Towards Understanding and Supporting Exploratory Searches

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ABSTRACT

Exploratory search is an intuitive concept in interactive information retrieval. It is known that searchers use exploratory search strategies when learning and investigating a new domain. Many definitions for Exploratory Search have been proposed. However, the main dimensions involve high uncertainty with respect to the problem context, the user expertise, and the search process. In this work, we study exploratory search in the literature, and we provide a conceptual model of exploratory search. We also conduct a user study to examine how literature searches are exploratory and what factors influence the exploratory dimensions and characteristics. Moreover, we review the exploratory support tasks, and we try to better design and evaluate exploratory user interfaces.

CCS CONCEPTS

• **Information systems** → **Search interfaces**.

KEYWORDS

Exploratory Search, Literature Search, User Interface

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1 MOTIVATION AND RELATED WORK

Searching the literature to find relevant references for a report or publication is typically considered an exploratory search task by the Information Seeking and Retrieval (ISR) community [4, 8, 12, 19]. However, there is a lack of empirical evidence supporting the claim that reviewing the literature is an exploratory search task, and the literature lacks studies on searchers' behaviors and experiences when conducting exploratory searches. Various researchers have offered different ways to characterise how exploratory a search task is [2, 9, 11, 23]. However, the proposed definitions involve high uncertainty concerning the exploratory dimensions, including the problem context, the user expertise, and the search process.

The information space has become increasingly complex regarding its sizes, types, and ways to access it [15]. The enormous amounts of online information might make searchers feel lost [3], especially when searching for a new topic in a new domain. The current search tools serve searches where the target\information need is well defined or where a single fact is needed [11, 16]. However, they provide less support and need to be better at assisting searchers with various information needs who might work on exploratory or complex search tasks involving scientific discovery, learning, and decision-making contexts such as searching the literature [5, 22, 23]. Therefore, search interfaces need to support searchers by providing them with more than ten blue document links, their snippets and metadata. Understanding the behaviours and experiences of exploratory searchers is crucial to better designing and evaluating new solutions that overcome the limitations of the current search interfaces.

Many researchers proposed exploratory support interfaces to overcome the limitation of the traditional interfaces, which require searchers to evaluate the results sequentially and assess their relevance to their information needs. Some researchers proposed interfaces by adapting visualisation, categorisation, or clustering methods to foster learning and browsing when conducting exploratory searches [1, 5, 13, 14, 18, 19]. Other researchers used ontology or knowledge graphs as "navigation maps," [10, 17] or as tools to help searchers when crafting queries [6]. Despite the increased interest in exploratory search and designing interfaces to help and support users who conduct exploratory strategies, there is still room for improvement. It has been noticed that many of the interfaces that were proposed to help conduct exploratory strategies were not very much used nor were adopted by major search engines. Moreover, most proposed interfaces have limitations regarding helping users understand where they are in the information space, the different concepts related to their interest domain, or how they relate. Furthermore, those interfaces do not help with the information path searchers have to take to complete their tasks.

In sum, after the literature review analysis we conducted regarding the exploratory search and the exploratory support interfaces, we noticed that some researchers proposed exploratory support interfaces without defining the exploratory search or its dimensions. Also, many proposed support interfaces were never evaluated, and some other interfaces were designed and evaluated in only one iteration. We believe users should be at the heart of the designing process, especially when designing exploratory support search interfaces. Thus, our work investigates the nature, definition, and characteristics of the exploratory search. Also, we try to understand the searchers' behaviour and experience when conducting exploratory searches. Additionally, we learn how to design and evaluate better exploratory support interfaces. In a nutshell, our research focuses on understanding searcher behaviours when conducting exploratory searches and proposing better ways to design and evaluate support user interfaces.

