Designing Automated Help Using Searcher System Dialogues

Bernard J. Jansen
School of Information Science and Technology
Pennsylvania State University
University Park, Pennsylvania 16801-3857
jjansen@acm.org

ABSTRACT - *This research utilizes a cognitive model of interactive information retrieval seeking to improve the performance of Web information retrieval (IR) systems. Building on the stratified model, we define interactions at the surface stratum that shed light on the cognitive, affective, and situational strata during the information retrieval process. We propose that one can utilize these interactions to improve the design information retrieval systems. This paper presents the development technique used to modify an existing IR system that monitors these interactions and, using associated assumptions about situational relevance, recommends search tactics to the user. The result is an increase in the performance of an IR system as measured by precision. The system design and results of an evaluation are presented. Research thus far indicates that user – system interactions at the surface stratum can be used to improve system performance. Using these interactions, one can develop the stratified model to a level of granularity useful for the design of Web IR systems.*

Keywords: Cognitive models, information retrieval, information seeking, software agents

1 Introduction

Researchers have proposed numerous cognitive models of information seeking for end-user searching on the Web. However, most cognitive models are not sufficiently developed for the design of information retrieval (IR) systems, with the result that current IR systems may not effectively or efficiently support users' information seeking needs. The purpose of this research is to utilize a cognitive model of IR searching to a level of granularity to be useful in the design of a Web IR system.

This article begins with a review of cognitive models for information seeking and retrieval, with a deeper discussion of the stratified model. Building on the stratified model, modifications that utilize the entire range of user – system interaction during the search process are discussed. We present a development technique that utilizes these interactions for the design of an IR system. Ann existing IR system is modified using this approach. The article discusses the improved system, the results of a user evaluation, and then concludes with recommendations for future research

2 Related Research

Cognitive models have been successfully utilized in human – computer interaction, and there are numerous models of interactive IR systems [1-5]. Most models attempt to document the interaction between the user and IR system, identify patterns, relate these patterns to retrieval effectiveness, and incorporate the patterns that increase the performance of IR systems [6]. However, most of these models are not yet sufficiently developed to a level where one can conduct empirical tests or utilize them for IR system design [5, 7].

2.1 Cognitive Models of Information Retrieval and Seeking

As end user searching continues to proliferate, researchers have proposed several cognitive models specific to interactive IR. Ingwersen's [8] cognitive model identifies the processes of cognition, which occur during the search process. Ellis [9, 10] proposes a behavioral model of information seeking that identifies behavior patterns across situations and contexts. Many of these cognitive models have not been tested, may not be testable, and are difficult to apply to the development of IR systems [6]. Belkin, Oddy, and Brooks [11] consider the central issue in IR to be representing the user's Anomalous State of Knowledge (ASK), as defined in the episode model. However, the episode model does not address the design of IR systems that optimize these strategies.

With the Web affecting almost every facet of information seeking, several cognitive models specifically addressing a hypertext environment have emerged. Marchionini [12] proposes a model, based on the behavioral model of Ellis [9] but accounting for the browsing aspects of hypermedia environments. Choo and Turnbull [13] examined information seeking behavior of information managers on the web to develop a model of browsing and searching, and Kalbach [14] has developed specific design criteria using this web model; nevertheless, how these criteria and suggestions relate to the overarching model is not clear. However, in the end these models of hypertext IR seem more a collection of empirical, grounded theory observations.

2.2 Stratified Model of IR interaction

One of the more developed models is the stratified model [6]. It is grounded in several studies of IR interaction, including [15-18]. The stratified model views the interactive-searching process as a dialogue between participants, which are the user and the computer system. Each of the participants, user and system, has different levels or strata. The model defines interaction as the interplay between various strata over time. The dialogue occurs within these connected strata, converging at the surface stratum. The exchange of information between participants in the dialogue occurs through an interface at a surface stratum.

