarian. Among the dimensions heavily employed by users are, for example, 'author intention' with a novel, the 'plot', the 'genre', 'time, place and environment', 'main characters', 'emotional experience', 'ending', and 'front cover colours and pictures'. The five search strategies applied to fiction are (Mark Pejtersen, 1979):

Bibliographical A, later called *browsing*, in which the searcher pick out books from shelves ad random, asking about their content;
Bibliographical B, asking for a specific known title or author;
Analytical, in which one or several of the dimensions are employed;
Empirical, the intermediary selects books based on user stereotyping;
Similarity searching, or searching by analogy, and added later to the 'Bookhouse'; the user wants books similar to a known one;

While factual IR is supported by a large amount of retrieval tools, fiction IR is characterized by very primitive tools, including the electronic ones. Consequently, the intermediaries must rely on their own book (IR) knowledge. The 'Fixed' search, i.e. 'ask and rush', is therefore the predominant search mode in fiction retrieval, explicitly applied to the Bibliographic B strategy, implicitly in other strategies.

The understanding of the representative dimensions of *user aboutness* and preferences, not at all accounted for in public libraries, lead Mark Pejtersen to further investigations of childrens' retrieval patterns (1986) and finally to the design and implementation of the 'Bookhouse' – a prototype fiction retrieval system for adults and children, with an icon-based intermediary mechanism, at present in action in several Danish public libraries (1989). The 'Bookhouse' contains all the dimensions and the 'Bibliographical' (Browsing), 'Analytical' and 'Similarity' strategies in addition to a fourth one, the icon-based 'subject search' strategy. The stereotypical 'Empirical' strategy was omitted, since it requires substantial user-dialogue and well-established intermediary 'experience' in order to function properly. The 'Bookhouse', a typical product of the emerging cognitive IR research approach, will be dealt with in more detail in Chapter 7.1.

5.4 Pre-search interviewing investigations, excluding retrieval

Opposite to Mark Pejtersen's and Ingwersen's investigations, viewing the IR interaction as a *heuristic* problem solving activity with the interview integrated during retrieval, Atherton-Cochrane and Belkin et al. view the interview as a *systematic problem solving activity*. This mode of search interviewing implies that the negotiation mainly takes place prior to retrieval, i.e. in a *pre-search stage*. Atherton-Cochrane (1981) applied videotape recording of the reference process and specified eight general tasks, or rather functions, comprised of those of Ingwersen (Chapter 5.1.3) and the Monstrat functions (see Chapter 5.4.1 below).

All Atherton-Cochrane's tasks are *tuned towards the user side*. Because the goals of the project was limited to discoveries concerned with pre-search processes, the system-associated tasks mirror intermediary functionalities in relation to future events, not actual ongoing search events. In other words, they display negotiation about, for instance, which database *might be* the appropiate one to search and which strategy to apply in a search session in future. In contrast to the previously mentioned projects and Belkin et al.'s investigations, Atherton-Cochrane's analyses did not cover the verbal interaction between user and intermediary, i.e. question-answering relationships and influence on the proceeding dialogue, for instance leading to turntaking, were not studied.

Belkin, Oddy and Brooks (1982) conducted their investigations in a university library setting with access to the local online information service. As in Ingwersen's investigations, they applied tape recording and protocol analysis, although basically of the pre-search interactive activities. They base their empirical studies partly on the experiences gained from the THOMAS system by Oddy (1977), partly on a further development of the theory and hypotheses of ASK (Anomalous State of Knowledge) and Belkin's concept of information (1978) – previously outlined in Chapter 2.2.

In a preliminary design study, 27 novice users, who were going to require information from the service, "were to be asked to discuss *the problem* with which they were faced prior to presenting a more formal request to the system" (1982, p. 145). These real-life problem statements obtained via interviews were recorded and went through a simplistic (surface-level) text analysis, producing structural representations, e.g. in the form of association maps. In addition, selected abstracts were analysed, and both types of representations were evaluated for the degree of similarity to the original sources by their corresponding generators, i.e. users and abstract authors. The users' problem statements (i.e. their ASKs) were analysed for characteristics and patterns, leading to two basic types of ASKs, i.e. well-defined and more – or – less ill-defined ones.

In relation to retrieval, the idea was to evaluate the degree and patterns of overlap between the structured representations of abstracts and problem statements, in order to define means to improve existing IR strategies and techniques. These interesting initial analyses result in the suggestion of interviewing the user, *more* about what he *knows* to be *his problem*, than what he wants to know but is more or less unable to formulate, i.e. what he does not know yet. Hence, it seems important to the intermediary mechanism to *build a model of the user's problem space* (including the state of uncertainty), getting at information-rich problem statement(s). Such statements, in the author's opinion, may most likely be obtained from users with already well-defined problem spaces and uncertainty states. Naturally, rich problem statements will probably lead to rather well-defined requests for information. This cause-effect relationship was not investigated further – nor were the cases grounded in ill-defined problem statements. Conceivably, such frail problem spaces may result in rather ill-defined information requests.

Along similar theoretical lines, Belkin and Kwasnik later proposed a design for a retrieval mechanism which attempts to look for similarities and matching between associative graphs of narrative problem statements and document text structures, in order to choose appropriate IR techniques (1986).

5.4.1 The MONSTRAT Model

The design study by Belkin's team mentioned above was followed up by a functional analysis of six rather extensive pre-search user-librarian interactions. The results are presented by Belkin and Brooks (1983), Belkin (1984), Brooks (1986b) and Daniels (1986) and demonstrate an analysis scheme consisting of 11 categories and a number of sub-categories. Fundamentally, the meta-categories of the scheme are identical to the *intermediary functions* that constitute the analytic *Monstrat Model* (MOdular functions based on Natural information processes for STRATegic problem treatments) developed by Belkin, Seeger and Wersig slightly earlier (1983). Figure 5.3 demonstrates the basic functions of the model. One may note that the ASK assumption is underplayed, merely replaced by 'problem' situation and problem treatment. It seems that the model displays a merger between Wersig's and Belkin's thinking from the seventies on the concept of 'information', outlined in Chapter 2.2. A concept of 'information need' does not exist in the model – only the concept of 'problem'.

The analyses of the interview protocols lead to an extension of the original Monstrat Model, by defining a number of sub-categories or tasks (Figure 5.4). Belkin (1984) in addition proposed an overall model of the IR communication system (p. 114), "roughly based on the model presented by Ingwersen (1982, p. 171)". Belkin does not, however, consider the intermediary-IR system and user-IR system interaction in his analyses, although the cited communication model demonstrates his awareness of this issue. Clearly, Belkin is able to show what the Monstrat Model essentially is about, namely

> that interactive model-building between intermediary and user actually takes place, particularly concerning user's problem, goals and [knowledge] background – useful in the successful conclusion of user/intermediary interaction (Belkin, 1984, p. 127).

Name of function	Description
Dialogue mode (DM)	Determine appropiate dialogue type for situation, e.g. natural language, menu, form-based.
Problem state (PS)	Determine position of user in problem treatment process, e.g. formulating problem for a paper (student)
Problem mode (PM)	Determine appropriate mechanism capability, e.g. reference IR or referral to institutions and persons
User model (UM)	Generate description of user type, goals, beliefs, e.g. graduate student, thesis or paper, R&D person, etc.
Problem description (PD)	Generate description of problem type, topic, structure, environment, wanted attributes in texts (doc.type)
Retrieval strategy (RS)	Choose and apply appropriate retrieval strategies to knowledge resource, e.g. exact match, extended Boolean
Response generator (RG)	Determine propositional structure of response to user appropriate to situation, e.g. list document titles;
Input analyst (IA)	Convert input from user into structures usable by functional experts e.g. parce NL request text, note option selection;
Output generator (OG)	Convert propositional response to form appropriate to user and situation, e.g. display new menu, rank titles;
Explanation (EX)	Describe mechanism operation, capabilities, etc. to user as appropriate.

Fig. 5.3. Functions and their description for the MONSTRAT model (Belkin et al. 1987, p. 399).

The model has been modified slightly over the years and contains at present the 10 major functions displayed in Figure 5.3 (Belkin et al., 1987, p. 399), to be performed in the IR interaction processes (Daniels, Brooks and Belkin, 1985). The most profound description of the model is found in Belkin, Brooks and Daniels (1987).

Belkin et al. describe the properties of the model by stating (1987, p. 399–400):

> The MONSTRAT model specifies ten functions which an IR mechanism needs to perform in order to achieve its goal of helping the user with his problem....In the general information seeking interaction, the IR system needs to have:
>
> * an understanding of the state of the user in the problem solving process (PS) [Problem State];
> * an idea about what kind of response or system capability is appropriate for this user and problem (PM) [Problem Mode];
> * a *m*odel of the *u*ser himself, including goals, intentions and experience (UM);
> * a *d*escription of the *p*roblem the user is facing and the user's knowledge about it (PD);
> * a hypothesis about what sort of *d*ialogue *m*ode is appropriate for this user and problem (DM);
>
> This information will be gained through interaction with the user, which will require analysis of the user's part of the dialogue (by the IA) so that it can be used by the other functions. The results can then be used to specify what aspects of the knowledge resource or database might be relevant to the user at this time (RS). From this potentially relevant 'world' a response particular to the specific situation can be generated (OG). Finally, it may be necessary to explain the IR system's operation and competence to the user (EX). These functions are necessary for solving sub-problems of the overall IR problem. Routines solving these sub-problems thus constitute the 'expert' components of a distributed expert model of an IR system.

Associated with the ten main functions, the Monstrat model at present operates with 23 tasks that have been elaborated and extensively studied by Brooks (1986a, 1986b) and Daniels (1986). Brooks has concentrated on the very important Problem description (PD) and Retrieval strategy (RS) functions, while Daniels deals with the User modelling (UM) function. Figure 5.4 outlines the tasks and their description.

One may observe that certain tasks mirror the academic library setting within which the empirical investigations took place, for instance *RESEARCH* (in Problem description) or *PROBDIM* (in Problem state). These have been generalized by the author. In addition, the model holds certain *Meta-goals* which are tasks necessary to carry out in order to *PLAN* interviewing and implement strategies, e.g. for the case that the initial search obtains zero postings. A *MATCH* task serves to compare the models that participants holds of aspects of each other.

In the author's view the Monstrat model can be seen as aiming at:

1. *Supportive IR intermediary design*, i.e. a highly interactive intermediary mechanism that relies on *implicit user and domain models*, based on extensive field studies of actual domain, tasks and user preferences;
2. '*Intelligent' IR intermediary design*, i.e. an intermediary mechanism that relies on both implicit models *and* interactive, actual and *explicit user and problem modelling*;
3. *Education*, i.e. be the framework for training future information specialists in IR interaction;

Monstrat function	Task name	Description
Dialogue mode (DM)		Determine appropriate dialogue type, e.g. NL or menu options;
Problem state (PS)	*PREV*	Determine the user's previous reference activities;
	PREVNON	Determine the user's previous non-reference activities;
	PROBDIM	Determine the problem dimension; this refers to anything which is temporally coded within the state of research [or work task activity];
Problem mode (PM)	*CAPAB*	Explain the capabilities of the system[s] [and the intermediary] to user;
User model (UM)	*UGOAL*	Determine the user's goals;
	USER	Determine the status of the user, e.g. student/researcher;
	KNOW	Determine the user's knowledge state of the field;
	IRS	Determine the user's familiarity with IR systems and retrieval;
Problem description (PD)	*SUBJECT*	Define the subject area or background to the search;
	SUBJLIT	Determine formal characteristics of the subject literature [in domain];
	RESEARCH	Specify the content of the user's research [work task activity];
	TOPIC	Specify the search topic;
	DOCS	Determine the content or description of documents that the user would like to retrieve;
Retrieval strategy (RS)	*TERMS*	Select the terms for searching;
	QUERY	Formulate the query;
	STRATEGY	Evolve the search strategy (how query will be implemented);
	DBSELECT	Select the database to be searched;
Response generator (RG)		Determine propositional structure of response to user [from IR system]
Input analyst (IA)		Convert input from user into usable structure;
Output generator (OG)	*OUTPUT*	Determine the output requirements [or convert propositional response from (RG) to form appropriate to user & situation];
Explanation (EX)	*EXPLAIN*	Bring the user's knowledge of IR up to the minimum level necessary for functioning;
	DISPLAY	Literal display of some aspect of the [IR] system [or intermediary];
	INFORM	Explain the intermediary intentions to the user;

[ ]: Explanation added by Ingwersen to disambiguate or generalize (1991, p. 52).

Fig. 5.4. Monstrat functional tasks, (Daniels, Brooks, Belkin, 1985; Brooks, 1986b; Daniels, 1986).

The first purpose or use of the model implies that the user may recognize his domain, tasks and preferences in the intermediary, which assists or guides him in the IR interaction, providing appropriate support during this process. Certain Monstrat functions, such as Problem state, Problem mode, Dialogue mode, and User model will then have a passive role, displaying options, being transparent and *already* adapted to its potential users.

The second purpose, the 'intelligent' intermediary design, is aimed at "a distributed problem solving model with individual experts for particular functions" (Sparck Jones, 1987, p. 9). This 'expert intermediary' will have its functions playing an active role of user modelling, posing questions and using the answers to infer further actions according to the implemented models.

This two-fold distinction between design purposes is exemplified in Chapter 7, discussing selected IR intermediary designs.

5.4.2 Critique of the MONSTRAT Model

As with Atherton-Cochrane, the *pre-search framework* for the investigative setting and analysis makes it difficult to observe the possible *impact* of actual, ongoing searching events and effects of conceptual feedback, for example, in the form of term lists or networks, reference tool pages, or special features from the IR system. *This limitation in the scope* of the investigations makes the resulting Monstrat model of intermediary functions geared heavily towards the centre and right-hand side of Figure 3.2. With this limitation in mind, however, these detailed analyses of human-human interaction evidently extract elucidating data, fundamental to eventual designs of some, but not all, the components in automated intermediary mechanisms supported by AI techniques.

The *limitations of the pre-search framework* become transparent when observing the explicatory notes to the functions and tasks of the model. Although the model "was intended to be a *general* model, applicable to different types of information systems" (Belkin, et al., p. 400), it is the author's opinion that there are yet important hidden functions and assumptions underlying it.

First of all, no *System model* and *System dialogue functions* exist, although Problem mode (PM), Retrieval strategy (RS), Response generator (RG) and Explanation (EX) require rather detailed models and functions to either 'determine', 'choose and apply' or 'describe' IR system facilities. This constraint should be seen in relation to Figure 3.2 and the intermediary functions, analytically arrived at in Chapter 5.1.3. There, the 'System model', 'System feedback' and 'System dialogue' functions serve to contain knowledge of local or remote IR systems, and to find out about or adapt to such systems. That kind of *IR knowledge* is explicitly demonstrated in all IR models by Ingwersen (1982 →) as an essential part of an intermediary mechanism (see for example Chapter 6.1). Therefore, (EX) must be capable of informing about the intermediary itself *and* external IR systems. In relation to the (EX) function Belkin has reviewed his verbal protocols to identify clues for broadening its scope (1988).

Secondly, the Monstrat model ought to possess a *Domain knowledge model* or a conceptual knowledge function related to a 'User model', in order to at least analyse the user input (IA) and/or to determine the user status and knowledge (UM) by model *building*; especially, if the intermediary system is supposed to understand the problem in question (PD) before turning it over to Retrieval strategy (RS). This Domain knowledge model is explicitly present in the cognitive IR models, presented in Chapter 6.1.

Thirdly, the Monstrat model explicitly works on the user's *problem*, underlying the desire or need for information. However, as the model is designed, scarce explanation exists with respect to cases where users may *not* be capable of, or do not want to, state their problem, interest or goal in a well-defined manner. Logically, such cases imply that information needs likewise may be ill-defined. In other words, the Monstrat model seems very suitable in IR situations with relatively well-defined problem statements, in which users may (or may not) be able to formulate their need for information (i.e. assuming the original ASK assumption). The Monstrat Model's Problem Description sub-function may, like a human intermediary, have difficulty in getting to an ill-defined problem, including the determination of this situation, without profound Domain and Conceptual knowledge models.

The aim of the model, i.e. to get at the problem, is closely linked to the question about whether users always make a distinction between problem and information need. The underlying 'problem' may simply be to obtain information, as in connection with emotional experience (Request: I want a funny novel. Why? – Because I want to read something to kill time!), or the 'problem' or goal and information need are identical (Request: I want something about the tuning of car engines. What is your problem? – I want to tune my car engine!). In fact, the distinction seems only adequate when users have ill-defined information needs and well-established problems (Request: I want information about tuning. Why? – Because I want to tune the engine in my Honda 1.3 Civic Sedan).

Fourth, an underlying assumption seems to be that the Monstrat model is to be directly applied to *simulate* user-human intermediary interaction in a man-machine environment in the form of an IR expert intermediary system. To this end, the model seems adequate and in line with the interface design suggestions by J.L.Bennett (1972), H. Ramsey and J.D.Grimes (1983) and E. Hollnagel (1979, 1987). Their suggestions are discussed in relation to selected intermediary designs in Chapter 7.1.

In the light of the discussion of the cognitive viewpoint (Chapter 2), a slightly different assumption would be to make the model aim at supportive aspects of IR, as suggested in the previous chapter. This would imply *stimulating* (not necessarily simulating) the interactivity by supporting the user's IR interaction. This objective has, however, so far not been the intent behind Monstrat.

In her discussion of the Monstrat model seen as a general, distributed IR expert mechanism, K. Sparck Jones states (1987, p.11):

> Though it is possible to argue about the proposals [by Belkin et al. on the use of Monstrat], it is clear that something like these functions have to be carried out by information provision mechanisms. The set of functions also reflects an approach to information systems from the

> perspective of the user: a broader view could suggest *other functions*, for example a 'matching function' and, in the most general case, a 'document indexing function', for example. However, there is no doubt that the functions listed are material ones, and that the Problem description function in particular, is central to the whole concept of an information retrieval system. [Emphasis by this author].

This demonstrates an awareness of the limitations inherent in the Monstrat model in its present state. In one way or another, however, the model seems fit for further development in order to design 'intelligent' intermediary mechanisms for 'stand-alone' IR research configurations. This use of the model is rather advanced but may not in all IR situations be the optimal choice for an intermediary mechanism. This most certainly depends on the actual requirements in the IR environment for which the intermediary should be designed.

The Mediator Model (Chapter 8), contributes to the further development of the Monstrat model by adding appropriate functions and tasks, also incorporating IR system-related functionalities. Further, the chapter attempts to make recommendations for the use of the functions, depending on requirements imposed by the work domain including IR systems, tasks and user preference parameters. The additional requirements adhere from the empirical investigations and the analytic studies discussed in this chapter. This extension of the existing model is in line with some of the suggestions by Belkin et al. (1987), who state that further specification of the model is required.

5.5 User-oriented analytic studies of IR interaction

This chapter discusses selected aspects of IR interaction. The first sub-section aims at a detailed analysis of the nature of the information need, as proposed by R.S.Taylor (1968). Taylor's assumptions have had a great influence on several empirical investigations, for instance leading to the discovery of the 'label effect' in requests for information. Chapter 5.5.2 demonstrates empirical evidence which supports and extends some of Taylor's proposals. Chapter 5.5.3 outlines analytic research on question analysis and browsing in IR, followed by theoretical approaches to user modelling and search interviewing, in Chapter 5.5.4. User-oriented analytic design of interfaces to operational online IR systems is briefly discussed in Chapter 5.5.5.

5.5.1 The nature of the information need

The most interesting theoretical assumptions about how an information need or information problem may develop in the mind of a user are made by R.S. Taylor (1968). His work is a significant innovation in IR research, since it postulates that a particular psychological state of mind of the user may lead to an expressed request for information. Directly and indirectly, the theory has inspired several research projects of both an empirical and analytic nature up to the present day. Based on interviews with academic librarians, Taylor suggested four levels of question formation. Three are intrinsic and the fourth constitutes the request for information to the IR system. He states that "these four levels of question formation shade into one another along the question spectrum...along a continuum" (p.182):

Q1. *The visceral need*, the actual but unexpressed need for information.

> ..there is the conscious or even unconscious need for information not existing in the remembered experience of the enquirer. ..It is probably inexpressible in linguistic terms. This need (it really is not a question yet) will change in form, quality, concreteness, and criteria as information is added, as it is influenced by analogy, or as its importance grows with the investigation.

Q2. *The conscious need*, the conscious, within-brain description of the need.

> ..a conscious mental description of an ill-defined area of indecision. It will probably be an ambiguous and rambling statement. The inquirer may, at this stage, talk to someone else to sharpen his focus.

Q3. *The formalized need,* the formal statement of the need.

> At this level an inquirer can form a qualified and rational statement of his question. Here he is describing his area of doubt in concrete terms and he may or may not be thinking within the context or constraints of the system from which he wants information.

Q4. *The compromised need,* the question as presented to the information system, [i.e. the Request].

> ..the question is recast in anticipation of what the files can deliver.. Unless the inquirer knows the information specialist well, he is inclined to pose his first question in positive and well-defined terms.

Like several other researchers in the field, Taylor refers to what D.M. Mackay calls "a certain incompleteness in his [the inquirer's] picture of the world – an inadequacy in what we may call his 'state of readiness' to interact purposefully with the world around him in terms of a particular area of interest" (Mackay, 1960). Both Mackay, Taylor and the author see the 'inadequacy' as the *mental trigger* for the proceeding internal activities concerning the desire for information. One may regard Mackay's 'area of interest' as the individual's *work space* in a domain (see Figure 6.3, Chapter 6.1).

Following the information concept for information science, discussed in Chapter 2.2.1, one operates with actual 'state of knowledge', 'problem space' and 'state of uncertainty'. 'Problem space' being a situation specific state of mind in which the individual recognizes its lack of knowledge, e.g. in order to choose between possibilities of action, of solutions to problems, or in relation to the fulfilment of factual or emotional goals. If not capable of filling or reorganizing this problem space by thinking, the individual's state of mind may end up in a 'state of uncertainty', which may be reduced by external information through interaction with the world around it, e.g. by accessing an information retrieval system.

One may hence view Mackay's 'inadequacy state of knowledge' (ISK) as equal to Belkin's ASK (1978) and the 'state of uncertainty' (USK). It is the state of uncertainty which produces the desire for information, i.e. is responsible for Taylor's 4 stages, *directly* relating to the stages Q2 and Q3. The relationship is discussed below.

Besides, Taylor touches upon important aspects of the inquirer's background knowledge, the *familarity effect*, i.e. the user's knowledge of the librarian and vice versa (Ingwersen and Wormell, 1988, p. 100–101), and the possible means for the librarian to interview the user backwards towards Q3 or Q2. To this end he outlines 5 *filters* which may be regarded as 'intermediary functions' (1968, p. 183):

Taylor's filters	**Monstrat functions**
1. Subject definition	Problem description
2. Objective and motivation	User model
3. Personal characteristics of enquirer	User model+Problem state
4. Relationship of enquiry description [request] to file organisation.	Problem mode+Retrieval strategy
5. Anticipated or acceptable answers.	(User model+Output generator)

The filters 2 through 5 are all concerned with investigating the intentional cause (the problem or goal in problem space) underlying the information need. The filters may thus be compared to the Monstrat functions, discussed in Chapter 5.4.1. Except for the last filter, the Monstrat model covers them all. The reason for exposing a certain doubt about the equivalence between filter 5 and the suggested Monstrat functions (User model+Output generator) is caused by the fact that the Monstrat model does not incorporate tasks that explicitly handle users' estimation of acceptable answers. This may be due to the different settings for investigation: Taylor's experiences are with academic researchers, who often know what to expect, while Belkin, Brooks and Daniels (1987) mainly deal with students as users, who may seldom possess such knowledge. However, one may assume that 'anticipated answers', Filter no. 5, may form part of the task 'Ugoal', belonging to the User model function, in Figure 5.4. (Similarly, the filter might belong to 'Docs' in the Problem Description function).

Because of the conception of the five filters, in particular the second one, it is evident that Taylor is *fully aware* of eventual mental factors that give cause to the development of information needs, i.e. factors underlying his four stages. Very often, this rather crucial *motivation* aspect of Taylor's theories has been neglected in later research on information need development.

Hence, Taylor's four stages do not deal directly with the 'problem' or 'goal' of the individual, but with developing *representations* of the resulting information need. The stages form a *theoretical framework* for investigating formations of various types of information requests.

The process through Q1 to Q3 can be seen as internal representations of increasing cognition or awareness of the need for information in the individual's mind. The stages are thus encompassed by the individual's *problem space* – the Figures 2.3 and 3.2. We may attempt to translate Taylor's assumptions into the conceptions inherent in the models shown in these figures.

Following Taylor (1968, p. 181) the individual has three lines of action to follow from the Q1 stage, the 'visceral need' representation: 1) he may solve the problem or goal himself by producing the required information by thinking, going through the stages Q2 and possibly Q3, never reaching stage Q4. He is in problem space during this period of time; 2) he may decide that he *cannot* solve the problem or goal *without external information*. He is *then* in a 'state of uncertainty', being into stage Q2 (the conscious need). He asks a person or an IR system by presenting questions, which *per se* imply *ill-defined* requests for information. Such question(s) to the outside world may be expected to be adjusted or 'compromised', since the inquirer must anticipate or expect something in relation to the asked colleague or system. By perception of some potential information, his problem space and state of uncertainty may be modified. The representation of the information need may (or may not) reach the characteristics of the 'formalized need'. From here, he may proceed following action-line 1), repeat action-line 2) or go on, following the third line of action: 3) the third line of action implies that the individual may represent his information need as 'formalized' or verbally rather defined. This stage is internal and he is still in an 'uncertainty state'. According to his goal, he may present his 'formalized need' to an IR system (or a person), represented by a *compromised need* for information. This Q4 stage (the request) may exactly, or only partially, represent a well-defined information need, depending on his anticipation of the system or person. Hence the 'conceptual distance' δ discussed in Chapter 5.1. A dynamic interaction may continue until the current problem situation is solved or goals fulfilled – or it may stop to be taken up later.

Obviously, this understanding of Taylor's four stages implies that request statements (basically Q4 statements) may mirror Q2 representations (ill-defined ones) or Q3 representations (well-defined ones), the latter either in an exact Q4 form of statement or in more vague forms.

This distinction is important since the *intermediary,* at the *initial* request by the user, will not know in *which conceptual state* the user finds himself. The requests may display characteristics of such a nature that the two types of representation, that is, Q2 or Q3 representations, are *indistinguishable.* For instance, a user may state: 'I want information on tuning'. At this point in the interaction nobody will know which kind of tuning, e.g. tuning of car or boat engines, radios, etc.?

Also, this distinction is important for setting-up experiments to investigate the nature of the 'compromised need' in relation to actual internal representations of the information need *and* the underlying problem or causality in problem space. Chapter 5.5.2 demonstrates such investigations.

One may compare Belkin (1984) and his team's (1982, 1985, 1987) investigations with Taylor's assumptions. The former are preoccupied with the user's *problem statements*, and consider Belkin's ASK assumption (1978) "as an extension of Taylor's model" (Belkin, Oddy, Brooks, 1982, p. 66). Otherwise, Belkin et al. do not relate to Taylor's stages, nor to his filters.

Mark-Pejtersen's investigations show more or less elaborated Q4 statements (1980).

5.5.2 Types of information needs – the label effect

In order to investigate how the development of information needs occurs, i.e. essentially to study the theories proposed above by Taylor (1968) concerning the relationship between the Q3 and Q4 stages, the experimental settings b) plus c), outlined in Chapter 5.2.1, were used. The theories state that users may formulate their requests in a 'compromised' way, Q4 statements, depending on their model of the information provision mechanism. By recording the individual user's own browsing by means of the thinking aloud method, setting b), the investigators possess a profound knowledge about the user's information need as well as an idea of the underlying problem or goal at the event of search interview initiation. The librarian approached by the user, however, has no such knowledge about the actual need during the application of setting c). In all four analysed protocols a so-called *label effect* occurs, i.e. that the user:

> compromises the subject description of the real need in terms of a label...which consists of one or several concepts out of the context which forms the real, formalized need. Even when users in the phase of thinking aloud during their own search have specified statements clearly in mind, this label effect appears.
>
> This label effect often misrepresents the subject area to the intermediary... who hence has to be aware of this possibility of misguidance (ambiguity). The *limited* [number of] concepts which constitute the label often describes subject categories related to *several* different topic areas or aspects (Ingwersen, 1982, p. 178).

An example is demonstrated in (1982, p. 178). The 'tuning' example in the previous chapter shows similar effects. Other protocol analyses, for instance by Belkin, Oddy and Brooks (1982) and Belkin (1984), often demonstrate this label effect. One may consequently state, that Taylor's 'compromised need' statement, i.e. the request, takes the form of a label which not always clearly represents all aspects of an information need.

As pointed out by Ingwersen (1986, p. 221–224) in a discussion of the reasons for this effect, the problem for the intermediary is to find out whether a formulation consisting of, say, two concepts only is a label for a more elaborated need, or really *is* the need. The label effect is thus a manifestation of the *conceptual distance 'δ'* between underlying need and actual request formulation, discussed in Chapter 5.1.

Based on the protocols, the label effect as well as the results of the previously analysed empirical studies of IR interaction, the author proposes the classification of *three fundamental types* of information needs in IR (1986, p. 223):

> 1) *Verificative needs*, or locational information problems, i.e. the user wants to verify or locate items, e.g. some specific articles [or a list of client addresses]. Characteristic bibliographic data [formal data, Chapter 3], e.g. source, pages, author name, title words [or ZIP code area], are in this case *known* to the user.

2) *Conscious topical needs*, i.e. the user wants to clarify, review or pursue aspects of *known subject matter*.

3) *Muddled topical needs*, or ill-defined information problems, i.e. the user wants to explore some new concepts or concept relations *outside known* subject matter.

In relation to Taylor's stages both Verificative as well as Conscious topical needs are supposed to mirror Q3 representations. The cognitive structures of the individuals are regarded as strong. Muddled topical needs, however, are representing weak knowledge structures internal to a user, as to the topic in question. One may assume that this third need type is related to the Q2 stage, the conscious need.

The label effect evidently always occurs in type 3), but may in addition transpire in the two other types as well. This may cause serious problems for an intermediary (human or computerized) in, for instance, a multi-system or multi-work domain environment, in which a request for information formulated in a very short statement will give raise to heavy ambiguity. Therefore, it is necessary for the intermediary to know about the user's actual *work task* and knowledge of the *underlying problem or goal*, when asking the user for the request. One may observe that the empirical investigations lead to *poly-representativity* concerning information need (and problem or goal) representations, similar to the poly-representativity mandatory in knowledge representation (Chapter 3).

Another consequence of the label effect in combination with the three information need types is the *degree of conceptual support* required to aid the user in defining and formulating his need (and underlying problem). The author points to four different 'support mechanisms' in intermediaries (1986, p. 228–233). Another mode for support related to the information need types is demonstrated by Ingwersen and Wormell (1986; 1989). They suggest initially the use of text representation in NL in connection to Conscious needs *with* label effect as well as to the third type – the muddled need type. Further, one may suggest review of the nature of the different IR techniques (Chapter 4), in order to suggest *which combinations* of, for instance, partial match techniques may be most effective as supporting features regarding the information need types. Without doubt, speading activation and clustering must be optimal for Muddled needs, while probability and clustering combined ought to satisfy the Conscious topical type, with no label effect.

One may observe that too often the Conscious topical need type, without any label effect, constitutes that type of request applied in traditional laboratory test settings.

The combination of *filtering out* whichever information need type is in question, and obtaining information about the user's actual *knowledge of the topic,* is incorporated in the Euromath design, in Chapter 7.1 (McAlpine and Ingwersen, 1989). For instance, if a user claims to know a fair amount about the actual subject domain, but only provides very few request concepts, there exists the probability that he a) wants what he states, b) has provided a label only, and c) does not possess as much background knowledge as he believes, i.e. he may be in a rather 'muddled' state of knowledge. In the latter case, he may indeed have a quite profound idea of his work task, but may not know how to proceed conceptually, e.g. because he is outside his regular domain.

Above, the empirical evidence demonstrated that Taylor's Q3 and Q4 stages occur. In a research setting slightly different from that applied by the Danish team, Chen and Dhar very recently investigated the Q2–Q3–Q4 relationships (1990). By means of thinking aloud and logging they examined the use of an interface based on a semantic network. By analysing the "radicality of change of meaning during interaction" in the Q4 statements, they claim to find examples of Taylor's 'conscious need' (Q2) representations at the start of interaction (producing radical change of meaning over time) and initial 'formalized need' representations (Q3) – producing only new words in the Q4 statements, but no change of meaning (1990, p. 125). Although the Danish investigations also made the users thinking aloud during their own searching, Ingwersen (1982) does not claim to observe Q2 representations, when examining the protocols covering this part of the IR interaction, i.e. setting b), to the point when setting c) starts.

The point to make concerning Taylor's 4-stage assumptions is, that it may render it difficult to control the experiment and to state that one has observed Q2 (conscious need) statements, since all statements to the intermediary and IR system *per se* must be 'compromised' to a certain extent. Thus, the researcher cannot know for sure whether the recorded statements really are Q2 representations or very compromised (ill-defined) Q4 statements, which during interaction become less compromised – or better representing a 'formalized need' (Q3). Since 'muddled needs' and the label effect both introduce heavy ambiguity problems, the observed changes of meaning may simply mirror that a disambiguation of a label has occured, via an adequate *contextualisation*. See for instance the 'tuning example' above. A radical change in meaning can also be explained by serendipity effects – leading to a *new* need for information (and a modified problem), caused by the influence of the interaction. However, Chen and Dhar clearly demonstrate that formation development takes place during IR interaction.

5.5.3 Question analysis and browsing issues

Saracevic provides a detailed framework and review for question analysis (1978, 1980), followed up in (1988). He suggests experimentation along semantic and syntactic lines, i.e. dealing with formation and understanding of user questions, and strategies for searching IR systems. He proposes use of a term net, originating from Doyle's semantic road map suggestions (1961), document clusters or ranked output and other feedback as means to let *users themselves* explore and adjust their internal questions and external requests. In addition, Saracevic outlines a framework for the categorisation of questions through IR interaction, ranging from problem over information need and request, to analysis of request, query formation, searching and answer. He operates with linguistic means for the analysis within the framework, i.e. grammatical status of terms, their structural, thesaural status, and specificity of meaning. Several of Saracevic's proposals have been elaborated and applied in experimental work during the eighties, also in traditional IR research contexts, and for example more recently by Smeaton and van Rijsbergen (1988).

In relation to accommodating online searchers (users and human intermediaries) M. Bates (1979a,b) proposed a framework for applying search tactics in online retrieval that may guide searchers of such systems to obtain new conceptual ideas and means to broaden, narrow or otherwise modify information problems during searching. In (1981) the same author reviews research on psychological aspects of searching for information, carried out in the seventies. Bates analyses the role of online IR systems, in particular concerning their *exploratory potentials* and functions in relation to ill-defined problems and information needs (1985). Bates follows-up the suggestions by outlining browsing techniques in interface designs (1989). Also, incorporating browsing facilities in interfaces to operational systems is suggested and discussed by C. Hildreth (1982), and slightly later by P. Noerr and K. Bivins (1985).

Inspired by Bates and their own research results, Ingwersen and Wormell put forward (1986) a design model for the use of interactive feedback and browsing facilities in an exact match environment, based on analysis of information need or problem states and types. The use of natural language versus controlled vocabulary representation is suggested in conjunction with characteristic information need types. In a context of an inhouse retrieval environment the authors transfer the model to be applied by information specialists and librarians (1988). Chapter 7.5 explores these suggestions in greater detail, since the proposals belong to a cognitive R&D approach to IR.

5.5.4 User models and search interviewing

User model characteristics have been analysed by E. Rich (1979) and further discussed in (1986). She operates with several dimensions, such as a canonical user model vs a model collection, explicit models specified by designer vs system inferred models, and long-term models, e.g. of user expertise, vs short-term user characteristics, e.g. the actual problem. Like several other scholars, Rich advocates the view of treating user modelling in IR in a *dynamic* fashion. C. Borgman explicitly explores users' mental models of information retrieval systems (1986). T. Bellardo investigates intermediary performance characteristics (1984). P. Daniels reviews user modelling research in IR (1986).

Search interviewing has been analysed on a theoretical basis by several researchers, either in relation to the reference interview in libraries or in connection to interface design issues. G. King (1972) made the library environment and education aware of the use of question types, i.e. the use of open and various closed questions.

G. Jahoda indicated that human intermediaries ought to apply open questions in the initial interview stages and closed questions in the final stages (1975), in order to extract more information from the user which later can be verified by the intermediary. Similarly W. Katz. advocates the use of open questions (1978), which both Lynch (1979) and Ingwersen (1982) find are only scarcely used in actual interviewing. However, Katz points to important elements of the negotiation by stressing the application of non-verbal clues and expressions, as well as suggesting that underestimation by the user of the librarian may be a cause for Taylor's 'compromised need'. In relation to online IR, A. Sommerville divides the pre-search interview into four groups of elements, recommending their application depending on the user's knowledge level with respect to online searching and whether the user is present during searching or not (1977). In-depth reviews of the search interview process are provided by Belkin and Vickery (1985) and E. Auster (1983) who, in addition, outline research on non-verbal issues of the negotiation process. The former review is genuinely profound and focusses on human information interaction, including human intermediary functionalities, and encompasses the psychological and AI aspects of IR, including a brief review of IR techniques which opens up a more comprehensive understanding of the scope for IR research.

5.5.5 Intermediary design in online IR settings

Interesting designs of interactive intermediary mechanisms were made by R. Marcus et al. in (1971), operating with two kinds of dialogue, namely system-to-user and user-to-system. The rather detailed, but general guidelines to design are followed-up later, for instance in (Marcus, 1982). Here, Marcus develops and tests an intermediary mechanism which is intended to replace a human one, explicitly containing functionalities concerning the exact match IR systems' complex data structures and command languages. User problem analysis exist in a very simplistic manner, although the mechanism is tailored to inexperienced end-users. Also in 1982, after several years of experimentation, Meadow et al. produced a prototype on rather similar lines to Marcus'. The intermediary is, however, more geared towards the operational, exact match retrieval systems, attempting to correct and support the user in online searching. Very recently, E. Sormunen reports a study combining both analytic and experimental evidence concerned with expertise and searching heuristics for intermediary mechanisms (1989). The analysis draws upon the suggestions by Bates (1979a,b) and the empirical results obtained by Belkin and his team (1982–1987) as well as by the author (1982–1986). Very recently Bates has analysed the user interface research landscape, mainly within the online environment, and produced a framework for present and future R&D work in this area of IR (1990).

Human information seeking behaviour, directly related to the design of information retrieval systems, is explored by Rouse and Rouse (1984).

5.6 Summary of analytic and empirical user-oriented studies

The user-oriented approach to IR research provides IR theory with a substantial insight into users' mental behaviour and the information seeking characteristics on an individual level as well as in a social/organisational context. In addition, the research efforts supply a fair amount of knowledge on human-human information interaction, for instance between librarian or information specialist and user. Furthermore, the role of the (human) intermediary can be defined in relation to user modelling by means of search interviewing and feedback from IR systems. However, as in the traditional R&D approach which disregards the user, the user-oriented tradition tends to overlook the full complexity of a variety of IR system factors. Up to the mid-eighties, *no* investigations took place that involved other IR techniques than those based on exact match and including different methods of representation as well as intermediaries and users. This 'monolithic' situation seems understandable, since without established formal models of searcher (users and intermediaries) behaviour, such experiments would not yield results, valid for design and test purposes, not to speak of IR theory development.

With respect to *users'* 'pre-information searching' behaviour (Figure 5.1), real-life investigations have provided an understanding of the formation of the information need. Request formulations do not necessarily exactly mirror internal need and problem situations. Users' own seeking behaviour seems to depend on background knowledge, the subject domain in question, and the extent to which their need, or underlying problem is developed. Also certain social factors play important roles, in particular regarding the nature of the environment – for example, research libraries vs public ones.

Several analytic studies provide the suggestions and hypotheses leading to empirical R&D projects. Several analytic assumptions are thus modified, e.g. the use of open questions in search interviewing. Some are confirmed, for example Taylor's hypothesis about the nature of the 'compromised need' which, constituting the request, may carry a 'label effect'. This effect is visible in three fundamentally different types of information need: the Verificative, the Conscious topical, and the Muddled needs.

Human-human interaction in IR situations, i.e. 'information searching' behaviour (Figure 5.1), can be divided into a pre-search interview stage, followed by searching activities. Apart from this rather systematic search interviewing mode, a heuristic mode seem useful to apply, whereby interviewing and searching take place simultaneously. Which mode to apply seems to rely on the problem state of the user. Also the IR environment plays a role – in particular in a substantial number of Anglo-American investigations, mainly carried out in operational online environments. Because of heavy online costs, presearch interviewing is a paramount feature in practice as well as in the research settings applied. The most important outcome of this pre-search interviewing framework is the Monstrat Model, based on both analytic and empirical findings.

In more encompassing real-life settings, fiction retrieval strategies, representatitive dimensions, and the formation of emotional desires for information are established.

Human *intermediary* characteristics become thus rather well-established, mainly in relation to user-modelling, and other primary functions tuned toward the user side of Figure 3.2. The various types of knowledge which it is necessary to implement in intermediaries becomes modelled and specified. Knowledge of search strategies and tactics, and of conceptual domains and types of information need, is established. Looking at user modelling, it seems adequate to separate user problem (in problem space) from the resulting information need (caused by a state of uncertainty), allowing or driving the user to elaborate on his problem. Designs of simplistic automated intermediary mechanisms take place, mainly functioning as front-ends to operational, large-scale bibliographic information systems, and an emerging awareness arises as to parameters for the application of various intermediary functions. Again the IR environment seems to play a consequential role.

The user-oriented research gives rise to a significant question, namely the degree to which an IR system and IR interaction ought to be designed to accommodate individual users in definition of their problem, in defining their need for information or in solving their underlying problem? All such activities are actually found to occur during information retrieval. Aside from the retrieval of information, it is the author's opinion that IR should accomodate both problem and information need definition. Both processes are fundamental for successful retrieval. However, IR is not the main objective in a decision or problem solving activity. Although decisions are constantly made during IR interaction, and users may indeed often solve their underlying problem through IR, information retrieval must be considered a vital but *supportive* process in problem solving and decision making.

One must emphasize the additional potential in user-oriented IR research. On the one hand to support effective management of information resources, for instance in organisational environments, on the other hand to act as a password to other information dependent disciplines within the computer and systems sciences.

In many aspects, the user-oriented IR research approach can be seen as a precursor to a cognitive turn in IR research. As stated at the beginning of this chapter, the cognitive viewpoint has had an apparent influence on theory building and experimental settings in a substantial number of user-oriented projects. It is worth noting that the analyses of user behaviour as well as intermediary designs increasingly touch upon the relationships between IR system features, specific intermediary functions and behaviour, and user characteristics. We are hence on the very edge of actually combining the different, but complex models into theories and frameworks for the design of interactive IR systems, involving non-human, knowledge-based intermediary mechanisms. Chapters 6 and 7 discusses selected research along these lines.

6. IR INTERACTION – the COGNITIVE TURN

The cognitive turn in IR takes place when the research has established sufficient empirical and analytic evidence which supports further tailored investigations of the cognitive and behavioural relationships between the variety of components displayed in Figure 2.1 (Chapter 2).

In approximately at 1985/86 such premises were attained, as demonstrated by Belkin and Vickery (1985) in relation to the user side, and Belkin and Croft (1987) concerning traditional retrieval techniques. From this point on it became a question of combining the results of these research efforts into hypotheses and models dealing with the design of interactive IR systems that can be tested. For example, in connection with in-house Boolean retrieval systems with several layers of knowledge, Ingwersen and Wormell suggest the following model:

> As a consequence [of the knowledge levels], in-house IR systems may use author-defined natural language (e.g. SAP indexing technique) making a specific document accessible to a certain group of users that formulate the development of the domain, e.g. researchers in the field. *In addition*, the system should use a controlled vocabulary with index terms *especially dedicated* to other potential users of the document, e.g. R&D persons from other fields, managers and production staff. Thus, the probability of retrieval of a specific document, relevant to several, different users with different goals and conceptual background ought to increase (1988, p. 108).

The authors continue to recommend the application of these combined strategies of representation in a variety of ways, incorporating densely structured conceptual feedback, tailored to the different types of information needs discussed previously (1989).

In a recent publication Ellis makes a profound attempt to view traditional evaluation models and more cognitive-behavioural IR systems designs from a birds-eye perspective (1990). In order to perform evaluation of such complex design proposals and ideas, the methodology must undergo changes.

Chapters 6.1 and 6.2 discuss in detail the variety of individual as well as more collective cognitive models which, grounded in the results from cognitive science as well as the user-oriented empirical investigations, explicitly deal with IR situations, processes, and components.

