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Social Navigation

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Abstract. In this chapter, we present one of the pioneering approaches in supporting users in navigating complex information spaces: *social navigation support*. Social navigation support is inspired by the natural tendencies of individuals to follow traces of each other in exploring the world, especially when dealing with uncertainties. In this chapter, we cover details of various approaches in implementing social navigation support in the information space, and we connect the concept to supporting theories. The first part of this chapter reviews related theories and introduces the design space of social navigation support through a series of sample applications. The second part of the chapter discusses the common challenges in design and implementation of social navigation support, demonstrates how these challenges have been addressed, and reviews the more recent direction of social navigation support. Furthermore, as social navigation support has been an inspirational approach for various other social information access approaches, we discuss how social navigation support can be integrated with those approaches. We conclude with a review of evaluation methods for social navigation support and remarks about its current state.

1 Introduction

Navigation through the ever-changing information space is becoming increasingly difficult. Recent research efforts have highlighted the interactive nature of information access behavior, and have promoted the potential value of harnessing user activity patterns to drive navigation in information space. “Social navigation”, defined as “moving towards a cluster of people” has been introduced for the Web as a response to the problem of disorientation in information space [30]. The idea of social navigation in information space stems from the natural tendency of humans to follow both direct and indirect cues of one another when they are feeling lost [5]. Social navigation in information space, as well as the term social navigation, was introduced by Dourish and Chalmers [30]; however, the idea of social navigation is frequently traced back to the pioneering Edit Wear and Read Wear systems [55, 54]. In this system, Hill and Hollan introduced the idea of physical wear in the domain of document processing as “computational wear.” Computational wear is the visualization of the history of authors’ and readers’ interactions with a document. Such a visualization of the history enables new users to quickly locate the most viewed or edited parts of the document. As Dieberger suggests [25], social navigation support does not necessarily change users’ navigation behaviors, but it increases their awareness inside the information space. Social navigation support is offered by using traces of activities of latent users to guide newer users; for example, which links have been traversed by a majority of users [114, 25] or which pages are being explored by other users at the moment [71, 107].

Introduced in few pioneer projects in 1990s in the context of navigation in information space, the ideas of social navigation attracted a lot of followers from other areas of information access. In a number of follow-up papers and books [26] the term "social navigation" was used to refer to other kinds of social information access, such as collaborative filtering. For example, Wong et al. defined social navigation as a mechanism to "enable actions not based on spatial or semantic information, but on social information" [116]. However, this chapter focuses on social navigation in its original context, as an approach to help users navigating in information space by using traces of behavior that are left behind by previous users. We attempt to provide a comprehensive view of social navigation by discussing how it supports users' navigation in the information space, theoretical support, original approaches in implementing it in the information space, and evaluation methods of the existing implementations. Furthermore, we have tried to discuss how the advancement of social computing fields has advanced implementation approaches in social navigation. We end the chapter by highlighting challenges for researchers and practitioners interested in social navigation in information space.

2 Supporting Theories

Social navigation is inspired by principles that have been discovered in nature, as people have observed a variety of interesting behaviors among insects or animals. Animals and insects, such as birds, fish, ants, or termites, engage in collective or swarming behavior [77]. A swarm is a collection of unsophisticated agents that cooperate to achieve a goal. Each agent follows simple local rules from their environment in a relatively independent manner; but collectively, they achieve the swarm's objectives. This emergent collective intelligence is known as "swarm intelligence (SI) [7]." "SI is the property of a system whereby the collective behaviors of (unsophisticated) agents interacting locally with their environment cause coherent functional global patterns to emerge" [7]. An example of SI in nature is the food-foraging behavior of ants. Ants use their pheromone to mark trails that connect the nest to food sources. The pheromone gets richer and richer as more ants follow the trail to carry food to the nest. At each point, the trail with the highest pheromone density has the highest chance of being chosen by the ants.

