Professional Collaborative Information Seeking: On Traceability and Creative Sensemaking

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Abstract. The development of systems to support collaborative information seeking is a challenging issue for many reasons. Besides the support expected for an individual user, such as query formulation, relevance judgement, result set organization and summarization, the smooth exchange of search related information within the team of users seeking information has to be supported. This imposes strong requirements on visualization and interaction to enable user to easily trace and interpret the search activities of other team members and to jointly make sense of gathered information in order to solve the initial information need. In this paper, we briefly motivate specific requirements with a focus on collaborative professional search, review existing work and point out major challenges. In addition, we briefly introduce a system that has been specifically developed to support collaborative technology search.

Keywords: Collaborative search · Information behaviour · Search user interface

1 Introduction

With the increasing amount of digitally stored data and information the requirements and expectations on information search systems, in particular web search engines, steadily grow. To achieve an appropriate user experience, search systems not only have to retrieve web documents related to the explicit given (keyword) search query, but also have to consider the user's context and ideally support the whole search process, i.e., all steps from query formulation over relevance judgement to result set organization and summarization. Current search engines already provide several features to support users regarding context, e. g., by considering the location, previously used search queries or already visited result pages, to adapt query suggestions or the search result set. But if the user's information need gets more complex and the search goes beyond a simple fact finding task the support provided by existing systems is still rather limited.

In this paper, we focus on search systems for domain experts, also called professionals. This group of users usually not only need to retrieve simple facts

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or explore an area of interest, but have to satisfy a complex information need. For professionals the search is rather a creative process in which domain specific information is collected and very often used to derive solutions for an application domain. For example, a frequent task in the business area is to perform an extensive technology research to keep up to date, know about state-of-the-art methods and hence to be competitive. In addition, since the tasks to be solved by professionals are usually complex, they often have to be processed by a team of experts in order to solve the task in reasonable time and appropriate quality. Therefore, adequate support methods for collaborative information seeking (CIS) tasks are needed. Unfortunately, we still lack tools and methods to support complex search tasks [11] and collaborative search tasks [14], especially for professional searchers.

Different (theoretical) models for information seeking, or more general information behaviour, have been proposed [17,35]. These models underline the complexity of the search process, describe essential components and consider the search process from different perspectives. However, the majority of the models rather consider information seeking as a process that is performed by an individual and not a group of users. Therefore these models have to be adapted and extended to be applicable to support design and evaluation of search systems that enable collaborative information seeking by a team of professionals. To make collaborative information seeking feasible, a search user interface (SUI) is required that covers all steps of the search process and its phases, such as planning, exploration, sensemaking and summarization. That is, the search system should enable the team of searchers to trace the seeking process and to collaborate in understanding structure and meaning of the revealed information [11]. Hence, we start in the following with a discussion of aspects and issues of complex information seeking processes and then propose two SUI concepts that focus on supporting traceability and creative sensemaking in collaborative search. Section 2 provides a brief overview of information seeking, established models and illustrates their relation to collaborative search. In Sect. 3 we address the process of collaborative information seeking from different perspectives and describe important aspects. Afterwards, we provide two suggestions for SUIs, that support traceability (Sect. 4) and creative sensemaking (Sect. 5). The last section summarizes the paper and provides an outlook towards prospective, collaborative search systems.

2 Related Work

Information behaviour models provide the most general approach to describe a user during information acquisition and exploration. The models are used to characterize and formalize seeking behaviour, context information, possible dialog partners and the search system itself. The literature provides a huge variety of models that address different levels and aspects of information behaviour. In Wilson [35] several models are summarized. A more recent overview can be found in Knight and Spink [17]. Wilson's nested model of information behaviour