Chapter 6.3 explores the necessary variety of methodological approaches to the evaluation of truly interactive IR systems which incorporate cognitive and behavioural models in their design.

6.1 Personal cognitive structures relevant to IR

The variety of individual cognitive structures in the mind of each human recipient and generator of potential information constitutes his model of the world, including expectations, intentionality, emotions, intuition and experiences. These structures interact with one another during the processing of sense data, potential information and knowledge, and are responsible for how the individual perceives and understands the world and himself. Following the cognitive view, the model is the prerequisite for further changes in personal mental states. One may outline the present situation concerned with how the human information processing, thinking and memory is interpreted, in particular associated with information retrieval. The central model for this understanding originates from P.H.Lindsay and D.A.Norman (1977), R.C. Shank and R.P. Abelson (1977), and P.N.Johnson-Laird and P.C.Wasow (1977). The basic concepts in the model are Short Term Memory (STM), Long Term Memory (LTM), and a filter.

STM is thought of being able to store smaller amounts of perceived and assimilated information 'elements'. The 'car renting' example outlined below proposes how STM may work at an IR event (Ingwersen, 1986, p. 211–214).

The LTM operates on semantic and episodic memory and is responsible for filtering the data received by the individual via attention, expectations and intentionality. LTM is therefore also governing the perception and the further processing of potential information, for instance in IR situations. Among other cognitive structures LTM holds the mental representations of concepts, concept relations and categories that may engage in perception and processing of information.

Semantic memory is thought to refer to "the class of information characterized by the definitions of concepts that people have within their memory. *Episodic memory* refers to information about particular events, experienced by the individual" (Lindsay and Norman, 1977, p. 399). The distinction was originally made by E. Tulving (1972). Together, the two types of memory supposedly carry the individual's knowledge of itself and the world in the form of 'something', as stated by Weizenbaum (1984). Chapter 2 demonstrated profound disagreement between cognitivistic, cognitive and hermeneutic researchers about the existence, form, functions, and content of this 'something' and the mental representations, thought to form the underlying mental models. In cognitive science the discussion of mental representations or *mental models* has been running for more than a decade. Originally coined by Craik (1943), the nature of the concept has been approached in a cognitivistic sense by, for example, Johnson-Laird (1983, 1988) proposing his theory of language comprehension and inference. Others have used the concept as a definition of a psychological domain of inquiry and analysis rather than a theoretical construct. Rumelhart and Norman have claimed three distinct functionalities of mental models (1983): beliefs predict behaviour; inference can be made by mental simulation; mental representations can be analogical. The latter authors also assume that mental models are based on physical (and perceived) experience, by stating that such models contain a strong experiental component. From a cognitive viewpoint Shank and Abelson (1977), Shank and Leake (1989) have advocated case based reasoning based on analogical applications of earlier episodes to new situations, incorporating elements of social interaction. Very recently, S.J. Payne provides an overview of mental model research and attempts to unify basic elements from the diversity of theories, including from AI and anthropology, by illuminating certain aspects of Johnson-Laird's understanding of the issue (1991).

In common with the mental model approach is its present limitation in scope, merely pointing to ad-hoc results of ad-hoc experiments. Also, emotional and social factors as well as dynamics seldom form part of the resulting models of mental representations. Most often, the resulting models point to one-to-one relationships between a human mental representation and world objects in a given experimental situation, as if the human brain and mind function like a computer (or act like paging a book) (Chapter 2.1).

Already Bartlett's studies of the re-telling of culturally based stories demonstrated a high degree of complexity and variation of underlying individual cognitive structures, mixed with social and cultural background knowledge. In addition, the previously described empirical studies of IR situations display similar great complexity and diversity with respect to the processing and transformation of information into knowledge. Thus, the author sees the concept of mental models as too confined and prefers to apply the more general concepts of *cognitive structures*, or knowledge structures, and cognitive models; the former as defined in Chapter 2 in relation to the cognitive viewpoint. The latter concept is defined as the individual knowledge structures of highly dynamic and interchangeable nature that encompass the individual's knowledge of itself and the world through time, including emotional, social and related types of conscious and sub-conscious being. In this mental landscape LTM may contain semantic and episodic memory, a non-intended dichotomy which does not exclude other 'memories', such as emotional ones. Since we really do not know what Weizenbaum's 'something' – the knowledge structures – look like, we will apply a 'geographical map' metaphor (Figure 6.1) to illustrate what might be thought to happen, for instance during search interaction in IR (Ingwersen, 1986, p. 211, 213), or during processing of emotional information.

The metaphor refers to the fact that geographical teaching in preliminary schools often made use of batteries of maps hanging from the classroom ceiling. Pulled down, such maps might show entire continents or single countries, with or without locational names on them.

The important issue is to underline the multi-dimensionality and semantic changeability of concepts and conceptual relations *on* the maps over time for the individual. By interacting with the world, the socio-behavioural aspects constantly influence the contents of the 'maps'.

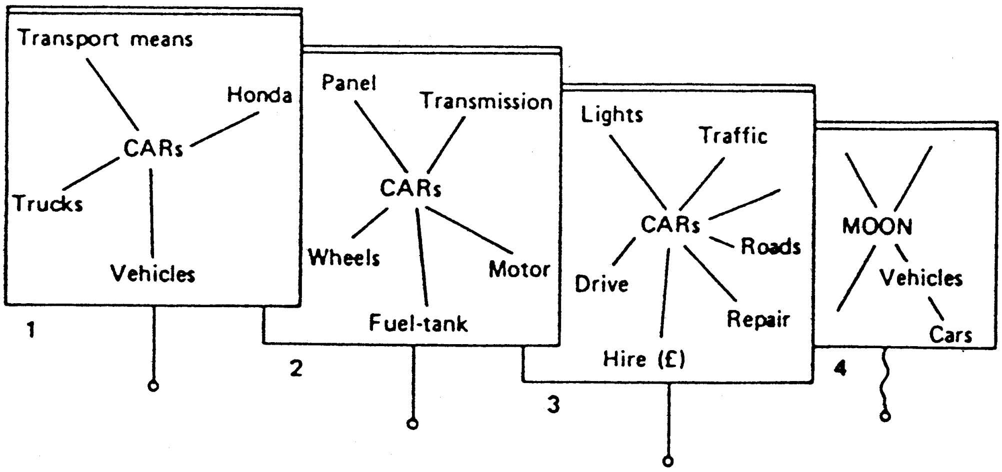

Fig. 6.1. A map visualization of some knowledge structures in LTM concerned with the concept 'cars' (Ingwersen, 1986, p. 213). Based on an idea by the late Povl Timmermann.
Concept relations: **Map 1: generic; Map 2: part-whole; Map 3: situational; Map 4: situational**

One may work on *several maps simultaneously*, or associate to new maps, far from one another, conceptually or emotionally. Different maps may cover the same material (e.g. 'vehicles' on the maps 1 and 4) ordered to various overriding concepts. Some maps in the mind of the individual may contain 'blank' regions (e.g. the 'Moon map', map 4), others being non-existent for that individual (e.g. a map containing 'car-trains – The Channel' relations). Some of these maps may be non-verbal, as in the classroom, while others may contain loosely connected concepts. In the course of discussion or interaction, new maps may be pulled down and others up, as needed to follow conceptual developments. Blank regions may be filled out (= individual learning). A complete change of series of maps, perhaps loosely connected, as well as a total cognitive re-generation of concepts and relations on single maps, may occur in a sequence of mental operations or during conversations (serendipity effects). Behind certain relations may be fixed or loosely composed pictures (or 'movies') of events, e.g. behind the 'Moon' – 'vehicle' relation. Emotional factors may influence the individual dynamics of the cognitive processes, making use of the maps.

For example, if a person associates 'intercourse' to map 3, either because he is going to do, is doing, or he is reading about such a situation, he may immediately associate to maps that host affective concepts like 'sex', 'desire', 'aids', or 'forbidden', somewhere else in his mind. The concepts may subsequently trigger emotions like 'love', 'affection' or 'disgust', and colours or images, associated with the ongoing act or the imagination of it – when reading a novel or seeing a movie. We may indeed reach into the sub-conscious and the personality, the 'something else' in the cellar beneath the classroom. Another person might not hold exactly the same maps, or might hold them without wishing to pull them down for various reasons, or might not possess them at all (e.g. a small child), or might not perceive the concept 'intercourse' when reading a book, because of lack of attention.

The relation between STM and LTM can be illustrated by another simple thought experiment related to Figure 6.1. A person operating a videotex terminal wishes to 'hire a car'. LTM pulls down an appropriate map (e.g. map 3), 'telling' the filter guiding the perception to draw attention to words and phrases containg the required concepts and other relevant details. After some attempts, by which different series of maps have been pulled down (and up again), triggered by computer output on the screen, the person sees the words:

**** Rent a CAR – HONDA CIVIC : $ 20 a day >>> tel: 759 362 954 ****

Depending on his (social) experiences, previous knowledge, etc. and his degree of attention, he may reason that 'renting a car' is identical to 'hiring a car'. (We assume in this case that in LTM a relation becomes established between the '20$ a day' concept and at least one map elsewhere containing the knowledge that 'xx $ a day means to hire something'). Alternatively, he recognizes the word 'rent' on sight, pulling down a new map containg the pre-established relation 'rent = hire'. This process is memory recall. Unfortunately for for our person, no printer or pencil is available. He must thus try to memorize the price and telephone number he just ascertained.

The STM may easily store the '20$ a day' concept for a time since it consists of only 4 elements of data; 7 elements ± 2 seem to be the average. The telephone number is more difficult. He may remember them if he is able to relate the figures to some known items in his memory, adding the number on to some relevant maps in LTM.

Semantic memory seems usually to develop from knowledge contained in *episodic memory*. This can be illustrated by map 4 on Figure 6.1. An individual sits in front of his TV-set and looks at an early American Moon landing. A strange vehicle is jumping over craters and driving through white Moon dust. This is an event. He pulls down a fresh map, placing 'Moon' on it. Perhaps momentarily, he links 'car' to 'Moon', slightly later adding 'vehicles', since the speaker talks about 'Moon vehicles'. Because Moon landings go out of fashion, the map becomes rusty; but then some years later he observes a snow truck with big wheels, which reminds him of the 'Moon-vehicle/car' event. This relation then becomes more fixed or defined in LTM, perhaps linking 'Moon' to map 1 through 'vehicles', perhaps by dusting map 4.

Semantic memory may thus be established through interaction with the world, e.g. in schools, where society attempts to (uni)form people's definitions of concepts and relations, and their way of thinking. Semantic memory may therefore contain concepts, conceptual structures and associations (paths), as well as related emotions *shared* by several individuals, but always in dynamic and multidimensional networks not exactly identical. 'Collective' or paradigmatic cognitive structures of importance to IR are discussed in Chapter 6.2.5 below.

LTM is hence a determining factor for perception, understanding and interpretation, thinking and memory structuring, and it becomes clear that when individuals interact with syntactically or semantically structured concepts in the form of other persons' semantic road maps, e.g. in classification schemes or thesaurii, the structures may only match partially or not at all. For instance, the maps 1 and 3 do not mirror the Danish Classification scheme (DK5) on the 'car' subject.

LTM is supposedly also responsible for conceivable 'breakdown' situations and 'thrownness', the 'car-driving case' (Chapter 2.4). It constitutes the 'horizon' of the individual, the generator's as well as the recipient's at the event of communication. Deep knowledge signifies rather rich and firm contexts of experienced situations or abstract concepts that may be evoked by information which may make use of and transform or modify such contexts. Shallow and surface knowledge, e.g. of IR systems and processes, indicate more frail couplings of contexts or contextual elements at a given point in time, with which information may act in more dynamic ways at a moment of interaction.

6.1.1 Categorial and situational classification

This semantic and episodic interpretation of knowledge has been extended by Ingwersen in direct relation to IR (1986, p. 213–214), by introducing the findings made by A.R.Luria (1976) on how individuals classify objects in a social context. Luria's contributions develop around two ways of dealing cognitively with objects: *categorial* and *situational* classification. Figure 6.2 demonstrates one of his empirical experiments with nomads in Central Asia in the thirties.

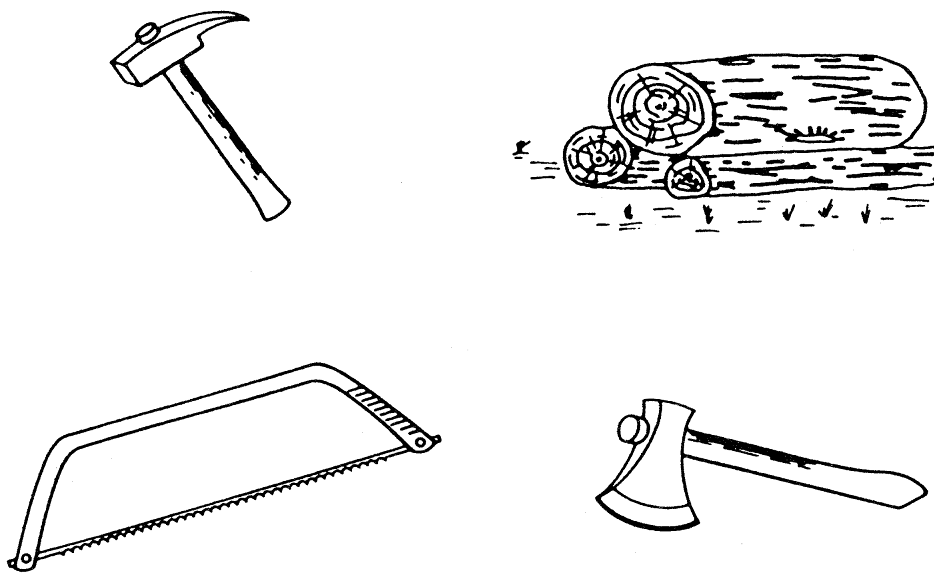

Fig.6.2. Illustration of Luria's experiment with object classification. Which object to be excluded - and why? (from Ingwersen, 1984c)

'Categorial' classification means that individuals sort out an abstract concept and choose the objects which can be included under this concept. 'Situational' classification implies that individuals involve the objects in different concrete situations, thereby grouping objects which belong together.

The experimental setting is interesting. To individuals from various groups of nomads with different educational background, Luria showed sets of pictures of objects, always in a combination of four out of which one object was supposed to be excluded. The subjects were then asked to classify the objects and *explain why* the grouping was made in that particular way.

Individuals with several years of school training primarily excluded the 'wood', grouping the remaining three objects on Figure 6.2 under the label 'tools'. This is 'categorial' classification. (Tried out in Denmark, some persons exclude the 'saw', seen as pure metal, and group the remaining objects under 'things with wood [properties]'). Other subjects, most often with less school training, excluded the axe associating to 'carpentry' or 'constructing a tent' – or 'cutting timber', by sometimes excluding the hammer, sometimes not. The latter three classifications are all 'situational'. Indeed, one might also think of 'forestry' (not the nomads in Central Asia, however). In the case where all four objects were classified together in a situation, the nomadic subjects maintained that this grouping identified a normal situation. Often, their wood was too thick to be cut by the axe alone. The hammer was then used to hammer on the axe, and all the objects thus belonged together. This mode of situational classification clearly contains elements of causality.

In the 'situational' cases the formal education tended to be of shorter duration. One of the conclusions of this experiment is that to the individuals all the various classifications were valid and explicable, based on their actual models of the social (nomadic) world. The cultural and educational background knowledge played an important role for their way of classifying.

Luria's results are significant for information retrieval.

The 'situational' classifications are always providing *contexts*, whereas conceivable 'categorial' contexts often have the form of rather abstract, vertical relations.

When an IR systems designer has a general idea of the background knowledge of his user population, he may hence tailor the classification of topics and concepts accordingly. If users derive from very different educational and cultural levels, e.g. in a public library, the IR system should apply both situational and categorial groupings. As stated earlier in Chapter 4.1, the Danish DK5 classification system used in public libraries is basically organized in categorial structures. Without additional *situational support*, the average public library user is put at a disadvantage from the start when interacting with this system.

Luria's large-scale experiments ought in addition to be of core interest to hermeneutics. The 'situational' classification events are nice examples of 'thrownness' while the 'categorial' classification shows signs of initiated 'breakdowns'.

The studies of L.S.Vigotsky (1962) demonstrate that during learning processes situational patterns seem to be used in order to understand and memorize concepts, later leading to more categorial memory structures, also incorporating categorial classes of processes, i.e. situations and procedures, e.g. 'representation' =

'classification' + 'indexing'. Hence, an intermediary ought to feed back conceptual structures of a situational nature to novices, casual users, and users outside their formal knowledge background. Further, a psychological reason for asking people about their underlying *problem situation*, as suggested and verified by Belkin et al. (1982 →) and Ingwersen (1982) (Chapter 5.3), is to let intermediaries receive situational *contexts*, which may ease their adaption to a new information need.

In general, a single concept may usually point in two different directions: toward one or many processes or situations, and toward its generic and part-whole sub and superordinates – as with the concept 'car' on Figure 6.1. As demonstrated in Chapters 4.1 and 4.2, the use of thesaurii (mainly categorial structures) and faceted indexing systems (always situational) have been explored for decades in IR. Combinations of these tools have been used in recent years for knowledge representation purposes in the form of case frames and semantic mapping.

As suggested by Ingwersen (Ingwersen and Strunck, 1980) and exemplified in Ingwersen (1992), this type of conceptual structuring could be applied as a *platform for structured questioning* (or tailored feedback) by intermediaries to knowledgeable users, in addition to its application in knowledge representation only. The user may then inform the intermediary about which context the concept 'cars' belongs to, for example 'car driving', not 'repair'. A complex conceptual situation may then become disambiguated.

A major consequence of the dichotomy between the two kinds of classification is that a document, e.g. being about 'car driving', holds the *potential* of in addition providing information about 'roads' (situational) and therefore also on 'road types' (categorial/sub-generic relation to 'roads'). This implies that an assigned indexing phrase, say 'car driving', may contain *several semantic values*, or contexts, potentially for a user asking for 'highways'. We assume here that neither 'road types', nor 'highways' are explicitly represented as terms in the IR system, linked to this particular document. Or, in the case of usage of partial match techniques, that the terms carry insignificant weights in certain texts and thus are omitted from retrieval. In fact, the terms may not even exist, but contexts in documents may implicitly connote such, as yet missing, significations. This issue is directly concerned with the problem of *user aboutness*, discussed in detail in Chapter 3 and persued further in Chapter 7.5.

'Categorial' and 'situational' classification are weaved into 'semantic' and 'episodic' memory. This can be exemplified for 'semantic' memory by Figure 6.1. The maps 1 through 3 belong to semantic memory and contain the two types of classification. 'Episodic' memory however, dealing with events in the individual's life, will often be of 'situational' nature, map 4. Yet, links to categorial relations in semantic memory can be drawn intuitively during events, and an event in episodic memory may contain *categorial* relations as well, for instance: the first time one visits the USA as a European, one may never forget that one is an 'alien' = non-US citizen, while one thought that 'alian' = 'extra terrestrial creature'. When one returns the next time, the emigration situation triggers this particular generic US-categorisation in one's episodic part of the mind.

A final interesting observation from the studies of Luria and Vigotsky is the possibility of subdividing or reorganising the situational and categorial classes into three groups of cognitive structures: associative structures, containing elements from both classes; causal structures, mainly drawing upon situational relations in Luria's studies, but conceivably also incorporating categorial relations; procedural structures, consisting of situational contexts.

6.1.2 Personal knowledge states in IR

In relation to Figure 2.3 and the development of a need for information in IR, the above mentioned cognitive structures can be seen to be interweaved within the following *knowledge states of the individual*:

Cognitive model, i.e. a model of itself and of the environment, images, expectations, emotions, intentionality, experiences, imagination, intuition & values, conceptual knowledge of domains, including affective domains, cognition, perception, and

Work space, i.e. cognitive structures associated with external work domains, work tasks & information systems, activity, goals, preferences and interests related to domains, information seeking behaviour, problem solving, decision making, and

Actual state of knowledge, i.e. what is known and emotionally experienced at a given moment, attention, actual intentionality, and

Problem space, i.e. a situation specific state of mind in which the individual recognizes lack of knowledge, e.g. in order to choose between possibilities of action, of solution to problems, or in relation to fulfilment of factual or emotional goals, and conceivably

State of uncertainty, i.e. a state of doubt in which the individual's own state of knowledge, work space and cognition cannot fill the problem space by thinking, causing interaction with the world around it to obtain supplementary information, e.g. by accessing an IR system.

The individual 'Cognitive model' contains all the other states of knowledge. 'Work space' holds all interests, work domains and tasks. 'Actual state of knowledge' is what is known at a given point in time about domain and task, e.g. at the event of IR. 'Problem space' signifies an actual, recognized problem situation, and 'State of uncertainty' implies the state of desire for information.

Figure 6.3 below illustrates the relations between these five states and the surrounding world. We may exemplify the role played by each knowledge state of an individual, say a mathematician working in a research institute, seen from the perspective of a designer of a work station for the staff.

By means of a field study the designer has found evidence that the staff members in their mathematical domain have the following *work tasks and goals* (from the Euromath Project (McAlpine and Ingwersen, 1989):

Do R&D work in mathematics;
Apply to national and EEC funds for financial support;

Find out what kind of research other (European) institutes do;
Find out what other colleagues do in R&D work worldwide;
Be in contact, individually, with other front researchers worldwide
Write scientific papers;
Receive and distribute pre-prints quickly

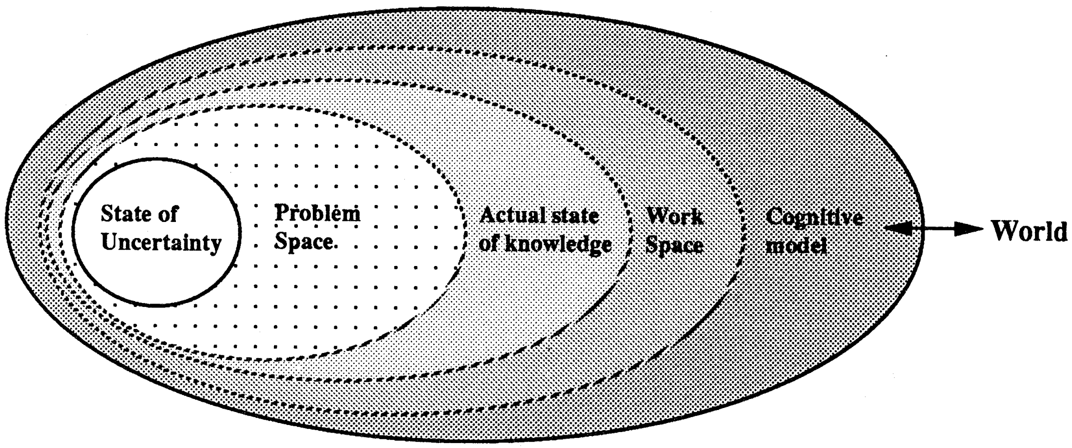

Fig. 6.3. Individual knowledge states in context of its environment, associated with IR (from Ingwersen, 1991, p. 83.

These and other conceivable tasks will produce certain *requirements* in this particular domain, which are associated to the individual *work spaces* that a future intermediary mechanism may encounter. Hence, the designer decides to implement access to the mainframe holding the math-calculation software. Also, some local programs, word processing, electronic mail, and local databases of dedicated addresses and names of relevant institutes, journals and future conferences are implemented. The latter bases are updated (by auto-download) from the files of the Association of European Mathematicians (AEM). In addition, the association keep close contact to the EEC and provide an index of grants and funding organisations. In order to let the users find out about their colleagues' work, the online versions of *Zentralblatt* and *Mathematical Science Index* can be accessed, in addition to

Conference Papers Index (CPI) and *Science Citation Index* (SCI).

The field study shows that the staff in general comprehends Boolean logic, as expected, but 75% have never searched online, only used the printed versions of the two core mathematical indexes, and very few understand the use of *SCI*. They all find online searching too expensive. Nobody knows about *CPI*. 25% do not like the online command languages, which in this domain are somewhat different from file to file. However, two staff members are very good at online IR, being trained information specialists.

In the total picture of the individual *work spaces*, these mixed *user preferences* lead, for example, to three different dialogue modes in the IR part of the workstation: one, directly using the different command language versions (for IR specialists); one, with a uniform command language for Euromath to all the remote files; one, driven by menu-options in a rule and knowledge-based intermediary.

Furthermore, the 'work space' contains *IR searching behaviour*. Many staff members prefer to use their received pre-prints for retrieval, as well as previously found information relevant to their ongoing projects. Each of the dialogue modes thus must enable access to these particular files. This seeking behaviour in 'work space' is extended by the fact that the researchers remember interesting topics from certain events, e.g conferences, in which they participated. Also, they prefer to proceed directly from where they halted last time they retrieved information. However, by observing their *actual state of knowledge*, one may find that rather often they do not remember exactly the point in the process where they ended up one or two weeks ago. Similarly, their capacity to remember names is not immense. Their *problem space*, leading to *state of uncertainty*, consists of situations in which they, for instance, wish to find an interesting article they have retrieved before, but only vaguely remember any data about; or, they want to get an overview of a research area, only holding a few or not sufficiently specific concepts in their memory at that given moment; or a researcher has written a paper, wanting some additional references, for instance to the work of colleagues he opposes scientifically in the given subject; or a researcher may have the question: what is Dr. X's theorem about Y really called?

This outline of how the various knowledge states in individuals may be seen to function emphasizes two factors: 1) It is necessary for the designers of an intermediary mechanism, and the underlying IR systems as well, to hold a *general model* of the domain and of the users' conceivable work spaces and states of knowledge, which enables the mechanism *to model* the states and needs of the actual user. 2) Similarly, a mutual *model of the system* must be established within the work space and actual state of knowledge of each user, for example by making transparent the intermediary 'information space' and functionalities.

This is in line with the cognitive models for human communication and man-machine interaction, suggested and discussed by E. Hollnagel (1979), and outlined in Chapter 7.4.

6.2 Cognitive models for IR interaction

The original cognitive models for IR, underlying the Figures 2.1 and 3.2 and incorporating intermediary knowledge structures of various kinds, are presented below. They have been developed from the end of the seventies in an international context and are fundamentally based on the empirical findings outlined in Chapter 5.3. The models may serve as a framework for the following Chapters, in particular for the Mediator Model (Chapter 8).

The proceeding section displays the basic model of the cognitive communication system for IR interaction, originally published by Ingwersen (1982, p. 171). The following sections discuss the variety of basic types of knowledge necessary in intermediaries, whether human or computerized. This issue has been briefly discussed previously in Chapter 2.2.2. Knowledge structures in users, leading to fundamental user categories at the event of searching, are emphasized and discussed in Chapter 6.2.3. Collective cognitive structures of a paradigmatic nature and of importance to IR are analysed in Chapter 6.2.4.

6.2.1 Major knowledge structures in information space

To the left of Figure 6.4, each generator of potential information, whether this information originates from authors or system setting designers and indexers, possesses an 'image' as part of its cognitive model.

According to his intentions, beliefs and knowledge about future recipients, i.e. a user model, an author may produce potential information in the form of text or images, by transforming his 'work space' and 'state of knowledge' ('conceptual knowledge'), guided by his image. In the same way, an IR systems designer may implement a database, structured according to *his* user model. One or several indexers may index the author generated content of the database in the form of some kind of representation, partly relying on *their* user models, partly following certain indexing rules made-up by some other individuals. The various transformations end-up in a conglomeration of potential information – the *information space* (notation] on the model) – which can be accessed by a searcher, i.e. an intermediary and/or an end-user. This access may be to the full-text documents, e.g. on shelves in libraries or in databases, or it may take the form of looking-up in various types of indexes, representing the potential information.

The notation 'information' refers to human intermediaries. In this case, communicated 'data' may become information to the intermediary, according to the information concept (Chapter 2.2). A consequence of an intermediary mechanism is that all interactive transfer remains 'data' to both the IR system and the intermediary.

The retrieval mode can be via exact match or partial match, which at the same time may serve as a rule-based, non-human indexing facility. The relations between representation and IR techniques are discussed in detail in Chapter 4. The model also covers other media than solely textual ones, for instance video. Typically in video collections and shops, the potential information (or emotional experience) in the videos is represented by a crude classification of the stock on the shelves, while the front-cover pictures plus some text serve as means for representing each item.

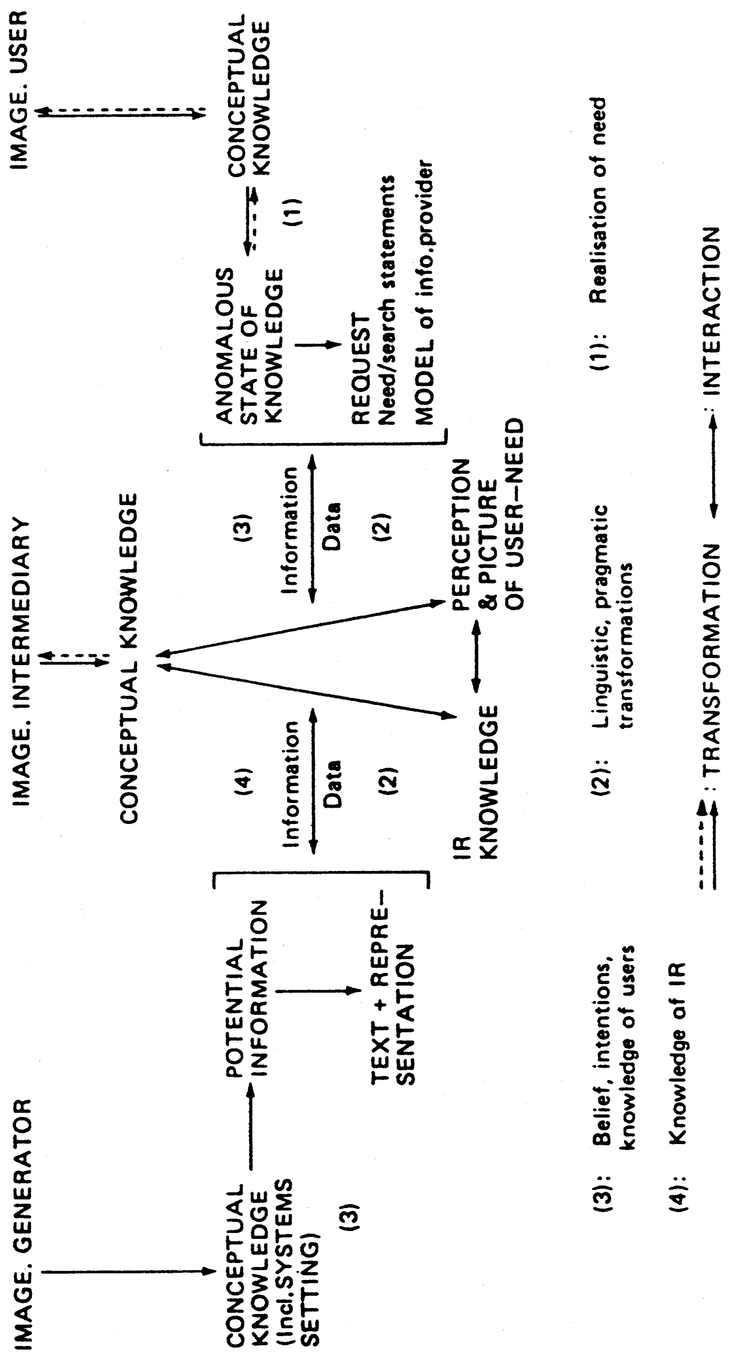

Fig. 6.4. A cognitive communication system for IR interaction. Further development of Belkin, Oddy and Brooks (1982, p. 65) and Ingwersen (1982, p. 171; 1984a, p. 469; 1986, p. 222).

In total, the following major *individual generators*, each with their own particular cognitive model, work space and state of knowledge, take part in IR interaction on the left-hand side of the figure:

Generators:	***Responsible for:***
Authors (in general terms)	Potential conceptual information
Indexing system designers	Rules of representation
IR technique designers	IR technique or command language
Indexer (& maintenance staff)	Actual representation & dbs-update
System/database designers	Database structures and features
System producer	Searcher model, selection policy

In certain cases, e.g. in smaller in-house IR systems, all generators with the exception of authors, may be the same person. Frequently in experimental IR, the designer of an indexing system and IR technique(s) as well as the indexer may be one individual or a team (the researcher(s)), e.g. in the case of partial match technique experiments. The model Figure 6.4 thus explains, from a cognitive view, why such experiments provide rather good results within their constraints: without user and intermediary knowledge structures, very *few different knowledge structures* participate in the experimental setting, which consequently eases the matching of those structures.

When we are dealing with an online host, the IR technique has been fixed long ago into a specific command language, e.g. CCL, and each database structure will be tailored to suit the host by its system designers. Each database will have its own method of representation and policy for subject and document coverage, but the host's system producer will have responsibility for the searcher or user model. At present this model typically contains two characteristic searcher groups: the IR specialists, and the casual end-users or novices. This fact is mirrored by two different types of retrieval modes: a user-instigated Boolean command language, and system-initiated menu-driven searching.

6.2.2 Major knowledge structures in intermediaries

At the centre of the model, Figure 6.4, is the intermediary's cognitive model containing its work space and actual state of knowledge at the event of IR ('image'). Fundamentally, the model contains *two* different *kinds of knowledge structures* (Chapter 2.2.2):

***IR knowledge**,* i.e. knowledge about:

- *System setting*, i.e. various IR systems and information sources, IR techniques, software features (incl. feedback facilities), database structures, methods and rules for representation, actually applied indexing, database producer policies;

- *IR processes*, i.e. search interviewing, strategies (incl. system selection), tactics, logic, system interrogation;

Conceptual knowledge, i.e. knowledge about:

– *Domains* and domain *tasks*, including subject & affective areas, concepts and concept relations, paradigmatic structures, user seeking behaviour and preferences; and including:

– *Intentionality*, expectations, imagination, values, planning.

'IR knowledge' is tuned toward the 'IR system(s)' that are potential to the work domain (e.g. *Zentralblatt*, Chapter 6.1.2), *and* toward the user, since knowledge of the 'IR processes' incorporates search interviewing techniques. To the human intermediary, this kind of semantic knowledge is his professional expertise.

In relation to the tri-partite distinction between knowledge involved in IR, and analysed in briefly in Chapter 2.2.2, the 'System setting knowledge' equals 'Passive system knowledge'; 'IR process knowledge' signifies 'Active system knowledge'; and 'Conceptual knowledge' implies 'Passive conceptual knowledge'.

During IR situations, 'IR knowledge structures' interact dynamically with the 'Conceptual knowledge' which is geared mainly toward the user and the actual work domain. Knowledge of subject areas, concepts and paradigmatic structures in a field is in addition related to the conceptual contents of documents stored in the IR systems, i.e. text and actual indexing terms. By means of *triangular interactive processes* within the human intermediary he attempts to bridge user concepts, his own semantic and episodic conceptual knowledge, and concepts in the 'information space'. Intentionality, imagination, etc. are included, playing significant roles in human intermediary IR behaviour (Chapter 5.3.1).

As the third leg of this triangle, the intermediary possesses *actual user & request model building* abilities (= perception of user & need, Figure 6.4) as well as an *established user model* (= picture of user, i.e. knowledge of preferences and behaviour). The existence of the model, and the abilities to carry out model building, are in accordance with the assumptions made by Taylor (1968) in relation to his five filters and the notion of the 'compromised need' (Chapter 5.5.1). They are empirically verified by Ingwersen (1982), Belkin (1984) and Daniels (1986).

By 'actual user & request model building' we mean to find out:

1) to which domain and subject area in a multi-domain environment the request adheres;
2) which work task the actual user is up to;
3) the actual user's state of background knowledge of IR and the domain in question;
4) the actual user's information need and/or his underlying problem;
5) to which information need category the actual user belongs.

For human intermediaries the *user model* is a dynamic mental construct, holding *general ideas* of what to expect from users in the actual domain or work place, in terms of 'Seeking behaviour', 'Preferences', 'User expectations & intentionality' and the users' knowledge of IR and domain concepts (Figure 6.5). A newly "installed" information specialist, say a research librarian, may need some time to build-up his user model in his semantic memory, in particular if the domain is outside his academic field. As a researcher himself, he may possess 'meta'-knowledge about the behaviour of academics in general which speeds up the process. Being within his own field however, he will automatically hold a user model, and contain a rather exhaustive 'map of concepts' and conceptual structures, relevant to the domain. In contrast, the generalist intermediary, say a public librarian, will never hold a deep-structured conceptual map, covering on the one hand the vast 'information space', and on the other hand the infinite conceptual possibilities in the user area. Hence, the generalist's cognitive situation is far more inhibited and his user model much more general or meta-like in relation to each potential user, than the expert's in a more narrow domain. Generalist intermediaries therefore often rely heavily on their passive and active IR knowledge and the IR systems in the environment to compensate. Human intermediaries, and generalists in particular, must constantly *adapt* to new events by interrogating IR systems and probing for additional knowledge. A non-human intermediary will have to rely only on the presuppositions and expectations implemented by its designers, that is, *their* cognitive structures. In contrast to a human intermediary, whose cognitive model and work space ('image') may change during IR (vertical →, Figure 6.4), the non-human's knowledge structures are fixed – although they may certainly contain adaption rules. Its ability for actual user model building depends thus on the quality of a *pre-established user model,* for example extracted by field studies and cognitive analysis, as outlined in Chapter 6.3.

System Setting, i.e. various IR systems and information sources, IR techniques, software features (incl. feedback facilities), database structures, methods and rules for representation, actually applied indexing, database producer policies;

IR Processes, i.e. search strategies (incl. system selection), tactics, logic, system interrogation;

User Model, i.e. seeking behaviour, user preferences & values, user expectations, user intentionality, IR knowledge, domain knowledge;

Actual User & Request Model building, i.e. search interviewing on: information need, terms, underlying problem, User Model attributes;

Domains and domain tasks, including subject & affective areas, concepts and concept relations (conceptual maps), paradigmatic structures;

Intentionality, expectations and experience, values, imagination, planning.

Fig. 6.5. Six blocks of major knowledge structures forming intermediary mechanisms in IR interaction. Based on human intermediary behaviour.

Figure 6.5 demonstrates a reorganisation of the two fundamental knowledge structures (or the three active and passive structures) into six major structures or blocks, which by implementation constitute a non-human intermediary. Certain characteristics are evident.

First, we may talk only of an intermediary mechanism, if the design contains the following three blocks: *Intentionality*, expectations, etc., *IR System Setting*, and *IR Processes*. Without causality, means to and objects for action, the mechanism cannot function.

Secondly, the key-block in the design is the *User Model*. This component, as well as the associated 'domain and task' knowledge, are the most difficult to organize, since they require rather profound field studies, or tightly controlled transfer from other, similar domains, in order to function properly. The degree of domain complexity will influence the causality in the mechanism and complicate inferential rules and processes. On the other hand, the installment of a 'conceptual map' in the mechanism, e.g. in form of a thesaurus or semantic case-frames, is a moderate task in a well-defined domain. Fundamentally, a conceptual map as well as the 'Setting' and 'IR Process' blocks are far more suitable to implement in computers than to teach to information specialists. The significance of the computer memory capacity, as well as the *structural nature* of the contents of the two blocks, facilitate implementation. The research interest in IR intermediary design is consequently concentrated on the four remaining major components, their contents, functionalities, and interaction with one another as well as with users and the IR system(s). Chapter 7.1 will explore examples of different designs associated with *characteristic combinations* of these four blocks in knowledge-based or so-called 'intelligent IR': *Domain & Task* knowledge, including 'Conceptual mapping', *Intentionality, User Model*, and *User & Request Model Building.*

The borderline between intermediary mechanisms and other, rather simplistic host and database dependent features is established *when* we are no longer talking about implementing and executing 'IR process' knowledge, i.e. when the mechanism holds no means to communicate with an IR system nor a user on its own. The mechanism then contains only 'System Setting' knowledge, and is reduced to a 'tutorial or help' feature, e.g. anchored in front of an online host system, as done by Dialog and other large vendors. The feature may only be manipulated by the end-user.

In addition, one may envisage a case without any System Setting, IR process knowledge and causality, but comprising a simple 'User Model' and 'Domain knowledge'. The mechanism would be reduced to a conceptual feature connected to a traditional online database and making it slightly more advanced, e.g. Inspec (the core database for physics and computer science). Inspec incorporates domain knowledge in the form of a thesaurus (= conceptual map). Also a so-called 'Treatment field' exists which mirrors how topics are scientifically treated by authors, e.g. in form of analysis, experiment, theory, etc. The Inspec designers, quite correctly, have presupposed that their supposedly scientific users share this mode of classification (= simplistic user model). However, again the end-user must access and manipulate these facilities.

The model Figure 6.4, as well as the specified types of knowledge involved in IR interaction and intermediary mechanisms (Figure 6.5), can thus be seen to serve as a framework for designing intermediary mechanisms, consisting of larger and smaller building blocks. A less elaborated model of conceivable design features for present and future IR research has recently been presented by Bates (1990). Chapter 8 will combine these blocks with the analytical intermediary functions of Chapter 5.1.3, and the Monstrat functions of Chapter 5.4, and demonstrate the Mediator Model.

6.2.3 Users' cognitive structures

The right-hand side of Figure 6.4 outlines some, but not all, of the knowledge structures involved at the event of retrieval. These are shown and discussed previously in great detail in connection to Figure 6.3.

In Figure 6.4, the 'image' holds the user's 'work space'. The notion 'Conceptual Knowledge' contains his actual 'state of knowledge' which is transformed into a 'problem space' and a 'state of uncertainty'. These two states replace 'anomalous state of knowledge' (ASK) on the model. Only if the 'state of uncertainty' is reached, according to the Chapter 2.2, may the user carry a need for external information. According to his 'Model of the information provision mechanism', inherent in his state of knowledge, the user may pose a request to the intermediary (or IR system). The nature of this initial request may be characterized as discussed in relation to Taylor's four steps and the types of information needs (Chapters 5.5.1–5.5.2). Hence, it may be formulated as a 'compromised need' – as a label – or in a form which more fully represents the information need and/or problem underlying it. If the intermediary in the model is human, the request may be perceived, and conceivably transforms the intermediary's state of knowledge. It then becomes 'information' (Figure 6.4).

In case of an intermediary mechanism, the request statement will remain 'data' to the mechanism and be processed according to its implemented presuppositions and knowledge structures. The various designs in Chapter 7.1 will obviously process a given request in different ways. Similarly, the interaction processes will depend on the actual design.

The major role for the intermediary is, as stated in Chapter 6.1, to match the IR systems' *information space* with the user's *problem space* (notion [on model). Given that the IR situation results in the provision of some conceptual information potential to the user, he may perceive it, and it may reduce or otherwise support his state of uncertainty, transforming his problem space and his state of knowledge as information (→, Figure 6.4). During IR interaction this process may take place recurrently, e.g. generating slightly different problem spaces. At a given point, the information need may be realized, the actual problem partly solved or the emotional experience brought closer to fulfilment.

Viewing Figure 6.5 as a general model, one may realize that the six major knowledge structure blocks may characterize users (and designers) as well:

'System Setting' and 'IR Process' knowledge constitute the user's 'Model of the IR system', including his ability to search. 'Domain and task' knowledge as well as 'User Model' comprises his 'Work space' or the model of himself. 'Actual User & Request Model Building' can be seen as his own 'actual state of knowledge', incorporating 'problem space' and 'uncertainty state'. 'Intentionality, expectations, etc.' form part of his total cognitive model.

Consequently a specific user may hold a certain combination of *IR knowledge* and *Conceptual knowledge*, at the event of IR. In addition to other user characteristics related to retrieval processes, Chapter 6.2.4 discusses four fundamental types of searchers based on significant combinations of knowledge structures.

6.2.4 Knowledge characteristics of the actual user

By combining the two basic types of knowledge structures involved in IR interaction, discussed in Chapter 6.2.2, one may observe *four basic types of searchers.* This way of characterizing users adheres originally from (Ingwersen, 1984a, p. 473) and became elaborated in (1986, p. 216–218). Figure 6.6 demonstrates the four user types, also associated to the actual *level of experience in use* of intermediary and/or IR systems.

The idea of combining IR knowledge and conceptual knowledge in a matrix originates from the fact that the individual participating users (and librarians) showed *learning effects* during the experiments outlined in Chapter 5.3. However, at *each new IR situation*, it became aparent that the *actual combination* of the two knowledge types was the determining factor for actual seeking behaviour.

The notions of the four types of searchers on the figure emphasize the *knowledge* characterizing them, not their possible roles in IR. The role-orientation has in general been based on statistical groupings made in investigations of the online population in various countries. Unfortunately, by doing so the searcher types could be viewed as static groups only – not as individuals covering specific knowledge attributes at the event of searching. The groups obviously exist. However, the idea underlying the four types is to stress that at *each event of IR*, a particular user may find himself in a situation belonging to *only one* of the types. Since this fact was not put forward in clear terms (Ingwersen, 1986, p. 218), the scheme materialized as un-dynamic. For example, for this reason Sormunen refers explicitly to Ingwersen's searcher categorisation from 1986 as being too stable to be useful for interface design (1989, p. 27).