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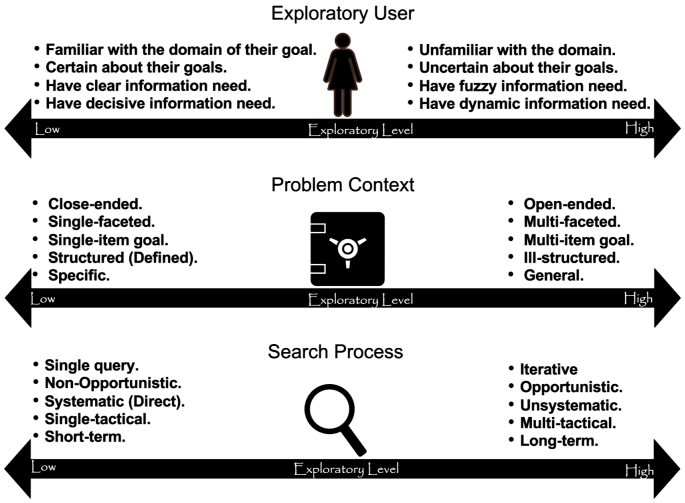

Figure 1: Our Conceptual Model of the Exploratory Search that consists of three main dimensions: the user, the problem context, and the search process –along with the different characteristics associated with each dimension [21].

2 RESEARCH QUESTIONS

Ultimately, we try to understand the exploratory search, the behaviour and experiences of the exploratory searchers, and how we can design and evaluate support user interfaces to help searchers when conducting exploratory search strategies. Here are the main research questions we are trying to answer:

RQ1. What are the main dimensions and characteristics of exploratory search?
RQ2. What are the problems people face when employing exploratory searches?
RQ3. How can we better design user interfaces to support searchers conducting exploratory searches?

3 RESEARCH METHODOLOGY

We answered the first research question and partially the second questions by conducting a literature analysis and a user study where we studied the experiences when conducting a literature review [21]. More details are following.

3.1 Phase 1: Understanding the Exploratory Search

While lookup search has a well-defined definition, exploratory search definition is still vague and considered to be complex, multi-faceted, and keeps evolving [23]. Therefore, we needed to conduct a literature analysis to study the exploratory search in the ISR field. We reviewed many core papers and previous studies about exploratory search and its support interfaces. It was noticeable that most of the previous researchers followed White & Roth's [23] attempt to define the exploratory search. We also found that the problem context and the search process are commonly used in the literature as the main dimensions to describe the exploratory search. However, there is inadequate focus on other dimensions, such as users who engage in the exploratory search, users' information needs, the exploratory goals, and the knowledge gain. Moreover, the literature mentioned some characteristics of the problem context and the search process but did not define or fully explain all of them.

Based on our literature analysis [21], we proposed a conceptual model of exploratory search that consists of three main dimensions that describe the exploratory search and have a significant effect on the exploratory levels: users who engage in the exploratory search, the exploratory problem context, and the exploratory search processes. Also, we provided definitions of the fourteen key characteristics of these main dimensions. Figure (1) shows our proposed model. We then used the model to design a web-based online questionnaire to collect data related to participants' experiences when conducting a literature review task, how literature searches are exploratory, and what factors influence the exploratory dimensions and characteristics. Our analysis of the 368 responses reveals that about 84% of the participants described their literature review task as somewhat exploratory or very exploratory in nature, which confirms previous assertions in the literature that reviewing the literature is indeed exploratory [21].

Our findings also suggest that the characteristics that best describe the exploratory users are unfamiliarity with the domain and having dynamic information needs. Moreover, the main characteristic that best describes the exploratory problem context is ill-structured (ill-defined). Furthermore, the characteristics that best describe the search process are opportunistic, multi-tactical, and long-term [21]. Our analysis points to another dimension of the exploratory search, the knowledge gain/change dimension. The fourth dimension includes learning new keywords and concepts, finding surprising or unexpected information, encountering new concepts and investigating them further, changing the review's topic, and rewording the search query many times while searching. The results show that exploratory searches are associated with learning new concepts and keywords. Also, as participants searched, what they thought was relevant changed over time. We learned from these findings and built on them for the big aim, which is

