Collaborative Information Retrieval Environment: Integration of Information Retrieval with Group Support Systems

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Abstract

Observations of Information Retrieval (IR) system user experiences reveal a strong desire for collaborative search while at the same time suggesting that collaborative capabilities are rarely, and then only in a limited fashion, supported by current searching and visualization tools. Equally interesting is the fact that observations of user experiences with Group Support Systems (GSS) reveal that although access to external information and the ability to search for relevant material is often vital to the progress of GSS sessions, integrated support for collaborative searching and visualization of results is lacking in GSS systems. After reviewing both user experiences described in IR and GSS literature and observing and interviewing users of existing IR and GSS commercial and prototype systems, the authors conclude that there is an obvious demand for systems supporting multi-user IR.. It is surprising to the authors that very little attention has been given to the common ground shared by these two important research domains. With this in mind, our paper describes how user experiences with IR and GSS systems has shed light on a promising new area of collaborative research and led to the development of a prototype that merges the two paradigms into a Collaborative Information Retrieval Environment (CIRE). Finally the paper presents theory developed from initial user experiences with our prototype and describes plans to test the efficacy of this new paradigm empirically through controlled experimentation.

Introduction

The late 1990s have witnessed huge proliferation of electronically accessible information and tremendous advances in electronic communication technologies. The former has led to a great deal of research and development in Information Retrieval (IR) to help users search for and quickly retrieve relevant and meaningful information, while the latter has spurred interest in collaborative computing technologies such as Group Support Systems (GSS). Independently, these two areas offer rich research opportunities and both are yielding promising results. For example, researchers are working hard to solve difficult problems applicable to both areas, such as the seemingly unresolved and persistently elusive problem of coping with information overload. It is surprising that very little attention has been given to the common ground shared by these two important research domains. We believe that user experiences in both areas suggest that, taken in conjunction, IR and GSS may create interesting and challenging new areas for research and development.

This paper describes how observations of user experiences in both IR and GSS led us to an effort to merge the two paradigms into a prototype system to provide the advantages of each and support collaborative information retrieval (CIR). The remainder of the paper is presented in three sections: Literature Review, Prototype Development and Refinement and Discussion and Future Research Objectives. The literature review focuses on research and development in IR and GSS that are relevant to the CIR perspective. Additionally it suggests some commonalties shared by the two domains. The prototype development section describes how user experiences with IR and GSS systems led to the design, implementation, and refinement of our "*proof-of-concept*" prototype. It presents user experiences that provided insight which led to refinement of both the user interface and the system functionality. The future research objectives section describes theory developed from user experiences and describes our plans to test our prototype CIRE system experimentally.

Literature Review

To gain further insight into IR and GSS we conducted a thorough literature review. For each domain This review presents a definition and an introduction to the field of inquiry. Following this, trends and recent developments relevant to the CIR perspective in each domain are presented. Finally the review summarizes commonalties shared by the two domains and suggests that their integration not only is appropriate but may in fact be beneficial to each area.

Information Retrieval (IR)

This section presents a conceptual and historical introduction to IR, new advances relevant to CIR, the IR paradox of a focus on individuals and the social nature of information seeking, and finally, research and development that has been done in the area of collaborative IR.

IR: an Introduction

Salton et al. [78] describe IR as a cross disciplinary field wherein the main question is "*how does one find the relevant documents in a collection of documents given a user query*?" Manber [48] explains that the history of IR dates back at least as far as 2000 BC, when the first Sumerian literary catalogue was constructed. Further, Manber [48] explains that the Inverted Index, the most fundamental IR technique employed today, is as old as the Sixteenth Century AD. Clearly, IR concepts and problems are not new; what is new are the information technology approaches to solving age old problems.

Hearst [36] suggests that the recent rapid proliferation of accessible "*digital*" documents has ignited an unprecedented interest in IR techniques. Hearst [36] suggests that this new interest may be due to the fact that traditional search techniques often fail to adequately handle currently available information. For example, Hearst [36] asserts that today's users foraging for information on the World Wide Web (WWW) receive an average of more than thirty-thousand (30,000) documents in answer to a single query. Hearst [36] also acknowledges that current information technology cannot yet emulate human search strategies very well, because most user queries are extremely ambiguous and rely heavily on common sense.

