Analyzing Effect of Roles on Search Performance and Query Formulation in Collaborative Search

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ABSTRACT

We investigate how explicit search roles assigned to group members affect their search performance and behavior in collaborative information seeking (CIS). Although several roles have been proposed in CIS, how these roles affect the search performances and behaviors of the members has not yet been explored. We focus on the existing Gatherer and Surveyor roles and analyze their effects on search performances and query formulation behaviors. The goal of our study is to understand the relationships between the roles and search behaviors and get insights into developing algorithms such as query suggestions or document rankings adaptive to the roles and behaviors. We conducted a user study with 20 participants in 10 pairs, where each pair of Gatherer and Surveyor were asked to perform a recall-oriented collaborative search task. We first analyzed the search performance of the two roles in terms of recall and diversity. We also analyzed how their queries were affected by their preceding queries or webpages that were visited through a questionnaire and log analysis. Finally, we discussed what algorithms would be required to support role-based CIS.

Categories and Subject Descriptors

H.3.3 [**Information Storage and Retrieval**]: Information Search and Retrieval

Keywords

Collaborative information retrieval, Role-based collaborative search

1. INTRODUCTION

Collaborative search, or collaborative information seeking (CIS), is an activity where a group of members who shares the same information need carry out search in a collaborative manner [1, 2]. According to a survey on 204 knowledge workers reported by Morris [5], 54.5% users had ever experienced cooperating with other people to search the Web, and 38.5% of such users cooperated on a weekly basis. CIS has recently been the subject of much research, and lots of proposals including algorithms [7, 8, 12] and user interfaces [3, 6] for CIS have been made.

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One important direction in this research area is *role*-based CIS. Several pieces of research have been done to study roles in CIS in order to improve the search performance [11, 12] or the quality of the outcome, e.g., report [4] of the task. Assigning different roles to a group of members makes clear their search strategies and make it easy for each member to collaborate. One well known role, for example, is the Gatherer and Surveyor roles proposed by Shah *et al* [11]. The aim of the Gatherer is to quickly find as much relevant information as possible whereas that of the Surveyor is to explore a topic and find diverse information.

Although several ranking algorithms adaptive to the Gatherer and Surveyor roles have been proposed and proved their effectiveness on search performance [11, 12], it has not been intensively studied how these roles affect the search performances and behaviors of users. Since the Gatherer and Surveyor roles are complementary, their search behaviors would be influenced by the other's behaviors as well as one's own behaviors. Analyzing such interactions and finding behavioral characteristics would help us deeply understand user behaviors in role-based CIS and develop more effective algorithms adaptive to their different roles and behaviors.

The goal of our study is to understand the relationships between the roles and their search behaviors and get insights into developing algorithms like query suggestions or document rankings adaptive to the roles and behaviors. We focus on the Gatherer and Surveyor roles and analyze their difference by conducting a user study with 20 participants in 10 pairs, where each pair of Gatherer and Surveyor was asked to perform a collaborative Web search. In this paper, we focused on two questions:

- **Search Performance:** How different are the search performances between Gatherer and Surveyor? We chose the recall-oriented exploratory task as our evaluation task and analyzed how the Gatherer and Surveyor collected relevant information as they performed the task. We analyzed not only the recall of the webpages collected by the Gatherer and Surveyor but also the recall of the intents in order to reveal the difference between the Gatherer and Surveyor in terms of the diversity of collected information.
- **Query Formulation:** How different are the queries issued by the Gatherer and Surveyor? We asked the participants to answer a questionnaire regarding what types of their own search behaviors and those of their partner affected their query formulations. We also analyzed the similarity between the queries issued and their past search behaviors including the queries and the visited webpages.

2. USER STUDY

In this section, we first briefly introduce the Gatherer and Surveyor roles and then describe the details of the user study. In this

Figure 1: Collaborative search interface used in user study.

study, we focus on a typical situation of CIS in which a *pair* of users collaborate [4, 8, 12, 14]. We also focus on a *remote* setting where each member is located in distant places [14].

2.1 Gatherer and Surveyor

Shah *et al.* proposed two complementary roles called "Gatherer" and "Surveyor." They explain, "*. . . the goal of the Gatherer is to scan results of the joint search activity of team members to discover the most immediately relevant information. The goal of the Surveyor is to browse a wider diversity of information to get a better understanding of the nature of the collection being searched, to understand where the current queries might be failing, and to identify potential avenues of exploration . . .*" [11].

