Supporting Collaborative Information Seeking and Searching in Distributed Environments

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Abstract

In various work domains, the collaborative performance of a work-task by a team can lead to a shared information need required to fulfill this task. Many empirical studies identified collaborative information seeking and searching (IS&S) as everyday work patterns in order to solve a shared information need and to benefit from the diverse expertise and experience of the team members.

This paper presents first empirical results in an ongoing research project: We report on a pilot user study that investigates the collaborative IS&S practices of three work groups in academic and industrial research facilities. The aim of the conducted pilot study was to capture the use of software technologies for realizing collaboration, information seeking and sharing in real-world work settings. We discuss resulting design implications as guideline for extending the *ezDL*[1] system towards supporting collaborative IS&S activities.

1 Introduction

In various work domains, the collaborative performance of a work-task by a team can lead to a shared information need required to fulfill this task. Many empirical studies identified collaboration during information seeking and searching (IS&S) as everyday work patterns. Collaborative information seeking and searching (CIS&S) is characterized by parties that share the same information need and explicitly work together to satisfy that need and to benefit from the diverse expertise and experience of the team members. This collaboration involves synergetic interactions between individuals, negotiations, discussions and the adoption of other perspectives to produce a solution or strategy, which results from the different knowledge and backgrounds of the co-workers [30]. Effective and efficient collaboration in distributed environments requires a number of awareness information. In addition to information about the current activities in the group, gathering information about participants, their special skills and knowledge is necessary to allow for combination of expertise and efficient achievement of goals [28].

Previous research in the field of CIS&S has conceptualized, implemented and evaluated tools and systems for use at each stage of the information searching process: (1) query construction, (2) obtaining results, and (3) evaluating and using the results. These tools have been developed, to a large extent, in experimental settings. They provide an environment where collaboration is mediated at different layers (depth of mediation, [9]). Using frontend mediation, integrated functions in the UI allow communication, exchange of information, and provision of awareness cues. Using backend mediation, each person's activities can be combined algorithmically to produce the desired retrieval effects. However, recent empirical studies show that, despite the increasing availability of tools that are specifically designed to support CIS&S, these technologies are not used in practice [18]. Instead, simpler communications technologies that are part of everyday work are applied as means to realize CIS&S. In such environments, people communicate about the search process and the search products, but neither user interface nor utilized services (e.g. search engines and digital libraries) are aware that people intend to collaborate.

An arising research question we want to address is, how team members can be provided with information on the best suited collaboration partners and the collaborative activity to be performed in order to increase the efficiency and effectiveness of IS&S tasks in such environments. To approach this question, we conducted a pilot user study that aimed at capturing the tools and means in use by practitioners of different work groups in academia and industry to collaborate with their colleagues. From the results of this study, we derive implications for the design of an environment supporting CIS&S activities in team-based work-task situations.

The rest of the paper is structured as follows: Section 2 discusses related studies in the field of CIS&S and gives an overview of systems and techniques especially designed to support CIS&S. In section 3, we present the results of the conducted survey. Section 4 discusses resulting design implications and presents the application of these design implications to an extension of the *ezDL* system [1]. Finally, section 5 summarizes this paper and gives a brief outlook on the next project tasks.

2 Background and Related Work

Various empirical studies identified collaborative information retrieval as an everyday work pattern in order to solve a shared information need that occurs in the context of a work-task. The concept of the task has been defined by Byström and Hansen as an activity that is carried out to achieve a specific goal or has a specific item of work in focus [5]. A task may consist of several sub-tasks. A work-task represents a specific task that is carried out to fulfill a separable portion of a person's duties to his employer. As result of an identified information need, a

[1] *ezDL*: Easy Access to Digital Libraries, www.ezdl.de

work-task may consist of information seeking tasks that are further decomposed into information searching tasks [5]. Information seeking generally focuses on the satisfaction of a complex information need. It involves several sources and consultations of them. Information searching is particularly concerned with the satisfaction of a separable fraction of that complex information need.

2.1 Related User Studies

Bruce et al. [3] present an empirical study that investigates the collaborative information seeking behavior in two design teams. The authors found that collaborative information retrieval is an integral part of the daily work to solve shared information needs of the team. Identifying, analyzing and defining the information need, as well as the development of search strategies is performed collaboratively. This involves intra-team as well as extra-team collaboration [23].

