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Contextual Search: from Information Behaviour to Information Retrieval

Abstract: Context influences information seeking behaviour; however, search systems have not made much use of contextual information to date. We present research that combines information behaviour and information retrieval approaches to develop a contextual search system for a software engineering work domain.

Résumé: Le contexte influence le comportement informationnel; cependant, les systèmes de recherche n'ont pas fait beaucoup d'utilisation de l'information contextuelle jusqu'ici. Nous présentons une étude qui combine des approches de comportement informationnel et de repérage d'information a fin de développer un système contextuel de recherche pour un domaine de travail de technologie de la programmation.

1. Introduction

Context plays a powerful role in shaping how people search for information and in determining the information they select and subsequently use. This has been recognized in key models of information behaviour (Dervin 1999; Wilson 2000) and interactive information retrieval (Saracevic 1996; Jarvelin and Ingwersen 2004). Taylor (1986) noted two decades ago that information needs consist of two distinct but inter-linked parts: the topic or subject matter of the need, and the situational elements that will impact how the information is used. Choo (1995) refers to these as "what information is needed", and "why is the information needed and how it will be used." Notably, mainstream information retrieval research adopted the former, and developed a model of search based on term matching in isolation from the broader information search context considered essential by Taylor. Search systems founded on the topic model are not able to filter results based on utility or value, which leaves the human searcher to manually review large amounts of information in order to meet their needs (Lawrence 2000). In response to this limitation, and with the goal of achieving more tailored and accurate search results, *contextual search* has recently risen to the top of the research agenda for information retrieval (Allan 2003).

The goal of contextual search is to incorporate a richer model of human searching behaviour into search systems, and as such, represents an opportunity for collaboration between information behaviour (IB) and information retrieval (IR), two fields which have hitherto progressed largely in parallel (Jarvelin and Ingwersen 2004; Vakkari 1999; Kuhlthau 2004). In this paper, we describe an approach to contextual search that bridges the gap between IB and IR and which serves as one example of how these fields can work together methodologically. We focus on contextual search as a means of improving search systems within the workplace. Our approach is grounded in empirical information behaviour research within a specific work domain, software engineering. We are using our findings to develop and test a context-specific search engine. While multiple contextual factors were potentially possible to consider (see Toms et al. 2004 for a brief discussion of the range of factors), we limited our examination to work task, information goal and document type, i.e., genre. We develop a model of the relationships

between work tasks, information goals and document types in this domain, and operationalize the model within a workplace search system. We will first provide some background to the study of context in information science in general and in information behaviour and searching, as well as reviewing some existing implementations of contextual search. We will then provide an overview of the methods and key findings of our contextual search project, with an emphasis on how the research design combines IB and IR approaches.

2. Background and Related Work

Context is a slippery but omnipresent concept in information science. A general definition of context indicates the breadth of interpretation and use: "the entire situation, background, or environment relevant to an event, action, statement, work, etc." (Online Dictionary for Library and Information Science). Other definitions describe context as a "container in which phenomenon resides*"* (Dervin 1997); or "some kind of background for something the researcher wishes to understand and explain" (Talja, Keso, and Pietilainen 1999). From this perspective, everything has context and everything is context. Although context can be viewed holistically in this way, the more common approach in information science involves deconstructing context into various spheres. This is nicely illustrated in terms of information searching in the general analytical model of information seeking and retrieval proposed by Ingwersen and Jarvelin (2004) and reproduced below (Figure 1), for which "the context for any node in the diagram consists of all the other nodes".

