COLLABORATIVE INFORMATION RETRIEVAL

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ABSTRACT

Collaborative information retrieval (CIR) encompasses the many varied social approaches to information seeking. Although some information retrieval systems have given an impression of individual access to resources, there is a growing realization that much information work is fundamentally collaborative in nature. We highlight key points in the recent history of CIR, particularly the difference between explicit and implicit collaboration.

INTRODUCTION

Collaborative information retrieval (CIR) is grounded in traditional pre-computer aspects of information seeking, help-giving and librarianship. However the growing availability of different computational

technologies has increased both the possibilities for various kinds of collaboration, and also sometimes the needs for such collaboration. In this article we consider a range of different activities and the technologies that support them from the perspective of more than one person interacting with an information system. The article first addresses certain challenges of definition: what do different researchers mean when they talk about CIR? Part of this difference and part of the difficulty in understanding and making sense of the CIR literature is that researchers come from different academic traditions, which leads them to focus on different aspects of the larger concept. Nevertheless this initially confusing diversity of approach and of the settings in which CIR has been studied can help us understand certain recurrent themes. We use Marchionini's analysis (1) of interactive search (one developed to illuminate individual search) as a way to understand CIR by asking at each stage how it might have a collaborative component. Finally, we draw a distinction between explicit and implicit kinds of collaboration, giving examples of each and considering the technologies currently developed to support them. In this way we aim to give an overview of a very disparate range of research activities involving both technological development and observations of how people use and appropriate technologies in order to explicitly or implicitly collaborate in searching for information.

ISSUES OF DEFINITION

It can be somewhat problematic to define CIR. The issue of definition is of more than pedantic interest because it underpins a key part of the conceptualization of what CIR is, what makes it important and how it relates to many other concepts and issues explored throughout this Encyclopedia.

Different researchers have created or used different definitions, including and excluding various activities in order to clarify their focus on a particular area of interest. For example Foster defines CIR as:

"the study of the systems and practices that enable individuals to collaborate during the seeking, searching, and retrieval of information (2).

For many researchers, their investigations and discussions of CIR are in reaction to what is seen as an exclusive or excessive focus on the individual aspects of information retrieval (IR). The individual focus can be found in some (but not all) analyses and models of the information seeking process. Talja & Hansen (3) ascribe the rarity of studies of collaborative information behavior to an LIS (Library and Information Science) analytic focus on "sources and channels" rather than contextualized, embedded (and social) processes. The individual focus is most apparent in research in computerized information retrieval, which until recently mostly concentrated on one person interacting with a computer. Of course the database was often stored on a server, so that the user of interest was frequently contending for access to limited computational resources (memory, processing power and bandwidth) with other users. However, it was seen as the challenge of the system developers to hide each user from all the others competing for resources, creating the illusion of a resource that could be used in solitary splendor. Other people using the resource were a 'problem' to be mitigated rather than a resource to be exploited.

Karamuftuoglu (4) seeks to broaden the conceptualization of IR so that "the fundamental theoretical issues of information retrieval are the production and use (consumption) of knowledge". This extension of the remit of IR to also consider information use and production means that it necessarily must consider aspects of collaboration.

Hertzum (5) builds on the work of Karamuftuoglu claiming that: "information seeking is just as much about making coherent sense of information as it is about finding extant information". In reaction to Foster's definition, Hertzum defines collaborative information seeking as "the information-seeking activities performed by actors to inform their collaborative work combined with the collaborative-

grounding activities involved in making this information part of the actors' shared understanding of their work".

This interest in the broader context of where information seeking happens, why, and the uses to which it is put, including the creation of new information, is a matter of growing interest (3,6,7). Although in this article we use the term CIR, other researchers also use the terms: "collaborative information behavior" (8), "collaborative information synthesis" (9), "collaborative information seeking" (5), and "collaborative information behavior" (3,7). Each of these terms has a precise, but often overlapping meaning. We use the term CIR but in a broad way that encompasses all of those meanings - the definition of CIR by Hansen & Järvelin seems to be suitably broad:

"CIR is an information access activity related to a specific problem solving activity that, implicitly or explicitly, involves human beings interacting with other human(s) directly and/or through texts (e.g., documents, notes, figures) as information sources in an work task related information seeking and retrieval process either in a specific workplace setting or in a more open community or environment" (6).

