# Intelligent Interfaces for Information Retrieval: A Review

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**Abstract**

An intelligent interface for an information retrieval system has the aims of controlling an underlying information retrieval system, directly interacting with the user, and allowing him to retrieve relevant information without the support of a human intermediary. Developing intelligent interfaces for information retrieval is a difficult activity, and no well established models of the functions that such systems should possess are available. Despite of this difficulty, many intelligent interfaces for information retrieval have been implemented in the past years. This paper surveys these systems, with two aims: to stand as a useful entry point for the existing literature, and to sketch an analysis of the functionalities that an intelligent interface for information retrieval has to possess.

## 1 Introduction

*Information Retrieval* (IR) [64, 75] is the discipline devoted to build software systems (IR systems) for the storing, management and retrieving of large amounts of unstructured data (typically, natural language texts, images, sounds, and so on). The task at hand is difficult: the standard 'syntactical' solutions used in database theory [25], based on the structured nature of the data, are not suited, and a new approach, at a more 'semantic' level, is needed. Moreover, often the user has to face some problems, for instance to express a need regarding an unknown field [37]. For overcoming this difficulties, the user of an IR system is usually supported by an human expert, an *intermediary*, that acts as an interface between the user and the IR system.

This solution is effective, but the growing diffusion of databases (CD-ROMs, Internet, and so on) creates a new scenario: the human intermediary is not always available and the user has to interact directly with the system. Of course, the system has to be modified: an *artificial intermediary* between the IR system and the user is needed, and this brings into the scenario the discipline of *human-computer interaction* [26, 55]. Moreover, for designing and implementing such artificial intermediary, *artificial intelligence* techniques [63, 34] seem to be promising, as the problems at hand are ill-defined (it is difficult, if not impossible, to define a formal, correct and complete relation between input and output): the obtained system is named *Intelligent Interface* (II) to an IR system, or II for IR.

The field of IIs for IR is thus the intersection of three fields: IR, human-computer interaction and artificial intelligence. All these three disciplines are difficult ones on their own, and the resulting area is obviously a complex one. As a matter of fact, no well established theorical model of the functionalities that an II for IR has to provide is available, though some proposals have appeared (MONSTRAT and MEDIATOR models [37]), and some studies have been published (for instance [6]). Notwithstanding all these obstacles, many experimental IIs for IR have been developed in the last decades: Table 1 reports, in temporal order, the IIs for IR described in literature. In each column, the table shows: the name of the system; the date of its realization, derived from the bibliographic references; and its main bibliographic references.

This paper presents a survey of IIs for IR, and has two aims: to stand as a useful entry point to the large literature on IIs for IR and to sketch the functionalities that the ideal II for IR has to possess. The description style is very schematic, in order to have the maximum synthesis and clearness. In the next section I select and briefly describe some of the most representative IIs for IR (the sixteen ones in boldface in Table 1). These systems are analyzed more in depth in Section 3. The last section concludes the paper.

# 2 Selected Intelligent Interfaces for Information Retrieval

In this section some of the most significative IIs for IR are selected and briefly described. The selection is made on the basis of the functionalities provided by the systems: it is by no means intended to classify the goodness of the systems.

Table 1: The IIs for IR described in literature. The entries labelled with (*) do not have a system name; I have used the name of the author.

| Name | Year | Refs. |
|---|---|---|
| THOMAS | 1977 | [56] |
| RITA | 1978 | [79] |
| EUREKA | 1979 | [13] |
| **CITE** | 1979 | [27] |
| **GRUNDY** | 1979-83 | [61, 62] |
| TTIRS | 1980 | [81] |
| CSIN | 1981 | [36] |
| **CONIT** | 1981 | [41, 42] |
| **Shoval** (*) | 1981-85 | [66] |
| IIDA | 1982 | [48, 49] |
| OL'SAM | 1982 | [73] |
| OASIS | 1982-85 | [82, 83] |
| IRUS | 1983 | [5] |
| IR-NLI | 1983-86 | [8, 33] |
| OKAPI | 1983-95 | [28] |
| POISE | 1984 | [22] |
| NP-X | 1984 | [68] |
| CIRCE | 1985 | [3] |
| RABBIT | 1985 | [19] |
| **RUBRIC** | 1985-87 | [45, 74] |
| **EP-X** | 1985-89 | [69, 70] |
| FIRSTUSER | 1986 | [20] |
| FRED | 1986 | [38] |
| RESEARCHER | 1986 | [40] |
| **CANSEARCH** | 1986-87 | [57, 58] |
| Eurisko | 1987 | [4] |
| IRNLI-II | 1987 | [9, 10] |
| **IOTA** | 1987 | [15, 16] |
| GRANT | 1987 | [18] |
| CODER | 1987 | [29] |
| COALSORT | 1987 | [52] |
| IMIS | 1987 | [80] |
| PROBIB-2 | 1987 | [80] |
| **PLEXUS** | 1987-88 | [77, 78] |
| **I3R** | 1987-89 | [23, 72] |
| TOPIC | 1988 | [17] |
| OAKDEC | 1988 | [46] |
| ODA | 1988 | [53] |
| MenUSE | 1988 | [59] |
| KIRA | 1988 | [65] |
| Tome | 1988-89 | [76] |
| **EUROMATH** | 1989 | [44] |
| OFFICER | 1989 | [21] |
| KIWI | 1989 | [39] |
| **BOOKHOUSE** | 1989 | [43] |
| OAK | 1989 | [47] |
| MOSS | 1989 | [54] |
| ESOCKS | 1989 | [84] |
| IANI | 1989 | [85] |
| **Gauch** (*) | 1989-90 | [30, 31, 32] |
| **ISIR** | 1990 | [60] |
| SIMPR | 1990 | [67] |
| RADA | 1990 | [71] |
| **AI-STARS** | 1990-93 | [1, 2] |
| INQUERY | 1992 | [14] |
| LYBERWORLD | 1994 | [35] |
| **FIRE** | 1995-96 | [11, 12] |