Consequently, by focussing on the *individual knowledge characteristics* ***at each IR event***, one may use the scheme for design purposes in IR.

Searcher types	IR knowledge included	IR knowledge excluded
Conceptual knowledge included	EXPERT	SUBJECT SPECIALIST
Conceptual knowledge excluded	IR SPECIALIST	NON SPECIALIST
Levels of use Experience	Experienced ←–– Casual ←–– Novice	

Fig. 6.6. Basic types of searchers in retrieval, characterized by combinations of conceptual and IR knowledge structures *at event of IR.*

A *non-specialist* is a person who, in his *actual* state of knowledge and problem space at event of IR, possesses insufficient knowledge of both types to perform retrieval effectively in a given 'information space'. He might be a 'layman', but just as important, he may be a person who belongs to one of the *other three types* – in other circumstances! For instance, a research librarian or a documentalist (i.e an 'expert') might desire to obtain information from outside his traditional work domain – and be forced to apply an IR system he has never used before. In this case he is a 'non-specialist' – and a *novice*. We may also visualize an IR specialist searching for 'business information' in a totally unknown retrieval system. Momentarily, he will also be a 'non-specialist', since he does not know much of the business domain.

During retrieval, including working with an intermediary mechanism, the 'non-specialist' will probably acquire some new knowledge – of both types. The next time he uses the same intermediary mechanism within a similar work domain, he will be more familiar with both. He may hence end-up as 'expert' and an 'experienced user'. Some public library users belong to this category, when they frequently look for information in their hobby domain. If the next search session, however, takes place several month after, the user has lost his touch and may to a maximum belong to the 'subject specialists' at that event, and be regarded as a 'casual user'.

A subject specialist is a person who possesses conceptual knowledge within that domain in which he is performing retrieval at a given moment. A user, knowledgeable in fiction may, the first time he searches the 'Bookhouse', be regarded as a 'novice' and a 'subject specialist'. When he or she has tried the system several times, he or she becomes an 'experienced expert user' in that system. It is among the non-specialists and subject specialists we may find the traditional end-user, casual and novice users.

An IR specialist is a person who may be regarded as a subject generalist, except within the domain of IR in which he supposedly is an 'expert'. As argued above, he may momentarily be brought into a non-specialist position. Like an 'expert', he ought to adapt quickly to unknown IR systems. His problem is the degree to which his conceptual knowledge (his domain model) is sufficient, e.g. when interviewing an end-user in an IR situation.

An expert is a person who possesses both types of knowledge at the event of retrieval. His state of knowledge and problem space match the actual 'information space'. As pointed out above, such a person may lose his 'expert' status in other IR situations.

Traditionally, both 'experts' and 'IR specialists' serve as human intermediaries in information retrieval. However, with the introduction of operational intermediary mechanisms, more and more 'subject specialists' will become 'experts' working daily with the same interface within a specific information space. They will then in addition be regarded as 'experienced users'. Notwithstanding, one may observe 'IR specialists' in in-house environments, who apply 4–5 databases very frequently and 2–3 less often. In relation to the latter databases, they are 'casual users'.

The categories in Figure 6.6 shade into one another. One might for instance introduce more detailed differentiation for both knowledge types, resulting in several new types. For example, it would be possible to apply some or all of the six 'knowledge blocks' producing a more rich typology. However, this is only productive if an intermediary mechanism and/or underlying IR systems may accomodate such a differentiation.

In relation to the shading from *novice* over *casual* into *experienced user* in the figure, one may refer to Hollnagel's distinction between 'surface', 'shallow', and 'deep knowledge' with respect to the actual searcher's system processing knowledge (1987). Clearly, the important issue is to be aware of the problem of system *complexity* in relation to Figure 6.8 below. Evidently, a particular searcher may be 'experienced' (have deep knowledge) in the use of an intermediary mechanism, and *simultaneously* be 'casual' (have shallow knowledge) or 'novice' as to one or several *underlying IR systems*, to which the user (based on the topical nature of his information need) becomes referred in a multi-domain and system environment.

The four basic user or searcher types, together with this (dual) system experience status, have consequences for *intermediary design*. The Monstrat model (Chapter 5.4), contains two of the three relevant functional tasks: KNOW (conceptual knowledge) and IRS (knowledge as to IR systems), but not the third factor, the user's *level of use experience* as to the intermediary. This level will have implications as to how much and in which way the intermediary needs to support a user accessing the intermediary, whereas IRS settles the support-level related to a particular remote IR system, presumably at a level different from accessing a local (stand-alone) IR system, already inherent in the intermediary itself.

From the insight provided by the empirical investigations we may extract what happens during IR interaction to searchers who are either 'subject or non-specialists'.

With reference to Ingwersen (1982, p. 175–177), the main results concerning the users' own searching (experimental setting b), Chapter 5.2.3), i.e. browsing along the shelf organisation in a state of uncertainty with their own information need more or less well-defined, are:

1) the overall structure of the class system is not understood by inexperienced users. They show great difficulty in finding any (logical) order.
2) they often try to make an alphabetical order out of the written indications identifying classes.
3) they attempt to adapt their need to categorial-generic signs.
4) they often think that all aspects of the same topic are physically placed together.
5) down in the class structures, moving from left to right, they often get surprises, i.e. the perception of the logic in the sub-structures creates problem spaces and states of uncertainty as to retrieval itself.
6) by browsing the shelves picking out books, some users seem to sharpen their definition of the information need.

One of the major problems, regardless of the actual user's library and IR experiences, is the fact that nearly all topics may be related to *several aspects*, out of which one is the preferred one (by indexers). Because of DK5's hierarchical characteristics, the user is mainly forced to make generic (categorial) classification of his need. This user classification does not always result in hitting the relevant aspect in DK5. One reason behind this problem may refer to user expectations. All daily-life tools (e.g. telephone books) are arranged alphabetically, including their topical volumes. Why not here? The fiction literature and the geo-historical groups seem less complicated, because of their generally one-faceted organisation. Fiction is arranged alphabetically by author name, biographies after the person in question, and the geographical and historical groups mainly by country and chronologically, respectively. The remaining groups seem to produce disorientation. For example, 'why is religion placed just ahead of social science?'.

The points 2) and 3) are interesting. These imply that classification of a need is related to the mode people are used to applying in department stores. However, very rarely have Danish public libraries put up an alphabetical list of mega-generic categories, pointing to various parts of the library.

The *consequence for intermediary design* is to install such alphabetical lists of broad subject headings which users may point to, as well as to provide some kind of clustered support containing concepts, with pointers to the various major aspects related to these concepts. However, a traditional (categorial) thesaurus structure is not sufficient. The cluster structure must in addition contain pointers to *situational* concept relations. From the protocols, the 'Boolean logic' example may illustrate this. This user's rather well-established topical knowledge makes him manoeuver from 'philosophy' over 'computer science' to 'mathematics' – all relevant aspects of the topic. However, the user could not know that his own particular intention, i.e. to apply the logic in 'electronic circuit design', makes him stop too early at the shelf, since the correct class group is placed some meters to the right, under the aspects of 'Applied sciences, electronics'.

With respect to point 6) above, the finding seems to be certified by Chen and Dhar (1990). They claim that during interaction with IR systems (browsing), the user may refine his information need, transforming the need from Taylor's Q2 to Q3 stage, Chapter 5.5. Since the researcher does not know the user's *own internal definition* at the start of the experiment, this Q2–Q3 relationship is likely to exist, but one cannot be sure. What is indubitable, however, is that developments within the Q3 stage take place, e.g. by producing request formulations which gradually elaborate and extend initial labels.

6.2.5 Collective cognitive structures in IR interaction

The reason for bringing up this issue in relation to IR is the fact that collective knowledge structures, or 'paradigmatic structures' (Kuhn, 1970), influence the entire retrieval situation. The issue is slightly elaborated on in Ingwersen (1986, p. 215–216):

> The paradigmatic approach makes it probable that IR is more likely to be effective when a majority of the involved [generators, users and mediators] within a subject field share common knowledge structures. Scientific views, terminological patterns and vocabulary can thus be kept under control. The 'match of concepts' may then have a chance for a time, for example, within very limited and specialized subject fields....However, such permanent conditions rarely exist in developing fields, whether in differentiating or in interdisciplinary fields, such as the social sciences, the humanities, and in several of the current technological domains.

Although all professional training aims at producing more or less conforming collective cognitive structures in the form of 'schools' or socially defined '(pre)-paradigms', the established conformity and its consistency detoriate rapidly, driven by social and technological changes.

During fragmentation, as well as mergers or collaboration between different disciplines in later years, the terminological patterns change radically, are scattered, re-established in new shapes, and further developed. For each scientist, not to speak of non-scientists, it becomes easy to find himself in rather unfamiliar information landscapes, i.e. that the 'information spaces' in adequate IR systems tend to cause intricate efforts to be fully explored. Information needs and request formulations, although well-defined, may be slightly out of context with the representations applied to potential information in relevant IR systems.

Paradigmatic structures caused by this develoment might be called *horizontal* paradigmatic structures. In addition, more *vertical* paradigmatic structures influence and complicate the IR situation. Within all disciplines and subdisciplines, and in the social sciences and humanities in particular, *epistemological* issues are determining factors for scientific as well as most other communication – via journal articles, textboks, IR systems, magazine and newspaper contributions. Mammen's outline of seven scientific viewpoints within psychology (1983), which have to be taken seriously by producers of IR systems, indexers, intermediaries and foremost by end-users, exemplifies the problems for IR.

The difference between 'horizontal' and 'vertical' paradigmatic structures is associated with the phenomenon of *representation*. 'Horizontal' structures are in general observable in the IR systems, or may be made as such by use of advanced IR techniques and natural language representation, for instance SAP (see Chapter 4).

In contrast, the 'vertical' structures are mostly hidden, rarely or not explicitly stated in texts. They are somehow regarded a kind of 'soft' information. Even in cases where they are stated explicitly, say in titles, the combination of rules of representation and indexing practice may make the indexer avoid adding adequate epistemological keywords. In general, human indexers do not tend, or are not forced by producers, to add data on scientific viewpoints during indexing. Furthermore, because of his *own* view, not coinciding with the text's, the indexer may add another term, or he may in fact not be sure to which 'school' the text belongs. The result is evidently a substantial lack of consistency. Hence, it becomes extremely difficult (or impossible) to extract this type of information automatically from texts. Interestingly enough, one of the more important dimensions in Mark Pejtersen's indexing scheme for fiction, implemented in the Bookhouse system (1989), concerns 'author intention', which is merely of a similar nature to scientific viewpoint.

There exist two known but unsatisfactory ways of tracing 'vertical' paradigmatic structures. Both may be of potential use in intermediary mechanism design:

1) Using the *citation pearl strategy* in a online citation index to generate citation chains or clusters of citations, starting with *known author(s)* adhering to a specific view;
2) Using the outcome of 1) as starting point in a *similarity search* in ordinary databases.

The first search mode may not be completely trustworthy because authors also tend to cite their scientific 'opponents' from different paradigmatic views.

Although the second strategy can be applied by all matching techniques and carried out algorithmically, it may still display subject areas with mixed scientific views, since the same indexing terms are used for all views in the area. Notwithstanding, this search mode is heavily used in the behavioural sciences during IR (Ellis, 1989). The implication for intermediary design in such domains is to be aware of this mode or value as an important *user preference*, forming part of a user model (Figure 6.5). Thus, in relevant domains, this search functionality can be implemented and explicitly explained, along with other means of retrieval. At the end, it is the user who judges the relevance of the search outcome.

6.3 Design and evaluation methodologies in IR interaction

Modern information systems design involves a generally accepted design cycle which among its elements contains as a minimum two important phases: systems analysis and evaluation of systems performance (Burch and Grudnitski, 1989). Both phases may include empirical field studies as well as analytic assessments. The latter method is normally applied by the systems analyst or researcher before prototyping, in order to verify the design and the scope of the system (its functionality, purpose, etc.), and to avoid waste of resources. *Analytic top-down verification* may naturally be used concurrent with *empirical qualitative validation* in the evaluation phase of a prototype or an existing system in relation to its *functional use*. As for design, all evaluation studies – and analytic verification in particular – require established knowledge of or experience with that work domain, problem solving and interest activity, and the information seeking behaviour the system should accomodate. Thus, empirically based field study evidence must somehow exist, underlying and guiding the design or evaluation.

This chapter discusses criteria and methods of evaluation for IR systems which, as a consequence, in addition can be applied to design of IR systems. In particular, empirically based methods have proven suitable for this purpose, as emphazised by Ingwersen and Mark Pejtersen (1986, p. 111–124). The chapter does not deal with cost-efficiency and cost-effectiveness methods.

In their contribution Ingwersen and Mark Pejtersen first outline certain drawbacks as to IR systems design within the traditional IR approach. This is followed by suggestions and brief characteristics of relevant empirical methods which are exemplified involving aspects of the design of bibliographic databases of both fact and fiction literature, the latter stressing the mediation of cultural values and goals. Based on a systems theory view, the authors present a model of design variables in IR (Figure 6.7 below). The figure outlines a framework for the proceeding discussion.

The model is an elaborated version of Figure 2.1 and a further development of the IR communication model, Figure 6.4. It contains 'System Setting', i.e. the various structures made by the designers and embedded in an IR system, and 'System Objects', i.e. the conceptual structures originating from authors (conceptual knowledge) and indexing (knowledge representation). On the right-hand side is that 'Environment' of the system which it ought to serve, including its individual user's conditions and the organisational or social requirements, preferences, tasks, values, etc. within a dynamic working domain. The conditions of the individual user contain his work space, including his actual knowledge state and problem space, information seeking behaviour, etc. An important variable are the *spin-off effects* in relation to new IR systems, on an individual as well as an organisational or social scale. The notions 'Work domain' and individual 'Work space' refer to affective *and* cognitive issues. The notion '← Models →' refers to Hollnagel's view that each participant in IR has some kind of model of other components (1979, 1987). The models contain the expectations and knowledge of how other components behave, and have been displayed in various ways in the general IR models presented in Chapter 6.2 above. '← Models →' appearing in IR system components and non-human intermediaries are implemented by the designers or producers, and consequently stable.

In order to select appropriate methods the authors make a distinction between (Ingwersen and Mark Pejtersen, 1986, p. 115):

1. *designing new* IR systems or modifying existing ones;
2. *evaluating an existing* system in relation to its scope.

The authors discuss laboratory vs field data, the objects for investigation, i.e. past or present events, as well as the nature of data deriving from various outlined methods for data collection, such as questionnaires, open-ended or structured interviews, introspection, thinking aloud, recording and observation.

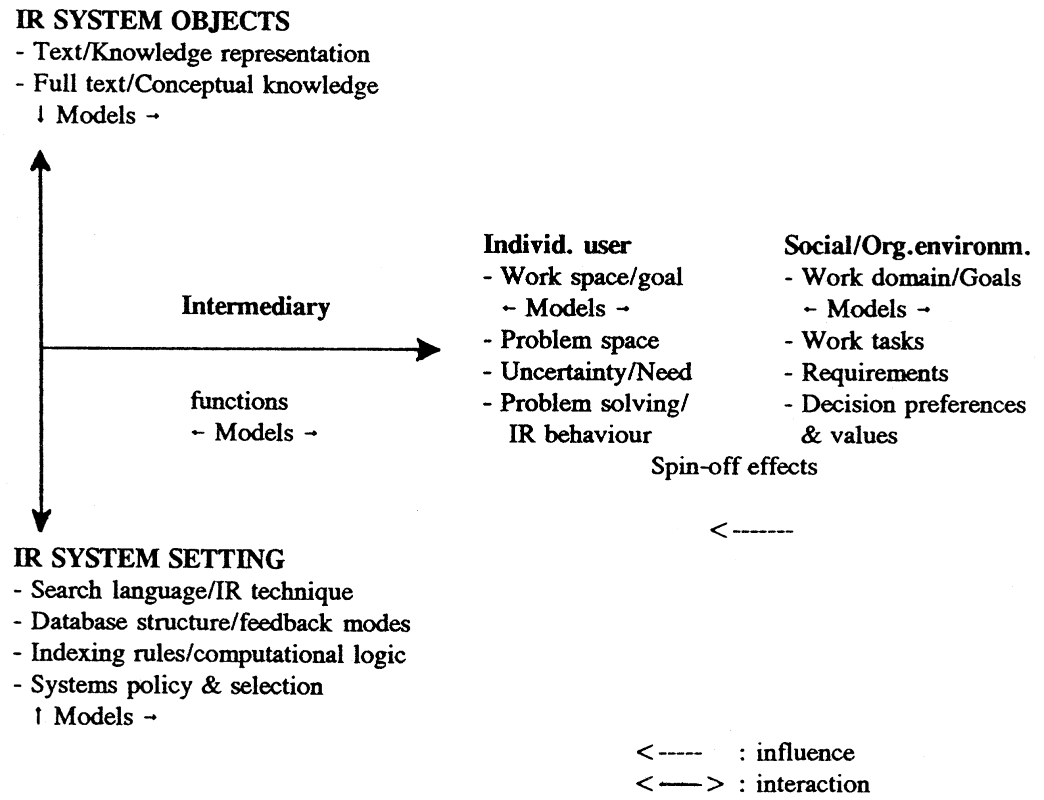

Fig. 6.7. Design variables. Further development of Samuelson, Borko and Amy (1977, p. 72), Ingwersen and Mark Pejtersen (1986, p. 113), and Rasmussen (1990, p. 9-10).

A significant conclusion is their recommendation to *apply several **complementary** methods in combination* – for both design and evaluation purposes. This conclusion is based on the experiences gained from the investigations outlined in Chapters 5.2–5.3 on user-oriented IR research. Essentially, the suggestion is to follow up the complementarity between the cognitive and the socio-behavioural approaches to IR research by similarly combining qualitative methodology with quantitative sociological methods.

6.3.1 Planning design and evaluation

When the purpose is design of a *new* IR system, an intermediary mechanism or modification of an existing system, the main object for investigation is the 'Environment' variables. The combination of recording/observation and interviewing (structured and open-ended) of actual problem solving and goal-oriented events seem adequate methods. If no prior knowledge of information behaviour in a domain is available, except for theoretical assumptions, such qualitative methods may provide clues or general evidence as to the work domain, decision behaviour, tasks, preferences and values in the *social/organisational context* – the epistemic *what* and *who*.

When (prior) knowledge of domain specific information behaviour exists, the researcher has ideas about what to look for. The clues or evidence may *then* act to structure in-depth interviews or questionnaires, or structure the analysis of recorded verbal protocols (e.g. from thinking-aloud studies). Mental behaviour and considerations, including intentional causalities by *individual users,* often 'hidden' from the researcher, may come into light yielding detailed patterns for design – the epistemic *why* or *why not* and *how*. Examples are: the strategy 'searching for fiction novels similar to the book just returned at the desk' (Mark Pejtersen, 1980); or the belief 'I thought all texts on the subject were placed together – regardless application' (Ingwersen, 1982). The former leads to the implementation of a 'searching by analogy' strategy in the Bookhouse (Mark Pejtersen, 1989), the latter to browsing facilities incorporated in tutorial systems (Mark Pejtersen and Ingwersen, 1986) and the use of the Zoom facility in an operational online service (Ingwersen, 1984a).

The research strategy of combining methods has been applied in relation to decision support systems design and analysis. Bjørn-Andersen applied an elegant combination of observation, interviewing and a structured diary technique. During two weeks subjects were asked to fill in a structured questionnaire for each task (and decision) performed. Based on six of the most important decisions taken during the period, in-depth interviews were made in order to verify and validate various models for decision making (1974, p. 243–258).

Croft et al. (1990) applied logging and structured questionnaires in order to "understand how people think about complex documents .. how they specifiy queries about documents they had previously seen (known item searching = verificative need type). The objectives were to determine 1) what formal attributes are most likely to be used, e.g. dates, title, tables incorporated in text, document size, etc.; 2) the certainty with which users can recall specific attribute values; 3) whether users distinguish between the importance of an attribute and their certainty about its value" (Croft et al., 1990, p. 601). The aim of the experiment, which yields interesting results for office work station design, was to analyse seeking behaviour and evaluate a prototype called OFFICER. Concerning information quality factors in business environments, Olaisen established a theoretical foundation of service quality, derived from service management, in order to obtain a framework for setting the quality factors in a business context. The framework was then compared with empirical research results obtained from bank and insurance managers by means of semi-structured interviews and structured postal questionnaires (1990, p. 91–92). Olaisen's work is an interesting example of *transfer* of evidence from one domain to another, testing the comparability (see also Chapter 6.3.4).

When evaluating an *existing* IR system and/or intermediary mechanism, e.g. a prototype, all components in IR interaction are objects, because, in principle, the success or failure of any one of the components will be reflected in the overall performance of the interactions as a whole. This implies that the entire Figure 6.7 (or Figure 3.2) is under investigation. The substantial number of variables requires a very structured methodological approach and well-established knowledge of information seeking behaviour and situations in the work domain and individual work spaces.

There exist several approaches to evaluation:

Are we evaluating the *overall performance* of an IR system, including an intermediary? – are we making a performance test of *separate components* or their parts? – or are we evaluating *across several IR systems*, and if so, why? In addition, one may ask whether the evaluation ought to be 'objective' or 'subjective' – and if we are looking for performance assessments, which type of performance: *functional use* or *relevance?*

6.3.2 Functional use assessments in evaluation

Aside from analytic verification of design functionalities, we may want to test the *functional use* of parts of IR interaction components, facilities, and processes. Functional use is seen as the *fit* between such IR components, including intermediary functions, and the users' individual work space and situation specific problem space, uncertainty state, etc., the IR system intends to accomodate. By means of empirical bottom-up analysis the researcher *validates* the results of his systems analysis, in particular his interpretation of the social/organisational part of the environment. Functional use may reveal problems in the design as to, for instance, operational readability, understandability, effectivity, and effect over a given time period, of navigation, screen layout, implemented strategies and IR techniques, etc. 'Effectivity' means 'what *can* (if at all) be used', and 'effect' implies 'what *will* be used', i.e. essentially spin-off effects.

Recording methods and logging of processes combined with a statistical significant number of pre- and post-interviews and use of questionnaires, that are purposefully structured, have proved to be valuable tools. Firstly, spin-off effects may be discovered and adjusted for in the design, if necessary. For example, the above mentioned 'searching by analogy' strategy was found to be applied in unforeseen way(s). It merely replaced the traditional 'browse document description' strategy in the Bookhouse, leading to future modifications of the possible handling of IR strategies in the system (Goodstein and Mark Pejtersen, 1989). Secondly, the functional use analysis may make the designer discover gaps in his initial systems analysis, e.g. in relation to characteristics of the potential user group(s). Thirdly, by applying more than one method of a complementary nature for data collection, it becomes possible to discover contradictions or to ensure that results are (statistically) valid. It is the *quality*, less than the use of information in problem solving, interest fulfilment, or achievement of emotional goals and values, i.e. the assessment of 'relevance' or search outcome, that plays a role in this kind of IR evaluation.

Concerning functional use validation, B. Hedberg and S. Jönsson (1978) review several evaluation projects in organisations in environments under constant change.

Several methods, such as recording, logging and interviewing were applied in order to test the role and effect of new computerized decision support systems, deliberately designed to ease problem solving by making room for curiosity during information retrieval. Hjelms Jørgensen (1985) used thinking-aloud and logging in order to find out how users learn to carry out mailing tasks with the UNIX Mail system and to identify users' misconceptions in dealing with sophisticated features in the system. As with Croft et al. (1990) the main purpose was to test the work domain, developing an intelligent prototype, in this case a help system for UNIX Mail.

6.3.3 Relevance assessment issues

If we understand IR interaction performance *only* in terms of *relevance* of retrieved and non-retrieved texts, we are likely to get into some difficulty; in particular, if we want to assess the overall performance of one IR system, across systems or detailed parts or functions of an IR system. The reason being that we need to move from the left-hand side of Figure 6.7 towards the environment, which in the end incorporates the users, rendering it difficult to control variables and leading to *subjective* relevance assessments. Since IR interaction heavily involves the environment, subjectivity and uncertainty in relation to predictivity are inescapable. Yet, uncertainty may be reduced by statistical means. In addition, evaluation by means of relevance across several systems is only interesting within one particular work domain, in which the user characteristics and behavioural dimensions and variables are supposedly known.

Chapters 3 and 4.5 outlined the traditional framework for and results of evaluation of IR systems using *standard criteria* for relevance assessments, involving fixed queries with known recall-ratios in laboratory experiments. In the experiments no users participate and assessments are made by the researchers. Evaluations across systems may then be measured according to obtained recall and precision ratios, but *limited* to assessments of IR techniques or methods of representation. As pointed out by C. Cleverdon (1974), this test method mirrors the systems management view of evaluation, and is limited to non-interactive IR.

As stated, such measurements have deficiencies, in particular concerning large-scale operational IR systems, because of lack of control of recall, and require a definition of relevance upon which there has been lack of agreement, also within the traditional research approach. Relevance might mean the (degree, measure) of (correspondence, utility, satisfaction, use..) between a (document, text representation incl. abstract, part of document..) and a (query, request, information need, problem..) as determined by a (researcher, designer, intermediary, user, user group..) – (Saracevic, 1975, p. 328) and (van Rijsbergen, 1990, p. 23,30).

Distinct from relevance, Saracevic (1980) has defined the concept 'pertinence', which is 'the property that assigns an answer to information need'. (Relevance seen as the property that assigns an answer to a question [request]).

Relevance might also be 'the degree of *use* of information by a user in a state of uncertainty as determined by the user', i.e. the degree to which external information reduces uncertainty, solves a problem or fulfils a goal, provided that the information concept (Chapter 2.2.1), is applied. This is an extension of pertinence, by moving a step further to the right in Figure 6.7. Like other definitions of relevance, this one is only operational within its constraints, i.e. that non-retrieved potential information in the situation does not form part of the assessment. The potentiality of 'dark matter' in information space seems thus unattainable. The recently developed concept of *informativeness* of IR systems may turn out to open up new, more useful assessment methodologies (Tague-Sutcliffe, 1992a,b).

In order to avoid the use of recall as a criterion and to allow for user evaluation, *utility* has been suggested (Cooper, 1973, 1979). By user assignment of a specific utility value to each retrieved document, according to the experience with it, one may calculate an average utility value across all users for a particular IR system. Since the same standard utility value may be applied to several systems, e.g. time or money a user wishes to offer for an experience, systems can be compared. What appears difficult is to apply the results for detailed design purposes.

Besides discussing the traditional methods for evaluating retrieval effectiveness, Belkin and Vickery review the utility approach, as well as the applications of satisfaction and use as criteria (1985, p.188–198). In view of Figure 6.7, *user satisfaction* attempts to measure overall performance of the IR system and its individual components, as determined by the user. By application of rating scales, the degree of satisfaction with qualitative factors influencing IR interaction can be established for a particular system – and with statistical care compared to other IR systems.

6.3.4 Evaluation from a social-organisational perspective

Use of information has been suggested, for instance by B. Whittemore and M. Yovits in relation to decision making processes, and by D. Soergel (1976) in relation to user satisfaction. From a sociological and communication point of view T. Wilson and D. Streatfield have investigated the environmental part of IR interaction, i.e. how individuals apply information in their social context (1977) – the right-hand side of Figure 6.7. They used 'structured observation' as mentioned in Chapter 5.2; D. Ellis' work in a social science work domain is along similar lines (1989). Also in the context of social behaviour, B. Dervin and M. Nilan (1986) review the connection between information need development and use (or 'sense-making') of information.

Very recently L. Schamber et al. have produced an excellent review, re-examining the concept(s) of relevance in IR research, and consequently the means for evaluation of IR interaction (1990). Explicitly, they point to "the social, behavioural dimension of information seeking as an alternative to a more cognitive, individual approach" (p. 770). They build on H. Gardner's views on cognitive science (1987, p. 6): "a feature [of cognitive science] is the deliberate decision to de-emphasize certain factors which may be important for cognitive functioning but whose inclusion at this point would unnecessarily complicate the cognitive-scientific enterprise. These factors include the influence of affective factors or emotions, the contribution of historical and cultural factors, and the role of the background context in which particular actions or thoughts occur". Schamber et al. go on, emphasizing (p. 770):

> Yet it is the affective dimensions, the *value-based* and *environmental* influencies on internal cognitions, that need to be addressed. If information science is to subscribe to an alternative paradigm, it will more likely draw on theories related to the social context and languages of human behaviour than on theories related to individual human factors or topical language representations. These theories may lie in other behavioural fields such as psychology, linguistics, communication, and social science (see Ingwersen, 1984c;..Vinograd & Flores, 1986) (Emphasis by this author).

As discussed previously in the Chapters 2.4 and 5.2, this author sees no contradiction between a user-oriented approach to individual cognitive phenomena and a more socio-contextual one. Schamber et al.'s approach is a dynamic and situational view on how individual users perceive information relative to their information need situation. The user is "active in a cognitive, non-physical, real-time environment" (p. 771). Their focus is on *use of information*, and includes assessment of value in the framework of the 'environment' (Figure 6.7, extreme right).

They present an agenda of 12 research questions to be dealt with in evaluation by means of mainly open-ended, structured interviewing, which include characteristics of users and 'System objects'. For instance, in relation to the user:

1. What criteria do users employ in assessing the value (to them) of information (internal and external) in actual information seeking and use situations?
2. Do users employ these criteria consistantly?
3. What characteristics or traits of documents (text, images,etc.) are included in these criteria? (What characteristics are perceived by users?)
4. What document characteristics do users say they want or use when seeking info. from systems?
5. Do users say they want or use these characteristics consistantly? (Are there patterns of desired characteristics within and across users?)

....

8. Can users recognize, or do they recognize, these clues [document clues of the characteristics]

This interesting approach addresses the epistemic *what* and *who*, but not the important *why*.

One may here point to the more comprehensive scope of the proposals by Rasmussen et al.(1990). They provide a detailed *user-oriented taxonomy for field analysis of work domains*, i.e. they emphasize what are the essentials to be measured. This taxonomy consists of 7 dimensions and a substantial number of structured categories, mainly dealing with the environmental part in relation to the function of the information system. Rasmussen (1990) states (p. 1):

> For modern work places, the ergonomic [functional use] concern in design of work stations is not primarily the human-computer interaction in a separate tool or 'application', but the concurrent influence of technology on work conditions, work organization, and management structures and, consequently, the influence on *information requirements* of operators in a cooperative network. In

> most work places, we find dynamic environments and concern with flexibility and rapid adaption to new requirements. In order to be useful for design of information systems in this situation, a modelling framework should serve the identification of a resource envelope within which an agent can navigate also in unforeseen situations. The identification of such an envelop depends on separate representation of the work domain, the generic cognitive decision tasks, and the useful strategies for such decisions tasks together with the subjective criteria of choice.

The 7 dimensions of the framework are (p. 12–13):

1. Work domain, Task space
2. Activity analysis in domain terms
3. Decision analysis in information terms
4. Information processing strategies
5. Allocation of decision roles
6. Management structure, Social organization
7. Mental resources, Competency, and Preferences of the individual actor.

The framework seems well suited for both *design and evaluation* of IR systems and interaction, since it partially originates from Mark Pejtersen's design and test work on the Bookhouse (1980–1990). It is intended to serve systematically and explicitly to bring to the mind of a researcher or designer the various relationships influencing the match between work requirements and agent resources. Its transverse scope may in future make researchers capable of *transferring* and reviewing suitable design and evaluation functionalities from one work domain to another. Essentially, Rasmussen et al.'s taxonomic framework has influenced the generation of the *Mediator Model* (Chapter 8), for example, by pointing to the necessity of Domain, Task and Systems models as well as System adaption and Feedback. In addition, the taxonomic dimensions make it possible to *re-analyse* previous research data, e.g. verbal protocols, with new hypotheses in mind.

In relation to *prediction* and the possibility of *transfer*, Rasmussen states (1990, p. 7):

> For taxonomic development in general, the implicit assumption is that a taxonomy should serve an exclusive *classification* of a set of complex items for later *identification* of items. In fact, what we are looking for in our efforts to create a conceptual framework for description of tasks, activities, work domains, etc. is a model framework, a framework for *description* which can serve to compare results from analysis made in different contexts and domains, which can serve to *predict* what kind of phenomena are to be expected in one work situation, given results from studies in other environments. Under influence of the present acceptance of mental processes and cognitive phenomena, the basic assumption underlying analysis and description will be one of complex interaction between characteristics of the work requirements, tasks as generated by actors, activities of actors to comply with tasks as perceived, the cognitive processes applied, the criteria governing the individual actor's preferences and the social factors determining the allocation of roles to the individual.

This taxonomic approach possesses a potentiality to guide and structure analytic verification of functionalities, combined with empirical evaluation of functional use, in a qualitative way. In a sense, the concept of 'functional use' incorporates the 'use of information' with a broader scope than in general attributed in IR. 'Use of information' not *only* implies the use of retrieved conceptual information, but *also* the functional application of other information structures, communicated during IR interaction, such as structures deriving *from the system setting*, Figure 6.7 (e.g. database field codes or command language syntax). The approach indicates means to qualitative evaluation across IR systems in different work domains, and of different, cooperative information systems, including IR systems, in the same domain.

6.3.5 Dimensions of Information Quality – IQ

In line with the trends in information science, demonstrated in Chapter 1.2.1, concerning accessibility and use, selectivity, as well as value and quality of information in relation to its application in sociaty, recent attempts have been carried out to produce workable concepts for information quality assessments. Although the use of all types of information by all types of users in society, not scientists alone, constitutes an important characteristic for the user-oriented approach to IR research, and consequently also for a cognitive approach, the major contributions on IQ adhere to another core area of information science: *information management*.

Quite obviously, the development of information management into strategic information management requires rather strong justification with respect to the technological and intellectual investments made. Aside from general statements that 'information is good' – and 'good information is better' – information managers have continuously been forced to generate evidence as to the profit business might gain by use of value-added data. Hitherto, the most promising conceptualisation of this important IQ issue has recently been published by D. Marchand (1990).

Marchand outlines and define eight dimensions of information quality:

1. Actual value	*2. Features*
3. Reliability	*4. Relevance*
5. Meaning over time	*6. Validity*
7. Aesthetics	*8. Perceived value*

In addition, he generates five ways of defining IQ, two of which are recognisable from an IR standpoint. Below, the five definitions are related to the relevant dimensions:

User-based	Perceived value and Aesthetics
Product-based	Actual use, Features and Meaning over time
Production-based	Relevance and Reliability
Transcendent	Meaning over time and Validity
Value-based	Trade-offs between dimensions

The Product and Production-based approaches to IQ are similar to those applied in traditional IR research (Production-based) and more user-oriented views (Product-based). One might argue that the Utility assessments applied to IR are similar to the

User-based approach to information quality. The notion 'production-based' is very similar to the description Cleverdon gave of the recall/precision/relevance techniques, calling them 'manufacture' related assessments (1974).

The most interesting IQ approaches are the Transcendent and the Value-based ones. Evidently, the latter concept implies involvement of costs, pricing, benefits – in relation to the variety of dimensions. It is apparent that five of the dimensions are highly dependent on the users and the actual environment in question: Perceived value, Aesthetics, Actual use, Meaning over time, and Validity. Also Reliability possesses aspects of relative judgment. From a methodological point of view, not dealt with by Marchand, it is clear that both quantitative as well as qualitative methods must be applied in order to analyse the effects of the dimensions in a specific environment as well as in society. Whether one likes it or not, the entry of information science and IR into society, caused by the demand for selective, value-added and qualitative information which is critical at all levels, forces information professionals to take up the challenge of "justifying and articulating their contributions to the bottom line" (Marchand, 1990, p. 16). It is at the applied and implementation level of the design of IR systems, also included in office automation systems, that we may see such issues appearing in the nineties. Aside from actually using the IQ dimensions for the purpose of evaluation, the job of theoretical IR research is to provide the professional in the field with sound and solid evidence about features and characteristics underlying IR interaction.

6.4 Summary statements

The cognitive turn implies focussing on the individual cognitive, emotional and motivational mental activities inherent in all the components of IR interaction. Further, it involves the social environment surrounding the act of retrieval. IR models become rather complex. Cognitive models from a variety of generators, mediators and users are responsible for the IR processes during information transfer. Hierarchical categorial as well as situational and contextually based knowledge structures have been shown to be interwoven with semantic and episodic memory in human IR participants. The consequences are more or less loosely coupled multi-dimensional conceptual networks ('maps'), representing conceptual relations at several levels of cognition. This implies that IR systems design must attempt to accomodate such cognitive structures, whether a searcher possesses deep, shallow or surface knowledge of the topic in question, intermediary functionality, or underlying IR system structures. One way forward is to make use of situational, event and work task related conceptual structures and tailored feedback from systems.

Based on the concepts of IR knowledge and Conceptual knowledge it is demonstrated that intermediary mechanisms may be designed by combining six fundamental building blocks of characteristic knowledge types involved in IR. A consequence of the cognitive turn is the change of evaluation criteria among which functional use, work tasks and quality dimensions become crucial parameters.

7. The COGNITIVE IR RESEARCH APPROACH

During the eighties the aim shifts from simply understanding searchers' (i.e. users and human intermediaries) mental behaviour during retrieval to understanding the bridging functions and tasks of automated intermediaries, based on user, system and intermediary modelling. Similarly, results change into designs of such intermediary components, increasingly applying AI techniques in order to make representations of requests and domain knowledge in systems. We are then moving into a cognitive synthesis.

One may state:

> The transformation from the user-oriented and the traditional approaches into a cognitive one happens when IR research comes to have each other's isolated models in mind and recognizes the fundamental cognitive interaction in the general information system between characteristics of the information (spaces), the functions and characteristics of intermediaries, and characteristics of users and information problems – and acts upon it in research. .. In the mid-eighties it becomes obvious to both approaches that each possesses IR models useful to the other, and that joined they may contribute to an overall IR theory. If one compares the Monstrat Model for design of information systems, generated by the user-oriented approach (Belkin, Seeger and Wersig, 1983) with Croft's and others IR design models from within the traditional approach (Croft and Thomson, 1985), the similarities are many (Ingwersen, 1988, p. 159).

The Monstrat Model was presented and discussed in Chapter 5.4.1, Figure 5.3. Croft's model for the data structures accessed by expert rules in his I3R system is shown in Figure 7.2 below. The interesting point is that although the architecture of I3R resembles that recommended by Monstrat in many ways, it is based on an entirely different model of IR. The basis of this model is that retrieval is a process of *plausible inference*, where information about relevance is gathered from a variety of sources. I3R thus emphasizes the formulation of a detailed request model implying some kind of *poly-representation* as a natural consequence of this approach.

By bringing together the hitherto rather isolated research experiences and results in a mutual effort to explore in detail the complex phenomena of IR interaction, information retrieval research concentrates on three aims:

1. exploration and understanding of *fundamentals in knowledge-based IR*;
2. problems associated with *natural language, meaning and information* in IR;
3. achievement of a more comprehensive or *unifying theory for IR*.

The points 1 and 2 are of fundamental cognitive nature. The third research aim most certainly involves cognitive aspects, as will be demonstrated in Chapter 7.5 below.

The first research area – 'knowledge-based retrieval' – currently displays two distinct approaches, already touched upon in Chapter 5.4.2 in the critique of the Monstrat Model, aiming at:

a) *Supportive IR intermediary design*, i.e. focussing on understanding and design of intermediary mechanisms that relies on *implicit* user, domain and system models, based on field studies of actual domain, tasks and user preferences (and involving inference);

b) *'Intelligent IR' intermediary design*, i.e. concentrating on theories and designs of intermediary mechanisms that rely on both implicit models *and* interactive, actual and *explicit* user model building and inference.

The differences concern the contents and use of the knowledge-base, the different views with respect to the role of IR underlying the two design types, and the fact that approach b) performs actual user model building. Both the Monstrat Model and systems like I3R adher to b), while the Bookhouse (Mark Pejtersen, 1989) belongs to category a). Chapters 7.1 and 7.2 explore a selection of the various designs and prototypes from both intermediary categories in two characteristic frameworks, making use of the six 'blocks' of knowledge structures (Chapter 6.2.2, Figure 6.5), in order to discuss their potentiality for further progress. A merger into a more unified design principle, the 'Supportive User Model Building' approach, is proposed and argued in Chapter 7.3. A crucial device for performing supportive IR is related to *system feedback* (Chapter 7.3.1).

Important features associated with 'intelligent retrieval', as opposed to the supportive type, are the discussion and problems related to the *nature* of model building and the use of *natural language representation*, in particular concerned with user request formulation and processing. This NLR issue connects 'intelligent' retrieval and research aim 2 above, and is considered and critiqued in Chapter 7.4.

Finally, the designs and prototypes from the two intermediary categories demonstrate that thus far the supportive mechanisms are almost totally designed for exact match environments, while the other category mainly operates within an experimental partial match environment (Figure 7.8).

Elements of a *unifying* cognitively based IR theory are discussed in Chapter 7.5, encircling conditions for use of NL and the problem of meaning, the plausible inference approach to IR, and the notion of semantic values.

The cognitive IR research approach displays the following major characteristics:

1. *Aim and foci:*
   Study of interactivity and combinations of poly-representativity, all (knowledge) structures and processes in IR. The emphasis is on IR interaction, including all components of the general information system, whether human or mechanical. They may all be regarded as knowledge-based contextual information processing devices.
   Field studies, cognitive task analyses, real-life tests as well as laboratory analysis and testing are used for design and evaluation purposes.

2. *Type of results and consequences:*
   Highly complex, interactive and cognitive models for the design of information systems. IR is viewed as an individual, problem solving and goal oriented process in which not only the user and the intermediary mechanism, but also the different information processing components in the information space participate interactively, all guided by goals, intentions and expectations.
   Uncertainty is inherent in all IR processes, in particular in relation to the actual user and his information need.

3. *Understanding of information:*
   Information as necessary for problem solving, interest fulfilment and goal satisfaction going beyond the concept of meaning.
   Similar to the user-oriented approach, information is understood in a wide context, including abridged or non-scientific material, emotional and cultural information. IR is understood to play an important critical and qualitative role in information transfer and communication at all levels of society.

4. *Use of supporting disciplines:*
   Cognitive sciences (including e.g. sociology) and computer sciences as well as mathematics as basic supporting disciplines. Similar to the user-oriented approach, cognitive and experimental psychology as well as psycho-linguistics are applied to user-intermediary behaviour and understanding of request formulations.
   Computer science (AI) and systems science are applied to the refinement of the design of intermediary mechanisms and IR system components.
   Information science as a supporting and exporting discipline for AI.

'Information' is here understood in the sense of the cognitive view, i.e. that non-human information and information processing deal with information only in a metaphorical sense. However, the goal of IR research is clearly, as stated under 'Aim and foci', an attempt to be capable of rising to a contextual stage from the present structural one.

7.1 Selected intermediary designs in IR

The variety of design possibilities and combinations of the major types of knowledge structures, discussed in Chapter 6.2.2 and associated with Figure 6.5, are outlined in Figure 7.1, below. Three basic rules are applied to define the design combinations:

1) An intermediary cannot carry out any functions without possession of Expectations and Intentionality, and not without System Setting and IR Process knowledge.
2) No User Model Building can take place without a User Model or Domain and Task knowledge.
3) No User Model can exist without Domain and Task knowledge.

	Cases:	**1**	**2**	**3**	**4**	**5**	**6**
IR knowledge	**System setting knowledge**	*	*	*	*	*	*
	IR process knowledge	*	*	*	*	*	*
	Actual user Model Building Interview on terms & **User Model attributes**	*			*	*	
Conceptual knowledge	**User Model** Seeking behaviour Preferences, Knowledge	*	*		*		
	Domains, tasks	(*)	*	(*)	*	*	
	Conceptual maps	*	*	*		*	
	Intentionality expectations	*	*	*	*	*	*
(*): weak model	**Intermediary systems:**	**I3R**	**Book-house**	**KIRA**	**Euro-math**	**IR-NLI**	**OAKDEC**

Fig. 7.1. Major cognitive structures classifying conceivable intermediary design. From Fig. 6.5.

Rule 1) is logical and implies that without communication means to and a model of the IR system(s) as well as causality, the intermediary cannot access and interrogate the IR systems, (i.e. selecting, matching and being informed). It does not exist as a true intermediary.

Similarly, rule 2) is logical, implying that search interviewing, whether via direct questions in Natural language (NL) or by menus and options to obtain knowledge of user's background knowledge, search preferences, information need, etc., may only take place based on an *established* platform, i.e. a User Model or a model of the Domain and its Tasks.

Figure 7.1 displays 6 possible intermediary design combinations. Within each case, one may organize the various minor knowledge categories belonging to each major knowledge type or block (Figure 6.5), in order to suit particular design goals.

