The SST method: a tool for analysing Web information search processes

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Abstract

The article presents the Search Situation Transition (SST) method for analysing Web information search (WIS) processes. The idea of the method is to analyse searching behaviour, the process, in detail and connect both the searchers' actions (captured in a log) and his/her intentions and goals, which log analysis never captures. On the other hand, ex post facto surveys, while popular in WIS research, cannot capture the actual search processes. The method is presented through three facets: its domain, its procedure, and its justification. The method's domain is presented in the form of a conceptual framework which maps five central categories that influence WIS processes; the searcher, the social/organisational environment, the work task, the search task, and the process itself. The method's procedure includes various techniques for data collection and analysis. The article presents examples from real WIS processes and shows how the method can be used to identify the interplay of the categories during the processes. It is shown that the method presents a new approach in information seeking and retrieval by focusing on the search process as a phenomenon and by explicating how different information seeking factors directly affect the search process.

Keywords: Information searching; Information retrieval; Information seeking; World Wide Web

1. Introduction

Too little is known about people's Web information search behaviour. The purpose of this paper is to present a method[1] that can be used to analyse Web information search (WIS) processes. In order to understand the nature of WIS processes it is necessary to identify the interplay of factors at the micro-level, i.e. to understand how search process related factors such as the actions performed by the searcher on the system are influenced by various factors that might explain it, e.g. those related to his work task, search task, knowledge about the work task or searching etc.

There are both *academic* as well as *technological* motivations for gaining such knowledge. The main argument for performing basic research is the need to gain a more complete understanding of the phenomenon under study. Our approach is an example of such a study. Web information searching represents a phenomenon that millions of people engage in on a regular basis and which affects their everyday life. To get basic insight into what factors influence this kind of behaviour would benefit not only the research community of information science, but also the searchers themselves, in other words, the general public. There are textbook prescriptions on how web searching should be done. However, human behaviour rarely follows textbook prescriptions, in particular, when non-professional searchers are performing the process. If the prescription is not a valid description, then, what is the process and how is it guided?

From a technological point of view we would argue that both developers of Web software and Web content providers would benefit from deeper knowledge about how their target groups use their products. To develop better software and web resources that are suited for helping the information searchers to perform their tasks could in our view be a side effect of improved

[1] In reality we have made a method schema (Eloranta, 1979) which is more general than a method. This schema can be used to derive specific methods for specific research problems. In this text we use the term method.

knowledge about WIS processes. Thus we would argue that the research problem also has an applied research aspect, even if the main argument for doing discoveries in this area would be to learn more about the phenomenon as such.

Several information seeking and retrieval (IS&R) studies (e.g. Dervin, 1983; Ellis, 1989; Ingwersen, 1992; Kuhlthau, 1993; Belkin, Marchetti & Cool, 1993; Byström & Järvelin, 1995; Wilson & Walsh, 1996; Saracevic, 1996a; Spink, 1997) have identified many factors (see Fidel & Soergel, 1983 for an overview of possible factors) that influence the selection and use of sources for information seeking and retrieval. What we lack is knowledge on whether, and how, these factors influence the actual search performance. Web information searching often seems to be rather haphazard behaviour where searchers seem to behave irrationally, i.e. they do not follow optimal textbook prescriptions (e.g. Henry et al, 1980; Belkin & Vickery, 1985; Ingwersen, 1992; Marchionini, 1995), and seem to neglect many relevant factors when performing their actions.

In the research literature it is claimed that factors related to the searcher's personal characteristics, search task, and social/organisational environment influence the searcher during his selection and use of information sources. These factors have been classified and discussed in great detail in the literature, and more recently also the searcher's work task has been focused on as playing a major role (e.g. Byström & Järvelin, 1995; Vakkari, 2001). We agree that such factors need to be taken into account. We would therefore like to focus specifically on the search process and how it is affected by external factors.

In the IS&R literature, there are several studies which focus on search processes (e.g., Saracevic et al, 1988; Su, 1992; Marchionini et al., 1993). These studies have used logged and/or video taped data on online bibliographic search processes. However, their scope has been on search tasks and searcher characteristics, focusing on term selections and results evaluation. The process itself has

not been looked at as a phenomenon to be explained. Similar examples can be found in the Web searching context (e.g., Wang & Tenopir, 1998; Fidel et al., 1999; Silverstein et al, 1999; Jansen, Spink & Saracevic, 2000), these studies analyse characteristics of the WIS processes, such as term selection, search task strategies and searcher characteristics, but do not aim at explaining the process itself and the factors that guide it. We believe that it is fruitful and important to focus on explaining the process at a micro-level – how it is structured, if at all, and what affects it.

Previous studies of Web searching to a large degree has used log analysis (see review in Jansen and Pooch, 2001) or surveys (e.g., GVU's WWW user surveys (2001), and the Nielsen surveys (Nielsen netratings, 2003)) as their data collection methods. Log analysis can provide researchers with data on large numbers of user-system interactions focusing on users' actions. Most often log analysis has been used to see how searchers formulate and reformulate queries (e.g., Spink et al, 2001). The user surveys have focused on demographics of web users and collected information on the use of different kinds of web resources, time spent on web use, e-shopping etc. Although both these kinds of methods may reveal important information about how and why people use the Web they are unable to point out what causes the searcher to perform the actions he/she does. We cannot use these methods if we want to learn how the work tasks, search task, and searcher's personality directly affect the WIS process.

According to Newell (1969) a method consists of the following three parts: (1) a problem statement or domain, (2) a procedure, and (3) a justification. The problem statement, or *domain,* which is used in the following, states the properties of the problem and their relationships. This designates the type of problems that may be solved or handled by the procedure.

The *procedure* is what we in daily terms would call the method itself. It is "what delivers the solution to the problem" (Newell, 1969, p. 370). The procedure refers to the operations that

should be applied to reach a solution. It may, for example, include specification of the kinds of data needed to identify a certain effect.

