REDUCING INDETERMINISM IN CONSULTATION: A COGNITIVE MODEL OF USER/LIBRARIAN INTERACTIONS

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Abstract

In information facilities such as libraries, finding documents that are relevant to a user query is difficult because of the indeterminism involved in the process by which documents are indexed, and the latitude users have in choosing terms to express a query on a particular topic. Reference librarians play an important support role in coping with this indeterminism, focusing user queries through an interactive dialog. Based on thirty detailed observations of user/librarian interactions obtained through a field experiment, we have developed a computational model designed to simulate the reference librarian. The consultation includes two phases. The first is *handle search*, where the user's rough problem statement and a user stereotyping imposed by the librarian are used in determining the appropriate tools (handles). The second phase is *document search*, involving the search for documents within a chosen handle. We are collaborating with the university library for putting our model to use as an intelligent assistant for an online retrieval system.

1. Introduction

While archival information sources such as libraries are relying increasingly on the electronic storage medium for organizing large volumes of information, *access* to such information is often difficult, thereby limiting the usefulness of computer-based retrieval systems. For the inexperienced user, the problem of finding documents that are relevant to a query can be difficult for three reasons:

1. it requires knowing what information sources (we refer to these as *handles*) are available in a library, and which of these might be useful,

2. it requires knowledge about the classification scheme (such as the Dewey Decimal classification or other indexing schemes) pertinent to the handles, and

3. the query itself is not well defined because the user is not clear about the topic for which answers are being sought.

Several directions have been proposed for improving subject access. The National Library of Medicine's CITE public access online catalog offers natural language query input, automatic medical subject headings display, closest match search strategy, ranked document output, and the use of dynamic end user feedback for search refinement [4]. The system also supports conventional known-item search options. Other directions include improved classification schemes for documents such as the Dewey Decimal Classification [3], providing more extensive linkages between fields in different records that allow users to browse and navigate through a database [11], and the application of the "hypertext" concept to catalogs, that is, breaking the linearity of the traditional file structure and providing links in a variety of different directions in records [8]. In addition, "intelligent front end" or "expert" systems have been built in several well-defined domains [16] [12] [7] [17] [6]. In general, however, such approaches have not significantly enhanced accessibility for a large cross section of users. Rather, libraries continue to rely on reference librarians to shoulder the major responsibilities of responding to users' queries. Given the increasing proportion of electronic information and the increasing remote access to retrieval systems that is being planned or provided by many libraries, the need for intelligent online assistance for users is becoming a practical necessity.

Our position is that in order to make large information banks more accessible by computer, it is fruitful to first try and understand how reference librarians actually help users, and to try and induce some of their capabilities into online systems. The significance of the role of these librarians becomes all the more apparent if we consider the diversity of users and subject areas they deal with effectively, without being experts in all subject areas or knowing the detailed backgrounds of their patrons.

In this research, conducted in collaboration with our university library, we have begun by observing in detail, interactions between reference librarians and users in diverse subject areas. The results presented in this paper are based on records of thirty such interactions. Specifically, we have developed and implemented a cognitive model of the consultation as a process involving *handle search* followed by *document search* within a handle; both search processes are conceptualized as reducing the *indeterminism* associated with a query. We are currently exploring the potential of this model for supporting users with access to documents using the online catalog system in the university library.

2. Background

While there have been several proposals for engineering more accessible systems, there have been surprisingly few theoretical or empirical analyses about the real *causes* underlying users' access problems. More recently however, [2] has argued that access to documents based on subject areas becomes problematic because of indeterminism involved in the process of both indexing documents and searching for them. Specifically, the factors that make subject based access problematic are as follows:

Indexing Uncertainty: The indexing of most catalogers is partly indeterminate and probabilistic. Evidence suggests that different indexers, well trained in an indexing scheme might assign different indexes for a given document. It has also been observed that an indexer might use different terms for the same document at different times [9] [14].

Searching Uncertainty: An even higher degree of indeterminism has been observed in the terms users employ in describing concepts. One study revealed that on average, the probability of any two people using the same term to describe an object ranged from 7 to 18 percent [5]. In summary, evidence suggests that there is considerable latitude involved in i) the classification of a document into a particular category, and ii) the term a searcher might use to describe a subject area.