IR Advances Relevant to CIR

The IR field has seen many break-throughs in recent years, far too many to mention within the scope of this paper. Many new tools for searching and for visualizing the results of queries have been designed and developed, by researchers and practitioners alike. Some promising new IR developments relevant to CIR include: collaborative filtering [32,47,75] self-organizing maps (SOMs) [8,10,13], concept spaces [9,11,12], intranet collaborative searching [32], and computerized support for collaboration between browsers in a library catalogue system [86]. Each of these offers a more efficient and effective way for users to search through large volumes of information, either independently or collaboratively.

IR Paradox: Individual Focus vs. Social Nature of Information Seeking

Our review of the IR literature shows that the vast majority of work on IR concentrates on *individual users working independently* to find information for themselves or to pass on to others. Most IR systems are designed for individual users working alone, and of those the authors have seen which allow for multiple users, none provides for "*Social Awareness*" among the users, which has been asserted [88] to be an important aspect of collaborative work.

IR researchers have suggested that information seeking *has always been a social process* [77,93]. For example, Root et al. [77] noted that software engineers like to discuss their work *around coffee machines,* hoping to get suggestions from their colleagues. Wilson [93] presented a model of information seeking in which other searchers were an important resource. For example, IR studies [7,43] that have observed conventional libraries found collaborative searching, query formulation and browsing to be common occurrences.

This presents an IR paradox. On the one hand, IR research and development has focused almost exclusively on individuals. On the other hand, observation of people performing searches reveals that, regardless of whenever and wherever a search occurs, whether in a library, in business organizations or in groups of tourists wandering around cities, information resources are often used collaboratively to seek information and to make decisions. The authors assert that focusing solely on individuals may ignore some aspects of how people actually use information, especially when they are working as members of a team. The next section reviews IR research and development that has begun to explore the collaborative aspects of searching.

Collaborative IR Research and Development

In recent years some attention has been paid to the collaborative aspects of IR. This section discusses research and development in the areas of collaborative filtering and collaborative browsing and presents commercial tools that incorporate some collaborative IR features.

Collaborative Filtering

Collaborative filtering has received much more attention than other IR related collaborative tasks. According to Maltz and Ehrlich [47], the concept of collaborative filtering originated with the Information Tapestry project at Xerox PARC [32]. Among its other features, Tapestry was the first system to support collaborative filtering by allowing users to annotate documents. Other Tapestry users can retrieve documents based on both document content and on other users' document annotations. Tapestry provides free text annotations as well as explicit "*like it*" and "*hate it*" annotations to enable users to pass personal taste judgments on the value of documents they read. Another example, GroupLens, created by Resnick et al. [75], allows collaborative filtering of UseNet newsgroups.

The Annotate system, developed by Ginsburg [31] at New York University (NYU) allows collaborative information seeking in an Intranet. Annotate supports three major annotation components: free-text form; integer-valued quantitative appraisals; and a choice of predefined explanations of why a particular document warrants specific annotations. To model a conversational style of communication, each document has only one level of annotations -- annotations to annotations are not possible. The annotations are used to alter the retrieval mechanism. Annotate adopts human face icons, as described by Koda and Maes [44], to express appraisals. At the time of this writing, Ginsburg told the authors that an experimental evaluation of the system was currently under way.

In order for collaborative filtering systems to be successful some critical mass of annotations is required. However, as Orlikowski [69] observed in her case studies, Lotus Notes (www.lotus.com) was not well utilized because workers had little or no incentive to share information. We are of the opinion that the situation becomes less problematic when the search domain is the entire WWW, which consists mostly of voluntary contributions. We found it surprising that we could not find any collaborative search systems that supports WWW searches. There are some systems that support collaborative WWW browsing, however, and a few of these are discussed in the remainder of this section.

Collaborative Browsing

With the advent of the WWW in 1994 both IR and Knowledge Management (KM) researchers started to explore the collaborative aspects of the browsing process. Researches at the University of Ulm [81] developed the CoBrow system to support collaborative browsing and justified it as follows:

> *If someone browses for information, there is a high probability that someone else is interested in the same subject at the same time, but people browsing the WWW are unaware of the presence of any fellow browsers.*

Twidale et al. [86] assert that truly user-centered systems must acknowledge and support collaborative interactions between users. They argue that collaborative work implies a need to share information at two levels, search product and search process. They also point out that people may search for other people. Twidale et al. [86] introduce the ARIADNE system as an example of computerized support for collaboration between browsers in a library catalogue system. ARIADNE supports collaboration by promoting awareness of the activities of others, visualization of the information data structures being browsed and a more effective means of communicating the browsing process. ARIADNE captures the users' input (*keystrokes*) and the database/library system's output (*text-based screen dumps*). This information is then combined to form a series of command-output pairs, each pair being represented as an item in the ARIADNE browser. The creators of ARIADNE also emphasize a learning element to the search process and the importance of collaboration for efficient learning.