This allows us to explore a range of activities including a group of people searching together, as well as help-giving, making use of the search and information use of others, coordinated search activities that extend over hours, weeks or even decades, rapid ad hoc information sharing, unsolicited offers of possibly relevant information, individual information search activities that happen to have embedded social components, and the use of links, annotations, votes and recommendations from colleagues and complete strangers. All of these activities may be mediated by a range of different technologies, face to face, and remotely.

RESEARCH TRADITIONS

CIR researchers can come from and draw on a variety of research traditions, both within Library and Information Science (LIS), but also from other disciplines. Within LIS these include studies of the reference interview, studies of information seeking in different contexts, studies of information use, including not just information search but its use in the creation and dissemination of new information by social, scholarly and business communities, digital library development and use, and information retrieval. CIR also draws on research from the areas of Computer Supported Cooperative Work (CSCW), Human Computer Interaction, Computer Supported Collaborative Learning, Recommender Systems and Knowledge Management. Technological developments in these research areas as well as the growth in the availability of applications – particularly networked web-based applications such as search engines, blogs, wikis, bulletin boards and web services all contribute to a consideration of the practice and potential of collaborative aspects of information search, use and transformation. Underlying the variety of web services and applications described as 'Web 2.0' is a recognition of the centrality of re-conceptualizing people as not just consuming services and information but co-creating it and adding value through their use.

The particular kinds of collaboration that are studied, and the ways in which they are studied, depends substantially on the intellectual tradition that is the basis for the research. Those with a technological background in information retrieval, databases or CSCW are understandably more inclined to focus on the ways that technologies support (or fail to support) collaboration. By contrast, those with a background in studies of information use, information needs and information seeking behavior inevitably focus on what people do, what they want to or try to do and the ways in which these activities have a social dimension.

MAKING SENSE OF CIR – WHY DOES IT MATTER?

Given the variety of activities, contexts and technologies that can fit within a broad definition of CIR, it can help to consider the ways that collaboration can have an impact on the simpler case of Individual Information Retrieval (IIR). From this we can try and explain why it is worthwhile to consider collaboration as an extra factor.

Firstly, the collaboration may be a component of the larger context in which the information seeking occurs. That is, it may be necessary to consider collaborative issues that occur because of what is done before and after the (perhaps individual) information retrieval activity. For some researchers this larger context is inherently social and is a critical part of understanding the information need, and what results. There may be an interaction that is a critical subpart of the overall process that needs to be understood and perhaps improved by managerial, educational or technological interventions. For example, the reference interview is a well known and well studied collaborative interaction within an information seeking process, even if it is assumed that all prior and subsequent aspects of that process are solitary. People may collaborate in reaction to the complexity of the underlying task, the difficulty of obtaining any information at all, or the difficulty of dealing with too much information. Both information dearth and information glut may be addressed by collaborative endeavors with several people working on a problem to try and make some headway on it. Finally, new technologies may make collaboration easier or cheaper, or new kinds possible.

Consequently, CIR can be seen as about highlighting social aspects of IR that can get overlooked. Why this matters is that application development needs to take account of assumed, overlooked or implicit uses, features and activities. If these are not explicitly designed-in they can be much more difficult to employ in actual use. For example, paper does not have to be specially designed to be annotatable – online documents do. Therefore it can be important to design to allow for existing collaborative activities, particularly where the application is intended to be integrated into a pre-existing socio-

technical infrastructure. Additionally, a sensitivity to social aspects of information search and use allows researchers to imagine new kinds of collaboration that technology might enable.