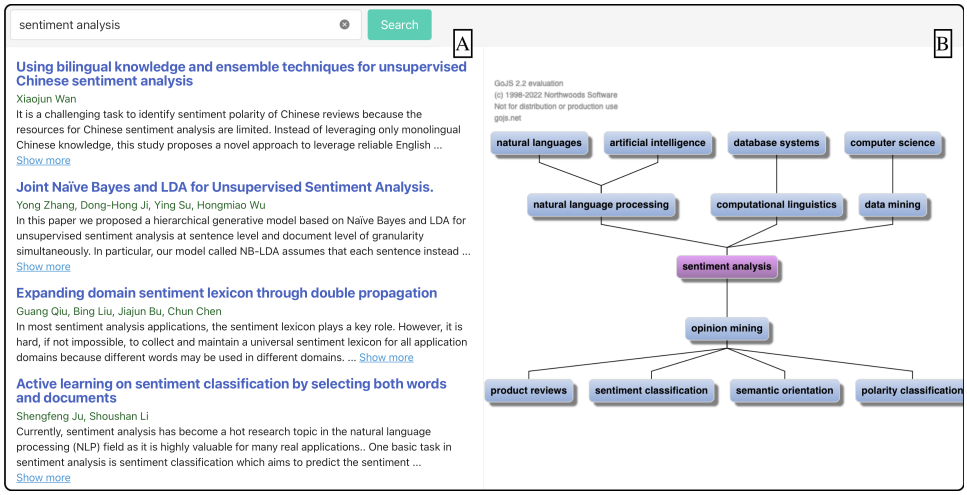

Figure 2: Out interface showing (A) a couple of results in the SERP and (B) a concept map, both results related to the query of "Sentiment Analysis".

designing and evaluating better information retrieval exploratory interfaces.

3.2 Phase 2: Toward Better Support Interfaces

This phase of our research focused on reviewing different interfaces to support exploratory searches. Also, we proposed a support interface and used it to learn more about how to better design and evaluate user interfaces.

Traditional information retrieval systems allow users to enter queries concerning their information needs; the system then returns ranked lists of documents, metadata, and, optionally, snippets. The vast information space makes it difficult for searchers who want to learn about a new domain, as it might be hard to comprehend all concepts in a specific domain and how they are related. Searchers need user interfaces that support them when conducting exploratory search strategies, forming better queries, learning about new topics, exploring documents, navigating through concepts, learning new key terms, and discovering information related to the interested domain.

Previous researchers tried to overcome the limitation of traditional interfaces by designing systems and interfaces that support users who conduct exploratory searches by adapting visualisation, categorisation, or clustering methods to foster learning and browsing. For example, some researchers worked on supporting the exploration behaviour by designing advanced user interfaces with interactive keywords/key-phrases visualisation [1, 5, 13, 14, 18, 19]. Other researchers focused on supporting faceted browsing beyond obvious facets such as content type and source [7]. Some researchers designed interactive timeline visualisations to identify periods of importance [20]. Many of the support interfaces were ontology-based solutions. Some researchers worked on using ontology graphs as a "navigation map". For example, Maksimov et al. [10] built an ontology based on a set of documents relevant to a search topic. Hoper et al. [6] used a concept knowledge base to help searchers who struggle with crafting queries by generating a query space that represents the query terms concerning the concepts searchers describe. Additionally, Sarrafzadeh et al. [17] proposed a system that combines knowledge graphs with document retrieval to support exploratory users with their complex search tasks.

Despite the different features proposed by these systems, more studies are needed to understand how these systems support exploratory searches and how searchers think about these systems. Moreover, these interfaces have many limitations; they show much data (e.g., nodes, links, relationships, texts, shapes, colors, etc.), which might be cognitively demanding. Also, some interfaces show key terms or concepts related to a specific domain, but the relationships between the concepts are non-intuitive; sometimes, it is hard to tell which concept is general and which is in-depth, especially for beginners who want to learn about a new topic. Thus, we try to understand users' challenges when using these systems. We also want to investigate better ways to design support interfaces that increase learning outcomes without demanding many cognitive levels. Moreover, we propose a Concept-Map-based interface to help us understand how can we support searchers with the unstructured/ill-defined nature of the exploratory problem context. Also, we aim to learn how to design the interface better to make searchers' information needs apparent and to help them form better queries and make sense of the massive number of concepts and how they relate to each other.

We aim to use our proposed interface to learn how to support searchers in understanding the information space. We also want to study how presenting the information in a structured way, such as a concept map, can help searchers learn and investigate the general concepts related to the central concept they started with or go in-depth and learn about a more specific topic to their interest. Moreover, we aim to study how searchers can investigate these concepts and draw themselves a learning path that meets their needs without the need to read every document thoroughly. Using the proposed interface, we want to study how we can help users

understand the information space around the topic of their interest and help them find their way in that space.