CIS&S activities often involve information sharing. Talja [29] observed and classified different types of information sharing in an academic environment. These types are (1) strategic sharing, (2) paradigmatic sharing, (3) directive sharing, (4) social sharing, and (5) no sharing. Her investigations showed that in academia, collaborative information seeking is as common as individual information seeking. Scholars usually belong to different networks, i.e. social networks. According to Talja, these networks not only influence their choices of information seeking strategies, but are the place where information is sought, interpreted, used, and created.

A study conducted by Hansen and Jarvelin [10] analyzed the information seeking behavior of the employees of the Swedish patent office when engaged in the patent application process. They observed collaborative activities in all stages of the IS&S process: e.g., planning tasks, problem definition, search topic selection, query construction, and relevance assessments. The authors categorized the observed collaborative activities into document-related and human-related activities. Their study shows that collaborative activities are an important characteristic of IS&S tasks in professional settings.

Twidale et al. [31] observed collaboration between students at the computer terminals of the university library, although these systems weren't designed for collaborative usage. They identified several collaborative search strategies, such as asking for help, reusing searches. They categorized the observed activities into product-related and process-related activities. Morris [17] conducted a survey regarding web-search practices among the employees of a large IT company. She found that collaboration is largely accepted: over 97% of all users reported having used some form of collaboration when searching the web. Similar to Twidale et al., Morris identified activities regarding the search product and the search process.

Reddy and Spence [24] present a field study regarding the collaborative search behavior in multi-disciplinary teams in the context of medical care. The authors identified four triggers for collaborative IR activities: (1) complexity of information need, (2) fragmented information resources, (3) lack of domain expertise, and (4) lack of immediately accessible information.

2.2 Systems and Techniques

This section presents an analysis and classification of recent work in the area of CIS&S system support. As a basis for the classification of collaborative activities and techniques, we use the model developed by Landwich, Klas, and Hemmje [15] to describe an information searching task. Landwich et al. pursued the approach of an interactive information dialogue cycle as developed in [11]. They describe the information searching task as a dialogue between user and system consisting of six activities and assigned them to three stages (the so called interaction modes of the user):

(1) Access: Query construction and submission (Exploration),
(2) Orientation: Move within and refinement of the result set, change of focus (Focus, Navigation, Inspection),
(3) Assessment: Identification of relevant information objects (Evaluation, Store).

The dialogue cycle starts with a first query and ends after *n* cycles with a resolved or at least reduced information deficit. Figure 1 depicts this model integrated at the information searching level of the task model developed by Byström and Hansen [5].

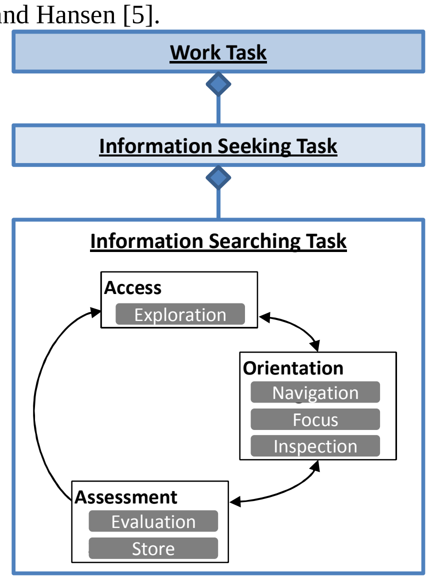

Figure 1: Task model of Byström and Hansen with integrated information searching activities as defined by Landwich et al.

Access

During *Access*, users are able to benefit from their co-workers by exchanging query definitions, modifying and executing them for their own purposes. This is realized in different ways. **Query Re-Use** refers to the activities that realize the exchange of (complete) query definitions between co-workers. The co-workers are able to perform the exchange interactively by

(1) choosing the query definition from a shared repository [25, 32],
(2) choosing the query definition from the query-history of another co-worker [20, 27], or
(3) exchanging the query definition as separate, persistently stored object [14, 31].

Group Feedback refers to a group based adoption of relevance feedback methods. This class of collaborative activities incorporates the - explicit or implicit - relevance judgments of the group members and modifies the query accordingly by adopting the weights of the query terms or expanding the query with additional query terms. This includes various approaches of query expansion techniques that typically extract search terms from highly ranked documents of previously issued queries [13]. Algorithmically extracting query terms based on relevance judgments and suggesting them to the co-worker in a scenario with asymmetric user roles is presented in [22].