Commercial Collaborative IR Tools

Commercial software developers have implemented some of the features mentioned above by researchers. "Blaze" (www.speeditup.com) has an organizer to help keep track of bookmarks and search results. In addition to searching, WiseWire (www.wisewire.com) claims to provide the ability to do research. The WiseWire system stores user actions, so they do not have to wade through the same information more than once. WiseWire claims to blend innovative strategies that can be helpful in searching, such as "*adaptive collaboration,*" which provides the ability to find out what others are looking at. With recent versions of Netscape (www.netscape.com), web surfers can play "*follow the leader.*" As the leader surfs to sites, the follower's browser windows are updated to the same pages. This allows a "*What You See Is What I See*" (WYSIWIS) metaphor, as first explored by Stefik et al. [83] at Xerox PARC, to be applied to WWW browsing.

Zhao and Kantor [94] noticed that very little attention has been paid to the *human channel of information exchange* in both IR research and practice. While addressing the digital libraries community, Levy and Marshall [46] noted that

> *. . .support for communication and collaboration is as important as support for information-seeking activities, and ... indeed, support for the former is needed to support the latter.*

However, Twidale et al. [86] assert that

> *Authors writing about digital libraries sometimes comment on how their (proposed) systems may facilitate interaction between users, though none of them appear to regard this as a key issue.*

We think that this problem extends to almost the entire IR community, affecting both research and the development of commercial search tools.

Based on our IR literature review we assert that there is currently no published research involving the following:

- Explorations of collaborative query formulation and query triggering and their effects on search task process and results
- Study of collaborative information retrieval processes with respect to validity and sufficiency of information space coverage
- Organizational aspects of team information forage
- Empirical comparisons of the efficiency and effectiveness of collaborative team searches with "summed" independent team member searches
- Evaluation of user satisfaction with both process and product of team members involved in collaborative searches

Group Support Systems (GSS)

This section gives a conceptual and historical introduction to GSS, explains the need for general purpose software modules, points out the need to match systems to work life, and stresses the importance of information access to GSS success.

GSS: An Introduction

Group Support Systems (GSS) grew from the Decision Support System (DSS) concept articulated by Gerrity [30] as "*an effective blend of human intelligence, information technology and software which interact closely to solve complex problems*" [2,20,39,45]. Although most early DSS implementations were for "*single users,*" however DeSanctis et al [20] assert that, theoretically, the concept applies equally well to groups.

GSS is defined in the literature as a computer-based information system to support intellectual collaborative work that consists of networked computers, special software, and typically a public screen [42,59]. Nunamaker et al. explain that GSS provides techniques, software, and technology designed to focus and enhance the communication, deliberation, problem-solving and decision-making processes of groups.

Nearly two decades of research and development have demonstrated that groups using GSS may become far more productive than might otherwise be possible [26,27,29,71,92]. This is supported by numerous published research studies and industry reports [23,38,41,52,53, ,72,74,91].

Nunamaker et al. [59] identified a number of potential sources of process losses and process gains associated with collaborative work. They assert that GSS technology can reduce process losses and increase process gains, thereby improving the efficiency and effectiveness of group performance. We think that the same principles may be applied to CIR. When considering CIR, it is possible that increases in a number of process gains and decreases in a number of process losses will carry over and thus improve both the efficiency and effectiveness of team search processes and the quality of team search results.

For example, synergy and more information similar to GSS idea triggering may be seen in CIR as "*query-triggering,*" wherein one user builds a new query from those of other users and thus finds additional information that might have been missed if each member of the team had searched individually. This type of process gain may lead to more thorough coverage of the search space and additional information that may help the team come to a better informed or more objective decision or solution to a problem.

Need for General Purpose Software Modules

Nunamaker et al. [67] argue that groups need "*general purpose*" software that comprehensively covers a broad range of group tasks. They also stress that emphasis should be placed on flexibility that supports groups, yet does not constrain them. GSS research [67,49,59,21] has demonstrated what Huber [40] had speculated early on:

> *integrated software tool kits that provide software modules to support specific group <u>activities</u> (for example, idea generation, voting) are more effective than systems designed to support entire <u>tasks</u> (such as negotiation).*

Turoff et al. [85] argue that computer systems to support geographically distributed teams will need to support *a full range of tasks* involved in project work, including planning, searching for and sharing information, conflict resolution, and decision making.

