Chapter 6
Collaborative Information Seeking

Abstract The notions that information seeking is not always an individual activity and that people working collaboratively for information-intensive tasks should be studied and supported are more prevalent now than ever before. Several new research questions, methodologies, and systems have emerged around these ideas that may even prove to be useful beyond the field of collaborative information seeking (CIS), as they are relevant to the broader areas of information seeking and behavior. This chapter provides an overview of several key research works from a variety of domains, including library and information science (LIS), computer-supported cooperative work (CSCW), human-computer interaction (HCI), and information retrieval (IR). It starts with explanations of collaboration and how CIS fits in different contexts, emphasizing the interactive, intentional, and mutually beneficial nature of CIS activities. CIS's relationships to similar and related fields such as collaborative information retrieval (CIR), collaborative information behavior (CIB), and collaborative filtering are also clarified. Finally, the chapter presents a synthesis of various frameworks and models that exist in the field today.

6.1 Introduction

While it is natural for us to collaboratively work on difficult or complex tasks [10], many situations involving search, retrieval, and synthesis of information are not typically conceived as communal processes. This apparent paradox can be seen in many daily scenarios. Imagine planning a vacation with your family (an example often used in the literature by Morris [49]; Morris and Horvitz [51]; Pickens and Golovchinsky [54]; and Golovchinsky et al. [29]). There are many parts of this complex project that revolve around looking for relevant information, comparing and synthesizing various pieces of information from multiple sources, making decisions, and finally using the synthesized solution(s). Typically, all interested parties (friends, family members) become involved in some or all of these processes. This is an example of people working together to accomplish an information seeking task. Other day-to-day life examples include coauthors working on a scholarly article, an engaged couple doing wedding planning, and a recruitment committee working on their new hiring project [61, 69]. Notice that these examples go beyond simply searching together; they include information seeking, sharing, synthesis, and

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decision-making. In addition, they all have a mutually beneficial end goal for all parties involved. Such CIS projects typically last several sessions and are motivated by participants' desire to contribute to and benefit from results. Not surprisingly, the whole process is highly interactive. To incorporate these characteristics, the focus in this chapter will be on collaborative processes that are intentional, interactive, and possibly mutually beneficial.

Before proceeding further, it is important to note that collaboration is not always useful or desired. A brief discussion on this is given in the proceeding "Limitations of Collaboration" subsection, with the remaining parts of the chapter focusing on the situations where collaboration is useful and/or required. Also, while collaboration itself has been studied widely in fields ranging from civil services (e.g., [30]) to CSCW (e.g., [59]), this chapter focuses on reviewing research that grapples with collaborative projects that largely involve information seeking, particularly in the Web environment. Having said that, there are two ways of looking at the connection between collaboration and information seeking.

6.1.1 Collaboration to Help Information Seeking

Collaboration is used to solve problems that are too difficult or complex for an individual, such as information seeking. Take, for example, searching for a house to buy. This project is quite complex in nature and typically involves multiple parties, including joint buyers, the real estate agent, and the mortgage consultant. Because they all have the same mutually beneficial goal (buying a house), this information seeking project is inherently collaborative, and thus an example of CIS.

6.1.2 Information Seeking to Help Collaboration

We can also look at the connection between collaboration and information seeking by acknowledging that a collaborative project often requires information seeking. Think about the family vacation example. The whole project is collaborative, and a part of it (planning) is focused on information seeking.

To summarize, one could participate in CIS via an information seeking project or a collaborative project. It is often difficult to distinguish these two kinds of scenarios, and for the most part that will not affect the discussion in this chapter. However, it is important to point out these intertwined relationships among information retrieval/seeking and collaboration for conceptual understanding. Figure 6.1 is a simplistic view of these connections, showing CIS in the context of information seeking, information retrieval, and collaboration.

Given this *dual* nature of CIS, the material presented here will approach the topic from two different sides: collaboration and information seeking. The next section will provide a brief summary of various views on collaboration, and the following

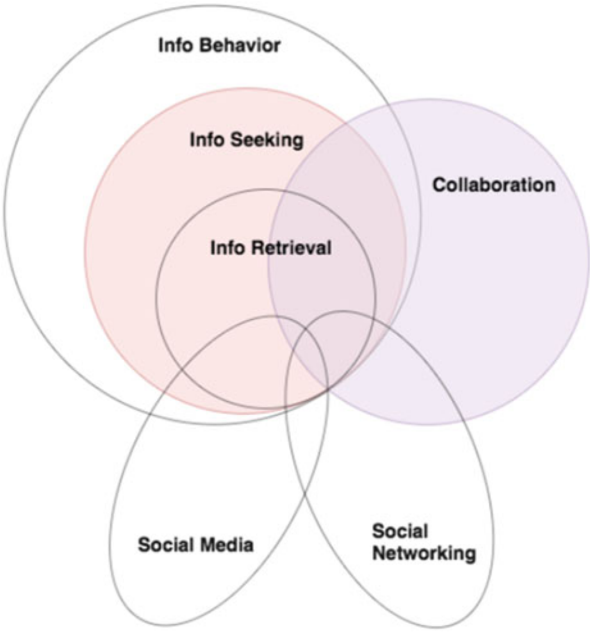

Fig. 6.1 A schematic view of collaborative information seeking in the context of related concepts

section will detail CIS in the context of information seeking/retrieval, as well as several other related concepts such as co-search and co-browsing. Then we will dive into some of the frameworks and models that are used in CIS studies. Some of these will come from the CSCW field.

Note that much of the material is taken from a previously published book by the same author and the same publisher [64], as well as the author's review article in the Journal of Association for Information Science and Technology (JASIST) [65].