Orientation

During *Orientation*, division of labor strategies are implemented using **Result-Set Splitting,** i.e. the algorithmic division of a search result among the group members. The result set of a query is distributed algorithmically among the co-workers. These sub-sets are disjoint, i.e. the participants will only obtain documents that no other group member has seen before [8]. This splitting of search result sets can further be based on specific roles that are assigned to the participants, e.g. Prospector and Miner [22], or based on personal relevance, i.e. thematic focus and interests of the participant [19].

In addition to this, result sets can be enhanced algorithmically or manually using documents identified by other group members. **Result-Set Merging** is based on the similarity of the user profiles and the similarity of queries: Documents returned by previous queries and judged as relevant by co-workers will be added to the result set of a recently executed query [21]. **Document Recommendation** includes the interactive recommendation of documents or links. Information objects that have been identified by other participants and estimated as possibly interesting for another co-worker, are recommended and added to the work list of the co-worker [14, 27].

Assessment

During *Assessment*, collaboration addresses the diversity of knowledge across the group: **Combination of Judgments** refers to the combination of the different document assessments of the group members. The relevance of a document is determined by the opinions of multiple users through interactive voting: in [25] a scale-based approach is implemented, in [6] a traffic light based approach is used. **Re-Ranking** refers to the algorithmic re-ordering of the results. The ranks of the search results are determined not only by the relevance to the individual user, but also by the relevance to the entire group. This might be realized by using term frequencies in the stored objects or bookmarks of group members [19].

2.3 Discussion

Research at information searching level has conceptualized, implemented and evaluated collaborative activities for use at each stage of information searching process. Figure 2 depicts the classes of activities available for a team member to collaborate with the rest of the team. Previous research has focused on further improving collaborative tools by algorithmic optimization, e.g. improving similarity measures, as well as on improving human-human and human-computer interaction by facilitating communication, control and awareness mechanisms. However, these systems do not provide information on the best suited collaboration partners and the collaborative activity to be performed to increase the effectiveness and efficiency of the collaborative performance of IS&S tasks.

3 Pilot User Study

This section reports on a pilot user study that investigated the CIS&S practices of three work groups in academic and industrial research facilities. The conducted pilot study did not aim at analyzing the CIS&S processes in detail but rather at capturing the use of software technologies for realizing collaboration, information seeking and sharing in real-world settings.

Similar to the online survey conducted by Crescenzi and Capra [7], we made implicit assumptions about the components involved in the collaborative processes. Those were (1) a search component in which co-workers conduct searches to look for information, (2) a communication component in which co-workers coordinate their activities and communicate regarding the search process, and (3) an information sharing component in which collaborators share their search products.

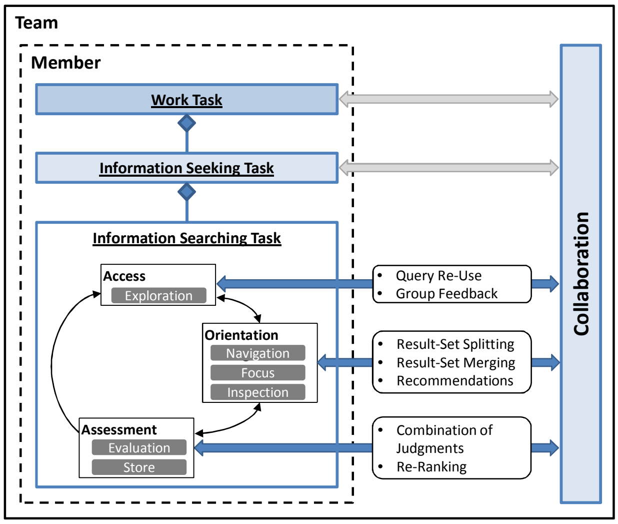

Figure 2: Summary of collaborative activities of a member within a team at information searching level

3.1 Method

Nowadays, scientists have a wide variety of software tools available to meet the daily work demands. To identify which technologies and means constitute the collaborative environment used by researchers to perform collaborative work-tasks, an online survey (implemented with Google Drive) has been conducted. We invited researchers to answer questions regarding the acquisition of required information for the collaborative performance of their work-tasks. In addition to questions regarding demographics, we were particularly interested in how they (1) collaborate with colleagues when performing a search task, (2) communicate with their colleagues and share information, and (3) how they identify colleagues who could be most helpful in regard to answering their questions and solving problems.