While interacting with complex information spaces, humans behave similar to animals in trying to achieve collective intelligence. Information seeking tasks on the Web can be mapped to a biological society. The Web represents the society and the surfer represents the animal, which is an autonomous agent with limited knowledge, given the abundance of available information. Desired information is the "food" for which the surfer is browsing. Click-streaming and other browsing behaviors are the Web pheromones and the popularity of the Web page represents the density of the pheromone. Wu and Aberer [117] conducted a "Quest for Treasure" experiment to evaluate the collective intelligence behavior of humans in information space.The experiment involved 12 rooms that visitors could navigate to. Two of the rooms had a treasure chest in them. For each link, they presented the raw visit click and pheromone density. Pheromone density was calculated by accounting for both positive and negative feedback. Positive feedback includes accumulation of visits and spreading of pheromones from other links. Negative feedback includes diffusion of the popularity of a link and was modeled by a half-life time function. By following the link pheromone, one could quickly find the treasure chests. The results of this experiment showed a simple form of self-organization and demonstrated the value of "swarm of Internet surfers."

The effect of social navigation in information spaces can be explained by the *information foraging theory*. Related to SI, the information foraging theory [94] is analogous to food foraging strategies among animals, which states that "when feasible, natural information systems evolve toward stable states that maximizes gains of valuable information per unit cost." Information foraging is the result of human adaptation to the explosive rates of information growth. The central problem that the theory tries to address is the allocation of attention to the most useful information. The goal is to maximize the overall profitability of information resources by increasing information gained per unit cost. Information scent is used to assess the profitability of information resources. The information scent is the "perception of the value, cost, or access path of information sources obtained from proximal cues, such as bibliographic citations, WWW links, or icons representing the sources."

Information foraging has mainly focused on explaining the information -seeking behavior of individual users. Pirolli introduced the idea of "Social Information Foraging" (SIF) [93]. SIF is based on the idea that information foragers engage in the social exchange of information. Connected to the idea of swarm intelligence, information foragers cooperate to increase the likelihood of high-value information discoveries. The basic SIF model assumes the existence of hints from the group of information foragers about the likely location of useful information patches. It attempts to model the benefit of cooperation and social capital in information-seeking tasks. Recent social Web technologies such as blogs, collaborative tagging, and recommender systems have emerged to exploit or enhance SIF. The success of those technologies implies the overall effectiveness of social information foraging.

SIF connects social navigation with information foraging. Social navigation support (SNS) can enrich the information scent and assist in scent detection to judge the potential relevance of information resources. Information foragers have to navigate through information patches to find what they need. SNS can decrease the cost of information gain by both enriching between-patch and within patch foraging gains. Figure 1 depicts the possible effect of SNS on information gain. To satisfy information needs, first, information foragers should find the relevant patches. As they go through the information patches they gain information as represented by the information gain function up to the point that they reach the information gain threshold. Social navigation cues can enrich between-patch information gain by highlighting the patches with useful information and decreasing the time needed to assess different patches. While navigating inside a patch, social navigation support can improve the return from a patch by highlighting the useful resources inside the patch; for example, by highlighting the part of the document that received the most attention by previous users.

Lunich et al. have proposed a theoretical framework to explain the social navigation process in information space from a communication perspective [78]. They explain social navigation in terms of users' decision to generate traces and to follow traces, as well as the attributes of the content. The model proposes that users' decisions can be influenced by personal traits, interpersonal relationships, contextual factors, and content.

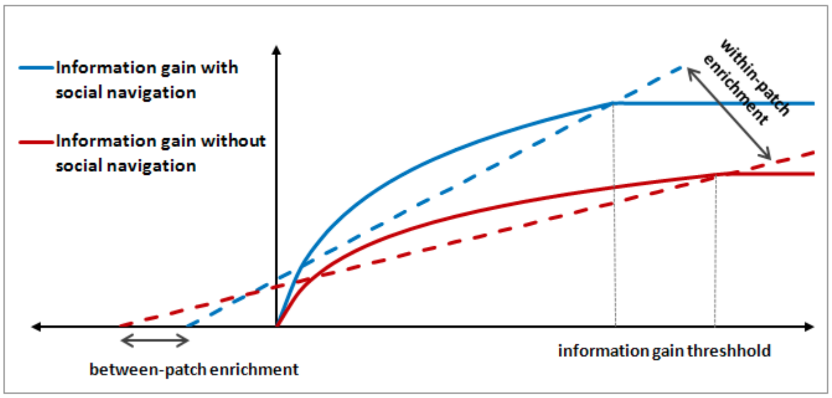

Fig. 1 Information foraging model with social navigation support

3 Influencing Users' Experiences

Supporting social navigation in information spaces has the potential to improve user experiences through four main mechanisms: guidance, persuasion, engagement, and social presentation. Below, we describe each mechanism and provide some supporting theories.