The *justification* of the method constitutes of supplying arguments that make it rational to believe that the procedure works. This entails testing the method with the specified data to show that it delivers the solution to the problem.

In this paper our main foci will be the general characteristics of the WIS process in the domain and the method's procedure. We will show how it can be used through examples on real empirical data.

The article first presents previous research on Web information searching and relevant general findings from information retrieval and information seeking research. Then we give a short introduction to the domain of the method. This is followed by a section which focuses on how to apply the method on real data. In the final section we discuss our findings and draw conclusions.

2. Previous research

In this section we investigate important research papers in order to identify factors that influence during Web information searching. For a thorough overview of this area we recommend Jansen and Pooch's (2001)-review. We also investigate general models of information seeking and retrieval to identify supplemental factors. These factors will form a basis for modelling our method's domain.

2.1 Web searching

The majority of studies of Web interaction focus on single sites and are based on server log analysis (Jansen & Pooch, 2001). We examine two large search engine studies based on log analysis; the Excite studies (reported in e.g. Jansen, Spink & Saracevic, 2000 and Spink et al., 2001) and the Alta Vista study (Silverstein et al, 1999) as well as several smaller studies focusing on the client side of interaction. The major limitations of these studies include that they only catch a narrow facet of the users' Web interaction and that we hardly know anything about the user, his/her goals, strategies, and motivations. On the other hand log analysis is an easy way of getting hold of data that can be treated with quantitative methods and we can use it to get statistically significant data about users' choice of terms and use of syntax for querying search systems.

Jansen, Spink, and Saracevic (e.g. 2000) have analysed more than 50000 queries in Excite's query log and found that users use few terms when searching the database (2.21 per query). This indicates that the users spend little effort per search task in a single search engine although the paper says nothing about whether users search for different topics during a session, i.e. we do not know if they tried to solve more than one task in one session. The survey also shows that only approximately 5 % of the users use advanced search features like the Boolean AND-operator (*very few* use OR and AND NOT) and relevance feedback (the latter is used in 5 % of all *queries*). A third important point is the examination of search results. Only 20 % of the users looked beyond the first two result pages. On average each user looked at 2,35 pages. A follow up study based on analysis of one million queries in Excite (Spink et al., 2001) showed that searchers move towards shorter queries and that they view fewer pages of results per query (Wolfram et al, 2001).

Silverstein and colleagues (1999) have performed a similar analysis of approximately 1 billion requests, or about 575 million non-empty queries - from Alta Vista. Their findings support the

notion that Web users behave differently from users of traditional IR systems - they use few query terms, investigate only a small portion of the result list, and seldom modify queries. It is however impossible to tell what the situation would have been like if the search engines had similar response times and the same features that professional IR systems have. If one wishes to compare differences in use between Web search engines and traditional IR systems, one should take into account both the users, the system and the intermediary, i.e. different human computer interaction (HCI) dependencies like bandwidth, features of the client program, etc. To obtain such knowledge it is necessary to study interaction also from the user side.

There are surprisingly few studies that have focused on the user, or client side, of Web transactions (Catledge & Pitkow, 1995; Wang & Tenopir, 1998; Wang, Hawk & Tenopir, 2000, Hölscher and Strube , 2000). There are, however, a few studies that have focused on children's and high school students' use of the Web to solve assigned specific search tasks (e.g., Fidel et al, 1999; Large, Beheshti & Moukdad, 1999; Bilal, 2000; 2001). Lots of user-centred surveys have, on the other hand, been performed with other hypertext systems (e.g. Shneiderman et al., 1989; Marchionini, Lin & Dwiggins, 1990; Rada & Murphy, 1992; Qui, 1993a-b).

An interesting survey was done at the Georgia Institute of Technology (Catledge & Pitkow 1995). 107 persons belonging to the Institute agreed to have their client logs captured over a period of three weeks. The client logs contained the URL of the users' current and target page, as well as information on the technique they used to access the target. The data were analysed to compute path lengths and frequency of paths. A so-called Pattern Detection Module (PDM) algorithm was used and three kinds of Web users were found:

- Serendipitous browsers, i.e. users who avoided repeating long sequences.

- General purpose browsers, i.e. users performing as expected. These users have a 25 % chance of repeating complex navigation sequences.
- Searchers, i.e. users, who repeat short sequences infrequently, but long navigational sequences often.

The survey also gives some insight into which techniques and tools are being used to browse the Web. They found that in 93 % of the cases following links (52 %) and using the back button (41 %) was the method being used to access Web pages.

Wang and colleagues (Wang & Tenopir, 1998; Wang, Hawk & Tenopir, 2000) are interested in the cognitive styles and affective states of web searchers. One conclusion they make is that many users develop a general mental model that covers all Web search systems. Thus they may for example use the same syntax in different systems; "but there was little evidence that users changed their mental models after a few failed trials with no messages or clues from the system" (Wang, Hawk & Tenopir, 2000, p. 243). They also found that there is an advanced group of Web users who use advanced features of the search systems - erroneously. There was no significant relationship between search time and computer and search experience.

Hsieh-Yee (1998) has compared *simulated* searches for text with searches for graphic information as well as known-item and subject searches using Alta Vista. The author suggests that due to the structure of the Web a hierarchical approach (i.e. the searcher actively manipulates the URL of a page to access a particular level in a resource's hierarchy in order to explore it) is often used as an additional tactic to traditional tactics like keyword and author searching. The ideas put forward should be further investigated with data taken from actual web sessions.