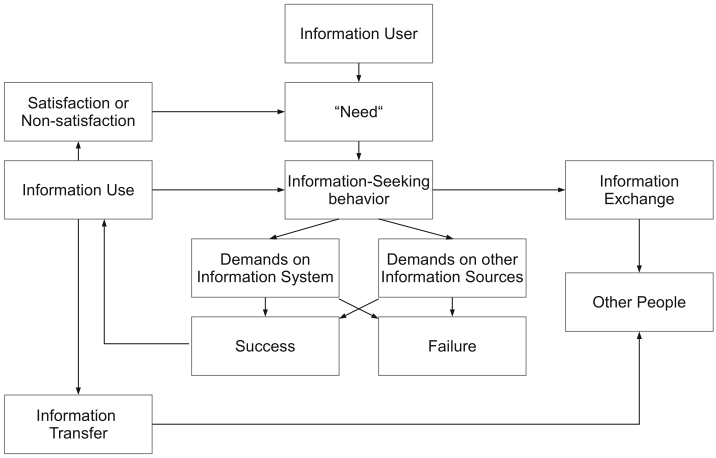

Fig. 1. Wilson's model of information behaviour from 1981 [35].

(as proposed in [35]) defines information seeking behaviour in the framework of information behaviour and considers these models as a subset. That is, information behaviour models additionally describe intervening variables, activating mechanisms and different information sources to embed information seeking behaviour. Models of information seeking behaviour cover all methods describing a user who is conducting a search to discover and yield access to information sources, i. e., all used strategies and tactics. In Wilson's first model of information behaviour [34] (see Fig. 1), the user recognizes an information need and starts seeking for information on different formal or informal information sources. Alternatively, the user can seek for information exchange with other people. If successful, the user may use the gained information to further refine his or her information seeking behaviour or to transfer information to other people. Furthermore, successfully gained information may be used to evaluate the current state of satisfaction and to (re-)formulate the information need. However, the model considers information (seeking) behaviour rather as an individual process: The user has an individual information need, seeks individually for information and merely exchanges or transfers information with other users, but not the need itself nor is the seeking process linked or synchronized with others.

Information-seeking can also be considered from other perspectives than proposed by Wilson. The cognitive or mental perspective allows to describe information seeking in several phases. For example, Kuhlthau [19,20] proposed a phenomenological model with six *stages*: Initiation, Selection, Exploration, Formulation, Collection and Presentation. Ellis (et al.) [7–9] discussed a model with empirically supported categories, termed *features*: Starting, Chaining, Browsing, Differentiating, Monitoring, Extracting, Verifying and Ending. If the models' perspectives coincide, they even can be aggregated, c.f. Wilson [35]. Especially in a collaborative setting this cognitive perspective can be used to describe the current state of understanding and sensemaking within the team.

Information seeking can also be studied from a perspective related to conducted information activities, i.e., interactions with the information system and its components, such as result information acquisition, comparison or planning, are addressed. To consider these activities for collaboration is essential as well, since the individual information needs and the resulting individual information seeking behaviour of the professionals need to be coordinated to contribute to the team's goal to solve a complex task. An established model for search activities was proposed by Marchionini [21] based on the concept of *exploratory search*. Exploratory search is usually motivated from the uncertainty of a user in his information need or lack of knowledge of how to tackle it. It combines a standard lookup-search with the activities learning and investigation. Lookup-search can be understood as a standard fact-finding search, with a specified query request, that is related to Kuhlthau's selection stage and contains activities like navigation, verification and question answering. Learning and investigation are both iterative processes, that involve different search strategies and contain activities like comparison, interpretation, synthesis and planning.