STUDIES OF CIR ACTIVITY

Numerous studies of how people search for, share and use information have noted a collaborative dimension to these activities, and in some cases collaboration is the *central* part of the activity. The use contexts studied include:

- Aero-engineers (10)
- Aircraft service engineers (11)
- Software developers (5,10)
- Patent analysts (6)
- Archivists (12)
- Academics (13).
- Students (7,14)
- Customer support (15)
- Lawyers (11)
- Military personnel (16)
- Elderly people and nurses at a chiropody clinic (17)
- Medical researchers (9)
- Healthcare teams (8)

Although there has been a substantial increase in the number of studies looking at CIR activity in the past ten years, earlier examples do exist. For example, the classic study by Allen (18) comparing the information -seeking behavior of engineers and scientists noted the existence of people who took on the role of gatekeepers, looking for and forwarding information to the group. Other early visionary work that considered how systems could be improved by adding in support for collaboration and reuse of the search activities of others include that of Bush (19) and Swanson (20).

WHAT CAN BE SHARED IN CIR?

Following Komlodi & Lutters (11), we use Marchionini's (1) eight steps in interactive search to characterize the variety of different collaborative activities that are or can be possible. No CIR setting must include all of these, and different kinds of CIR can involve various combinations of them. Each stage can use a variety of different technologies and resources.

Recognize and accept an information need

This can be a group-based activity, as when a work team discovers that they need some information to make progress on a larger task, or when the task itself is one of obtaining and analyzing information.

Understand and define problem

As a group activity, the need will have to be articulated, requiring greater clarity than in IIR. This can also involve task delegation, splitting up and assigning work roles and establishing the way that the work will flow from person to person over time.

Select information source

Multiple resources may be selected – libraries, physical and digital, databases, websites, personal and team collections of resources. It also can involve seeking or receiving advice on which resources to use, how to prioritize, and assessments of the quality, coverage, and authority of particular resources. The resources themselves can be other people. Consequently both people and technologies that act as 'matchmakers', suggesting people you might want to talk with on the basis of past and current activities can be part of this process.

Formulate query

Ideas about keywords and phrases to try and how to combine them can be generated collectively. This is likely to lead to a number of different queries to try on different iterations of the sequence.

Execute query

Even in collaborative interactions it is most likely that a single query will be executed by an individual. However, the eight step process is iterative and with collaboration it can also run in parallel. If several people are involved, it can be valuable to share the process information of which queries have been tried to date, which remain to be done and who is doing what. Queries can also be reused over time, either to see if new information has arrived that meets the older query, or as inspiration for more sophisticated subsequent searches.

Examine results

This involves discussion about the relevance of the results obtained and prioritization decisions about which to examine in more detail. If collaborating at the same time in the same place, this can be done around a shared screen. Otherwise, in order to support multiple collective relevance judgments, the lists

of results and the details of certain ones chosen to examine in more detail will need to be shared. If results are shared, it can be important to also share the process by which the results were obtained. This process information (as described in the other stages) is needed in order to make informed decisions both about what was obtained and whether additional search is justified to try and find what else might exist that could be relevant.

Extract information

Typically done from the full text, this requires document sharing along with annotation and collaborative editing features, although something as simple as a word processor and email can fulfill this need. It also requires a coordination and synthesis of the separate search activities performed by team members.

Reflect, iterate, stop

Reflection and iteration require knowledge of what has been done. In IIR this resides in the memory of the individual searcher and any available external artifacts and representations. In CIR, the thoughts and experiences of others need to be shared, requiring mechanisms for communication (text, audio, video, or face-to-face meetings) as well as the sharing of artifacts (the products of search and any process information). Iteration is a consequence of earlier steps having an impact on the understanding of both what has been found so far and indeed on the information need that can evolve in the light of what is discovered. With more than one person involved, it is necessary to ensure that these changing individual understandings are shared and re-coordinated.