Saracevic [6] discusses three strata for the user, which are: situational, affective, and cognitive. At the situational stratum, the user interacts with the given situation or problem that produced the information need. On the affective stratum, users interact with their intentions and associated elements, such as beliefs, motivations, feelings, desires, and urgency. The cognitive stratum is where users interact with the documents and information as cognitive structure. Cognitive processes at this stratum include interpretation, judgment, assimilation, relevance, and effects of changes in the state of knowledge.

The strength of the stratified model, relative to other cognitive models in IR, is that it decomposes the interactions into different strata, and it simultaneously separates the different participants within each stratum. This method of decomposition permits one to more easily develop the design characteristics and isolate the various components. One can view each component as a separate object with its own set of characteristics, which lens itself to coding and component design

3 Conceptual and Theoretical Framework

The stratified model currently focuses almost exclusively on the query, although mention is made of other interactions. This focus is similar to other cognitive models. For example, in the Ingwersen cognitive model [8], the query is the exclusive exchange at the interface level. The stratified model also implies the dominance of the query by referring to 'utterances' at the surface level. In Saracevic [5], the query is the only element depicted that summarizes elements from other strata of the user, and Saracevic states that the "query is the most important aspect of user modeling" [5 p. 323]. However, investigations at the surface stratum can concentrate on other interactions between the user and the system.

Reviewing empirical studies of interactive searching, one finds the query only one of many actions that the user takes when interacting with information objects. Marchionini [12] notes that the user examines results and extracts information. Byrne et al. [19] notes that the user takes several actions, including reading, viewing, listening, saving, duplicating, and printing. In a hypertext environment, the user also goes back, goes forward, bookmarks, and views the history list. These actions are expressions of the user's reaction to the information the system presents. Some expressions may be positive; others negative; others neutral, and other actions may express states of uncertainty. However, there are some actions that obviously stand out as positive expressions of the relevance of the information presented. These include bookmark, copy, duplicate, print, and save.

If the system utilizes these positive expressions of relevance at the surface stratum—the information object that caused the expression and the query that presented the information object—then the system would have additional information to assist the user in locating other relevant information. This assistance could include offering searching advice or suggesting other documents that match the query. If desired, the user could review and process this system-provided information, which could perhaps change elements at the user's cognitive, affective, and situational strata.

4 Research Design

We utilize the agent paradigm [20] to imbue a fully functional IR system, Managing Gigabytes (MG) [21], with the ability to monitor user utterances at the surface stratum and the ability to make utterances to the user on courses of action to improve the search process. Gleaning information from user – system interaction builds on the work of Kambia, Bharat, and Albers [22], who used user actions to personalize an on-line newspaper.

Interactive sessions between searchers and IR systems are typically extremely short both in terms of the number of queries and time and user interests are extremely varied [23]. We needed a method of rapidly recording the user's utterances, drawing inferences from these actions, and presenting utterances back to the user.

A technique used in adaptive hypermedia systems in which the user's information need is represented by of a set of pairs (*c*, *v*) where *c* is a *concept* and *v* is a *value* [24] is modified. This approach is altered for use in extending the stratified model. A series of action - object pairs (*a*, *o*) represents a user's pattern of utterances during a session. On any IR system *S*, a user *U* has an information need *I* expressed at the situational stratum during a session *s*. The sequence of (*a*, *o*) pairs is built using the searcher's normal utterances with the IR system. An action *a* represents a specific utterance of the user. An object *o* receives the action *a*. Therefore, *I* is represented by $^{s}\sum (a, o)$ on any *S*. Again, this applies to an information need expressed during a single search session. Naturally, there are information needs that may transcend multiple sessions. Our implementation does not yet address these information needs, although we can certainly extend the methodology to address these situations.

The agent currently monitors the surface level for five actions (*a*), stated as *a* is an element from the set {bookmark, copy, print, save, submit}. There are currently three objects (*o*) that the agent recognizes, stated as *o* is an element from the set {documents, passages from documents, queries}.

The valid object in the *(a, o)* pair varies with the type of action. Document objects are applicable to the actions of bookmark, print, and save. Passage objects are applicable to the action copy, and query objects are applicable to the action submit. For example, if a user bookmarks a file (e.g., Readings in IR), the *(a, o)* pair would be (*bookmark Readings in IR*). The agent records the series of *(a, o)* pairs during a session, and then offers assistance based on the series of *(a, o)* pairs recorded. Using this approach, one can model the user's information desires relatively rapidly.