7.1.1 The 'intelligent' IR expert system design – I3R

This combination is the most complex and advanced, and is currently under experimental investigation in the form of design models and some prototypes. However, although known as *the* model for 'intelligent' knowledge-based retrieval (IR expert systems), no prototype has so far been implemented going beyond the unitary or *stand-alone system approach,* i.e. that one IR system is directly contained as part of the intermediary system in one narrow domain. In relation to Figure 6.7 this approach implies that System Setting, System Objects as well as Intermediary functionalities are contained together in one *physical and conceptual configuration*. Conceivably for this reason, only very simple or weak domain and task knowledge has hitherto been implemented; (*) on Figure 7.1. Aside from actual user model building, this case holds potentiality for NL processing of user requests, and *simulation* of human intermediary performance. B. Croft and R.H. Thomson's I3R system, based on a black-board architecture, and a collection of independent experts communicating indirectly using a shared global data structure (1987), is the best representative of this combination.

The domain of I3R (Intelligent, Interactive Information Retrieval) is AI in the form of stored references to some 2500 articles on the subject, including their cited papers. The latter is in order for the user to apply the 'citation pearl' strategy, mentioned earlier. Figure 7.2 displays the models and data structures in I3R accessed by expert rules, controlled by a scheduler. As demonstrated by Belkin et al. (1987) there are similarities to the Monstrat model, in that a User Model and a Request Model (= Problem Description) exist. The Request Model also serves to obtain knowledge of the actual information need in pseudo-NL, i.e. that the user types his request in NL and then selects important phrases from this formulation as search concepts. Concepts are compared with the contents of the Domain Knowledge Model's semantic net (an elaborate AI synonym thesaurus). If recognized, the concepts are validated or replaced with preferred terms. If not recognized, the concepts may still be used for retrieval as single words.

The *User Model* conforms to the Monstrat model by making use of the Monstrat tasks UGOAL, KNOW and IRS. The model forms the basis for actual user model building via a 'User model builder' expert.

I3R Data Structures

Model	Conceptual Structure	Implementation
Request Model	Probabilistic request	Hash Table of Structures
Domain Knowledge Model	Semantic Net	Hash Table of Structures
User Model	Stereotypes and Expectations	Association List
Document Representation	Network of Documents and Terms	Relational Database
Browsing Model	Semantic Net fused with Net of Docs. & terms	Hash Table of Structures

Fig. 7.2. Models and data structures accessed by expert rules in I3R (Belkin et al., 1987, p. 404)

In I3R UGOAL (User Goal) holds two possibilities: precision-oriented searching (i.e. search outcome = few, highly relevant refs.) or recall-oriented (i.e. outcome = several relevant refs.). KNOW (user's background knowledge related to actual topic), holds a detailed model of knowledge level options the user may point to, for example from 'have read a news magazine article about subject', .. 'have read scientific article', .. 'have *written* scientific article about subject', to 'have written *textbook* about subject'. The option(s) selected by the user determine the number of searches to be run by the scheduler. IRS (user's IR and computer experience) is similarly determined, for instance from the option 'use word processing', over 'know programming' to the option 'have used online IR systems'. Information in IRS is used to determine mode of response in I3R to users. By linking user identification with the acquired user knowledge (mainly IRS), I3R remembers the user profile and applies it during the following sessions, adjusting it accordingly. Its User Model and its User Model Builder rely on rather simplistic user attribute stereotypes, but more universal than in the Monstrat Model, I3R demonstrates an advance into mixed-initiative dialogue with a nice Explain function, relevant support in IR situations, as well as several IR techniques, relevant use of which is inferred by the actual user and request model building.

The implemented IR techniques are partial match, i.e. probability and clustering techniques, as well as exact match Boolean logic. The two former techniques are mixed according to the UGOAL and KNOW knowledge. For example, precision-oriented searching by a subject specialist will infer clustering, since it provides slightly higher precision than probability. If in recall-oriented mode, the two techniques will be combined, since they give slightly different results for the same query (Chapter 4.4.2). Search outcome is ranked and a query may be modified after user validation of the results.

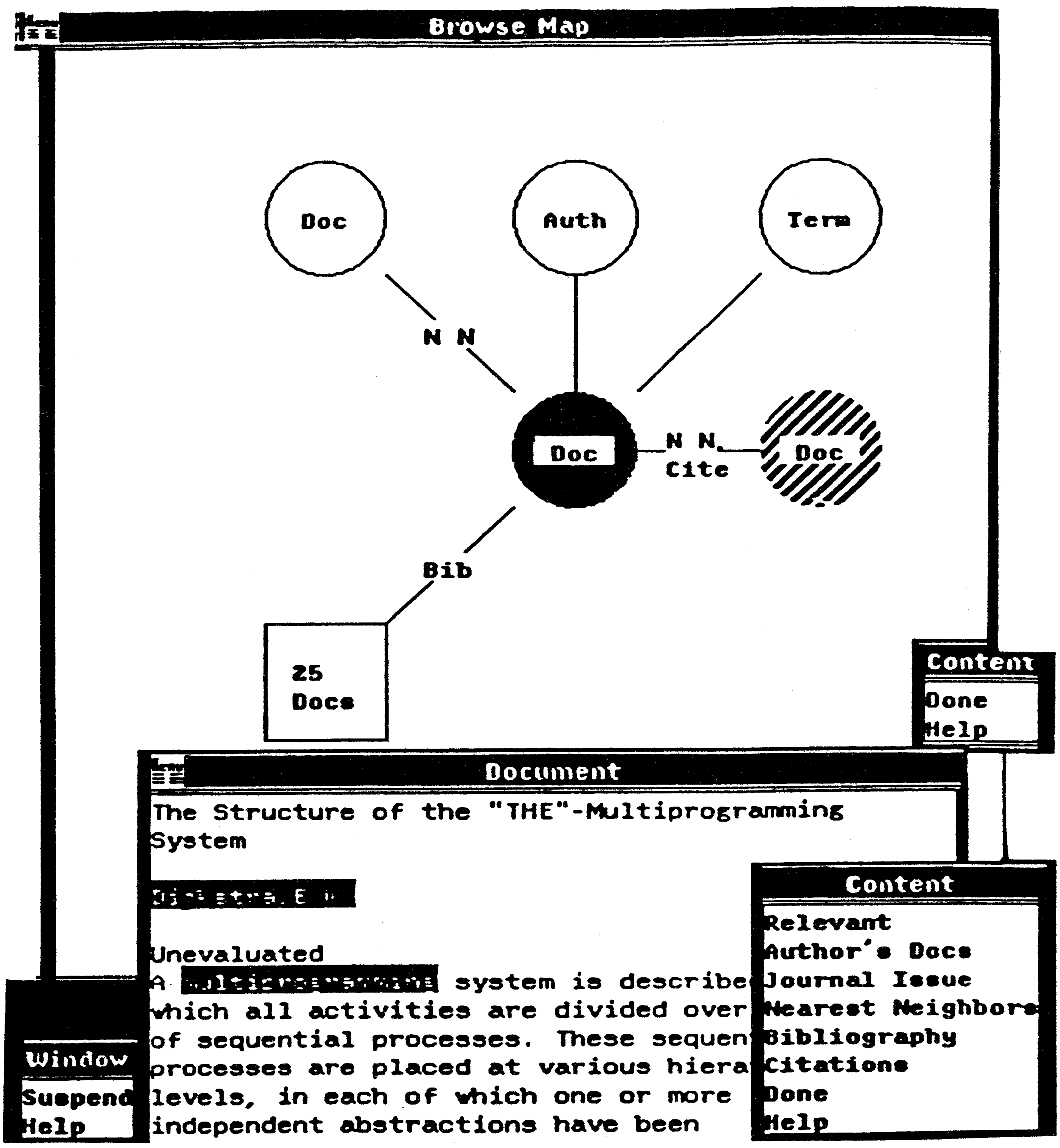

Fig. 7.3. I3R. Strategies in *information space*, starting from a retrieved document. (Private communication, W.B. Croft, June, 1987).

Hence, by applying the stand-alone system approach, I3R may take advantage of the partial match techniques, which per se are inherent in the intermediary's IR Process knowledge. Its IR System Setting knowledge is the contained database. I3R may therefore serve as a testbed for the combination of two powerful and advanced IR techniques and intermediary functionality, far beyond the laboratory test-beds applied in traditional IR research. A similar standalone intermediary system called CODER (Fox, 1987) is directly intended to try out a large variety of IR techniques as well as actual user model building. However, none of the two systems are based on empirical field studies.

An interesting supportive feature, Browsing, is displayed in Figure 7.3. It constitutes the *information space* in I3R, which can be applied by the user in order to navigate to a different strategy, e.g. 'nearest neighbor citation clustering' (N N Cite) – with a document just retrieved as starting point (document in lowest window). This feature is conceptually related to the screen picture in the Bookhouse (Chapter 7.1.2), which provides options for selection of search strategies.

The Plexus system (Vickery, Brooks and Vickery, 1986) is concerned with the gardening domain, in a multi-type user environment. The system is intended to handle referral to institutions and human experts as well as literature searching tasks within the domain. Certain field studies took place prior to the design, namely knowledge acquisition from information specialist in relation to IR procedures and search interviewing. Its domain and task model is generated analytically and mirrors the possibilities in the IR systems linked up to Plexus. Plexus' conceptual map represents concepts in the domain, organized in a semantic network of 11 facets with pointers to generic classes from the BSO system (Broad System of Ordering). At present, it holds a very general model of potential users. Actual user model building takes place in the form of a 'pre-search' interview concerned with the user's knowledge of Plexus, on gardening as well as modes of previous provision of information in the domain. The modelling controls mode of system response and internal retrieval rules. Plexus has been evaluated by S. Wade et al. (1988) against statistically-based (partial match) techniques, demonstrating that the best results were obtained by using terms suggested by Plexus as the basis for statistical retrieval.

Because of the faceted structures in the conceptual map in Plexus, NL requests may in future be processed to a syntactic level providing space for further research into additional advanced retrieval techniques applied to this design case.

7.1.2 Non-inferential IR design supporting user expertise – the Bookhouse

In this design case *the user model building* ability does not exist, i.e. that no interviewing and 'perception of user' takes place. This design requires a robust implicit, long-term user and domain model in order for the user to *recognize* his *own* behavioural characteristics, preferences and the IR systems' 'information space' within the intermediary. The design must make *transparent* tasks typical for the domain and associated search strategies, preferred by users. Further, it includes conceptual maps and structures. This design holds the potential to be extended with actual user model building features – if required. The idea behind these designs is quite different from the assumptions underlying the previous ones. It attempts to *support* users by relying on vast knowledge of their seeking behaviour and preferences, extracted from profound field studies of the domain, and does *not* strive at simulating human intermediary performance explicitly, e.g. by applying NL processing and smart inference.

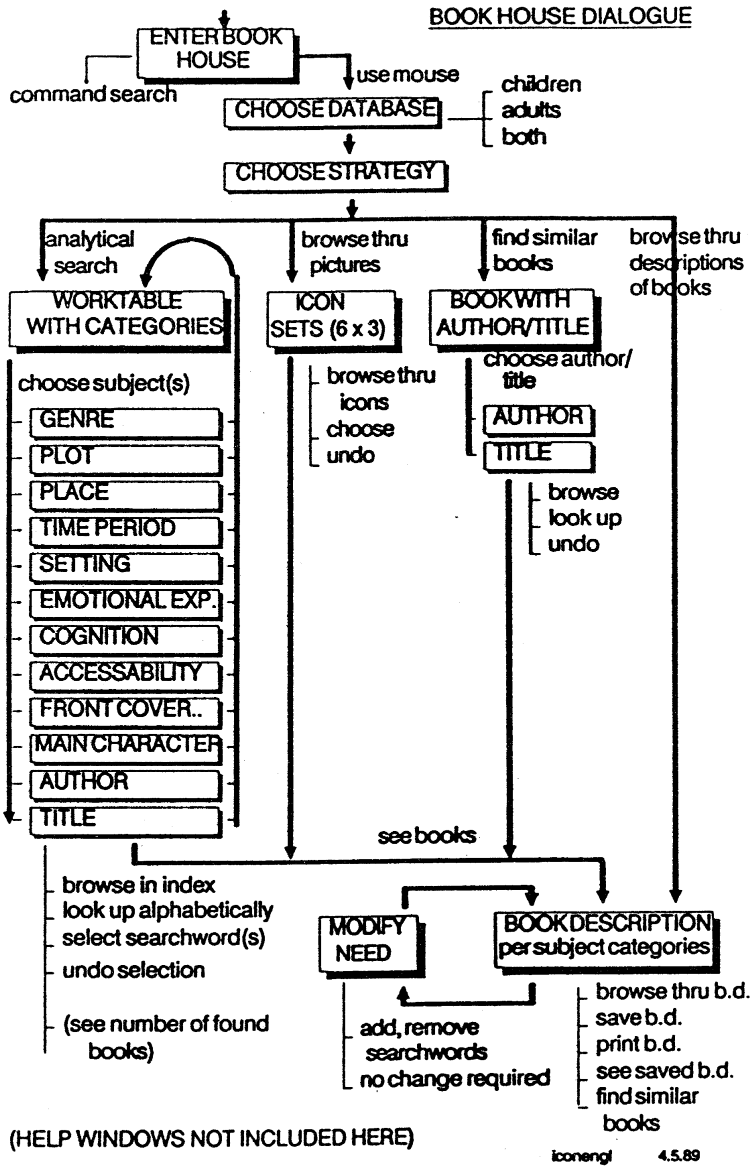

Fig. 7.4. The user-driven dialogue structure and information space in the Bookhouse (Goodstein and Mark Pejtersen, 1989, p. 63).

The 'Bookhouse' prototype (Mark Pejtersen, 1989) is a relevant example of this intermediary type. Figure 7.4 shows its dialogue diagramatically. As mentioned in Chapter 5.3.4, the system is based on highly detailed field-studies of entire IR situations concerned with *fiction retrieval*, providing emotional experiences. It contains approx. 3000 references to adult and childrens' books, all indexed according to *user preferences*, including 'author intention'. As such, it may be regarded a stand-alone system, since IR Process and Setting knowledge is under control by the system itself. However, the Bookhouse refers to 3 domains and their different tasks and preferences. Figure 7.4 demonstrates the sequential dialogue form, from the starting point downwards (Goodstein and Mark Pejtersen, 1989).

A picture of 'Rooms' is used as a metaphor for database selection purposes by the user. When into the selected 'room', the user is shown his four (preferred) strategical possibilities (the information space) in the form of a picture containing four thematic situations. When into a specific strategy, other strategies can be selected by option. It is possible to retrieve novels by topic, by means of 'analytic search' or 'icon-based' searching. Each icon represents several related topics, with terms associated from the controlled index terms. Icons are deliberately chosen by the designer in order to make explicit to the user a conceptual map, consisting of a great amount of *semantic values.* The map of icons can be browsed and the intention is to rely on *the user's* imagination and expectations. The meanings of the various icons have been tested to avoid too much semantic ambiguity. Unfortunately, at present, it is not possible to combine icons with one another, because of the small amount of stored items.

The 'find similar books' strategy equals the topical citation pearl searching described in Chapter 6.2.5, starting from a retrieved book. By means of a *partial match* algorithm the system retrieves the most similar books, i.e. via a ranking function based on different weighting of keywords in specific 'topical' categories in the book descriptions, i.e. time, plot, setting and cognition.

The Bookhouse is implemented on standard Macntosh and MS-DOS PCs using inverted file structures, basically applying Boolean logic. The response time equals those observed in standard commercial IR systems. Because of its multi-dimensionality to users and its open information space, some regard it as a hypertext expert IR system, which it is not. It is a true knowledge and rule-based non-inferential IR support system which, based on its implemented knowledge of user tasks, preferences and behaviour, explicitly makes use of people's *own* cognitive structures, matching problem space with information space.

Because of the implicit case-frame structure in the Bookhouse's topical categories, NL requests may in future be processed at a more structural level providing space for further research into more advanced retrieval techniques applied to this design case.

One reason for extending it with some capability of actual user model building would be to verify, and possibly adjust, its long-term user model during use.

7.1.3 Knowledge-based IR assistance design – KIRA

This intermediary type is slightly less complex than the previous ones, by functioning with neither a user model nor actual user model building. Several prototypes and operational intermediary systems belong to this category. They are either aimed at supporting retrieval from one or from many *remote* IR systems, in general (hitherto) only based on exact match IR. Since no user modelling nor user model features exist, this intermediary type is not capable of interviewing the user about the request. At a maximum, it may relate the request terms to its conceptual map in order to validate them before searching. So far, no domain and task model have been implemented in the designs. Typical examples are the KIRA system (Schmeltz Pedersen et al., 1988), the Tome Searcher, an extract from the Plexus Model, and the Cansearch system by S. Pollit (1986). Both Tome Searcher and KIRA (Knowledge-based Information Retrieval Assistant) operate on solid knowledge-bases containing IR Process (and Setting) knowledge, and including extended thesaurii. In Tome, the knowledge-base is a black box, while KIRA allows users to build their own dedicated conceptual maps in the form of semantic networks. Tome allows for NL input which is processed in a pseudo-parser, stripping off stopwords and using surface structure grammar (prepositions) to define AND and OR combinations.

KIRA (Esprit project 1117) is intended to operate in a Boolean environment, supporting both CCL and SQL command languages automatically. Hence, it is suitable for in-house office and IR systems. Menus are user-instigated. Its knowledge-base consists of elicited IR expert rules for searching major online hosts in CCL. Its most powerful feature, aside from the user-based conceptual map, is its ability *automatically* to generate Boolean search strings directed toward the relevant data fields in linked-up databases. The inference rules implemented to perform this facility are based on A. Motro's work on construction of queries from tokens (1986). When a user enters search terms in a 'topical search mode' (as opposite to the verificative 'document search mode'), they are validated by the semantic map. *Only* validated terms and phrases, or terms picked by the user directly from the map are allowed for further processing. Motro's rule works on the distances between concepts in the network, which also includes database subject descriptors linked to host names as 'objects'. The shortest 'road' to a database and host is chosen, i.e. KIRA may perform auto-database selection. In addition, selected terms remote from one another in the network, or close but related in the form of non-generic cases, are ANDed. This is based on arbitrary values added to the various cases or roles. Generic (or part-whole) relations including synonyms have values that make them ORed. Since several concepts in the network may have sub and super-generic terms linked, the algorithm will, in the first of the (often several) suggested Boolean search strings, take that one in which only sub-generic terms are ORed to the selected term, in order to maintain precision.

KIRA was intended to be expanded with the ability to download a number of references to be processed by the Extended Boolean Logic technique (Chapter 4.4.1), in order to *rank* the search output. This feature, however, was never implemented.

KIRA is among the very few prototype IR systems which actually select databases and carry out Boolean searching automatically. Consequently, it is very suitable for end-users without real online IR experiences. Among problems still to be solved are that it must be maintained by an IR expert, in order to enter and link bases and hosts properly to the conceptual network.

CanSearch (Pollit, 1986) is more narrow in scope, supporting medical experts in retrieving textual information on cancer from Medline. Its conceptual map makes use of the cancer-specific concepts represented in the database's controlled vocabulary (MeSh). Via knowledge of domain specific, logical and conceptual preferences built into its rules, the user is guided to the (most) relevant part of the base.

Design following the principles of case 3 is interesting. It holds the potentiality for processing NL requests via its semantic network up to a syntactic level, as in the cases 1 and 2.

7.1.4 Supportive user model building design – Euromath

This design case essentially makes the intermediary into a 'generalist'. No conceptual map is contained in this mechanism and it requires a solid state of IR knowledge and a user model. The intermediary may interview users about preferences and background knowledge in addition to the request formulation, and interrogate the IR system(s). Because of lack of a conceptual map, it has to rely on an optimal use of the conceptual structues inherent in the underlying IR systems' 'information space'; for instance, by presenting *conceptual system feedback* tailored to the actual user via actual user model building. This design cannot understand the meaning of the user request, e.g. made in NL, and must rely on form-based input. However, if functioning in a partial match environment, it may apply NL formulations in single terms for retrieval. If only in possession of a simple domain and task model of the users, this design is not adequate in a multi-task and complex work domain, e.g. in an office environment. Similar to the designs in Chapters 7.1.2–7.1.3, it would tend to assist or support users in IR – but in a more tailored fashion. The intermediary design by Ingwersen at present under implementation in the Danish Parliament as an interface to the parliament's information system, is a very simplistic version of this kind of design, but is based on task analysis and contains a synonym domain thesaurus.

The Euromath work station design model (McAlpine and Ingwersen, 1989) is a typical solution. Euromath's domain, task and user preferences are outlined in Chapter 6.1.2, exemplifying personal knowledge states influencing intermediary design. An overview of the sequence of windows related to user modelling and retrieval is shown as Figure 7.5. The adequate sequence is chosen after the user has picked his work task in the system. The tasks are local, e.g. word processing, shared, e.g. finding addresses of mathematical institutes, or remote, e.g. IR online searching.

In the present case 'remote searching via *Zentralblatt*' is selected from the transparent information space of the work station – in principle as in the Bookhouse, but without the use of metaphoric means.

Thus, Euromath does not infer or select which database or file for the user to access. All adequate IR sources are options, containing well-known academic names for reference tools in printed versions, e.g. '*Zentralblatt*'; not the name picked by the online host, i.e. Mathfile.

The facts about mathematicians' behaviour, actual state of knowledge and frequent information problems and uncertainty states, acquired via field analysis (Chapter 6.1.2), entail the implementation of actual user model building. Euromath ascertains the user's background knowledge in relation to the topic in question, his actual seeking preference, e.g. using 'saved searches', and his estimation of expected answers, all asked for on the 'Information Need form', Figure 7.5 (left) and shown in 7.6. In the present case the user has answered that he wants to search a 'topic' he says he knows 'precisely' (Figure 7.6). Also, he estimates the number of references to be between 10 and 30. His online IR experience he estimates as 'little'. The sequence is therefore 'topic' to 'Query form for a Topical Need'. If, however, he enters two or less topical terms on this form, as in Figure 7.7, the system infers that his background knowledge is 'vague' or muddled. (Had he entered three or more concepts, he would immediately proceed to 'Search', Figure 7.5).

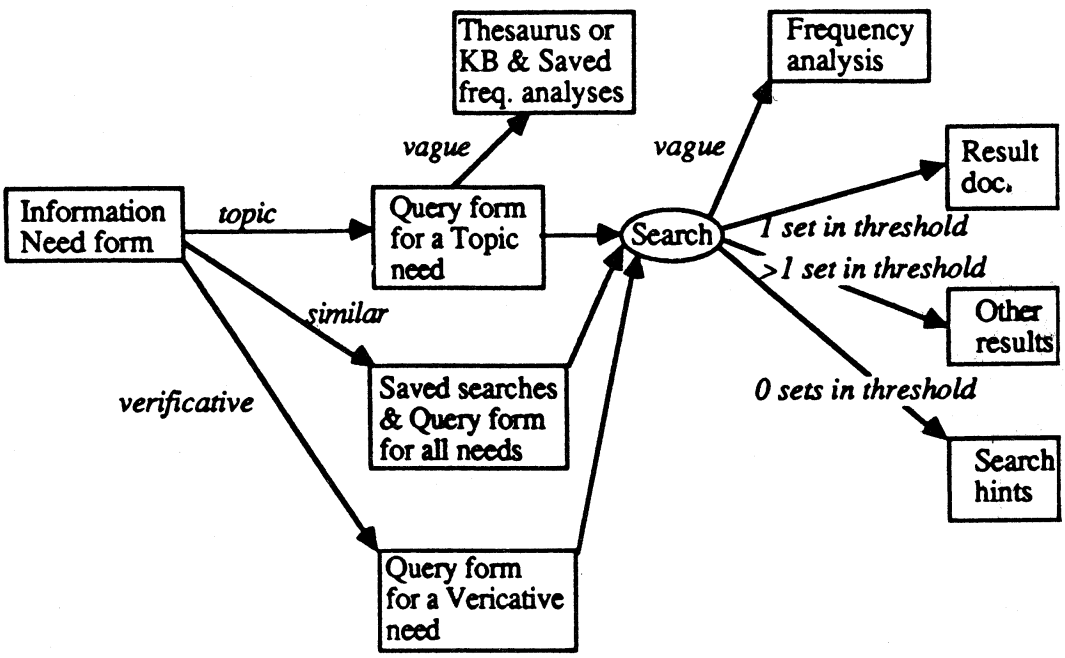

Fig. 7.5. Window sequences & options in Euromath. (McAlpine and Ingwersen, 1989, p. 54)

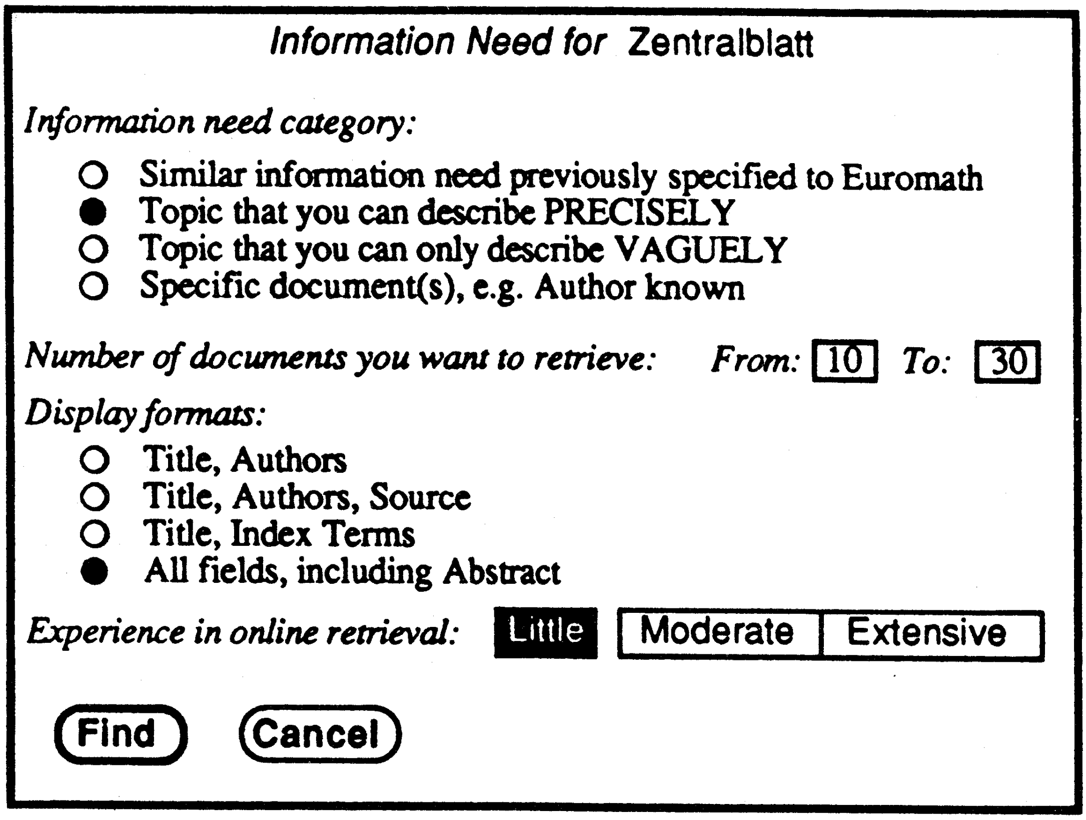

Fig. 7.6. 'Information need form', Euromath.
(Ibid, p. 53)

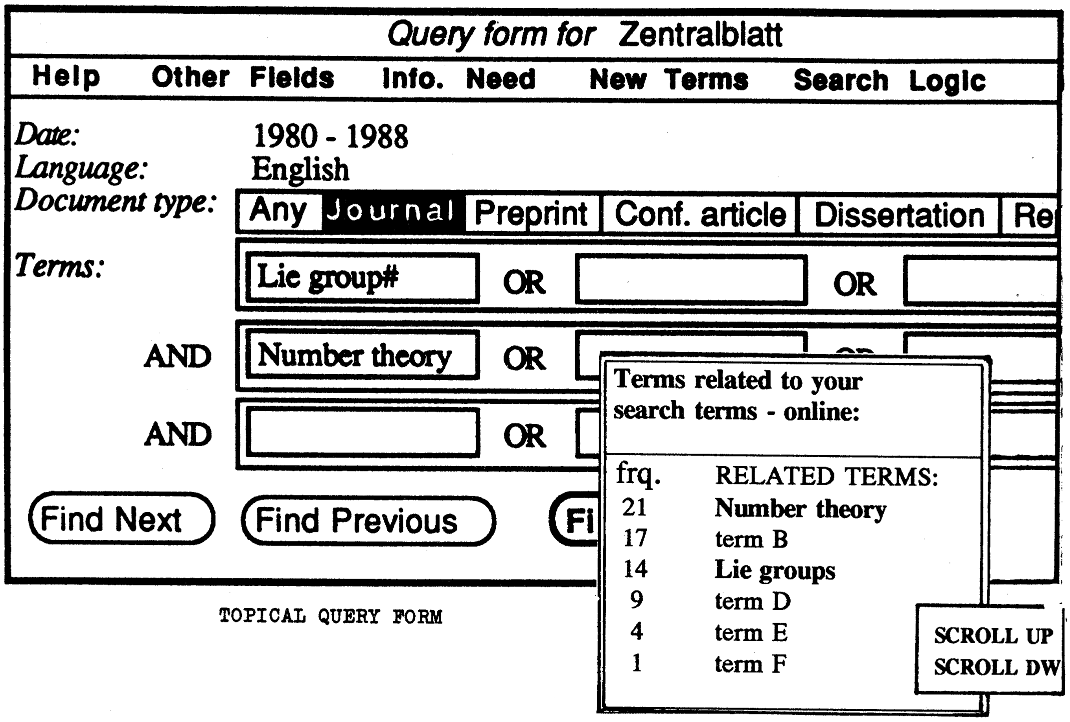

Fig. 7.7. Query form for a topical need, Euromath. Auto-frequency analysis of index terms related to (Lie groups AND Number theory) in remote dbs shown in right-low window.

Since the two core mathematical indexes both operate with 'frequency analysis' of index terms in retrieved sets (i.e. indexer aboutness) these features can be inferred by the special user model condition 'vague'. Euromath very simply sends the appropriate command, letting the remote mainframe software do the analysis (Figure 7.7, right-hand corner, small window). The resulting frequency list of indexing terms may hence be seen as a structure of mixed categorial and situational relations to the entered search statement (see Chapter 7.3.1 for further examples). No thesaurii exist in the remote databases, implying that later, if necessary, Euromath might be improved by implementing a local conceptual map (in box with Thesaurus or KB, Figure 7.5). As an alternative, the individual user may choose to look through those saved term frequency lists of his that contain the actual search term(s) in use, via the option 'New terms' (Figure 7.7). Both features may support his actual state of knowledge by provoking/triggering associations in his work space and cognitive model.

Euromath's actual user model building capability is based on another approach than the I3R system above. The *user himself* picks that retrieval mode appropriate for him (Figure 7.6), which determines the mode of system response back to the user during the session. For each search Euromath asks about the actual background knowledge, only providing two options, and not always trusting the answer. In Euromath this rather simplistic actual user model building is used to infer the degree and *nature of conceptual support* for each search session. In contrast, I3R applies user model building to infer the IR technique and the number of search runs to be applied. Both designs use mixed-initiative dialogue.

Both KIRA and Euromath display automatically generated Boolean search strings, which no human intermediary in general is able to generate because of their complexity and multitude. The Euromath design model ought to be improved concerning display forms, and most certainly with respect to search algorithms. The latter might be enhanced by introducing quorum search logic between terms and a better ranking of retrieved sets of references.

7.1.5 'Intelligent' user model building design – IR-NLI

This design only lacks a User Model, but contains a User Model building feature which hence is based on knowledge of domains and tasks. This implies an *adaptable* intermediary mechanism, holding 'meta' intermediary knowledge of how to build up long and short-term user models. At the same time as supporting an actual user, it ought to supervise him and infer from his behaviour which preferences he, and other users with identical tasks, may display.

A way of approaching this adaption issue is suggested by G. Brajnik, G. Guida, and C. Tasso (1987). They propose a model called IR-NLI which consists of skeleton frames stored in a stereotype base, containing two basic sets of frames: 1) 'User Profile', and 2) 'User Knowledge'. Previous searches may be stored. Without explicit mention of it, the stereotypes and the frames presuppose a degree of Domain knowledge and IR Setting & Process knowledge.

The *'User Profile'* frame consists of features like 'educational field' and 'academic degree', 'professional background', 'IR background, experience & activity', as well as 'personal traits' such as communication attitude = cooperative; and 'usual search requirements', e.g. domain = computer science, with objectives = precision. These *general* data on individual status are then supplied with *general* information on *'User Knowledge'* with respect to 'subject domains', e.g. domain = computer science, with coverage = high; 'databases', e.g. File = Inspec; and 'IR systems', e.g. host = Dialog, use = medium.

One may observe that these frames adhere from the Monstrat model's User Model tasks KNOW, IRS and USER (Chapter 5.4.1), in a somewhat interesting blend. While the Monstrat tasks are supposed to be applied in actual user model building, IR-NLI intends to use the tasks to create a dynamic, long-term model of each user through user model building. In reality, IR-NLI relies on a 'pre-search' interview with an actual but unknown user to assess individual 'profile' and 'broad subject knowledge', in order to "tune the user-system dialogue in future sessions [by using] knowledge in the slots 'IR background & activity' to tailor the level and content of system-generated utterances to each individual user.. .. [and] completing the current problem representation using information extracted from 'usual search requirements' [which] provides defaults that can be used when more specific values are missing [in actual session]" (p. 314).

One may have several objections to this type of adaptive user model building, generating *implicit* user models.

First, the gathered information about each user is of such a *general nature* that one may seriously doubt its usefulness when a user is going to search. For instance, to know that a user holds a PhD in computer science, does not help if the user asks about something on the borderline of his field, not to speak of searching a topic outside his computer science speciality. Obviously, it should be the *actual subject knowledge,* related to the actual information need, which the intermediary should ask for. And when it knows this (see e.g. I3R), the general knowledge is useless.

Secondly, the useful portions of personality data could be gathered much easily at the *event of searching* and then be stored for future use, as done by I3R or Euromath. The only useful long-term data are those concerned with 'IR background & activity', at the time of interviewing the user. Quite correctly, as the authors state, this kind of information may tailor the dialogue. Later, one must assume that the user obviously gets used to IR-NLI. At that time a threshold in the intermediary should simply infer an update of this IRS information.

Thirdly, advanced 'intelligent' user model building in general is supposed to go hand in hand with some sort of advanced, automatic retrieval, suggested by the intermediary mechanism – not the user. Hence, there is no need for knowing that the user is familiar with Dialog command language syntax, and in general adheres to Inspec. Naturally it should be the intermediary which inferred this and *other relevant* IR sources during actual sessions. If, by all means, this auto user model building intermediary is intended to support the user in searching, not retrieving anything by itself, one might simply have provided database options for the user to choose from. If he is knowledgeable in IR he is also able himself to select properly.

Fourth, an interesting question in relation to IR-NLI's model is: how should the intermediary mechanism act when confronted with a user holding a PhD in computer science, but his preferred domain is Biology? A human intermediary would infer, if asking that sort of question at all, that he knows about both. This can be used or suppressed depending on what the user really asked for.

This *is* an interesting design combination for IR *research purposes* in particular, and machine learning in general, which requires a very solid knowledge of the domain(s) and tasks in question, presumably made by field studies. With the knowledge of *tasks* as a platform, one may envisage a design *also* containing a Case 1 mechanism, which can be used as a research scenario for trying out various models for teaching intermediaries to model users. The behaviour, preferences and knowledge used, caused by the tasks, may then be measured against the user model already inherent in the Case 1 system. One might here imagine the application of neural networks in the 'User Model' component (Figure 7.1).

7.1.6 Inferential design supporting the search process – OAKDEC

This design case is the most simplistic intermediary mechanism, only consisting of the three core (and conditional) knowledge types.

The first basic condition mentioned, that a design must always hold System Setting structures, does not mean that *all* adequate structures must be present. It is sufficient if the mechanism may know where and how to interrogate IR systems, to obtain information on e.g. searchable fields and codes, or how to access term nets *inherent* in a remote database. The prerequisites are that the designer holds a detailed model of, for instance, access to external database structures, command language(s) and help functions in hosts. Furthermore, this functionality requires consistency in the host's data organisation, which is rarely the case in most US vendor systems. In addition, he must possess a model of how intermediaries and users may apply those IR systems. The inferential rules are applied to control the 'IR processes'. This design is fundamentally a supportive system, traditionally not regarded attractive for research purposes, since it looks so very 'non-intelligent' and unadvanced. For instance, this design case may not utilize NL request representations and no user model building exists. One may state that its potentiality has never been fully explored.

The most elegant example of this type of intermediary mechanism is OAKDEC by C.T. Meadow (1988), a follow up to his IIDA system (1982). The system provides engineers and scientists with access to a variety of online databases on various US hosts on energy matters.

Like Euromath it applies form-based menus and restricts the number of searchable fields to those primarily applied in online searching. OAKDEC is intended to support the user in his *IR problem solving process*, i.e. to guide the actual user in his own online searching activity by presenting recommendations of 'objectives' to be (possibly) performed next – not system functions. This means that the system attempts to understand the procedural problems in the actual user's IR process, making him capable of revising query formulation and review database and search options. As such, it can be regarded a *'procedural IR expert system'*. Its 'Intententionality and expectation' knowledge, its set of rules and parameters in the knowledge base, consists of IR process rules and search conditions. Its information store holds its knowledge of IR System Settings. Later, it is intended to save both previous searches and related user behaviour, e.g. in terms of responses to procedural advice, in order to make internal and external analyses for building up a general User Model. This is an interesting approach to self-model building, although at present it seems to be concerned with user seeking behaviour, based on the IR system model only – not domain tasks. Meadow's method seems sound. One of the major design principles is "the primacy of the user in decision making. The fact is that the user has a great deal of knowledge of the problem and decision making capability" (p. 451).

EasyNet and the IANI systems, both capable of accessing several online hosts by automatic translation of different command languages into one, and abilities to support the user's Boolean combinations, are also examples of this case, but of a much more simplistic stature.

7.1.7 Meta-characteristics of intermediary designs

The general pattern of designs in Figure 7.1 can be summarized by two observations:

a) a clear distinction between design cases incorporating *user model building*, with various degrees of automatisation, inference and search assistance, and cases providing a variety of *user support* only.

b) a conceivable differentiation in the *nature of NL processing* possibilities between the design cases in relation to understanding requests.

Concerning a), we have either intermediary systems *performing* user model building based on a user model, which in addition may support users in their own seeking behaviour, e.g. I3R and Euromath. IR-NLI can only be seen as a future development. Or we have intermediary systems characterized by *not performing* user model building, and thus acting as assistants, guides and *supporting* mechanisms, e.g. the Bookhouse, KIRA and OAKDEC.

The first group is system-driven to a certain point (= the pre-search stage) then continuing in a mixed-initiative dialogue, relying on inference facilities that automatically are supposed to retrieve relevant information to the actual user, according to an interpretation of him and his information need situation. It aspires to simulate some of a human intermediary's functionalities and, in particular within narrow domains, it tends to act as an IR expert system (I3R and Plexus).

In the second group, OAKDEC is mainly user-driven. The Bookhouse and the KIRA designs attempt to facilitate the actual user's own retrieval processes, by providing *transparency* of the intermediary itself and of relevant parts of the 'information space' in the underlying IR systems. The transparency may, however, be seen as 'indirect questions' of the type: 'is it this that you want, or this or this or ... that? or 'has what you just said (entered) something to do with x,y,z,p,...n? Thus, mixed-initiative dialogue can be said to occur often is these two cases.

Hence, the object for discussion is the degree to which the design supports users' own retrieval and interpretations, *balanced* against the intermediary carrying out 'intelligent' inference by user and request model building. This issue is dealt with in Chapters 7.2 and 7.3 below.

Concerning b), we touch upon the reasons for and nature of *NL request representation* and further processing. Theoretically the four cases 1–3 and 5 may all process NL requests to a certain degree, depending on the quality of their 'conceptual maps'. Apart from case 5, only case 1 designs may *attempt* to 'understand' (the meaning of) requests, because of the combination of conceptual map *and* user model building; the latter asset being the means to making the user encircle his problem space and state of knowledge. This is one of the purposes for 'intelligent IR' research.

The design cases 2 and 3 may indeed accept NL input and process it to a degree via their conceptual maps. If the Euromath design, case 4, receives NL input it may only be further processed in the form of single independent terms, because of lack of a conceptual map. However, these designs will have to concede to a high amount of *uncertainty* in the resulting request interpretations. Chapter 7.4 below summarizes the author's reservation concerning full NL understanding in IR.

7.2 'Intelligent' user model building vs supportive mechanisms in IR

In order to provide a framework for understanding this issue in more detail, the systems discussed above, as well as previously in Chapters 4 and 5, are seen in relation to the IR system domains in which IR research has produced results in the form of intermediary designs and prototypes. Figure 7.8 consists of a matrix, which horizontally is divided into intermediary systems that model users *and* provide support, and systems that give support only. In addition, each group is categorized into whether the actually used IR technique is partial or exact match. This division is carried out to explore to what degree IR research applies experience from the traditional R&D approach (partial match techniques) as well as from the user-oriented approach (user model and request building). Vertically, the division is according to the IR environment the intermediary in the design is intended to apply, in order to observe the degree of complexity in the IR domain, and thus implicitly, in the domain and task modelling. Other divisions might also have been carried out, for instance as demonstrated by Bates, who emphasizes the degree of inference functionalities in interface designs (1990).

Leading up to the user model building and support issue, one may observe two characteristic aspects of the IR R&D landscape concerned with intermediary design (Figure 7.8):

1. The amount of 'white spots', i.e. the *concentration* of research;
2. Dimensions of possible information management interest (industry) in IR research;

In relation to *point 1* the research concentrates on 'stand-alone systems', row 1, and on 'Multiple IR systems in remote hosts', row 4. A third concentration can be seen in column D, ranging from dedicated, unitary systems to more complex IR environments, box 4D. The empty row 5 is associated with research on networks of intermediary mechanisms and their adaption to one another. If various hosts or companies install knowledge-based front-ends (sometimes also called 'back-ends'), local intermediary mechanisms may be regarded as 'users' with the usual problems of building up models of the remote gateways, for instance in order to select the adequate one(s) in the actual IR situation. So far, this research issue has long-term perspectives.

Research on stand-alone systems takes place in all the possible *combinations* of model building and use of matching techniques, row 1, and is in general regarded as the area for 'intelligent IR' research, since the systems are capable of dealing with NL requests in some way. Research in the boxes 1A+B in particular is often seen as the *spearhead* development area, involving advanced, partial match techniques and expert system architectures. This may be a superficial observation indeed, since the stand-alone approach is confined to non-complex IR situations. For instance, no attempts have been made so far to extend research downwards in the rows A and C – towards more realistic IR system combinations, e.g. by combining several exact and partial match IR systems under one umbrella, possible in row 2. Database selection problems and adaption to more than one system and one narrow domain are not taken into account.

The author prefers to see the stand-alone systems research as a *test-bed area*, trying out specific functionalities in dedicated, domain specific systems, in future to be applied in other more complex designs. Within the cognitive research approach to IR, one may see most of the designs (and their goals) in row 1 as belonging to that category of long-term IR research which most faithfully continues the traditional research approach.

Another cluster of systems is found in box 4D, the research area for intermediary design connected to operational exact match IR systems. By means of various knowledge-based techniques, these systems attempt to cope with rather complex IR situations, involving a variety of differently implemented, remote knowledge structures. This research area displays rather *applied research* characteristics. They may provide very useful results as to retrieval support and database selection problems in the fields represented by the boxes 4A–C.

In the author's opinion however, the *most interesting and advanced* design fields in the displayed research landscape are placed in rows 2 and 4. In these fields research must encounter high complexity of domains, multi-work tasks, several different IR systems, both local and remote, and, in particular, severe user model building and retrieval support issues. A challenge lies in the boxes 2A and 2B, by combining different IR techniques in several *local IR systems*. Simarly, the boxes 2C and 2D are interesting, since they build up to solutions in row 4. The boxes 4A–C contain the highest degree of *challenge*, since these fields incorporate the highest complexity, most support problems, and the most realistic future IR environments.