The selected systems, in temporal order, are:

**CITE** allows the user to express his need as a natural language request. The system translates the request into a query for MEDLINE (a medical database) and returns a ranked set of documents. It also provides query expansion through relevance feedback: the user can judge the relevance of the retrieved documents and the MeSH (Medical Subject Heading, the controlled vocabulary of MEDLINE) terms contained in the relevant ones are automatically added to the query.

**GRUNDY** interacts with the user, asking him questions with the aim of building, updating, refining, and revising a model of the user. The model is then used for suggesting to the user a novel interesting for him. The user models are implemented via stereotypes, hierarchically organized: a stereotype, containing features like age, sex, perseverance, independence, political preferences, and so on, is assigned to the user. To each feature a numerical value, a confidence rating, and one or more justifications are associated. On the basis of the features of the user, the system selects the most adequate novel; if the user does not accept it, GRUNDY tries to find which feature(s) has to be modified, eventually asks other questions, and proposes something different.

**CONIT** interacts with the user through menus and a simple command language. The user expresses his need as a set of terms, and the system autonomously chooses to which of the available databases (DIALOG, ORBIT, MEDLINE) to send the query.

**Shoval** has the aim of reformulating an input query through spreading activation in a thesaurus. The spreading activation starts from the query terms, is governed by a production rules knowledge base, and the steps taken can be explained to the user.

**RUBRIC** takes in input a rule-based description of user's need. For instance, the two rules

"information" AND "retrieval"
$\Rightarrow$ "information retrieval" (0.6)

"information" ADJACENT "retrieval"
$\Rightarrow$ "information retrieval" (0.9)

mean that a document containing both the terms "information" and "retrieval" has a 0.6 probability of being about "information retrieval" and that this probability is 0.9 if the two terms are adjacent. The rule representation is then translated into a boolean query. This system is interesting and original: the user is the source of the domain knowledge, and the information need description may be more precise and flexible than through the usual boolean operators. The problems arise when the user has an ill-defined information need, and thus does not know the terminology of the field in which he is doing the search, or when he has not enough time for completely specify his need.

**EP-X** tries to work at a semantic level: its domain knowledge is represented as a hierarchy of frames (thus it is richer than a classical thesaurus), and this knowledge is used to understand user's query (a set of terms) and to reformulate it. The reformulation activity is not merely interactive query expansion: also linguistic ambiguities are resolved.

**CANSEARCH** is a menu-based interface that helps the user in formulating a query for MEDLINE using terms from MeSH. MeSH is hierarchically organized, with broader-term and narrower-term relations among the terms; the system proposes a series of menus on the basis of such hierarchy.

**IOTA** is an expert system prototype with the aim of experimenting the effectiveness of artificial intelligence techniques in IR. The system takes in input a natural language request and, using computational linguistic techniques (parsing, learning of new terms from the context), and linguistic knowledge (two vocabularies, one thesaurus), translates it into a boolean query. IOTA does not search in a real database, but in a unique document indexed by keywords. It also performs a limited automatic query expansion, inserting broader terms from the thesaurus and modifying the logical structure of the boolean query.