In addition to the activities directly attributable to one of Marchionini's steps, there are others that can belong in several. If more than one person is directly involved in the finding or use of the found

information, then the participants not only have to do the work but ensure that others are aware of what they are doing and establish a mutual understanding of what they have accomplished to date. Within CSCW research, considerable attention has been given to the issue of awareness; how in traditional co-located workplace settings people manage it in subtle but low cost ways, and how CSCW technologies need to provide explicit support for awareness, particularly for remote collaboration. As Hertzum notes: "Collaboration requires a certain level of agreement and shared understanding, often termed common ground. … The collaborating actors need not, and in practice do not, agree about everything but without common ground collaboration is unlikely to succeed."(5). This activity of grounding typically requires discussion not just of the products of search, but of the *processes*. Two kinds of process information that have been found to be particularly useful are explicit representations of search histories (11), and the history of an information object - what has been done with a document, annotations, log history and document link history (6). With an awareness of what others in a team are doing, it is possible not just to provide information or advice when asked, but also to volunteer information – a kind of collaborative information push rather than CIR.

Different people will have different skills in using particular technologies and domain expertise in judging and interpreting particular items and result sets which is why a collective approach can be useful. This can be by delegating particular activities to known or identifiable experts, and/or by those experts sharing their strategies and tactics with others, helping address difficulties and impasses and facilitating learning of more sophisticated search skills within the process of doing the work. These kinds of skill include not just how-to skills, but also valuable tacit knowledge and opinions about the interpretation of results and the quality of information sources (10). As a consequence, participants will be explicitly or implicitly teaching each other some of their skills (11).

EXPLICIT AND IMPLICIT COLLABORATION

Another way to consider CIR is the extent to which the collaboration is explicit or implicit. A medical research team undertaking a meta-review of the literature is clearly explicitly collaborating: they know each other and they are addressing a complex problem by a team-based approach of more people working on the task, bringing different kinds of expertise and allowing multiple reviews for avoiding error and oversight (9). Equally a reference interview is a kind of explicit collaboration, as is a suggestion from a colleague of a resource that might be of interest. But a person can be helped to find what they want by more indirect involvement of other people: a web page linking to another site, a research paper citing a book, a bestseller list giving recommendations based on the purchasing decisions of others. In all these cases, the person helped may have no direct contact with the people whose activity has helped them, may not even know them and indeed may never know them. Although implicit collaboration is possible without computational support, technologies make it much faster and easier and can enable whole new kinds of support.

CLARIFYING IMPLICIT COLLABORATION

There many kinds of implicit collaboration and the various technological possibilities can be very confusing. One way to make sense of this variety is to think about familiar examples from the non-digital world. Consider a solitary information searcher in a library. Parts of that information environment (e.g. books, documents, videos) have been created by other people (i.e. authors). Other parts of the environment have been structured (e.g. shelved books) by a further group of people (i.e. librarians). On top of this basic structure further additions (e.g. annotations, comments, ratings, “must read” suggestions) have been made. Additionally, the differential use of certain information in the past by that searcher and others will affect current use (e.g. well thumbed library books falling open at certain pages)

Further, the structuring information is constantly changing to reflect how other information searchers are interacting in, and with, the environment. Switching to online resources we find an ever-growing number of variants of these kinds of annotation, connections, recommendations and use-based data that can help us benefit from the actions of individuals and whole groups of strangers.

The environment faced by our initial searcher is dependent on the actions of many other people - though not all the aspects are easily identified with specific individuals. Some elements (e.g. books, comments) are readily associated with specific people, others (e.g. ratings, shelving decisions) are the result of decisions by unknown humans and some elements (e.g. shifting structures based on usage patterns) are anonymous aggregations. The act of navigating in such a structured information space is necessarily a piece of *social* navigation rather than a purely personal one. Arguably, even interacting with an unstructured collection of books is a piece of social navigation (the content would not exist without the authors); but one that we have become familiar with.

Some structures (e.g. subject classifications) are designed to improve the findability of items, and the retrieval of content can be viewed as a successful (but indirect) collaboration between the searcher and the librarian. This view of collaborative retrieval may seem overly broad. Consider instead that the searcher first sought help from a librarian, who directed the searcher to the content. Is the input of the librarian fundamentally different if it is expressed verbally or if it is embodied in the structure of the information space?