Need to Match Systems to Work Life

Mandviwalla and Olfman [50] performed a multidisciplinary literature analysis to identify important work group characteristics that led them to discuss limitations which suggest that "*current groupware systems do not fully match the work life of organizational work groups*" and then propose a '*generic set of groupware requirements.*' They assert that limitations of current GroupWare systems include group interaction that supports only a single-user perspective, a simplified view of groups, temporal and locational variations, piecemeal group support, and an implicit prescriptive worldview in design. van Genuchten, et al.[90] suggest that the next wave in GSS development will incorporate primary work processes. They argue that until GSS supports the day-to-day primary processes and tasks that knowledge workers must perform it will not become institutionalized within organizations

The requirements identified include the need to support multiple work tasks and methods, group development, interchangeable interactions, multiple behaviors, and permeable boundaries and contexts. They conclude that "*developers need to invent interoperable groupware that provides interchangeable and customizable features through new design metaphors and database structures*" [50].

Human-to-Human Communication in GSS

There is a large volume of literature on GSS in general [4,33,55,84,87,] that emphasizes the role of information and communication. More specifically, GSS researchers [3,18,19,28,33,70] have stressed the need to use information collaboratively to make decisions and perform team work. Aytes et al. [1] assert that participant-to-participant communication is an important issue in GSS meetings. Valacich et al. [89] assert that GSS participants may be "*socially aware*" and that this may affect both group processes and outcomes.

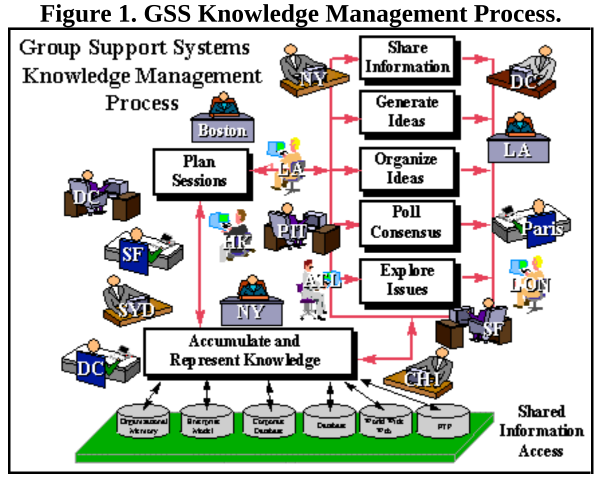
Finally one of the few GSS related theories, Briggs's Focus Theory of group productivity [3] asserts that regardless of the goal, group members accomplish their tasks by exchanging and thinking about information. This theory posits that there are three processes in which group members must engage to become productive: communication, thought, and information access. GSS provides information access in a number of ways: first, by bringing people with different backgrounds together; second by providing electronic transcripts of the sessions; and third, by providing tools to filter external information that exists in electronic format.

Knowledge Management As a Part of GSS

GSS researchers [21,34,59] suggest that members may need to organize and synthesize ideas, generate and evaluate proposed alternatives, devise plan a course of action and carry out that plan in order to accomplish their shared goals. Due to the volume of information and the dynamic and complex nature of tasks, groups may need a knowledge management process (See Figure 1) and an integrated environment to support that process [21,34, 59,76]. GSS environments may also need to support meta-information like date-and-time stamps, authorship, and ownership so that users have contexts for information within a session [21,34,59,76].

Nunamaker and collaborators [64] suggest that what is missing from such a knowledge management process is "sense making" in terms of *Information Retrieval*, automated situation analysis and brief generation, and automated course-of-action generation and recommendation. The latter two new GSS areas are outside the scope of this paper; although they may involve similar AI techniques and perhaps even incorporate some components of CIR, making them worthy of mention.

Figure 1. GSS Knowledge Management Process.



The above KM process starts with sharing information that users already have and does not address how they obtained that information. Collaborative tools have been developed to support all the phases shown in Figure 1. The authors believe that an additional IR phase is required within this knowledge management process to make it more comprehensive in terms of group support. To support such an additional IR phase will require development of specific tools designed for collaborative information retrieval and the integration of these new tools and techniques within larger GSS environments.

Literature Review Reveals Commonalties

The literature review reveals several interesting commonalties shared by GSS and IR that may make them not only compatible by also complementary to one another:

- Both IR and GSS began as *single user systems* and then evolved toward multi-user systems
- Both suffer the problem of single user perspective
- Many systems in both domains fail to fully match how individuals and teams work together to search for and share information and solve problems
- Both IR and GSS researchers assert that people use information collaboratively for many different joint tasks, including information seeking and decision making, and that this collaborative use is critical to success

While, one could look at this list of problems and conclude that both types of systems are failures in some respects, we prefer to see them as opportunities for each area to complement the other and to provide support that may begin fill in some of the gaps present in both areas. We believe that a number of these issues may be addressed though the development of an integrated knowledge creation environment in which IR and GSS are combined in such a way as to provide integrated group support for all tasks required for teams to work together, including information retrieval.