3.1 Guidance

Social navigation support has been initially motivated by the challenge of information overload in information spaces. While navigating the Web, users are often faced with a large amount of information and an overwhelming set of options to follow in search of their desired information. It is commonly documented that users on the Web often experience information overload and anxiety when dealing with too much information and too many choices [52, 8] To address the challenge of information overload, researchers have been studying ways to provide guidance to users in information spaces. Motivated by the natural human tendency to follow traces of one another, especially when feeling lost, researchers have studied social navigation support in information spaces as an approach to visualize and highlight the information traces of users within the space. The ability to relatively easily track user activities and traces in information spaces provides the opportunity to make use of these traces to guide individuals about what information others have been accessing, or seeking. As argued by Wong et al. [116], social navigation support can be employed to support information discovery and guidance in information spaces in three major ways: (1) by aiding navigation to the most popular content by highlighting what resources everyone else is accessing; (2) by supporting serendipitous discovery by highlighting important resources that have not drawn the attention of a large group of people; (3) by diverting attention from resources with the highest level of popularity and encourage navigating the "road less traveled". As will be discussed in the section on "Traces of Users Activities", different sources of user activities can be employed to provide social navigation support, including explicit user actions, such as liking or rating an information item, as well as implicit behaviors, such as clicks and time spent on an information item. At the same time, social navigation guidance can be based on traces of all users or on a specific group of users. As a result, different implementations of social navigation support can provide different levels of guidance, and as will be discussed in the "Challenges" section, the effectiveness of this guidance varies and can be misleading in some cases.

3.2 Persuasion

Supported by theories of persuasive communication, information about activities of others can persuade people to take a particular action. As a result, social navigation support has the power of persuasion by relying on and presenting information about the actions of others. The strength of persuasion interacts with the source of information [20]. For example, people are more likely to follow authority figures, others similar to them, or those with whom they have a strong relationship. Therefore, depending on the source of social navigation support, its power of persuasion can vary. In two experimental studies of social navigation in the form of augmented annotation in the context of news articles, Kulakarni and Chi [70] showed that users are likely to follow the recommendations of others as long as they are not total strangers, for whom they have no basis to assess the reliability of their actions.

3.3 Engagement

In addition to the power of social navigation support in providing guidance and persuading users to follow a particular path and access specific information, social navigation support can increase users' engagement within the information space by adding social affordances to the space. It has been shown that various activities, even those that are not intrinsically engaging, can become more engaging through integration with social interactions [69]. For example, Farzan et al. showed that individuals are more likely to be engaged with even a solitary game if the game is integrated with a social context and in association with teams [39]. Social navigation support can turn information seeking that has been traditionally thought of as a solitary action into social interactions through both direct and indirect communications with other users. Observing footprints of others or an ability to directly communicate with others can serve as a social mechanism that encourages further engagement within the information space.

3.4 Social Presentation

As discussed earlier, social navigation support adds a social dimension to information spaces and information-seeking tasks. At the same time, information about the activities of others is an indicator that their actions have been recorded by the system and will be presented to others. As a result, users may perceive that any action they take in the information space contributes to the way they have been presented to others. As suggested by Goffman [50], individuals alter their behavior and performance based on their audience to mange their self-presentation. Many studies have focused on the presentation of self in the current age of social media and online sites [56, 82, 90]. It has been shown that users of social networking sites tend to employ various strategies to manage their self-presentation and the presentation of their identity through the nature and amount of information they share with others [112, 113]. In turn, this perception of social navigation as a way of social presentation and self-presentation can influence their information-seeking behavior [70].