Collaborative search can be defined as a special case of a social search [10], in which all participants have the same information need and actively conduct a specific search together in order to achieve a common search goal [13]. While in [12] different roles and dimensions of collaboration are discussed, such as intent (explicit and implicit), depth of mediation, concurrency and location, Shah provides in [30] a more general introduction and definition of *collaborative information seeking*. Poltrock's et al. [25] definition of collaborative information seeking as "the activities that a group or team of people undertakes to identify and resolve a shared information need" (p. 239) nicely agrees with the activity related perspective as discussed above. Reddy and Jansen [26] study the collaborative information seeking behaviour of two healthcare teams in a business setting. They found that collaborative information behaviour differs from individual information behaviour on several dimensions and present a model in which they contrast the context (individual vs. collaborative information behaviour) with the actual behaviour (information seeking vs. searching). Capra et al. [5] study search strategies in a collaborative search task. Their results show that collaboration in a search task occurs at various stages. They present three higher-level search strategies how collaborative information seeking is carried out: Participants acted on their own, unaware of their collaborators (independent strategy), they also used their collaborators' previous work to do additional work in the same space (parallel strategy), and used knowledge of what their collaborators have done to take new directions (divergent strategy). In her early assessment Morris [22] advocates four aspects (coverage, confidence, exposure, and productivity) in which dedicated collaborative search systems can influence a user's search experience in an exploratory search task. A collaborative search system has been proposed by Morris et al. [24]. They study how personalization of web search can be achieved based on a membership in a group that works on the same task. They show how three techniques (groupization, smart splitting, and group hit-highlighting) can enhance the individual search experience in a collaborative context.

3 Information Seeking for Professionals

Powerful (web) search technologies have made a lot of business-relevant information available for domain experts of a company to explore, collect, and use in their problem-solving tasks. These experts satisfy most of the characteristics described by Knight and Spink [17]. The experts are not necessarily information professionals, i. e., are "unlikely to have any formal training in developing appropriate search queries or retrieval strategies", "likely to use a wider variety of search strategies, with more inconsistent results", and "more likely to be the'information user' of the information they are seeking." However, they often have (a lot of) domain expertise which influences individual search strategies and often leads to more successful findings than having little expertise [15,33].

Professionals often perform a complex, exploratory search task, to gather domain-related information for an underlying problem-solving task [21]. This search task is usually open-ended and has an uncertain process and outcome. Furthermore, problem-solving often requires collaboration in exploring the information space together, collecting domain-related information, making sense of it and using it. Professionals within an organization are often part of communities and typically know each other personally. Therefore, in addition to the exploratory nature of this task, there are further characteristics which can be attributed to the business setting in which a search is performed. The domain-related problems that need to be solved by the community often exist over a longer period of time which results in a continuous information need. That is, the search topics need to be updated, which leads to repeatedly executed search tasks dealing with similar or overlapping contents. In the following, we discuss crucial aspects of collaborative information seeking for professionals in more detail and provide a model that links essential components for search systems.

3.1 Aspects of Collaborative Information Seeking

Problem-Solving Context: The type of professional search we want to address is often part of a so-called *known genuine decision task* (c.f. Byström and Järvelin's [4] categorization in which they distinguish between five task categories based on a priori determinability of the tasks). In our case, the structure of the result is often known a priori but the procedures for performing the task, i. e., the needed information and the process are unknown. This kind of task often goes along with a complex information need. There has been some debate about what constitutes a complex information need or, more generally, a complex search task especially in contrast to an exploratory search task. Aula and Russell [2] present an interpretation that fits to our professional search scenario. Among other criteria they argue that complex search often requires exploration and more directed information finding activities, where the searcher often uses multiple sources of information. Additionally, a complex search often requires note-taking because of the searcher's limited ability to hold all gathered information in memory. Besides, relevant information is typically spread across lots of resources in the information space. This makes the information space sparse

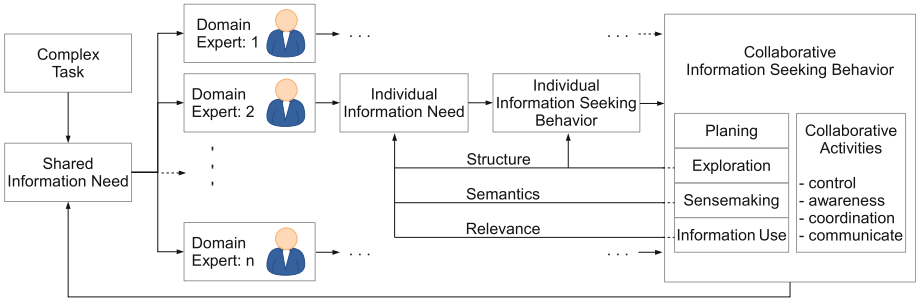

Fig. 2. Illustration of collaborative information seeking with an emphasis on a group of domain experts

with facts, as opposed to a dense information space where a single resource may contain all relevant information to sufficiently answer the information need.