LOCAL intermediary ↓	A User modelling + support Partial match	B User modelling + support Exact match	C Support Partial match	D Support Exact match
+ one IR system in Local UNITARY System 1	I3R **Coder**	I3R IR-NL Coder **PLEXUS**	**THOMAS** (1) **GRANT** (2)	**Chen & Dahr** (3) **SIMPR** (4)
+ MULTIPLE Local IR Systems 2			**BOOKHOUSE**	**BOOKHOUSE**
+ one IR system in REMOTE host 3				**CANSEARCH** TOME SEARCHER
+ MULTIPLE IR systems in REMOTE host(s) and Local 4		**EUROMATH**		**KIRA** **TOME** **SEARCHER** **OAKDEC;** **IANI; EASYNET**
+ MULTIPLE IR systems, REMOTE with intermediary frontend at host 5				

(1): Oddy, 1977 - Chapter 3; (2): Cohen & Kjeldsen, 1987 - Chapter 4.3.4; (3): Chen and Dhar, 1990 - Chapter 5.5; (4): Smeaton, Voutilainen, Sheridan, 1990 - Chapter 7.5

I3R: minor purpose **I3R: major purpose**

Fig. 7.8. The IR research landscape. Selected intermediary designs and prototypes.

This *realistic* aspect touches upon the *information management* issue in *point 2* above. The interest from industry, that is, the solution to problems concerned with office automation environments and their text (and multimedia) management and retrieval, will be increased when IR research moves into the various fields in the rows 2 and 4.

Aside from box 4D, at present only three of the boxes in the interesting part of the landscape contain attempts to meet these challenges: Euromath and the Bookhouse, both in exact match environments. The Bookhouse, existing as a well-tested prototype (Goodstein and Mark Pejtersen, 1989) is the most interesting design. Euromath is a design suggestion only. The Bookhouse, because of its transparency and supportive nature based on profound field studies, can be seen as the typical *alternative approach* to intermediary design, in strong opposition to the research views and expert system solutions expressed in the boxes 1A+B. Slightly less complete (Figure 7.1), both KIRA and OAKDEC belong to a similar 'supportive' intermediary design approach. One may also notice the number of supportive designs in column D, dealing solely with exact match problems.

Euromath is neither as complete as the Bookhouse nor as the systems in boxes 1A+B, by not containing any conceptual map facility, but attempting to make use of *conceptual feedback* from remote IR systems, making these structures transparent to the user. Although it provides a simple, but robust user model building facility, Euromath's principles for user support are in line with those behind the Bookhouse, KIRA and OAKDEC, namely to ease the user's *own* decision-making related to the IR processes and use of conceptual structures during searching.

Hence, the *user model building issue* is fundamentally a question of its *purpose* and *method to apply* during modelling. The question of *purpose* directly involves interpretations of the user-oriented research results (Chapter 5), and the cognitive view expressed in Chapter 2.

7.2.1 The purposes of user model building

1. If we recognize that *tasks* in a work domain give cause to problems which may be solved by information seeking behaviour, we must define those tasks in a given domain and obviously get a general idea of how users, having that task, prefer to obtain information, i.e. knowledge of *preferences and seeking behaviour* (Chapter 6.3.4 and Figure 6.7). Field studies and cognitive task analysis may supply user answers to these questions, producing some kind of a *user model*.

2. If we recognize that the users within a domain are grouped in different categories according to *actual level* of *conceptual state of knowledge* when going to search, we may want to assess this level at search time. The reason being that we may supply *conceptual support,* according to the nature of user's actual knowledge state. This problem of users' conceptual levels goes hand in hand with Taylor's (1968) 'compromised need' situation, Belkin, Oddy and Brooks' (1982) well-and ill-defined problems, and Ingwersen's (1982, 1986) so-called 'label effect' in requests.

3. Also related to user knowledge is the question of *IR knowledge levels*. Here, the issue is to define the appropriate mode of *intermediary response* in the actual

communication process. A secondary goal may be to assess which *search mode* the actual user may wish to, or should, apply.

The *one alternative* is the '*support only*' approach to intermediary design, provided most strongly by Mark Pejtersen (1989) in the Bookhouse and by Meadow (1988) in OAKDEC:

It is more effective to support users in making decisions than to try to decide for them.

or in other words:

> The intermediary mechanism selects or provides *conceptual* and *procedural support* during the session, *according to task, preference and seeking behaviour* (strategy) chosen by the actual user, in order to let him proceed following a self-determined search strategy.

This approach relies on strong implicit user models from which the actual user selects his task and search preference which are *transparent* to the individual user, who may then decide upon the further line of action. One might say that the actual user model building is carried out by the *user himself*, and that the intermediary's knowledge-base (or 'intelligence') is used to monitor, provide support and alternative routes, as well as 'smart' retrieval. The latter could for instance imply use of partial match techniques in specific strategies when chosen, e.g. in similarity searching, citation pearl growing (the Bookhouse), etc. – according to how the user proceeds.

The supportive approach implies that all users are treated equally regardless of knowledge level, i.e. that the intermediary is adapted to average or lowest-level user knowledge category, or contains an alternative communication language, as in the Bookhouse case, which provides an iconic and metaphoric language. In the case of the GRANT system (Cohen and Kjeldsen, 1987), box 1C, 'spreading activation' techniques are used by users and system to produce retrieval outcome. No User and Request Model Building take place. Thus, the supportive approach does not take into account the points 2 and 3 above on *actual* user levels of conceptual and IR knowledge. No inference can be performed as to these two user characteristics, only in relation to tasks and preferences (point 1 above).

The other alternative is the '*intelligent IR*' approach to intermediary design, put forward by for example Vickery, Brooks and Vickery (1987), Sparck Jones (1987) and Croft (1987):

The most effective approach is to make the system decide and execute retrieval, inferred by explicit user and request model building.

or in other words:

> The intermediary mechanism selects or provides *search strategy* (seeking behaviour), *according to actual user model building characteristics* and request

interviewing, established *prior to* strategic choice, in order to infer relevant information.

This research attitude differs from the previous one by a strong belief in simulating substantial functions of the human intermediary, e.g. skills in relation to communication, user model building, request understanding, etc. via some subset of NL. More modestly, the Euromath design approach uses menu options and forms for user model building.

Aside from the NL issue, dealt with in Chapter 7.4 below, the basic problem in this 'intelligent' approach to IR is associated with the *lack of task and preference modelling* of the domain, point 1 above. Hitherto, there seem to be little relationship between tasks to be performed and search preferences in the design models, box 1A+B. The questions posed in user model building adhere from the possibilities given by implemented IR techniques and the structures in the 'conceptual map'.

Without doubt, the 'stand-alone' systems design approach obfuscates task modelling to a certain extent, although Plexus demonstrates certain user preferences in its user model building component. Similarly, in this author's opinion, as an obvious consequence of the stand-alone approach, it does not make space for research on intermediary *adaption* to unknown IR systems, i.e. actual IR system model building. Interestingly enough, this IR task is constantly carried out by human intermediaries, but of course more rarely in those narrow academic domains which often supply the scenario for 'intelligent IR' research.

With a substantial task and preference model in hand, the user model building could be *concentrated* (limited) *to actual background knowledge* in the given IR situation, point 2 and 3 above. The proceeding inference would be less problematic or uncertain, since the user might be able to decide for himself – as in the supportive approach above or in Euromath.

Without a substantial task, preference and behavioural model of the users, the intermediary is forced to ask relatively many questions during a 'pre-search' stage related to user status and knowledge, as done in IR-NLI, before ariving at the essential object: the actual information need. The futility of this kind of general user model building has been discussed in Chapter 7.1.5.

Another general point in relation to the 'first model building – then inference' mode in intelligent IR is the presupposition that user concepts simply are provided *per se* during question-answering by knowledgeable users. This view relates to a belief in IR expert system solutions. These solutions are attractive, because the main features of expert systems, associated with rule-based representation of expert knowledge and flexibility of control via blackboard architectures, may be directly applied to IR (Croft, 1987). The I3R, Plexus and IR-NLI systems previously described are recent examples of this kind. As the author sees the the present IR research situation, there exist a danger of falling into the 'cognitivistic' trap, i.e. to begin to believe that the inference mechanism may actually provide all the necessary 'knowledge' or information processing for successful retrieval, based on expert system-like question-answering during model building.

This cognitivistic AI solution is a dead-end for IR, and one may view this research position as a left-over from the traditional research approach.

From a cognitive point of view the intermediary mechanism cannot infer more or more deeply than told to. Therefore, 'user and request model building', based on a leaky 'user & request model', cannot infer better or 'smarter' strategies and retrieval than allowed by these models. But, when in possession of solid models, the user on his cognitive level, with *adequate supplementary information*, may infer even better himself.

The problematic or paradoxal situation arises when the user possesses weak knowledge structures in relation to his need. The user's answers contain insuffient information for modelling the user or need:

> *The participants in the* ('pre-search') *interview cannot talk themselves out of a unsolvable problem: **Lack of shared knowledge**.*

It is exactly in the weak positions that users require intermediary support.

7.3 The supportive user model building approach

The Monstrat Model, based on the limited 'pre-search' research setting (Chapters 5.4.1–5.4.2), is fundamentally related to the 'intelligent IR' position. In addition to the model's actual KNOW, IRS, and UGOAL tasks, Monstrat's User Model displays several functionalities of a *general* nature that are less applicable in a *current* IR situation, e.g. user status, his general position in the domain, his formal education, etc.

In contrast, Taylor (1968), Ingwersen (1982, 1986) and others advocate the necessity of obtaining information on the present user's *actual* conceptual and IR knowledge as well as his current experience with the intermediary, and his actual task and preferences (Chapters 5.3 and 6.2.4). Knowledge of user status and formal educational background is in general rather uninteresting, superfluous and unusable for inferring anything reasonable by an intermediary in an actual situation. What is important may be the user's actual work task, e.g. as researcher, not that he is professor of Chemistry. Such general functionalities supply only marginal information.

There seems consequently to evolve a third more unifying cognitive and qualitative approach to 'knowledge-based IR' and the degree of user model building and support in intermediary design. From a cognitive point of view, the *most intelligent component* in IR interaction *is* the *user*, regardless his conceivable lack of knowledge in his problem space at a given moment. The best way to apply this highly intelligent component is to provide him with *conceptual support* as fast as possible in the IR situation. Not immediately to provide him with *the* relevant information eventually, but in order to *let him* provide the intermediary with *additional, possibly relevant* *contexts*. This method is based on the findings by Ingwersen (1982, p. 183–186) (Chapter 5.3.1), and called 'open search mode'. In the 'pre-search' experimental settings such supportive activities could not take place because of the non-involvement of IR systems, i.e. actual searching, in the experimental setting. Conceptual *feedback* and support never became an important issue.

User model building and request interviewing thus play a more modest and tailored role prior to, or at the same time as retrieval activity, than hitherto believed in 'intelligent IR'. The author therefore proposes a *Supportive User Model Building* approach, which is intended to:

a) obtain actual level of conceptual knowledge as to information need, to *infer the nature of conceptual support* from 'information space', i.e. from remote IR systems, conceptual map(s) or knowledge-base;

b) obtain actual levels of IR competence, to *infer mode of response* and explanation to user, i.e. to ease effective mutual adaption and communication;

c) obtain *request* formulations, to spot where in the conceptual information space support (and information) may be found;

d) obtain *additional context(s)* from the user on his problem, interest or goal *and* information need from his problem space and his state of knowledge – to *support* him conceptually if necessary by *tailored feedback* or transparent *options*;

e) obtain relationships between tasks, preferences and seeking behaviour as well as *actual* use of preferences, behaviour (strategies) and concepts, by monitoring the user's IR problem solving, in order to adjust the implicit individual and general user model.

This 'supportive user model building' approach makes use of the intermediary mechanism's knowledge-base and rules in a very interactive way which, at a modest level, in addition simulates the human intermediary in order to *stimulate* the user – as simplisticly demonstrated in certain facilities in the I3R and Euromath designs, eventually combined with the Bookhouse' and OAKDEC's supportive features.

It presupposes most certainly an *established user model* and model building of actual knowledge as well as solid *domain and system* models. Interestingly enough, this approach seem to be somewhat in line with S. Bødker's 'human activity approach' to user interface design (1989) as well as P. Bøgh Andersen's notion of 'user friendliness' (1990). Bødker advocates the views by Winograd and Flores (1986), borrowed from Heidegger, that "the human activity approach considers situations in which we act through operations without conscious planning and execution as the normal state of human activity, .. *thrownness*. Situations wherein we need to plan and act according to plans and to conscious evaluation of the situation are exceptions; they are called *breakdown situations*" (p. 174). Bødker continues this hermeneutic view by contrasting the more cognitive view that man's mode of execution of states is through seven steps (perception, interpretation, evaluation, goals, intention, action specification or remembering, and execution (Norman and Lindsay, 1977)). However, this systematic step-by-step model seems adequate when associated with novice or casual users' mental behaviour, merely possessing 'surface knowledge' of, for instance, a system or an interface. With 'deep knowledge' of a system, the execution becomes less conscious (Hollnagel, 1987, p. 40), as in the 'car-driving case' (Chapter 2.4).

Similar to Bødker's activity approach is the typical situation giving *cause to IR*, namely a 'breakdown' in the state of knowledge and problem space, leading to a state of uncertainty. Hence, when the user accesses the 'supportive user model building' intermediary, proposed above, he is faced with "a repertoire of actions and operations .. evolving continuously" (Bødker, 1989, p. 174). This repertoire, that is, the *conceptual support and feedback option*s, is intended to provide the user with ideas and curiosity, a user friendliness which makes 'thrownness' possible.

This Supportive User Modelling principle underlies the consolidated framework for intermediary functions, the Mediator Model, outlined in Chapter 8.

7.3.1 The role of feedback from IR systems

According to Figure 6.7 two basic types of system feedback exist: Conceptual feedback; and IR System Setting feedback. With reference to Ingwersen (1984a, p. 481–490) one may point to several *conceptual* feedback possibilities inherent in advanced operational online host systems. Aside from semi-automatic cross-file search features (Questindex, Dialindex), which may support intermediary mechanisms' database selection process, attention is focussed on the term *frequency analysis* feature Zoom on ESA/IRS. Belkin and Croft (1987) suggest that this and similar facilities must be considered general feedback features that may function in connection with all partial as well as exact match IR techniques.

Fundamentally, Zoom is implemented as a software dedicated to all the loaded databases on ESA/IRS, i.e. it requires a consistent field code protocol in order to function properly.

Its functionality is rather simple. In all the databases, a specific number of fields can be analysed, such as the author, title, index term and keyword, corporate source, journal name and abstract fields. It works on the linear file versions of the databases converted into the ESA-Quest (ESA software) file format. When a searcher selects a set of references on, say, 'micro computer(s)' in the Inspec file, this set can then be zoomed for frequency analysis of the contents of one (or several) of the fields mentioned, Figure 7.9.

At present two versions exist: Zoom and SuperZoom. Zoom may analyse up to 200 items while SuperZoom may analyse up to 20,000 references, and is consequently a charged service.

The frequency analysis is done by sorting alphabetically all phrases or single terms (optional) in the required field. Identical terms are extracted and calculated, and the resulting list is ranked according to decreasing frequency. In the case of Zoom on index term phrases, the idea is that the *preferred index term* in the set obtains the highest ranking, i.e. 'microcomputers' on Figure 7.9. This implies that it is possible to enter a phrase in NL and *switch to* the relevant index term automatically. In the case of a more complicated search profile one may see the most frequent *domain aspects* related to (in co-occurrence with) the profile ranked highly and the more specific aspects in the subject area ranked in lower positions.

```
                                   Text Analysis Results
Frq    Words/Phrases           Frq    Words/Phrases
-----  --------------------    -----  -------------------
   12  MICROCOMPUTERS              2  DATA ACQUISITION
    6  COMPUTERISED                2  DATA STRUCTURES
         INSTRUMENTATION           2  DECISION SUPPORT
    6  MICROCOMPUTER                    SYSTEMS
         APPLICATIONS              2  DIGITAL SIMULATION
    3  COMPUTER                    2  ELECTROENCEPHALOGRA
         ARCHITECTURE                   PHY
    3  MICRO COMPUTER              2  EXPERT SYSTEMS
    3  MICRO-COMPUTERS             2  MECHANICAL
    3  MICROCOMPUTER                    ENGINEERING
         CONTROL                        COMPUTING
    2  ACCOUNTING                  2  MEDICAL COMPUTING
    2  ADMINISTRATIVE              2  MINICOMPUTERS
         DATA PROCESSING           2  OCEANOGRAPHIC
    2  ALGORITHM                        TECHNIQUES
    2  COMPUTER SELECTION          2  OPERATING SYSTEMS
         AND EVALUATION                 (COMPUTERS)
```

Figure 7.9. Zoom on index terms, Inspec, March 1991. Search terms: *FIND MICRO COMPUTER?* Number of references analysed: 50 randomly out of 1193 refs.

One may notice that the zoom frequency list (Figure 7.9), may be generated to represent the *tf* values for each index term phrase in a given set. The zoom analysis must then be carried out on all references in the set, i.e. all 1193 refs, Figure 7.9. The relative *tf* value for a term $T = tf/I$, where I is the total number of index terms in the set. A set is here regarded as a 'document'. Since the complete frequency list is in the grasp (downloaded) of the intermediary, as is the *idf* value for the term *T*, simply by retrieval of the *T* (Chapter 4.3.4), the *tf x idf* values for terms in a given set can be assessed. A zoom-list can be regarded a conceptual 'star' cluster, related to the original search term, e.g. Micro Computer(s), and sets of such clusters may hence easily be weighted and ranked against one another. This is a simple method, since it does not imply download of references, only of the frequency list. In addition, selected terms from the lists must be retrieved to assess their idf values, for instance by introducing a threshold value which only allows selection of the first five to ten concepts on the list (= the major conceptual aspects of the original term).

Further, documents *within a set* can be ranked according to the same zoom technique: for each single document above a given threshold within a given set, generated via a search profile consisting of several concepts, one may zoom each document to produce a frequency lists of single terms, e.g. from the abstract and title fields or from title and index term fields. The *tf x idf* values per original term in each document can then be assessed and a kind of *Extended Boolean Logic* be applied in Vector Space (Chapter 4.4.1).

However, this retrieval technique, based on conceptual feedback, will naturally suffer from deficiences similar to those of exact (and partial) match methods: it will not be capable of reaching directly into the Dark Matter in information space. Notwithstanding, the zoom frequency list itself may provide new conceptual associations on the part of the user – whereby some of the hidden information space may be attained.

In addition to its potentiality as a relevance tool and as a conceptual structure providing ideas and associations to users (and indexers), Zoom may be used for *fact retrieval* and *forecasting*.

Fact retrieval can be done, for instance, in relation to author names, research profiles of known scholars, and core journals or research institutions in a confined subject domain. The facility hence may explore the bibliographical online databases in innovative ways.

Forecasting is carried out by zooming on selected broader domains in a database, divided into relevant time periods. By following the decrease and increase of frequencies for the various index terms as well as their ranking number on the lists, one may obtain patterns of subject areas indicating the degree of interest, for example in selected countries. Further it is possible to draw attention to research output within a specific science, e.g. Chemistry, in a specific country in quantitative terms (Ingwersen and Wormell, 1990).

It is evident that this conceptual feedback feature, as well as other inventions by advanced online hosts, ought to be used in 'Supportive User and Request Model Building' intermediary mechanisms, as suggested in the previous chapter. When, for instance, some request *terms are not recognized* by the mechanism, because its conceptual map is too small or not up-to-date conceptually, such a feature may serve to open up the user's own state of knowledge and problem space. Also, by storing and *indexing* such frequency lists, as carried out in Euromath, the intermediary mechanism may extend its own vocabulary. Naturally, a Zoom list is not a semantic structure in line with case-frames or thesaurii. However, there exists always a semantic relation between the original search profile and the zoomed outcome. Its capacity for fact retrieval may make it a valuable tool for certain work tasks in a domain, e.g. to obtain lists of localities doing similar research and development work to one's own institution.

In relation to Zoom the author may point to *effective combinations* of frequency analysis and the use of online thesaurii, as suggested by Ingwersen and Wormell (1986), leading directly to the HYPERLINE online facility on ESA-IRS.

Of other valuable inventions, basically provided by European online hosts, are the Quorum searching facility combined with frequency analysis on ESA/IRS and Fitz (Germany).

From the extensive empirical study at present carried out by Saracevic et al.(1989, 1990) we possess findings that definitively stress the importance of conceptual feedback, since precision ratios are dramatically increased by such features. One may note that the study only involves US hosts, implying that the number and quality of the feedback features are scarce.

There is hence no need of implementing such features locally, depending on *downloading* of records to be manipulated. In the author's opinion the features discussed in this chapter are all worth while considering when knowledge-based intermediary research initiates development work in complex domain and IR environments.

7.4 Knowledge-based adaptive IR interaction

Concerned with the issue of knowledge-based IR stated above, the interest is concentrated on the nature and composition of IR interaction, i.e. the parameters suggested for man-machine interaction which may promote communication, as well as the question of use of natural language in IR. One may view the mechanism's inference ability or 'intelligence' as the means to *adaption through model building and feedback, as well as to retrieval*.

Bennett (1972) advocates strongly the following factors as determining user interface design:

domain tasks, followed by
user attributes,
information (system) characteristics.

In addition, Ramsey and Grimes (1983) suggest the subsequent factors:

flexibility
initiative
interactive graphics
natural language dialogue

To these determinators Hollnagel adds:

adaptivity
credibility
intentionality
transparency

Domain tasks must not be confused with IR domain tasks, but adhere to the work domain in the user's environment, and the individual work tasks in the user's work space (Chapter 6.1.2). User attributes refer to a user model and user model building. Information characteristics, as well as (IR) system characteristics, are concerned with the information space. From this point of view, only the design cases 1, 2 and 4 (I3R, the Bookhouse, Euromath), in Figure 7.1, fully incorporate Bennett's parameters, while KIRA does not hold user characteristics and IR-NLI contains very general ones. Like OAKDEC, they lack a profound domain model.

Ramsey and Grimes propose the following dimensions as central to interface design: *Flexibility*, specified as applicability to a wide range of tasks, allowing multiple approaches to a given task and *multiple ways* of invoking the desired proceeding computer operation, adapting adequately to different user levels and groups, and allowing adaption of system behaviour based on user preferences (1983). Again, the task issue is stressed. Mainly I3R and the Bookhouse case design examples demonstrate the required capabilities concerned with flexibilty and multi-options during IR sessions. At present, Euromath only partially exhibits sufficiently flexible properties, basically because of lack of its own conceptual structures. One may here refer to the very recent suggestions by Turtle and Croft (1990) of applying multiple search modes and poly-representation in so-called plausible inference network-based retrieval (Chapter 7.5). This will influence the use of NL and meet the flexibility factor.

In addition, Ramsey and Grimes focus on *initiative, interactive graphics*, and *NL dialogue* as important dimensions. 'Initiative' is concerned with when to apply computer initiative, e.g. in the form of options, user-initiation, e.g. by means of command language, or mixed-initiative dialogue where both parties may instigate dialogue during communication. The functions in the user model serve as filtering mechanisms that may estimate the level of system experience associated with the type of initiative. The design cases exemplified by I3R, Plexus, Euromath, IR-NLI and the Bookhouse suit this parameter.

'Interactive graphics' and 'NL dialogue' are features thought of as central dimensions, which directly aim at I3R and Plexus in relation to natural language and the Bookhouse with respect to graphics, i.e. the use of procedural and conceptual icons and pictoral metaphors.

Hence, if we compare the various designs (Chapter 7.1), to the outlined design parameters, only three designs may survive as rather *complete*: I3R, Plexus and the Bookhouse (Chapters 7.1.1 and 7.1.2). In other words, the foremost sample types for the 'intelligent user model building' and the 'support only' IR design approaches are worthwhile elaborating on in future interactive IR designs.

In relation to *adaptivity*, Hollnagel's contribution on interactive issues (1987) follows up his views from (1979) and Hollnagel and Woods' (1983). The entire human-computer system should be considered an adaptive, cognitive system, where both parties interact with and idealistically adapt to one another. Both parties must have models of one another and of the whole situation.

Hollnagel demonstrates the cognitive view that in order to interact, each human participant must *share* some part of their environment, for instance work domain, work spaces or states of knowledge. Following Hollnagel, this implies models of one another that undoubtedly do not correspond to each party's model of itself. The parties must hence influence one another and the models involved. Besides requiring a common language or code and a shared understanding of essential parts of the environment, Hollnagel considers the requirements for the model building activity. He points to cognitive and affective *credibility and intentionality*. One of the important means to achieve credibility is, according to Hollnagel, to explain the structure of what is attempted to be communicated, and why. Thus, an 'explain function' is required, as also suggested by Belkin in connection to the Monstrat model (1988). This is called 'secondary communication', as opposed to 'primary communication', i.e. the consignment of the information. Intentionality also plays a part in secondary communication in that it seems important to transfer knowledge of *purpose* and *intention* between the parties about the engagement in the dialogue. This is gracefully carried out, for instance in the I3R design. One of the means to this end is to understand and model the users' problem solving and behavioural seeking patterns in work space.

From a hermeneutic view one may understand Hollnagel by replacing 'models' with 'horizons' and 'shared understanding' with 'shared pre-understanding'. However, Hollnagel goes slightly deeper into cognitive design factors than do for instance Winograd and Flores.

Related to *cognitive adaption* of computer and user to one another, Hollnagel's notion of *transparency* touches upon the degree to which the user possesses or may obtain understanding of the intermediary and the IR system(s). Aside from implicit transparency (via user-training), Hollnagel identifies transparency by explanation, e.g. either on demand by users or integrated during the IR process. Further, Hollnagel advocates the IR process itself as means to explanation, whereby the user by observing and performing IR may understand and model the retrieval functionalities. This latter mode of transparency is found to be the most perfect one (Hollnagel, 1987, p. 47–48). It may lead a user from a state of surface comprehension, over shallow into a state of deep-knowledge of the system. Hollnagel points out that the designer must have tight control of the system features (i.e. possess a detailed system model) and in-depth knowledge of the users' cognitive states and the work domain tasks, i.e. the designer must possess a solid user model and a specific domain model.

Examples of implemented designs meeting Hollnagel's recommandations are the *Bookhouse* and the *I3R* systems. However, only the *Bookhouse* fully holds in-depth knowledge of the users' states and tasks, as well as making the IR process itself explain to the user how it works. Further, because of their *transparency and graphical features*, that is, essentially in form of IR System Setting Feedback, both I3R and the Bookhouse may allow for faster adaption and credibility than, for example, Plexus or Tome Searcher.

If on the other hand there are too many unnecessary 'black boxes' in an intermediary, the user's *system model* may turn muddled and the system loses credibility. This may, in addition, create several *unforseen* problems in the intermediary mechanism's own 'problem space' – producing breakdown situations.

Hence, by having a model of the users's probable intentionality, strategies and other behavioural preferences in IR (see Figure 6.7), the intermediary mechanism may ease its own adaption to the actual user's problem space, increase its 'credibility' by making transparent its own information space and state of knowledge in a common code, *and* facilitate the user's adaption to the mechanism.

In relation to adaption, transparency and credibility, the *supportive user model building* approach to intermediary design, proposed in the previous chapter, is in line with Hollnagel's requirements. However, one may notice that the proposal is mainly concerned with the *conceptual supportive* and transparent aspects of cognitive adaption, and should be enhanced with transparency (feedback) of retrieval processing and system setting features.

7.4.1 Extending adaption to IR system features

Following the cognitive view outlined in Chapter 2, and underlined by Hollnagel, it is obvious that IR interaction contains other cognitive models than those of the intermediary mechanism and the user. The *implemented cognitive* structures in the IR system(s) underlying the intermediary also contain certain models of other participants and ought to be *adapted to by the intermediary* (Figure 6.7).

Sparck Jones, when discussing the relationships between AI and IR, in particular regarding Integrated Information Management Systems (IIMS), stresses this problem, (1989, p. 3):

> .. the greater variety and nature of the needs arising in a system of this sort [IIMS] mean that it has to have a knowledge base not only, or even primarily, to answer questions directly; .. it has to have a knowledge base with its inference mechanism to serve as an internal intermediary matching appropriate resources to different functional requirements. We will not, that is, get the necessary integration [in IIMS] without a proper characterisation of the system's *world*, for its own use in responding to the user *in relation to its various resources* [emphasis by this author].

This issue of knowledge-based adaption has in general *not* been dealt with in 'intelligent IR' research, since the developed stand-alone systems themselves contain the information resources in question, making adaption rather superfluous.

However, common to all the design cases in the boxes placed in rows (4) and (5), (i.e. mainly column D, Figure 7.8), is that *none* of the systems provide for the intermediary *adapting to* and learning about databases, hitherto *unknown*, for example within one and same online host. A related issue is that no design, with the execption of Euromath and Cansearch, really makes profound *use* of the extra mainframe *facilities inherent* in, for example, European host systems.

With respect to the latter issue, two predominant reasons exist.

First, many intermediary designs, but not all, are made in the US online environment – the most primitive in the world with respect to 'extras'. In Dialog there is nothing to go for in relation to 'smart' host facilities, except some online thesaurii. In contrast, European hosts, for instance ESA/IRS in Italy and Fitz in Germany, contain 'advanced' facilities, such as semi-automatic database selection online, frequency analysis of author names, index terms, and special data types in pre-selected sets of references (Chapter 7.3.1).

These and other host facilities should be made use of, in particular to increase *flexibility*. Instead of reinventing similar features locally, it might be more effective to exploit the powerful mainframe softwares at hand.

Typical examples are Tome Searcher and KIRA which, although linked up to ESA/IRS, do not utilize the zoom frequency analysis facility, for instance in order to support users conceptually, who enter terms not recognized by the intermediaries' own (and superficial) conceptual maps.

A second reason for not implementing the use of such *conceptual feedback* and other features is not of a theoretical, but very often of an economical nature. The designs rely on accessing and closing the sessions fast, to save search time costs. The designers do not wish the system to stay online-connected, e.g. during periods of thinking by users. Since several of the designs and prototypes have been created, the major European host (ESA/IRS) has changed its pricing policy, from 1989 charging for each *opening* of session and per printed and downloaded item of information, not search time. US researchers may connect to this host via Internet. (In the USA the hosts continue the traditional charging policy). For future IR research and designs on the European scene, this may indeed imply more flexible and supportive intermediary models in exact match environments, which take advantage of host features in an inexpensive way.

Future partial match dependent intermediaries, for example as placed in row 4, Figure 7.8 above, may hence be even more multi-functional than demonstrated hitherto.

With respect to the *adaption* capability and IR system modelling issues, the same reasons may apply. In addition, one of the problems is said to be the inconsistency in the machine-readable host files. However, the level of inconsistency ought to be minor, confronted with the problems in user request and NL processing. Again, the European hosts in general display a higher level of quality than applies on other continents.

7.4.2 Natural language in IR interaction

The NL issue in IR research reaches back to the problems of (text) representation (Chapter 4.3), and is related to AI research on NL processing, in particular with respect to stored potential information and user requests.

As early as 1980 L.C. Smith outlines the variety of possibilities offered by AI research to IR, a discussion taken up by the same author with special emphasis on human factors (1986). Smith describes the goal of NL processing in IR by stressing two roles: providing an easily learned interface to information systems and automatically structuring texts so that information can be more easily processed and retrieved. However, she also points out that "NL systems cannot yet, and perhaps never will be able to handle truly unrestricted natural language" (1986, p. 101).

This is exactly the point in question: should IR deal with 'truly unrestricted natural language'? Is it mandatory *fully to understand* the user and the meaning of texts (and other multimedia materials) in IR systems in order to perform retrieval?

These issues are important in AI fields such as language understanding and translation and in expert system research, but, as questioned in Chapter 2.1, does IR concern itself with translating requests and texts?

In her in-depth review of 'intelligent IR' Brooks states (1987, p. 376–377):

> In the case of an intelligent IR system, the nearest analogous systems are *advisory expert systems* (Coombs and Alty, 1983), of which there are very few. In addition, an analogy might also be made with expert systems designed for highly complex, multifunction problem solving tasks....A fundamental component of the [intelligent] system's role is essentially an advisory one, an aspect that has long been recognized in human "retrievers". The *user's contribution* to the retrieval process is *central*, and its key importance suggests the need for the system to cooperate with the user (and vice-versa) for the process to be successful – hence, the emphasis on the human-computer interface. Concomitant with the requirement to cooperate with the user is the need for the system to be *transparent*, that is, the need for the user to understand the workings and/or other components of the system.
>
> An intelligent (IR) system will need to communicate with its users in *natural language*. Using natural language as the principal means of user-system communication (rather than yes/no questions or menus) has the advantage of user convenience, flexibility, and expressive power....An information retrieval system, even if it were limited to a relatively narrow domain, would still need to employ an extensive vocabulary. Further, the "*understanding*" of the user and his/her problem and the "understanding" of the linguistically based documents and document descriptions that are essential to the system's functioning *require natural language understanding capabilities*. The NL interface should be able to handle ill-formed input; structure discourse; take into account the user's goals, plans, and beliefs; and support mixed-initiative dialogue.

One may take Brooks' outline as a description of the long-term goals for knowledge-based IR research, or rather, goals for a particular 'intelligent IR' research field in specific domains that does not move away from box 1A into more complex fields (Figure 7.8). In parallel however, one may observe the advisory role, the cooperative properties and the need for transparency which are in line with the 'adaptive and supportive' approach discussed above.

However, the author does not agree with the role of natural language in this scenario.

First of all, IR systems and intermediary mechanisms or interfaces cannot 'understand' – and will never come to understand, user requests and documents – if by 'understanding' we mean fully to understand, that is, getting the *exact meaning* implied by a user or stated by an author. This is not feasible following the cognitive view, but evidently hoped for in 'cognitivism'. There is no way to overcome this NL problem in mechanisms. Interestingly enough, human intermediaries often cannot either 'understand' the meaning of what is in the texts and what the user really means. From the pre-search interview investigations in even learned environments, on which the 'intelligent IR' field also is based, we know this can be the case (Brooks and Belkin, 1983). Naturally, this is more often the case in broad domains with different users (Ingwersen, 1982).

Very recently, Sparck Jones touches upon the problem of NL and how to apply AI techniques (1989). In line with the author, but on purely logical grounds not based on a cognitive view, Sparck Jones rejects the 'Strong AI' approach, taking a more moderate (weak AI) stand. She recommends IR research *not* to view information retrieval as question-answering. This is seen as a fundamental misconception because it is based on a wrong general model of IR, since question-answering presupposes "an amount of *definitiveness* in the perception and characterization of user need, and of document content, which is just not there. In the typical case, rather than non-typical case, the user has not got a need which can be couched, except formalistically and therefore trivially" (p. 6–7).

In other words, Sparck Jones warns against the idea of applying question-answering methods from AI (and expert system) research, because of the nature of *substantial uncertainty* in IR situations, and hence, the futility of acquiring 'meaning' where such a property seldom exists. This principle in IR was already put forward by van Rijsbergen in 1979 and stressed in (1986, p. 194): "It has never been assumed that a retrieval system should attempt to 'understand' the content of a document".

Hence, it is fruitless to attempt to make an intermediary capable of restructuring or "handling ill-formed input" in NL, or by NL input really to 'understand' a user's goals, plans and beliefs (which in many cases are uncertain).

As stated in Chapter 2.1, IR is concerned with information *beyond* meaning. IR does not require a translation 'expert' as part of an IR system. Aside from requiring an immense knowledge-base even in a restricted domain, the principle of translating requests and texts into meaning goes against the entire issue of *aboutness*, crucial in IR (Chapter 3). Because if an intermediary mechanism translates a request it will be on the premises of its knowledge-base, which either is implemented by another individual, mirroring *his* conceptual structures, goals, etc., or it is acquired by some rules via NL processing of texts and/or user statements. Consequently, the translated meaning will tend to be any other meaning than that of the actual user.

We may see a rather vicious circle explicitly outlined by Croft in his overview of problems related to 'intelligent IR' and AI applications (1987, p. 252–253):

– *The acquisition of domain knowledge from users and/or document texts*. This means to use NL processing to build knowledge bases. In the long term, [this] acquisition will be essential in the dynamic IR environment;
– *The level of domain knowledge that is required for effective IR*. We do not know if it is essential to have detailed knowledge of the specific domain of the documents or if similar results can be obtained using more general knowledge.
– *The amount of domain knowledge required for effective NLP.* Current systems make use of thesaurus knowledge, and general dictionaries can be made available online. In the IR situation, however, many documents will contain words that will *not* be in either of these categories. It is not clear how much these unknown words will affect the NLP required for IR.

– *The level of document content representation appropriate for document retrieval.* It has *not* been established that a representation based on the *meaning* of the document text (using case-frames, for example) is superior (from an IR perspective) to a representation that simply identifies such features as important word stems and noun groups (say).

By reading the first three statements it becomes apparent that IR ought to build domain knowledge acquired via NLP. Notwithstanding, we do not know how detailed this knowledge should be for effective IR. And we do not know the amount necessary for doing NLP effectively, in order to build a knowledge-base which is essential to dynamic IR.

What then can we use natural language for in IR? We can use it to provide intermediary mechanisms, IR systems and the actual user with *contexts* – which with a degree of certainty associate with a user's problem space and actual state of knowledge.

In this respect the essential point is Croft's last one. The NLP techniques for, say, morpho and syntactic analysis, may be applied in order to *identify semantic values* in context. For an outline of attempts at a more contextual and cognitive IR theory, one is referred to Chapter 7.5 below.

Brooks summarizes the overall research goals, issues and fundamentals to be addressed, as far as the development of an adequate human-computer interface for an 'intelligent IR' system is concerned. The needs are (Brooks, 1987, p. 377):

1. to cope with different users.
2. for the interface to be robust.
3. for the system to permit mixed-initiative interaction.
4. to communicate with the user in natural language (and not a highly restricted subset of it).

The author agrees with the points made by Brooks. However, the fourth need is seen in the light of the modest use of NL, expressed above. In addition, one may refer to Chapters 5 and 6 for a discussion of the fundamental roles and performance tasks of the intermediary. One may therefore add the subsequent major goals and needs to the list of Brooks:

5. to cope (know and adapt) with different domains and IR systems.
6. to permit conceptual and procedural support, also from remote IR systems.
7. to allow for dynamic modifications of search strategies and tactics.
8. to provide contextual potential information, not knowledge.
9. to learn from retrieval mistakes.
10. to permit modification of pre-established user models, connecting tasks and preferences with actual behaviour.

The *conclusion* is that by moving toward more heterogeneous IR system settings and complex domains, intermediary design *necessarily becomes adaptive* in a true sense, in order to perform retrieval effectively. By applying its knowledge-based features to learn about both users *and* IR resources in information space, exploiting the user's valuable mental assets and the advanced software facilities in IR systems, the intermediary's 'cognitive model' becomes enriched for the key purpose of retrieving information.

This adaptive framework for IR interaction is in harmony with the 'supportive user model building' approach, previously proposed by the author.

7.5 Towards a contextual IR theory?

Based on an adaptive and supportive approach we have attempted to discuss various ways of exploiting representations inherent in texts combined with other representative means and advanced host features providing contextual support to users, for example as suggested by Ingwersen and Wormell (1986, 1988). Also under influence of the cognitive view, both authors have discussed the dedicated application of major partial match techniques in relation to types of information needs, in order to supply users in future in-house IR landscapes with improved retrieval methods (1989). The basic principle is the notion of *contextualisation*, i.e. the *third stage* in De Mey's evolutionary understanding of information processing (1977) (Chapter 2.1).

The need for this contextual support emerges from the empirical findings (Chapter 5.3), and Luria's investigations (Chapter 6.1.1), where *situational contexts* in particular play an important role for human intermediaries to grasp a user's information need through conversation. Reversed, users seem to be able to redefine their information need and modify/refine request statements via contextual conceptual and structured feedback.

In common to these contributions are the assumptions that user and request model building may be improved if initial, tailored conceptual support in context is provided, applying *several dedicated means of representation* and IR techniques, supplied with other more transverse feedback features, such as Zoom. During the user's request modifications the intermediary mechanism may apply its ability of inference to suggest elements of information from information space.

In the shape of adaptivity and supportive user and request model building, one attempts to unify *adequate* research results from traditional and user-oriented IR research. Although this principle seems promising for future IR and intermediary design, two fundamental problems remain to be discussed:

1. The issue of *concept interpretation*, not complete text understanding, causes the main trouble in representation, both within IR systems and for the actual user, as pointed out by Sparck Jones (1979).

2. More recently, van Rijsbergen has raised the relevant question of 'uncertainty' as an approach to IR (1986).

The discussion of the two issues may lead directly to an IR theory currently under development. From a cognitive view this emerging theory, and the concurrent IR techniques, can be seen as a *contextual IR theory*, taking into account the *uncertainty* inherent in IR interaction.

Very recently, a similar view is reflected by Sparck Jones concerning a relevant application of NL in IR (1989, p. 9):

> We have three sources of *uncertainty*, namely imprecise need, indirect access [to IR systems and texts], and inconsistent expression [of texts]. What is the best way of supporting information management in the integrated system [IIMS]?
>
> The only place to start here is from ordinary natural language, because this is in fact our successful public means of communication. The issue then is how to offset the effects of inconsistency of expression on indirect access to information, given imprecise needs. We [IR] can only succeed here by working through *redundancy*: *different ways* of referring to the *same concept* and of linking different concepts. We should think therefore of having an access structure in the form of a network thrown over the underlying information objects.

Also in relation to concept interpretation and representation, Blair provides an alternative to the use of language in IR (1990). Some overlapping exists between Sparck Jones' proposals, the cognitive approach to IR as outlined previously, and Blair's ideas based on Wittgenstein's later philosophy.

Although Blair often seems to equalize 'document retrieval' and 'information retrieval', nevertheless he introduces a useful *contextual* approach for the discussion of some central problems in IR: those of language and meaning. Blair states:

> Any theory of document representation, and, by consequence, any theory of IR, must be based on a clear theory of language and meaning. In this work, traditional mentalistic, behaviouristic and representational theories of language are rejected in favor of an "ordinary language" or implementational view of meaning as developed in Wittgenstein's late philosophy. Such a view has important consequences for IR. Specifically, the *indeterminacy* observed in document representation will not be remedied by training indexers better, or developing new classification schemes, or devising new retrieval algorithms (though these techniques may offer marginal improvements) because this indeterminacy results in large part from the *use of document representations in linguistically unorthodox ways*.
>
> To be more successful, document representation must be used in ways similar to the ways ordinary language is used. Since most ordinary language is learned by demonstration rather than definition, and such demonstration requires *immediate feedback*, IR systems must be built to facilitate the process of *adaptive communication* which typifies ordinary language usage.
>
> IR systems should not only be highly interactive, but "learnable"; and since the theory of language developed here claims that meaning in language can only be understood by looking at the activities in which it is used, the use of document representations must be similarly grounded in *the activities* in which IR is embedded and serves. Consequently, to understand IR, we must work to understand these activities better, and we must also relate document representations to these underlying activities by *expanding the usage of contextual information* to represent documents (Blair, 1990, p. VII–VIII) [emphasis by the author].

Both Sparck Jones and Blair recognize the *unorthodox* (uncertain) ways in which representations are *used*. Further, Blair identifies feedback and adaptivity as necessary instruments in IR.

Clearly, Blair rejects what is called 'mentalistic' (semiotic) theory, as well as more behavioural semiotic theory building, which maintain an unavoidable dichotomy between expression and contents. Instead of asking "what does an expression mean/signify?", he points to the question: "how is an expression used?" (1990. p. 136). In other words, Blair suggests avoiding abstract or objectively defined meanings of expressions. Instead he points to the *pragmatic* position of making use of and investigating the *actual usage of language* in relation to *activities*. This standpoint implies the use of pragmatic contexts, e.g. pointing to the *work tasks and preferences*, in a cognitive sense, in which users actually apply concepts (and language). This view involves the expectations (intentionality and pre-suppositions) of the inquirer of information.

To the author, Blair's position is very similar to that of hermeneutics by Gadamer and the position taken by the cognitive viewpoint on these issues (Chapter 2.4). The similarities as to the concepts of meaning and interpretation are illustrated by the Mark Twain Painting Case (Chapter 2.1). However, two significant differences exist between Blair's use of Wittgenstein's late philosophy and the cognitive view applied to IR: 1) Blair does not seem to consider the role and function of 'information' – neither in IR as different from 'meaning', nor in a wider and more general sense; 2) with Wittgenstein's expression "the disease of thinking", Blair rejects mental states and mental representations as playing any role in the process of conceptualisation and meaning interpretation. This latter controversy is somewhat blurred, since Blair through his examples admits the presence of mental conceptual representations, e.g. in the form of individual, pragmatic contexts, underlying individual inquiries (see for instance the 'author name' example (Blair, 1990, p. 138). From a cognitive point of view, this is exactly what happens at a cognitive level of information processing.

A third point is to what extent Blair will allow for *redundancy*, or poly-representation – as suggested by Sparck Jones above. Blair's idea is to *replace* the traditional forms of representation – as so many before him – with a user-orientated, pragmatic mode of representation. His aim is not to combine the variety of approaches in a tailored way.