The nature of such roles can affect the search behavior of the Gatherer and Surveyor. In particular, their behaviors can be influenced by their preceding search behaviors. For example, since the Gatherer seeks relevant information he or she tends to issue queries that are similar to the collected relevant documents or the queries that retrieved the relevant documents. Similarly, the Surveyor tries to issue queries dissimilar to the relevant documents already collected or the previously issued queries as his or her goal is to seek diverse information. Revealing such relationships is useful for us to understand how they issue queries, collect webpages, and develop methods for improving their search performances.

2.2 Search Interface

Figure 1 shows the collaborative interface used in the user study. The interface provides the fundamental functions for collaborative Web search, which have been discussed in the literature [10, 14]. The interface is implemented as a Web service and accessed by a Web browser. The interface consists of four areas:

Chat: An area to communicate with the partner. Both an outgoing message and an incoming message will be displayed in the area immediately with a notification sound.

Web Search: An area to perform Web searches. When a user issues a query to a textbox, the system retrieves the top 50 documents and 8 query suggestions from the Bing API and displays them to the user. Each search result has a button for adding a webpage to a shared bookmark.

Query History: An area to display the history of the queries issued by the pair. It shows all the queries issued by either the user or the partner in the reverse chronological order. The user can perform a Web search by clicking a displayed query.

Shared Bookmark: An area to show the documents saved by the pair. When the user or the partner adds a webpage into the shared bookmark, the system updates the area immediately.

2.3 Task

Morris *et al.* classified typical tasks in CIS into two classes: (1) the recall-oriented task where a group of members seek information exhaustively, and (2) the decision-making task, such as travel planning [5]. These two types of exploratory search tasks are often used in the evaluation of CIS. In this work, we focused on the recall-oriented task for our user study. As for the topic of the task, we chose global warming, which was also used in Soulier *et al*'s work [12]. The description of the task instructed to the participants is as follows:

> You and your partner are now enrolled in the same lecture in the university. You two have been asked to write a report about *world efforts on global warming*, and it has to be four A4 pages long. For 30 minutes, use the system and save the webpages you think are useful for writing the report into the shared bookmark. The goal is for you both to collect as many useful webpages on the topic as possible from as many diverse aspects as possible.

2.4 Participants

Participants were recruited via the recruiting webpage of Kyoto university. Overall, 20 participants in 10 pairs, all of whom were undergraduate or graduate students of the university, participated in the user study. Ten were male and ten were female, and their majors included agriculture, medical science, pharmacy, engineering, law, and economics. Participants were recruited as a pair to ensure that they did not have difficulty in communicating and collaborating each other. In addition, each participant was informed of the compensation (worth 20 US dollars) for participating in the study.

2.5 Procedure

Each experiment, which lasted about one hour, was conducted in the steps described below. In the user study, the participants used laptop PCs with Windows 7 and Chrome. Their resolutions were set to 1400×1050.

1. Participants, which were first gathered in the same place, were introduced to the study and informed that their search behaviors were to be recorded. They were then asked to fill out a questionnaire about their search expertise and prior knowledge about the topic of the task.
2. Participants were introduced to the system described in Section 2.2 and went through a training task in order to become familiar with the system. The training task, which took approximately five minutes, required the pair to find useful webpages about the sightseeing spots of a city and save them into the shared bookmark.
3. Participants were asked to read the task description described in Section 2.3. We explicitly assigned one participant to the Surveyor role and the other to the Gatherer role and asked them to collaborate with each other in consideration of their roles.
4. Participants were asked to move a different location so that they could not see their partners.
5. Participants were asked to do the task for 30 minutes.
6. After completing the task, participants were asked to answer a questionnaire, in which participants reported what information they perceived as influencing their query formulations. This questionnaire was close that used in the work of Yue *et al.*, who investigated the influences on query formulations in collaborative search [14]. More specifically, for each query

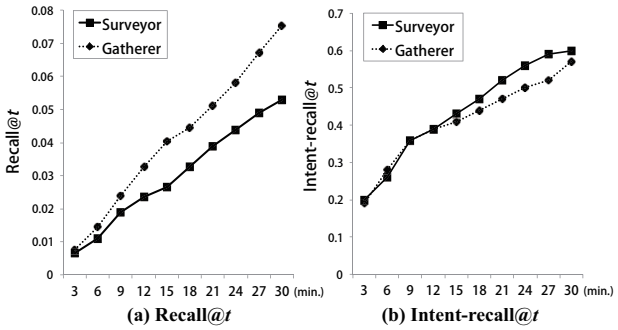

Figure 2: Recall@t and intent-recall@t with different timestamps t.