Matching: The uncertainty in indexing and searching reduces the likelihood of an exact match between the user's term and that of the indexer. Bates [2] argues that for a successful match, the searcher must somehow generate as much "variety" (in the cybernetic sense, as defined by [1]) in the search as is produced by the indexers in their indexing. The variety produced by an indexer can also be viewed as *redundancy* in the sense that it consists of partially overlapping meanings applied to a document. To increase the chances of a successful match, there should be a number

of labels for each document. This requires preserving the redundancy (generated by the indexer) associated with each document. In practice, however, catalog systems discourage redundancy [2], leading to a reduced likelihood of a successful match.

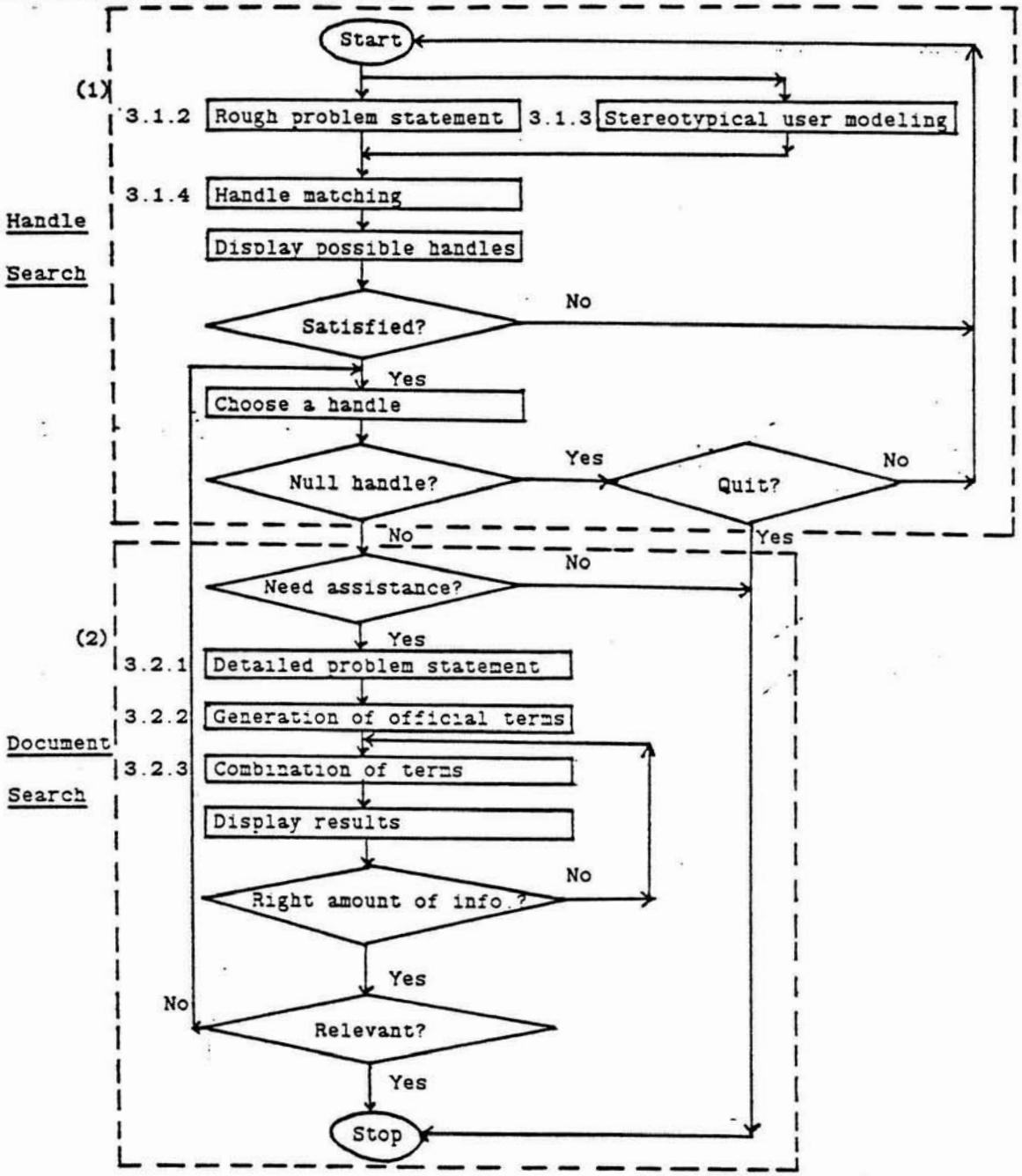
In this research, our goal has been to understand the consequences of the indeterminism inherent in indexing and searching for documents. Specifically, our objective is to understand the strategies used by reference librarians in coping with the indeterminism associated with helping users find documents relevant to their queries. In the following section, we present a cognitive model of the reference librarian involved in this activity.