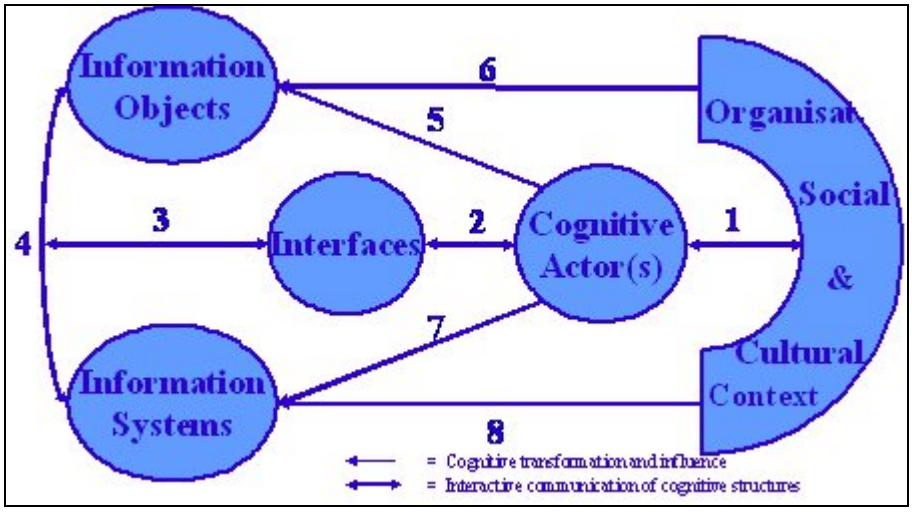

Figure 1: General Analytical Model of Information Seeking and Retrieval, reproduced from Jarvelin & Ingwersen (2004)

The motivation for studying context comes from two main sources (Johnson 2003). First, in human language and communication, context serves to disambiguate meaning. In natural language, the meaning of words varies significantly across disciplines and cultures and in some cases from sentence to sentence, so that some understanding of the contextual framework – cultural, linguistic, etc. – is essential to effective communication. Second, context influences, shapes, and to some extent deliminates social action. Common practices and patterns of

behaviour which are difficult to discern in the overall population under general conditions are much easier to identify among smaller groups, such as communities of practice, or in situations which share some common contextual variables, such as performing specific tasks. From both these perspectives, context plays a role in the core activities of information seeking and retrieval, i.e. expressing ideas and information needs, and seeking out and evaluating information. Furthermore, it is worthwhile noting that context is closely related to broad interpretations of the concept of *relevance,* which is fundamental to evaluation in information retrieval. If we consider the five dimensions of relevance (topical, system, situational, cognitive, and affective) described by Saracevic (1996) it is clear that a number of these are related to different contextual spheres, similar to those outlined in Figure 1 above. This connection is also made explicit in Mizzaro's (1998) framework for relevance, in which *topic*, *task* and *context* together form one of 4 dimensions of relevance, and in the framework that emerged from an empirically tested examination of relevance (Toms et al. 2005).

In the framework of this paper, *contextual search* refers to a general approach to information retrieval that is based not solely on terms and topics, but incorporates additional input with respect to the user, the documents, the domain, the search situation, the task etc. The primary goal of incorporating such context is to increase the relevance of results, although other outcomes, such as satisfaction, efficiency, and effectiveness could potentially be affected as well. In particular, contextual search has the potential to achieve "higher order relevance" – by retrieving information that meets user needs more fully, by supporting problem solving and task completion (Jarvelin and Ingwersen 2004). This is the type of contextual search that we believe can be achieved through collaboration between the information behaviour and information retrieval communities.

2.1 Information Behaviour and Context

Information Behaviour research has contributed greatly to our understanding of the role of context in general on information seeking and searching, as well as to the identification of a wide range of specific contextual factors that seem to influence these processes. A number of high level models emphasize the role of context on information behaviour. Taylor (1991) introduced the concept of work domain contexts as *information use environments (IUE) c*onsisting of "elements that (a) affect the flow and use of information messages into, within, and out of any definable entity; and (b) determine the criteria by which the value of information messages will be judged" (Taylor 1991, p. 216). Wilson's (1997) general model of information behaviour characterizes individuals and information needs as embedded in context, and delineates a whole range of additional intervening variables: psychological, demographic, role-related, environmental and source-related. Other influential frameworks that emphasize context are *sensemaking*, which suggests that information seeking is shaped by the context in time and space and the personal and emotive states of the individual (Dervin 1999) and *domain analysis*, which explores the ways in which different disciplinary paradigms shape the information seeking and needs of broader communities (Hjorland 2002). The impact of these theoretical frameworks has been felt in the large number of studies that focus on information seeking in context which have been produced over the past ~20 years (See for example Vakkari, Savolainen, and Dervin 1997) and in the development of theoretical models of interactive information retrieval (Ingwersen 1992; Spink and Saracevic 1997; Jarvelin and Ingwersen 2004).