4.1 Assistance Offered by the Agent

It was necessary for this stage of the research to narrow the agent's assistance, given the scores of user – system interaction issues [25]. The agent focuses on five areas of assistance, shown in Table 1.

Table 1: Web searching issues and agent areas of assistance.

System - Interaction Issue	Discussion	Agent Assistance
Structuring Queries	Users have difficulty properly structuring queries, namely applying the rules of a particular system, especially Boolean operators (e.g., AND, OR, NOT) and term modifiers (e.g. '+', '!').	When the user submits a query, the agent records this as a (submit query) pair, checks the query's structure based on the system's syntactic rules, correcting any mistakes.
Spelling	Searchers routinely misspell terms in queries, which usually drastically reduces the number of results retrieved. However, it is often difficult to detect these spelling errors because these queries frequently retrieve results from large document collections. The user may not realize the query contains a spelling mistake.	A (submit query) pair alerts the agent to check for spelling errors. The agent separates the query into terms, checking each term using an online dictionary. The AI^2RS agent's current online dictionary is *ispell* [26], although the AI^2RS agent can access any online dictionary using the appropriate API.
Query Refinement	Searchers do not refine their query, even though there may be other terms that relate directly to their information need. Studies show that searchers seldom modify their queries, or do so incrementally [27], and then typically only one or two times.	With a (submit query) pair and a thesaurus, the agent analyzes each query term and suggests synonyms and the contextual definitions of the query terms. The AI^2RS agent uses WordNet [28] but can utilize any online thesaurus.
Managing Results	Searchers have trouble managing the number of results. Generally, user queries are extremely broad, resulting in an unmanageable number of results. Few searchers view more than the first ten or twenty documents from the result list.	Using the (submit query) pair and the number of results, the agent provides suggestions to improve query. If the number of results is greater than twenty, the agent provides suggestions to restrict the query. If the number of results is less than twenty, the agent provides advice on ways to broaden the query.

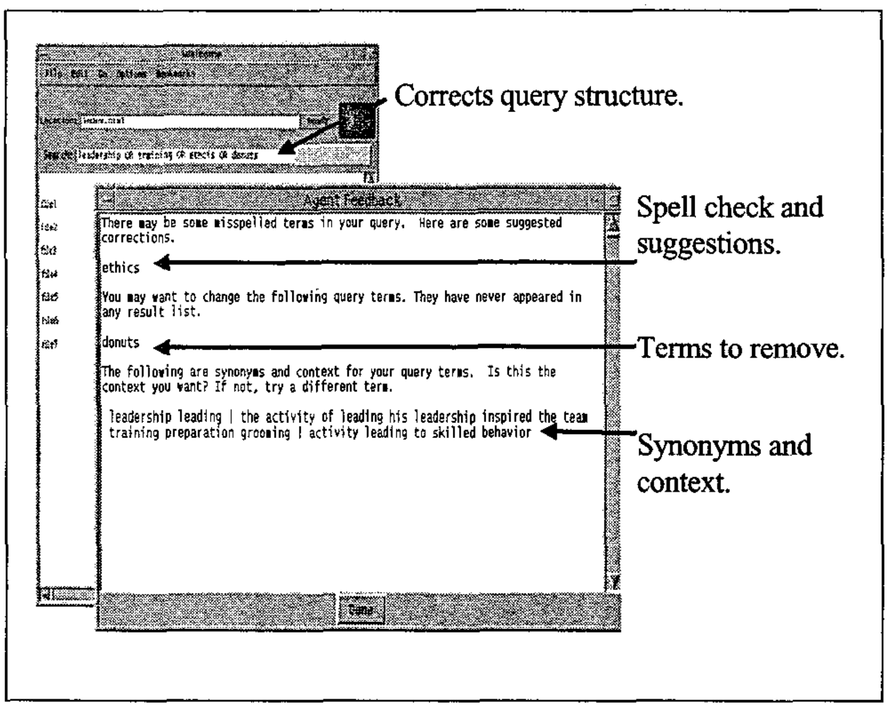
Table 1: Web searching issues and agent areas of assistance.