3. Process Model of Consultation

The consultation process in the user/librarian interaction consists of two phases. The first is what we call handle search. In this phase, a librarian categorizes the clues in the user's initial problem statement into a template that can be matched against characteristics of the various handles. The librarian also often stereotypes the user into one of several categories (described shortly), and determines what types of handles are likely to be most relevant to the user. During this phase, the librarian does not focus on the details of the query, but functions more like a "traffic controller", guiding the user to the right handle. For example, a freshman looking for materials for a term paper (a common occurrence) is likely to be directed to general textbooks instead of journals containing the latest research articles on the topic which might be more appropriate for a graduate student working on a Ph.D dissertation.

It can be the case, particularly with sophisticated users, that a user is not satisfied with the adequacy or relevance of the sources suggested by the librarian. In such cases where the librarian might not have understood the user's problem, the query is restated, typically in different terms, in order to rectify the misconception. On the other hand, if the user is not uncomfortable with the handles suggested by the librarian, the consultation moves into the document search phase. For users unfamiliar with the handle, the librarian goes a step further, helping with the document search. If the user is not satisfied with the documents retrieved after this phase, the consultation resumes with a different handle. The overall process model is schematized in Exhibit 1. In the remainder of this section we describe each of the components of Exhibit 1, along with a representation that models the knowledge used in the parts of the consultation. The numbers associated with each component of Exhibit 1 correspond to section numbers where they are described.

Exhibit 1. Process Model of Consultation



3.1. Handle Search

A library can be viewed as a large hierarchy of indexes, each index pointing to other indexes or to documents. In general, reference librarians have extensive knowledge about the library indexing scheme. For the librarian, the information sources are distinguished by their area of applicability and the types of documents they point to. In the initial stages of the consultation, the librarian performs a "goal-directed" questioning process aimed at extracting sufficient information to classify the problem statement and the user into a certain type. This process of categorization significantly reduces the type and number of potentially relevant handles and documents.

3.1.1. Classification Scheme for the Handle

Librarians appear to classify handles according to a few attributes, namely, the types of documents they point to (books, articles, etc.), the fields (psychology, engineering, etc.) and the geographical area (Central America, Asia, etc.) covered by them, and the time frame of documents to which they refer. Knowing about these features provides the librarian with a good general perception of the applicability of each handle. We represent a handle in terms of a frame-like structured object where the values of the above-mentioned attributes distinguish it from other handles. Exhibit 2 lists the attributes of the data structure.

Exhibit 2. Data structure of the handle

```
{object: handle
     area covered: <global, continent, country, state,...>
     currency:     <range of time>
     type of information:
                   <journal article, textbook, videotape,
                    government document, statistics, newsletter,...>
     field of applicability:
                   <psychology, business, engineering,
                    politics, law, medicine, ...>
}
```

Different combinations of slot values reflect the purpose or functionality of the handle. For example, the Business Periodicals Index (a handle) provides pointers to articles (type of information) in business (field of applicability) written in the last 30 years (currency) pertaining to any part of the world (area covered). Similarly, the Central America Monitor, is in the form of a newsletter (type of information), provides information about recent (currency) economic and political events(field of applicability) in Central America (area covered).

3.1.2. Rough Problem Statement

In the first phase of the consultation, the terms in the user's query are translated by the librarian into values that fill the slots of the handle structure. For example, when an user states "I am looking for GDP information in El Salvador" (dialog one in Exhibit 3) , the term "GDP" implies that the user is looking for statistics (type of information) in the business (field of applicability) area of El Salvador. The librarian can then ask questions that will result in values for those attributes where no information was supplied by the user. In this example, the librarian asks the user about the specific time frame of interest. During this initial interaction, the librarian attempts to solicit only those items of information that can suggest appropriate handle, without worrying about the details of the query. Exhibit 3 shows several sample dialogs illustrating the slot-filling process that characterizes handle searching.