6.2 Defining and Situating Collaboration

The discussion in this section is divided in three parts: explanation of how collaboration and related terms are viewed and presented, disclosure of the limitations of collaboration, and details on how collaboration can be studied in the context of information-intensive tasks.

6.2.1 Terms and Terminology Concerning Collaboration

Collaboration is not singularly defined. For example, London [46] interpreted the meaning of "collaboration" as "working together synergistically" (p. 8). Gray [30], on the other hand, defined collaboration as "a process of joint decision-making among key stakeholders of a problem domain about the future of that domain" (p. 11). Still, Roberts and Bradley [58] called collaboration "an interactive process having a shared transmutational purpose" (p. 209).

We often find people using the term "collaboration" in various contexts and interchangeably with terms such as "coordination" and "cooperation." It is very important that we first ground the meaning of the term "collaboration" before addressing various issues regarding collaboration. Denning and Yaholkovsky [11] suggested that coordination and cooperation are weaker forms of working together, though all of these activities require sharing some information with each other. Taylor-Powell et al. [74] added their contribution to this discussion, as they realized that effective collaboration requires each group member to make an individual contribution to the overarching process. Using communication, contribution, coordination, and cooperation as essential steps to collaboration, they showed how a true collaboration requires a tighter form of integration.

Based on these two works, a model of collaboration, called the C5 Model, is synthesized and presented in Fig. 6.2. This was originally presented in Shah [61] and then rectified in his later studies, [64] and [65]. It was most recently used by Shah and Leeder [66] to study collaborative work among graduate students. This model has five sets: communication (information exchange), contribution, coordination, cooperation, and collaboration. Using the idea of a set, the C5 Model demonstrates how various activities support each other. For instance, coordination is a subset of collaboration, which indicates that, for a meaningful collaboration, we need to have some way of coordinating people and events. Collaboration is a superset of cooperation, which means in order to have a true collaboration, we need more than mere cooperative behavior. The model applies to various situations where people work together or even simply interact and also identifies the nature of involved parties' joint configuration. For instance, we can classify scheduling a meeting as a coordinating task instead of collaborative one. In addition, the model allows us to recognize various components of a collaborative process. Let us take the same vacation-planning example mentioned earlier. While planning a trip, Claudia usually handles booking the flights and hotels, whereas her husband Charles starts researching their excursions, including food, attractions, and entertainment. They have particular interests and skills for both areas, and each one accepts the other person's authority in their specialty (cooperation). They both have the same goal, which is accomplished by coordinated efforts that help them each work independently and solve some subproblems (contribution). Often, they consult each other before finalizing a decision (communication). More applications and implications of this model can be found in Shah [61] and Shah and Leeder [66].

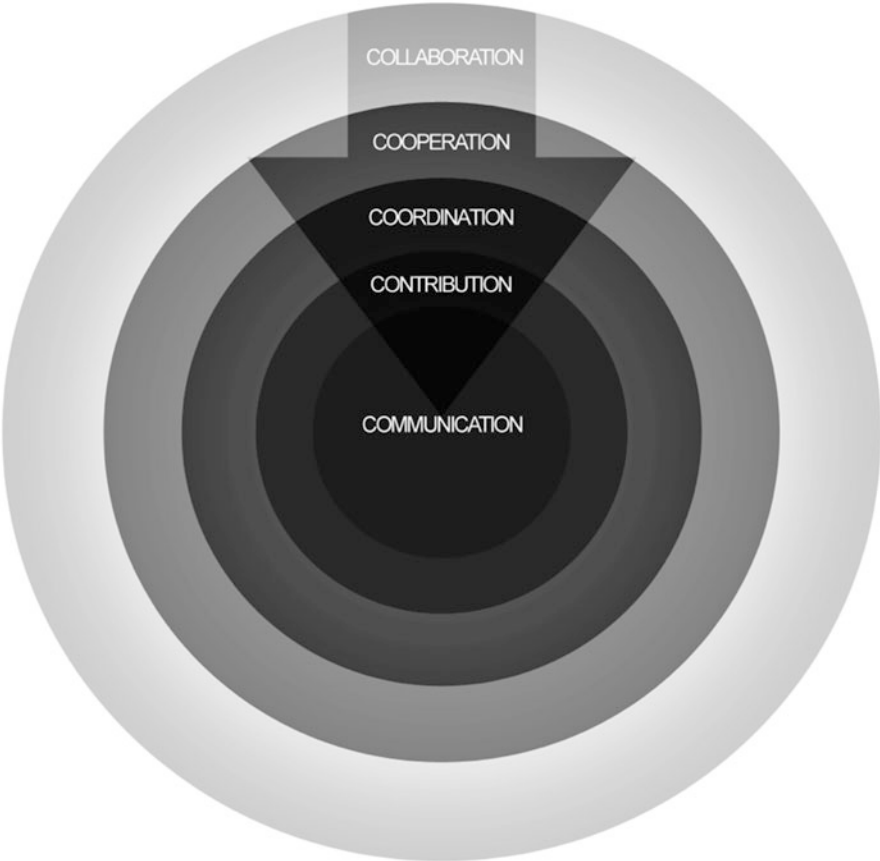

Fig. 6.2 C5 Model—a set-based organization of collaboration and related concepts. An inner set is essential to or supports the outer set

6.2.2 Limitations of Collaboration

It seems like collaboration is a great way to get things done, but is that always the case? Earlier, we noted that in many situations, collaboration is a natural choice, especially for solving difficult problems [11]. However, one must also understand the costs and benefits associated with a collaborative process in order to evaluate the usefulness and the effectiveness of that undertaking. London [46] identified the following limitations of a collaborative process:

1. Collaboration is a notoriously time-consuming process and is not suitable for problems that require quick and decisive action.
2. Power inequalities among the parties can derail the process.