A great number of contextual factors that play a role in information behaviour have been identified in the course of this research, but a general review of these is outside the scope of this paper (See Case 2002). Rather, we will focus our attention briefly on the contextual factors in use in this study: *information goals* and *work tasks*. Both are related to the concept of the *information need* that motivates and drives information behaviour. In traditional IR research, queries or search topics are generally considered to be reasonable representations of the information need; whereas, IB research has painted a much more complex and contextual portrayal of this notion. IB research has shown that people have a difficult time formulating queries to express information needs, whether as a result of some process of compromising their needs to accommodate perceived limitations of the information system or intermediary (Eichman 1978; Taylor 1968) or as a result of not knowing what it is that they lack (Belkin 1980). Studies of human reference interactions have shown that in order to meet peoples' actual underlying information needs, it is necessary to elicit a description of the context surrounding the need, i.e. the *search situation* – the task, motivation, problem, and intended use of the information (Taylor 1968; Dervin and Dewdney 1986; Harter 1986).

A task can be described in general terms as "a piece of activity to be done in order to achieve a goal" (Vakkari 2003), however in terms of search behaviour it is useful to distinguish between *search tasks* (i.e. looking for currency conversion tables) and *work tasks* (i.e. preparing an audit). Different types and characteristics of *work tasks* (time constraints, importance, domain, stage of completion) and of *information tasks* (complexity, uncertainty) seem to affect information behaviour (Vakkari 2003; Hansen and Jarvelin 2000; Bystrom 2002; Chang and Yee 2001). For instance, as tasks increase in complexity, searchers will tend to use a greater number and variety of sources, and will be more likely to turn to people as information sources (Bystrom and Jarvelin 1995). Nested with the work task is another layer of context for the search situation: the *information goal.* Information goals refer to the kinds of information people are seeking and what they intend to do with it. Limberg (1999) found that students with different broad information goals (fact-finding, assessing an issue and reaching a decision, understanding a topic) handled and evaluated information differently with respect to a number of parameters, including relevance, bias, information quantity and authority. Studies of searching behaviour have also found that different types of searching and selecting behaviours are observed for different types of information goals, such as known item searches, subject or topical searches, fact finding, and question-answering (Hsieh-Yee 2001).

Research in information behaviour has focussed extensively on identifying contextual factors and modeling search behaviours in different contexts. It has made fewer contributions to discovering the nature of the relationships between and among such contextual factors and processes (Johnson 2003; Talja, Keso, and Pietilainen 1999). Much of this research has implications for the design of information retrieval systems; however, many of the findings are reported at a relatively high level such that they do not lend themselves to design and implementation (Toms and Bartlett 2001).

2.2 Implementation of Context in Information Retrieval

Information retrieval research has focused more on documents than on users to date. This is reflected in an emphasis on *textual* context, rather than *user* or *problem* context in implementations of contextual search. There is still a long way to go before search systems can support anywhere near the contextual richness of human search interactions, but some progress

has been made in this direction. To follow is a brief overview of the various approaches to contextual search that have been implemented to date.

Text Snippets as Context
The main approach to context in IR systems research has been to mine the information objects in the collection for data on the frequency, location and co-occurrence of terms, a type of context defined as a. "sequence of semantically related terms"(Stairmand 1997). This data is then used in a range of automatic techniques, such as pseudo-relevance feedback and latent semantic indexing. The use of text as context can also be used in interactive search, an example of which is Yahoo's new "contextual web search" system (Y!Q), which allows users to submit queries from within a webpage or section of a page, and then extracts terms from the page or section for query expansion. These types of techniques contribute primarily to topical relevance.