System - Interaction Issue	Discussion	Agent Assistance
Relevance Feedback	Relevance feedback is an effective search tool; however, searchers seldom utilize it when offered.	When a (bookmark document), (print document), (save document) or (copy passage) pair occurs, the agent implements a version of relevance feedback using terms from the document or passage object. For example, if the user examines a document from the results list and performs one of the actions (i.e., bookmarking, printing, or saving), the agent provides suggested terms from the document that the user may want to add to the query.

4.2 Alerting the User of Assistance

The agent communicates with the user via an interface button. The user can view the agent information or ignore the feedback notification with no impact on the normal operation of the IR system. Figure 1 shows the interface, agent dialog box, and text blocks with explanations.

Figure 1: Agent Assistance



4.3 Empirical Test

To evaluate whether or not the modifications improved system performance, the performance of the MG system and the MG – agent system was contrasted. The MG and the MG-agent system ran on the same computer, displayed the identical interface, and utilized the same document collection. Both systems were installed on a SPARC book 3 running Solaris 2.5. The subjects for the evaluation were 30 freshman college students, 26 males and 4 females. The document collection utilized for the testing was the Text Research Collection (TREC), volumes number 4 and 5, which are approximately 2GB in size and contain approximately 550,000 documents.

As a preliminary evaluation, two TREC topics were chosen, *Number 301: International Organized Crime* and *Number 340: Land Mine Ban*. There were 555 relevant documents (1%) in the collection. For this research, the interested was in the agent's effect on precision within the top 20 ranked documents. Thus, if more than 20 documents were returned for a particular query, documents numbered 21 and higher in the results list were ignored. If the query returned fewer than twenty documents, that number was utilized to calculate precision for that particular query.

The 30 subjects utilizing the two search topics and both IR systems generated 175 unique queries. There were 81 unique queries executed on the MG system and 94 unique queries executed on the MG – agent system. Each session was five minutes in duration. All searchers utilized the agent feedback at least once during the session. Precision for each set of unique queries executed on each system was calculated and analyzed, utilizing the documents that the user identified as relevant and the TREC relevant documents. Our analysis revealed a difference between the two sets of queries (paired $t = -3.417$; $p < 0.01$), with the precision of the MG – agent system performing significantly better than the precision performance of the base system. However, the performance of both systems was less than desirable (precision = 10% for the MG and 30% for the MG –agent system). Further evaluation will be needed for statistically meaningful results (e.g., more topics, longer sessions, etc.).

Naturally, when there is an increase in precision, there is typically a decrease in recall. However, given that the concern was with only the first twenty documents, recall was not a reasonable metric for this evaluation. With most users, especially on the Web, viewing only the first few documents [29, 30] , the impact of recall for most searches is dramatically less than that of precision. Of course, there are situations where recall is important. In these cases, one can use the agent's assistance to improve recall.

5 Conclusions and Significance of Research

Refining the stratified model, we identified utterances at the surface stratum that shed light on the cognitive, affective, and situational strata during the IR process. We successfully modified an IR system to use these surface utterances to assist the user in the search process. The (a, o) development technique permitted the extrapolation of user notions of relevance based on utterances at the surface stratum. Utilizing the (a, o) pair model, the agent provides this searching assistance solely from using the normal actions of a searcher during the session. The user performs no additional actions during the search process to obtain this assistance.

Evaluation of the modified system demonstrates that implementation of the stratified model may be a feasible avenue of research and may lead to improved support of Web and other IR systems during the searching process.

The research presented in this article is the first step in implementing a cognitive model of interactive IR. Overall, the results of the research conducted so far are promising. They indicate that the stratified model of IR can be refined to a granularity that can positively affect system design. Using this model in conjunction with advanced computer technology, IR systems can become active participants in the information-seeking dialogue.

6 References

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