Collaboration: Professional search often concerns a community of experts that face similar problems and thus have similar, overlapping information needs. A professional search tool, therefore, should allow these experts to work together in these tasks. Most experts within such a community know each other personally, which distinguishes it from other scenarios where collaborative search is analyzed. The collaboration is explicit, active, remote (mostly), and asynchronous. In the context of a collaborative exploratory search, it is important to note that it may not be known beforehand, who will take part in the search task. It may happen that some experts join the team while others have already started gathering and using information. Based on Reddy and Jansen [26], reasons why users engage in collaboration are (1) the complexity of information need, (2) fragmented information resources (sources reside in multiple and dispersed systems), (3) the lack of domain expertise and (4) the lack of immediately accessible information.

Updates: Professionals are often required to update their knowledge about the domains they are responsible for which is why they have to repeatedly perform search tasks about various, sometimes overlapping search topics. Professional search requires the ability to investigate, update and extend previous search tasks. In Kotov et al. [18] such tasks are considered cross-session tasks which often evolve over time. The information need in a cross-session task is typically complex and progressively refined with each new update.

The diagram in Fig. 2 is based on Wilson's information behaviour model [34] (c.f. Fig. 1) and provides an extension regarding collaborative information seeking with an emphasis on a group of domain experts. After the emergence of a complex task, the group of professionals has to discuss about and define the corresponding, shared information need. Even if the need cannot be specified precisely (due to the exploratory character of the task), the group has to divide it in sub-needs that can be (at least initially) processed by an individual. As a result each domain expert can start to satisfy their resulting individual information

need by performing individual information seeking. Since this information seeking occurs in the context of a collaborative task the collaborative information seeking behaviour component emphasises that search-related and collaborative activities have to be taken into account when the experts reveal new information. Here, it is important that the group can organize the seeking process and that they can follow and participate in understanding the revealed information. The organization can be enabled by the collaborative activities illustrated on the right. The tracing and the cognitive phases of the seeking process are supported by planning, exploration, sensemaking and summarization (as depicted on the left). By exploration, the team reveals structural information that can influence the individual information need or the information seeking behaviour directly. Sensemaking and information use allow to reveal new insights and key aspects that influence the information need on a semantic level and to perform a relevance evaluation. In the end, the gathered and combined information discovered by the collaborative seeking may influence the initial shared information need.

3.2 Traceability and Creative Sensemaking

When it comes to search-related activities that are performed by the whole group of collaborating searchers exploring an information space, making sense of collected information and using this information in a problem solving situation should be *traceable* for each individual, so that he or she understands how the various contributions of the searchers relate to each other. Every team member needs to be able to understand their joint search strategy in order to make better or more relevant contributions and benefit from each others' domain knowledge and search expertise. The second challenge in professional search is *sensemaking* in context of the underlying genuine decision task in which the search process is embedded in. Sensemaking can be understood as the "process of searching for a representation and encoding data in that representation to answer task-specific questions" [27]. It is an integral part of many information seeking models because it describes how a searcher (mentally) models, interprets, disambiguates, and interacts with the information that is gathered during search. The requirements on traceability and sensemaking can be defined as follows:

Traceable Collaboration: Traceability in collaborative search describes the team's ability to understand the structure, semantics, and relevance of their collaborative information seeking behaviour. Traceability concerns especially the search-related activities exploration, sensemaking, and information use. Co-searchers should be able to understand how they explore the information space as a team, what information they collect in the resources they discover, and how they synthesise/interpret this information with respect to their search goal.