3. The norms of consensus and joint decision-making sometimes require that the common good take precedence over the interests of a minority.
4. Collaboration works best in small groups and often breaks down in groups that are too large.
5. Collaboration is meaningless without the power to implement final decisions.

Gray [30] listed five circumstances under which it is best to avoid collaboration: (1) when one party has unchallenged power to influence the final outcome, (2) when the conflict is rooted in deep-seated ideological differences, (3) when the power is unevenly distributed, (4) when constitutional issues are involved or legal precedents are sought, and (5) when a legitimate convener cannot be found.

Sometimes we see collaboration forced on a group of people. Examples of such forced collaborations include the merger of two companies or instructor-enforced class groups. In such situations, the process may begin with acts of cooperation, during which the participants are merely following a set of rules to work with their fellow group members. Later, such cooperative events may result in collaboration as the participants take action (intentions) to drive the process of working together for a common goal. However, collaboration may still be unsuccessful if the participants do not trust each other or if power and benefits are unbalanced [30, 46].

Collaboration can also have limited advantages if the costs and benefits are unevenly distributed among the participants. As one of the eight challenges of groupware system development, Grudin [31] talked about disparities in benefits and responsibilities among the participants. He claimed that it is almost impossible to have an equitable groupware system in which every participant does the same amount of work and/or receives the same benefits. His examples show that some participants of a groupware system do more work and receive fewer rewards. Due to such inequality, the groupware application may become increasingly less useful and may even phase out.

While the kind of collaboration that is considered here (intentional and mutually beneficial) is slightly different than Grudin's notion of groupware, and the discussed CIS systems are considerably different than the groupware systems Grudin talked about, several of the issues he raised and the recommendations he made are relevant. For instance, for the abovementioned challenge, Grudin recommends that a system developer ensure that the process benefits all participants. This recommendation stemmed from the realization that many groupware systems were failing due to uneven cost-benefit ratios among their users (e.g., managers benefiting more than average workers while contributing less to the coordinated efforts). At the same time, Grudin identified the challenge this poses developers because the very authority figures who gain more benefits with less effort are the decision-makers. Pleasing the upper management personnel is equally important as (or more important than) pleasing other participants who have to do additional work.

This disparity of benefits also stems from the highly asymmetric roles that can be involved in such collaborations. Ensuring diversity among participants could be very useful for a successful collaboration [73], but as Aneiros and Estivill-Castro [2] argued, roles dictated by positions (manager vs. knowledge workers) could

Table 6.1 Various group activities and examples to demonstrate how aspects of collaboration play a role in information-intensive tasks

Activity	Definition	Examples
Communication	Exchanging information between two agents	Email, chat
Contribution	Offering of an individual agent to others	Online support groups, social Q&A
Coordination	Connecting different agents in a harmonious action	Conference call, net meeting
Cooperation	Agents following some rules of interaction	Wikipedia, Second Life
Collaboration	Working together synergistically to achieve a common goal	Brainstorming, coauthorship

create several constraints to CIS processes. They advised against such a master/slave model of collaboration and proposed a method of unconstrained co-browsing with asymmetric roles.

6.2.3 Collaboration in the Context of Information-Intensive Tasks

To understand the model of collaboration presented earlier (Fig. 6.2) in the context of information seeking, these five sets are listed in Table 6.1 with examples.

Sending an email or conversing on an IM client are forms of communication that could be parts of a collaborative project (see that communication is a subset of collaboration in Fig. 6.2). In fact, email is one of the most commonly employed methods of communication in collaborative work [50]. While communication tools can generally be used to share contributions between agents, there are specialized tools and places for doing so. Among these, online support groups and social Q&A sites, such as Yahoo! Answers, are very popular. The askers and answerers (contributors) on these sites, however, are not truly collaborating; one agent (user) is merely helping the other with their information need. To make this type of assistance more effective and explicit, people use conference calls or net meetings, which require coordinating the agents (people as well as systems). Once again, such a coordinated event could be one component of a collaborative project. If we combine coordinated contribution with a set of rules that the participating agents need to follow, we have examples of cooperation. On Wikipedia,[1] the participants not only contribute in a coordinated fashion but also follow rules when participating and

[1] https://www.wikipedia.org.

contributing. When users disagree, there are guidelines that suggest how to make such an interaction work. Beyond cooperative activities, true collaboration involves a group of agents working toward a common goal with explicit interactions. This can occur, for example, when coauthoring an article. The authors involved in this project not only contribute and coordinate with each other, but they also follow some set of rules that guide the aggregation of contributions and their mutual interactions. The authors also interact with each other to create this common product, which may be greater than the summation of their individual contributions.

We can draw on the terms "coordination" and "cooperation" to see how they fit around this understanding of collaboration. Austin and Baldwin [3] noted that while there are obvious similarities between cooperation and collaboration, the former involves preestablished interests, while the latter involves collectively defined goals. Malone [47] defined coordination as "the additional information processing performed when multiple, connected actors pursue goals that a single actor pursuing the same goals would not perform" (p. 5). Though this definition echoes our ideas about collaboration, one can argue that it still fits in the model described in Fig. 6.2 because it says nothing about creating solutions. For instance, organizing a meeting involves coordination among the attendees, but it is not a collaborative activity.

From the definitions and models described above, we can conclude that, in order to have a successful collaborative information seeking episode, we need to create a supportive environment where:

1. The participants of a team come with different backgrounds and expertise.
2. The participants have opportunities to explore information on their own without being influenced by the others, at least during a portion of the whole information seeking process.
3. The participants should be able to evaluate the discovered information without always consulting others in the group.
4. There has to be a way to aggregate individual contributions to arrive at the collective goal.

See Shah [65] for more information on how these four points were derived. They are missing one important aspect: the type of task involved in a collaborative project. There may not be a real reason to collaborate for simple fact-finding information tasks. As Morris and Horvitz [51] hypothesized, tasks that are exploratory in nature are likely to benefit from collaboration.