CIRE Advantages

We believe that there are a number of potential advantages to building a collaborative information retrieval environment to support teams seeking and retrieving information they need to accomplish work together. We identified several potential advantages that may result from using our prototype CIRE system:

1. Automatic creation of an *Information Retrieval Memory* that includes lists of pages visited, queries executed, and both comments and relevancy evaluations for sites and queries.

2. The ability to allow multiple users to share both queries and search results, thus permitting team members to synergistically build on the work of others to create queries and thus results that they would not have thought of nor achieved had they worked by themselves

3. Elimination of "*same-time same-place same-technology*" constraints, thus allowing team members to search together even if they are distributed physically, temporally and technologically. Team members no longer will need to sit together at one workstation and perform a single search, rather, they can work off-line and in parallel to improve their efficiency and effectiveness.

4. Redundancy in query and search results may be significantly reduced when users share a *"structured social awareness"* of the collaborative search process. This may in turn result in time savings, more objective evaluations of critical situations, and a better understanding of the overall information space.

With these advantages in mind we set out to develop a prototype collaborative information retrieval environment. The next section describes how user experiences with the early prototype led to refinements and added functionality that could not have been discovered without building a system and having users test it.

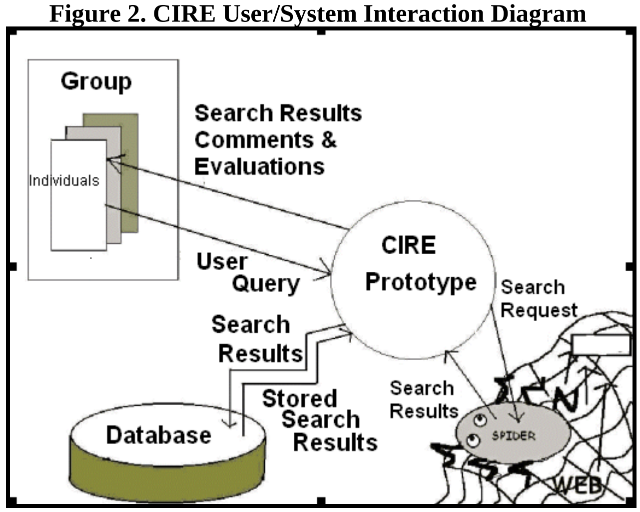
Prototype Development and Refinement

Prototype Architecture

This section describes the architecture of our prototype. CIRE is a Client-Server Application. The bulk of processing takes place on the server side (thick server). The server programs are CGI scripts. The client side only requires an HTML browser (Thin Client). The server program interacts with a commercial Internet search engine (Alta-Vista). It accepts a user query from an HTML form and forwards it to the search engine. Then the search engine sends back the query results and the server application displays them for the user and also records relevant information into the database.

We ensure that the most up-to-date search engine query form is presented to the users by downloading this form from the engine site each time the user logs into the system. We also preserve all advertisement material put into the search form by the commercial search engine. This provides the user with the feeling that they are working with the original search engine interface with a few extra fields added to the original form to provide for the collaborative features. Figure 2 presents the a diagram of the interaction among the entities involved: the user, the Web, CIRE and the search engine.

Figure 2. CIRE User/System Interaction Diagram



To begin to build our CIRE prototype we explored the basic requirements and system features of both IR and GSS systems. Typical Individual Search Functions are listed below:

Typical Individual Search Functions

- Query Creation
- Query Submission
- Query Result Review
- Query Refinement

We designed and built our CIRE system to provide team members with at least the same functionality as single-user IR systems and then to extend this with collaborative search functions based on the literature review and user experiences with both GSS and IR tools. These collaborative functions are displayed in the introduction screen described in the next section on CIRE Features.