The difference then between social navigation and collaborative information interaction is difficult to pin down. Is the intent of the actors relevant? The work of information architects is clearly supposed to help searchers achieve their goals. However, the information they use (e.g. transaction logs, purchase decisions) often has no collaborative intent at all and may be used without the knowledge of its originators. This re-purposed information has a collaborative intent that was not originally present. The

same can be said of Google's use of the link structure of the Web in the PageRank algorithm (21). The intent of a Web author to link two pages together has been re-purposed by Google to rank content from a search with a given query. The ranked search results could really come with a note: "these results are brought to you by the link structure produced by thousands of web authors". Similar socially-enhanced structures at Amazon.com ("What Do Customers Ultimately Buy After Viewing This Item?") and at YouTube ("Videos being watched right now …") are collaborative to the extent that they aid (or are intended to aid) searchers.

The re-purposing and aggregation of information often happens behind the scenes, where many small data points (e.g. purchase decisions) are processed to produce something concrete, such as a recommendation, for a user. This style of indirect social interaction is very different from a reference interview but both are part of a continuum of sociality in information retrieval.

TECHNOLOGIES FOR SUPPORTING EXPLICIT AND IMPLICIT COLLABORATION

EXPLICIT

Explicit collaboration can occur huddled round a shared screen, or passing annotated paper documents around, using the telephone, email, video-conferencing or a variety of other technologies, both using purpose-built applications and repurposing existing ones. As an example of the latter, consider how the presence of laptops and wi-fi access in meeting rooms allow for real-time fact-checking and discovery within a meeting rather than only before or afterwards. This simple case of computing ubiquity creates a potential for more situated IR no longer necessarily performed as a separate activity (in the library or at a work desk terminal). This can be IR *for* collaboration as well as collaborative IR.

Within CSCW, the range of different technologies and their contexts of use are often typified as supporting either synchronous or asynchronous collaboration, as well as either co-located or remote collaboration. So a large shared screen supports synchronous, co-located collaboration, and an emailed list of queries and search results supports asynchronous remote collaboration. In extended, contextualized use CIR activities are likely to be mixtures of these dimensions, interleaved by individual IR activities and non-IR activities, both collaborative and individual. Although not yet discussed much, the growing availability of wireless connectivity, very light and portable laptops and even more portable smartphones means that more mobile and ephemeral CIR settings are likely to emerge, although embedded in a larger use context.

The following are a selection of systems specifically developed to support at least some of the phases outlined above. A relatively simple example is the support of synchronous remote CIR using text chat and a shared window to show results (8). Romano et al. (22) took research and technologies developed in the field of Group Support Systems and applied them in the context of CIR, in particular enabling relevance evaluations and annotations to be shared. More recent work by Pickens et al. (23) involves a search engine explicitly designed to take account of synchronous collaborative actions to coordinate activities between people taking on different search roles, rather than supporting just post hoc merging and discussion of results.

The work on Answer Garden (24) aimed to help people find information, or if it was not available, find the right person to ask. This issue of merging knowledge of information and of people who possess certain kinds of information is one that recurs in the Knowledge Management literature, where increasingly it is found that information needs contextualization and interpretation by people to be useful and reusable.

In the context of web search by members of team, it can be helpful to have an awareness of the sites other people have visited, both to avoid unnecessary duplication and to coordinate the synthesis of a final collective result (25). Recent work has looked at how novel input and output devices (tangible computing and large tabletop displays) can enhance synchronous co-located collaboration (26,27,28).

IMPLICIT

As noted earlier it is possible to use many small pieces of data (such as ratings or purchases) to produce socially-enhanced navigational structures. Where such data is captured incidentally it is referred to as being *implicit*. We may base a recommendation on an explicit rating (four stars out of five) or an implicit rating (the user spent a lot of time looking at that item). In the 1990's work on collaborative filtering used both explicit and implicit inputs from many users to produce individual recommendations. The GroupLens project applied minimal explicit rating (one keypress) to Usenet News (29) and others used purely implicit indicators (such as reading time) to act as a proxy for explicit ratings (30). Kelly & Teevan (31) provide a good summary of early work using implicit indicators; in effect the background to the socially-enhanced experience we can observe at Amazon.