Large, Beheshti and Moukdad (1999) investigated the moves (or actions) made by primary school pupils during web searching. Fidel and colleagues' (1999) study focused on high school students and found that they were focused and flexible searchers, but that training and search support was necessary to release the great potential of the Web as an information gathering resource. In Bilal's two articles (Bilal, 2000; 2001) on 12-14 year old children's use of the Yahooligans! Web search engine she examines their cognitive, affective, and physical behaviour when using the search engine. She has among other things compared how these use the search tool for solving tasks of different complexity and found that "children had more difficulty with the research task", i.e. tasks that are open-ended, "than with the fact-based task" (Bilal, 2001, p. 135).

Hölscher and Strube (2000) focus on how search and background knowledge affect Web search strategies. They have a process-oriented view of Web searching looking at transition probabilities for different interaction techniques. The authors conducted a two-stage-study combining various data collection techniques (including, interviews, observation, client program logging, and having the searchers instruct intermediaries how to perform simulated search tasks.) They found that both kinds of knowledge independently and combinatorily affect search strategies and that lack of either knowledge results in compensatory search behaviour.

Table 1. Summary of representative previous studies of web information search behaviour

	Characteristics								
Study	**Search session (process)** actions	**Search task** strategy	**Search task** complexity	**Searcher** Cognitive style	**Searcher** affective style	**Searcher** topic knowledge	**Searcher** search knowledge	**Search results** success	**Search system** support
Catledge & Pitkow (1995)	•	•							
Hsieh-Yee (1998)	•	•							
Wang & Tenopir (1998)		•		•	•				
Fidel et al. (1999)		•					•		•
Large, Beheshti & Moukdad (1999)		•							
Silverstein et al (1999)	•								
Jansen, Spink, Saracevic (2000)	•								
Wang, Hawk & Tenopir (2000)		•		•	•				
Bilal (2000; 2001)	•	•	•	•	•	•	•	•	
Hölscher and Strube (2000)	•	•				•	•		

Table 1 provides a summary of the aspects of Web information searching treated by previous studies. Past studies have focused on a rather limited set of factors and almost all studies could be claimed to relate to the idea of web search strategies. The four central factors are the searcher, the search task, the search system, and the search session. Significant factors that are not dealt with in these articles are work task and information needs, which can be explained by the fact that these studies either use anonymous transaction log data or use assigned or imposed search tasks[2]. With the notable exception none of Hölscher and Strube (2000) none of the articles deal with web searching from a process perspective. Hölscher and Strube also present the only explicit model of what happens during Web information searching.

The variety of studies presented above are able to shed light on a few factors that influence web searching. They have, however, limited explanatory capability because fairly little interplay of the different factors is taken into account. We cannot, e.g., see from these studies how the searcher's organisational background affect her search task strategies or how the complexity of the search task affects the time spent searching the system.

2.2 Factors affecting information searching

In addition to Web searching specific literature we have examined the general IS&R literature which suggests at least five categories that influence information searching: the *work task* (e.g., Byström & Järvelin, 1995; Hansen, 1999; Vakkari, 2001), the *searcher* (e.g, Belkin, Seeger & Wersig, 1983; Ellis, 1989; Ingwersen, 1992), the *social/organisational environment* (Rasmussen, 1990; Hjørland & Albrechtsen, 1995; Audunson, 1999), the *search task* (Järvelin, 1986; Marchionini, 1995), and the *search process* (Fidel, 1985; Spink, 1997). All these categories in turn can be

[2] It might be argued that in the study made by Fidel and colleagues (1999) the searchers are given an assignment by their teacher which can be considered a work task. They are, however, given clear rules about how to solve

described by a variety of attributes, in Table 2 we list some representative attribute examples found in selected articles and books. For further discussions and examples of attributes we refer to Pharo (2002).

Table 2 A representative set of information searching categories and attributes

Study	**Work task** complexity	**Work task** goal	**Work task** stage	**Searcher** education	**Soc./org. environment** domain	**Soc./org. environment** strategies	**Search task** goal
Byström & Järvelin, (1995)	•	•					•
Kuhlthau (1991)			•				•
Ellis (1989)				•	•		
Hjørland & Albrechtsen, (1995)					•		
Audunson, (1999)						•	
Marchionini (1995)							•

In the literature (e.g., Saracevic et al., 1988; Ingwersen, 1992; Marchionini, 1995) there are claims that these kinds of factors and their attributes affect search processes. We cannot see, however, that previous research has dealt with *how* such factors directly influence the processes. This may be due to the lack of applicable methods. Our aim has been to develop a method that makes it possible to study the effects of such factors during the WIS processes. For this purpose we suggest the SST method.

3 A model of Web searching

We have selected five broad categories (Figure 1) or concepts that seem to be relevant for analysing what happens during *task-based WIS-processes*. These categories and their attributes have been collected from the literature studies presented in the previous sections and complemented by a pilot study of real web search sessions. In the pilot study we used grounded theory (Strauss & Corbin, 1990) on three search sessions in order to identify additional categories and attributes.

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the task, i.e. required to use the Web in order to solve the assignment, although it could have been solved by using other means.

The pilot study in particular was fruitful in identifying how search processes can be divided into search situations and transitions (see below). The data collection procedures used in the pilot study is presented in Section 4.

In the literature there has been a lack of consistency concerning the use of the word "task", which can be used to refer to "work task" as well as "search task". We will therefore use the following definitions:

Work task is defined as a series of actions in pursuit of a certain goal typically outside a plain information seeking context.

Search task is defined as a series of information seeking and searching actions in pursuit of a certain goal of obtaining some more or less precisely specified information.

A work task and a search task may share the same characteristics, even be identical. The latter would be the case when the task performer is an intermediary whose work task is to perform a search task for a client and submit the result in form of a printout, list of references, etc.