3.1.3. Stereotypical User Modeling

The users' problem statement may only partially constrain the scope of handles that might be appropriate. In such cases, "stereotypical" information about the user provides further constraints on what handles might be most appropriate.

During the consultation the librarian develops an understanding of the type of user being dealt with on the basis of verbal and non-verbal clues. Usually, the type of question brought up, the age of the user, appearance, and the way the question is phrased all play a role in the formation of the stereotype. Some of these clues may be "confirmatory" (i.e. a freshman may be expected to dress in a certain way). We have found that the level of education of the user and the scope of the inquiry are the two major factors involved in the formation of stereotypes. A higher level of education is associated with greater subject familiarity. Users with a higher level of subject familiarity (i.e. Ph.Ds) are likely to require more academically oriented information. In contrast, users with lower levels of subject familiarity are likely to require less scholarly treatment. It is also the case that users with higher levels of education tend to work on research projects, while users with lower levels of education tend to work on limited scope class projects or papers. The possible stereotypes can be visualized as cells in Exhibit 4, each corresponding to a unique set of education level and scope of the query.

Because of the correlation between level of education and scope of the query, the more commonly encountered stereotypes can be expected to fall along the diagonal line in the table.

The stereotypes can be useful in constraining or confirming what information sources might be

Exhibit 3. Segments of protocols indicating problem statement categorization

Dialog	area	currency	type	field
U:..GDP..El Salvador..	Central America		statistics	business
L:When?				
U:1977 to 1980s		77-87		
L:Index to International Statistics or Central Banks Publications				
U:..article..brain drain			article	
L:What?				
U:..foreign engineer brought to US..	US			
L:When?				
U:..last year..		85-87		
L:Which field?				
U:business				business
L: Business Periodical Index				
U:..economic development ..Costa Rica	Central America			business
L:General information?				
U:Yes.			article	
L:Central America Monitor or Latin America Regional Reports				
U:..compare short term therapy to long term therapy..psych. disorder..				psychology
L:Article?				
U:Could be.			article	
L:Recent article?				
U:Yes.		70-86		
L:Psychological Abstracts				

U: User; L: Librarian

appropriate. For example, journal articles tend to have a more academic treatment than magazines or newsletters. Knowing the level of education of the user and the scope or purpose of the query can provide important clues about the relative usefulness of these sources to the user. We represent the gradation of information in the sources in Exhibit 5.

A stereotype (a cell in Exhibit 4) is represented as an ordered list of information sources, where the ordering is a heuristic reflecting decreasing usefulness of sources to that stereotype. For users

Exhibit 4. Stereotypes: $S_{1,1}$, $S_{1,2}$, ... $S_{4,4}$.

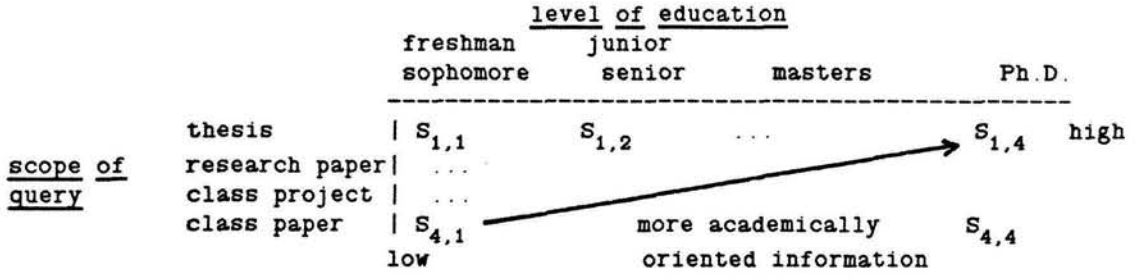
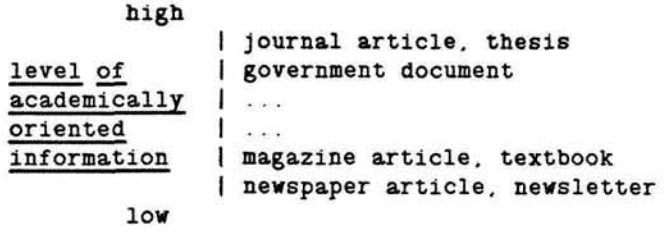


Exhibit 5. Gradation of different types of information



that are ranked higher along the diagonal line of Exhibit 4 (e.g. Ph.D. working on thesis), where the librarian generally suggests sources such as journal articles and government documents, the ordering is a "top down" version of Exhibit 5. For users that fall toward the lower left hand corner of Exhibit 4 (e.g. freshman working on a class paper), the reverse ordering applies. Other stereotypes have different orderings. The general process of matching users to sources is described more precisely in the following subsection.