We asked members of two work groups of a university research facility (each in the field of life sciences) and the members of an industrial research department (in the field of information technology). The survey has been provided via e-mail distribution lists addressing (in sum) 52 people. 24 completed the entire survey, yielding a 46.2% response rate. The survey consisted of both free-text and multiple-choice questions

3.2 Results

Demographics

The age of the participants ranged from 24 to 43, with an average age of 33.25 years (s.d. = 5.14). 75% of respondents were male. Respondents were specialized in different fields of study. We clustered them into two groups: 37.5%

of respondents are specialized in the field of life sciences (including biology, molecular biology, biochemistry, and medicine), 62.5% of respondents are specialized in the field of information technology (including computer science, computer engineering, mathematics, and physics).

We wanted to estimate the degree of experience the respondents have in collaborating with colleagues. The number of articles published by multiple authors is often seen as a measure of research collaboration [4]. We decided to use this measure although not every research collaboration results in a publication and not all co-authored papers are result of collaborative research [4]. Participants were asked for the number of co-authored writings (papers of all types, grant application, project reports, etc.) they have contributed to. The given figures cover a broad range of values and thus yielding a large standard deviation (s.d.) of 23.8. The average number of co-authored writings is 18.73.

Additionally, we asked for the highest academic degree: 9% of the respondents hold a Bachelor's Degree (or equivalent), 26% of the respondents hold a Master's Degree (or equivalent), and 61% of the respondents hold a Doctor's Degree (or equivalent). The remaining 4% were Students before their first academic degree. Participants were asked to self-rate their search experience. On a five-point Likert scale, 4% rated themselves as inexperienced, 13% as moderately experienced, 67% as experienced, and 13% as expert. No respondent self-rated as "very inexperienced" user. Results show that, in addition to the high level of familiarity in search practices, the group of respondents is characterized by high degree of education, research and collaboration experience.

Search Habits and Result Management

Participants were asked about the (electronic) information sources they frequently use (figure 3) as well as tools utilized to organize and manage their search results (figure 4), i.e. scientific literature. Respondents could select electronic sources of information in a multiple choice box.

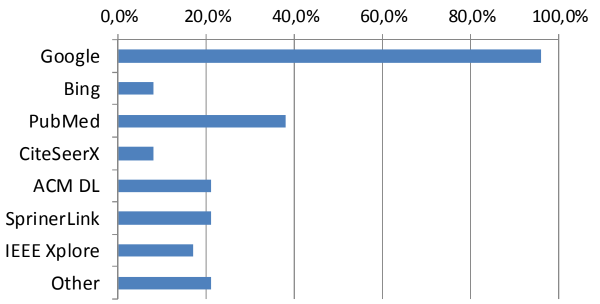

Figure 3: Electronic information sources used by respondents

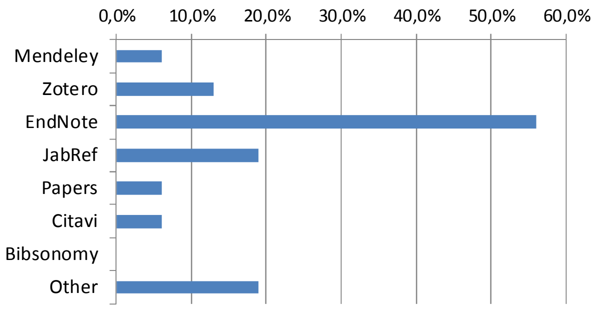

Figure 4: Literature management tools used by respondents

Additionally, they were able to extend this list by naming further tools (Other).

Figure 3 summarizes the selected sources of information. Other included Microsoft Academic Search, "Zentralblatt MATH", DBLP, and Ecosia. The results show Google as a common favorite choice, but they also provide evidence of the diversity of electronic information sources consulted during work-task performance. Figure 4 summarizes the selected literature management tools. Others are: www.citemaster.net, BibTeX, Citavi, and the Windows Explorer. In total 10 distinct tools have been named by the respondents. This too points to a broad variety of tools in operation.