Figure 1 is a representation of the framework's categories and the relationships existing between them. The search process category consists of two subcategories; *search situation* and *search transition*. These categories constitute a conceptual framework that explicates the *domain* of our proposed method. Also they can be said to represent a model of a sub-domain in information seeking and retrieval. We will briefly discuss the search process category here, the other categories and their attributes are well known from the IS&R literature. We have given each category a set of relevant attributes which we believe are sufficiently self-explanatory (for details see Pharo,

2002). The novelty of our model is that we aim at analysing how the categories/attributes directly affect the search process. We shall show examples of this in a later section.

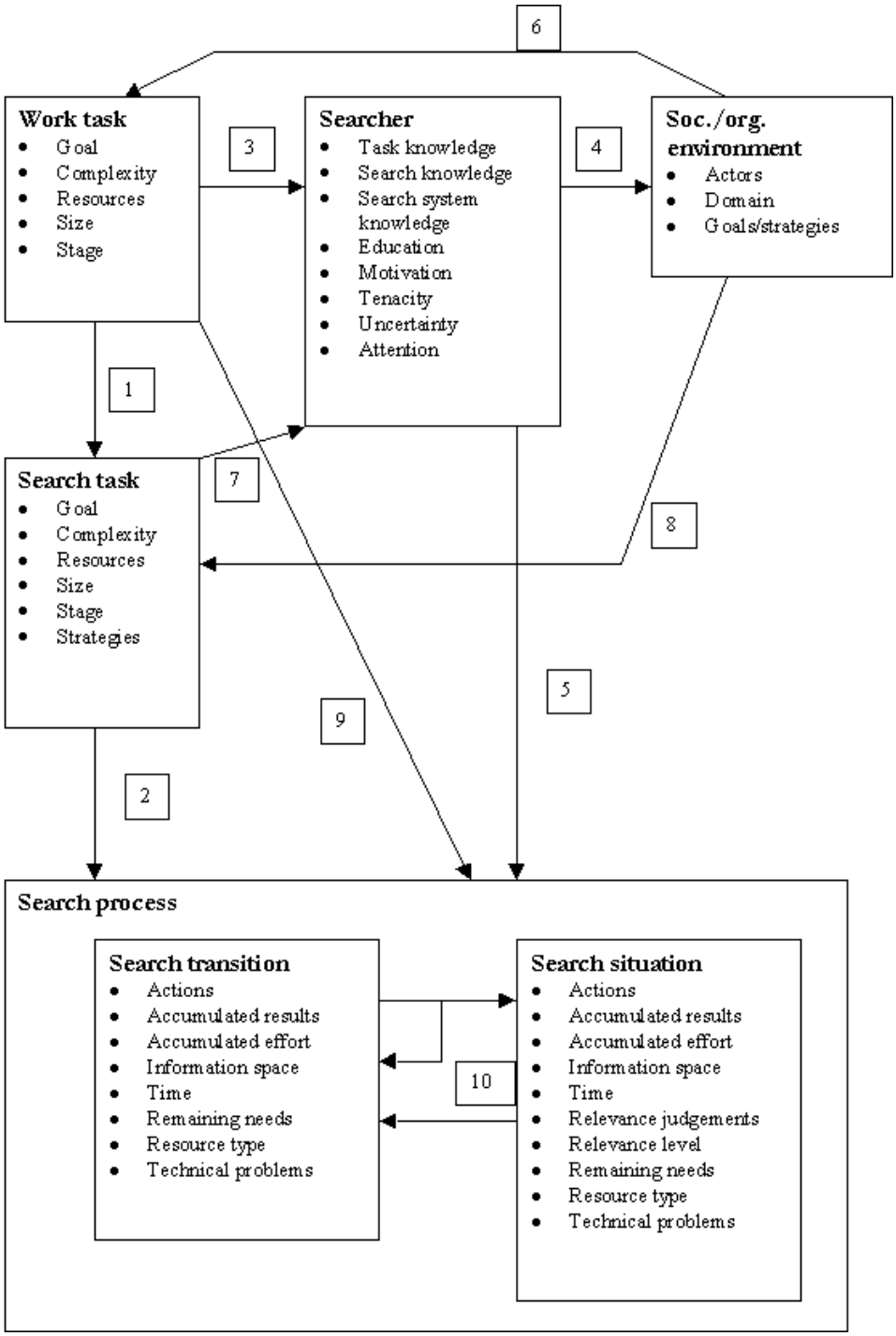

Figure 1. The conceptual framework - the domain of the method schema

In the presentation of the process we discuss whether log analysis or surveys, which seem to be the most common data collection methods in Web IR&S, can be used to collect the necessary data on each category and attribute. In general the problem with:

- Survey-type of WIS analysis is that neither the specific work tasks/search tasks nor the specific processes are captured. Ex post facto findings in surveys provide only overviews individuals' conceptions of WIS in general;
- Log analysis-type of data on WIS analysis is that it is not informed by anything happening in front of the computer screen.

In fact, even if one combines these types of analyses, one cannot analyse the processes properly for the effects of characteristics of work tasks, search tasks, or specific processes because the primary determinants are missing from the study setting. For this reason we have argued for the use of triangulation as a general approach for data collection, which we shall return to later.

3.1 The search process

With our approach we want to focus on capturing clear, logical and whole processes for interpretation and analysis – data both on the concrete searching process and the searcher's intentions and motivations. A search process is a series of transitions and situations and switches between them, following the three basic rules:

1. a search process always starts with a transition
2. a transition may be followed by a transition or a situation
3. a situation is followed by a transition or by the end of the process

3.1.1 Search situations and transitions

Search *situations* are the periods during a search process when the searcher examines a resource in order to find information that may be of help to her to execute her work task. Situations may take place in the same kind of resources as transitions depending on the search task; if the searcher wants to learn more about the structuring of subject indices it would be natural to examine such resource types for that purpose.