6.3 Collaborative Information Seeking in Context

It is often difficult for researchers and practitioners in this field to agree on a definition for CIS. Even if they do come to a common understanding of this term, there is still the question of how it relates to many other seemingly similar terms. The literature is filled with concepts such as collaborative search [71], collaborative information retrieval [5, 19, 38], social searching [13, 17], concurrent search [4], collaborative exploratory search [54, 55], co-browsing [16, 27, 33], collaborative navigation [43, 44], collaborative information behavior [39, 57], collaborative information synthesis [6], and collaborative information seeking [24, 36, 69]. Many definitions and conceptual understandings exist in previous research. Foster [24] defined CIS as "the study of the systems and practices that enable individuals to collaborate during the seeking, searching, and retrieval of information" (p. 330). Shah [61] referred to CIS as a process of information seeking "that is defined explicitly among the participants, interactive, and mutually beneficial" (p. 1). Table 6.2 summarizes several of these related works, along with the primary context of the collaborative activity each studied and the roles that both systems and users played.

Using this table and the earlier discussion on how CIS relates to concepts such as information seeking, information retrieval, and collaboration (Fig. 6.1), one can identify the following key aspects of CIS (see [63] for details on how these aspects were derived):

1. *Common goal and/or mutual benefits.* This is covered in the definition of the kind of collaboration that we're considering here. Often, it is the common goal and/or the possibility of mutual benefits that brings people together for collaboration. For the most part, this is not a function of a system. While systems can provide support for people with common goals who want to collaborate and reap the benefits of that collaboration, they do not typically spur a collaborative undertaking. On the other hand, a few systems are able to connect their visitors to the same Websites to foster collaboration. Donath [12] provides an example. These systems operate based on the assumption that people browsing the same Websites may have the same information needs.
2. *Complex task.* Morris and Horvitz [51] showed that simple tasks, such as fact-finding, do not significantly benefit from collaboration. Denning and Yaholkovsky [11] also recognized the larger benefit of collaborating while solving "messy" or "wicked" problems. While listing the conditions under which it is not useful to collaborate, London [46] argued that if a task is simple enough, it does not warrant collaboration. This may imply that the task should be exploratory in nature and may span several sessions.
3. *High benefits to overhead ratio.* Often, a simple divide and conquer strategy could make collaboration successful. However, such a process may have its overhead. London [46] noted that collaboration is only useful if such an overhead is appropriate for the given situation. Fidel et al. [21] showed that collaboration induces an additional cognitive load, what they referred to as the collaboration load. The collaboration in question has to meet or exceed expected benefits for it to be viable with the cognitive load that it brings.
4. *Insufficient knowledge or skills.* A common reason to collaborate is the insufficient knowledge or skills an individual possesses for solving a complex problem. In such cases, the participants can collaborate so that they can achieve something bigger or better than their individual potential. In other words, the whole can be bigger than the sum of its parts.

Table 6.2 Summary of CIS-related works, their focus, and contexts, as well as system and user roles

Research works	Information-related operations	Context	System role	User role
Collaborative search [71]	Search and retrieve	Filtering search results within a group/organization	Actively manipulating results	Recipients of filtered results
Collaborative information retrieval [5, 20, 38]	Search and retrieve	Search and retrieval of information with often colocated group	Support mechanism	Actively sharing and discussing results
Social searching [13, 17]	Search and retrieve	Social interactions among people while searching online	Support mechanism	Actively searching, sharing, and discussing results
Collaborative exploratory search [54, 55]	Search and retrieve	Recall-oriented tasks performed by a pair of users with the help of specialized search systems	Actively manipulating results and their rankings	Assuming different roles to optimize collaboration
Co-browsing [16, 27, 33]	Browse	Serendipitously creating connections among like-minded people based on their information tasks in Web environment	Monitoring and supporting user activities	Casual browsing turned to more intentional collaboration while looking through Websites
Collaborative navigation [43, 44]	Browse and locate	Serendipitously creating connections among like-minded people based on their information tasks in Web environment	Monitoring and supporting user activities	Casual browsing turned to more intentional collaboration while navigating through Websites
Collaborative information behavior [39, 57]	Seek, share, and use	Collaboration among healthcare professionals during diagnosis, patient care, and treatment	Support mechanism	Actively seeking, sharing, and analyzing information
Collaborative information synthesis [6]	Collect and consolidate	Collaborative behaviors of scientists in medical and public health	Support mechanism	Actively seeking and communicating information
Collaborative information seeking [23, 65]	Seek, retrieve, and use	Information seekers in online environments doing complex tasks	Both a support mechanism and an active component based on the task at hand	Active participants doing seeking, retrieving, sharing, and using information

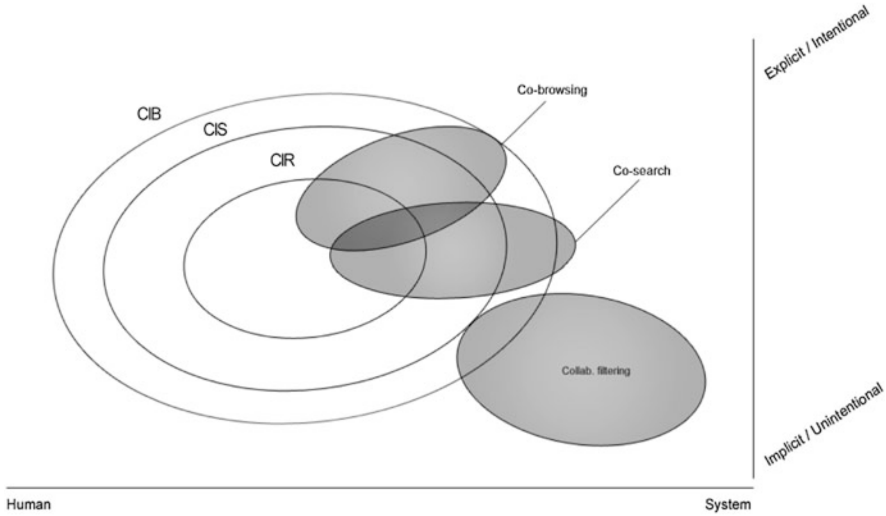

Fig. 6.3 Depiction of collaborative information seeking (CIS) and related topics, such as collaborative information retrieval (CIR) and collaborative information behavior (CIB), using the dimensions of human-system and explicit-implicit collaboration