4 Pioneering Examples of Social Navigation

Following the ideas introduced in the seminal Edit Wear and Read Wear system [54] and an early attempt to conceptualize social navigation in [30], two pioneering systems played an important role in the development of a social navigation research stream. These systems, Juggler [25] and Footprints [114], implemented the ideas of social navigation in two meaningful contexts and demonstrated how it could help users who are navigating through two kinds of information spaces: a Web site and a text-based virtual environment.

Footprints [115, 114] introduces the idea of interaction history to digital information, which is taken from the extensive human use of history traces in the physical world. Footprints provides contextualized navigation through the use of several interface features, such as maps, path views, annotations, and sign posts. The system tracks all transitions from different sources, such as selecting a link, typing a URL, or selecting a bookmark. It visualizes the interaction history by presenting the traffic through a Web site, percentage of users following each link, and popular paths to Web sites. Additionally, Footprints allows users to provide direct guidance by adding signposts that express their opinions about different resources and the path used to reach the resource. Figure 2 shows different views of the documents and navigating through the documents in Footprints, as well as how they are augmented with social navigation support, such as coloring the nodes that represent the popular documents in the site map interface or by showing what percentage of users have followed each link on the page by annotating the links with the percentages, as shown in the right bottom side of the figure. Footprints does not present any identifiable information, and social navigation support is offered based on aggregated and anonymous user activities.

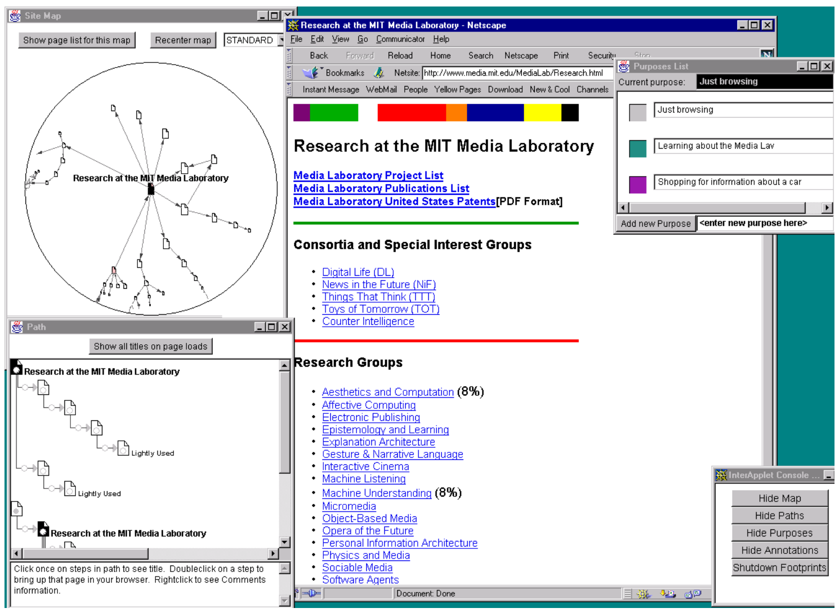

Fig. 2 Social navigation support on different views of the Footprints systems. Image retrieved from `http://alumni.media.mit.edu/~wex/Screenshots/final-fullscreen.gif`

Juggler [25] was designed to support interaction between a teacher and students in a remote teaching support system. By its nature, it is a text-based virtual environment (known as a MOO) enhanced with a Web browser for displaying Web pages. Juggler provides an example of implementing a history-enriched environment in a MOO context. It highlights major navigation paths through different textual bulletin boards (rooms), and adds the computational wear to each bulletin boards by showing the number of times that it was accessed. Juggler also supports an intentional form of social navigation by encouraging users to directly recommend useful resources (such as URLs) to each other.