A key advantage for implicit indicators is that they can be collected automatically without active user input; this reduces collection costs and does not impact on the time of the user. Other forms of implicit indicators (such as whether a document has been added to a favorites list or has been printed) are being examined to determine whether they can function as a reliable proxy for (the presumed ideal of) explicit rating (32). In practice it is likely that many real-world systems will be hybrids that use both implicit and explicit rating data.

Implicit indicators are a mechanism for users to participate in social navigation and recommendation systems with minimal effort. In fact, we suspect many users are participating in them without being

aware of their existence. At this point we reach the boundaries of whether we can accurately refer to these interactions as “collaborative”: can you collaborate without being aware of it?

Finally, capturing implicit data for collaborative recommendations may have privacy implications. As users’ activities are captured incidentally, it is easy for them to be unaware of precisely what has been recorded, and the purposes for which it will subsequently be used. However, it should be noted that detailed user profiles are not usually needed to build recommender systems; anonymous usage data is often sufficient (33).

Social Browsing makes use of browsing activity of others to help a user decide where to go next in a hyperlinked environment such as a website. Social Search does the equivalent for search, exploiting similar searches done by others and their use of the results to influence the ranking of the current result set. Brusilovsky (34) reviews a number of systems that use information about the activity of others in ranking search and browsing results.

In an earlier review of the field of CIR (14) we had noted how bibliographic databases and digital libraries supported browsing for documents but not browsing for people. This is now changing, both within databases as it becomes easier to click from reference to reference to author to co-author, and on the web where social networking sites are all about ‘people-browsing’. I2I (35) is an example of system that attempts to serve as a matchmaker, introducing people based on the similarity of their search interests, using the information retrieval as a way to enable potential future collaborations.

Various online services allow people to register their opinions about other websites, blog posts, bulletin board postings, or the quality of goods and services offered. Examples include Slashdot, Epinions, Ebay and Amazon. These can be considered a form of collaboration in that other people are providing recommendations about importance that can inform a searcher about which resources to give greater

attention to. The difference from team-based CIR is that there may be no shared work goal and the participants need not know each other. But such recommendations can still be very valuable in helping deal with large amounts of information.

Social bookmarking and tagging (36) are also ways in which the activities of others can help a searcher in finding relevant results. All these approaches have parallels with the traditional selection, advisory, recommending, cataloguing and classification activities of librarians. However they are done on the web in a far more open and unsystematic manner. The volume of activity serves to outweigh the extremely variable quality of individual contributions.

As well as 'votes' for or against a particular information item informing ranking decisions, ever easier mechanisms to add to online resources via wikis, blogs, forums etc. mean that more people are co-creating information. A classic example is Wikipedia. So is this CIR too? It is a large scale collaborative activity, certainly, and involves the retrieval, re-processing, and sharing of information, as well as considerable discussion (in that section of each Wikipedia article) about the process of creating derived information. This seems to fit the broader considerations of CIR advocated by Hertzum (5) and Karamuftuoglu (4), and is an example of the new kinds of collective activities having CIR components that networked computational resources make possible or dramatically easier.

CONCLUSION

Although it can be somewhat problematic to precisely draw the line, there are a range of uses, activities and technologies that involve the activities of others, explicitly or implicitly, in finding and using information. Work in CIR examines these issues, with different researchers choosing to look at different areas along this continuum of 'degree of collaborativeness'. The boundaries are becoming ever fuzzier as new technologies and lowering costs allow us not only to use information resources more, but to turn

that use into data itself to inform subsequent use, and to merge the retrieving with the modifying, transforming and creating of information.

REFERENCES

1. Marchionini, G. *Information Seeking in Electronic Environments*; Cambridge University Press, Cambridge, 1995.

2. Foster, J. Collaborative information seeking and retrieval. Annual review of information science and technology. **2006**, *40,* 329-356.