Based on these points and related works, CIS can be defined as an information seeking process that takes place among a small group of participants (potentially with different sets of skills and/or roles) who are working on a collaborative project (possibly a complex task) that is intentional, interactive, and mutually beneficial. Note that such a collaborative project could itself be an information seeking endeavor (e.g., siblings looking for diabetes-friendly recipes for their mother), or it could include information seeking as only one of its components (e.g., coauthors searching for and sharing relevant literature as a part of writing an article). Here, "information seeking" could mean more than searching and retrieving; browsing, sharing, evaluating, and synthesizing information may also be involved.

Now, we'll attempt to classify various related works into categories that include labels such as collaborative IR (CIR), co-browsing, and social search. We'll also explore the relevant topic of collaborative filtering. Figure 6.3 is a depiction of various concepts around CIS.

As seen, these concepts are placed on dimensions of human-system and explicit-implicit collaboration. While the figure is not drawn to scale by any measures and researchers have not reached a firm agreement as to how different fields connect and overlap, it provides a schematic view of how various domains related to CIS can be seen in context. For instance, co-browsing and co-searching span across CIR, CIS, and CIB depending on the task at hand. Examples include CoVitesse system [44] for co-browsing that allows search and retrieval in addition to serendipitous browsing and CoSearch system [1] for co-searching that could also facilitate group sense-making (later implemented as CoSense system [53]). There is also a slight overlap between co-browsing and co-search since often these systems (and corresponding research) could support and study both searching and browsing. For instance, SearchTogether [51], a co-search system, could also let its participants engage in Web browsing activities to find novel information that may be relevant to their task.

6.3.1 Collaborative Information Retrieval (CIR) and Co-search

The discussion will now focus on collaborative setup scenarios where the goal is to satisfy a mutual information need through group information seeking. As discussed earlier, if/when the problem of IR is difficult to solve, a carefully executed collaboration can help. Smyth et al. [71] argued that incorporating collaboration into the search phase of an information seeking process is one possible way to connect users to information that is difficult to find. They showed how collaborative search could act as a front end for existing search engines and re-rank results based on the learned preferences of a community of users. They attempted to demonstrate this concept by implementing the I-Spy system [25]. I-Spy captures the queries and related results for a given workgroup and uses that information to provide users with filtered content that is, presumably, more relevant. Thus, I-Spy acts more as a collaborative filtering process than a synchronous collaborative searching tool.

While I-Spy attempts to extend content-based filtering techniques by incorporating communities, several collaborative IR systems have been developed by extending a traditional IR model to incorporate multiple users. However, such an extension is often ineffective or nontrivial. For instance, Hyldegård [37], who studied information seeking and retrieval in a group-based education setting, found that although people in a collaborative group to some extent demonstrated similar cognitive experiences as the individuals in Kuhlthau's information search process (ISP) model [41], these experiences did not only result from information seeking activities but also from work-task activities and intragroup interactions. Her further work also indicated that group-based problem solving is a dynamic process that shifts between a group perspective and an individual perspective [38]. Such a finding necessitates a thorough investigation into CIS that moves beyond an extension of a traditional IR system for multiple users. As Olson et al. [52] suggested, "The development of schemes to support group work, whether behavioral methods or new technologies like groupware, should be based on detailed knowledge about how groups work, what they do well, and what they have trouble with" (p. 347).

Unlike applications for co-browsing, which typically focus on Web browsing, works on CIR often focus on specialized domains for searching. For instance, Twidale and Nichols [77] presented the Ariadne system, which allowed a user to collaborate with an information expert remotely and synchronously over a library catalogue. The idea behind Ariadne was to allow the patron (naive user) to collaborate with a reference librarian (search expert) for an information need in a library situation. The authors identified the importance of supporting the social aspects involved in information searching and showed how their system can address them. However, Ariadne did not have support for asynchronous collaboration.

Morris and Horvitz [51] presented the SearchTogether system that allowed a group of remote users to collaborate synchronously or asynchronously. Awareness, division of labor, and persistent collaboration provided this system's foundation. In terms of awareness, they posited that it might enable lightweight collaboration, which would reduce overhead involved in explicitly asking group members to provide related information. Awareness was provided using per-user query histories, page-specific metadata, and annotations. Division of labor was implemented using integrated IM as well as a recommendation mechanism, by which a participant can recommend a page to another participant. SearchTogether also provided "Split Search" and "Multi-Engine Search" options for automatic division of labor. Finally, persistence was implemented by not only storing all session states but also automatically creating a shared artifact that summarizes a collaborative search's findings.

MUSE [40] supports synchronous, remote collaboration between two people searching a medical database. MUSE lets its users perform standard single-user searches, with a provision of chat and the ability to share metadata that pertains to current database results with their partners. S3 system [51] is not quite a CIS system, but its relevance lies in the fact that a set of its users can asynchronously share retrieved results.