CIRE Features

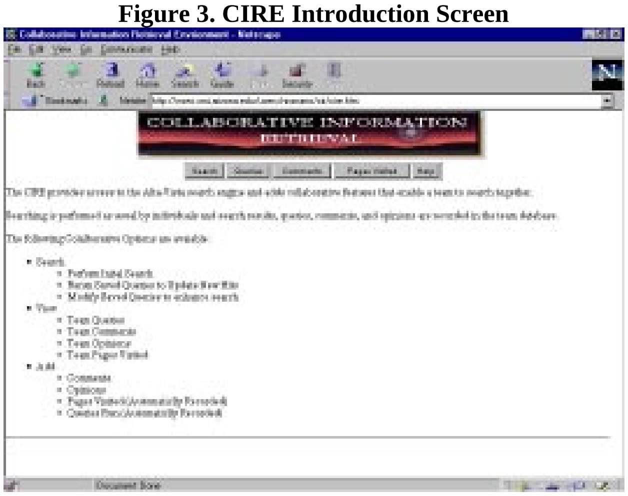
Uses activate CIRE features through direct manipulation by either pressing a button of clicking on a link. In both cases, our server automatically generates an HTML page and presents it to the user. The search function has already been described in the architecture session. The function to rerun saved queries to update new hits allows the users to request a report with all the Web pages that match the user query but were not found last time the query was run. Users modify queries by simply editing the query string in the input field on the form, just as in as they would in the standard search engine form.

Users may view the team queries. If the queries have been annotated, the annotations are also presented in a second window. Users may request to see the list of pages that the team has visited. While browsing the search results, users can submit annotations, respond to others' annotations, or submit an evaluation of the page in terms of relevance to the search task.

Introduction Screen

The CIRE Introduction screen, shown in figure 3, is designed to inform the user of the systems' collaborative capabilities.

Figure 3. CIRE Introduction Screen



User Experiences Drove Design Changes

A team of three researchers performed the initial prototype development. While one researcher focused on systems design and development, the other two performed ongoing usability studies. The researchers and other individuals and teams performed several different-place different-time search sessions. Search topics included but were not limited to *the concept of collaborative information retrieval collaborative browsing and Internet search engines*. Some usability study results led to changes and refinements to the user interface and the database schema. This section presents lessons learned from user experiences with the first version of the prototype and introduces the integrated prototype which resulted from refinements and enhancements.

Familiar Search Form Aids User Learning

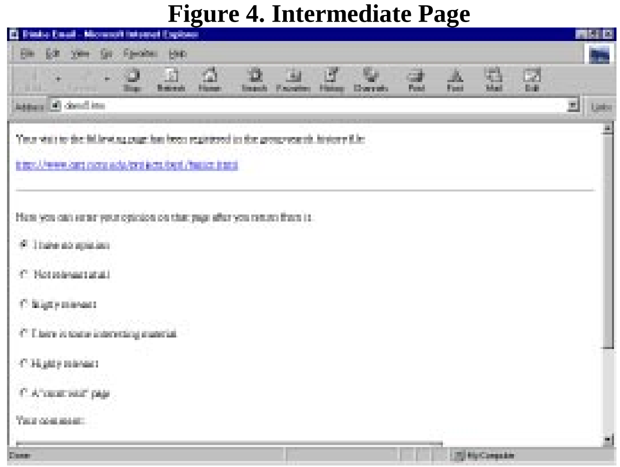
The system employs a search form identical to that of the commercial Internet search-engine Alta-Vista. This means that that there is no need for users to learn a new search interface nor a new search syntax, because most of them are already very familiar with this search paradigm and the associated standard query syntax. Novice users can perform simple queries and then learn more advanced syntax by viewing the queries of other more sophisticated team members as examples.

Users entered their queries and received results in the same format as the search engine presents them. Our initial observations of user experiences with the prototype confirmed observations by Hearst [36] that users rarely venture beyond the top thirty (30) documents presented by a search engine in rank order of relevance.

Intermediate Evaluation Page Confusing

When users found a document they thought was of interest, they followed the link leading to this document. However, instead of jumping directly to the page of interest the system displayed an "*intermediate*" evaluation page as shown in Figure 4.

Figure 4. Intermediate Page



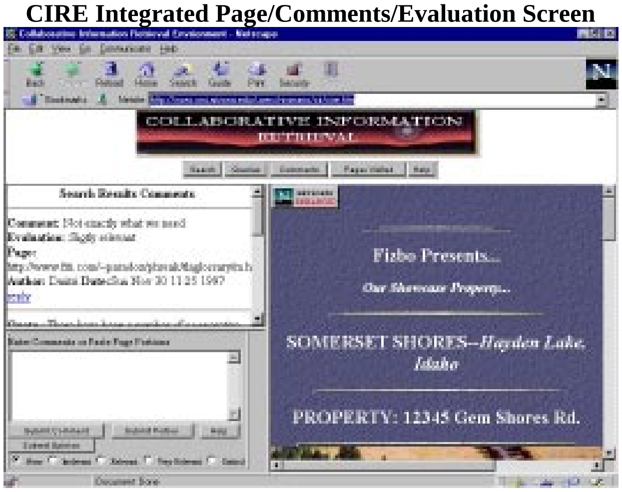
This intermediate page had two purposes: first, to keep track of pages visited, and second, to allow the user to annotate pages and provide an opinion.