3.1.4. Handle Matching

After the initial problem statement and the stereotyping of the user, the librarian knows the type of information the user is looking for, the field, the geographical areas, and the time frame pertinent to the query. Since each handle has specific values corresponding to each of the attributes, the problem of selecting a handle is one of matching the two sets of attribute values. In other words, the librarian attempts to find handles that cover the user's information requirements based on the four attributes. Two heuristics have been observed in this handle matching process.

A. Minimum Superset Heuristic

In some cases there may be more than one handle that is appropriate for the user's query. In this situation, the librarian generally recommends the handle that provides "just-enough" information since it saves the user the trouble of eliminating information from the handle that is irrelevant to the query. For instance, a user looking for information in psychology is likely to be pointed to the Psychological Abstracts instead of Social Sciences Index even though both might qualify as candidate handles based on their attribute values for a query. We refer to this heuristic as the minimum superset heuristic and define it as "the ratio of extent of information in the handle to the extent of information needed by the user" as measured by the attribute values of the query and the handle. The lowest score a superset handle (a handle that completely covers the requirement of the query) can have is one, which implies an exact match. Handles that are over-qualified have a score higher than one. All qualifying handles are arranged as an ordered list according to decreasing scores.

B. Partial Match Heuristic

In some cases, there might not be any handle that meets the user's requirements completely. For example, a user looking for in-depth information on political trends and economic development in Asia may discover that the Business Periodical Index covers articles in business whereas the Social Sciences Index provides information on the politics of the region. In such cases, the librarian builds a list of partially-matching handles where the ordering reflects the relevance of the handles to the query. The ordering is based on "the ratio of the extent of information supplied by the handle that is required by the user to the total extent of information needed by the user" along the four attributes defined earlier. For example, if a user wants information in two distinct fields whereas a handle provides information in only one of these fields, the handle is assigned a score of 0.5 on that attribute. The same scoring scheme applies to the two attributes: the area of applicability and type of information (listed in Exhibit 2). For the currency of information attribute, if a user wants documents dated from time x to time y and a handle provides documents from time s to time t where x is less than s, and t is greater than y, the handle is assigned the score (y-x)/(t-s). If t is less than y, the score is (t-x)/(t-s); if t is less than x, the score is zero. The ordering of the handles is based on the overall scores of the matching. If there are both over-qualified handles and partial-qualifying handles which cover the user's query, the over-qualified handles are ranked higher than the partially-qualifying handles.

When a suggested handle is not deemed as an appropriate one by the user, it is generally reflective of a misconception of the problem by the librarian. If none of the suggested handles are appropriate, the query is restated by the user, and the handle search starts over. Except for very

sophisticated users, it is not generally the case that a user can determine the relevance of a handle solely by its label. Rather, assessing the relevance of a handle generally requires exploring what documents it actually points to. This latter search process, what we term *document search*, is the second phase of the consultation model depicted in Exhibit 1.

3.2. Document Search

The way in which a handle is explored depends on the specific access methods provided by it. For example, strategies for finding information in an online database differ from those used for Central Banks Annual Reports which are stored on microfiche. In this study, we limited ourselves to online access tools. These tools include the library's online catalog system and several other commercial online databases.