One should have in mind that concept representation *always implies* a free fall downward (is reduced) to a structural level (Chapter 2.2.2). The cognitive approach suggests applying this structural level from which one may make use of the redundancy and linguistic ambiguity, in a *deliberate* attempt to provide IR system(s) and user(s) with conceivably relevant contexts – or semantic values. NL should hence be applied to communicate representations of semantic values from user to intermediary in the form of NL requests, in the form of associated concepts to IR systems in the form of queries, and from system to user (and intermediary) in the form of potential information in context.

We may thus apply the 'monadic' and 'structural' levels (De Mey, 1977) for text analysis, intentionally producing *several semantic values* for each sentence or concept in a text, i.e. sets of *possible* meanings, for example by morpho and syntactic parsing of that sentence. We will hence *not* care for *the* meaning, striving at a 'cognitive level', but are satisfied with the sets of semantic values. This implies that the sentence 'time flies like an arrow' will have at least 4–5 semantic values, potential to users and IR systems.

The idea is expressed by C.J. van Rijsbergen, one of the leading present IR theorists, originally in (1986) and explained in relation to *extending* the traditional concept of *aboutness* toward the user (1990, p. 34–35):

> We may make the simple assumption that a document is its set of sentences. This is not the only way of proceeding, a more natural assumption is to say that a document is a possible world, and at any one time we only have a partial description of that world, namely a small set of propositions

> or sentences interpreted in that world. Such an interpretation involves the assignment of *semantic values* to sentences. ... A logic based on a formal semantics can be the carrier of information. Usually a query is an expression of a lack of information, a retrieved document is intended to fill that information gap. In the theory of IR that I am proposing, sentences do not have to occur in the documents to be used to describe a document. A limited case would be to identify a document with all the sentences that are true of it. This would mean that at any one stage we only have a finite set of sentences describing the document, *but a potential for finding further sentences.* A sentence would then be *about* the document rather than in it. In this way, one would emphasize the *informativeness* of a document. Information is ultimately dependent on the interpretation the user puts on a meaning, a logic is a tool which a user can use to get at the information.
>
> In IR we do not seek an answer to the *meaning* of language, instead we seek a model that will enable the user to find information, that is, discover something she did not already know. Simply retrieving meanings is not enough; these meanings must carry information, hence this form of retrieval is inherently uncertain.

As a tool van Rijsbergen suggest the application of the 'logical uncertainty principle' (1986, p. 200):

> Given any two sentences x and y; a measure of the uncertainty of y → x relative to a given data set, is determined by the *minimal extent* to which we have to *add information to the data set*, to establish the truth of y → x.

The author's interpretation of Rijsbergen's model makes it possible to see a document as a *kernel* of sentences, all true of it, with a space around it consisting of *explicit* and *implicit* semantic values representing the potential information in the document. The 'explicit' values are those which directly refer to meanings of sentences true of the document, as in the example 'time flies ...'. The 'implicit' semantic values are those that are *not present* in the text, but could be from a logical point of view. For each 'explicit' set of values there will consequently exist sets of 'implicit' values. It seems reasonable to this author to assume that van Rijsbergen basically is interested in the 'implicit semantic values'.

We may associate 'implicit semantic values' with the *Dark Matter* problem in IR, discussed in Chapter 3.1.2. The kernel of sentences as well as the explicit values are directly observable objects. However, we know that potential information in the form of implicit values is present there, a concealed matter in information space, and extremely difficult or impossible to acquire by simple and independent means alone, these being individual methods of text representation or particular IR techniques.

Two kinds of 'implicit semantic values' can be envisaged: *user-generated, associative interpretations* of explicit values; potential values (meanings) generated by *additional contexts*, lacking from explicit values.

The first type of implicit values are related to Hutchins' *pre-suppositions* (1978) underlying a user's desire for information (Chapter 3.1.1), or can be seen to associate to Blair's 'expectations'. The values may be those which a user reads into a text. A solid User and Domain Model might contain general ideas of domain tasks and preferences, factors that to a certain extent may accommodate such pre-suppositional characteristics. By 'Supportive User and Request Model Building' an intermediary mechanism may obtain such additional information from an actual user, to be manipulated by the logical uncertainty principle. Inherent in these 'associative and implicit' semantic values is natural uncertainty.

The second type implicit values refer to the contexts *missing from* an explicit semantic value or a given text – but *which might have been*. For instance, in the 'time flies like an arrow' example the 'locational' role or facet is not present. Thus, 'time flies...' might be in "London, last year", or elsewhere. The missing context is open for interpretation, but it is structured according to general syntactic rules. Other contexts, however, might indeed hold the locational role filled in, in addition to other syntactic roles carrying words. By playing on *several contexts*, their roles and terms, lacking or present, one may cross the contexts in information space, including some of the Dark Matter areas, and retrieve potential information by nearness. The two types of implicit values may be of a complementary nature, overlapping one another.

From the intermediary's and the IR systems' viewpoint, request formulations may indeed similarly display the dual types of implicit semantic values.

The idea of the latter type of implicit semantic values was originally underlying the assumption proposed in Chapter 6.1, about *structured questioning* by intermediaries and the use of *situational classification* (Ingwersen, 1986, 1992). The example used was that a text represented by the concept 'car driving' (which could have been a sentence), in addition holds the potential of being about 'roads' – and consequently also potentially being about 'road types' and 'highways' – *without actually containing* these terms (or sentences).

The possible information to a user in the implicit semantic value 'highways' of the concept 'car driving' may be retrieved by means of the logical uncertainty principle. It becomes a question of 'nearness' in the information space whether the text on 'car driving' is found or not – starting with 'highways'.

The problem to face is to produce sufficient contexts to retrieve 'car driving'. Only three sources exist to do this: the user, the intermediary, and the texts themselves in the IR system. However, this can be done *through IR interaction*.

What is important is that *extra context* is required added to encircle the place in information space of the underlying IR system that may hold the implicit sematic values of interest. For example, if we start with 'I want something about HIGHWAYS in EUROPE', how do we then get to texts containing explicit values in the form of '... car driving'?

To obtain these sets of context, the intermediary may ask the *user* to produce them for two reasons: 1) the user may not have stated his entire information need completely (the 'label effect'); 2) his state of knowledge and his problem space is rather defined, so he may actually be able to produce the extra context(s). In case 1) the user may or may not be capable of producing context on his own, i.e. he requires relevant questions and support from the intermediary. In the second case he requires at least some questions. In total, these problems constitute a reason for *using supportive user model building*, followed by request model building.

The intermediary's knowledge-base is assumed to be always insufficient. The mechanism hence takes the explicit semantic values of, for example, 'highways in Europe' and retrieves a variety of corresponding sentences in the stored (remote) texts, displaying them in condensed structures. Term frequency is one method

(Chapter 7.3.1), thesaurus structures may be another.

The internal thesaurus might, for instance, tell the user that HIGHWAYS = AUTOSTRADA. In another window we might produce a frequency analysis of explicit semantic values extracted from the retrieved texts and their added index terms. The thesaurus structure combined with the frequency list of terms may display words that trigger the user to produce a second request version: 'I want ... SPEED LIMITs on HIGHWAYs in ITALY'. ('Speed limits' deriving from the frequency list; 'Italy' triggered by the thesaurus synonym 'autostrada').

In order to reduce the amount of explicit (and derived implicit) semantic values undergoing processing, the intermediary must control the user's mode of answering by structuring its requirement for more context. A third contextual answer ought, for instance, to be structured by a question to the *problem underlying the need*, as suggested by Ingwersen in relation to the matching of cognitive structures by controlled questions (1982, p. 182) and inherent in the Monstrat Model. The intention behind the desire for information may thus be produced as a third statement, conceivably in the form of situational classification: 'I want to DRIVE to ITALY in my CAR'.

It is here assumed, relying on the investigative results in Chapter 5 and 7 as well as on the cognitive models for individuals, that we must *distinguish* between information need and problem situation in problem space. Hence, we may let the user *generate different contexts*, all directly related to his information need: by the need itself as well as by being the intentionality behind it.

As a possible result of this supportive action and controlled questioning, the intermediary is in possession of the following three request statements, all in the form of explicit semantic values: 'Highways in Europe'; 'Speed limits on highways in Italy'; 'Drive to Italy in car'. According to the method of text analysis applied to the three statements, the intermediary may for example have an idea of the conceivable case-grammar roles played by the individual terms in the contexts provided by the user.

In the stored *texts,* similar explicit semantic values exist, with terms in similar roles. As pointed out by van Rijsbergen, we (the designer) have control as to the degree of representation and 'nearness' of semantic values we allow in the IR system. An additional mode of questioning would be to direct questions towards terms in roles not present in the statements hitherto supplied by the user. For instance, the 'instrumental' role is missing in the first and second user statements above.

One may note that the intermediary does not understand the meaning of the three user requests and statements. To a high degree it works on a syntactic level. It is the user on his cognitive level who provides associations and 'understanding' – supplied by the structured 'semantics' in the thesaurus, e.g. 'for term 'highway' retrieve also 'autostrada''. The variety of user statements may be applied to delimit that portion of the information space which contains the explicit values in stored sentences. Within and encircling this delimited space the intermediary may find the implicit semantic values which may be of importance to the actual user, for example 'near' text sentences *containing* 'car driving', 'Italy' and 'roads', but *neither* 'highways' *nor* 'autostrada'. The 'nearest', often overlapping text portions may hence be retrieved, according to van Rijsbergen's logical uncertainty principle, and the contexts displayed, e.g. ranked by decreasing nearness.

It is then the *user who perceives* (or reads into the text) and consequently may have his state of knowledge changed by reading the retrieved sentences, that is, interpreting and obtaining *information*, for example, from contexts not containing the initial request terms: 'Driving fast in Italy by car is not problematic, because of the network of toll roads that covers the entire country. In general you pay ...'.

It is worth noticing that the SAP method (Chapter 4.3.3), working with titles, chapter headings and table captions, may be applied to this framework. Further, paintings and pictures as well as other non-textual materials may be retrieved by this approach. If the title of, say, a painting says 'Deer hunting in the Alps' but the painting also contains a hunter and his dog, it is probable that it may be retrieved via implicit semantic values, if a user asks for a painting with a hunter. The condition is that a *real semantic relation* must exist between the content of the picture and its title. One may refer back to the "Mark Twain Painting Case" (Chapter 2.4). With reference to Mark Pejtersen's Bookhouse design, one may emphasise the implicit semantic values inherent in each topical icon in the system (1989).

The principle underlying the connections between implicit and explicit semantic values, which may lead to associative chains made in interactive collaboration between intermediary and user, seems strongly related to Umberto Eco's point that by means of five chains only, one may travel conceptually 'from something to everything' (1988).

Aside from applying syntactic parsing, one may point to the SIMPR Esprit II project (box 1D, figure 7.8), which makes use of more simple techniques with similar potentiality for deliberate use of inherent uncertainty. SIMPR is not entirely an intermediary design. However, its means for retrieval via an appropiate interface is rather exhaustive. Aside from chapter heading hierarchies extracted from the texts in the domain (car manuals), which can be seen as SAP strings in NL, SIMPR attempts to classify text portions and produces index terms in the form of 'analytics' in a semi-automatic way. Also, the project works on TSAs (Tree Structured Analytics) which are extracted from the texts by morpho-syntactic analysis (Smeaton et al., 1990). The TSAs are *deliberately* made uncertain in a semantic sense, and may thus represent possible (explicit) semantic values for each sentence analysed. Since request versions may be analysed the same way, one may perceive the TSA structures as one of several methods of representation applicable in this contextual framework.

Very recently, Wendlandt and Driscoll have extended the use of the vector space model by introducing weighting of the thematic roles in the text sentences (1991). The thematic roles, indicated by prepositions and other words, are of the same nature as the 'roles' discussed in Chapter 4.2. Like for the TSA extraction, text parsing is necessarily involved to produce the syntactic explicit structures underlying the weighting calculations – for text sentences as well as for request formulations.

This multitude of means to automated representation might be applicable in smaller local information systems. In-house IR systems may, for instance, make use of SIMPR and similar indexing technologies, in order to combine several indexing methods for each text entity in a *tailored* fashion. "Author-defined natural language (e.g. SAP indexing or TSAs) could be used, making a specific text accessible to a certain group of users, for example researchers in the domain, *in addition to* a controlled vocabulary, in which the index terms are dedicated other potential users of the text, for instance R&D persons from other fields, managers, and production staff. Thus, the probability of retrieval of a specific text entity or document, relevant to several, different users with different goals [or pre-suppositions] and conceptual background, ought to increase" (Ingwersen and Wormell, 1988, p. 108). The SIMPR indexing machine is capable of dealing with different 'indexing strategies', each one dedicated a specific purpose. The produced variety of 'analytics' can be validated automatically by synonym thesaurii. In practice, this solution is similar to the suggestions by Bates (1985, 1990) and Kemp (1988) concerning the use of search thesaurii.

Turtle and Croft have suggested a way to apply a variety of representativeness, the *plausible inference networking technique* (1990). This technique may best work on several types of representation techniques *and* several user request versions, preferably in NL. Documents are parents to sets of terms (or sentences) that may be extracted by different methods of representation. Concepts, adhering from the request versions, can be seen as roots in a query network. A single query concept node may have several representation concept nodes as parents. The query concept nodes define the mapping between concepts used to represent the document collection and the concepts used in the queries.

This inference technique thus operates on the *explicit* semantic values that are represented in various ways. This variety of text and request representations assures at least as much, or more, effective IR than if, for example, probability is applied, processing results of one single method of representation only (Croft, 1987).

The author sees no reason for not applying this technique to van Rijsbergen's theory of implicit semantic values providing suplementary contextualisation, as interpreted above. It is the author's opinion that the semantic value approach may lead to a unifying IR theory, based on principles of uncertainty, plausible inference applying poly-representation, and contextualisation. Clearly, such a theory adheres to the cognitive research approach by explicitly drawing upon knowledge contributions from all participants through interaction in order to function adequately.

7.6 Summary

The cognitive IR research approach is strongly associated with the functionality of knowledge-based intermediary mechanisms which are seen as the bridging component between IR systems and their conceptual structures on the one hand, and the user and his desire for information on the other; a Janus-like figure.

Further, IR seen from a cognitive viewpoint entails serious attempts to create a unifying IR theory based on contextualisation. Such a theory should make use of dynamic, adaptive and learnable intermediary mechanisms in order to provide users with potential information, not only from the explicitly attainable information space, but also from portions of Dark Matter – hitherto mainly untouched, but always inherent in this space for each retrieval session.

Knowledge-based intermediary design can be categorized into six basic cases and two fundamental approaches, according to the knowledge types and functions built into them: 'supportive only' and 'user model building' (intelligent IR) designs.

In the latter 'intelligent IR' approach natural language processing (NLP) and understanding ideally play very dominant roles. In the former design approach the idea is to make deliberate use of the user's own knowledge capacity and intelligence.

This chapter proposes to decrease the importance and functionality of user model building by limiting it to ascertaining a user's actual knowledge levels as to the topic in question, the IR processes and settings, and in relation to the user's current experience with the actual intermediary mechanism. The suggested 'Supportive User Model Building' approach to design makes additional use of solid Domain and User Models, accommodating general knowledge of work tasks, preferences and searching behaviour in the domain(s).

Adaptivity, tranparency and flexibility are proposed, directed from an intermediary towards both users and the underlying IR systems, in much more complex R&D scenarios than hitherto in use in IR.

Condensed conceptual feedback is regarded as crucial for the success of IR, and forms part of the intermediary designs based on 'supportive user model building'. By replacing the principle of 'first model building – then retrieval inference' with the empirically based principle of 'first user model building and support – then user inference and retrieval', the idea is to make maximal use of the user's own cognitive abilities in a dedicated and tailored way.

Full NL understanding is thus not at all necessary. In contrast, the natural ambiguity inherent in NL should be employed to produce several different representations in the form of a variety of semantic values of texts in information space as well as of request statements. The latter ought to be presented in several versions in a controlled manner for each information need.

This poly-representativity, or tailored combinations of means to representation and IR technique application, is mandatory in future IR theory development, with the intermediary mechanism as a functional mediator between information space and a user's problem space.

8. The MEDIATOR MODEL

This chapter outlines the consolidated framework for intermediary requirements in IR interaction. Chapter 8.1 summarises the 13 fundamental functions which are described in more detail in Chapter 8.1.1., outlining the model's 54 sub-functions. Chapter 8.2 discusses the use of the model.

The Mediator Model is based on six sources of an empirical and analytic nature, supplied with proposals and points in relation to IR interaction, discussed previously in this volume.

The six sources are:

1. The Monstrat Model and critique, outlined in Chapter 5.4;
2. The empirical and analytical findings, Chapter 5.3 and 5.5.
3. The cognitive models of IR interaction and major types of knowledge structures involved, Chapter 6.2;
4. The design cases, Chapter 7.1, in particular the I3R, Euromath and the Bookhouse systems;
5. The discussion of knowledge-based intermediary mechanisms and the role of feedback, Chapters 7.3 and 7.4.
6. IR theory building of a contextual nature, developed in Chapter 7.5.

Although Mediator in particular is aimed at an adaptive and supportive user model building approach to the design of intermediaries, the model is regarded as universal and it may consequently be suitable to other design approaches as well. The functions and their associated sub-functions are annotated as if the mechanism ought to work in a *multi-domain and multi-IR system* environment.

8.1 The framework of the Mediator Model

The fundamental functions of the Mediator Model are outlined below. Each function is defined and its main applications described.

FUNCTIONS	DESCRIPTION
1. Domain Model	Contain knowledge of *work tasks* in the domain(s), major subject (and affective) areas, possible paradigmatic views, and *conceptual map(s)*, i.e. concept and concept relations;
2. System Model	Contain knowledge of 'system setting', i.e. *IR systems* and other information sources relevant to the domain, *IR techniques* for searching, database structures and description (coverage), rules for representation, and *(host) software*, incl. feedback facilities;
3. User Model	Contain general knowledge of *seeking behaviour, user preferences, values and expectations*, user *intentionality* in relation to work tasks in domain(s), as well as user *knowledge status and levels;*
4. System Model Adaptor	Generate knowledge of remote database structures, o.a. by *interrogation*, using *System Model* properties, leading to system *learning;*
5. User Model Builder	Generate analytic knowledge of *actual user* characteristics, based on attributes in the *User Model* or (to a minimum) associated to the Domain and System models;
6. Retrieval Strategy	Choose and carry out (or provide to user) appropriate IR strategies in local and/or remote IR systems, based on functions 2 & 3 as well as the actual user model from functions 5 & 9, i.e. carry out *matching of query;*
7. Response Generator	Determine and examine response to user appropriate to situation, i.e. evaluate result of *Retrieval Strategy* leading to *Feedback, Transformation or System Model Adaptor* (interrrogation);
8. Feedback Generator	Generate *internal or external* conceptual feedback according to situation;
9. Request Model Builder	Generate analytic knowledge of *actual information need* and underlying *problem* in form of concepts and concept relations;
10. Mapping	Generate, update and *store* relevant knowledge from individual *User Model* and *map conceptual associations* between contents in Request Model Builder and functions 6-8, i.e. saving searches and conceptual relations made by user;
11. Explanation	Describe mechanism and remote IR system operation, capabilities, etc. to user as appropriate, depending mainly on *User Model Builder and Mapping;*
12. Transformer	Determine *Dialogue Mode*, based on *User Model Builder* and *Mapping* knowledge; *convert* input and output data from user as well as from IR system(s);
13. Planner	Processing rules for all other functions based on *Intent, Expectations, and Values*, implemented in the intermediary;

Following the taxonomy of models in interface design by J. Nielsen (1987), the entire framework can be regarded as a 'composite model' of the form R(U+C+(U+C(IR))), i.e. the Researcher's model of the following processes: how Users' think when interacting with a Computer which dynamically builds up its models of that User as well as of Computer IR systems.

In comparison to the Monstrat Model, nine of the 13 requirements are either completely new (six), partially new with several added sub-functions (two), or totally reorganized (one). These are:

1. Domain Model	(new)
2. System Model	(new)
3. User Model	(partial)
4. System Model Adaptor	(new)
5. User Model Builder	(new)
7. Response Generator	(new)
8. Feedback Generator	(new)
11. Mapping	(partial)
12. Transformer	(reorganized)

One of the new functions, Response Generator has kept its old name but consists of completely new relevant sub-functions, not in existence in Monstrat. The reorganization of the Transformer function is done by adding together several of the stand-alone functions Monstrat consists of, all concerning conversion and manipulation of input and output to the mechanism.

The Mediator Model is universal and enables an intermediary mechanism to function in order to achieve its goal of helping the user with his information need in a state of uncertainty, and his problem solving task or goal in problem space. The model can achieve these goals, founded as it is on strong empirical evidence and analytic results worldwide.

The philosophy behind the framework is three-fold:

1) To view the intermediary as an *independent participant* in IR interaction, facing both users and IR systems. A major consequence of this view is the need for *adaption* to its surrounding world and the cognitive tasks this environment produces that result in retrieval processes.
2) Aside from having adaptive characteristics, the intermediary is viewed as a *transparent and supportive* mechanism. User Model Building is consequently mainly applied (or minimized) to *infer adequate backing* of the user, in order to make maximum use of *human intelligence*.
3) To base user model building on long-term, pre-established domain, system and user models, i.e. *to separate 'blue-print' from act of construction*. The author does not believe in the possibility of not having categorized beforehand, at least to a certain extent, the users' collective cognitive structures, their conceivable search behaviour, expectations and work tasks.

Does this approach mean, however, that holding a detailed domain and user model, one ought to ask the user many specific questions in order to perform effective retrieval? In the author's opinion the answer is no. On the contrary, solid background models may serve the user better when applied to support him, making him use his own associative capabilities. Many detailed questions are only required when such models are weak or missing, or when the intermediary mechanism is supposed to simulate (or rather copy) human question behaviour during long periods of pre-search interviewing.

As Mediator is constructed, the first three major functions are general and structural models that should be produced by application of field studies and cognitive task modelling. Ideally, they ought to become dynamic over time. In Nielsen's notation they would be regarded as static models (1987). They are seen as the foundation on which the ten remaining instantaneous, analytic and dynamic functionalities carry out their operations. Since the underlying principle is adaptively to bridge a user with an information requirement and local and/or remote IR systems of various kinds, Mediator demonstrates a corresponding symmetry of functionalities. This fact constitutes the major difference to the Monstrat Model. Figure 8.11, in Chapter 8.2, displays the Mediator model in this symmetrical way, distinguishing between three levels of functionality: cognitive task modelling, cognitive adaption, and IR effectiveness.

8.1.1 Sub-functions in the Mediator Model

The eventual tasks or sub-functions, adhering to each major Mediator function, are outlined below. The descriptions are organized in Figures 8.1 – 8.10. In each table the main functions are in CAPITALS. **New** major functions and sub-functions, added by the author to the Monstrat model, are **in bold**. The original Monstrat sub-functions are kept in *italics.* Specifications preceding the notation '(Monstrat)' refer to the original functional explanations in that model; specifications proceeding from the notation are added in order to explain further what the sub-function is about and to which other sub-functions it is related. These specifications attempt to universalize the Mediator Model. Examples are as far as possible kept within the same task throughout all the sub-functions.

The major empirical and analytic contributions to the Mediator functionalities are emphasised in connection to each function.

The *Domain Model* is a natural consequence of the contents in Figure 6.7. Its contents owes therefore to the works by J. Rasmussen et al. (1990) and Ingwersen's and Mark Pejtersen's work on empirically based studies of user-intermediary-system behaviour (1986). Because work domain, tasks and subject areas seem to play significant roles in user-librarian negotiation as well as user-IR system interaction, the following sub-functions have been introduced: Work Tasks; Subject Areas; Paradigms; Conceptual Maps.

1. DOMAIN MODEL

Work Tasks	Specify all tasks in work domain(s) that may lead to information searching behaviour. Can be broader than may be accommodated in 'System model'. Ex.: writing paper; receive preprints; perform research tasks; play games; do R&D profiles; software development & reuse; read novels, watch TV;
Subtasks	Specify the content of users' *research* (Monstrat), i.e. specify possible subtasks underlying single 'Work tasks'. Ex.: 'writing paper' → getting tables / list of authors on topic / view received preprints / get experimental error parameters / subject retrieval.
Subject Area	Specify major subject areas in work domain(s). Ex.: Energy + Environmental sc. + Transport.
Paradigms	Specify core politico-scientific views, important 'Preference' to problem solving or goals in domains. Ex.: Pro-government views; 'scientific schools'; author intentions.
Subjectlit	Specify formal characteristics of the subject literature (Monstrat), i.e specify literature in 'Paradigms', 'Subject areas' in work domain(s). Ex.: document types; software types; media types; meta-literature.
Conceptual Maps	Specify existence and usability of pre-established local or remote conceptual structures in 'Subject areas'. Ex.: term lists; lexicons; thesaurii; semantic maps; knowledge-bases.

Fig. 8.1 Sub-functions in the *Domain Model* in Mediator.

Work Tasks is a fundamental sub-function. It should mirror tasks and problems in the work domain which may affect the individuals' cognitive work space and activities. One of these activities will be IR, both of a formal and informal nature. In a complex domain, retrieval may take very differentiated forms, as we attempt to exemplify in Figure 8.1. Various work tasks may lead to 'Subtasks' and be intermingled with 'Subject Area' and 'Subjectlit'.

Subject Areas are mandatory in multi-domain environments in order to have control of e.g. terminological problems across several areas, and to be able to relate underlying IR systems adequately. Another point is that all areas do not need to be of the same knowledge level. For example, in in-house environments some areas are purely scientific for research reasons, others are applied in order to suit production, and others again can be business and news related. Areas are often of a mixed nature. So are the operational IR systems, but not necessarily following the same patterns.

Paradigms are added for two reasons. First because this facet is important in humanities and behavioural science (Ellis, 1989) (Chapter 6.2.5). Secondly, this dimension seems crucial in fiction retrieval (Mark Pejtersen, 1980, 1989). The author sees scientific viewpoints and author intentions as adhering to the same issue. If important, it forms part of the 'Preference' sub-function in the 'User Model'.

The *Conceptual Map* is a sub-function for two reasons. Foremost, it is valuable to separate internal conceptual structures from external ones, e.g. thesaurii, which often display a much wider subject coverage than internal knowledge-based structures. However, the latter may be of a more specific and tailored nature. Secondly, AI research sometimes overlooks the potentiality of existing semantic maps in the form of thesaurii, which can be purchased, e.g. as subsets, as done in the Tome Searcher.

The Domain Model should hold a rather complete overview of conceivable tasks leading to retrieval. The mechanism may hence be capable of *referral* of potential users to alternative systems (or persons) in the cases where work tasks in the domain presumably (or logically) could be carried out by the mechanism – but is not performed for various reasons. See for instance the example in the 'Subtask' sub-function, in which a valid subtask during the 'Work task' activity 'research' would be to know about 'error parameters'. However, the subfunction 'Capabilities' in the 'System Model' function (Figure 8.2), cannot accomodate this valid task and refers to the paper-based confidential archive, out of range of this intermediary mechanism.

The 'Subject Area' and 'Conceptual Maps' sub-functions are connected, with 'Paradigms' as an additional factor.

2. SYSTEM MODEL

IR Systems	Specify (remote) characteristics of hosts, relevant for work domain(s). Ex.: access; command language(s); database policy & subject coverage (≈Subject Area); online tutorial layout consistency.
Databases	Specify dbs. coverage, searchable fields & codes, dbs.-specific info., indexing methods. Ex.: Author code always AU=; basic index; ?FIELDSn = field codes for file n.
IR Technique	Specify matching techniques (exact/partial) associated with hosts & dbs., their syntax, and instigation. Ex.: CCL command syntax, e.g. FIND AU=X; Clustering/vector space algorithm instigation (locally or remote).
Software	Specify remote host programs that are useful for manipulation of records & user support. Ex.: Frequency analysis (ZOOM); cross-file searching; quorum searching algorithm; download command & protocol; thesaurus-validation of terms (HYPERLINE).
Capability	Specify (for 'Explanation') the capabilities of the systems (Monstrat=Problem Mode function), i.e. specify the information space and the intermediary (non)capabilities in relation to 'Work tasks'. May point to alternative sources. Ex.: E-mail; retrieve fiction; experimental error file → GO ASK paper Archive (confidential!).

Fig. 8.2. Subfunctions in the *System Model* in Mediator.

In the *System Model* all sub-functions are logical and in relation to the various models of IR interaction by the author (for example the Figures 6.4 and 6.7).

They take into account exact as well as partial match techniques in the IR systems that correspond to the requirements of the domain(s). The sub-functions are necessary for the operationality of other IR system-related major functions, such as System Model Adaptor, Retrieval Strategy, and Feedback Generator. It is intended to accomodate both local and remote IR systems underlying the intermediary mechanism. Although as a whole it may look stable, it should be made dynamic and modifiable when implemented. Modifications are made by the System Model Adaptor (Figure 8.4), for instance in connection to the launch by a host of new files or features, relevant to the domain(s), or when a database is reloaded, for example presenting new searchable fields.

The 'Capability' sub-function from the Monstrat model is placed here according to its description in Monstrat. It is meant to mirror the actual capabilities mediated by the intermediary, and may thus refer certain major work tasks involving retrieval, which it cannot serve, to appropriate sources outside its information space.

3. USER MODEL

User Status	Determine the status of the users (Monstrat: User), i.e. specify the variety of possible user status *if necessary* to know for 'Mapping' for reason of dedicated *location* of retrieved materials, e.g. in libraries. Only asked once per user. Ex.: academic visitor; researcher; PhD student; layman; hobbyist.
Background	Determine users' background (Monstrat), i.e. specify institutional affiliation, *if useful* for later provision of retrieved material in hard copy, or used for referral. Only asked once per user. Ex.: department, branch, home address;
User Goals	Determine the users' goals (Monstrat), i.e. specify the intentionality behind 'Work Tasks' and 'Subtasks' in the 'Domain Model' that are possible to perform according to 'System Model' (Capability). Imply fast delivery by mechanism. Ex.: writing paper → submission in 2 weeks to Energy World Conf. → subject IR
Search	Specify the users' searching behaviour in relation to 'User Goals', i.e. obtain knowledge of preferred strategies in the domain(s). Ex.: writing paper → subject retrieval → citation pearl / similarity search / ranking of items / very specific(→ clustering) / high recall (probability+clustering);
Preference	Specify the users' search preferences & values (e.g. 'Paradigms') in relation to 'Search' behaviour. Ex.: citation pearl → from known author / from topic / from document to be retrieved before further action / from scientific viewpoint.
IR Knowledge	Specify the possible types of knowledge related to 'IR system(s)' (Monstrat: IRS) *underlying* mechanism. Leading to 'User Type' (User Model Builder). Ex.: expert; IR specialist (can be more specific).
Knowledge	Specify the possible types of conceptual knowledge (Monstrat: KNOW), i.e. specify the levels of states of knowledge found in domain. Leading to 'User Type'. Ex.: subject specialist; non-specialist (can be more specific).

Fig. 8.3. Sub-functions in the *User Model* in Mediator.

The *User Model*, Figure 8.3, adheres to the Monstrat model, containing its most important sub-functions: User Status (called 'User' in Monstrat), Background ('Back'), and 'User Goals'. The idea behind the User Model is to have *general knowledge* in the mechanism of the searching, preference and knowledge characteristics in the user population within the domain(s) served. This model is the 'blue-print' underlying the 'User Model Builder'. The author is most inclined to stress the knowledge held by *Search, Preference, IR Knowledge, and Knowledge.* These sub-functions are clearly demonstrated in Ingwersen's verbal protocols in relation to users' own searching behaviour as well as the librarians' search procedures and search modes (Chapters 5.3 and 6.2.4).

The underlying philosophy relates to the empirical fact that the same task may invoke different behaviour with different preferences. In the specifications of 'Search' and 'Preference', one may observe that the Domain Model's 'Work tasks' and 'Subtasks' lead to particular search behaviour and search preferences in the 'User Model'. For instance, the subtask 'subject retrieval' may lead to specific modes of searching by different users, e.g. citation pearl, similarity searching, etc., each with different preferences. These general characteristics of user behaviour in the domain(s) are made actual via the 'User Model Builder' sub-function 'User Mode' (Figure 8.4).

The former Monstrat functionalities IRS and KNOW are maintained and lead similarly to actual user model building in 'User Type'. Daniels (1986) used "knowledge acquisition by means of cognitive task modelling, resulting in a domain specific User Model" (p. 170) which then was implemented as hierarchically structured frames with slots signifying the attributes and values. For instance, the 'User Status' frame was an instance of the 'User' frame, and contained domain specific User Types as one of the attributes. In her case, the slot values under User Type were 'academic' vs 'non-academic' which superficially equal 'subject specialist' and 'non-specialist' in 'Knowledge' (Figure 8.3).

Daniels' very general values are relevant in a university library environment. However, similar to other User Model sub-functions, which may be much more specific, such functions as well as their values may only be useful if they lead to a relevant and applicable *differentiation* during subsequent inference, feedback and retrieval. For example, that 'non-academic' users in general are regarded less knowledgeable than 'academic' ones may be a precarious deduction in the *actual situation*. It is not so much a question of *what* a person *is* as what he *knows*. The *variety of states of 'Knowledge'* with respect to the domain as well as to the 'IR Knowledge' of systems are henceforward mirrored in the relevant sub-functions in the 'User Model' which, at the *actual IR situation,* become applied to the user by the 'User Type' functionality placed in the 'User Model Builder' function (Figure 8.4).

As in the 'System Model' the 'User Model' should be constructed to be able to accommodate *new categories* of users, search behaviour and retrieval preferences. Space must be available for adding unexpected attributes and values, e.g. caused by new curriculum programmes if the environment is a university library. To this end open neural networks combined with inferential features placed in monitoring 'experts' might be introduced and tested. The results should be stored in the 'Mapping' function (Figure 8.8).

4. SYSTEM MODEL ADAPTOR

Interrogate	Determine and obtain knowledge of hitherto unknown (host) 'IR systems' or 'Databases', based on application of general knowledge in 'System Model', i.e. also updates of tutorial, 'Database' and 'Software' information. Ex.: use (host) 'Software' commands to check/make update of dbs information on field codes and search mode; get unknown dbs.X; use general knowledge of database-tutorial access to ask ?FILEx + ?FIELDSx to obtain dbs. coverage and searchable fields.
Learn	Store relevant information via 'Transformer' (Manipulate) in 'System & Domain Models' for later use. Ex.: add Energynet's subject coverage to 'Subject Areas' and file to 'Databases'; add new field code information to 'Databases' for specific file, e.g. TR= (treatment) in Inspec.

5. USER MODEL BUILDER

Experience	Analyse and determine user's actual experience as to *mechanism*, to be stored in 'Mapping' for up-dating. Only asked once per user. Can be more specific. Ex.: experienced; casual; novice; know other mechanisms.
User Mode	Analyse and determine user's actual characteristics, based on the 'User Model' sub-functions, i.e. in general *User Goals, Search and Preference.* Ex.: paper submission in 2 weeks to Energy World Conf. (→ fast delivery of hard copies) → writing paper → subject IR → citation pearl strategy, based on topical area.
User Type	Analyse and determine the type of user in work domain as to *actual* 'IR knowledge' of underlying IR System(s) and *actual* conceptual 'Knowledge' in relation to 'Request' (Request Model Builder). Can be more specific. Ex.: expert; IR specialist; subject specialist; non-specialist;

Fig. 8.4. Sub-functions in the *System Model Adaptor and User Model Builder* in Mediator.

The '*System Model Adaptor*' is new and a consequence of the adaption principle. It may extract data about hitherto unknown databases launched by a known online host via knowledge from the 'System Model'. It may thus update information in the 'System model', e.g. to be re-used by the 'Retrieval Strategy' function (Figure 8.5). The 'Interrogate' sub-function can be applied to *periodic monitoring* of remote databases for updated information. In order to interrogate remote host computers the transmitted data must be consistent. For instance, the consistent use of the same field code to the same kind of data (regardless of its producer field name) is here crucial. Certain European hosts actually demonstrate such qualities.

Similarly, the '*User Model Builder*' extracts data about the actual user's knowledge levels as to the *current request* provided by the 'Request Model Builder' function, in an amount necessary for the mechanism to produce adequate conceptual support, e.g. as carried out in Euromath, to filter out possible label effects in requests from otherwise knowledgeable users (Chapter 7.1.4).

A new sub-function, *Experience,* analyses the user's actual state of knowledge of the intermediary. It is based on the discussion in Chapter 6.2.4. One must note that a 'familiarity effect', known from in-house environments, definitively will occur, that is, the mechanism over time becomes increasingly known to its user population. This would also happen in a general (public library) milieu. In order not to ask the same questions in session after session, the Mapping function stores this and other user-related data, whereby short-cuts in the dialogue process are possible. An algorithm may upgrade the information from 'Experience' in order to display different 'Explanations' according to familiarity with the mechanism. From Goodstein and Mark Pejtersen (1989) one is informed that after approximately 8–10 sessions with the Bookhouse, most of its facilities were known to the subject.

The *User Mode* facility enables the mechanism to establish knowledge of actual user's goals, seeking and preference schemes. Often it is not necessary to ask about goals, since the adequate task or subtask may have been chosen earlier in the session (design dependent).

The *User Type* sub-function refers to the four basic types of users discussed in Chapter 6.2.4, concentrating on their levels of knowledge in general in the domain(s). In an in-house environment there might be subject specialists only, as in Euromath. However, these specialist may turn out to be non-specialists from time to time, depending on their actual need for information. With respect to IR knowledge a design ought to take into account that they may progress into 'experts', i.e. that spin-off effects occur.

Deeper specificity in the 'User Type' sub-function, and hence in the 'IR knowledge', and 'Knowledge' sub-functions in the User Model (Figure 8.3), is only useful if the mechanism may accommodate such specificity in the further retrieval activity, for instance, by providing specific 'Explanation' or 'Dialogue Modes' accordingly. The I3R system contains more differentiated categories than shown here in order to infer the number of search runs (Croft and Thomson, 1987) (Chapter 7.1.1).

Except for 'Match', all the sub-functions in the *Retrieval Strategy* function, Figure 8.5, originate from the Monstrat Model (Brooks, 1986b). The 'DB Select' sub-function can be applied early in the process in connection with 'Work Task' and 'Sub Task' selection or other sub-functions, e.g. the 'User Goal/Mode' functionalities. This would be necessary if *external feedback* is supposed to be applied *immediately* according to 'Need Type' in the 'Request Model Builder'. 'Retrieval Strategy' is thus used for *support purposes* in the first place – only later for final retrieval reasons.

In more narrow domains the user himself may select relevant databases; in complex domains the mechanism may make use of remote host mainframe software to select files, possibly combined with local inference based on request terms.

Terms and concepts to be used by 'Terms' are provided by the 'Request Model Builder' (Figure 8.7). If NL input is allowed, the 'Input Analyst' in the Transformer main function (Figure 8.10), may apply parsing algorithms for linguistic processing, e.g. morpho-syntactic analysis. It is hence important that possible verificative information needs are defined, prior to execution of a linguistic analysis which in such a case can be regarded as overkill. Exact match retrieval strategies are sufficient for retrieval of such needs.

6. RETRIEVAL STRATEGY

DB Select	Determine and select the database(s) to be searched (Monstrat), based on either 'User Model Builder' information from 'User Goal', on previous 'Subtask' selection, or on 'Request Model Builder' data. Can also be done via 'Feedback' from remote host system (Cross-file searching algorithm) or by user's own choice. Actual selection is based on 'System Model' knowledge. Ex.: ParliamentInfo →..Begin GOVERN; get Energy files → QUEST TOPIC ENERGY.
Terms	Select terms (Monstrat) and formal data from 'Request Model Builder' as well as from 'Conceptual Map' (and Feedback Generator). Ex.: CO2 tax? - econom? - (local communit? = bigger city/cities) - year: 1991.
Strategy	Evolve the search strategy (how query will be implemented)(Monstrat), i.e. select appropiate strategy according to 'DB Select', 'System Model' information on dbs., and by inference via 'User mode' (User Model Builder), leading to 'IR Technique' selection. Ex.: exact match → CCL, topical need; citation pearl from author name / topic.
Query	Formulate the query (Monstrat), i.e. implement 'Terms' and other data in pre-established or inferred strategies. Can apply host 'Software' knowledge, e.g. let host make quorum searching Ex.: FIND CO2 tax? AND econom? AND (local community OR bigger cit?) AND PY=1991; followed by other established algorithms.
Match	Send the search string(s) off from 'Query' to local and/or remote IR Systems, after 'Transformer' has got access to selected database (in host or locally). Ex.: (in GOVERN): FIND ....; or (in GOVERN): RUN QUEST QUORUM → CO2 Tax ...; → execute extended Boolean (via Download combined with term freq. algorithm for tf x idf formular).

Fig. 8.5. Sub-functions in the *Retrieval Strategy* function in Mediator.

The *Match* sub-function was originally suggested by Sparck Jones (1987), since the Monstrat model, as discussed previously, does not provide interaction with IR systems. 'Match' may obviously be viewed as belonging to 'Response Generator' as well, since this latter requirement works on the result made by 'Match'. It is, however, logical to place it within the frame of 'Retrieval Strategy', because the immediate input to be matched to internal or external IR systems is found here. The functionality of 'Match' is defined by the contents of the System Model, in particular the 'Database', 'IR Technique' and 'Software' sub-functions. In addition, the introduced System Model Adaptor may provide supplementary or updated data.

In Figure 8.6 the *Response Generator* holds three sub-functions that correspond to the 'Match' sub-function in 'Retrieval Strategy'. The Response Generator is deliberately separated from the 'Feedback Generator' because it mainly deals with retrieval whilst the 'Feedback Generator' supplies supportive potential information in restructured or condensed form, not records, text entities or entire documents.

7. RESPONSE GENERATOR

Evaluate	Examine response from IR system or selected database in relation to 'User Mode', 'Documents' characteristics (Request Model Builder), implemented checking (e.g. for zero postings), leading to a) different 'Match' algorithm, b) 'Feedback generation' for user support, c) 'System Model Adaptor' (or System Model) for check on e.g. field code (PY= changed to PD=), or to d) the 'Transformer' to 'Manipulate' the results. Ex.: PY=1991 → zero hits; Check PY= → OK; check dbs-update (via System Model Adaptor) → December 1990.; tell 'Transformer' to tell user why zero result.
Get Records	Retrieve records in format given by default or deriving from 'Preferences' and 'Documents' (User & Request Model Builders). Can be done by user. Which records (of several different sets) is determined by user or by algorithm in 'Evaluate' compared with 'Documents' and retrieval algorithm(s) in 'Match'. Ex.: Title format (default); get set with lowest no. of postings that satisfies highlighted concepts, e.g. 'CO2 tax?' and 'local community'.
Download	Download specific (default) number of records via 'Transformer' for internal processing (Manipulate) according to 'IR technique' and 'Software' (System Model). Ex.: DL FORMAT X 20 (latest records of last set).

8. FEEDBACK GENERATOR

External	Retrieve specific type of conceptual support from remote database in use, based on actual knowledge from 'User Mode' (User Model Builder) and 'Need Type' (Request Model Builder), combined with 'Evaluate' by using 'System Model' information. Ex.: Freq. analysis (Zoom) of index terms or of author names (checking names in 'Evaluate'); cross-file searching; term validation (Hyperline);
Internal	Retrieve from mechanism (Conceptual Map) structures related to terms in 'Request Model Builder'. Can be done automatically. Ex.: Thesaurus structure: Economy → Business economy, etc.; local community = bigger city/cities.
Combine	Use both sub-functions, for instance, if user 'Request' is in incomprehensible NL. Ex.: Thesaurus: CO2 Tax (not found) → (Zoom CO2 Tax) → Energy taxation → Thesaurus: Energy taxation → Carbon Tax + Oil production tax.

Fig. 8.6. Sub-functions in the *Response Generator and Feedback Generator* in Mediator.

The *Response Generator* (Figure 8.3), is a new requirement under a name taken from the Monstrat Model. In various Monstrat versions this function either stands alone or holds the 'Output Generator'. In this framework the 'Response Generator' is employed for several reasons. Usually during IR interaction, the human intermediary attempts to *evaluate* search outcome in parallel to the user's own evaluation. This facility does not exist in the Monstrat model, mainly caused by the pre-search setting, i.e. there is nothing to evaluate. Ingwersen's empirical results as well as the hitherto obtained findings by Saracevic et al. (1990) demonstrate this activity. Here, evaluation does not necessarily imply problems of relevance. 'Evaluation' is merely concerned with error tracking, as exemplified in Figure 8.3. 'Get Records' and 'Download' are two different functionalities because they lead to two different activities. The former sub-function implies displaying records or parts of records to the user, according to certain user specifications previously made. Most often, the display formats from external hosts are not as consistent as could be, while the download formats are tightly controlled by protocols. The latter function may hence serve a facility for internal processing and storage, the former not.

The '*Feedback Generator*' is based on the empirical findings presented in the Chapters 5.3/5 and 7.3. In a complex IR and domain environment this function will play a crucial role with respect to the provision of adequate conceptual support to the actual user. Its functional use depends on data aquired by the 'User & Request Model Builders'.