Another pioneering system to acknowledge is EFOL, an online food store developed by Kristina Höök and her colleagues in the PERSONA project [26, 107, 108]. Unlike Juggler and Footprints, which were inspired by the ideas of history enriched space of Edit Wear and Read Wear, the PERSONA team was motivated by the recognized need to support users navigating in information spaces [4] and the idea of adaptive navigation support introduced by adaptive hypermedia [10]. However, in contrast to traditional adaptive hypermedia, where navigation supported was based on knowledge engineering provided by system creators, the PERSONA team called for "Edited Adaptive Hypermedia" [57], where navigation support could be offered on the basis of both explicit and implicit activities of earlier system users. EFOL also implemented the idea of a populated information space where the synchronous presence of other users in different parts of the information space (recipe clubs) was indicated by their avatars, which encouraged other users to navigate to a populated place. Once in the same "club", users were able to chat with one another, just like in a real information space.

While these pioneering systems were more proof-of-concept than practical systems highly utilized by regular users, they played an important role in defining the design space for social navigation. Using these systems as motivating examples, their authors promoted social navigation in a series of workshops and books [26, 86, 60]. Altogether, this work has established social navigation as research direction and defined its research agenda.

5 Exploring the Design Space of Social Navigation

Social navigation augments the information space with traces of activities of others. In design of such augmentation, one can observe three main foci: (1) history-enriched environments that attempt to enrich users' experiences by visualizing history of users' interactions; (2) co-presence enriched environments that aim to enrich users' experiences by visualizing the presence of others and to increase users' awareness of others in the information space; (3) organized guided information seeking that aim to guide users' navigation through the information space through explicit cues provided by other users.

5.1 Users' Activities and their Traces

Independent of design focus, various tracers of users' activities can be leveraged to offer social navigation support. We classify these traces along two dimensions – intention and synchrony. The *intention* dimension represents whether the users are leaving traces with an explicit intention of providing feedback to the system and to others, or whether they are just performing their activities on the system, which may be used as implicit indicators of feedback to the system [108]. *Synchrony* indicates whether users are communicating the feedback to each other synchronously and directly, or if the feedback is asynchronously communicated to others [26]. This is an extension to the original classification suggested by Dieberget et al. to distinguish social navigation based on the communication modes between the actors into "direct social navigation", when the actors are in direct communication with each other and "indirect social navigation", when contacts between the actors are anonymous and indirect [28]. Examples of each kinds of traces are shown in Table 1.

Table 1 Classification of users' activities and traces of the activities

		Synchrony Asynchronous	Synchronous
Intention	Implicit	Clicks, time spent on downloads, highlighting text, scrolling, bookmarking, mouse movements	Editing a shared document such as Google documents, browsing a Web page
	Explicit	Likes, Ratings, Recommendations, Comments, Actions	Web page recommendation in a chat message

Independent of the source of user traces, in implementation of social navigation support, it is possible to employ traces of all users of the system or a specific group of users. At the same time, the anonymity of social navigation support traces can range from aggregated and anonymous to individual and anonymous or individual and non-anonymous. Each of these decisions influence how social navigation support affects user decisions in the information space, and they have been topics of interest in various research studies, as we discuss in the section "Evaluation Methods". While protecting user privacy is important and necessary, visibility and translucency can help to increase both trust and awareness [32].

Mapping the design space to the classification of user activities, as described in Table 1, synchronous explicit approaches are more in the form of recommendation that are less strongly considered as social navigation and other chapters of this on recommender system provide more details on that. Below, we discuss each approach in details and provide examples for each approach.

5.2 History Enriched Environments via Implicit Asynchronous Traces

In search of solutions for the challenge of information overload and difficulty in finding the most desirable information, researchers explored the idea of enriching information spaces with the navigation history of the latent users. These approaches often rely on *asynchronous and implicit* traces of those who have already navigated the information space. These traces, such as click-throughs or download history, can be employed to provide social navigation support.