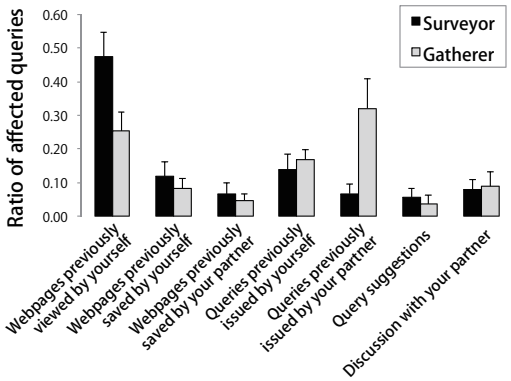

Figure 3: Results of questionnaire regarding resources that affected query formulations (+SEM).

issued by the participants during the task, the participants were asked to choose from a list of the important resources that affected query formulation. The resources were webpages previously viewed by yourself, webpages previously saved by yourself, webpages previously saved by your partner, queries previously issued by yourself, queries previously issued by your partner, query suggestions, and discussion with your partner.

3. RESULTS

3.1 Search Performance

To measure the search performance for each role, we first measured the recall of the webpages saved to the shared bookmark, which is the most important aspect of the recall-oriented exploratory task. In this work, we treated any webpages saved by any pairs to be relevant to the task. In other words, the union of all webpages saved by each pair was treated as a universe of relevant webpages. From the user study with 10 pairs, we obtained 306 unique webpages as the entirety of relevant webpages. Given this universe, the recall of the webpages saved by a user of a pair at a timestamp t can be computed as follows:

$$\text{Recall@}t = \frac{|D^{(t)}_{\text{saved}}|}{|D_{\text{universe}}|}\ , \tag{1}$$

where $D^{(t)}_{\text{saved}}$ represents the set of pages saved by the user up to timestamp t and D_{universe} represents the universe of relevant pages.

Another important aspect of the recall-oriented exploratory task is *diversity*, which measures how diverse information was retrieved. Since existing measures like recall are not enough to measure the diversity, we propose measuring the recall of *intents* rather than the recall of relevant webpages in CIS. Recently, search result diversification has attracted the interests of many researchers, and many intent-sensitive evaluation frameworks have been proposed. In this work, we employed an approach that is similar to the one taken in the NTCIR IMine and INTENT tasks [9] to measure the diversity of the saved documents.

We first pooled all the queries issued in the user study and obtained 421 unique queries. We then manually clustered them into intents by using the clustering tool described in [9]. From this process, we obtained a set of ten intents such as "causes of global warming," "renewable energy," and "international framework for global warming." Let I be the set of obtained intents. We define $\text{Intent-recall@}t$ which measures the recall of intents of a given timestamp t as follows:

$$\text{Intent-recall@}t = \frac{\#\text{ of intents covered by } D^{(t)}_{\text{saved}}}{|I|}\ . \tag{2}$$

When a saved webpage d was retrieved by a query q and q was clustered into an intent i, we assumed that the webpage d covered the intent i.

Figure 2 shows the results of Recall@t and Intent-recall@t for the Gatherer and Surveyor roles by ranging the timestamp from the start of the task to the end of the task. As for the recall, when we see in Figure 2 (a), the Gatherer obtained many more webpages compared with the Surveyor. As for the intent recall, from Figure 2 (b), we can see that there seems to be no big difference in the first 15 minutes of the task, whereas the Surveyor found more diverse webpages than did the Gatherer in the last 15 minutes. One possible explanation for this result might be that, in the early stage of the task, both the Surveyor and Gatherer had to spend time on learning about the topic, and the Surveyor could not find good queries that broadened the topic. In contrast, as the Surveyor learned about the topic, he or she could find good queries that could retrieve unexplored information.

When we see the last three minutes of the task, however, the difference of the intent recalls between the Gatherer and Surveyor becomes small. This indicates that, as the Surveyor spent much time on exploring the topic, he or she may have had difficulty in finding topics that had not been explored yet.

3.2 Query Formulation

We found that participants could carry out their tasks on the basis of the assigned roles from Section 3.1. This subsection analyzes the queries formulated by the participants through both the questionnaire and the behavior logs to further investigate their search strategies.