Creative Sensemaking: Creative sensemaking can be defined as satisfying (complex) information needs in a problem solving context to "form a coherent functional whole" and reorganize "elements into a new pattern or structure through generating, planning, or producing" (c.f. Anderson and Krathwohl's [1] taxonomy of learning). The core task is to make sense of the gathered information of

a search task and create solutions to the underlying domain problem. Therefore, creative sensemaking inherits some properties of information use as well. Since professional search is often embedded in a problem-solving task creatively using the collected information and generating new ideas, concepts, or solutions to solve the problems is very important. Creative sensemaking is central to search tasks with complex information needs where solutions in an application domain have to be generated based on the collected information.

Traceability and creative sensemaking are still rarely addressed in (collaborative) search settings. They are, however, particularly important in order to support experts engaged in a professional search task. Since the type of professional search we outlined above refers to an explicit collaboration between experts, one approach of supporting them is to design specially-tailored user interfaces that provide new types of visualizations and interaction methods. Before we outline an example of a tool that is designed with traceability and creative sensemaking in mind, we briefly discuss current shortcomings of collaborative search tools and our general approach in the next section.

3.3 Challenges of Collaborative Search User Interfaces

There already exist some interesting approaches towards supporting explicit collaboration in a search task with the help of special collaborative search user interfaces. Some of them are mentioned in Sect. 2. However, there are reasons why collaborative search tools have not become widely accepted (yet). Hearst [14] argues that in order for users to move from a solitary to a collaborative search tool there "must be enough additional value as yet in the tools offered." In particular, Shah [29] mentions cost factors that one should keep in mind when designing collaborative search tools, e.g., the *cost of learning* a new system, *adaption/adoption costs* when using a collaborative system, and the *collaborative costs* when being part of group task. Capra et al. [6] study how searchers perform ongoing, exploratory searches on the web and share their findings with others. Their results show that searchers employ a variety of tools and techniques that go "beyond the functionalities offered by today's search engines and web browsers", e. g., note-taking, information management, and exchange. The study by Kelly and Payne [16] confirms these results. They also find that (collaborative) searchers want to "repurpose" their search results at the end of the task to arrange them into a more meaningful way. Shah [28] proposed guidelines for the design of a collaborative search tool that focus on behavioural aspects of collaboration. These include that a tool should allow for effective communication, encourage individual searchers to make contributions, coordinate the individual actions and needs, and provide means to explore and negotiate individual differences. When it comes to concrete features that a collaborative search tool should support, various authors have contributed their ideas:

- *Awareness:* "knowing what other people are doing" during collaborative information behaviour activities [23,26].
- *Communication:* share information with other members of the collaboration team bilaterally or in conference [26].

- *Division of Labour:* reduce individual effort by avoiding redundant actions and allow for effective "divide-and-conquer" techniques [14,23].
- *Feedback:* with respect to collaborative search includes a "feeling of accomplishment"; Co-searchers should be able to step back and get an understanding of what actions are required next and by whom [14].
- *Overview:* refers to a visualization of the "land-scape" that the team has covered in their collaborative search task that also allows them to depict what they still have to do [14]. "Users must have access to a visualization of not only their search process, but also of their collaborators. ... [This] will allow users to discuss each other's searches and provide feedback on how to improve them." [26]
- *Persistence:* makes the context, content, and task of a search session available for future access and for others in a collaboration; In particular, it is the precondition for remote and asynchronous collaborative search [23].
- *Personalization:* means to provide "structure to let individuals define what their personal constraints or preferences are" when they engage in collaborative search [14].