Collaboration during Search

To learn more about practices of collaboration during search, we asked the participants in which stages of the search process they consult their colleagues or have been consulted. We asked about collaboration during data source selection (Q1) and query formulation (Q2a and Q2b). According to Marchionini [16], query formulation involves (a) an action mapping of the information seeker's search strategies and tactics onto the features the system interface provides, and (b) a semantic mapping of the information seeker's vocabulary onto the system's vocabulary. Therefore, we included questions on collaboration with respect to the interface and its functions (action mapping, Q2a) as well as collaboration regarding the query formulation (semantic mapping, Q2b). Furthermore, Q3 and Q4 address the result refinement as well as the result evaluation. Figure 5 depicts the results.

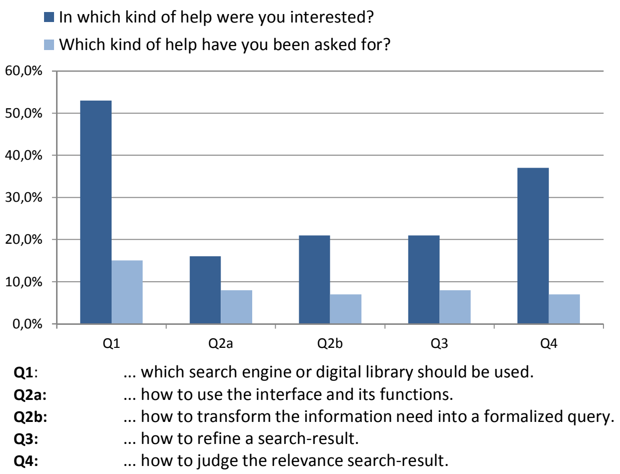

Figure 5: Percentages of respondents who collaborated during different search stages

Collaboration was found to be at its highest during the information source selection stage as well as during the assessment stage. However, collaboration can be identified in each stage of the search process.

Communication and Information Sharing Tools

We were also interested in communication (figure 6) and information sharing (figure 7) habits. As result of the growing prevalence of social networking [2, 18], we wanted to determine the degree to which such technologies are utilized for daily work routines. In a multiple choice grid, respondents could select (on a 5-point Likert scale) the frequency of technology usage in times per day. In addition, respondents were able to extend the provided list by adding tools not listed yet.

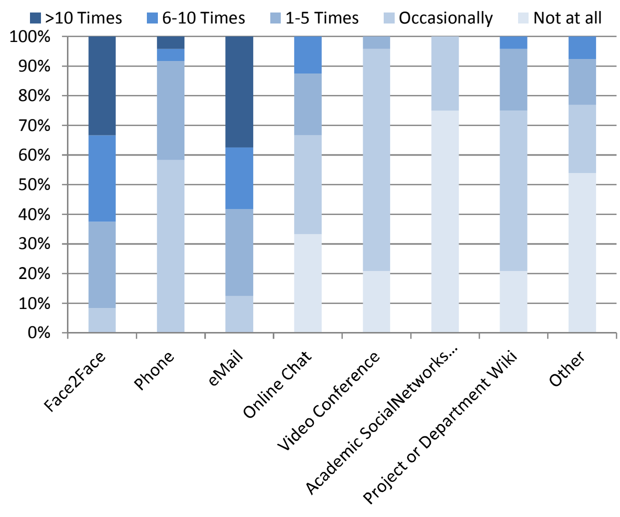

Figure 6: Frequency of use of various communication technologies among respondents

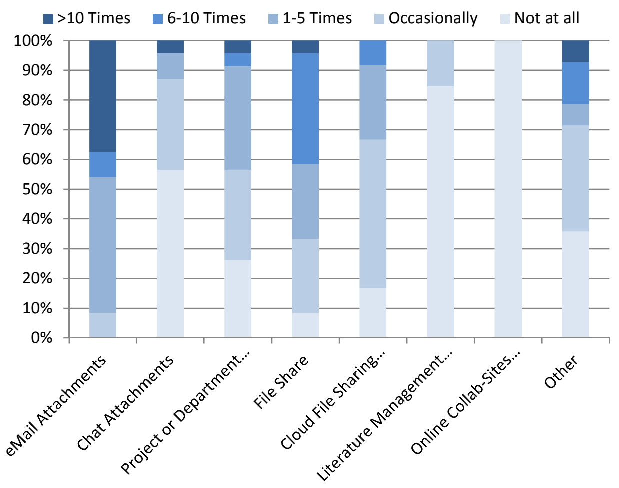

Figure 7: Frequency of use of different technologies for data and information sharing among respondents

