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Implicit search feature based approach to assist users in exploratory search tasks

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ABSTRACT

Analyzing and modeling users' online search behaviors when conducting exploratory search tasks could be instrumental in discovering search behavior patterns that can then be leveraged to assist users in reaching their search task goals. We propose a framework for evaluating exploratory search based on implicit features and user search action sequences extracted from the transactional log data to model different aspects of exploratory search namely uncertainty, creativity, exploration, and knowledge discovery. We show the effectiveness of the proposed framework by demonstrating how it can be used to understand and evaluate user search performance and thereby make meaningful recommendations to improve the overall search performance of users. We used data collected from a user study consisting of 18 users conducting an exploratory search task for two sessions with two different topics in the experimental analysis. With this analysis we show that we can effectively model their behavior using implicit features to predict the user's future performance level with above 70% accuracy in most cases. Further, using simulations we demonstrate that our search process based recommendations improve the search performance of low performing users over time and validate these findings using both qualitative and quantitative approaches.

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1. Introduction

Analyzing people's online search behaviors has become a major topic of interest within the domain of Information Retrieval as well as within the search engine industry in order to improve search and retrieval features. Examples of some recent studies include providing personalized search results based on geographical location and user profiles (Bennett, Radlinski, White, & Yilmaz, 2011; Sugiyama, Hatano, & Yoshikawa, 2004), re-ranking search results based on user's past search behavior (Matthijs & Radlinski, 2011) and providing trending news and stories based on different factors (Al Bawab, Mills, & Crespo, 2012) using services such as 'Google trends' and 'Yahoo Trending now'. Since the early 90s when the World Wide Web (WWW) was introduced, information seekers have greatly benefited from these technologies and the vast amount of information that could be accessed, which was a rarity up until that point in time. With the advent of Web search engines, users became accustomed to using a search engine to retrieve relevant information with keyword-based searches without having to sift through the vast amount of information repositories available on the World Wide Web.

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In any Web search there are two major constituents. One is the search system and the other is the user. User and system interaction has been explained in the stratified interaction model by Saracevic (1997). In an online Web search environment, usually the system is a Web search engine. Since each user is unique and the way people search varies depending on different factors such as information need, demographics, previous search experience, knowledge of the topic being searched on, cognitive abilities, personal traits, etc., understanding the user is a vital first step towards providing a personalized search experience. Understanding the user can be accomplished by building a user behavior model through observing his/her search activities and constructing a user profile to thereby make predictions and personalizations that help the user find relevant information.

In the domain of user behavior modeling, past research has focused on deriving user behavior models and then building sequential models to capture behavior patterns. Fox, Karnawat, Mydland, Dumais, and White (2005) described user behavior patterns as sequences and identified correlations between behavior patterns and user satisfaction. White and Drucker (2007) investigated how different user behavioral sequences can be linked to different types of Web users such as navigators and explorers. They identified that users who exhibited consistent behavioral sequences among different search sessions were mostly *navigators* while users with variable behavioral sequences were considered *explorers*. This type of user categorization based on behavioral patterns exhibited in the user search logs gave rise to interesting dimensions of modeling user profiles that could be leveraged to personalize and also assist in the user's search.

Another interesting analysis was performed by Wildemuth (2004) to examine the search tactics of users when searching for information. Common search tactics were found among the study participants. It was also observed that tactics changed over time during a longitudinal study depending on the level of domain knowledge accrued using state transition matrices and maximal repeating patterns techniques.

There has been some notable work on temporal modeling of user search behavior in order to capture how users interact with information and the system while conducting information seeking tasks. Azzopardi (2014) analyzed user search behavior by introducing a new economic theory-based model where the different interactions that could be performed by the users on the search interface were analyzed as a cost/gain model. This model considered eight interaction hypotheses pertaining to search interactions with the system and were found to be in line with past empirical observations and the expected user behaviors. Smucker and Clarke (2012) evaluated the search process more effectively using a time-based gain measure. Their work focused on assessing how a user evaluates a search results page over time and modeling the gain by viewing a document ranked at rank k . Their work provides a better evaluation framework for document ranking by accommodating aspects of the search process such as time, decay, and gain that are ignored by traditional effectiveness measures. Further work on search results relevance personalization was performed by Bennett et al. (2012) by analyzing searchers' short-term (session) and long-term (historic) behaviors. They found that substantial benefits could be gained in search relevance at the beginning of a session using historic behaviors while session behavior contributes mostly in an extended search session. Another interesting finding is that the combination of both session and historic behavior outperforms using either factor in isolation in providing relevant documents, thus enhancing search personalization.

Although, there has been work done to build meaningful user behavioral models, to the best of our knowledge there is a lack of research regarding the development of user behavioral models specifically for exploratory search tasks. Given that exploratory search is open ended, multi-faceted, and lacks clear boundaries, the way users behave during an exploratory search task is highly variable. The main aspects of exploratory search that make it complex and unique compared to other types of information searches such as known-item and fact-finding searches are uncertainty, creativity, innovation, knowledge discovery, investigation, and learning (Bawden, 1986; Marchionini, 2006; Foster & Ford, 2003). Also, since such tasks tend to extend over longer time spans or even multiple sessions, the importance of user search assistance and direction to improve the user experience and user goal achievement becomes paramount.

Therefore, providing an approach one could use to reasonably analyze the behavior patterns of a user when performing an online exploratory search task would be extremely helpful in identifying how a user is performing. This would also provide much better recommendations and a more personalized information seeking experience, which in turn results in better user satisfaction and achievement of search goals.

In this article, we develop a framework to understand the underlying search process by using the user's search actions and implicit features to analyze exploratory search through a quantitative approach. Explicitly we try to address the following research questions.

- **RQ a:** How effectively can we model different aspects of exploratory search such as knowledge discovery, creativity, exploration using implicit features extracted from the user search process to identify underperforming users?
- **RQ b:** How effectively can we provide search process based recommendations to improve user search performance?

2. Background on exploratory search

Analyzing a user's search behavior when performing online search tasks could be used to discover insights that might enable one to assist the searcher in a more successful search experience. Out of the many types of online information seeking tasks that occur every second on the Web, this article only focuses on exploratory search tasks that usually require longer time spans with multiple search queries. Exploratory search is a specialization of information seeking, which describes the activity of attempting to obtain information through a combination of querying and collection browsing (White & Roth,

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