Several problems with this design and implementation became evident from initial user experiences with the prototype. First, most users became frustrated and disoriented by the "*intermediate*" evaluation and annotation page for one of two reasons: 1. They had not yet seen the page and were being asked to evaluate it immediately; or 2. They expected to see the page of interest immediately, because this is the standard action in the WWW browsing paradigm. Second, following the link from the intermediate page opened multiple browser windows; one for annotations and evaluations, and one for each page of interest. This disoriented novice users and even some practiced users, because they did not always remain aware of the fact that other open windows were present in the background. As they focused on reading the material they forgot about the earlier windows that gave them an opportunity to comment on and evaluate the pages. Users indicated that they were often uncertain about how to add comments or evaluations about the page that they were viewing and about how to view the comments and evaluations of others.

Following user interface guidelines from the literature [54,56,80,82], we redesigned the interface to minimize the number of steps required, to minimize cognitive, perceptual and physical loading, and to make available options persistent on the screen. The result is the more explicit interface with persistent controls and multiple windows, shown in Figure 5. Users found this interface to be less confusing and disorienting than the original interface.
This *integrated* interface allows users to view the page content itself and the comments and evaluations of others, as well as to enter their own comments and evaluations without having to switch windows or remember functions.

Since the intermediate page, which explicitly told the user that their visit to the page was recorded in the database, no longer appeared, the system needed to record visited pages in a manner that is hidden from users and does not employ the intermediate page. This reduces the users' cognitive load, allowing them to focus on the page content and not be concerned with the recording process. A similar integrated multi-window interface next to the search page that is used to present queries along with their comments and evaluations, allowing users to review previous queries while they formulate new ones.

Figure 5.
CIRE Integrated Page/Comments/Evaluation Screen



Unexpected Search Depth Requires Storing All Pages Visited

Because the items listed in the search results are hypertext documents, users can link from them to other documents that are not listed in the search results. This is one of the powerful advantages of the WWW, but it is also a consideration that must be taken into account when designing tools to monitor and store the sites users visit during sessions. User experiences revealed that interesting documents were very rarely found only on the pages listed as search results. Rather, on average, the "*depth*" of exploration starting from the search results was between two (2) and four (4) links.

In the original implementation of the prototype the system only recorded visits to pages directly listed in the search results. This meant that the history of pages visited was incomplete and limited to search results only. To ensure that the history of pages visited was accurate and complete, the architecture of the prototype was enhanced so that it registers visits to all pages, not only the initial page listed in the search results. This enables the new version of the system to maintain a richer and more complete set of data describing the foraging process by the team members. Additionally, the system can track whether pages are visited from the search results or from side forays via links from those pages. This may reveal useful information for future designers of WWW IR tools. We plan to collect and analyze this data when we perform our experimental study on CIRE.

Relevancy Evaluations Useful to Search Task

We observed that team members tend to disagree on the validity and relevance of search results and on the degree of completeness of their search task. Taking into account GSS literature addressing voting, prioritization, and consensus assessment [22,24,59,60,66,73,79], we set out to implement electronic polling.

We recalled that the literature review on collaborative IR revealed a number of methods for evaluation of search results and decided to consider each of these as a possible alternative. We rejected them all of for the reasons explained below.

The Tapestry system [32] offers the ability to evaluate search results with personal taste judgments of "*like it / hate it.*" We think that this dichotomous scale based solely on personal taste may not be complete enough, nor relevant enough to the task of searching, to provide meaningful information for team members. For example, a user might evaluate a page with the "*hate it*" judgment even though the content may be very relevant to the search task. This may then lead to others not reviewing that material and thus minimize the relevant search space coverage.

The Annotate system [31] offers integer-valued quantitative appraisals of search results. While this is a useful method, numerically evaluating content in terms of relevance to a search task may not be very precise. Numeric scales may be interpreted differently by different users and thus lead to problems similar to the one described in the example presented for the Tapestry system. We believe that explicit textual options are less likely than numeric options to be interpreted differently and thus are more likely to provide useful information to search team members.