The 'Feedback Generator', as well as the 'System Model Adaptor' and the 'Response Generator', display the fundamental difference between the Monstrat Model and Mediator.

The function assumes a 'System Model' that holds data concerned with conceivable feedback facilities in remote or/and internal softwares. ESA/IRS is not the only European online host with such service facilities. Frequency analysis exists also in other hosts, such as Fitz in Germany, under the name of Select. Several other feedback possibilities are exemplified in Figure 8.6. An interesting aspect of these 'smart' facilities is that they often can be used in two ways: directly to inform and support the user during retrieval; indirectly to check certain intermediate retrieval results internally in the mechanism. The latter case is exemplified under the 'Combine' sub-function. Finally, by applying the remote mainframe programs, mainly for calculation and additional support purposes, one may talk of a kind of parallel processing.

One may not overlook the potentiality of external conceptual structures as supplement to internal conceptual maps. The 'Manipulator' (in the Transformer) is hence intended to process results from external feedback, in order to augment the internal semantic structures. If, for example, a user enters a natural language term not recognized by the internal map, a frequency analysis of that term will produce the preferred index term in the external database within a specific subject area, as shown in Figure 7.9. If neither of the terms are recognized internally, the preferred index term can be stored as part of a structured conceptual net, in relation to the original NL term.

The *Request Model Builder* is separated from the 'User Model Builder' in order to make it possible to manipulate request formulations from an actual user independently of actual user modelling. The function is virtually identical to the Monstrat function 'Problem Description'. However, without a 'User Model Builder' facility the intermediary is reduced to relying on its general 'Domain Model', implying insufficient data in the 'Need Type' sub-function for further action. It will hence be difficult to infer adequately tailored support to the user.

9. REQUEST MODEL BUILDER (Monstrat: Problem Description)

Previous	Determine the user's retrieval processes in relation to actual need (Monstrat); based on 'Mapping' knowledge and/or determined by question to user. Ex.: continue searching on Energy topic (for paper) halted last week;
Request	Obtain request formulation from user (Monstrat: Topic) via 'Transformer' (Dialogue Mode & Input analyst). Specify concepts and/or formal data. Ex.: 'energy production' in the 'EEC'.
Subject	Analyse and determine actual 'Subject Area' (Monstrat); based on 'Domain Model' by use of 'Previous', 'Feedback Generator' or via user pointing to 'Subject Area' → 'DB Select'. Ex.: energy (from 'feedback' from system, instigated by 'Request').
Need Type	Analyse and determine the user's actual type of information need as well as *possible label effect*, based on 'Work task', 'Subtask', and 'User Model Builder' (actual knowledge attributes, goal, search preference) and entered concepts and/or formal (bibliographic) data from 'Request'. According to type, 'Feedback Generator' is invoked. Ex.: verificative; conscious topical; muddled or ill-defined; label effect.
Problem	Determine the problem dimension (Monstrat: Probdim),i.e. determine by questioning/feedback the problem *underlying* 'Request', i.e. provide a new formulation. Possibly related to 'Work task' and 'Subtask' (User Goal & Mode). Ex.: Question: *What are you going to use the information for?* → "To define the relationship of CO2 taxation and local community economy."
Context	Analyse and specify actual *aspects* in *context* in 'Request' and/or 'Problem' to be presented by use of 'Conceptual Map', 'Feedback' and 'Transformer' (Input Analyst) or via *structured questions* to user. Ex.: 'energy production' or 'CO2 taxation' as actual focus of *action;* EEC as 'agent'; what is 'instrumental' role? - or 'object' for action?
Documents	Determine description or content of documents that the user would like to retrieve (Monstrat). Related to 'Subjectlit' (Domain Model). Specify no. of *expected* (parts of) documents and output format, e.g by *weighting* of fields and most important concepts, to be used by 'Retrieval Strategy' and 'Response Generator'. Ex.: governmental reports; conf. papers; publication period (high weight); publication language (low weight).

Fig. 8.7. Sub-functions in the *Request Model Builder* in the Mediator Model.

The idea is to *combine selected data* from 'Work Task' in the Domain Model, 'User Type' and 'User Mode' in the User Model Builder (from 'Knowledge', 'User Goal', 'Search' and 'Preference' in the User Model) with 'Request' and 'Subject' data in order to infer the *actual* information 'Need Type' – *prior to* inference and execution of Retrieval Strategy functions with a 'Query'. The 'Need Type' may be verificative or topical, with or without label effect, or it may be ill-defined or muddled. Often users do not distinguish between topical and verificative searching and do not know that they may provide more adequate information in *subsequent statements* of potential use for later retrieval. The reasons for execution of the 'Problem' and the new 'Context' sub-functions are exactly to obtain such subsequent and need related statements. Tailored conceptual support may, in concordance with the application of the Request Model Builder sub-functions, help the actual user to modify, refine or extend his requirements. A 'Conceptual Map', in addition to remote conceptual support, can then initially be applied in order to back the user's request formulation and problem or interest description. The KIRA system is a simplistic example of a mechanism not performing user model building (Chapter 7.1.3). The I3R and Euromath designs in contrast contain that amount of user model building required to guide adequate conceptual support (Chapter 7.1.1/4).

In contrast to the Monstrat philosophy, the Request Model Builder operates with a differentiation between *information need* statements (the 'what') and *problem* statements (the 'why'), relaxing the ASK assumption, as discussed in Chapter 2.2.

The 'Context' sub-function is added in order to impose structured questions on the user, e.g. on possible semantic values in the statements (Chapter 7.5).

This deliberate *versioning* in a controlled manner of request formulations serves to enhance the poly-representativeness of the state of uncertainty, problem space, and actual state of knowledge of the current user. It minimizes the δ problem (label effects), and increases the probability of reaching out into the Dark Matter in information space.

10. MAPPING

Store Model	Store and adjust (via algorithm) individual 'User Model' characteristics (User Status, Background), 'IR Knowledge', 'Experience', etc. for use next time user accesses mechanism. Apply model to infer specific 'Output Generation' according to 'User Status & Background' as well as 'IR Knowledge'. Ex.: novice +1 time = novice / if researcher (= no finance files); if visitor (= only demo files) / affil.: Nebraska Branch (= E-mail: nielsen@townplan.com).
Map Search	Combine and store actual *search profile* (Request Model Builder & Retrieval Strategy) with possible saved search ('Index'), internal and external 'Feedback' structures, for possible use in next sessions.
Supervisor	Monitor actual user's seeking behaviour and track down possible 'breakdowns' on the user's side which ought not to happen according to other 'Mapping' information on user or information from 'User Model Builder'. Evoke 'Output Generator' ('Explanation'). Ex.: repeated use of a particular action device in mechanism, e.g. an 'activity icon' in a graphical interface; illogical use of mouse-pointer at this stage of IR.

Fig. 8.8. The sub-function *Mapping* in the Mediator Model.

The principles in *Mapping* (Figure 8.8) are not new. However, only very few IR system prototypes operate with facilities to update and store detailed user profiles and knowledge. As mentioned in Chapter 7.1.5, the IR-NLI design attempts to carry out this functionality on a general level. Euromath and I3R contain some of the Mapping utilities, i.e. the 'Map Search' sub-function.

The 'Mapping' functionalities rely on the characteristics in the 'Domain Model' which are mirrored in the 'User Model' and obtained via the 'User & Request Model Building' functions. As in the 'User Model', space should be left for new hitherto unknown user categories or characteristics. A given threshold can be stored which, when exceeded, makes a new category functionable. For instance, a new production line in a company may introduce new types of users with work tasks, goals and preferences altering from the original ones. 'Store Model' and 'Map Search' contain the characteristics as well as the corresponding search profiles. An open neural network technology combined with controlled inference might detect patterns common to users belonging to new categories.

The 'Supervisor' functionality monitors non-expected, uncommon or wrong seeking behaviour. The feature may in addition be used to evaluate interface ergonomics. The sub-function is symmetrical to the 'Evaluation' functionality in the 'System Model Adaptor'.

11. EXPLANATION

Explain	Bring the user's knowledge of IR up to the minimum level necessary for functioning. Ex.: Pls. CLICK YOUR MOUSE ONCE for GETTING ACCESS.
Display	Literal display of some aspect of the [IR] system(s) or mechanism. Ex.: show all internal conceptual feedback possibilities to user on demand.
Inform	Explain the intermediary's intentions to the user, i.e. in a language according to 'Mapping' or 'User Model' knowledge. Ex.: In order to know your level of knowledge ...
Show Model	Compare models that mechanism holds of actual user (Monstrat: Match), by 'Display' of 'Mapping' information of actual user. Ex.: (after a category threshold surpassing in 'Mapping'): Do you often perform this 'XXX' task and these other displayed Work Tasks. Please click on relevant tasks.

Fig. 8.9. The *Explanation* sub-function in Mediator.

The *Explanation* function has kept the Monstrat Model's tasks as sub-functions. 'Display' relies on information stored in the 'System Model' and operates through the 'Transformer' function.

The '*Transformer*' function, Figure 8.10, holds several original stand-alone Monstrat functions, such as 'Input Analyst', 'Dialogue Mode' and 'Output

Generator', since they all manage incoming and outgoing messages. This is a logical reorganization. The Output Generator is extended to continue processing of information already dealt with, for example by the 'Manipulate' sub-function.

12. TRANSFORMER (several Monstrat functions combined)

Input Analyst	Convert input from user into usable structure (Monstrat function), i.e. convert input from 'Request Model Builder' to structures feasible to 'Conceptual Map', 'Retrieval Strategy', o.a. functions. Ex.: CO_2 Taxation → CO_2 TAX?; EEC=institution → CS=EEC; find stopwords; keep prepositions between request terms and convert: Tax on Oil → Oil Tax..
Dialogue Mode	Determine appropriate user dialogue type (Monstrat Function), i.e. according to result in 'User Model Builder'. Dialogue form is initiated in a default mode which may be adjusted in 'Mapping'. May be picked by the user. Ex.: form-based menues with windows; hypertext; NL input; iconic and metaphoric; combinations;
Index	Perform internal text representation of information from 'Download', 'Feedback', 'User Model & Request Model Builders', transformed for further use by mechanism , e.g. 'Manipulate'. Ex.: index saved search profile; index frequency analyses + request terms; validate terms by use of thesaurus; extract index terms from mark-up text.
Manipulate	Transform data from 'Download', 'System Model Adaptor', 'Feedback' or external paper-based sources (e.g. via SMGL standard) into usable structures in mechanism, e.g. in 'Conceptual Map' or 'System Model'. Ex.: keep only pre-determined downloaded fields for 'Indexing'; rank downloaded records according to internal 'IR technique', e.g. probability; mark scanned documents.
Output Generator	Determine the output requirements (Monstrat function), i.e. specify and transform to user data from other functions (Explanation, Response Generator, Conceptual Map, 'User Status', etc.) according to 'Dialogue Mode' and 'Request Model Builder' information. Ex.: display window with Zoom result, explaining its semantics; highlight 'view more results?'-option; display 'Request' formulations and 'Query' on screen simultaneously.

13. PLANNER

Plan	Specify the plan for all structures of activity according to implemented rules.

Fig. 8.10. Sub-functions in the *Transformer and Planner* functions in the Mediator Model.

The contribution in relation to the 'Transformer' is to add the *'Manipulate'* sub-function which is a consequence of the existence of Download, System Model Adaptor and Feedback Generator. The philosophy is to be able to tailor output from external sources to internal use, e.g. as outlined previously in relation to external feedback or downloaded records. Without this functionality and the 'Index' utility (Sparck Jones, 1987), the introduction of, for instance, extended Boolean logic or clustering of downloaded documents would not be possible.

The 'Input Analyst' and 'Manipulate' sub-functions are symmetrical input managers. 'Manipulate' may also serve to mark-up documents that are scanned, e.g. by use of the SGML standard.

The 'Index' sub-function in the 'Transformer' may subsequently apply given algorithms to represent the text by extracted and validated terms and other relevant data. The SIMPR Esprit Project contains these functionalities which produce socalled 'analytics', i.e. index term phrases, from scanned documents. Similarly, requests are analysed to produce request analytics (Chapter 7.5).

The '*Planner*' functionality depends on the chosen design implementation. In a blackboard architecture it would be required, for instance as in the I3R system in which the function is called 'scheduler'. Under the name of 'central manager' in object oriented designs, the 'Planner' serves to instigate execution of actions on objects. In purely supportive and often sequential systems designs its role would be minimized and taken over by the user. The degree of functionality in such a case would depend on the strength of the system's domain, system, and user models.

8.2 The use of the framework

Mediator may be used for three different purposes in relation to IR intermediaries:

* *Analysis and design*
* *Assessment*
* *Education and training*

In relation to *analysis and design* of intermediary mechanisms the model is primarily intended to serve two goals: 1) to provide designers with a scheme which pin-points the basic questions to be answered; 2) to point to a variety of combinations of functions, or building blocks, that may result in different designs for radically different purposes. Compare also the different objectives of the intermediary designs shown in Figure 7.8.

With respect to the first goal for design, one must again emphasize that the Mediator framework is developed for complex domains and IR environments. Obviously, certain functions will be reduced in scope if a design is supposed to be local only, for example in line with the stand-alone design cases (Figure 7.8, row 1). Hence, the domain may often be narrow. However, it is recommended that *cognitive task modelling* of the domain and its users always should be performed (Figure 8.11). Chapter 6.3 points to several recent contributions in this area. By neither accommodating any Domain nor a User Model, User Model Building becomes rather futile. No user knowledge attributes would be in existence, from which to build an *actual* model of the user. In this case, we are dealing with a version of the case 6 design (OAKDEC) (Figure 7.1). This kind of design is strictly supportive, but may in addition carry out very simple Request Model Building, as in EasyNet and IANI. With a Conceptual Map held by the mechanism, it may improve its conceptual support, as in the KIRA system. Another reason for performing cognitive task modelling is that *adaption* to changed conditions in the environments is more easily performed when based on the hitherto known prerequisites.

If the cognitive task modelling principle – the blue-print concept – behind the Mediator model is followed, we are now in possesion of a *variety* of possibilities for design, each depending on its purpose.

The functions can be viewed symmetrically, centered around the intermediary's internal nucleus constituted by the *triangular* interactive processes taking place intrinsically in the intermediary's cognitive model (Figure 6.4, centre). In this figure the intermediary's Conceptual State of Knowledge (on top) communicates interactively with its State of IR Knowledge (lower left side) and its dynamic and actual Picture of the User and Need (lower right side).

Figure 8.11 demonstrates this triangular view and displays three 'levels': Cognitive task modelling, Cognitive adaption, and IR effectiveness, the latter two levels being viewed as serving various design goals.

	1. DOMAIN MODEL		
2. SYSTEM MODEL		**3. USER MODEL**	**Cognitive task modelling**
4. SYSTEM MODEL ADAPTOR		**5. USER MODEL BUILDER**	**Cognitive adaption**
6. RETRIEVAL STRATEGY	**9. REQUEST MODEL BUILDER**		
7. RESPONSE GENERATOR	**12. TRANSFORMER**	**10. MAPPING**	**IR effectiveness**
8. FEEDBACK GENERATOR	**13. PLANNER**	**11. EXPLANATION**	

Fig. 8.11 Three-level global framework of Mediator functions in IR intermediary mechanisms

The level of *Cognitive adaption* holds two symmetrical and *actual* model builders. Without the necessity of remote IR systems linked to the mechanism, the System Model Adaptor block is obsolete. However, in the case of use of remote sources the design is only fully adaptive with both blocks. Such designs have not yet seen light in the IR environment. One may easily envisage designs without any adaptability, for instance complex but local in-house systems that are 'support only' mechanisms, like the Bookhouse. By recognition of his own transparent User Model, the user performs the adaption to the (pre-adapted) system himself. If designed adequately, both system and user share common models of one another.

On the *IR effectiveness* level several combinations can be imagined. The minimum necessary functions in the framework are the System Model, Retrieval Strategy, Response Generator, Request Model Builder (simple), Transformer, and Planner. One may thus enhance the supportiveness of a design by use of a Feedback Generator, provided that a Conceptual Map and/or remote host facilities exist. Their properties are known via the analysis connected to the System Model sub-functions.

One may add the Mapping block in order to save frequent users' time. Explanation may be installed to smooth interaction. Single sub-functions may be set or removed from a design, in order to underline specific functional purposes.

However, several sub-functions are functionally connected and ought not to be scattered. One may, for instance, approach the model from a connectionist point of view. Tight functional relations exist between all the right-hand side functions in the triangle, i.e. from the Domain Model (1) right down to Explanation (11). In a stand-alone IR system these functional design blocks would constitute what in general is called the user *interface functionalities*. Similarly, strong connections abide between the Domain Model down to the Feedback generator (8), at the left-hand side of the Mediator framework. These design blocks compose a *machine* or system *interface*.

With respect to *assessment* the framework may serve analytic evaluation of functionality. The framework is more detailed than the table (Figure 7.1), and may be used in verificative assessments. Furthermore, it may provide a guide to the *transfer* of functionalities from one domain to another. Certain features, in particular related to the cognitive modelling level, may associate to Rasmussen et al.'s taxonomy (1990), referred to in Chapter 6.3.4. Functional use validations are possible by applying the model as a foundation for empirical studies of IR interaction behaviour. Further, it can be utilized as a scheme for classification and clarification of methodologies applied to IR products.

The third application area – *education and training* – contains two dimensions: a human and a machine dimension.

In the education of information scientists and IR specialists the framework may be employed to teach methods and problems in relation to the design and evaluation of interfaces and intermediary mechanisms, even though the framework presupposes substantial IR knowledge. In addition, the functions point to some aspects of retrieval that are more rarely touched upon in the education of information scientists: the need for more intelligent use of existing systems' potentialities and the recommendation of improved explanation to users. Also, the framework points to more active domain and user modelling of the work place, bridging IR and information management processes.

The machine learning dimension is interesting since several functions of the model may be used as frames in this respect. Chapter 7.1.5 discussed a machine learning experiment, combining the I3R and IR-NLI approaches, in order to make a system learning to build a detailed User Model in a specific domain. One may easily visualise experiments with System Model Adaptors in relation to Retrieval Strategy, attempting to teach the mechanism new retrieval strategies within particular IR techniques. Likewise, one may envisage experiments with automatic enhancement of internal conceptual structures, based on user and remote system input.

9. CONCLUSIONS

The discussions in this book demonstrate that information retrieval R&D develops into three fundamental approaches, a classic or traditional, a user-oriented and a cognitive approach. This tripartite taxonomy characterizes the different goals and foci displayed during three decades of IR research activities. Currently, all three research views run in parallel, and one may conclude that by being preoccupied with the retrieval processes in IR systems, the traditional approach demonstrates the most profound paradigmatic force retrospectively. However, it is undergoing changes towards understanding and modelling of domains and users, in order to produce innovative IR concepts and ideas.

Also the user-oriented approach is increasingly turning toward more cognitive and behavioural aspects of IR interaction situations, directly aimed at interface design. The emerging cognitive approach to IR research is seen as a natural extension of the two prevailing IR approaches, gradually integrating into one. It walks hand in hand with recent developments in the field of artificial intelligence and systems science, attracting scholars from both fields and IR.

A second aim of this book was to investigate and discuss the role of intermediary mechanisms in IR interaction. Empirical as well as analytic evidence clearly demonstrate the central position of the intermediary. Regardless of whether in a partial match or an exact match environment, effective IR performance requires an adaptive and supportive component that may mediate conceptual structures as well as models of one another from user to underlying IR systems and informations sources, and vice versa. One may conclude that the fundamental role of the knowledge-based intermediary mechanism is to provide the actual user with adequate and sufficient means to use *his own* intelligence, associative power, and decision making capabilities during retrieval.

Hence, a third aim became to construct a global framework of intermediary functions. The *Mediator Model* is deeply indebted to previous and contemporary results of colleagues, combined with the author's own empirical investigations and analytic contributions. By considering *all* the participating knowledge structures in the entire IR interaction process, and isolating the fundamental knowledge elements internal to an intermediary, Mediator evolves around 13 integrated functions on three levels, and 54 subfunctions.

The underlying principles refer to the concepts of adaption, supportiveness and transparency. In addition, the Mediator Model is intended to be applied to complex domain and IR environments with a variety of users involved in information retrieval. These principles are illustrated by its three-level construction. Ideally, total adaptability involves interaction with the actual user, *as well as* actual model building of (often remote and rather unknown) IR systems. Without a degree of adaption and transparency, a supportive user modelling approach to intermediary design cannot be achieved in complex domains. From a cognitive viewpoint the alternative 'intelligent IR' approach is unachievable if the its aim is to make intelligent retrieval by the mechanism itself. The reason is that a 'drop' constantly takes place from a cognitive, human and intelligent level *outside* the system, down into a monadic, structural or contextual level of information processing, metaphorically speaking, *inside* the system. Since information goes beyond meaning, even full-proof machine translation will not get IR research further.

Hence, user and request modelling, as well as other functions leading to inference are primarily seen as integrative instruments for providing dedicated and structured *feedback* of a conceptual nature to support the user on his cognitive level.

Because of their holistic characteristics the Mediator functions are viewed as building blocks that may be added together according to specific design objectives. The framework is thus recommended primarily to serve as a tool for analysis, design as well as assessment of intermediary mechanisms and IR products.

The discussions in previous chapters concerning the differences between the cognitive view, hermeneutics, and cognitivism demonstrate clearly the more comprehensive scope underlying the cognitive viewpoint. Based on this epistemological view, it is the author's opinion that fruitful prospects exist to generate an IR theory founded on the idea of acceptence of contextualisation and uncertainty in IR, which may provide a unifying framework for further progress of the field. To this end, the author has found it essential to propose a refined concept of information for information science, which introduces conditionals as to when to talk about information, on both the sender and the recipient side, at the event of information transfer.

Although certain differences exist between hermeneutics and the cognitive viewpoint, the major incongruities being concerned with the interpretations of the concepts of 'representation' and 'cognitive models', the cognitive viewpoint in IR is seen as closely related to hermeneutic philosophy. The comprehensive nature of the viewpoint is founded in its explicit recognition of cognitive structures embedded in information systems. Consequently, the viewpoint, as well as the cognitive approach to IR research, cannot and will not exclude confirmed rationalistic solutions to the variety of problems raised in IR interaction.

The challenges in IR research are *to define combinations* of classic IR solutions, *poly-representation, contextualisation, and interaction that are relevant to particular information need manifestations and user knowledge levels*, as well as to encompass *adaptivity, flexibility, supportiveness, and transparancy* in IR systems design.

The logical next step in information research is to enhance IR theory *beyond adaptivity* at a contextual level of information processing into a level of truly knowledge-based *self-regulation* at a cognitive level. According to the discussion of De Mey's (1977) evolutionary 'four stages' of information processing (Chapter 2.1), this self-regulatory behaviour requires 'self-generated expectations', or non-imposed pre-suppositions, that are produced by the processing device itself. The paradox is that man is competent of both adaption and self-regulatory mental behaviour; but in case of that the processing device is a machine, man has so far not found means to augment its 'behaviour' beyond adaption. Hitherto, we have not been intellectually capable of conceptualising that situation – nor in a technological sense. Essentially, the question is: how do we regulate ourselves to the unknown?

Meanwhile, it is important to emphasise that both individualistic cognitive and linguistic *as well as* socio-behavioural processes are heavily involved in and influencing IR interaction. As a consequence of this *inherent complementarity* of these scientific approaches, the variety of related qualitative and quantitative investigative methods must be applied to research scenarios in dedicated *supplementary combinations.*

A final aim of this publication has been to suppress the belief that only one method of investigation and evaluation, of representation, IR technique, communication, and intermediary design is the optimal one in IR research. Such isolated attempts have proven to be dead ends for the field. Because of the nature of unstructured data in the form of texts, graphics, images, etc., and the individual qualities of potential users, the answer is to assess the conditions as to when, how and why to synthesize specific retrieval elements with particular means of representation, and definite combinations of intermediary functionalities. The underlying conditions are found outside the proper systems. The vortex is where persons obtain and make use of information.

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DEFINITIONS

Aboutness. Fundamentally, the concept refers to 'what' a document, text, image, etc. is about, and the 'who' deciding the 'what'. Several definitions exist. In this book, aboutness is dependent on the individual who determines the 'what' during the act of representation. Aboutness is divided into *author aboutness, indexer aboutness, user aboutness,* and *request aboutness* (p. 50)

Author aboutness. The *aboutness* determined by the author through natural language representation, e.g. by the use of a variety of partial match techniques or other NLR methods. For instance, an author-generated abstract mirrors author aboutness. If the method of representation transforms terms or concepts, the aboutness is *indexer aboutness* (p. 50).

Categorial classification (or relations). To categorize objects of any kind in a hierarchical and abstract manner, e.g. by means of generic or part-whole relationships. Individuals performing categorial classification selects an abstract concept and choose the objects which can be included under this concept. For example, a person chooses 'tools' to cover hammer and saw. Related to *situational classification*. (p. 128–129).

Cognitive model (individuals). A model of the individual itself and its environment, images, expectations, emotions, intentionality, experiences, imagination, intuition and values, as well as *conceptual knowledge* of domains, including affective domains, cognition, perception, and *work space, state of knowledge, problem space,* and *state of uncertainty* (p. 131–133).

Cognitive models (of IR activities or information systems). Models demonstrating the influence and interaction of *knowledge structures* (or cognitive structures) taking part in information transfer and *IR interaction*, or being imbedded in *IR systems* or *intermediaries* (p. 134).

Cognitive structures, see *Knowledge structures*

Cognitive viewpoint. An epistemological view. Its central point is that any processing of *information*, whether perceptual or symbolic, is mediated by a system of categories or concepts which, for the information processing device, are a model of his/its world – whether the device is a human or a machine. According to this view, the 'world model' consists of *knowledge structures* (or cognitive structures), which are determined by the individual and its social/collective experiences, education, etc. The cognitive viewpoint is born out of investigations of human mental behaviour; computers (and their behaviour) are seen as non-semantic manifestations or simulations of certain human mental processes, but not all (p. 16–19).

Cognitivism. The epistemological view that the brain is (regarded as similar to) a digital computer and that the human mind is (regarded as similar to) a computer program. According to this view, and in contrast to the *cognitive viewpoint*, the thinking process is information processing, that is, symbol manipulation only, and human mental activities are carried out as if they are processed in computers. Cognitivism does not claim, unlike the related position of 'strong AI', that computers have feelings and thoughts (p. 19–25).

Conceptual knowledge. *Knowledge* of domains, work tasks, topics, concepts and concept relations, as well as emotions, intentionality, expectations, and experiences (p. 36, 136–145).

Delta problem (δ-problem). The empirical fact that a conceptual 'distance' often exists between an information need, as represented in the actual user's mind, and the user's *request* formulation(s). Requests may consequently take the form of *labels* (p. 116–118).

Episodic memory. Those parts of the human memory (long term memory) which refer to *knowledge* of (or *information* about) particular events experienced by the individual. The concept is related to *semantic memory*, and is eventually intermingled with *situational* and *categorial classification* (p. 124).

Front-end. An *intermediary* mechanism placed (locally) in front of one or several remote online hosts' *IR systems*, and providing access to such systems. Often, it may support the user conceptually during retrieval of *potential information* from the host(s)' databases and information systems. In this book the term 'front-end' is not used, but replaced with the concept *intermediary* mechanism.

Indexer aboutness. The *aboutness* determined by an indexer or indexing device, implying a natural language analysis which results in a transformation of original terms and concepts into those accepted by the indexer or indexing device. The use of controlled vocabularies or a thesaurus will result in indexer aboutness (p. 51–52).

Information. The concept of information, from a perspective of information science, has to satisfy dual requirements: on the one hand information being the result of a transformation of a generator's *knowledge structures* (by intentionality, model of recipients' states of knowledge, and in the form of signs); on the other hand being something which, when perceived, affects and transforms the recipient's *state of knowledge*. Information is seen as supplementary or complementary to a conceptual system that represents the information processing system's *knowledge* of its world. If only the first condition is met, we are talking about *potential information*, i.e. data or similar entities stored in *IR systems*, that is of potential value to recipients (whether humans or machines) (p. 30–37).

Information retrieval. The processes involved in representation, storage, searching, finding, and presentation of *potential information* desired by a human user (p. 49).

Information space. That part of information systems which consists of *potential information* associated with the *system objects*, structured according to the *system setting*. In the case of *intermediary* participation, the space is extended with this component's *knowledge structures* (p. 134–136).

Intelligent IR. A particular approach to *knowledge-based IR* which attempts to solve *information retrieval* problems by application of expert system-like solutions. Intelligent IR relies heavily on user and request model building (*pre-search interviewing*) prior to automatic retrieval inference, and builds on the idea of real natural language understanding with respect to *requests* as well as to the intrinsic language processing (p. 178–181).

Interface, see *User interface*

Intermediary (human or machine). A person or a mechanism placed physically between *IR system(s)* and actual user with the purpose to transform interactively *requests* for information into *query* formulations that suit the retrieval components of one or several IR systems, to model and support the actual user as to his information need and underlying goals, and to provide information of potential value to that user from IR systems. These and other functionalities are dependent on the actual level of the *conceptual knowledge,* IR knowledge, and communicative skills present in the mediating person or mechanism. The functionalities particularly addressing the user are named the *user interface*. The intermediary may be placed locally as a *front-end* to one or several IR systems, or it may be in full control of (being part of) the underlying IR system's *system setting* and *system objects* (stand-alone systems) (p. 87–91, 136–140).

IR interaction. The interactive communication processes that occur during retrieval of *information* by involving all major participants in IR, i.e. the user, the *intermediary*, and the *IR system* – the latter consisting of *potential information*, mainly in the form of text and text representations as well as IR *system setting* (p. 134).

IR system. An information system which is constituted by interactive processes between its *system objects, system setting*, and the environment, capable of searching and finding *information* of potential value to an actual searcher of information (p. 16, 147–148).

Knowledge. An individual's total understanding of itself and the world around it at any given point in time, incorporating (sub)conscious memory, thinking and cognition, as well as emotional and intuitive properties. *Knowledge* is *structured* in a variety of ways and displays semantic as well as pragmatic characteristics. In contrast to computers and other man-made mechanisms storing data, human knowledge and knowledge structures are capable of self-regulation and acute, non-predetermined transformations, based on self-generated expectations. Being perceived, *potential information* may, in the form of *information*, affect and transform knowledge (p. 30–34).

Knowledge-based IR. The *cognitive viewpoint* applied to *IR interaction* in IR research and applications. The concept implies viewing all communication processes that occur during *information retrieval*, as interactive processes between the individual *knowledge structures* implemented in *IR systems* and *intermediaries*, as well as forming part of an actual user's *cognitive model* (p. 160–202).

Knowledge structures. (or cognitive structures). The system of categories and concepts which, for an information processing device – whether human or machine – constitute his/its model of the world, i.e. the *knowledge* of the device. At any given point in time, the actual knowledge structures are determined by the individual and its social/collective experiences, education, etc. In *information retrieval* one may operate with *conceptual knowledge* as well as 'IR knowledge', that is, knowledge of *System setting* and IR processes, i.e. knowledge of search strategies, request modelling, IR tactics, etc. (p. 16, 135–140).

Label effect. The phenomenon that *request* formulations may often consist of one or several concepts which are of a more general nature or out of the context which constitutes the real information need. Thus, the label effect is a manifestation of the *delta problem* p. 116–118).

Potential information. Those data structures which are the result of a transformation of a generator's *knowledge structures* (by intentionality, model of recipients' states of knowledge, and in the form of signs). *IR systems* contain potential information, or *information* metaphorically speaking, that is, information of potential value to recipients. When perceived, it may affect and transform the recipient's current *state of knowledge*. Only if effect and transformation take place has the system provided information (p. 31–33).

Pre-search interview. The preliminary stage during *information* seeking in which the *intermediary*, without actually interrogating the *IR system(s)*, communicates with the user in order to obtain request formulations, to define the information need and subject areas (for database selection) of relevance to that need, and to model the actual user's attributes and goals. The objective underlying pre-search interviewing is to carry out request and user model building prior to actual (often costly) retrieval performance. During the proceeding *information retrieval* processes, the communication between user, intermediary and IR system(s) is called 'search interviewing' (p. 105–112).

Problem space (individuals). A situation specific state of mind in which the individual recognizes lack of *knowledge*, e.g. in order to choose between possibilities of action, of solution to problems, or in relation to fulfilment of factual or emotional goals. The problem space forms part of the actual *state of knowledge* and the *cognitive model* of the individual at any given point in time and may change properties through time (p. 27–28, 131–133).

Query. A transformation of a *request* formulation made by an *intermediary* (mechanism) in order to interrogate an *IR system*'s conceptual objects. Boolean expressions, as well as the result of NLP or partial match technique algorithms, are regarded as queries. Only if no transformation takes place are the request and query identical concepts (p. 56).

Request. The formulation of the information need, or the underlying goals, as provided by the actual user to an *intermediary* or directly to an *IR system*. If directly formulated according to an IR system's retrieval technique, the request is identical to a *query* (p. 56).

Request aboutness. The *aboutness* of the *request* formulation. If not transformed into any new structure or concepts, the aboutness is determined by the user. If a transformation takes place during processing of the request, e.g. by the *IR system* or the *intermediary*, the aboutness is related to *indexer aboutness*, and the request transforms into a *query* (p. 52, 56).

Semantic memory. Those parts of the human memory (long term memory) which refer to the class of *knowledge* (or *information*) characterized by the definitions of concepts that people have acquired during their experiences of the world. Semantic memory is dependent on the individual's socio-cultural experiences, education, etc., and may demonstrate conceptual relations and definitions shared by many individuals (collective *cognitive structures*), e.g. within particular social groups. The fundamental role of, for instance, primary schools and universities is to generate shared knowledge and semantic memory (p. 124–140).

Semantic values. Linguistic interpretations of a sentence in a text. Through (morpho-)syntactic analysis, one or several possible 'explicit' interpretations can be made out of a sentence. For example, the sentence 'Time flies like an arrow' may contain at least four different explicit semantic values. For each explicit value a set of 'implicit' semantic values may exist:the user-generated associative interpretations; the potential values (meanings), generated by that additional context which is not present in the explicit value. The former implicit value refers to interpretations associated by a reader, e.g. that 'time flies' (insects) like (to approach) the (flower called) 'arrow'. The second implicit value type refers to the lack of syntactic roles, e.g. the time-place roles in the sentence. For instance, that the 'time flies' only like to approach the 'arrow' in the month of 'May' (p. 196–198).

Situational classification (or relations). To categorize objects of any kind in a process or event-related structure of concepts. Individuals performing situational classification involve the objects in different concrete situations, thereby grouping objects together, e.g. 'hammers are used to hit nails driving them into wood when building houses'. 'Related terms' in a thesaurus consist mainly of situational relations. Related to *categorial classification* (p. 128–129).

State of knowledge (individuals). The state of the individual's *cognitive model* and *work space* which, at a given moment, holds what is known and emotionally experienced by the individual, including its attention, actual intentionality, as well as its *problem space* and *state of uncertainty* (p. 131–133).

State of uncertainty (individuals). A state of conscious doubt in which the individual's own *state of knowledge, work space* and *cognitive model* cannot fill the *problem space* by thinking, causing interaction with the world around it to obtain supplementary *information*, e.g. by accessing an *IR system* (p. 27–28, 131–133)

Supportive IR. An approach to *knowledge-based IR* which aims at making use of the actual user's own cognitive capacities, intuition, and intelligence during retrieval of information. User and request model building, as well as inferential techniques, are basically applied in order to provide conceptual and retrieval support to the actual user (p. 164–171).

System objects. The items of a structured conceptual nature stored in an *IR system*. Two basic types of system objects exist: representations of contents of text or pictures generated by means of interpretation and indexing through application of relevant rules or algorithms in the *system setting*; the entire texts, pictures, or other conceptual manifestations of *information of potential* value to individuals (p. 16–17).

System setting. Structures implemented in *IR systems* representing the systems designers' conceptions of how to process the *system objects*, e.g. IR techniques, indexing rules, database structures, selection policy, etc. (16–17, 136–138).

User aboutness (or user-related aboutness). That *indexer aboutness* which attempts to tailor representations of documents, texts, images, etc. to known pre-suppositions of the users in domain(s). User aboutness implies providing points of contact from the known to the desired information, e.g. by the use of a different indexing vocabulary for each of several different potential user groups, also taking into account the potential use of *information* presented in each item (p. 52).

User interface. The functionalities of an *intermediary* (mechanism) directed towards the user of an *IR system*, e.g. user and request model building and analysis, explanation facilities, interrrogation devices, etc. If no intermediary (mechanism) participates in the *IR interaction* processes, the user interface consists only of the 'display' and interrrogation (command) facilities provided by the IR system(s) (p. 222).

Work space (individual). The individual's *cognitive structures* associated with external work domains, work tasks, and information systems, activity, goals, preferences and interests related to domains, information seeking behaviour, problem solving, decision making, and actual *state of knowledge*. The work space forms part of the individual's *cognitive model* (p. 131–133).

REFERENCES

References are entered after first author or editor. Common abbreviations are used for the following bodies, journals and annual periodicals:

ACM/SIGIR:	Association for Computing Machinery/Special Interest Group for Information Retrieval.
ARIST:	Annual Review of Information Science and Technology. White Plains, NY: Knowledge Industry Publishers.
ASIS Proc.:	American Society for Information Science, Annual Meeting Proceeding.
IRFIS:	International Research Forum for Information Science (1977–1985).
JASIS:	Journal of American Society for Information Science.
Journ. of Doc:	Journal of Documentation.

ALBRECHTSEN, H. (1990). Software concepts: knowledge organisation and the human interface. In: R. Fugmann (ed), *Advances in Knowledge Organisation*. Vol. 1, p. 48–53.

ALLEN, T.J. (1969). Information needs and uses. *ARIST*, 4, p. 3–31.

ARTANDI, S. (1973). Information concepts and their utility. *JASIS*, 24, p. 242–245.

ATHERTON-COCHRANE, P. (1978). *Books are for Use: Final Report of the Subject Access Project*. Syracuse, NY: Syracuse University, School of Information Studies.

ATHERTON-COCHRANE, P.A. (1981). *Tasks Performed by Online Searchers in Presearch Interviews: A Report of the Presearch Projects*. Syracuse: School of Information Studies.

AUSTER, E. (1983). User satisfaction with the online negotiation interview. *Reference Quarterly*, 23, p. 47–59.

BARNES, M. (1980). Relationships between public library staff and users. *Crus News*, 9, p. 6–9.

BARTLETT, F.C. (1932). *Remembering: A Study in Experimental and Social Psychology*. Cambridge University Press.

BATES, M.J. (1979a). Information search tactics. *JASIS*, 30(4), p. 205–214.

BATES, M.J. (1979b). Idea tactics. *JASIS*, 30, p. 280–289.

BATES, M.J. (1981). Search techniques. *ARIST*, 16, p. 139–169.

BATES, M.J. (1985). An exploratory paradigm for online information retrieval. In: B.C. Brookes (ed). *Intelligent Information Systems for the Information Society*. Proc. of IRFIS 6, Frascati 1985. London: North-Holland, 1986. p. 91–99.

BATES, M.J. (1989). The design of browsing and berrypicking techniques for the online search interface. *Online Review*, 13(5), p. 407–424.

BATES, M.J. (1990). Where should the person stop and the information search interface start? *Inf. Processing & Management*, Vol. 26 (5), p. 575–591

BEATTIE, G.W. (1981). Cognitive psychology and conversational analysis: Their application to user-librarian negotiations and information search procedures. *Social Science Information Studies*, 1, p. 121–127.

BELKIN, N. (1977). *A Concept of Information for Information Science*. London: University of London. Doctoral dissertation.

BELKIN, N. (1978). Information concepts for information science. *Journ. of Doc.*, 34, p. 55–85.

BELKIN, N. (1983). *Recent trends in information science research in the UK, USA, and Canada*. Berlin: Project Instrat, Overview of Research Development. Internal report, 12p.

BELKIN, N. (1984). Cognitive models and information transfer. *Social Science Information Studies*, 4, p.111–129.

BELKIN, N. (1988). On the nature and function of explanation in intelligent information retrieval. In: Y. Chiaramella (ed), *ACM/SIGIR Conf. Proc.* Grenoble: Press Universitaires de Grenoble. p. 135–146.

BELKIN, N. (1990). The cognitive viewpoint in information science. *Journ. of Information Science*, 16(1), p.11–16.

BELKIN, N. et al. (1987). Distributed expert-based information systems: an interdisciplinary approach. *Inf. Processing & Management*, 23(5), p. 395–409.

BELKIN, N., Brooks, H. & Daniels, P. (1987). Knowledge elicitation using discource analysis. *Int. Journ. of Man-Machine Studies*, 27, p. 127–144.

BELKIN, N. & Croft, W.B. (1987). Retrieval techniques. *ARIST*, Vol. 22, p. 109–145.

BELKIN, N. & Kwasnik, B. (1986). Using structural representations of anomaleous states of knowledge for choosing document retrieval strategies. In: F. Rabitti (ed), *ACM/SIGIR Conf. Proc.* Pisa: Pisa University. p. 11–22.

BELKIN, N. & Marchetti, P.G. (1990). Determining the functionality and features of an intelligent interface to an information retrieval system. In: J.-L. Vidick (ed), *ACM/SIGIR Conf. Proc.* Bruxelles: Bruxelles University. p. 151–178.

BELKIN, N., Oddy, R. & Brooks, H. (1982). ASK for information retrieval. *Journ. of Doc.*, 38, p. 61–71 (Part 1); p. 145–164 (Part 2).

BELKIN, N. & Robertson, S.E. (1976). Information science and the phenomena of information. *JASIS*, 27, p. 197–204.

BELKIN, N., Seeger, T. & Wersig, G. (1983). Distributed expert problem treatment as a model for information systems analysis and design. *Journ. of Information Science.*, 5, p. 153–167.

BELKIN, N. & Vickery, A. (1985). *Interaction in Information Systems.* London: British Library. (LIRR, 35).

BELLARDO, T. (1984). *Some Attributes of Online Search Intermediaries that Relate to Search Outcome.* Drexel University. Dissertation.

BENNETT, J.L. (1972). The user interface in interactive systems. *ARIST*, 7, p. 159–196.

BJØRN-ANDERSEN, N. (1974). *Informationssystemer for Beslutningstagning*. København: Busck. Doctoral dissertation.

BLACKSHAW, L. & Fischhoff, B. (1988). Decision making in online searching. *JASIS*, 39, p. 369–389.

BLAIR, D.C. (1990). *Language and Representation in Information Retrieval*. Oxford: Elsevier.

BLISS, H.E. (1929). *The Organization of Knowledge and the System of Science*. New York, Holt.

BOBROW, D. & Collins, A.M. (1975) (eds). *Representation and Understanding: Studies in Cognitive Science*. New York, NY: Academic Press.

BODEN, M. (1977). Cognitive science: an integrative approach to the mind. In: *CC 77: Int. Workshop on the Cognitive Viewpoint.* Ghent: Ghent University. p. 225–228.

BOOKSTEIN, A. (1985). Probability and fuzzy-set applications to information retrieval. *ARIST*, vol. 20, p. 117–151.

BORGMAN, C. (1986). The user's mental model of an information retrieval system: an experiment on a prototype online catalogue. *Int. Journ. of Man-Machine Studies*, 24(1), p. 47–64.

BORGMAN, C. (1989). All users of information retrieval systems are not created equal: an exploration into individual differences. *Inf. Processing & Management*, 25(3), p. 237–252.

BORKO, H. & Bernier, Ch.L. (1978). *Indexing Concepts and Methods*. New York, Academic Press.

BOULDING, K.E. (1971). *The Image*. Michigan: Michigan University Press.

BRADFORD, S.C. (1934). Sources of information on specific subjects. *Engineering*, 137, p. 85–86.

BRAJNIK, G., Guida, G. & Tasso, C. (1987). User modelling in intelligent information retrieval. *Inf. Processing & Management*, 23(4), p. 305–320.

BROOKES, B.C. (1975). The fundamental problem of information science. In: V. Horsnell (ed), *Informatics 2.* London: Aslib. p. 42–49.

BROOKES, B.C. (1977). The developing cognitive viewpoint in information science. In: *CC-77: Int. Workshop on the Cognitive Viewpoint*. Ghent: Ghent University. p. 195–203.

BROOKES, B.C. (1980). The foundations of information science: Part 1: Philosophical aspects. *Journ. of Information Science*, 2, p. 125–133.

BROOKS, H. (1986a). *An Intelligent Interface for Document Retrieval Systems: Developing the Problem Description and Retrieval Strategy Components*. London: City University. PhD thesis.

BROOKS, H. (1986b). Developing and representing problem descriptions. In: Brookes, B.C. (ed), *Intelligent Information Systems for the Information Society*. Amsterdam: North-Holland. p. 141–161.