3. Talja, S.; Hansen, P. Information sharing. In *New Directions in Cognitive Information Retrieval*; Spink, A., Cole, C., Eds.; Springer: Dordrecht, 2005; 113-134.

4. Karamuftuoglu, M. Collaborative information retrieval: Toward a social informatics view of IR interaction. Journal of the American Society for Information Science and Technology **1998**, *49* (12), 1070-1080.

5. Hertzum, M. Collaborative information seeking: The combined activity of information seeking and collaborative grounding. Information Processing & Management **2008**, *44* (2), 957-962.

6. Hansen, P.; Järvelin, K. Collaborative information retrieval in an information-intensive domain. Information Processing & Management **2005**, *41* (5), 1101-1119.

7. Hyldegård, J. Collaborative information behaviour: exploring Kuhlthau's information search process model in a group-based educational setting. Information Processing & Management **2006**, *42* (1), 276-298.

8. Reddy, M.C.; Jansen, B.J. A model for understanding collaborative information behavior in context: A study of two healthcare teams. Information Processing & Management **2008**, *44* (1), 256-273.

9. Blake, C.; Pratt, W. Collaborative information synthesis I: A model of information behaviors of scientists in medicine and public health. Journal of the American Society for Information Science and Technology **2006**, *57* (13), 1740-1749.

10. Fidel, R.; Pejtersen, A.M.; Cleal, B.; Bruce, H. A multidimensional approach to the study of human-information interaction: A case study of collaborative information retrieval. Journal of the American Society for Information Science and Technology **2004**, *55* (11), 939-953.

11. Komlodi, A.; Lutters, W.G. Collaborative use of individual search histories. Interacting with Computers **2008**, *20* (1), 184-198.

12. Hertzum, M.; Pejtersen, A.M.; Cleal, B.; Albrechtsen, H. An analysis of collaboration in three film archives. A case for collaboratories. In *Proceedings of the Fourth International Conference on Conceptions of Library and Information Science (CoLIS 4)*; Bruce, H., Fidel, R., Ingwersen, P., Vakkari, P., Eds.; Libraries Unlimited: Greenwood Village, CO, 2002; 69-84.

13. Talja, S. Information sharing in academic communities: Types and levels of collaboration in information seeking and use. New Review of Information Behavior Research **2002**, *3*, 143–159.

14. Twidale, M.B.; Nichols, D.M.; Paice, C.D. Browsing is a collaborative process. Information Processing & Management **1997**, *33* (6), 761-83.

15. Ehrlich, K.; Cash, D. Turning information into knowledge: information finding as a collaborative activity. In *Proceedings of the First Annual Conference on the Theory and Practice of Digital Libraries (DL'94)*; Schnase, J.L., Leggett, J.J., Furuta, R.K., Metcalfe, T., Eds.; Texas A&M University: College Station, TX, 2004; 119-125.

16. Prekop, P. A qualitative study of collaborative information seeking. Journal of Documentation **2002**, *58* (5), 533-547.

17. Pettigrew, K. Waiting for chiropody: Contextual results from an ethnographic study of the information behaviour among attendees at community clinics. Information Processing & Management **1999**, *35* (6), 801-817.

18. Allen, T.J. *Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information within the R&D Organization*; MIT Press: Cambridge, MA, 1977.

19. Bush, V. As we may think. The Atlantic Monthly **1945**, *176* (1), 101-108.

20. Swanson, D.R. Dialogues with a catalog. Library Quarterly **1964**, *34* (1), 113-125.

21. Brin, S.; Page, L. The anatomy of a large-scale hypertextual Web search engine. Computer Networks and ISDN Systems **1998**, *30* (1-7), 107-117.

22. Romano, N.C.; Roussinov, D.; Nunamaker, J.F.; Chen, H. Collaborative information retrieval environment: integration of information retrieval with group support systems. In *Proceedings of the Thirty-Second Annual Hawaii International Conference on System Sciences*. 1999; Vol. 1., 1053.