Domain as Context
Search systems that serve specific disciplines or domains, such as CiteSeer a search engine for scientific literature, make use of contextual homogeneity to reduce the linguistic ambiguity of documents and queries. In some cases, domain specific search systems, such as Pubmed, make much more active used of context, by introducing controlled vocabularies, query processing and expansion, and search filters that reflect the needs of a specific community of users. Such systems tend to work from a static model of context, rather than responding to dynamic changes of user or task context, and thus can be considered to be limited implementations of contextual search.

Environment as Context
A very different type of "contextual search" deals with the development of search systems for mobile computing (Jones and Brown 2004). In this case, *context* refers to the physical surroundings (issues such as ambient noise and light) and/or the system (issues such as size of displays, interaction techniques). Research in this area is dealing primarily with the impact of these different environments on the use and usability of search systems, rather than on relevance.

Use and Preferences as Context
There are a whole range of contextual approaches that attempt to model and predict user needs and preferences. The most well-known of these is Google's PageRank algorithm that uses the link structure of the web to assign value rankings to pages and predict the likelihood that people want to retrieve them (Brin and Page 1998). This approach is related to that of personalization and recommender systems, which make use of usage and/or preference data from large user communities to infer the likely preferences of a specific user within the community (Freyne et al. 2004). A well-know example of this type of system is the personalized recommendations provided for users of Amazon.com. One of the key research questions for these types of systems, is whether implicit measures of user behaviours, such as clicking, display time, printing, etc. can be used to model user preferences (Kelly and Belkin 2004).

Search task / Information Type as Context
Another approach to contextual search is to consider information types in addition to topics. This is related to the idea that for different types of search tasks, people are often seeking specific types of information, such as research papers, homepages or summaries. A simple way

of providing this context is to provide users with search results categorized by type, as is done by the Guru-Net search engine. A more sophisticated approach was implemented in the Inquirus2 system, which asked searchers to select the type of information they wish to find, and then incorporated this information into the ranking algorithm. The IR research community has begun to focus attention on the search task and information type through the High Accuracy Retrieval of Documents track of the Text Retrieval Conference (TREC), and some interesting work is being done in this area which may find its way into future search systems (He and Demner-Fushman 2003; Belkin, Muresan, and Zhang 2004).

To date, limited use of context has appeared in operational systems; more research has been done, although on a selected basis which has yet to have migrated to working systems. This is somewhat surprising considering the rich literature from IB demonstrating some of the contextual factors that affect the search process.

3. Contextual Search Project

Against this background, we now move to a discussion of a research project underway for the past two years, to design and test an implementation of contextual search in the workplace. In this study, we undertook to explore and model the information behaviour of a specific work domain, in order to discover contextual factors and relationships that could inform the design of an improved search system. Our approach is consistent with the research imperatives that Kuhlthau (2004) outlined as a means of meeting the challenge of designing task-oriented information systems:

- sustained attention to a problem to develop concepts
- application of LIS conceptual framework
- development of collaborative research projects
- follow through to applications in system design

We took an end-to-end approach to designing such a system, beginning with a study of information habits within a particular work domain and following through to the (pending) implementation and evaluation of an experimental system. This project aims to connect research practices from the information behaviour and information retrieval communities, and as such is an interesting methodological case involving multiple methods and multi-disciplinary collaboration. We argue that contextual search is an area in which this type of collaboration is essential to the development of more effective search tools.

An outline of our research design is presented in Figure 2; the various stages are described briefly below. We identified 7 stages in the process, with the initial stages more in the information behaviour research tradition, and the remaining stages in the tradition of information retrieval and interactive information retrieval. More detailed accounts of different stages of the study are forthcoming (Freund, Toms, and Clarke 2005; Freund, Toms, and Waterhouse 2005).