3.2.1. Detailed Problem Statement

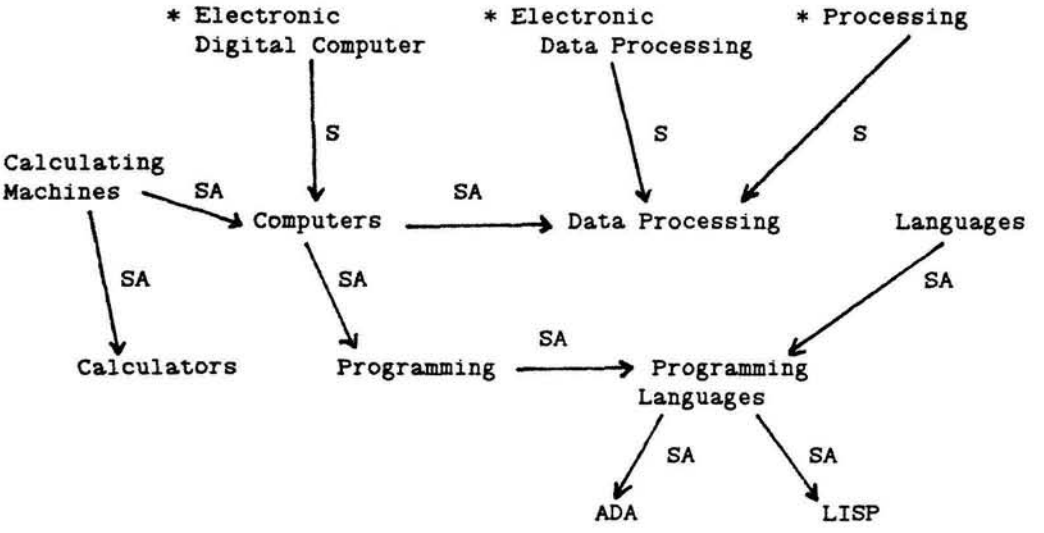
In order to be able to retrieve documents that will address the specific needs of the user, the librarian elicits specific terms from the user. This leads to a somewhat more detailed problem statement than what was expressed initially. This more detailed statement must then be sharpened and translated into a form where "official terms" (used in the indexing scheme) are included in it. Further, in order to capture the "semantic content" of the problem, the ordering of such terms and the operators (these could be Boolean operators such as AND, OR and NOT) used must be chosen appropriately. If the user can provide as many detailed terms as possible, it creates more potential access points to the official terms, which in turn increase the chance of matching.

3.2.2. Generation of Official Terms

The chances of terms in the user's query matching official terms is generally low. The librarian therefore initiates a "terms translation" process which includes consulting the Thesaurus and a brainstorming process aiming at eliciting official terms that might be similar to terms in the detailed problem statement.

The Thesaurus contains not only official terms, but also other "unofficial" terms which point to the official ones. The Thesaurus can be viewed as a large semantic-network of terms (concepts) where links are of two types: relations between unofficial and official terms, and set-superset relations (like IS-A links). Exhibit 6 shows a portion of the semantic-network corresponding to the Library of Congress subject headings.

Exhibit 6. A sample network of LCSH terms



* --- unofficial term
S --- see reference (lead unofficial term to official term)
SA --- see also reference (lead broader term to narrower term)

As an example of the usefulness of the network, consider the query "I am looking for information about *memory devices* on the *electronic digital computer*." The librarian can check the Library of Congress subject headings and find that the term *computers* captures the general meaning of *electronic digital computer* (from the link in the thesaurus, schematized in Exhibit 7). On the other hand, since the term *memory device* is not listed anywhere in the Thesaurus, the user and the librarian must come up with other terms that can express the same meaning, and use these to converge on the official terms.

In this stage of the consultation, both the user's and the librarian's familiarity with the subject area play an important role in determining the appropriate requirements. If the user or the librarian is familiar with the subject area, more terms might be proposed, increasing the chance of matching terms in the Thesaurus. The librarian might suggest terms directly, or urge the user to provide them. The goal is to end up with a query which includes only official terms.

3.2.3. Combination of Terms

After the official terms have been generated they must be arranged in a way that expresses the "semantic content" of the user's problem. The combination of terms is generally limited by the facilities available on the system. For example, many online databases provide boolean operators for combining terms. Some of these allow for the generation of temporary sets for further processing. The ordering of terms and operators are generally suggested by the user, with the librarian sometimes providing predictions on how large the resulting sets are likely to be.

Combining the terms results in a listing of documents that match the structured query. If the resulting set contains too many documents, the query must be tightened; this can be done by substituting ANDs for ORs in the query and/or rearranging the terms. Similarly, if the resulting set is too small, the query must be tightened by substituting ORs for ANDs or as before, rearranging the terms.