23. Pickens, J.; Golovchinsky, G.; Shah, C.; Qvarfordt, P.; Back, M. Algorithmic Mediation for Collaborative Exploratory Search. In *Proceedings of the 31st Annual International ACM SIGIR Conference on Research and Development in Information Retrieval.* ACM: New York, NY; 2008; 315-322.

24. Ackerman, M.S.; McDonald, D.W. Answer Garden 2: merging organizational memory with collaborative help. In *Proceedings of the 1996 ACM Conference on Computer Supported Cooperative Work*. ACM: New York, NY; 1996; 97-105.

25. Diamadis, E.T.; Polyzos, G.C. Efficient cooperative searching on the web: system design and evaluation. International Journal of Human-Computer Studies **2004**, *61* (5), 699-724.

26. Blackwell, A.F.; Stringer, M.; Toye, E.F.; Rode, J.A. Tangible interface for collaborative information retrieval. In *CHI '04 Extended Abstracts on Human Factors in Computing Systems*. ACM: New York, NY, 2004; 1473–1476.

27. Morris, M.R.; Horvitz, E. SearchTogether: an interface for collaborative web search. In *Proceedings of the 20th Annual ACM Symposium on User interface Software and Technology*; ACM: New York, NY, 2007; 3–12.

28. Smeaton, A.; Lee, H.; Foley, C.; McGivney, S. Collaborative video searching on a tabletop. Multimedia Systems **2007**, *12* (4), 375-391.

29. Konstan, J.A.; Miller, B.N.; Maltz, D.; Herlocker, J.L.; Gordon, L.R.; Riedl, J. GroupLens: applying collaborative filtering to usenet news. Communications of the ACM **1997** *40* (3), 77-87.

30. Claypool, M.; Le, P.; Wased, M.; Brown, D. Implicit interest indicators. In *Proceedings of the 6th International Conference on Intelligent User Interfaces (IUI '01)*. ACM: New York, NY, 2001; 33-40.

31. Kelly, D.; Teevan, J. Implicit feedback for inferring user preference: a bibliography. ACM SIGIR Forum **2003**, *37* (2), 18-28.

32. Fox, S.; Karnawat, K.; Mydland, M.; Dumais, S.; White, T. Evaluating implicit measures to improve web search. ACM Transactions on Information Systems **2005**, *23* (2), 147-168.

33. Bollen, J.; Nelson, M.L.; Geisler, G.; Araujo, R. Usage derived recommendations for a video digital library. Journal of Network and Computer Applications **2007**, *30* (3), 1059-1083.

34. Brusilovsky, P. Social information access: The other side of the social web. In *SOFSEM 2008: Theory and Practice of Computer Science*; Gefert, V., Karhumäki, J., Bertoni, A., Preneel, B., Pavol Návrat, P., Eds.; Lecture Notes in Computer Science 4910; Springer: Berlin, 2008; 5-22.

35. Budzik, J.; Bradshaw, S.; Fu, X.; Hammond. K.J. Supporting on-line resource discovery in the context of ongoing tasks with proactive software assistants. International Journal of Human-Computer Studies **2002**, *56* (1), 47-74.

36. Hammond, T.; Hannay, T.; Lund, B.; Scott, J. Social bookmarking tools (I): A general review. D-Lib Magazine **2005**, *11* (4). http://www.dlib.org/dlib/april05/hammond/04hammond.html (accessed October 2008).

FURTHER READING

Goh, D.; Foo, S., Eds. *Social Information Retrieval Systems: Emerging Technologies and Applications for Searching the Web Effectively*. Information Science Reference: Hershey, PA.; 2008.

Höök, K.; Benyon, D.; Munro, A. J., Eds. *Designing Information Spaces: The Social Navigation Approach*. Springer: London, 2003.

Kelly, D. Implicit feedback: using behavior to infer relevance. In *New Directions in Cognitive Information Retrieval*; Spink, A., Cole, C., Eds.; Springer: Dordrecht, 2005; 169-186.

Twidale, M.B.; Nichols, D.M. Computer supported cooperative work in information search and retrieval. Annual Review of Information Science and Technology. **1998**, *33*, 259-319.