So far, we have a working system with a Concept-Map interface that allows users to enter queries relating to their information needs; the system then retrieves related documents from a collection and shows standard list-based results and a portion of a graph where the root concept is variable and changes according to the closest concept to the query. The concept map contains the root concept, general concepts (super concepts), and in-depth concepts (sub-concepts). Figure (2) shows the interface, including a portion of the standard list-based results and the concept map.

We conducted a pilot study to learn if including a concept map in the interface gives users an idea of the information space during the search process, makes it easier to issue queries, and finds search directions effectively. Since the resources used in designing our interface are mainly related to computer science, we recruited undergraduate and post-graduate students with Computer Science or related field backgrounds through social media platforms(e.g., WhatsApp, Twitter, Facebook, etc.). We told the participants that we were designing a tool to make it easier for researchers to learn about a new topic or review the literature and asked them to help improve it. We conducted ten interviews (face-to-face and remote interviews over video calls using Zoom technology). Each interview lasted for around one hour.

We allowed the participants to choose between two simulated work tasks that we designed following Wildemuth and Freund [24] guidelines. We asked the participants to use our interface to learn more about the topics that interested them the most. We asked our participants direct questions about their knowledge and familiarity with the chosen topic to ensure they were unfamiliar with that topic. Through the work task, participants were allowed to ask about the interface's functionality or things they needed help understanding. At the end of the work task, we asked them questions regarding the interface and their opinion on the concept map, if it was helpful, why they think it was useful, how it helped them learn concepts and how they are related. Also, we asked them about what they liked and disliked about the interface. Moreover, we asked about their thoughts on things that should be added, improved, or modified in the interface to give them the best experience in learning about the topic.

Participants of our pilot study expressed that the concept map took their attention first. Additionally, they found it useful and easy to use and navigate the different concepts. They expressed that the most important thing about the concept map is showing them different aspects and concepts related to the central concept and helping them learn new concepts and how they relate to each other. On the other hand, some participants have negative comments about the interface. Some participants wanted a way to see where they came from (the previously clicked concept/ node). They wanted to see more concepts related to a node and maintain the displayed concept map structure. The majority of the participants mentioned that adding a Wikipedia definition whenever the mouse hovers over a concept node in the concept map would be helpful, as they are unfamiliar with the topic and its concepts, so adding such definitions will help them in the knowledge acquisition and will help them decide to explore the concept further or not. Also, they suggested adding a better way to distinguish between the general and the in-depth concepts.

The pilot study provided indicative findings to help us understand our potential users more to improve the interface design in future research.

4 FUTURE PLANS

We will conduct more analysis of the pilot study data as we aim to understand the exploratory users better. Understanding the exploratory users and their exploratory behaviors and needs will guide us to build better interfaces that are explicitly designed to address the challenges that the exploratory users face when conducting exploratory searches. The proposed interface will be improved based on the feedback. We will use the improved interface to answer our third research question (How can we better design user interfaces to support searchers conducting exploratory searches?). We plan to evaluate the improved interface by conducting a controlled laboratory study with one independent variable: the search interface. We will also compare it to a baseline interface (google-like interface). We also will continue improving the interface and designing better features to support searchers conducting exploratory searches. We aim to build upon the results of the previous research phases to help searchers navigate the information space, find their learning paths, help them gain the maximum knowledge effectively, track their knowledge, and share their learning paths.