A stream of research came out of the CIR group at the University of Washington. They studied situations where members of a work team are collaboratively seeking, searching, and using information and showed how such a process can be realized in a multi-team setting. This started with Fidel et al.'s work [19], where the authors defined CIR "as any activity that collectively resolves an information problem taken by members of a work-team regardless of the nature of the actual retrieval of information" (p. 604). They employed a cognitive work analysis framework to guide a field study examining information seekers' social, organizational, cognitive, and individual characteristics and then focused their findings on collaborative situations [19]. From their studies involving two design teams working in collaboration, Bruce et al. [8] found that (1) the nature of the task and the structure and the culture of the organization in which tasks are performed are important factors that determine CIR behavior, and (2) not all information behavior takes place collaboratively, even in teams that carry out CIR. In their further work in this realm, Poltrock et al. [56] found that (1) any information retrieval activity (identifying information needs, formulating queries, retrieving information, evaluating it, and applying it to address the need) may be performed by an individual on behalf of the team, by an ad hoc group, or by the team working together in a meeting, and (2) technologies intended to support teamwork could be more effective by recognizing and supporting collaboration in the activities that comprise information retrieval and their coordination. This suggests that a successful CIR/CIS system should not try to lock the users down in a certain type of imposed framework; it should rather let the participants choose their own way of collaborating and provide enough support for carrying out those various methods.

The efforts of connecting multiple users for information seeking (retrieval or browsing) continue to produce systems either by reinventing the wheel of traditional IR or by extending existing IR systems to accommodate more than one user. In practice, none of these systems have been widely adopted. Why? Several reasons contribute to the narrow visibility of collaborative systems, including the cognitive load involved in using these systems, the learning curve to start using these environments, and the sparsity of integration of information seeking into other parts of a collaborative process. Further, explanations to why such groupware systems fail and what can be done to address their problems can be found in [31].

6.4 Frameworks and Models for CIS

In this section, we will explore different ways in which researchers have studied CIS and its various aspects. This will start with the traditional way of classifying collaborative activities along space and time dimensions, move on to control-communication-awareness framework, and then to the nature of mediation in CIS. Finally, a synthesis of these frameworks and models using an extended set of dimensions for defining and studying collaborative activities will be presented.

6.4.1 Space and Time Aspects of CIS

The classic way to organize collaborative activities is based on two factors: location and time [59]. Recently, Hansen and Järvelin [34] and Golovchinsky et al. [28] also classified approaches to collaborative IR using these two attributes. Figure 6.4, inspired by Twidale and Nichols' [75] depiction, shows various activities, methods, and environments on these two dimensions.

As we can see from this figure, the majority of collaborative activities in conventional libraries are colocated and synchronous (e.g., face-to-face meetings, reference interviews), whereas collaborative activities relating to digital libraries are more often remote and synchronous (e.g., digital referencing, virtual meetings). Social information filtering, or collaborative filtering—a process benefiting from other users' actions—is asynchronous and mostly remote. Email also serves as a tool for doing asynchronous collaboration among users who are not colocated. Chat, or IM, enables synchronous and remote collaboration. For a detailed literature synthesis on how remotely located scientific collaborations are conducted and studied using laboratory without walls, or collaboratives, see an excellent review by Finholt [22].

The placement of a CIS environment on this figure has implications for its implementation, functionalities, and evaluation. For instance, Adobe Connect facilitates

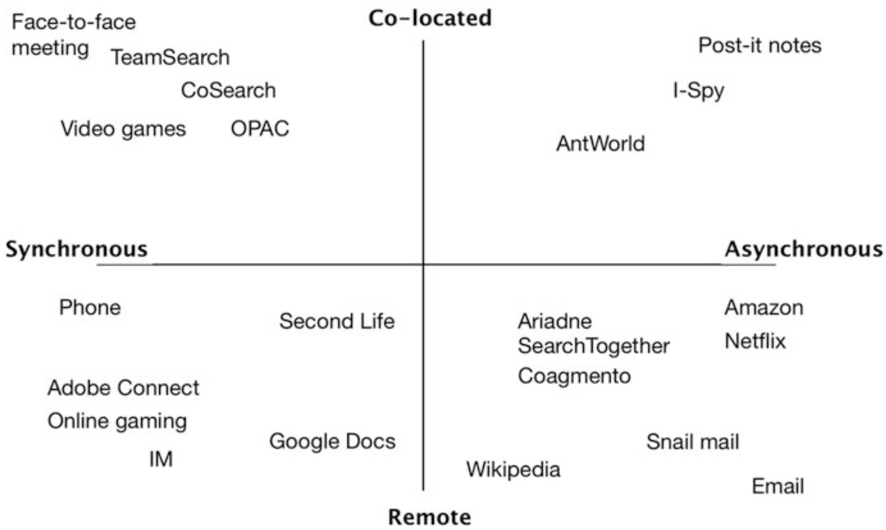

Fig. 6.4 Various collaborative activities, tools, and methods organized on space-time dimensions

online meetings where the participants can share and discuss information. Such an environment will fall under synchronous remote collaboration in Fig. 6.4. Thus, this environment needs to have (1) a way to connect remote participants, (2) a shared space for exchanging information, and (3) a communication channel to provide real-time message passing among the participants.

6.4.2 Control, Communication, and Awareness in a CIS Environment

Three components specific to group work or collaboration that are highly predominant in the CIS or CSCW literature are control, communication, and awareness.

6.4.2.1 Control

Rodden [59] identified the value of control in CSCW systems and listed a number of projects with their corresponding schemes for implementing control. For instance, the COSMOS project [78] represented system control with a formal structure. It used roles to represent people or automatons and rules to represent the flow and processes. Roles included a supervisor, processor, or analyst. Rules defined conditions that must be satisfied in order to start or finish a process. Due to structures seen in projects like COSMOS, Rodden classified these control systems as procedural-based systems.