The Juggler and Footprints systems reviewed above provide two early examples of history-enriched environments that leverage implicit asynchronous traces of user navigation. This work motivated a number of follow-up projects that attempted to expand this approach in several directions. The Social Navigation swiki or CoWeb [27] provides an interesting example of implementing the ideas of social navigation in the context of a Wiki system; namely, a user-expandable hyperspace [73]. Unlike a regular Web site where the end users can only browse by leaving their clickstreams, a Wiki system allows all users to both update existing pages and to create new ones. In this context, page creation and update activities form another stream of implicit traces. The Social navigation Swiki provides a history-enriched page view that shows the recency of user page updates and browsing by attaching two kinds of visual cues to Swiki page links (Figure 3): one to show the recency of page updates ("new" sign) and another to show the recency of page usage (a pair of footprints). The color of each visual cue (red-hot, yellow, gray) reflects three levels of recency.

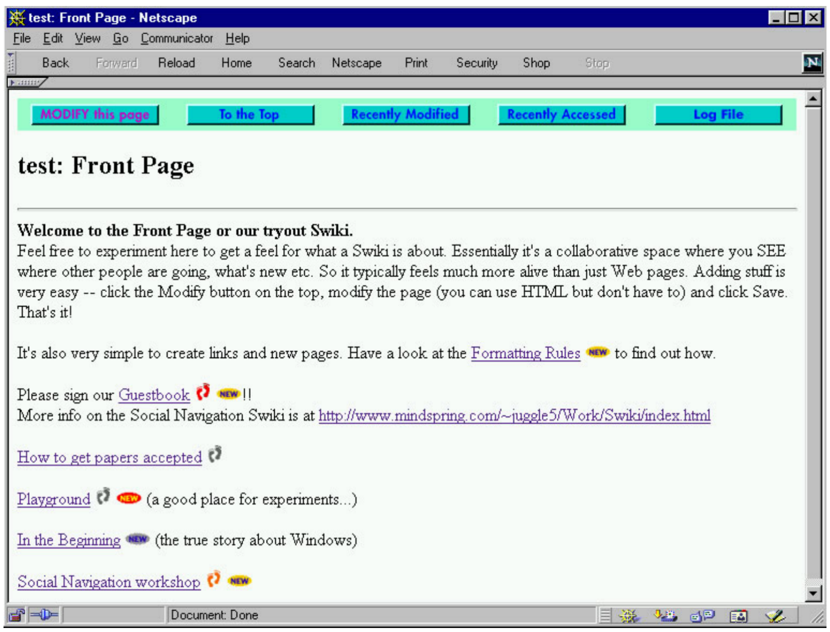

Fig. 3 Social navigation Swiki page showing recency footprints for browsing and page updating activities. Used with permission from [27]

KnowledgeSea II [12], an educational information system, was designed to help students find relevant information among hundreds of online tutorial pages distributed over the Web by augmenting the interface for accessing educational resources with information about the collective behavior of students in a class. It provided social navigation support based on prior students' interactions with the online resources and pages that they visited every week as the course progressed. More specifically, it used the number of clicks made by all students in the class on a specific page or topics as a sign of its importance in the context of the class, and used a blue color of a different intensity to visualize this social importance to the users. Figure 4 shows the main interface of the system, which includes a grid of course topics annotated with background color and other social cues based on students' activities in a particular class, and shows the content of each topic cell as the list of resources in that cell. KnowledgeSea II introduced two extensions of the original idea of history-enriched hyperspace that was introduced by Footprints [114]. First, it offered two-level social navigation that starts by leading readers to valuable topic cells by visualizing a cumulative importance of its resources, and then allows users to select valuable resources within the topic cell. Second, it offered social comparison by contrasting a user's own navigation (shown as the intensity of the human figure's color) with the navigation of the whole class (shown as the intensity of the background color).