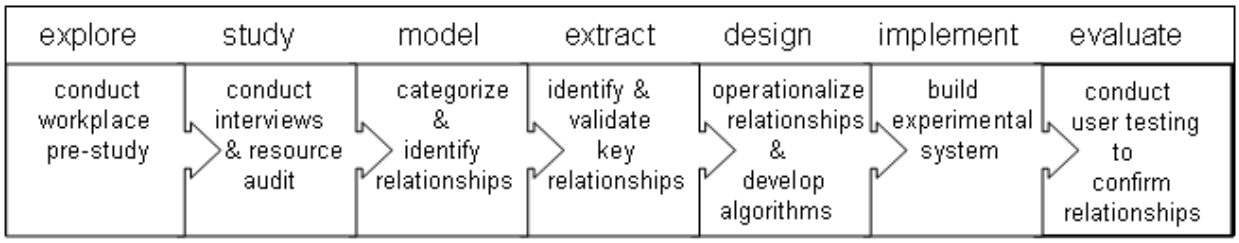

Figure 2: Research Design Outline for Contextual Search Project

3.1 Study Domain and Population

We conducted our research in a large hi-tech corporation working with a target population of software engineering consultants. These consultants provide clients with a range of services with respect to specific software products. The scope of their work and the knowledge required is extensive, so they rely heavily upon digital information sources. They are frequently involved in on-site engagements working directly with knowledgeable clients and they are expected to be experts among experts. The documents used by this group are widely dispersed on intranet sites, internal databases, and also in external web sites. They exist in a range of genres, some more general, such as tutorials and presentations, and others that are specific to this domain, such as engagement summaries and integrated scenarios. Genre is used as a means of categorizing documents in most of the large repositories used by this group, although the genre taxonomies are not standardized.

3.2 Exploring – Workplace Pre-Study

As a first step, we conducted an on-site exploratory study of workplace information practices through weekly visits over the course of a number of months. This study was guided by an understanding that existing information systems were not meeting the needs of this group. We took a holistic approach to understanding how information is used in this information use environment and domain, while at the same time trying to ways in which a contextual search system could make a contribution to work practices. We used a range of methods:

Focus group: using electronic meeting software, 5 consultants identified and ranked the importance of the kinds of tasks they do, the problems they encounter, and the information sources they use.

Semi-structured interviews: five consultants elaborated on their work practices and information use.

Job shadowing: 3 work days were spent with one consultant at a customer site to observe workplace information practices directly.

Resource audit: documents and sources of digital information were assessed to understand the types of resources available to this group.

Some of the key findings of the first phase are as follows:

- these are highly motivated and focused information seekers – information is often mission critical and they are often searching under severe time constraints;
- Because they work on a project basis, contextual parameters change significantly over the course of their work and shape to a great degree their information seeking behaviour;
- the main contextual spheres that influence searching behaviour are: consultants, projects, work tasks, problems and information goals.

- the information in use by this group is divided into multiple separate collections which are used for different purposes; there are a large number of document types (genres) in use, only a few of which are well-known and understood by the consultants.

3.3 Studying – Structured Workplace Study

This methods and instruments for this phase of research were developed based on the findings of the pre-study phase. This phase was guided by the following research questions:

A. What contextual factors of information searching influence selection?
B. What contextual factors of information content (documents) influence selection?
C. What relationships exist between (A) factors of search context and (B) factors of information context that could be exploited to improve information retrieval?

Interviews: We conducted detailed, semi-structured interviews from 1-2 hours in length with 14 software consultants. Participants were software engineers from two product groups in the company. We used a contextual model of information seeking as a framework for our interviews, similar to that of (Kari and Savolainen 2003). The interviews were digitally audio-recorded and transcribed for qualitative analysis using Qualrus software. Qualitative analysis focused on the identification of themes, categories of tasks, information problems and sources, and correlations between work practices and information behaviour.