Most of these systems were studied in office environments, where the subjects interacted with one another through personal conversations, group meetings, and phone calls. Several recommendations and findings from these studies were primarily based on observations.

To express control in a collaborative environment, early CSCW systems used various mechanisms to spread messages, which were often called structured definition language (SDL) messages. In the most basic sense, these were email messages that were sent back and forth among a collaborative project's participants. However, such a project requires more support than a simple messaging exchange. SDL provides this support by imposing a structure to these messages and incorporating additional fields of information that can be used to appropriately filter and distribute them.

For instance, Malone et al. [48] proposed the InformationLens framework, in which the messages carried additional information (some of which was automatically generated). This could later filter and classify these messages, thus suiting individuals' needs within their group. Later, Malone extended the above framework to ObjectLens [42], in which the participants could create objects in addition to messages to purvey information. Each of these objects would be imbued with a similar structure that could guide further control and distribution processes. ObjectLens also let people create links among the objects they formed. Malone pointed out that this was similar to hypertexts on the World Wide Web.

6.4.2.2 Communication

This is one of the most critical components of any collaboration. In fact, Rodden [59] identified message or communication systems as the class of systems in CSCW that is most mature and most widely used.

In order to craft CIS systems that allow their participants to engage in an intentional and interactive collaboration, there must be a way for the participants to communicate. In fact, collaboration could begin when a group of users is allowed to communicate with each other. For instance, Donath and Robertson [13] presented a system that allowed a user to connect with others who were viewing the same Web page and then communicate with those people to initiate a possible collaboration or at least a co-browsing experience. Providing communication capabilities even in an environment that was not originally designed for carrying out collaboration is an interesting way to encourage collaboration.

Using four multidisciplinary design situations in the United States and Europe, Sonnenwald [72] came up with 13 communication roles. The author showed how these roles can support collaboration, other aspects of an information seeking process such as knowledge exploration and integration, and task and project completion. Filtering and providing information, as well as negotiating differences across organizational, task, discipline, and personal boundaries, facilitated all of these processes and activities.

6.4.2.3 Awareness

Awareness is one of the most important issues that is identified and addressed in the literature. One of the often-asked questions about awareness is "awareness of what?" Schmidt [60] argued that we should talk about awareness not as a separate entity but as someone's consciousness of some particular occurrence. In other words, the term "awareness" is only meaningful if it refers to a person's awareness of something. Heath et al. [35] suggested that awareness is not simply a "state of mind" or a "cognitive ability" but rather a feature of practical action that is systematically accomplished within the course of everyday activities.

The literature uses several related terms and definitions to discuss awareness in collaborative projects. For instance, Dourish and Bellotti [14] defined awareness as "an understanding of the activities of others, which provides a context for your own activity" (p. 107). Dourish and Bly [15] suggested the following definition for awareness: "Awareness involves knowing who is 'around', what activities are occurring, who is talking with whom; it provides a view of one another in the daily work environments. Awareness may lead to informal interactions, spontaneous connections, and the development of shared cultures – all important aspects of maintaining working relationships which are denied to groups distributed across multiple sites" (p. 541).

Early works detailed a set of theories and models for understanding and providing awareness. Gaver [26] argued that focused collaboration in which people work closely toward a mutual goal is characterized by an intense sharing of awareness. He further claimed that less awareness is needed for division of labor, and that more casual awareness can lead to serendipitous communication, which can turn into collaboration. Bly et al. [7] also identified the importance of such general awareness by saying, "When groups are geographically distributed, it is particularly important not to neglect the need for informal interactions, spontaneous conversations, and even general awareness of people and events at other sites" (p. 29).

There are several ways of defining and implementing awareness. Various research projects have used their own taxonomy and interpretation of awareness for creating frameworks and systems. For instance, Gutwin and Greenberg [32] classified awareness into two types—situational and workspace—and suggested that situational awareness underlies the idea of workspace awareness in groupware systems. Unlike other definitions that focused on awareness of the workspace itself, their work accounted for personal reactions within the workspace. Simone and Bandini [70] identified two kinds of awareness: by-product awareness that is generated in the course of the activities required to accomplish a group's collaborative tasks and add-on awareness that stems from an additional activity. Add-on awareness can cost collaborators something within their tasks and is discretionary because it depends on their assessment of the contingent situation. Chalmers [9], likewise, divided awareness into two kinds: awareness of people and awareness of information artifacts. He suggested implementing an activity-centered awareness tool that would focus on presenting people's ongoing appearances and activities.

Shah and Marchionini [67] extensively used four kinds of awareness as presented by Liechti and Sumi [45] for their work with CIS. They are listed below:

1. *Group awareness.* This type of awareness includes providing information to each group member about the status and activities of the other collaborators at a given time.
2. *Workspace awareness.* This refers to a common shared workspace where group members can bring and discuss their findings and create a common product.
3. *Contextual awareness.* This type of awareness applies to the application domain rather than its users. Here, the objective is to identify what content is useful for the group and what the goals are for the current project.
4. *Peripheral awareness.* This relates to the type of information that results from an individual's and the group's collective histories and should be kept separate from what a participant is currently viewing or doing.

6.4.3 Materializing Control, Communication, and Awareness

Several systems supporting collaboration have identified the issues of control, communication, and awareness as critical to their design. For instance, Farooq et al. [18] presented a collaborative design for CiteSeer,[2] a search engine and digital library of research literature in the computer and information science disciplines. Based on a survey and follow-up interviews with CiteSeer users, the authors presented four novel implications for designing the CiteSeer collaboratory: (1) visualize query-based social networks to identify scholarly communities of interest, (2) provide online collaborative tool support for upstream stages of scientific collaboration, (3) support activity awareness for staying cognizant of online scientific activities, and (4) use notification systems to convey scientific activity awareness.