**PLEXUS** asks questions to the user for building a user model and getting a natural language description of user's need. The request is translated into boolean form by semantic analysis (the system has a dictionary containing the terms of the domain, gardening, and a description of their meaning) and, using a stop-word list and stemming algorithms, sent to an underlying IR system. If not items are found, the automatic reformulation phase starts: some of the tactics contained in a knowledge base (tactics based both on the query structure and on the meaning of terms) are applied for modifying the query in order to retrieve at least one item.

**I3R** is one of the more complete IIs for IR. It is based on a blackboard architecture, with seven cooperating expert systems ('User Model Builder', 'Request Model Builder', 'Domain Knowledge Expert', and so on) coordinated by a 'Control Expert'. Initially, the system asks questions to the user, with the aim of building the user model (via stereotypes) for choosing the better interaction style. On this basis, the system tries to build the model of the information need, and then searches in the database. If the results are not satisfying, the reformulation starts: the user can browse an integrated, filtered by the system, hypertext-like network of concepts and documents, evaluate documents, and insert new terms in the query.

**EUROMATH** tries to model the need of the users in a more complete way than the usual one. It asks to the users (mathematicians), besides the classical topic aspect of user's need [11, 12, 50, 51], the type of the need (verificative, similar to a previous one, conscious topical, ill-defined). This information, that is continuously verified during the interaction on the basis of user's behavior, and eventually updated (by either the user or the system), is used for choosing the best kind of interaction with the user. Also the preferred type of documents is asked to the user and used in the retrieving phase. Thus, EUROMATH builds and maintains a primitive form of user model, and uses it both for the interaction and the search.

**BOOKHOUSE** supports, through an icon-based graphical interface, unexperienced users and librarians for the retrieving and indexing of documents, respectively. This system is supportive: it does not simulates an human intermediary, but supports the user that works autonomously.

**Gauch** supports the user during the search of relevant passages in a full-text database. The system accepts a boolean query and the number of desired passages, performs a search and, if the results are not satisfying (*i.e.* not matching the desired number of hits), starts an automatic reformulation phase in which the knowledge bases of the system (domain knowledge, *i.e.* terms from a thesaurus and stemming, and expert knowledge, *i.e.* tactics [7]) are used for modifying the query and retrieve the wanted number of items. The query can be modified in three ways: via addition or replacement of related terms, via relaxation or reinforcement of the proximity operators, and via structural modification of the boolean operators.

**ISIR** provides a graphical interface that allows the user to search in different commercial databases, connected via TELNET, and to browse the thesaura of the databases (INSPEC, MeSH, ERIC), with a unique syntax.

**AI-STARS** uses linguistic knowledge (morphological analysis, stemming, thesaurus) for improving the indexing of documents, the interpretation of the query and the query expansion. AI-STARS takes in input a query in natural language, translates it into a boolean representation and presents it to the user in a way similar to a spreadsheet, helping the user to understand the meaning of the boolean operators (AND and OR) and allowing him to directly manipulate the terms, dragging them with the mouse for changing the logic of the search. The system can also add or substitute terms in the query, thus providing help for reformulation.

**FIRE** has the main goal of emulating some of the functions of a human intermediary by interacting directly with end-users and by supporting them during query reformulation. These capabilities are accomplished by FIRE through explicit representations of knowledge about the intermediary skills (tactics [7] and plans, namely predefined sequences of tactics, that a human intermediary executes for reformulating the query) and about the subject domain (thesaura and morphological knowledge). FIRE allows the user to enter a boolean query, to retrieve relevant documents, and to read and classify them. If the user is not satisfied with the obtained results, he can start a query reformulation process, in which FIRE selects and controls a general strategy for a semi-automatic reformulation: starting from the initial representation of the information need, it proposes to the user a set of alternative or additional terms, among which the user can choose the ones that better describe his need.

# 3 Analysis of Intelligent Interfaces for Information Retrieval

In this section, four tables are presented, in order to analyze the main features of the selected IIs for IR. The tables report features about: the knowledge used in the systems, the interaction system-user, the representation of the need, and the user model built by the system, respectively.

In Table 2 the *knowledge* types used in the IIs for IR and the sources from where such knowledge was obtained are described. The values in the cells of this and the following tables are: • for present, ∘ for partial, a void cell for absent and ? for unknown. The columns have the following meaning:

**Area** groups the columns representing the types of knowledge possessed by the system. The letters in the column headings stand respectively for knowledge about:

- **I:** (Information) the information retrieval activity;
- **S:** (System) the information retrieval system(s) underlying the interface;

| **Knowledge** | Area | | | | | Source | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I | S | D | P | U | U | D | L | P | E |
| CITE | • | • | • | | | | ? | • | ? | ? |
| GRUNDY | • | | • | • | • | | • | | | |
| CONIT | | • | | | | | | | | |
| Shoval | • | | • | | | | • | ? | | |
| RUBRIC | • | • | • | | | • | • | ? | | |
| EP-X | • | • | • | | | | • | • | • | |
| CANSEARCH | | • | • | | | | ? | ? | | ? |
| IOTA | • | • | • | • | • | • | • | • | | • |
| PLEXUS | • | • | • | • | ◦ | ◦ | • | • | • | • |
| I3R | • | • | • | • | • | • | • | • | | |
| EUROMATH | • | • | • | • | • | | • | • | | |
| BOOKHOUSE | • | • | • | • | | | | • | • | |
| Gauch | • | • | • | | | | • | • | | |
| ISIR | • | • | • | | | | • | • | | |
| AI-STARS | • | • | • | | | | ? | ? | ? | ? |
| FIRE | • | • | • | | | | • | • | | • |

Table 2: Types and sources of knowledge used in the systems.

- **D:** (Domain) the database domain, often limited to terminological knowledge represented as a thesaurus;
- **P:** (Population) the user population, *i.e.* the features that the users of the particular system possess;
- **U:** (User) the specific user interacting with the system.

**Source** groups the possible sources used for obtaining the knowledge:

- **U:** Users;
- **D:** Designers;
- **L:** Literature;
- **P:** Protocol analysis;
- **E:** Experts (*i.e.* human intermediaries).

In Table 3 some aspects of the *interaction* between the user and the system are summarized. The meaning of the columns are:

**Modality** groups the columns regarding the modality of the interaction:

| **Interaction** | Modality | | | | | | Ctrl | General | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | C | N | M | W | I | G | | A | F | I |
| CITE | | • | | | | | S | | | S |
| GRUNDY | • | | • | | | | S | • | ○ | A |
| CONIT | • | ○ | • | | | | U | | ○ | ? |
| Shoval | • | | | | | | S | | | S |
| RUBRIC | | | | • | | | U | • | | A |
| EP-X | | • | | | | | S | | | S |
| CANSEARCH | | | • | | | | U | | • | A |
| IOTA | | • | | | | | S | • | • | S |
| PLEXUS | | • | | | | | S | | | S |
| I3R | | • | • | • | | • | M | • | ○ | A |
| EUROMATH | | | • | • | | • | M | • | • | S |
| BOOKHOUSE | | | | | • | • | U | • | • | A |
| Gauch | • | | | | | | S | | | S |
| ISIR | | | • | • | | | U | | • | S |
| AI-STARS | | • | | | | • | M | | • | A |
| FIRE | | | • | • | | ○ | M | | • | S |

Table 3: Interaction user-system.

**C:** Command line;

**N:** Natural language;

**M:** Menus;

**W:** Windows;

**I:** Icons;

**G:** Graphic.

**Control** indicates who (the system or the user) has the initiative of the interaction. It can assume as value:

**S:** System;

**U:** User;

**M:** Mixed.

**General** groups the columns regarding general aspects of the interaction:

**A:** (Adaptable) describes if the systems adapts his behavior to the specific user;

| **Need** | Topic | | | | Task | | | Tools | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B | F | S | L | O | C | T | E | F | C | D | Cl |
| CITE | | | | ● | | | | ● | ● | | | |
| GRUNDY | | | ● | | | | | | | | | |
| CONIT | | | ● | | | | | | | | | |
| Shoval | | | ● | | | | | ● | | | | |
| RUBRIC | ● | | | | | ○ | | | | | | |
| EP-X | | ● | ● | | ? | ● | | ● | | | | |
| CANSEARCH | | | ● | | | | | ○ | | | | |
| IOTA | ● | | | ● | | | | ● | | ○ | | |
| PLEXUS | ● | | | ● | | | | E | | | | |
| I3R | ● | | ● | ● | ● | ● | | ● | ● | ● | ● | ● |
| EUROMATH | ● | ● | | | ● | ● | ● | ● | ● | ● | | |
| BOOKHOUSE | ● | | | | ● | ● | ● | ● | | ○ | ● | ● |
| Gauch | ● | ● | | | ○ | ● | | ● | | | | |
| ISIR | | | ● | | | | | ○ | | ● | | |
| AI-STARS | ● | ● | | ● | | | | ● | | | | |
| FIRE | ● | ● | | | ● | ● | | ● | ● | ● | | ● |

Table 4: Expression of the user's information need.