Questionnaire Result. We first analyzed the participants' subjective responses regarding the resources that affect their query formulation. Figure 3 shows the result of the questionnaire described in Section 2.5. The results of a t-test shows that there were significant differences ($p < .05$) between the Surveyor and Gatherer for "webpages previously viewed by yourself" and "queries previously issued by your partner." As for the Surveyor, the result indicates that many Surveyors formulated their queries by considering "what they have retrieved" and tried to formulate queries that could retrieve unexplored information. In contrast, Gatherers were likely to formulate their queries in consideration of their partners', i.e., Surveyors', queries.

Log Analysis. We analyzed the query log obtained from the user study to further investigate the participants' query formulation. We analyzed the similarity between one's query and one's or partners preceding queries or visited webpages. To compute the similar-

Table 1: Mean similarity between issued query and previously issued query(s) or visited webpage(s) (±SEM).

	Surveyor	Gatherer
Queries previously issued by oneself	0.21(0.02)	0.24(0.04)
Queries previously issued by partner	0.19(0.03)	0.21(0.03)
Query most recently issued by oneself	0.27(0.03)	0.32(0.05)
Query most recently issued by partner	0.19(0.03)	0.26(0.03)
Webpages previously viewed by oneself	0.23(0.02)	0.24(0.03)
Webpages previously viewed by partner	0.19(0.03)	0.23(0.03)
Most recent webpage viewed by oneself	0.10(0.01)	0.12(0.01)
Most recent webpage viewed by partner	0.07(0.01)	0.09(0.01)

ity, each query was represented as a feature vector generated from snippets of the top 10 search results of the query, from which we generated a bag-of-words vector with tf-idf weighting. Similarly, each webpage was represented as a bag-of-words vector generated from the content of the webpage.

Table 1 shows the average similarity between one's query issued and the past queries previously issued before the query. It also shows the average similarity between one's query issued and the previously visited webpages. "Most recent(ly)" in the table represents the similarity between issued query and the most recent query or webpage visited by oneself or the partner. From the table, we can see that the Gatherers' queries were more similar to the past behaviors of the pairs in all aspects than were the Surveyors' ones. This indicates that the Gatherers tried to issue queries similar to what had already been retrieved, while the Surveyors tried to issue queries dissimilar to it.

As described above, we found that the Gatherers reported that the queries issued by their partners affected their queries. When we see Table 1, we can see that the similarity between the Gatherers' queries and their partners' most recent queries was much higher (0.26), compared with their partners' past queries (0.21). We could not find a similar trend in the Surveyors' queries. The results from both the questionnaire and the log analysis suggest that the Gatherers often considered the Surveyors' past queries, especially the recent queries, and formulated queries similar to them. In other words, the Gatherers tried to search where the Surveyors had already explored to collect more relevant webpages.

As for the Surveyor, we could not find any trends that support the questionnaire result only from the data in Table 1. We plan to analyze the similarity between the Surveyors' queries and their visited pages with different stages of the task. Our hypothesis is that the Surveyors' queries are similar to the visited webpages in the early stage of the task as they found good queries appeared in the webpages, whereas, in the latter stage, the Surveyors' queries were dissimilar to the visited webpages as they learned about the topic and thus could choose good queries that did not appear in the recently visited webpages.

4. CONCLUSIVE DISCUSSION

In this study, we investigated the effects of the Surveyor and Gatherer roles on their search performances and query formulation. Although the experiment was small and conducted under the limited conditions, the results suggested several directions for supporting role-based CIS. As discussed in Section 3.1, as the Surveyor spent time on exploring a topic, he or she had difficulty in finding topics that had not been explored yet. This suggests that the system should suggest queries for unexplored topics by considering what the pair has already found.

From the result in Section 3.2, we found that the Gatherers decided what they will search on the basis of what the Surveyors had explored. This suggests that it is useful for the Gatherer to suggest queries similar to the Surveyor's queries, but the Gatherer could retrieve information that the Surveyor has not found.

We believe that the findings of the paper could apply not only to role-based CIS, where each participant is explicitly assigned to a role, but also to one where the system predicts their implicit role from their behavior [12]. Moreover, the Gatherer and Surveyor roles are so general that we could apply the findings even to individual search. It is well known that, during the exploratory search, the searcher switches back and forth between the Gatherer-like phase and Surveyor-like phase, e.g., *focused searching* and *exploratory browsing* [13].

In the future, we plan to conduct a user study with more participants and conditions such as having the participants in the same place and having them perform a decision-making task to reveal the behavioral differences between the Surveyor and Gatherer. Also, we would like to propose query suggestion and document ranking algorithms adaptive to the roles on the basis of the findings of the analysis and evaluate their effectiveness in role-based CIS.

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