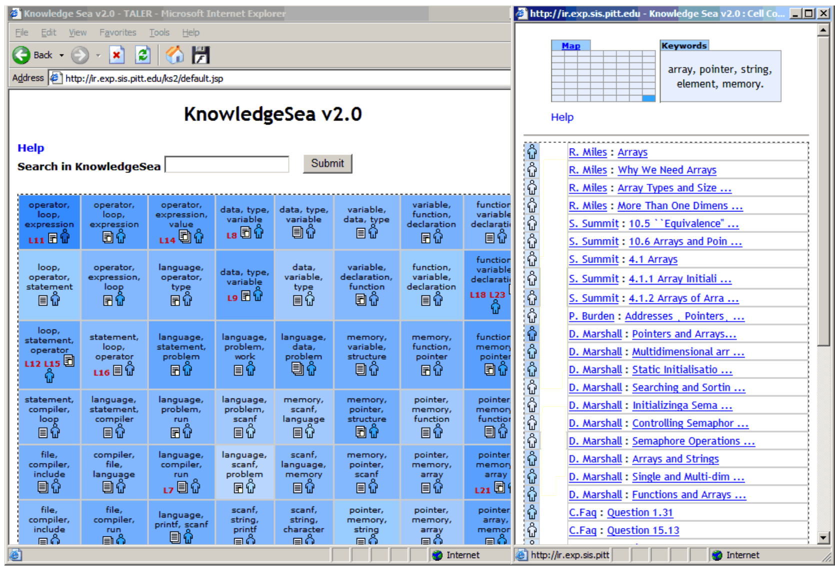

Fig. 4 Social navigation support in the main interface of Knowledge Sea II system

5.3 *Co-Presence Enriched Environments via Implicit Synchronous Traces*

While approaches in implementing history-enriched environments rely on asynchronous and implicit traces of users' activities, another set of approaches aim at enriching users' information navigation experiences by presenting a live and social image of the information space and where other users are at the moment. These approaches still rely on implicit traces of users; i.e. users do not explicitly communicate with each other, but they are aware of the presence of one another *synchronously*. The value of *awareness* of the presence of others has been traditionally studied and highlighted within the computer-mediated communication field [91, 16]. Research in the field of social navigation has followed these ideas to extend the values of co-presence to *information navigation support*.

A classic example in this context is EDUCO [71]. EDUCO is a collaborative learning environment that has implemented social navigation support to enrich learners' experiences in Web-based learning. EDUCO supports synchronous social navigation by visualizing the presence of others in the learning environment. As users of the system access the educational Web documents, others can view their presence as dots next to the documents, as shown in Figure 5. The color of the documents represent the popularity of the document among the users based on how many times they have been clicked. Furthermore, users can leave comments associated with documents that are visible to others who are navigating to the document.

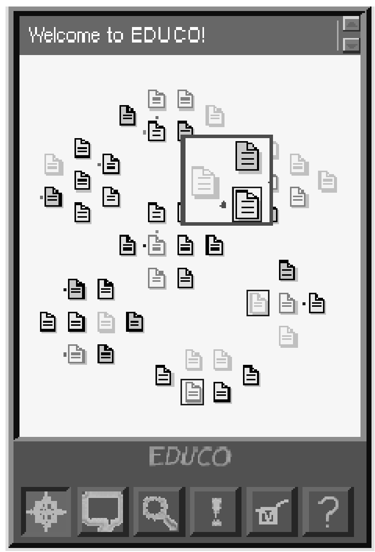

Fig. 5 Representation of documents and users within the EDUCO learning environment

5.4 Sharing Destinations and Paths via Explicit Asynchronous Traces

While Dourish and Chalmers [30] originally defined social navigation as navigation towards a cluster of people, or navigation that occurs because other people have looked at something, Dieberger [25] argued that various kinds of direct information sharing (i.e., sharing a web page in a bulletin board post or sharing it on a "pointer" page such as a list of bookmarks, or a list of favorite links on one's home page) should be considered as examples of social navigation. In a classification of social navigation approaches introduced in [26], this kind of direct information sharing is considered to be *direct asynchronous* social navigation.

Due to its complexity, direct information sharing could be classified into sharing individual destinations and sharing sequential paths. Sharing destinations (i.e., Web URLs) is a simpler kind of explicit information sharing. In the early days of the Web, when search engines had not yet reached their current power, research teams explored a range of ideas for explicit sharing of URLs both in-context and out-of-context for a specific page. At that time, various kinds of bulletin boards, such as USENET newsgroups, provided an easy mechanism for explicit sharing of "out-of-context", i.e., generally useful links. However, the original bulletin-board format offered no useful interface for funding and re-using this information. The need to improve the mechanism for direct sharing of USENET information prompted several interesting projects [51, 110, 80]. A classic example of leveraging USENET information to support more convenient direct social navigation interface is offered by the PHOAKS system [110]. PHOAKS used a set of rules to extract useful links shared by the users in their posts to USENET newsgroups and listed the extracted links for each group as recommendation to its users. Links were ranked by its social support, i.e., number of users recommending the link. At the same time, a few educational hypermedia systems offered their users the ability to share useful links "in-context"; i.e., by adding a new useful link on a specific hypertext page [43, 85]. The ability to add a new link to an existing page also became a part of the core functionality of Wiki systems.