**F:** (Friendly) describes if the system is easy to use for an unexperienced user;

**I:** (Intermediary) describes the approach chosen in the design of the system. It can assume as value:

**S** for a system that Simulates the intermediary;

**A** for a system that follows an Alternative approach.

In Table 4 some aspects of the representation of the user's *information need* are presented. The meaning of the columns is:

**Topic** groups the columns describing how the topic of the information need is communicated from the user to the system:

**B:** Boolean;

**F:** Facets;

**S:** Single term;

**L:** natural Language.

| User Model | LT | ST | Can. | Ind. | Expl. | Ded. | Stat. | Dyn. |
|---|---|---|---|---|---|---|---|---|
| GRUNDY | • | | • | • | • | • | | • |
| IOTA | | • | • | | | • | • | |
| PLEXUS | | • | • | | • | ? | • | |
| I3R | • | | • | • | • | | • | ∘ |
| EUROMATH | | • | • | | • | | • | |
| BOOKHOUSE | | | • | | | | • | |
| FIRE | • | | • | • | • | • | | • |

Table 5: User model types.

**Task** groups the columns describing if the task and context [11, 12, 50, 51] of the search are communicated from the user to the system:

**O:** search Objectives (for instance, high recall or high precision);

**C:** Constraints on the search (for instance, the desired number of retrieved documents);

**T:** Type of the need (for instance, verificative *vs.* conscious topical *vs.* muddled [37]).

**Tools** groups the columns describing which tools support the user's expression of his need. Each column describes if the system possesses tools for:

**E:** query Expansion (adding —or substituting— to the terms in the query other related terms);

**F:** relevance Feedback (adding to the query terms taken from relevant documents);

**C:** Concept browsing (allow the user to browse the domain knowledge of the system);

**D:** Document browsing (allow the user to browse the documents);

**Cl:** Classification of documents (allow the user to classify the retrieved documents as relevant, not relevant useful, not useful, etc.).

Table 5 reports the features of the system's *user model* [24] (only for the systems that have a user model, see Table 2; also FIRE is included, though its user model capabilities are not yet integrated in the system, but only foreseen). Each column describes if the user model:

**LT and ST:** (Long Term and Short Term) is stored or not stored at the end of the session for being re-utilized;

**Can. and Ind.** (Canonical and Individual) represents a canonical user or the actual user;

**Expl. and Ded.** (Explicit requests and Deduced) is built asking questions to the user or deducing information from user behavior;

**Stat. and Dyn.** (Static and Dynamic) changes during a session.

## 4 Conclusions

Some of the most representative IIs for IR have been presented and analyzed. On the one side, this work is useful for a high level view of the existing IIs for IR. On the other side, it has some interesting future developments: on the basis of the analysis of the systems, it is possible to individuate a set of functions that an ideal system has to possess, and to provide a detailed specification of such a system. This specification, being based on already implemented functions, is more likely to be really implementable than more theorical models like MONSTRAT and MEDIATOR: only integration problems will occur.

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## References

[1] P. G. Anick, J. D. Brennan, R. A. Flynn, D. R. Hanssen, B. Alvey, and J. M. Robbins. A direct manipulation interface for boolean information retrieval via natural language query. In *Proceedings of the 13th ACM SIGIR*, pages 135–150, New York, 1990. ACM.

[2] P. G. Anick and R. A. Flynn. Integrating a dynamic lexicon with a dynamic full-text retrieval system. In *Proceedings of the 16th ACM SIGIR*, pages 136–145, New York, 1993. ACM.

[3] V. Aragon-Ramiez and C. Paice. Design of a system for the online elucidation of natural language search statements. In *Informatics 8: Advances in intelligent retrieval*, pages 163–190. ASLIB, London, 1985.

[4] C. Barthes, J. Frontin, and J. Glize. Eurisko: An artificial intelligence tool for automatic online information retrieval. In *Online Information 87: 11th Inter-*

*national Online Information Meeting*, pages 431–442, Oxford, 1987. Learned Information.

[5] M. Bates and B. J. Bobrow. Information retrieval using a transportable natural language interface. *SIGIR Forum*, 17(4):48–86, 1983.

[6] M. J. Bates. Where should the person stop and the information search interface start? *Information Processing & Management*, 26(5):575–591, 1990.

[7] M.J. Bates. Information search tactics. *Journal of the American Society for Information Science*, 30(4):205–214, 1979.

[8] G. Brajnik, G. Guida, and C. Tasso. Design and experimentation of IR-NLI: An intelligent user interface to bibliographic data bases. In L. Kerschberg, editor, *Expert Data Base Systems*, pages 151–162, Menlo Park, CA, 1987. Benjamin/Cummings.

[9] G. Brajnik, G. Guida, and C. Tasso. User modeling in intelligent information retrieval. *Information Processing & Management*, 23(4):305–320, 1987.

[10] G. Brajnik, G. Guida, and C. Tasso. User modeling in expert man-machine interfaces: A case study in intelligent information retrieval. *IEEE Transactions on Systems, Man and Cybernetics*, 20(1):166–184, 1990.