The results in figure 6 show the importance of face-to-face communication and established remote communication technologies, i.e. phone and email. This is in line with other studies that identified communication technologies that are part of the everyday work as means to realize CIS&S [18]. It is noticeable that academic social networks seem to play only a small role in enabling communication between colleagues. Figure 7 depicts technologies for realizing data and information sharing utilized by the respondents. A predominance of e-mail attachments and the usage of file shares (local and cloud based) can be found. In contrast to this, integrated group support in literature management systems as well as online collaboration sites are rarely in use. A large list of additional tools (Others) has been named by respondents, which includes Google Drive, version control systems (namely GIT), Streamworks, and SAPmats (each specified twice). Furthermore, AeroFS, Teambox, and Adobe Connect have been added. This particularly large number of technologies used for realizing collaborative activities indicates a very heterogeneous collaboration environment where each co-worker uses his personally preferred tools.

Finding a Partner

We wanted to learn more about how respondents identify colleagues that are expected to be helpful in answering their questions. We asked two questions (1. *How did you know who might be able to help you*? 2. *How did you contact the person you asked for help?*) and provided an optional free-text field for answers. Twelve respondents provided insights on this process. Some answers show that colleagues are predominantly approached only after a first clarification using web-based search wasn't satisfying or helpful:

> *"I try to Google the issue* [...]. *If that's unsuccessful, I personally contact the colleagues who have experience with that [topic]. I explain my concrete scenario and ask them for help. Sometimes, they don't know the solution but give some new input where to look for."*

After analyzing all answers, we identified three categories of approaching colleagues when looking for help:

(1) Random contacting: Respondents ask colleagues without knowing whether they can provide the required information or not (e.g. "*Asking around in the team*", "[*asking*] *whoever is closest*").

(2) Specific contacting: Based on a personal network and an awareness of the qualifications of their team mates, colleagues are directly approached (e.g. *"I asked another biologist who is well versed with [the topic] and has demonstrated that in many fields."*, "[*I asked*] *colleagues who have a longer research experience and/or better background knowledge* [...]").

(3) Expert searching: An attempt is made to identify potentially helpful colleagues by looking at the University/research group websites.

Typical ways of contacting colleagues include e-Mail, Chat or personal contact with face-to-face communication (i.e. "went to their office").

Limitations

The demographic targeted by this survey is characterized by high academic degrees and a high experience in research collaboration. Respondents were residents in Germany. Additionally, the relatively small number of respondents might limit the significance of this study. The data we report can probably not be generalized beyond this demographic.

4 Conclusions

4.1 Design Implications

The results of our pilot study indicate that nowadays, collaboration is performed in a heterogeneous environment: It must be assumed that team members use their own personal configuration of software tools for the different information activities (i.e. communication, data and information sharing, seeking and searching, and result management). This configuration is based on personal preferences, work habits, and the special needs (e.g. thematically specialized DLs). The results indicate that a coupling of tools used in everyday work routines represents a necessity for an environment supporting CIS&S. Instead of providing communication and information sharing means integrated in one system, connecting to external tools and mediating between the co-workers seems to be a promising way. This might also allow for evaluating the mediated information to infer awareness-cues to facilitate group performance.

In line with other research [12], our results show that CIS&S often involves looking for informed people. We identified three approaches of identifying a potentially helpful colleague: expert search, random and specific contacting. The results indicate that collaboration could become more efficient, if team members could better identify co-workers who might be most helpful regarding their questions and problems. Also in line with previous studies (see section 2.1), collaboration can be observed in all stages in the search process. Our results indicate that collaboration during search preparation and result evaluation seems to be predominant. Providing group support for these aspects could most likely increase the efficiency and effectives of the CIS&S tasks.