Document Analysis: We compiled a proportional sample of 200 documents from 11 core document repositories to identify features of the information space that could be exploited by a contextual search system. The key features that we identified were: document source (repository), format (pdf, ppt, doc, etc), document length, and document type (genre). By comparing various genre categories in use over 6 repositories, we developed a set of ~20 genres that are in common usage in this domain.

This stage produced a large amount of data with respect to information seeking and use in this domain. One of the key findings was the identification of a set of contextual factors that influence searching in this domain (Figure 3). These relate to the *consultant* as user who has a particular *engagement* (project) that involves particular *work tasks*, which give rise to *problem situations*. The data from this phase was also used to develop the model in the next phase..

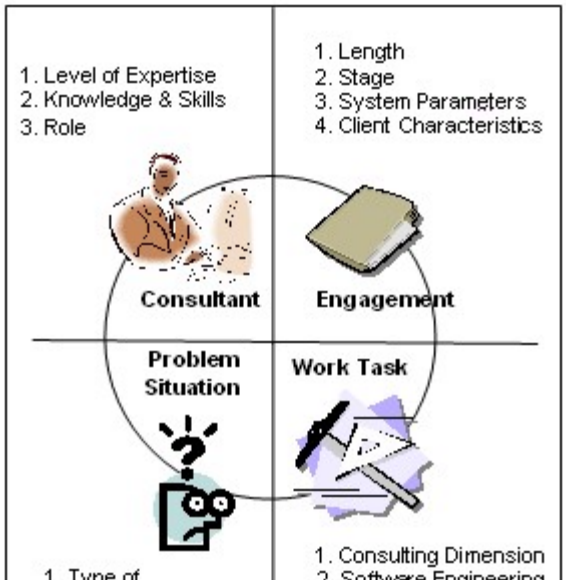

Figure 3: Contextual Spheres & Factors that Influence Searching & Selecting

3.4 Modeling – Categorizing and Identifying Relationships

We developed a general model of the contextual factors involved in information searching in this domain (Figure 4). The proposed model indicates that conditions within the four contextual spheres determine some information access constraints (time and source availability) as well as shaping the general characteristics of the information that is sought. These constraints and characteristics in turn, determine the strategies that consultants use to find information. In particular, they influence choices with respect to channels, sources and genres**.** At this stage we also developed broad taxonomies for each of the contextual factors, including a set of ~12 work tasks and ~5 information goals.

3.5 Extracting – Key Relationships

At this point, we moved from a qualitative and descriptive research paradigm to an experimental paradigm. In order to implement and test the potential contribution of contextual factors in a search system, we needed to isolate a small set of factors and relationships. We assessed the overall set of factors, considering both the relative strengths of relationships between various contextual factors and searching and selecting behaviour as indicated in the interview data, and the more pragmatic issues of being able to operationalize and capture the necessary contextual data. From the general model, we selected the following factors to test: Work Tasks, Information Goals and Document Genres. We developed the general hypothesis, that for a given search situation, the relevance of different document genres would be related both to the type of work task being undertaken and the specific information goal of the search. There was evidence from the interviews that these relationships existed, ie, that a user doing a certain work task and having a certain information goal, would be likely to find different genres of varying usefulness. However, before we could implement this in a system, we needed to have clearer measures of the strength of association between these factors. In order to collect this type of data, we conducted two additional studies.