[11] G. Brajnik, S. Mizzaro, and C. Tasso. Interfacce intelligenti a banche di dati bibliografici. In D. Saccà, editor, *Sistemi evoluti per basi di dati*, pages 95–128. Franco Angeli, Milano, 1995.

[12] G. Brajnik, S. Mizzaro, and C. Tasso. Evaluating user interfaces to information retrieval systems: A case study on user support. To appear in ACM SIGIR'96, 1996.

[13] T.G. Burket, P. Emrath, and D. J. Kuck. The use of vocabulary files for on-line information retrieval. *Information Processing & Management*, 15:281–289, 1979.

[14] J. P. Callan, W. B. Croft, and S. M. Harding. The INQUERY retrieval system. In *Proceedings of the 3rd International Conference on Database and Expert System Applications*, pages 78–83, New York, 1992. Springer Verlag.

[15] Y. Chiaramella and B. Defude. IOTA: A full text information retrieval system. In F. Rabitti, editor, *Proceedings of the 9th International Conference on Research and Development in Information Retrieval*, pages 207–213, 1986.

[16] Y. Chiaramella and B. Defude. A prototype of an intelligent system for information retrieval: IOTA. *Information Processing & Management*, 23(4):285–303, 1987.

[17] S. Cisler. Searching for a better way: Verity inc. TOPIC software. *Online*, 12(6):99–102, 1988.

[18] P. R. Cohen and R. Kjeldsen. Information retrieval by constrained spreading activation in semantic networks. *Information Processing & Management*, 23(4):255–268, 1987.

[19] P. Craven and C. Craven. Fifth generation librarians — The challenge of knowledge engineering. *Outlook on Research Libraries*, 7(8):1–3, 1985.

[20] R. G. Crawford and H. S. Becker. A novice user's interface to information retrieval systems. *Information Processing & Management*, 22(4):287–298, 1986.

[21] W. B. Croft, R. Krovetz, H. Turtle, and G. L. Pancaccini. Interactive information retrieval of complex documents. Technical report, Department of Computer and Information Science, University of Massachusetts, Amherst, MA, 1989.

[22] W. B. Croft and L. Lefkowitz. Task support in an office system. *ACM Transactions on Office Information Systems*, 2:197–212, 1984.

[23] W. B. Croft and R. H. Thompson. I3R: A new approach to the design of document retrieval systems. *Journal of the American Society for Information Science*, 38(6):389–404, 1987.

[24] P. J. Daniels. Cognitive models in information retrieval — An evaluative review. *Journal of Documentation*, 42(4):272–304, 1986.

[25] C. J. Date. *An Introduction to Database Systems*, volume 1. Addison-Wesley, Reading, MA, 5th edition, 1989.

[26] A. Dix, J. Finlay, G. Abowd, and R. Beale. *Human-Computer Interaction*. Prentice Hall, New York, 1993.

[27] T. E. Doszkocs and B. A. Rapp. Searching MEDLINE in english: A prototype user interface with natural language query, ranked output, and relevance feedback. In *Proceedings of the American Society for Information Science*, pages 131–139, White Plains, NY, 1979. Knowledge Industry Publications, Inc.

[28] M. Fieldhouse and M. Hancock-Beaulieu. The changing face of Okapi. *Library Review*, 43(4):38–50, 1994.

[29] E. A. Fox. Development of the CODER system: A testbed for artificial intelligence methods in IR. *Information Processing & Management*, 23(4):341–366, 1987.

[30] S. Gauch and J. B. Smith. Search improvement via automatic query reformulation. *ACM Transactions on Information Systems*, 9(3):249–280, 1991.

[31] S. E. Gauch. Evaluation of an expert system for searching in full-text. In *Proceedings of the 13th ACM SIGIR*, pages 255–277, 1990.

[32] S. E. Gauch and J. B. Smith. An expert system for searching in full-text. *Information Processing & Management*, 25(3):253–263, 1989.

[33] G. Guida and C. Tasso. An expert intermediary system for interactive document retrieval. *Automatica*, 19(6):759–766, 1983.

[34] G. Guida and C. Tasso. *Design and Development of Knowledge-Based Systems — From Lyfe Cycle to Methodology*. John Wiley & Sons, Chichester, England, 1994.

[35] M. Hemmje, C. Kunkel, and A. Willet. LyberWorld — A visualization user interface supporting fulltext retrieval. In *Proceedings of the 17th ACM SIGIR*, pages 249–259. Springer-Verlag, 1994.

[36] A. J. Horowitz and R. F. Bergman. Improved productivity in multisystem information retrieval through the CSIN intelligent terminal. In *Proceedings of the Second National Online Meeting*, pages 287–292, New York, Medford, NJ, 1981. Learned Information.