Depending on the domain and type of application, different CIS systems have different ways of providing awareness to the collaborators. Take, for example, Ariadne [76], developed to support the collaborative learning of database browsing skills. To facilitate complex collaborative browsing processes, Ariadne presents a visualization of the search process. This visualization consists of thumbnails of screens that look like playing cards, which represent command-output pairs. Any such card can be expanded to reveal its details. The support for awareness, in this case, is driven by the specific domain (library) and application (catalogue search).

SearchTogether [51], on the other hand, was based on information seeking (application) on the Web (domain). It instantiates awareness in several ways, one of which is per-user query histories. This is done by showing each group member's screen name and their photo and queries in the "Query Awareness" region. The access to the query histories is immediate and interactive, as clicking on a query

[2] citeseerx.ist.psu.edu.

brings back the results from when it was executed. Because query awareness allows group members to both share their search strings and learn from each other's formulation techniques, the authors identified it as a very important feature in collaborative searching. Another component of SearchTogether that facilitates awareness is the display of page-specific metadata. This region includes several pieces of information about the displayed page, including group members who viewed the given page, and their comments and ratings. The authors claim that such visitation information can help a participant either avoid another group member's previously visited pages, thereby minimizing wasted duplication, or perhaps choose to visit pages that appear to be promising leads as indicated by the presence of comments and/or ratings.

6.4.4 Nature and Level of Mediation

Yet another way to study CIS (or generally, collaborative) systems is by looking at how collaboration is mediated. Pickens et al. [55] saw two extremes: system or algorithmically mediated and user or interface mediated.

6.4.4.1 System/Algorithmically Mediated Collaboration

Here, the system (more specifically, the behind-the-scenes part of the system) acts as an active component for collaboration and helps the collaborators get the most out of their shared projects by doing any of the following:

- Combining various inputs from the users (e.g., queries, annotations) to produce better versions of them
- Joining multiple streams of results—produced by different people doing the same action (e.g., search)—into a better set of results
- Redistributing the results, keeping in mind every participant's abilities, roles, and responsibilities
- Optimizing workload for each individual involved in collaboration

Pickens et al. [55] showed how algorithmic mediation could be provided in a time-bound, recall-oriented task to allow the collaborators to find results that they would have individually missed. Their algorithm was based on catering to different (predefined) roles played by the collaborators. Later, Shah et al. [69] showed how a system-mediated collaboration that considers collaborators' asymmetric roles could enhance both relevance and novelty in retrieval.

Often, system-mediated CIS systems come close to being collaborative filtering tools but are set apart by the notion of intention. Because those working with system-mediated collaboration are explicitly involved in the process, it appears that they have the intention to collaborate. Collaborative filtering, on the other hand, may not have the explicit consent or intentionality of those involved or affected.

6.4.4.2 User/Interface-Mediated Collaboration

This method of collaboration implies that either the participants fully control the collaborative processes and/or such control is being exercised through the system's user interface. In other words, the collaboration in question is very transparent to the involved parties, and the control rests with the users. To keep control with the users, the system serves as a passive element that helps with aspects such as communication and awareness.

For example, the Ariadne system [75] allows the collaborators (a reference librarian and an information seeker) to work through their information seeking process using the system's co-browsing interface, which does nothing more than respond to user actions. Recent systems such as SearchTogether [51] and Coagmento [62][3] could also be seen as interface-mediated CIS tools where the users maintain control, though such systems often employ a few system-mediatory components. For instance, SearchTogether has a split search feature, whereby a team could ask the system to intelligently split the search results among the collaborators. The authors, however, found this feature to be underused [51].

6.5 Summary

In different fields and contexts, researchers have recognized the need to study and support people working in collaboration. In the area of information seeking/behavior, the focus has been on extending single-user environments to accommodate multiple participants in information-intensive situations. However, most of these approaches have been application driven, and we still need a set of models, specialized tools, and best practices that help us effectively support CIS. This chapter identifies these gaps and offers a research agenda in its conclusion. We discussed a set of key works from various fields to put collaboration and CIS in perspective. Early works primarily focused on support for collaboration in information-intensive domains within office environments or library settings. More recent projects have targeted online information seeking situations.

CIS stands at a very interesting intersection. It is both a long-standing domain within CSCW and a relatively young field that has been shaped by several veteran domains such as IR, CSCW/groupware, and HCI. Another way to think about CIS-centric research is that while we have seen a tremendous amount of interest and outcomes in the recent years as evident by the publications, systems, and events around CIS, many ideas have come from previous research in well-established forums of SIGIR, CSCW, and CHI. Having said that, it is worth noting that while modern CIS's interdisciplinary nature retains the traces of these domains, it is also

[3] http://coagmento.org.

constantly evolving and creating its own identity by carving out a unique space of research problems.

There are several issues that emerge from different aspects of the CIS field. For instance, a researcher who wishes to pursue the HCI components of CIS may study issues such as interface design for CIS systems, how to reduce participants' collaborative load, and how to foster appropriate amounts and kinds of awareness.

The advent of the Web 2.0 and the fact that an increasing number of people have access to online information sources have steered new CIS developments toward building tools that leverage on these provisions. However, it is time we start paying more attention to some of the fundamental issues in CIS. They include understanding user requirements and behavior in CIS environments, identifying motivations and best practices for people doing collaboration, and sketching effective design guidelines for CIS systems. Above all, there is a dire need to devise new models, theories, and evaluation matrices for CIS. These issues are at the core of the CIS domain (see [63] for more discussion on this), and studying them could help us get closer to better understanding people's behavior in CIS environments and better designing of CIS systems.

Finally, we need to acknowledge that "collaboration" and "social" are not just some two independent dimensions but rather quite intertwined in most cases and should be studied together. The next chapter takes us in that direction.

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