There are still many features missing in today's collaborative search tool stack [14]. Therefore, two design decisions are central to our approach presented in the following. First, we create an independent collaborative layer that can be used in conjunction with any (standard) solitary web-search tool. This additional layer should integrate seamlessly and effortless into the user's web-search infrastructure. The idea is to be as little intrusive to the user's search environment as possible. The layer adds custom collaborative features to enhance the individual's collaborative search experience while maintaining most of the solitary appearance. Second, searchers should be able to personalize the outcome of a collaborative search task given they often have individual needs within the collaboration. This is achieved by allowing searchers to create personalized views with which they can interpret the outcome of the collaborative search task in their own individual context.

4 Traceable Collaborative Search

Most of the current collaborative search systems are designed to "allow participants to find, save, and share documents, and see the activities of others in the collaboration group" (Hearst [14]). These tools are used, e. g., to increase awareness, communication, control, and coordination of the collaboration. In our attempt to make a collaborative information seeking more traceable within a group we focus more on the search-related activities of the task. In particular, we seek to make individual exploratory and sensemaking activities of each participant more transparent and understandable for the others.

Our general approach is to treat exploratory search like an orienteering hike where participants use maps and other tools to navigate in previously unfamiliar terrain to find special points of interest (control points) within a given time. In exploratory search points of interest are resources that contain information that

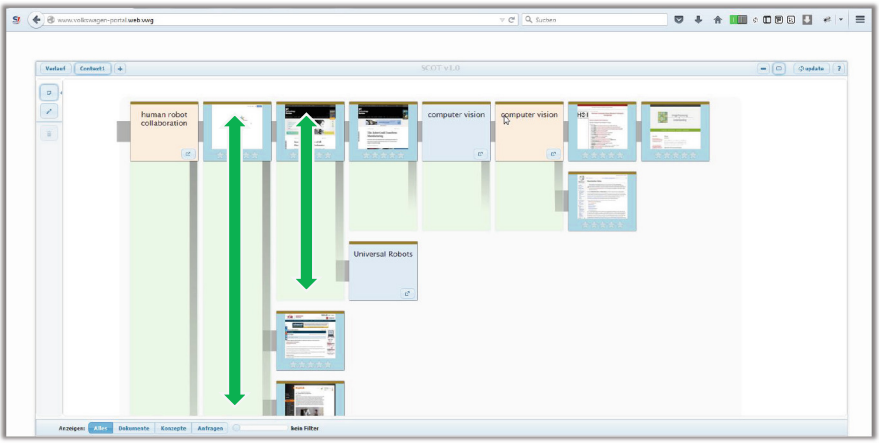

Fig. 3. UI: Search map.

(partially) answer an information need. One of the main differences between orienteering and exploratory search is that in orienteering the maps of the terrain are provided upfront to help navigation, whereas maps of the information space typically do not exist in exploratory search. In contrary, even the "terrain" of the information space is unknown beforehand and unveils itself dynamically in the course of the exploration. Moreover, in our case exploration is carried out as a team endeavour. Members need to be able to trace what part of the information space they have covered as a team, i. e., what directions they took, where they found relevant information, and how they arrived there. Similar to the idea of a land-scape that provides a visual overview of search activity our approach is to create a map of the explored information space during (collaborative) search on-the-fly. This map displays relevant exploratory actions of each searcher and sets them into context with those of the others. The idea is to visualize how their individual information seeking behaviours complement each other so that they are able to see the outcome of their joint exploration graphically.

A concrete implementation of such a map, which we call a Search Map [31], is shown in Fig. 3. A Search Map lays out exploratory activities (of a team of searchers) as tiles in 2-dimensional space. The tiles are organized as a horizontal tree where the root is left, so that exploration paths can be read from left to right. We have chosen a tree visualization because it provides a definite start (root) and end (leaf) for each path. We considered using a more general graph-like visualization instead to emphasise that exploratory search allows cycles but choose not to in favour of readability. A user study is still needed to confirm our decision. There are a couple of interaction features we have implemented into the Search Map. For example, it is possible to zoom in and out of the map so that searchers can either receive a general idea of what paths have been taken in general or look into details of a path and examine the actual actions. Since such a map can become large quickly, especially in a collaborative context, it is also possible to fold/unfold or hide exploration paths on demand, e. g., by