[37] P. Ingwersen. *Information Retrieval Interaction*. Taylor Graham, London, 1992.

[38] G. Jakobson, C. Lafond, E. Nyberg, and G. Piatetsky-Shapiro. An intelligent database assistant. *IEEE Expert*, 1(2):65–79, 1986.

[39] KIWIs Team. The KIWI(s) project: Past and future. In *ESPRIT 89: Proceedings of the 6th Annual ESPRIT Conference*, pages 594–603, Netherlands, 1989. Kluwer Academik Publications.

[40] M. Lebowitz. An experiment in intelligent information systems — RESEARCHER. In R. Davies, editor, *Intelligent information systems: Progress and prospects*, pages 127–149. Ellis Horwood, Chichester, 1986.

[41] R. S. Marcus and J. F. Reintjes. A translating computer interface for end-user operation of heterogeneous retrieval systems. I. Design. *Journal of the American Society for Information Science*, 32(4):287–303, 1981.

[42] R. S. Marcus and J. F. Reintjes. A translating computer interface for end-user operation of heterogeneous retrieval systems. II. Evaluation. *Journal of the American Society for Information Science*, 32(4):304–317, 1981.

[43] A. Mark Pejtersen. A library system for information retrieval based on a cognitive task analysis and supported by an icon-based interface. In *Proceedings of the 12th ACM SIGIR*, pages 40–47, New York, 1989. ACM.

[44] G. McAlpine and P. Ingwersen. Integrated retrieval in a knowledge worker support system. In *Proceedings of the 12th ACM SIGIR*, pages 48–57, 1989.

[45] B. P. McCune, R. M. Tong, J. S. Dean, and D. G. Shapiro. RUBRIC: A system for rule-based information retrieval. *IEEE Transactions on Software Engineering*, 11(9):939–944, 1985.

[46] C. T. Meadow. OAKDEC, a program for studying the effects on users of a procedural expert system for database searching. *Information Processing & Management*, 24(4):449–457, 1988.

[47] C. T. Meadow, B. A. Cerny, C. L. Borgman, and D. O. Case. Online access to knowledge: System design. *Journal of the American Society for Information Science*, 40(2):86–98, 1989.

[48] C. T. Meadow et al. A computer intermediary for interactive database searching. I: Design. *Journal of the American Society for Information Science*, 33:325–332, 1982.

[49] C. T. Meadow et al. A computer intermediary for interactive database searching. II: Evaluation. *Journal of the American Society for Information Science*, 33:357–364, 1982.

[50] S. Mizzaro. Le differenti relevance in information retrieval: una classificazione. In *Proceedings of Annual Conference AICA'95, Chia (Cagliari), Italy*, volume I, pages 361–368, 1995.

[51] S. Mizzaro. Relevance: The whole (hi)story. Research Report UDMI/12/96/RR, University of Udine, Department of Mathematics and Computer Science, Via delle Scienze, 206 — Loc. Rizzi — Udine, Italy, 1996. Submitted to 'Journal of the American Society for Information Science'.

[52] I. Monarch and J. Carbonell. CoalSort: A knowledge based interface. *IEEE Expert*, 2(1):39–53, 1987.

[53] A. Morris, G. M. Tseng, and G. Newham. The selection of online databases and hosts — An expert approach. In *Proceedings of 12th International Online Conference*, pages 139–148, 1988.

[54] A. Morris, G. M. Tseng, and K. P. Walton. Moss: A prototype expert system for modifying online search strategies. In *Proceedings of 13th International Online Information Meeting*, pages 415–434, 1989.

[55] W. M. Newman and M. G. Lamming. *Interactive Systems Design*. Addison Wesley, Wokingham, 1995.

[56] R. N. Oddy. Information retrieval through man-machine dialogue. *Journal of Documentation*, 33(1):1–14, 1977.

[57] A. S. Pollitt. A rule-based system as an intermediary for searching cancer therapy literature on MEDLINE. In Roy Davis, editor, *Intelligent Information Systems: Progress and Prospects*, pages 82–126. Ellis Horwood, Chichester, 1986.

[58] A. S. Pollitt. CANSEARCH: An expert system approach to document retrieval. *Information Processing & Management*, 23(2):119–138, 1987.

[59] A. S. Pollitt. MenUSE for medicine: End user browsing and searching of MEDLINE via the MeSH thesaurus. In *RIAO '88: User-oriented content based text and image handling*, pages 547–573, Cambridge, MA, 1988. MIT.