Search *transitions* are executed in order to find resources in which the searcher believes there may be information that can help her execute her task. The transitions consist of source selection and inter-source navigation. A third way of explaining it is to say that the transitions deal with *meta*-information.

The main difference between situations and transitions is that during transitions the searcher interacts with information surrogates with the intention of finding resources that she believes may help her solve his task. Thus a transition can be compared to an information-seeking strategy (ISS) (Belkin, Marchetti & Cool, 1993) performed in a meta-information resource. As the searcher has no contact with potentially task-solving resources during transitions, no direct relevance judgements can be made. Of course the searcher will decide which links to follow or reject in a query result list or a subject index, but as soon as a link is selected a situation starts. Thus all relevance judgements during transitions are based on surrogates and lots of rejections take place "silently".

3.1.2 Attributes of situations and transitions[3]

Search situations and transitions have many attributes in the model (Figure 1). These were identified partly in the pilot study (see Pharo, 2002) and partly in existing literature. The attributes relate to the process directly and to the external factors (e.g., searcher's motivation and knowledge) as discussed below.

Action is used to describe the moves (Fidel, 1985) made by the searcher during a situation. In web interaction this is following of link, entering of query, or reading a page. This is a kind of information easily captured by log analysis. The actions may be influenced by the, e.g., search task strategy.

The *accumulated results* refer to the information already found. This includes information found in previous situations as well as information found in the current one. The search process is characterised by the searcher constantly stacking (usable and useless) results into a pile and choosing to use (or not to use) whatever is in that pile in the current transition. Accumulated results relate to the completion of the information need (or the futility of trying that). In order to obtain knowledge about the accumulated results one needs data about the work task, which can be collected in interviews with the searcher, as well as the comments made by the searcher during the process. We cannot use logs or surveys to collect this kind of information.

The *accumulated efforts* refer to how much work the searcher totally has had to invest from the start of the present session (or in prior sessions) upto the current position. In addition it can refer specifically to effort invested in the current situation. This can be captured by the analysis of the search log of the current session.

[3] Search situations share many characteristics with search transitions, therefore, unless otherwise stated, the

The *information space* refers to the part of the Web that the searcher has navigated, as well as the information space anticipated by the searcher. The searcher has developed a cognitive model of the information space based on his knowledge about the Web and the existing resources on the Web, but also on his knowledge about institutions and organisations that he expects to be represented on the Web. Log analysis can capture the pages actually visited by the searcher. Surveys can be used to identify general user models. In order to obtain a task specific user model one needs to collect data on work and search tasks and have the present searcher comment the process in real time.

Time can be used to specify how the total amount of time spent during a search process influences the current situation, but it can also relate to the specific time used in that situation. Time is clearly related to effort and as time goes so will the accumulated effort logically increase. Time relates to, e.g., the searcher's motivation. Log analysis can easily collect this kind of data, but it cannot capture the effect on other attributes, such as motivation, for that purpose one needs the searcher's comments on the present process.

The *remaining needs* refer to what the searcher has planned to search for in the continuation of the session process and possibly in subsequent search processes. The remaining needs can only be interpreted from knowledge about the work task, search task and the searcher's comments. The remaining needs directly relate to work task, search task and searcher's motivation.

There are lots of *resource types* available in the Web, which differ from each other with respect to content and format. Some are known from the world of paper-based publishing, such as newspapers, scientific journals, dissertations, novels, and collections of poems, but there are many new genres that have originated on the Web (home pages, various kinds of interactive

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reader should read the term situation as "situation/transition"

resources etc) (Shepherd & Watters, 1998). The logs will not directly reveal what resource types are used, but they will include URLs that can be used to reach the actual resources for analysis. To understand the searchers behaviour it will be necessary to identify the resource types. This relates to, e.g., the search task strategies and the actions performed in the process.

The term "*technical problems"* is used to describe problems caused by the software in use, both on the client and server sides of interaction. Lack of bandwidth may also cause problems, for example in accessing resources that heavily depend on transmission of large amounts of data. Web pages that have disappeared also cause this kind of problem. Technical problems influence, e.g., the searcher's motivation. Log analysis can capture this kind of data, although not directly its influence (although one may be correct in guessing that frequent occurrences of technical problems followed by an abrupt ending of the process indicates some activation in the searcher's motivation).

Situations and transitions share many attributes. Two unique attributes are only present in situations: relevance judgement and relevance level.

Relevance judgement relates to the searcher's evaluation of the pages found, which may be of use to him in different degrees. We do not state any predefined categories for relevance judgements, whereas in other studies binary (relevant or not relevant) or ternary (adding "partially relevant" to the former two) relevance measures have been used (Spink, Greisdorf & Bateman, 1998). See Borlund (2000, p. 35-37), Sormunen (2002), and Kekäläinen and Järvelin (2002) for an examination of degrees of relevance. Neither log analysis nor surveys can capture this kind of data during the process, we need to get it directly from the searcher during the process. The relevance judgements affect, e.g., the accumulated results and the searcher's motivation.

By *relevance level* we mean that the criteria used for evaluation may be related to the work task, which is what Saracevic (1996b) calls situational relevance, but they can also be related to other levels, e.g., when an intermediary judges relevance for a (potential) user. Relevance judgements are also taken in accordance with the organisational preferences, thus socio-cognitive relevance (Cosijn & Ingwersen, 2000) may also affect the judgements. This data also needs to be collected from the searcher, and it strongly relates to the work task and the search task.

3.1.3 Relationships between process and external categories

Arrows between the boxes in Figure 1 represent relationships. Here we shall only briefly summarise relationships between search process and the other categories (number in parentheses refer to relationships in Figure 1). Study settings which lack the categories also lack the chance to study these relationships. In other words, if work task is not included in the setting, one cannot study its effects on other categories. Most WIS studies take the easy way out and exclude many of the categories. The price one pays in our approach is demanding data collection and analysis.