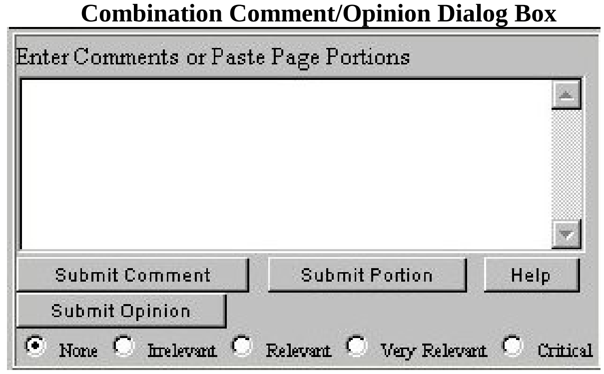
We think it may be important to go beyond the personal taste judgments of "*like it / hate it*" and integer-valued quantitative appraisals and offer more explicit opinion evaluations that deal directly with the relevance of the material to the search task at hand. We think that this may be more useful to members involved in the team search process. To support this evaluation technique we developed the relevancy based scale described below.

Search Results Evaluation Relevance Scale

We assert that the relevance to the search task of the material found may be the most useful opinion that a team member can offer. With this in mind we developed the opinion scale shown in figure 6 and integrated it into the combination comment/opinion dialog box shown in the figure.

One area for future research we think will be important is the determination of voting types and scales that will prove to be useful for teams performing collaborative IR.

Figure 6.
Combination Comment/Opinion Dialog Box



Annotation Justification Should Be Free Form
Annotate [31] offers a set of predefined reasons to explain why a particular document warrants specific annotations. We considered this option, but then recalled that the GSS literature offered an alternative method of justification through discussion and deliberation. We think that annotation justification may best be supported within the annotations themselves, in which members can discuss and argue for their points of view to explore the decision space fully and can arrive at consensus. This has been shown to be efficient and effective in several GSS studies [25,5,68,6,37]. We think that any set of predetermined reasons to warrant an annotation may limit the users and thus lead to narrow inquiries into why something is useful or meaningful to the search process.

Collaborative Features Not Often Used
User experiences with the initial prototype revealed that ability to browse other team members' comments, view pages visited by other team members and read query annotations were frequently forgotten or ignored features. Users requested that these features be made more directly available at all times so they could remember to use them and have direct access to them.

To encourage users to take advantage of the collaborative features, we decided to find a way to make group search history more visible. For example, when a team member visits a page that has been annotated by the other team members, the new interface design at the same time presents the annotations on the screen in a separate window (see Figure 6). To encourage users to pay attention to the queries of other team members, our new user interface displays them right next to the form on which the user enters a new query, allowing them to be reviewed as new queries are formulated.

Persistent Collaborative Buttons Ease Access
Many users complained that they forgot to use the collaborative features because they could not recall what they were or how to access them. Following interface guidelines presented by Shneiderman and Smith [80,82] we minimized the memory load on users by not requiring by providing explicit labels in a common persistent format for novice and intermittent users. This was implemented with a permanent button bar to activate desired features at any time during the session shown in figure 7.

Figure 7. CIRE Button Bar and Banner Logo

Annotation and Citations are Different
Users mentioned two major reasons for submitting text annotations to a visited page: 1. to submit an opinion regarding the page; and 2., to submit a citation from the visited page (since marking or modifying the external web pages is not supported in the modern browsing paradigm). In the new design we decided to differentiate those two objectives explicitly by supporting both comments and citations as textual annotations. Users may now cut and paste a citation and then submit it to the team database with a special citation indicator.

Discussion, and Future Research Objectives

This paper describes how user experiences with tools and techniques in the domains of IR and GSS led us to combine the two paradigms and develop a prototype Collaborative Information Retrieval system. Prototype design, development, and refinement based on user experiences and usability studies have led to what we believe is a potentially very useful system for collaborative information retrieval. Based on user experiences with the final prototype, we feel that the using the CIRE system will make the performance of teams more efficient and more effective.

Based on the literature review and our initial observations of user experiences, we have begun to develop a theory as to why we believe that teams using the CIRE will be more productive and better satisfied with both the process and the product than teams whose members use the same search engine individually and then combine their results after they finish searching.

Our future research objectives are to design and implement empirical experiments to validate our theories and our systems' architecture, interface, and functionality. Then, based on the results of refining the prototype, we eventually will try to develop a robust CIRE module that can be effectively integrated into GSS environments. If this proves to be successful we also have plans to integrate multi-dimensional visualization modules into support of both IR and GSS aspects of team work.

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