filtering classes of actions like queries, documents, or snippets, or by issuing meta search queries that highlight parts of the map that match these queries. Additional interactions with the map encompass annotations, like comments or symbols, that can be pinned on the map to communicate (meta) information concerning the exploration. Such meta information can be, for instance, a hint on a dead-end in a search path or the need for future updates. Also, while moving the Search Map (up and down or left and right), a special layout algorithm automatically adjusts the placement of the tiles so that the tiles of a search path are moved up and down such that the path remains visible. Green arrows in Fig. 3 illustrate the movement of two tiles that belong to the topmost search path. If the map is moved downwards the tiles move down, too, and upwards respectively. Some of the tiles represent visited resources (like websites). Other tiles show search queries that a user issued to a search engine[1]. Again other tiles show extracted snippets from websites. These snippets often contain information that helps to answer the shared information need. We distinguish two types of snippets. Searchers can extract sentences or images from resources which, for them, contain useful facts. They can also extract keywords from these resources that are often concepts or entities that relate to the search topic. By displaying these keywords, facts, or images as tiles on the map, we seek to make it easier for the team to understand the outcome of a search path. The keywords are also used as input to the creative sensemaking interface, which is part of the collaboration layer described in the next section.

Since the overall idea is to interfere as little with solitary information search tools as possible the Search Map interface can be faded over any active website in a browser window using a hotkey or a button on a browser toolbar, but remains invisible otherwise. So, whenever individual searchers want to know what the current progress of the collaborative search is, they can investigate the Search Map. In order to personalize the collaboration, searchers can create individual views of the Search Map by organizing tiles or whole paths according to their needs. These views can be considered as "sub-versions" of a Search Map that automatically merge new tiles or paths according to the changes that have been made. By visualizing the joint search strategy of a team with the help of a Search Map we enable individuals to trace and be more aware of how they explore the information space together. Considering that search tasks need to be extended at a later time, this is aimed to quickly access the resources that have been particularly helpful when answering the information need and understanding how the team arrived at these resources. They can also be used to pick up loose ends and drill into topics for which no answers were available before.

5 Creativity-Focused Sensemaking

As outlined in Sect. 3.1 sensemaking in professional search often goes along with generating solutions to a given (domain-related) problem within a group of experts. There are some major challenges that arise when designing a search

[1] The actual search engine being used does not affect the Search Map, so searchers are able to use any search engine they want, even Intranet search engines of companies.

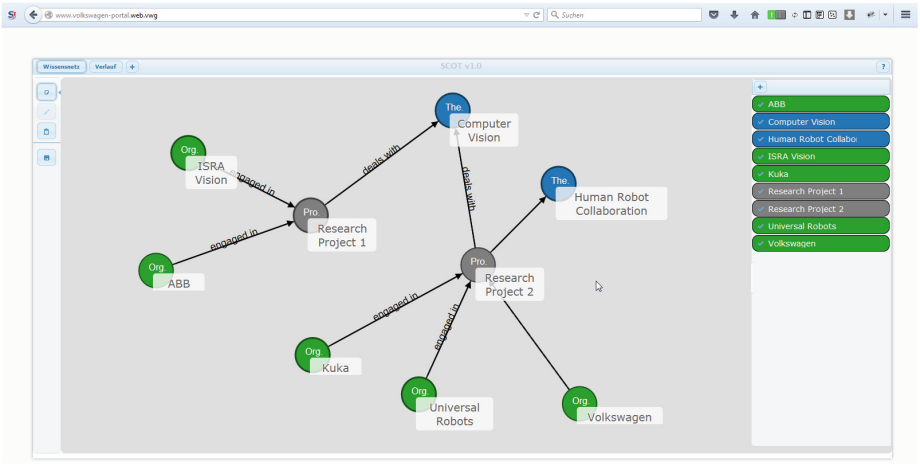

Fig. 4. UI: topic graph.

user interface to support this creative process: The interface should provide interaction capabilities so that the group can express and discuss their (individual) concepts and merge these into a coherent whole; the interface should be based on a visualization that allows each individual searcher to (1) contribute their view, and (2) draw their own conclusions when the task is completed. Our general idea is to augment the collaborative layer created by the first interface by supporting the creative sensemaking and use of gathered information of the search task.