Search task – search process (2): The search task strategy is used to plan what resources to use and what actions to take in order to reach the goal of the search task, thus it clearly is a relationship between the search task and the search process. Search task complexity may affect the time and effort invested in the search process. This can neither be captured by log analysis nor surveys.

The search process in turn affects the search task, by setting constraints on the strategies that are possible to execute. For example there may be resources that cannot be used as planned, or time spent may affect what search task goal(s) to pursue. Investigators cannot learn from the logs about such matters, only that certain web sites are unavailable.

Searcher – search process (5): There are many possible relationships between searcher and search process. Lack of attention may prevent him from identifying relevant resources or it may make him perform unnecessary actions. Great tenacity may benefit a searcher who has to wait for a long time in order for his action to be executed by a search engine. The latter example could also be used to illustrate how the search process influences the searcher; given that technical problems slowing down the process make the searcher less motivated. This kind of knowledge will not be captured by surveys because it is specific for the current task and context and varies by task even for a single individual. The transaction logs are not informed on anything happening in front of the screen.

Work task – search process (9): In addition to the indirect influence of work tasks, via search tasks, on search processes, we believe that the work task also directly affects the process. Search processes are dynamic and during them the work task goal may change due to the results found, which in turn may invoke actions that were not originally planned. Vakkari (2001) has identified the stage of the work task as influencing searching. In our case study we shall examine the work task – search process relationship. Neither surveys nor logs can be used to collect data on the influence of individual work tasks.

Search transition– search situation (10): Search situations and transitions are closely related. As we discussed above they alternate during the search process. The attributes are to a large degree identical, i.e., the information space used is the same in situations and transitions although different parts of it may be activated. Time, effort, and results will accumulate during transitions as well as situations illustrating the tight connection between these two subcategories. This analysis is at a higher level than that of individual moves. They are meaningful chunks for interpretation and difficult to identify in logs alone.

4 A method for analysing Web searching

To collect and analyse data using our method we have proposed a set of techniques (the method's *procedure*). The data collection techniques are well known from general literature on research methods so we will not discuss these in much detail. The most important difference between previous approaches and ours is that we suggest systematic use of triangulation as a general approach, i.e., to combine different data collection techniques in order to get as rich a picture of the WIS process and related categories as possible. We suggest the use of the following data collection methods for the domain described above:

- The search process can be captured using a combination of video logs and observation. This kind of data will provide information on all of the proposed attributes of situations and transitions discussed above. It will also provide data on the other categories.
- The work task can be captured using a combination of interviews and output data, such as, e.g., theses, articles, reports and other written material.
- The search task can be identified from the interviews as well as utterances made by the searcher during the process (observation and video logs)
- The searcher can provide information about him/herself in interviews and questionnaires/surveys
- The social/organisational environment can be described through interviews, annual reports, and other written material documenting the organisation's activities and policies

The core data would be collected using some kind of screen capturing or video recording of the computer screen during the processes. This, however, should be combined with simultaneous recordings of the searchers utterances, and the searchers should be instructed to talk aloud (Ericsson & Simon, 1996) during searching. Alternatively Web transaction logs could be used,

but then it would be difficult to capture non-action-related features of the process, e.g., whether the searcher is really reading a page. In addition an observer could follow the session in the background. Additional data about their work tasks, their search tasks, and personal characteristics can be collected using questionnaires, pre- and post-search interviews, diaries, reports and theses and other kinds of written material.

In order to show the usability of our method we performed a case study of 9 real-life web search sessions performed by 13 students (some worked as pairs). This study was designed and performed prior to the final design of the method; a selection of the recorded session of this study was used in our pilot study (in all three sessions – see Section 3). The goal was to test the applicability of the proposed method for analysing WIS processes *not* to make any statistically significant claims regarding the nature of WIS processes in general.

The study subjects were third year students working on their theses in library and information science (LIS) at Oslo University College. All third year students (in total 110 persons) were asked to participate, of which 55 returned a questionnaire on search skills, general search strategies, work tasks, and demographic data. In all 13 students volunteered to participate in our study where they agreed to have Web search activities related to their thesis recorded and observed. This resulted in 9 (successfully recorded) search sessions, which in total lasted 12 ½ hours. The theses (work tasks) included "To create a web site containing information on and by fictional authors for high school students", "Write a biography/bibliography on Norwegian author Jo Tenfjord", and "Analysis of digital newspapers on the Web". The search tasks performed included "search for information about and by specific authors", "search for graphical elements for design of web site", and "search for data on digital newspapers". Thus the search tasks differed very much in specificity.

All 9 sessions were used in the case study. In the case study (Pharo, 2002) from which we show examples below, we have used the following data:

- *Questionnaires* answered by students working on theses for the bachelor degree in library and information science. The data were used to learn about searchers' work task knowledge, search knowledge, search system knowledge, education, the work task goal and actors in their environment;
- *Interviews* with the searchers prior to and after search sessions. The sessions are driven by search task goals which are defined by the searchers and which are related to their theses. The data gathered from these interviews were used to learn about different attributes of the work task and search task;
- *Observation* notes made during each of the sessions. The data were used partly in a pilot study where a subset of the sessions was used for the initial categorisation of the search process attributes. Partly these data have also been used as a supplement to the video recordings of the sessions (see below);
- *Video recordings* of each of the sessions. The recordings were transcribed and used to document the search processes, the transcription focused on actions that took place, resources used, and utterances made by the searchers. The data were used to identify attributes of the search process, as well as attributes related to the other four categories;
- The *final theses*. These were used to collect additional data about the work task.

In general the collected data were used to interpret, based on triangulation, the video recordings into session stories which we explain below. A very important feature of our data is that the search sessions are very long and the searchers well motivated. Therefore we believe they are good examples of how people actually search, and the kind of effects the context/external categories have on the process.