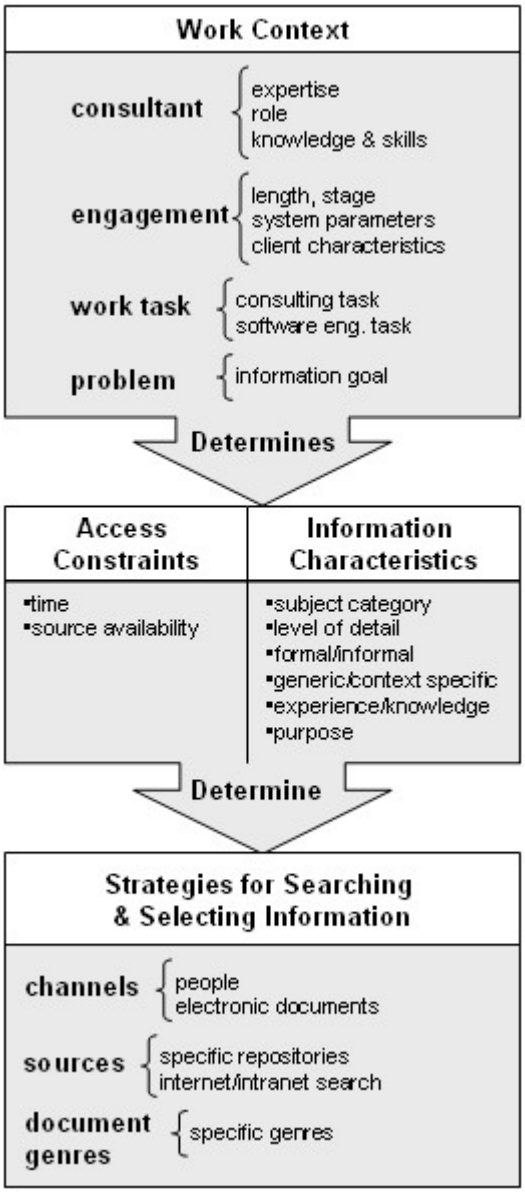

Figure 4: Model of Work Context and Information Searching

Metadata Analysis: Our data set was an existing document repository both created and used by our target population, in which documents were meta-tagged by *purpose* (task and information goal) and *document type*. We conducted a correspondence analysis of 5800 pairs of tags to identify the nature of the associations between them (Freund, Toms, and Clarke 2005).

Validation Survey: We designed a web survey to obtain additional data on the relationships between: 5 different information goals (learning, doing, finding facts, solving problems, getting advice) and 17 document genres – participants scored each genre on a Likert scale for likely usefulness for each of the goals; and between 11 different work tasks and task-based information characteristics.

Based on the findings of these two studies, we were able to determine two sets of relationships, between work tasks and document genres and between information goals and document genres. The relationships are expressed as being positive, negative or neutral. As a result, we are able to assign positive and negative weights to document types based on the search situation context. This is illustrated in Figure 5, which shows how the set of document types would be weighted for a particular contextual scenario (task = software architecture; goal = finding facts). The genres in the bottom left are positively correlated with both the task and goal, and thus are most likely to be useful; whereas those in the upper right are least likely to be useful for the specified search situation.

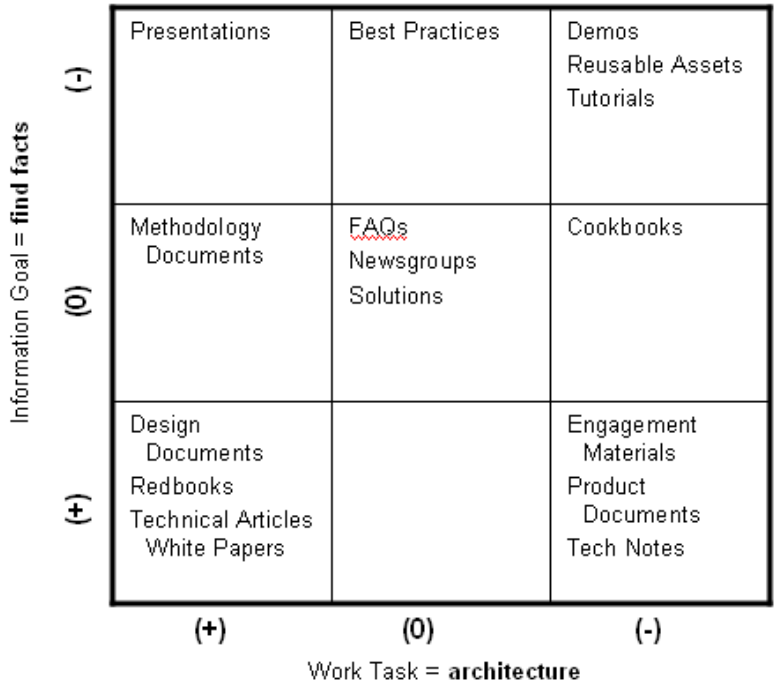

Figure 5: Example of Genre Distributions for a Specified Search Situation

3.6 Design – Operationalize the Relationships

At this stage, we began to collaborate with a group of information retrieval researchers on the design stage of the experimental system. We made a number of design decisions.