4.2 Project Aim

The working hypothesis of our ongoing research project is that effective and efficient CIS&S requires the integration and coupling of various software tools which form the heterogeneous collaboration environment. This environment harbors knowledge in form of link-potential between the IR activities in the group and the data accessible through these tools. Besides the textual content created and managed by the tools in use, co-workers also interact with each other in many ways and build a collaboration network (CN):

- People are connected to other people as result of being a frequent communication partner or friend, or by being co-workers.
- Information objects are related to each other as result of citations or common attributes, like domain categories or keywords. Additionally, relations between documents may have been maintained manually or semi-automatically by users in form of tagging or clustering.
- Information objects are directly associated with people by the authorship relation, but also as result of reading, storing, assessing of and commenting on an information object.

We exploit this environment by collecting semantic knowledge about the individuals and their relation information: By tracking and storing this semantically linked data, i.e. information objects, user and their activities, a graph-based representation of the CN can be obtained. This representation is than analyzed and evaluated by means of semantic link analysis to generate situational support for the co-workers in each stage of the search process. Based on specific rules R_S for each stage *s* of the information searching process, the user support aims at increasing the group performance by (1) encouraging query diversity, (2) providing already discovered information, and (3) facilitating the alignment of result assessment.

In a first project phase, the CN shall be evaluated with the aim of identifying synergetic potential in the group (e.g. identify redundant activities or assessment conflicts). In a second phase, the CN shall be evaluated with the aim of activity suggestions to facilitate the effectiveness of the CIS&S tasks (e.g. query term suggestion, result set merging or splitting, result re-ranking). The objective of these suggestions is to increase the search performance of the group based on proposed measures for CIS&S [26].

Figure 8 depicts this concept (from bottom to top): CIS&S tasks are performed in a heterogeneous environment that connects co-workers and information objects via the utilized tools. The activities are tracked and stored in the CN. Rules extract awareness-cues during the CIS&S tasks for each stage of the search process.

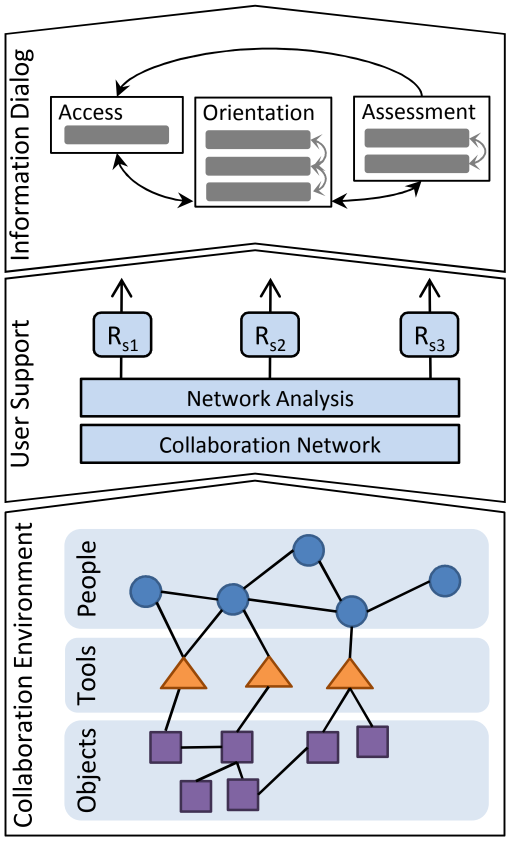

Figure 8: Layer model for supporting a group during IS&S tasks

4.3 Architecture

ezDL is the continuation of the Daffodil [14] project and implements meta-search in digital libraries and strategic support for users. The upper half of figure 9 shows the structure of the system. *ezDL* consists of a set of agents providing different aspects of the system functionality. Agents use a common communication bus for transferring messages between each other. Beginning on the left, a client connects to the MTA (Message Transfer Agent), which represents a connection point to the backend. The connection to remote search services (e.g., digital libraries) is managed by wrapper agents. A search request from the client is forwarded via the MTA to the Search Agent (SA). The SA collects all answers from all the remote DLs, merges the result lists and re-ranks them.