These techniques return a large amount of data, and we propose to make *session stories* in order to extract relevant data and to combine the different data sets. These stories centre on the search process data, which can be transcribed into the format shown in Table 3. Each table row contains four cells where the following information was recorded: the *action* performed, the *time* spent in minutes and seconds, the *resource* visited, and the *utterances* made by the searchers. The final column is also used by the observer to include comments about the searchers' behaviour and/or utterances (e.g. if the searcher mumbles, or has a humorous or sarcastic tone of voice etc.), and characteristics of the resource used that may be significant.

In the notation in Table 3 we have used "." to denote a pause of up to 5 seconds, i.e. in row 3 in Table 3 "....." signifies a period of silence lasting between 20 and 25 seconds.

Table 3. Excerpt from video transcript

Action	**Time**	**Resource**	**Utterances**
Selects link [bøker]		Index to cultural resources in VG	….. [slow line]
Interrupts transfer			
Reloads page	0.57	Index to cultural resources in VG	… [sighs] .
Interrupts transfer			
Selects back			
Selects link		Index to cultural resources in VG	…….[re-selects link, still slow line]
Selects link	0.58		…….. [sights– finally the wanted screen appears!] … this took insanely amounts of time
Scans page	0.59	Index to book reviews from VG	.. so this is where they sort by date, no searching here? I remember being here yesterday, but I don't know if I managed to get it right
Selects link			……
Looks at page	1.00	VG search page	Oh at last
Scans embedded menu		VG search page	Let's see ….
Enters query: debatt og VG dirkte [predefined categories]		VG search page	…. Now I went into VG debate cause I know, I don't know if it was in VG, but Anne Holt has had a debate on crime with another, or several other authors
Scans page	1.01	Search page [no query results]	But here nothing happened

The data in Table 3 are about a searcher trying to use a tabloid paper (VG) to find information about a specific crime author. The excerpt represents parts of a situation; the interaction does not take place on the document surrogate level. Rather the searcher uses a document in order to find

information related to her search task. It takes place 1 hour into the search session and we see that she is disturbed by slow data transfer and that the organisation of the page is unfamiliar to her, she has problems orienting herself due to the sorting rules used and the lack of query options.

The idea of our process stories is to summarise each WIS process based on the multiple types of data we have on it. The stories seek to report on what happened and why as a reasonable interpretation of the data. Thereby it supports data analysis for identifying any traces of effects of work task, search task, searcher, and environment. We propose the following procedure for story creation:

- The stories focus on the transitions and situations, and their attributes, and the relationships between these categories and their attributes as well as relationships with the external categories and their attributes;
- The stories must be built up in a way that set the context of each session in the beginning and then have the session described in natural terms. If necessary, terms that represent each category that appears are added to explicate the occurrence (see sample below). Text in Italics represents interpretative parts of the sample;
- The attributes must be coded with names in Italics either embedded in the text or in parentheses;
- The interpretation of actions must be based on either explicit phenomena in the video transcripts or on triangulation using the other data as well;
- Arrows should be used to indicate relationships. Attributes can in some instances be identified as affecting one another positively or negatively, the occurrences being coded by plus (+) and minus (-) signs, respectively.

Using this procedure leads to stories in the form shown in the excerpts below (from Pharo, 2002). We will use these to show how the method enables the researcher to identify traces of work task, search task, searcher, and environment in the search process.

> In S8_S2 the searcher scans the Gyldendal author biography index (*action – resource type*) for approximately 1 minute and 20 seconds without finding any of the needed authors. She comments that she should have done research beforehand to learn each author's publisher (*WT knowledge - → ST strategy - → time & effort*). In the end she selects a link to an index of external resources on authors published by Gyldendal. This index is also scanned (*action – resource type*) for a considerable amount of time (approx. 45 seconds) before she selects a link (*action*) to a presentation of Agnar Mykle made by Aftenposten Alex. The selection of the link is categorised as a transition to a new knowledge source (S8_T3 – 4 secs.) and ends Situation S8_S2 after 2 minutes and 12 seconds.

Excerpt 1. Searcher exploring a publisher's site I

Excerpt 1 represents a situation that takes place early in the process, where the searcher tries to implement her search strategy. The situation exemplifies a searcher who has developed a *search task strategy* without having the necessary *work task knowledge* (causing a negative effect), i.e. knowledge about an author's publisher. This in turn makes it necessary for her to spend extra *time* and *effort* (thus the negative effect on time and effort) during the process in trying to identify the correct publisher using different publishers' web resources.

This excerpt exemplifies the direct effects of *search tasks* on search processes. Here the *work task* indirectly influences the process, since it directly affects the search task, but work tasks can also affect the process directly, as shown in Excerpt 2.

Excerpt 2 represents a situation which is initiated by a query in a subject index, it is the fifth situation resulting from the query and the four previous situations have all been quite short; the searcher has quickly scanned the resources in order to identify the relevance of the resources. The searcher at this point looks for pages on a famous Norwegian author ("Gaarder") while previously in the session she has looked for a much less known Norwegian author ("Fangen"). The resources that the searcher collects are to be included in a web directory on authors aimed at high school students, thus the searcher in addition to satisfying her own needs related to her thesis also needs to play the role of an intermediary when picking out resources for presentation.

In situation 91_S10 the resource contains a presentation of a novel (*resource type*) by Gaarder called "I et speil i en gåte". Gaarder's publisher Aschehoug has made this page, which is bookmarked, but not included in the final resource (*relevance judgement*). The situation lasts only 13 seconds (*time* →) when the searcher backtracks to the query results list (*relevance level* ← *WT goal*).