- contextual input with respect to the search situation will be collected explicitly from the searcher via selection from controlled lists;
- document genre will be determined via pre-processing using an automatic classification process based on machine learning techniques;

- positive and negative context-genre relationships will be incorporated into the ranking algorithm, rather than used to filter or cluster result sets.

3.7 Implementing – Building the System

We are currently in the implementation stage of the project. Rather than build a search system for purposes of this project, we are working with a team of researchers who have an existing research search engine which we are modifying for purposes of this experiment. Working within the study domain, we will crawl and index the information space of our user group. We will then implement a baseline search system with no contextual features as well as an experimental search system that incorporates the task/goal/genre relationships.

3.7 Evaluating – Experimental User Study

We plan to conduct an experiment to compare the performance of our contextual search system vs. a baseline system that uses only query input. There are challenges in evaluating a contextual search system using traditional experimental methods, as the use of assigned tasks and standard recall/precision metrics will not be effective in measuring improvements in higher-order relevance. Therefore we propose to use simulated work task situations (Borlund 2003) rather than search topics, and to use a broad evaluation framework including metrics for recall and precision, efficiency, user satisfaction, usability, work task completion and quality of output (Jarvelin and Ingwersen 2004). The evaluation will take place within the workplace and on participants' own workstations in order to simulate a natural work environment, while at the same time collecting controlled data that can provide a clear measure of the effectiveness of the contextual factors.

4. Discussion

The implementation of contextual search that we have presented is yet to be fully built and evaluated, so it remains to be seen whether the task/goal/genre relationships will, in fact, bring significant improvements to system users in this domain. However, we believe that the process used to identify these factors and model their relationships was sufficiently rigorous to make some measure of improvement likely. The advantage of taking an information behaviour approach to the project, rather than a system development/requirements analysis approach, is that we were able to develop a general model of information seeking and searching in this domain that serves as a solid basis for hypothesis testing. In this implementation, we focus on several characteristics of the search situation – task, goal and genre; however, there are many other factors that were identified in the study that we will be able to test in the future. Chief among these are project parameters, such as the knowledge and role of the consultant with respect to a particular project, the length, scope and completion stage of a project, and the nature of the relationship with the client. The advantage of actually building a retrieval system and evaluating these relationships in a concrete manner is that this type of systematic approach will enable us to gradually untangle the contextual jungle of search, and identify those factors that can be operationalized to improve search systems. This has the potential to make a more serious contribution to search system users, than what has been made by the wide-ranging and rather haphazard implementations of contextual search to date. One of the limitations of this type of study is that it is, by necessity, context-specific, and will be of greatest use to a particular community of users. However, we believe that the general approach we have taken, of

exploiting task, goal and genre relationships is sufficiently high-level to prove useful for organizational searching in other domains.

5. Conclusion

Contextual search has the potential to fuel the next leap forward in search technology, which would see search engines become functional and efficient tools for task completion. Currently, search engines only go half the distance and leave searchers to walk the rest of the way by sifting through enormous sets of documents. The body of research on information seeking in context has the potential to contribute greatly to contextual search, and yet has had very little impact to date on the design of information retrieval systems (Jarvelin and Ingwersen 2004). This research represents a relatively rare combination of information behaviour and information retrieval research, and is valuable in that it not only develops an empirical model of information searching in a particular domain, but it also aims to test the model as implemented in an information retrieval system.

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