For the design of our creative sensemaking interface we lend some ideas from collaborative learning research. In collaborative learning mind maps, also called concept maps, have been reported to show good results when learners work together in a meaning-making and meaning-negotiation task (e. g., [3]). Therefore, the interface is designed like a mind mapping interface that we integrate into the collaboration layer. This interface can be used by searchers to organize and share their understanding of the search topic graphically and iteratively refine their individual and group's view during search. This is particularly helpful in an exploratory setting where this understanding develops over time and is seldom very elaborate at the beginning. A simple example of such an interface is shown in Fig. 4. We call this example a Topic Graph because it is a graph-based representation of the group's view about the search topic [32]. Nodes of the topic graph represent domain entities of a search topic and edges represent relationships between these entities. The entities are either extracted during exploration (see Sect. 4) or added manually. Typically, mind maps do not possess any limitation concerning the use of entity classes or relationship types. The topic graph, however, is based on a flexible schema that provides (some) structure and semantics. Although, this schema is originally derived from a domain ontology which was developed together with domain experts, the central idea of the schema is to remain open towards changes along the search process and, thus, be

more flexible in the creative process it is used in. This degree of flexibility is often not possible when using ontologies, especially when they become large/complex. The schema restricts the use of entity classes in the interface and the available relationships that can be added between them. The Topic Graph also makes the sensemaking results of the group traceable by allowing each member of the team to (formally) express their thoughts on the topic. Since experts sometimes have different backgrounds they are able to provide additional knowledge and context of their domain. Similarly to our Search Maps (Sect. 4), experts are able to express (contradictory) interpretations by creating their own Topic Graphs as tabs in the interface, so that they are visible for the rest of the group.

In practice, when working with the two interfaces presented above, Search Maps and Topic Graphs are aimed to complement each other. Topic graphs help to gain an overall understanding of the search topic by looking at the mind map-like representation of domain-related information. When a member of a team identifies an entity or a relation of interest they can use the Search Map to investigate the exploratory activities that led to its discovery. In a professional setting we believe this makes it easier to address complex search tasks more completely and synergies can be leveraged more effectively. For example, sparse information spaces can be explored more systematically even if new information becomes available at a fast pace. Especially in situations where new information may nullify previously collected data, working with Search Maps and Topic Graphs may help to understand and interpret these changes across search tasks.

6 Summary

Domain experts often perform professional information seeking tasks as part of their daily work. Designing adequate computer support is challenging, especially due to the often collaborative nature of these tasks, which demands for specialized interaction features. Experts typically have to solve an underlying domain problem using the information they gather together as a group. Solving these problems requires extensive exploratory search, collaborative sensemaking and repeated updates as new information becomes available. In order to tackle these challenges we highlighted two aspects of a collaborative search task that are still rarely addressed: traceability and creative sensemaking. Traceability describes a group's ability to understand the structure, semantics, and relevance of their collaborative information seeking behaviour. Creative sensemaking describes the group's ability to solve a shared domain problem together by reorganizing newly acquired information into a coherent whole that satisfies their underlying information need. We outlined how these aspects blend into the collaborative search process with the help of an extended model of collaborative information seeking that we built based on Wilson's earlier model. Although, we present user interface prototypes that support traceability and creative sensemaking in a collaborative search task, much of the challenges in professional information seeking still remain. Especially, for the design of future search systems it is important to investigate the dynamics and demands of the professional setting in more detail.

Search systems that allow a lean participation of group members and at the same time maintain much of their individual experience, will likely advance and may overthrow how we search together in a professional environment.

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