It is clear from examining the final resource that different criteria have been used when the students have chosen which pages they think are relevant for the individual authors (*accumulated results* → *WT knowledge +* → *WT goal* → *relevance level* → *relevance judgement). One possible reason for this is the amount of information available on the individual authors. The case of Fangen and Gaarder is a good example. Gaarder is a contemporary author that has received much attention internationally, and a phrase query on his name in FAST December 2000 receives 5288 hits. A similar query on Ronald Fangen returns only 111 hits. Thus it seem likely that the searcher would expect to find more information on Gaarder than Fangen and adjust her relevance criteria according to these expectations.*

Excerpt 2. Searcher exploring a publisher's site II

In the interpretation part of the story (in Italics), which relates to a larger context than space allows us to present, we observe that we can identify the importance of the *work task goal* for the

establishment of *relevance level* for evaluating the resources that the searcher deals with. Here the *accumulated results*, i.e. what the searcher has already found on Gaarder ("lots of resources") influence the searcher's *work task knowledge* ("it is a lot about him"), which in turn makes her adjust her *work task goal* (from "include *everything*" to "include *limited amount* of data on author") leading to sharpened *level of relevance* ("only include resources dealing with…" for deeming a resource relevant.

The page used as starting point in situation 92_S18 is VG's index to cultural resources (*resource type*) in which she selects the link (*action*) to "books". Data transfer is very slow (*time*) and the searcher interrupts the data flow twice before she in the third try (*technical problems* → *motivation* ← + *tenacity*) is able to access the book page.

Excerpt 3. Searcher in a tabloid newspaper

Excerpt 3 represents a story reflecting the first part of the data presented in Table 3. We have used this excerpt to show that our method can be used to show how *technical problems* due to lack of bandwidth obviously influence the searcher's *motivation*, but also that characteristics of the searcher's personality (in this case her *tenacity*) prevents her from giving up at an early stage in the situation.

5 Discussion and conclusion

There is a large body of research literature on Web information searching (WIS). One approach to WIS research is log analysis, which is based on log contents and furnishes researchers with easily available massive data sets. However, the logs do not represent the user's intentions and interpretations. Another common approach to WIS is based on user surveys. Such surveys may cover issues like the demographics of users, frequencies of use, preferences, habits, hurdles to

WIS etc. However, being ex post facto studies, they do not supply knowledge on how the searchers act in concrete WIS processes.

To understand and explain WIS processes, one needs to closely look at concrete processes in context. The literature of IS&R suggests several factors or categories like work task, search task, the searcher him/herself, and organisational environment as affecting information searching. A promising way to understand/explain WIS is through these categories. The current approaches to WIS, however, cannot shed light on what the effects are, if any. The goal of the present research was to device such a method. Its salient features are.

- Focus on task based concrete WIS processes;
- Triangulation – collecting multiple data sets that inform about the work task, the search task, the searcher, the organisational environment, and the search process as it actually unfolds;
- Synthesise the triangulated data into WIS stories describing each session as a meaningful sequence of actions and events from the searcher's point of view;
- Organising the stories as a sequence of transitions and situations – these being at a higher and more meaningful level than individual moves withing the process.
- Analyse these stories for any traces of work task, search task, searcher's knowledge or organisational context effects through the use of a coding strategy

The contribution of the proposed method does not lie in the individual data collection methods, but instead in their combination and the strategy of analysis described above.

The core of the method is the chunking of the process into situations and transitions, both having attributes relevant to the research questions at hand. In the empirical exercise of the present study we were interested in the effects of work task, search task, searcher, and

organisational environment on the search process – for explaining them. The WIS story excerpts showed how one may reasonably identify the effects of these factors in the process and thus answer related empirical research questions. This is not possible without concrete task-based WIS processes. More specifically no study, that does not include categories like the ones we have used explicitly in its setting, can answer empirical questions concerning the effects of such categories on the process.

Our method represents a new approach in information science. By combining factors that belong to and affect both information seeking and retrieval we are able to learn how characteristics of the searcher, her environment, work tasks, and search tasks directly influence the interaction with the information systems. Researchers have pointed out the relations between information seeking and retrieval previously (e.g., Wilson, 1999) but the direct effects of seeking factors on retrieval processes have not been explored on the level that our method allows. Previous research has focused on how some stable factors, such as search knowledge or topic knowledge (e.g. Marchionini et al., 1993, Hölscher and Strube , 2000), affect query formulations and search strategies, but not in the detail of our method.

Traditional textbooks (e.g. Henry et al, 1980; Belkin & Vickery, 1985; Ingwersen, 1992; Marchionini, 1995) typically represent information searching as a series of steps (e.g. Ingwersen, 1992, p 86) which roughly involves recognition of information need, query negotiation and formulation, querying the system, evaluation of query results, and reformulation of query. The steps may be repeated ad infinitum. The textbook models represent a very "rational" way of *pre*scribing search processes which is in opposition to our view. We believe that the influence of a large number of factors makes it impossible for the searcher to behave "rationally". For example, she will not be able to have complete overview of what possible sources to use, she will judge individual pages' relevance to the same problem differently over time due to the learning effects

during WIS processes, and she will be influenced by a varied set of factors, which are also unpredictable, at different stages of the process, e.g., her tenacity or technical problems on the server. Such a tendency, of course, will be strengthened when searchers use the World Wide Web, since it consists of a greater variety of information sources than any other system, but we believe that it will be fruitful to analyse information search processes also in other systems using our method.

The price one needs to play for the findings we are looking for is demanding data collection and analysis. Several facets of data to need to be collected to cover the effects of various categories. Video and interview transcriptions, and story analysis are also time-consuming and require a careful systematic approach to be reliable. The price to win is to be able to show whether, and how, work task, search task, and other categories affect the process. Past approaches have not answered such questions. While there have been many claims in the literature on the effects, they have rather remained as reasonable, but untested hypotheses than empirical findings. We now believe that it is time for the findings – for conjectures and refutations – also in this area.

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