[60] Y. Qiu. ISIR: An integrated system for information retrieval. In *Proceedings of the 14th IR Colloquium*, pages 79–91, Lancaster, 1990. British Computer Society.

[61] E. Rich. User modelling via stereotypes. *Cognitive Science*, 3:329–354, 1979.

[62] E. Rich. Users are individuals: Individualizing user models. *International Journal of Man-Machine Studies*, 18:199–214, 1983.

[63] E. Rich and K. Knight. *Artificial Intelligence*. McGraw-Hill, New York, NY, 2nd edition, 1991.

[64] G. Salton. *Automatic Text Processing – The transformation, Analysis, and Retrieval of Information by Computer*. Addison-Wesley, Reading, MA, 1989.

[65] G. Schmeltz Pedersen et al. Knowledge-based user-friendly system for the utilization of information bases. Technical Report 182/1988, 12-01, DDC, Copenhagen, 1988.

[66] P. Shoval. Principles, procedures and rules in an expert system for information retrieval. *Information Processing & Management*, 21(6):475–478, 1985.

[67] A. F. Smeaton, A. Voutilainen, and P. Sheridan. The application of morpho-syntactic language processing to effective text retrieval. In *Esprit '90 Conference*, pages 619–635, Dordrecht, 1990.

[68] P. J. Smith and M. H. Chignell. Development of an expert system to aid searchers of a chemical abstract. In *Proceedings of the American Society for Information Science*, pages 99–102, White Plains, NY, 1984. Knowledge Industry Publications, Inc.

[69] P. J. Smith, S. J. Shute, and D. Galdes. In search of knowledge-based search tactics. In *Proceedings of the 12th ACM SIGIR*, pages 3–10, 1989.

[70] P. J. Smith, S. J. Shute, J. S. Stevens, D. Galdes, and M. H. Chignell. Knowledge-based search tactics for an intelligent intermediary system. *ACM Transactions on Information Systems*, 7(3):246–270, 1989.

[71] T. C. Tan, P. Smith, and M. Pegman. RADA: Research and development advisor — An intelligent document retrieval system. In *Prospects for Intelligent Retrieval Informatics 10*, pages 331–342, Cambridge, 1990. ASLIB.

[72] R. H. Thompson and W. B. Croft. Supporting for browsing in an intelligent text retrieval system. *International Journal of Man-Machine Studies*, 30:639–668, 1989.

[73] D. E. Toliver. OL'SAM: An intelligent front-end for bibliographic information retrieval. *Information Technology and Libraries*, pages 317–326, December 1982.

[74] R. M. Tong, L. A. Appelbaum, V. N. Askman, and J. F. Cunningham. Conceptual information retrieval using RUBRIC. In *Proceedings of the 10th ACM SIGIR*, pages 247–253, 1987.

[75] C. J. van Rijsbergen. *Information Retrieval.* Butterworths, London, 2nd edition, 1979.

[76] A. Vickery. The experience of building expert search systems. In *Online Information 88: 12th International Online Information Meeting*, volume I, pages 301–313, Oxford and New Jersey, 1988. Learned Information.

[77] A. Vickery and H. Brooks. PLEXUS: The expert system for referral. *Information Processing & Management*, 23(2):99–117, 1987.

[78] A. Vickery, H. Brooks, and B. Robinson. A reference and referral system using expert system techniques. *Journal of Documentation*, 43(1):1–23, 1987.

[79] D. A. Waterman. Exemplary programming in RITA. In D. A. Waterman and F. Hayes-Roth, editors, *Pattern-directed inference systems*, pages 261–279. Academic Press, New York, 1978.

[80] C. R. Watters and M. A. Shepherd. A logic basis for information retrieval. *Information Processing & Management*, 23(5):433–445, 1987.

[81] M. E. Williams and S. E. Preece. Elements of a distributed transparent information retrieval system. In *Proceedings of the American Society for Information Science*, pages 401–402, White Plains, NY, 1980. Knowledge Industry Publications, Inc.

[82] P. W. Williams. How do we help the user? In *Proceedings of the Sixth National Online Information Meeting*, pages 397–407, Medford, NJ, 1985. Learned Information.

[83] P. W. Williams and G. Goldsmith. A completely automatic information retrieval system for the unskilled user. In *Proceedings of the Second National Online Information Meeting*, pages 263–272, Oxford, 1982. Learned Information.

[84] C. Yasunobu, R. Itsuki, I. Tsuki, and F. Mori. Document retrieval expert system shell with worksheet based knowledge acquisition facility. In *Computer Software and Applications Conference. Proceedings of the 13th International Conference*, pages 278–285. IEEE Computer Society Press, 1989.

[85] A. B. Ylinen. Single search language. *Information World Review*, 43:14, 1989.