If the iterative process of query refinement results in documents that are not relevant, the document search phase begins over again with a different handle. The consultation terminates when a reasonable number of documents have been found that the user feels are relevant to the query. Exhibit 7 shows a protocol segment of an interaction illustrating the process of document search.

Lines 1 through 7 in Exhibit 7 illustrate the process involving the generation of initial terms corresponding to the query. Italics indicate the user supplied terms. Lines 8 through 28 reflect the translation process of all the italicized terms into official terms using a thesaurus corresponding to one online system called ERIC[1] . The underlined terms in Exhibit 7 are the official terms used to represent the user's problem. The librarian performs the search on the database for the user using the boolean combinations of terms approved by the user (lines 29 through 33). The interaction terminates when the user feels comfortable with the relevance and number of documents (line 35 through 39) that are produced by a query stated in terms of the official terms and the boolean operators.

4. Discussion

An important consideration in building intelligent systems is the extent to which such systems must model their users. The central inference problem in user modeling can be stated as follows: given some observed behavior of the user, infer the state of the user model that accounts for the

[1] Educational Resources Information Center

Exhibit 7. A protocol segment indicating the document search phase

protocol	stages
1. U: ..compare two types of students..	Detail problem statement
2. *engineering* and *engineering technology*..	
3. looking at the difference in three variables	
4. ..first, *career maturity*..	
5. L: Is this widely accepted concept?..	
6. U: Yes..other variables..*self esteem*	
7. and *vocational interest*	
(The librarian uses the thesaurus of ERIC descriptors.)	
8. L: Have you used ERIC before?	Terms translation
9. U: No,..only use social science index and	
10. psych. abstract..	
11.L: ..ERIC uses engineers..and engineering	
12. technicians..also engineering technology..	
13.U: ..they are what I want..	
14.L: ..look at related terms..mechanical design	
15. engineers..	
16.U: No, that is different..	
17.L: ..OK..engineering technicians,engineers, and	
18. engineering technology..now we need to develop	
19. career maturity, self esteem and vocational	
20. interest...	
21.U: ..try vocational development or career	
22. development..	
23.L: ..they use career development..under that..	
24. there is vocational maturity..	
25.U:	
(After 5 minutes interaction.)	
26.L: ..so we have..career development,	
27. vocational maturity, vocational interest,	
28. career choice,self esteem,self adjustment..	
29.U: ..do we "or" these?..	Terms combination
30.L: ..yes..we can "and" thes two..then "or"	
31. these..do you think it will cover	
32. your problem?..	
33.U: ..yes..	
(Use the ERIC online database.)	
35.L: ..how does these articles look?..	Check the relevance and
36.U: ..one or two fit..	amount of information
37.L: ..how do you feel about 107 hits?..	
38.U: ..1967 is a little bit far back..but I want	
39. them all..	

U: User; L: Librarian

behavior [10]. The various views in the literature on the importance of being able to infer the user's evolving "mental states" in the course of a dialog appear to have been driven by specific features of different problem domains. While extensive user modeling is usually considered neces-

sary in tutoring situations where correcting users' misconceptions may be important [13], it is less clear whether the same type of modeling is necessary for explanation and text generation systems [15].

Given the idiosyncratic needs of the diversity of users in a library, one might expect that a detailed user model would be necessary in order to render useful advice to a user. However, since this is clearly a practical impossibility, the librarian must adopt cruder but more generic strategies that have a good chance of being successful and applicable to the cross section of users. The strategies that they use, as described in this paper, reflect an effective compromise between support tailored to individuals and support suitable for a large population of users.

From a practical standpoint, our model should prove useful in two ways. Firstly, it should remove some of the burden from reference librarians, particularly for routine types of queries. Secondly, given the increasing importance of providing remote access to library facilities, an intelligent online assistant should prove to be effective in increasing the accessibility to these facilities.

As a closing caveat, we should point out that we do not expect to replace the reference librarian, nor do we think it practically possible to do so. In the course of this investigation, we have observed some unusual cases involving extensive dialogs between users and librarians directed at clarifying requirements, with some of these taking the better part of an hour. In such situations, typically involving sophisticated users with unusual queries, the librarian has little choice but to engage in a detailed communication process and "learn" about the details of the user's problem in order to render reasonable assistance. Such situations are clearly out of the realm of computer based assistance. However, for the large majority of user queries, our model should prove to be a useful practical online assistant.

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