BROOKS, H. (1987). Expert systems and intelligent information retrieval. *Inf. Processing & Management*, 23(4), p. 367–382.

BROOKS, H., Belkin, N. (1983). Using discourse analysis for the design of information retrieval interaction mechanism. In: *ACM/SIGIR Conf. Proc.* New York: ACM, p. 31–47.

BURCH, J. & Grudnitski, G. (1989). *Information Systems: Theory and Practice.* 5th. ed. New York, NY: Wiley & Sons.

BYRNE, R. (1977). Planning meals: problem solving on a real database. *Cognition,* 1, p. 287–332.

BØDKER, S. (1989). A human activity approach to user interfaces. *Human-Computer Interaction*, 4, p. 171–195.

BØGH ANDERSEN, P. (1990). *A Theory of Computer Semiotics*. Cambridge: Cambridge University Press. Doctoral dissertation.

CAPURRO, R. (1992). What is information science for? – A philosophical reflection. In: B. Cronin and P. Vakkari (eds.). *Conceptions of Library and Information Science. Proc. of the First CoLIS Conf.*, Tampere, August 1991. London: Taylor Graham (in press).

CHEN, H. & Dhar, V. (1990). Online query refinement on information retrieval systems. In: J.-L. Vidick (ed), *ACM/SIGIR Conf. Proc.* Bruxelles: Bruxelles University. p. 115–132.

CHERRY, C. (1957). *On Human Communication: a Review, a Survey, and a Criticism*. Cambridge, Mass.: MIT Press. 2. ed. 1966.

CICOUREL, A.V. (1973). *Cognitive Sociology, Language and Learning in Social Interaction*. Harmondsworth: Penguin.

CICOUREL, A.V. (1977). Cognitive and linguistic aspects of social structure. In: *CC 77: Int. Workshop on the Cognitive Viewpoint*. Ghent: Ghent University. p. 1–7.

CLEVERDON, C.W. (1974). User evaluation of information retrieval systems. *Journ. of Doc.*, 39(2), p. 170–179.

CLEVERDON, C.W., Mills, J. & Keen, M. (1966). *Factors Determining the Performance of Indexing Systems. Vol 1: Design; Vol 2: Test results.* Cranfield, UK: College of Aeronautics.

COATES, E.J. (1983). *BSO Referral Test. FID/BSO Panel. Final Report*. Haag: Internaltional Federation of Documentation.

COCHRANE, P.A. see ATHERTON-COCHRANE, P.A.

COHEN, P.R. & Kjeldsen, R. (1987). Information retrieval by constrained spreading activation in semantic networks. *Inf. Processing & Management*, 23(4), p. 255–268.

COOMBS, M. & Alty, J. (1983). Expert systems: an alternative paradigm. *Int. Journ. of Man-Machine Studies*, 20, p. 21–43.

COOPER, W.S. (1973). On selecting a measure of retrieval effectiveness, *JASIS*, 24(2), p. 87–100 (Part 1); 24(6), p. 413–424. (Part 2).

COOPER, W.S. (1979). A perspective on the measurement of retrieval effectiveness. *Drexel Library Quarterly*, p. 25–39.

CRAIK, K. (1943). *The Nature of Explanation*. Cambridge: Cambridge University Press.

CROFT, W.B. (1980). A model of cluster searching based on classification. *Information Systems*, 5(3), p. 189–195.

CROFT, W.B. (1986). Boolean queries and term dependencies in probabilistic retrieval models. *JASIS,* 37(2) p. 71–77.

CROFT, W.B. (1987). Approaches to intelligent information retrieval. *Inf. Processing & Management*, 23(4), p. 249–254.

CROFT, W.B. & Thomson, R.H. (1985). *An Expert Assistant for Document Retrieval*. Coins Technical Report 85–05. Amherst, MA: Univ. of Massachusetts, Dept. of Comp. & Inf. Sc.

CROFT, W.B. & Thomson, R.H. (1987). I3R: A new approach to the design of document retrieval systems. *JASIS*, 38(6), p. 389–404.

CROFT, W.B. et al. (1990). Interactive retrieval of complex documents. *Inf. Processing & Management*, 26(5), p. 593–614.

CRONIN, B. (1984). *The Citation Process: the Role and Significance of Citations in Scientific Communication*. London: Taylor Graham.

CRONIN, B. & Vakkari, P. (1992) (eds.). *Conceptions of Library and Information Science. Proc. of the First CoLIS Conf.*, Tampere, August 1991. London: Taylor Graham (in press)

DAHLGREN, L. & Marton, F. (1978). Students' conceptions of subject matter: an aspect of learning and teaching in higher education. *Studies in Higher Education*, 3, p. 23–35.

DANIELS, P. (1986). The user modelling function of an intelligent interface for document retrieval systems. In: Brookes, B.C. (ed), *Intelligent Information Systems for the Information Society*. Amsterdam: North-Holland. p. 162–176.

DANIELS, P., Brooks, H. & Belkin, N. (1985). Using problem structures for driving human-computer dialogues. In: *RIAO '85 Conf. Proc.* Grenoble: IMAG, p. 645–660.

De MEY, M. (1977). The cognitive viewpoint: its development and its scope. In: *CC 77: Int. Workshop on the Cognitive Viewpoint.* Ghent: Ghent University. p. xvi–xxxii.

De MEY, M. (1980). The relevance of the cognitive paradigm for information science. In: O. Harbo (ed), *Theory and Application of Information Research*. London: Mansell. p. 48–61.

De MEY, M. (1982). *The Cognitive Paradigm.* Dordrecht: Reidel.

De MEY, M. (1984). Cognitive science and science dynamics: philosophical and epistemological issues for information science. *Social Science Information Studies*, 4(2,3), p. 97–110.

De SOLLA PRICE, D.J. (1976). General theory of bibliometric and other communicative advantage processes. *JASIS*, 27, p. 92–96.

DEBONS, A. (1974). *Information Science: Search for Identity*. New York, NY: Dekker.

DEBONS, A. (1980). Foundations of information science. In: O. Harbo et al. (eds). *Theory and Application of Information Research.* London: Mansell. p. 75–81.

DEBONS, A. (1983) (ed.). *Information Science in Action: Systems Design. Proceedings of the Third Nato Advanced Study Institute,* 1978, Crete. Oxford: Elsevier.

DEBONS, A. & Cameron, W. (1975). (eds). *Perspectives of Information Science.* Leyden: Nordhoff.

DERVIN, B. & Nilan, M. (1986). Information needs and uses. *ARIST*, 21, p. 3–33.

DEUNETTE, J. (1983). *Survey of UK Online Users: a Report on Current Online Usage*. London: Aslib, The Online Information Centre.

DILLON, M. and Gray, A.S. (1983). FASIT: a fully automatic syntactically based indexing system. *JASIS*, 34, p. 99–108.

DOYLE, L.B. (1961). Semantic road maps for literature searchers. *J. of the ACM*, 8, p. 553–578.

ECO, U. (1980). *Il Nome della Rosa*. Milano: Bompiani. English ed. Pan Books, 1984.

ECO, U. (1988). *Il Pendolo di Foucault.* Milano: Bompiani. Danish ed. Forum, 1989.

ELLIS, D. (1989). A behavioural approach to information retrieval system design. *Journ. of Doc.*, 45(3), p. 171–212.

ELLIS, D. (1990). *New Horizons in Information Retrieval*. London: Library Association.

FAIRTHORNE, R.A. (1967). Morphology of information flow. *J. of the ACM*, 14(4), p. 710–719.

FAIRTHORNE, R.A. (1975). Information: one label, several bottles. In: A. Debons & W. Cameron (eds), *Perspectives in Information Science*. Leyden: Nordhoff. p. 65–73.

FARRADANE, J. (1970). The Institute: the first twelve years. *Information Scientist*, 4, p. 143–151.

FARRADANE, J. (1976). Towards a true information science. *Information Scientist,* 10, p. 91–101.

FENICHEL, C.H. (1980). An examination of the relationship between searching behaviour and searcher background. *Online Review*, 4(4), p. 341–347.

FENICHEL, C.H. (1981). Online searching: measures that discriminate among users with different types of experiences. *JASIS*, 32(1), p. 24–32.

FOSKETT, A.J. (1971). *The Subject Approach to Information*. 2. ed. London: Bingley.

FOSKETT, D.J. (1962). The Classification Research Group 1952–1962. *Libri*, 12(2), p. 127–138.

FOX, E.A. (1983). *Extending the Boolean and Vector Space Model of Information Retrieval with P-Norm Queries and Multiple Concept Types.* Ithaca, NY: Cornell University. Doctoral thesis.

FOX, E.A. (1987). Development of the CODER system: a testbed for artificial intelligence methods in IR. *Inf. Processing & Management*, 23(4), p. 341–366.

FOX, C.J. (1983). *Information and Misinformation: an Investigation of the Notions of Information, Misinformation, Informing and misinforming*. Westport, Conn.: Greenwood Press.

FROHMANN, B. (1990). Rules of indexing: a critique of mentalism in information retrieval theory. *Journ. of Doc.*, 46(2), p. 81–101.

FROHMANN, B. (1992). Knowledge and power in library and information science: Towards a discourse analysis of the cognitive viewpoint. In: B. Cronin and P. Vakkari (eds.) *Conceptions of Library and Information Science. Proc. of the First CoLIS Conf.*, Tampere, August 1991. London: Taylor Graham (in press).

FUHR, N. & Buckley, C (1990). Probabilistic document indexing from relevance feedback data. In: J.-L. Vidick (ed), *ACM/SIGIR Conf. Proc*. Bruxelles: Bruxelles University. p. 45–62.

GADAMER, H.G. (1975). *Truth and Method*. New York: Seabury Press.

GADAMER, H.G. (1976). *Philosophical Hermeneutics.* Berkeley: University of California Press.

GARDNER, H. (1987). *The Minds New Science: A History of the Cognitive Revolution*. New York, NY: Basic Books.

GARFIELD, E. (1979). *Citation Indexing: Its Theory and Application in Science, Technology and Humanities.* New York, NY: Wiley & Sons. Reprinted by ISI Press, 1983.

GIBB, F. & Smart, G. (1990). Structured information management brings new techniques for processing text. *Online Review*, 14(3), p. 160–171.

GOFFMAN, W. (1970a). Theory of communication. In: T. Saracevic (ed). *Introduction to Information Science*. New York, NY: Bowker. p. 723–747.

GOFFMAN, W. (1970b). Information science: discipline or disappearance?. *Aslib Proceedings*, 22, p. 589–595.

GOODSTEIN, L.P. & Mark Pejtersen, A. (1989). *The Bookhouse. System Functionality and Evaluation.* Roskilde, Denmark: Risø Research Center. (Risø-M-2793).

GORN, S. (1983). Informatics (computer and information science): its ideology, methology, and sociology. In: F. Machlup & U. Mansfield (eds), The Study of Information: Interdisciplinary messages. New York, NY: Wiley & Sons. p. 121–140.

GOWIN, D.B. (1970) The structure of knowledge. *Educational Theory*, 20, no. 4. (Special issue).

GRIFFITH, C.B. (1980). (ed). *Key Papers in Information Science.* White Plains, NY: Knowledge Industry Publ.

HARBO, O. & Kajberg, L. (1980). (eds). *Theory and Application of Information Research. Proc. of IRFIS 2*, Copenhagen, 1977. London; Mansell.

HARBO, O. Ingwersen, P. & Timmermann, P. (1977). Cognitive processes in information storage and retrieval. In: *CC 77: Int. Workshop on the Cognitive Viewpoint*. Ghent: Ghent University. p. 214–218.

HATANO, G. et al. (1977). Performance of expert abacus operators. *Cognition*, 5, p. 57–71.

HAYES, O.V. (1975). Computer programming as a cognitive paradigm. *Nature*, 254, p. 563–566.

HEDBERG, B. & JÖNSSON, S. (1978). Designing semi-confusing information systems for organizations in changing environments. *Accounting, Org. and Society*, 3(1), p. 47–64.

HEIDEGGER, M. (1962). *Being and Time.* New York: Harper & Row.

HILDRETH; C.R. (1982). Online browsing support capabilities. *ASIS Proc*., 19, p. 127–132.

HITCHINGHAM, E. (1979). Online interviews: charting user and searcher interaction patterns. In: *Information Choices and Policies*. White Plains, NY: Knowledge Industry. p. 66–74.

HJELMS JØRGENSEN, A. (1985). *Human Interface Problem Areas.* Copenhagen, Lyngby: DDC/Eurohelp/006 (20/7). 13p.

HJERPPE, R. (1986). The Hypercat system. In: B.C. Brookes (ed), *Intelligent Information Systems for the Information Society*. London: North-Holland. p. 211–232.

HJØRLAND, B. (1991). Det kognitive paradigme i biblioteks- og informationsvidenskaben. *Biblioteksarbejde*, Vol. 12 (33), p. 5–37.

HJØRLAND, B. (1992). The concept of 'subject' in information science. *Journ. of Doc*. (in press).

HOEL, I.A. (1992). Information science and hermeneutics: Should information science be interpreted as a historical and humanistic science? In: B. Cronin and P. Vakkari (eds.) *Conceptions of Library and Information Science. Proc. of the First CoLIS Conf.*, Tampere, August 1991. London: Taylor Graham (in press).

HOLLNAGEL, E. (1979). The relation between intention, meaning and action. In: K. Gray (ed), *Informatics 5: The Analysis of Meaning.* London: Aslib. p. 135–147.

HOLLNAGEL, E. (1983). What we do not know about man-machine systems. *Int. J. of Man-Machine Studies*, 22, p. 39–57.

HOLLNAGEL, E. (1987). Cognitive models, cognitive tasks, and information retrieval. In: I. Wormell (ed), *Knowledge Engineering.* London: Taylor Graham. Reprint 1988. p. 34–52.

HOLLNAGEL, E. & Woods, P.D. (1983). Cognitive systems engineering: new wine in new bottles. *Int. Journ. of Man-Machine Studies*, 18, p. 583–600.

HOWARD, H. (1982). Measures that discriminate among online searchers with different training and experience. *Online Review*, 6(4), p. 315–327.

HUTCHINS, W.J. (1978). The concept of 'aboutness' in subject indexing. *Aslib Proceedings*, 30(5), p. 172–181.

INGWERSEN, P. (1974). *Lånernes Brug af Kartoteket.* København: Danmarks Biblioteksskole. (Studier fra DB, 8). Thesis.

INGWERSEN, P. (1982). Search procedures in the library analysed from the cognitive point of view. *Journ. of Doc.*, 38, p. 165–191

INGWERSEN, P. (1984a). A cognitive view of three selected online search facilities. *Online Review*, 8(5), p. 465–492.

INGWERSEN, P. (1984b). Information technology – which applications?. *Social Sc. Information Studies*, 4(2/3), p. 185–196.

INGWERSEN, P. (1984c). Psychological aspects of information retrieval. *Social Sc. Information Studies,* 4(2/3), p. 83–95.

INGWERSEN, P. (1986). Cognitive analysis and the role of the intermediary in information retrieval. In: R. Davies (ed). *Intelligent Information Systems*. Chichester: West Sussex: Horwood, p. 206–237.

INGWERSEN, P. (1988). Towards a new research paradigm in information retrieval. In: I. Wormell (ed), *Knowledge Engineering.* London: Taylor Graham, 1987. Reprint 1988. p. 150–168.

INGWERSEN, P. (1989). Research in information retrieval. *MIC News*, 5, p. 7–10.

INGWERSEN, P. (1991). *Intermediary Functions in Information Retrieval Interaction*. Copenhagen Business School. Faculty of Economics. Copenhagen: Samfundslitteratur. Doctoral dissertation.

INGWERSEN, P. (1992a). Library and information science in perspective. *Information Management Report*, March, p. 12–17.

INGWERSEN, P. (1992b). Information and information science in context. *Libri*, 42(2) (in press).

INGWERSEN, P., Johansen, T. & Timmermann, P. (1976). A study of the user-librarian negotiation process. In: *EURIM 2 Conf. Proc.* Amsterdam, 1976; London: Aslib, 1977. p. 203–207.

INGWERSEN, P. & Kaae, S. (1980). *User-Librarian Negotiations and Information Search Procedures in Public Libraries: Analysis of Verbal Protocols: Final Research Report*. Copenhagen: Royal School of Librarianship.

INGWERSEN, P., Kajberg, L. & Mark Pejtersen, A. (1986). (eds). *Information Technology and Information Use.* London: Taylor-Graham. 194p.

INGWERSEN, P. & Mark Pejtersen, A. (1986). User requirements – empirical research and information systems design. In: P. Ingwersen et al. (eds), *Information Technology and Information Use.* London: Taylor Graham. p. 111–124.

INGWERSEN, P. & Strunck, K. (1980). *Informationsprocesser: Emners beslægtethed, Brugerkommunikation, Informationssøgning.* København: Danmarks Biblioteksskole. Kompendium.

INGWERSEN, P. & Wormell, I. (1986). Improved subject access, browsing and scanning mechanisms in modern online IR. In: F. Rabitti (ed), *ACM/SIGIR Conf. Proc.* Pisa: IEI, p. 68–76.

INGWERSEN, P. & Wormell, I. (1988). Means to improved subject access and representation in modern information retrieval. *Libri,* 38(2), p. 94–119.

INGWERSEN, P. & Wormell, I. (1989). Modern indexing and retrieval techniques matching different types of information needs. In: S. Koskiala & R. Launo (eds), *Information, Knowledge, Evolution*. London: North-Holland. p. 79–90.

INGWERSEN, P. & Wormell, I. (1990a). Databases as an analytical tool in research management: a case study. In: B. Cronin & N. Tudor-Silovic (eds), *The Knowledge Industries*. London: Aslib. p. 205–216.

INGWERSEN, P. & Wormell, I. (1990b). *Informationsformidling: Teori og Praksis*. Copenhagen: Munksgaard.

INGWERSEN, P. & Wormell, I. (1992). Ranganathan in the perspective of advanced information retrieval. *Libri*, 42 (3). Thematic issue (in press).

JAHODA, G. (1975). *Instruction in Negotiating the Reference Query.* Florida: Florida State University, School of Library Science Report. (EDRS, ED111421).

JAHODA, G. (1977). *The Process of Answering Reference Questions: a Test of a Descriptive Model.* Florida: US Dept. of Health, Education and Wellfare.

JARDINE, N. & van Rijsbergen, C.J. (1971). The use of hierarchic clustering in information retrieval. *Inf. Storage & Retrieval*, 7, p. 217–240.

JOHNSON-LAIRD, P.N. (1983). *Mental Models*. Cambridge: Cambridge University Press.

JOHNSON-LAIRD, P.N. (1988). *The Computer and the Mind.* Cambridge, Mass: Harvard University Press.

JOHNSON-LAIRD, P.N. & Wasow, P. (1977). (eds), *Thinking: Readings in Cognitive Science: an Introduction to the Scientific Study of Thinking*. Cambridge: Cambridge University Press.

JONES, K.P. (1983). How do we index? A report of some Aslib Informatics Group activity. *Journ. of Doc.*, 39(1), p. 1–23.

JÄRVELIN, K. & Repo, A. (1983). On the impacts of modern information technology on information needs and seeking: a framework. In: *Representation and Exchange of Knowledge as a Basis of Information Processes.* Amsterdam: North-Holland. p. 207–230.

JÄRVELIN, K. & Vakkari, P. (1992). Content analysis of research articles in LIS 1965–85. In: B. Cronin and P. Vakkari (eds.) *Conceptions of Library and Information Science. Proc. of the First CoLIS Conf.*, Tampere, August 1991. London: Taylor Graham (in press).

KARETNYK, D., Karlson, F. & Smart, G. (1991). Knowledge-based indexing and morpho-syntactically analysed language. *Inf. Processing & Management* (in press).

KATZ, W. (1978). *Introduction to Reference Work. 3. ed., Vol II: Reference Services and Reference Processes.* New York, NY: McGraw-Hill.

KAY, M. (1991). Keynote address. *14th ACM/SIGIR Conference*, Chicago, October 13–16, 1991

KEEN, E.M. (1977). On the generation and searching of entries in printed subject indexes. *Journ. of Doc.*, 33(1), p. 15–45.

KEMP, D.A. (1988). *Computer-based Knowledge Retrieval*. London: Aslib.

KING, G. (1972). The reference interview. *Reference Quarterly,* 12(2), p. 157–160.

KIWI team (1988), see Schmeltz Pedersen, G.

KLASÉN. L. (1982). *Online Använding. DFI-Rapport.* Stockholm, DFI. p. 80–128.

KOCHEN, M. (1983). Library science and information science. In: F. Machlup & U. Mansfield (eds), T*he Study of Information*. New York, NY: Wiley & Sons. p. 371–377.

KUHN, T.S. (1970). *The Structure of Scientific Revolution*. 2nd. ed. Chicago: University of Chicago Press.

LANCASTER, F.W. (1968). *Evaluation of the Medlars Demand Service.* Bethesda, Md: National Library of Medicine.

LANCASTER, F.W. (1986a). The impact of technology on the use of information sources. In: P.Ingwersen et al. (ed). *Information Technology and Information Use*. London: Taylor Graham. p. 5–10.

LANCASTER, F.W. (1986b). *Vocabulary Control for Information Retrieval.* 2. ed. Arlington, Virg.: Information Resources Press.

LANCASTER, F.W. & Ja-Lih Lee (1985). Bibliometric techniques applied to issues management: a case study. *JASIS*, 36(6), p. 389–397.

LINDSAY, P.H. & Norman, D.A. (1977). *Human Information Processing*. New York, NY: Academic Press.

LOTKA, A.J. (1926). The frequency distribution of scientific productivity. *Journ. of Washington Academy of Science*, 16, p. 317–323.

LURIA, A.R. (1976). *Cognitive Development: its Cultural and Social Foundations.* London: Harvard University Press.

LYNCH, M.F. (1976). *Variety Generation: a Reinterpretation of Shannon's Mathematical Theory of Communication, and its Implications for Information Science.* Sheffield: School of Library and Information Science.

LYNCH, M.J. (1978). Reference interviews in libraries. *Library Quarterly*, 48, p. 119–142.

MACHLUP, F. (1983). Semantic quirks in studies of information. In: F.Machlup & U. Mansfield (eds): *The Study of Information*. New York, NY: Wiley & Sons. p. 641–672.

MACHLUP, F. & Mansfield, U. (1983). (eds). *The Study of Information*. New York, NY: Wiley & Sons.

MACKAY, D.M. (1960). What makes the question. *The Listener*, 63 (May 5), p. 789–790.

MAMMEN, J. (1983). *Den Menneskelige Sans*. København: Københavns Universitet. Disputats.

MARCHAND, D. (1990). Managing information quality. In: I. Wormell (ed.). *Information Quality: Definitions and Dimensions. Proc. of a NORDINFO Seminar*, Royal School of Librarianship, Copenh., Denmark, 1989. London: Taylor Graham. p. 7–17.

MARCUS, R. (1982). User assistance in bibliographic retrieval networks through a computer intermediary. *IEEE Transactions on Systems, Man, and Cybernetics*. SCM-12(2), p.116–133

MARCUS, R. et. al. (1971). The user interface for the INTREX retrieval system. In: D. Walker (ed), *Interactive Bibliographic Search.* Montvale, N.J.: AFIPS Press. p. 159–202.

MARK PEJTERSEN, A. (1979). Investigation of search strategies in fiction based on an analysis of 134 user-librarian conversations. In: *IRFIS 3 Proc.* Oslo: Statens Biblioteksskole, p.107–131

MARK PEJTERSEN, A. (1980). Design of a classification scheme for fiction. In: O. Harbo et al.(eds), *Theory and Application in Information Research.* London: Mansell. p. 146–159.

MARK PEJTERSEN, A. (1986). Design and test of a database for fiction based on an analysis of children's search behaviour. In: P. Ingwersen et al. (eds), *Information Technology & information Use.* London: Taylor Graham. p. 125–146.

MARK PEJTERSEN, A. (1989). A library system for information retrieval based on a cognitive task analysis and supported by an icon-based interface. *ACM Sigir Forum,* June, p. 40–47.

MARK PEJTERSEN, A. (1991). *Interfaces Based on Associative Semantics for Browsing in Information Retrieval*. Roskilde, Denmark: Risø National Laboratory. (Risø-M-2883).

MARK PEJTERSEN, A., Olsen, Sv.E., Zunde, P. (1987). A retrieval aid for browsing strategies in bibliographic databases based on users' associative semantics: A terms association thesaurus. In: I. Wormell (ed.). *Knowledge Engineering: Expert Systems and Information Retrieval.* London: Taylor Graham.

MARTYN, J. (1974). Information needs and uses. *ARIST*, 9, p. 3–23.

MARTYN, J. & Lancaster, F.W. (1981). *Investigative Methods in Library and Information Science*. Arlington, Va.: Information Resources Press.

McALPINE, G. & Ingwersen, P. (1989). Integrated information retrieval in a knowledge worker support system. *ACM Sigir Forum,* June, p. 48–57.

McGILL, M.J. & Huitfeldt, J. (1979). Experimental techniques of information retrieval. *ARIST*, Vol. 14, p. 93–127.

MEADOW, C.T. (1988). OAKDEC, a program for studying the effects on users of a procedural expert for database searching. *Inf. Processing & Management*, 24(4), p. 449–457.

MEADOW, C.T. et al. (1982). A computer intermediary for interactive database searching. I: Design; II: Evaluation. *JASIS*, 33, p. 325–332; 357–364.

MEADOWS, A.J. (ed.) (1987). *Origins of Information Science*. London: Taylor Graham. (The Foundations of Information Science, Vol. 1).

MICKHAILOV, A.I., Chernyi, A. & Giliarevskii, R. (1968). Informatics: its scope and methods. In: *Theoretical Problems of Informatics*. Moscow, Viniti. p. 7–25.

MOOERS, C.N. (1974). Analyis of the Hexagon of Notification. *Journ. of Doc.*, 30(2), p. 181–194.

MOTRO, A. (1986). Constructing queries from tokens. *Proc. of the ACM/SIGMOD Conf*, 1986, p. 120–131.

NEIL, S. (1982). Brookes, Popper, and objective knowledge. *Journal of Information Science*, 4, p. 33–39.

NEIL, S. (1987). The dilemma of the subjective in information organisation and retrieval. *Journ. of Doc*. 43(3), p. 193–211.

NEWELL, A. & Simon, H. (1972). *Human Problem Solving*. New Jersey: Printice Hall.

NIELSEN, J. (1987). The spectrum of models in software ergonomics. *Proc. 5th Symposium on Empirical Foundations of Information & Software Sciences.* Roskilde: Risø Nat.Lab. 16p.

NOERR, P. & Bivins, K. (1985). Browse and navigate: an advance in database access methods. *Inf. Processing & Management,* 21(3), p. 205–213.

ODDY, R.N. (1977). Information retrieval through man-machine dialogue. *Journ. of Doc.*, 33(1), p. 1–14.

OLAISEN, J. (1990). Information quality factors and the cognitive authority of electronic information. In: I. Wormell (ed), *Information Quality*. London: Taylor Graham. p. 91–121.

OTTEN, K. & Debons, A. (1970). Towards a metascience of information: informatology. *JASIS,* 21(1), p. 89–94.

PIAGET, J. (1929). Les deux directions de la pensée scientifique. *Arch. des Sciences Physique et Naturelles*, 134, p. 145–162.

PAYNE, S.J. (1991). A descriptive study of mental models. *Behaviour & Informtion Technology*, Vol. 10 (1), p. 3–21.

POLLITT, A.S. (1986). A rule-based system as an intermediary for searching therapy literature on Medline. In: R. Davies (ed), *Intelligent Information Systems*. Chichester, West Sussex: Horwood. p. 82–126

POPPER, K. (1973). *Objective Knowledge: an Evolutionary Approach.* Oxford: Clarendon Press.

RADECKI, T. (1988) The potential for improvements in commercial document retrieval systems. *Inf. Processing & Management*, 24(3), p. 215–371.

RAMSEY, H.R. & Grimes, J.D. (1983). Human factors in interactive computer dialogue. *ARIST*, 18, p. 29–59.

RANGANATHAN, S.R. (1952). *COLON Classification.* Madras: Madras Library association.

RANGANATHAN, S.R. (1957). *The Five Laws of Library Science.* Rev. ed. Madras (India): Madras Library Association.

RASMUSSEN, J. (1986). *Information Processing and Human-Machine Interaction: An Approach to Cognitive Engineering.* London: North-Holland.

RASMUSSEN, J. (1990). Models for design of computer integrated manufacturing systems: The human perspective. *Int. Journal of Industrial Ergonomics*, vol. 5 (1), p. 5–16.

RASMUSSEN, J., Mark Pejtersen, A. & Schmidt, K. (1990). *A Taxonomy for Analysis of Cognitive Cooperative Work.* Roskilde, Denmark: Risø Research Laboratory. Risø-M-2871.

RASMUSSEN, J., Mark Pejtersen, A., Goodstein, L.P. (1992). *Cognitive Engineering: Concepts and Applications.* Wiley & Sons.

RAYWARD, W.B. (1992). Restructuring and mobilizing knowledge in documents: a historical perspective. In: B. Cronin & P. Vakkari (eds.). *Conceptions of Library and Information Science. Proc. of the First CoLIS Conf.*, Tampere, August 1991. London: Taylor Graham (in press).

RICH, E.A. (1979). User modelling via stereotypes. *Cognitive Science,* 13, p. 329–354.

RICH, E.A. (1983). Users are individuals: individualizing user models. In: *Int. Journ. of Man-Machine Studies*, 18, p. 199–214.

RIJSBERGEN, C.J. van, use van Rijsbergen, C.J.

ROBERTSON, S.E. (1977a). The probability ranking principle in IR. *Journ. of Doc.*, 33(4), p. 294–304.

ROBERTSON, S.E. (1977b). Theories and models in information retrieval. *Journ. of Doc.*, 33(2), p. 126–148.

ROBERTSON, S.E., Maron, M.E. & Cooper, V.S. (1982). Probability of relevance: a unification of two competing models for document retrieval. *Inf. Technology, Research & Development*, 1 (1), p. 1–21.

ROBERTSON, S.E. & Sparck Jones, K. (1976). Relevance weighting of search terms. *JASIS*, 27, p. 129–146.

ROUSE, W.B. & Rouse, S. (1984). Human information seeking and design of information systems. *Inf. Processing & Management*, 20(1–2), p. 129–138.

RUMMELHART, D.E. & Norman, D.E. (1983). *Representation in Memory. CHIP Report 116.* San Diego: University of California.

SALTON, G. (1968). *Automatic Information Organization and Retrieval.* New York, NY: McGraw-Hill.

SALTON, G. (1975). *A Theory of Indexing. Regional Conference Series in Applied Mathematics, No. 18.* Philadelphia, Pa.: Society for Industrial and Applied Mathematics.

SALTON, G., Fox, E. & Wu, H. (1983). Extended Boolean information retrieval. *Communication of the ACM*, 26(11), p. 1022–1036.

SALTON, G. & McGill, J.M. (1983). *Introduction to Modern Information Retrieval*. New York, N.Y.: McGraw-Hill.

SAMUELSON, K., Borko, H. & Amy, G. (1977). *Information Systems and Networks*. Amsterdam: North-Holland.

SARACEVIC, T. (1970a). (ed). *Introduction to Information Science.* New York, NY: Bowker.

SARACEVIC, T. (1970b). The concept of relevance in information science: a historical view. In: T. Saracevic (ed), *Introduction to Information Science.* New York: Bowker, p.111–151.

SARACEVIC, T. (1975). Relevance: a review of and a framework for the thinking on the notion in information science. *JASIS*, 26(6), p. 321–343.

SARACEVIC, T. (1978). Problems of question analysis in information retrieval. In: *ASIS Proc.*, 15, p. 281–283.

SARACEVIC, T. (1980). *Classification and Structure of Questions in Information Retrieval. Research Proposal to NSF.* Cleveland, Ohio: Case Western Reserve University. Febr., 23 p.

SARACEVIC, T. (1987). Changing agenda for information retrieval: editorial. *Inf. Processing & Management*. 23(5), p. i–ii.

SARACEVIC, T. (1992). Information science: Origin, evolution, and relations. In: B. Cronin and P. Vakkari (eds.) *Conceptions of Library and Information Science. Proc. of the First CoLIS Conf.*, Tampere, August 1991. London: Taylor Graham (in press).

SARACEVIC, T. et al. (1988). A study of information seeking and retrieving. *JASIS*, 39, p. 161–216

SARACEVIC, T., Mokros, H, & Su, L.T. (1990). Nature of interaction between users and intermediaries in online searching: a qualitative analysis. In: *ASIS Proc.*, 27 (in press).

SARACEVIC, T. & Su, L.T. (1989). Modelling and measuring user-intermediary-computer interaction in online searching: design of a study. In: *ASIS Proc.*, 26, p. 75–80.

SCHAMBER, L., Eisenberg, M. & Nilan, M. (1990). A re-examination of relevance: toward a dynamic, situational definition. *Inf. Processing & Management*, 26(6), p. 755–776.

SCHMELTZ PEDERSEN, G. et al. (1988). *Knowledge-Based User-Friendly System for the Utilization of Information Bases.* Copenhagen: DDC, 182/1988, 12–01.

SEARLE, J.R. (1984a). Intentionality and its place in nature. *Synthese,* 61, p. 3–16.

SEARLE, J.R. (1984b). *Minds, Brains and Science.* Cambridge, Mass: Harvard University Press.

SHANK, R.C. (1975). The role of memory in language processing. In: C.N. Cofer (ed), *The Structure of Human Memory.* San Franscisco. p. 162–189.

SHANK, R.C. & Abelson, R.P. (1977). *Scripts, Plans, Goals, and Understanding: an Inquiry into Human Knowledge Structures.* Hillsdale, NY: Erlbaum.

SHANK, R.C. & Leake, D.B. (1989). Creativity and learning in a case-based explainer. *Artificial Intelligence*, 40, p. 353–385.

SHANNON, C.E. & Weaver, W. (1949). *The Mathematical Theory of Communication*. Urbana, Ill.: University of Illinois Press.

SHARIF, C. (1988). *Developing an Expert System for Classification of Books Using Expert System Shells*. London: British Library. (BLRD, 32).

SHERA, J.H. (1983). Librarianship and information science. In: F. Machlup & U. Mansfield (eds), *The Study of Information.* New York, NY: Wiley & Sons. p. 379–388.

SMEATON, A.F. & van RIJSBERGEN, C.J. (1988). Experiments on incorporating syntactic processing of user queries into a document retrieval strategy. Y. Chiaramella (ed), *ACM/SIGIR Conf. Proc.*, Grenoble: Press Universitaires de Grenoble. p. 31–52.

SMEATON, A.F., Voutilainen, A. Sheridan, P. (1990). The application of morpho-syntactic language processing to effective text retrieval. *Esprit '90 Conf.* Dordrecht: Klüver. p. 619–635.

SMIT, P.H. & Kochen, M. (1988). Information impediments to innovation of on-line database vendors. *Inf. Processing & Management*, 24(3), p. 229–241.

SMITH, L.C. (1980). Artificial intelligence: applications in information systems. *ARIST*, 15, p. 67–105.

SMITH, L.C. (1986). Knowledge-based systems: AI and human factors. In: P. Ingwersen et al. (eds) *Information Technology & Information Use.* London: Taylor Graham. p. 98–110.

SOERGEL, D. (1976). Is user satisfaction a hobgoblin? *JASIS*, 27(4), p. 256–259.

SOERGEL, D. (1985). *Organizing Information: Principles of Data Base and Retrieval Systems.* London: Academic Press.

SOMMERVILLE, A. (1977). The place of the reference interview in computer searching. *Online*, 1, p. 14–23.

SORMUNEN, E. (1989). *An Analysis of Online Searching Knowledge for Intermediary Systems.* Espoo, Finland: Technical Research Centre of Finland. (Research Report, 630).

SPANG-HANSSEN, H. (1976). *Roles and Links Compared with Grammatical relations in Natural Languages.* Dansk Teknisk Litteraturselskab. (Skriftserie, 40).

SPARCK JONES, K. (1973). Index term weighting. *Information Storage and Retrieval*, 9, p. 619–633.

SPARCK JONES, K. (1974). Automatic indexing. *Journ. of Doc.*, 30, p. 393–432.

SPARCK JONES, K. (1976). Automatic classification. In: A. Maltby (ed), *Classification in the 1970's: A Second Look.* London: Clive Bingley. p. 109–225.

SPARCK JONES, K. (1979). Problems in the representation of meaning in information retrieval. In: *The Analysis of Meaning. Informatics 5.* London: Aslib. p. 193–201.

SPARCK JONES, K. (1981). (ed). *Information Retrieval Experiment.* London: Butterworth.

SPARCK JONES, K. (1983). Intelligent retrieval. In: *Intelligent Information Retrieval: Proceedings of Informatics 7.* London: Aslib. p. 136–142.

SPARCK JONES, K. (1984). *User Models and Expert Systems. Technical Report 61*. Cambridge, UK: Computer Laboratory, University of Cambridge.

SPARCK JONES, K. (1987). Architechture problems in the construction of expert systems for document retrieval. In: I. Wormell (ed), *Knowledge Engineering.* London: Taylor Graham. Reprint 1988. p. 34–52.

SPARCK JONES, K. (1989). *Retrieving Information or Answering Questions. The 8th British Library Annual Research Lecture.* 14 p. (BLRD/c/130).

SPARCK JONES, K. & Key, M. (1973). *Linguistics and information science*. London: Academic Press.

SPARCK JONES, K. & van Rijsbergen, C.J. (1976). Information retrieval test collections. *Journ. of Doc.*, 32(1), p. 59–75.

SPARCK JONES, K. & Webster, C.A. (1980). *Research on Relevance Weighting*. Cambridge: Cambridge University, Computer Lab. (BRLD, 5553)

STEVENS, M.E. (1965). *Automatic Indexing: a State of the Art Report.* Washington D.C.: National Bureau of Standards. (NBS Monographs, 91). Reissued with additions, 1970.

TAGUE-SUTCLIFFE, J. (1992a). An introduction to informetrics. *Inf. Processing & Management*, Vol. 28 (1), p. 1–4.

TAGUE-SUTCLIFFE, J. (1992b). Measuring the informativeness of a retrieval process. In: N. Nelkin, P. Ingwersen, A. Mark Pejtersen (eds) *ACM/SIGIR Conf. Proc., Sigir Forum, 3/4,* New York, N.Y.: ACM (in press).

TAYLOR, R.S. (1968). Question negotiation and information seeking in libraries. *College and Research Libraries*, 29, p. 178–194.

TELL, B. (1969). Document representation and indexer consistency. *ASIS Proc.*, 6, p. 285–291.

TULVING, E. & Donaldson, W. (1972). (eds), *Organization of Memory*. New York, NY: Academic Press.

TURING, A. (1950). Computing machinery and intelligence. *Mind*, 59, p. 433–460.

TURTLE, H. & Croft, W.B. (1990). Inference methods for document retrieval. In: J.-L. Vidick (ed), *ACM/SIGIR Conf. Proc.* Bruxelles: Bruxelles University. p. 1–24.

TWAIN, M. (1965). *Life on the Mississipi*. New York, N.Y.: Airmont Publ.

van RIJSBERGEN, C.J. (1977). A theoretical basis for the use of co-occurrence data in information retrieval. *Journ. of Doc.*, 33(2), p. 106–119.

van RIJSBERGEN, C.J. (1979). *Information Retrieval.* 2. eds. London: Butterworths

van RIJSBERGEN, C.J. (1986a). A new theoretical framework for information retrieval. In: *ACM/SIGIR Conf. Proc.* F. Rabitti (eds). Pisa: IEI. p. 194–200.

van RIJSBERGEN, C.J. (1986b). (ed). Office Automation. *Inf. Processing and Management*, 22(2), Sp.Issue.

van RIJSBERGEN, C.J. (1990). The science of information retrieval: its methodology and logic. In: *Conf. Informatienvetenschap in Nederland.* Haag: Rabin. p. 20–38.

van RIJSBERGEN, C.J., Robertson, S.E. & Porter, M.F. (1980). *New Models in Probabilistic Information Retrieval.* Cambridge: Cambridge University, Computer Lab. (BRLD, 5587).

VICKERY, A., Brooks, H. & Vickery, B.C. (1986). An expert system for referral: the Plexus Project. In: R. Davies (ed), *Intelligent Information Systems.* London: Horwood.p.154–183.

VICKERY, B.C. (1975). *Classification and Indexing in Science.* London: Butterworths.

VICKERY, B.C. & Vickery, A. (1987). *Information Science in Theory and Practice.* London: Butterworths.

VIGOTSKY, L.S. (1962). *Thought and Language.* Boston: MIT Press.

WADE, S. et al. (1988). *A Comparison of Knowledge-based and Statistically-based Techniques for Reference Retrieval.* Sheffield: University of Sheffield, Dept. of Info. Studies.

WAPPLES, D. (1932). The relation of subject interest to actual reading. *Library Quarterly,* 2, p. 42–70.

WEIZENBAUM, J. (1984). *Computer Power and Human Reason: From Judgement to Calculation.* New ed. Harmondswoth: Penguin.

WELLISCH, H. (1972). From information science to informatics: a terminological investigation. *Journal of Librarianship,* 4(3), p. 157–187.

WENDLANDT, E.B. & Driscoll, J.R. (1991). Incorporating a semantic analysis into document retrieval strategy. In: A. Bookstein et.al. (eds.). *Proc. of the 14th ACM/SIGIR Conf.*, Chicago, October, 1991. New York, N.Y.: ACM. p. 270–279.

WERSIG, G. (1971) *Information – Kommunikation – Dokumentation.* Pullach bei München: Verlag Dokumentation.

WERSIG, G. (1973). *Informationssociologie.* Pullach bei München: Verlag Dokumentation.

WERSIG, G. (1992). Information science and theory: A Weaver Bird's perspective. In: B. Cronin & P. Vakkari (eds.), *Conceptions of Library and Information Science. Proc. of the First CoLIS Conf.*, Tampere, August, 1991. London: Taylor Graham, (in press).

WERSIG, G. & Neveling, V. (1975). The phenomena of interest to information science. *Information Scientist*, 9, p. 127–140.

WHITE, M. (1981). Dimensions of the reference interview. *Reference Quarterly*, 20, p. 373–381.

WHITTEMORE, B.J. & Yovits, M. (1973). A generalized conceptual development for the analysis and flow of information. *JASIS*, 24, p. 221–231.

WIENER, N. (1948). *Cybernetics or Control and Communication in the Animal and the Machine.* Cambridge, Mass.: MIT Press, l948; MIT Press & Wiley & Sons, 1961.

WILLETT, P. (1984). A note on the use of nearest neighbors for implementing single linkage document classifications. *JASIS*, 35 (3), p. 149–152.

WILLETT, P. (1988a). Recent trends in hierarchic document clustering: a critical review. *Inf. Processing & Management*, 24(5), p. 577–597.

WILLETT, P. (1988b) (ed). *Document Retrieval Systems.* London: Taylor Graham. (The Foundations of Information Science, Vol. 3). p. 1–22.

WILLETT, P. & El-Hamdouchi, A. (1987). Hierachic document classification using Ward's clustering method. In: F. Rabitti (ed). *ACM/SIGIR Conf. Proc.* Pisa: IEI. p. 149–156.

WILSON, T.D. (1980). Information system design implications of research into the information behaviour of social workers and social administrators. In. O. Harbo (ed), *Theory and Application of Information Research.* London: Mansell. p. 198–213.

WILSON, T.D. (1981). On user studies and information needs. *Journ. of Doc.*, 37(1). p. 3–15.

WILSON, T.D. & Streatfield, D. (1977). Information needs in local authority social services departments: an interim report on Project INISS. *Journ. of Doc.*, 33, p. 277–293.

WINOGRAD, T. & Flores, C.F. (1986). *Understanding Computers and Cognition.* Norwood, N.J.: Addison-Wesley. (1986/87).

WITTY, F.J. (1973). The beginning of indexing and abstracting: some notes towards a history of indexing and abstracting in Antiquity and the Middle Ages. *The Indexer*, 8(4), p. 193–198.

WORMELL, I. (1984). *Indexes and Text Analysis in Automated IR-Systems*. Copenhagen: Royal School of Librarianship.

WORMELL, I. (1985). *Subject Access Project – SAP. Improved Subject Retrieval for Monographic Publications.* Lund: Lund University. Doctoral thesis.

WORMELL, I. (1988). (ed). *Knowledge Engineering: Expert Systems and Information Retrieval*. London: Taylor Graham, 1987; reprint 1988.

ZHANG YUEXIAO (1988). Definitions and sciences of information. *Inf. Processing & Management,* 24(4), p. 479–491.

ZIPF, G.K. (1932). *Selected Studies of the Principle of Relative Frequencies of Language*. Cambridge, Mass.

ZUNDE, P. & Gehl, J. (1979). Fundamental principles and theories of information science. *ARIST,* 14, p. 67–92.

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