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REFERENCES

[1] Cecilia di Sciascio. 2017. Advanced user interfaces and hybrid recommendations for exploratory search. In *Proceedings of the 22nd International Conference on Intelligent User Interfaces Companion*. 221–224.
[2] Ahmed Hassan, Ryen W White, Susan T Dumais, and Yi-Min Wang. 2014. Struggling or exploring? Disambiguating long search sessions. In *Proceedings of the 7th ACM international conference on Web search and data mining*. 53–62.
[3] Drahomira Herrmannova and Petr Knoth. 2012. Visual search for supporting content exploration in large document collections. *D-Lib Magazine* 18, 7/8 (2012).
[4] Orland Hoeber, Dolinkumar Patel, and Dale Storie. 2019. A Study of Academic Search Scenarios and Information Seeking Behaviour. In *Proceedings of the 2019 Conference on Human Information Interaction and Retrieval*. 231–235.
[5] Orland Hoeber and Soumya Shukla. 2022. A study of visually linked keywords to support exploratory browsing in academic search. *Journal of the Association for Information Science and Technology* (2022).
[6] Orland Hoeber, Xue-Dong Yang, and Yiyu Yao. 2005. Visualization support for interactive query refinement. In *The 2005 IEEE/WIC/ACM International Conference on Web Intelligence (WI'05)*. IEEE, 657–665.
[7] Andrew Jackson, Jimmy Lin, Ian Milligan, and Nick Ruest. 2016. Desiderata for exploratory search interfaces to web archives in support of scholarly activities. In *2016 IEEE/ACM Joint Conference on Digital Libraries (JCDL)*. IEEE, 103–106.
[8] Taraneh Khazaei and Orland Hoeber. 2017. Supporting academic search tasks through citation visualization and exploration. *International Journal on Digital Libraries* 18, 1 (2017), 59–72.
[9] Bill Kules and Robert Capra. 2008. Creating exploratory tasks for a faceted search interface. *Proc. of HCIR* (2008), 18–21.
[10] NV Maksimov, OL Golitsina, KV Monankov, AA Lebedev, NA Bal, and SG Kyurcheva. 2019. Semantic search tools based on ontological representations of

documentary information. *Automatic Documentation and Mathematical Linguistics* 53, 4 (2019), 167–178.

[11] Gary Marchionini. 2006. Exploratory search: from finding to understanding. *Commun. ACM* 49, 4 (2006), 41–46.

[12] Ya R Nedumov and Sergei D Kuznetsov. 2019. Exploratory Search for Scientific Articles. *Programming and Computer Software* 45, 7 (2019), 405–416.

[13] Behnam Rahdari and Peter Brusilovsky. 2021. PaperExplorer: Personalized Exploratory Search for Conference Proceedings.. In *IUI Workshops*.

[14] Tuukka Ruotsalo, Jaakko Peltonen, Manuel JA Eugster, Dorota Głowacka, Patrik Floréen, Petri Myllymäki, Giulio Jacucci, and Samuel Kaski. 2018. Interactive intent modeling for exploratory search. *ACM Transactions on Information Systems (TOIS)* 36, 4 (2018), 1–46.

[15] Ian Ruthven. 2008. Interactive information retrieval. *Annual review of information science and technology* 42 (2008), 43–92.

[16] Bahareh Sarrafzadeh and Edward Lank. 2017. Improving exploratory search experience through hierarchical knowledge graphs. In *Proceedings of the 40th international ACM SIGIR conference on research and development in information retrieval*. 145–154.

[17] Bahareh Sarrafzadeh, Olga Vechtomova, and Vlado Jokic. 2014. Exploring knowledge graphs for exploratory search. In *Proceedings of the 5th Information Interaction in Context Symposium*. 135–144.

[18] Cecilia Di Sciascio, Vedran Sabol, and Eduardo Veas. 2017. Supporting exploratory search with a visual user-driven approach. *ACM Transactions on Interactive Intelligent Systems (TiiS)* 7, 4 (2017), 1–35.

[19] Soumya Shukla and Orland Hoeber. 2021. Visually Linked Keywords to Support Exploratory Browsing. In *Proceedings of the 2021 Conference on Human Information Interaction and Retrieval*. 273–277.

[20] Jaspreet Singh, Wolfgang Nejdl, and Avishek Anand. 2016. Expedition: a time-aware exploratory search system designed for scholars. In *Proceedings of the 39th International ACM SIGIR conference on Research and Development in Information Retrieval*. 1105–1108.

[21] Ayah Soufan, Ian Ruthven, and Leif Azzopardi. 2022. Searching the literature: an analysis of an exploratory search task. In *ACM SIGIR Conference on Human Information Interaction and Retrieval*. 146–157.

[22] Ryen W White, Gary Marchionini, and Gheorghe Muresan. 2008. Evaluating exploratory search systems. *Information Processing and Management* 44, 2 (2008), 433.

[23] Ryen W White and Resa A Roth. 2009. Exploratory search: Beyond the query-response paradigm. *Synthesis lectures on information concepts, retrieval, and services* 1, 1 (2009), 1–98.

[24] Barbara M Wildemuth and Luanne Freund. 2012. Assigning search tasks designed to elicit exploratory search behaviors. In *Proceedings of the symposium on human-computer interaction and information retrieval*. 1–10.