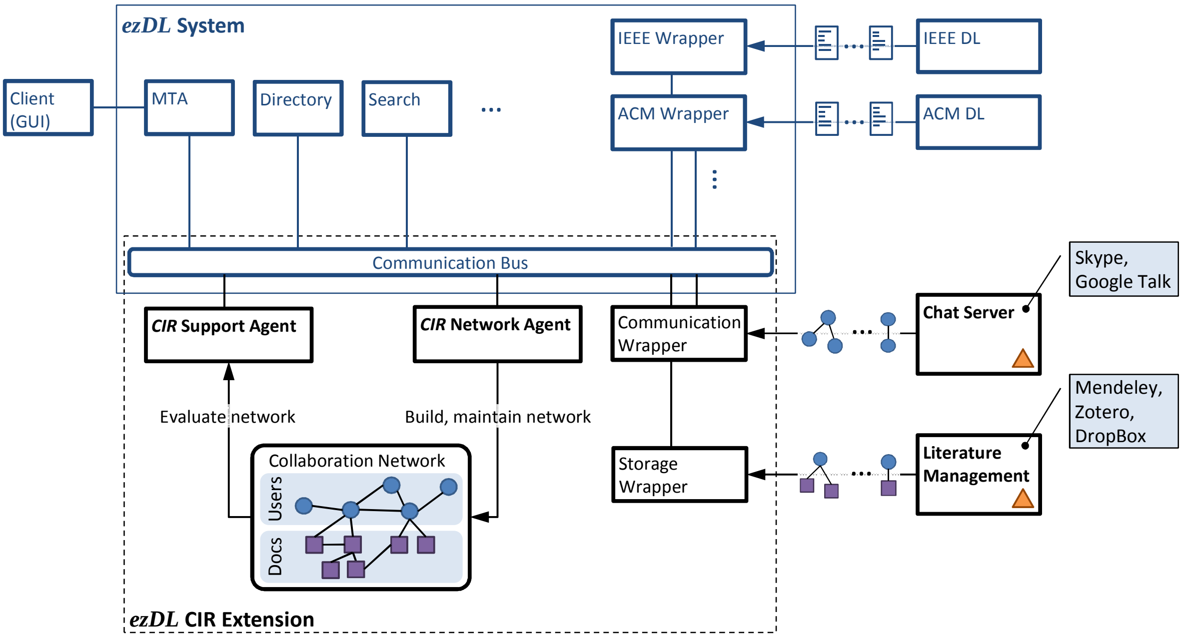

Figure 9: Structure of *ezDL* and intended extension for collaboration support at IS&S tasks

An extension of the *ezDL* system for supporting a group of collaborators is shown in lower half of figure 9. This extension addresses the identified design implications by connecting external tools utilized by the co-workers (CIR Network Agent), and by evaluating the gained information in order to generate awareness-cues (CIR Support Agent). External tools are connected by appropriate wrappers that connect, for example, to chat-servers. The objective of the CIR Network Agents is to gain information from the services about the users and its activities. These might be the communication frequency with co-workers or the stored documents. This information constitutes the collaboration network which is evaluated by the CIR Support Agent. Each time a search is performed, the client may request awareness-cues from the CIR Support Agent. The CIR Support Agent will handle support request regarding the stage *Access* (e.g. identify redundant and similar past queries), *Orientation* (e.g. bring up already discovered information), and *Assessment* (e.g. point to previous assessments and conflicting assessments of documents).

5 Summary and Outlook

In this paper, we reported on a pilot user study that investigates the CIS&S practices of three work groups in academic and industrial research facilities. The conducted pilot study captured the use of software technologies for realizing collaboration, information seeking and sharing in real-world work settings.

The results of our pilot study indicate that nowadays, collaboration is performed in a heterogeneous environment: It must be assumed that team members use their own personal configuration of software tools for the different information activities (i.e. communication, data and information sharing, seeking and searching, and result management). The results further indicate that a coupling of tools used in everyday work routines represents a necessity for the development of an environment supporting CIS&S.

We presented the design of an extension of the *ezDL* system that addresses the identified design implications by connecting external tools utilized by the co-workers, and by evaluating the gained information in order to generate awareness-cues. The aim of this is to provide group members with information on the best suited collaboration partners and the collaborative activity to be performed in order to increase the efficiency and effectiveness of IS&S tasks in such environments. The presented *ezDL* extension is currently being implemented. We plan an extensive evaluation of this system to address our initial research question: To which extend can group support in form of suggested activities improve the efficiency and effectiveness of CIS&S tasks in heterogeneous collaboration environments.

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