In the second part of the 1990s, collaborative bookmarking systems gradually emerged as a more efficient platform for the explicit sharing of Web links. The idea of collaboratively sharing and using bookmarks that were originally meant to be personal collections of valuable Web links appeared to be very productive. Between 1997 and 2005, researchers and practitioners explored multiple approaches for organizing shared bookmarks [64, 74, 31]. Gradually, an approach to characterize each link with multiple tags originally introduced by WebTagger [64] became dominant. With the introduction of collaborative tagging, social bookmarking systems, which started as a specific kind of social navigation, emerged into a new kind of social information access that can support both search and navigation. Since other chapters analyze collaborative tagging and bookmarking in detail [29, 88], we will not discuss it further in this chapter.

Systems for sharing paths and trails could be considered to be a more advanced case of explicit social navigation. In this case, users would share not just a single resource or destination, but a whole sequential navigation path. In some sense, this kind of social navigation could be also considered to be the oldest of its type, since the idea or sharing paths was introduced by Vannevar Bush as a key component of his visionary system Memex [17]. The inspiration provided by Memex ideas certainly contributed to the development of several practical "guided path" (or guided tours) systems at the end of the 1980s in the context of hypertext research [118, 81, 111]. The original guided tours have not fully implemented Memex's vision of sharing paths between users, serving instead as another tool in the hands of the original hypertext authors to enhance the usability of hypertext systems [81, 111]. However, just 10 years after the debut of guided paths in classic hypertext, the fast growth of the Web and the increasing engagement of end users as contributors has led to re-emergence of guided paths as true social navigation tools. The systems for sharing Web paths (or trails) appeared in the second half of the 1990s, in parallel with many other kinds of social information access systems

[89, 45, 53]. These systems were directly influenced by Memex and earlier work on guided tours, rather than by the early work on social navigation [30]. A classic example of a system for sharing Web navigation paths is Walden's Paths [45]. As with a number of other early social navigation systems [25, 71, 31], the Walden's Paths system was developed for an educational context. The key idea of the system was to separate path authoring from content authoring. In contrast to the common approach, the original paper declared that "in general the author of the path is not the author of the supporting documents" [45]. A "path" in the system was defined simply as a sequence of Web pages (URLs) where each page can be extended with annotation that comments on the page and its role in the path. The Walden's Paths system provided a powerful interface for any interested Web users to define and share "paths" and an interface for navigating shared paths (Figure 6). The navigation interface included the current page in the path, along with authored comments and an overview of the whole path that showed the position of the current page. The users were encouraged to explore pages around the path by following links from the current page. However, the user's position in the path was preserved, even when the user wandered away from path, and a "lost" user could return back to the path with a click of the "return back to the path" button. Walden's Paths has been evaluated in several contexts and some lessons learned were summarized in [102].

The success of Walden's Paths and other early trail-sharing systems encouraged a range of similar projects that explored tools and infrastructures for authoring and sharing guided paths for the Web, such as Ariadne [62], Ethemeral Paths [44], TRAIL-GUIDE [96], TrailTRECer [46], or HATS [68]. It is important to note that in contrast to the early work on shared guided paths that was inspired by Memex and was not positioned in the context of research on social navigation, more recent work in this area [96, 46, 48] clearly articulated the role of shared paths in the context of social navigation and other kinds of social information access. In turn, it helped to generalize the idea of shared trails as navigation support tools, which helped to move this concept from its Web origin to other kinds of electronic environments. An early example of this generalization is trail-based navigation in shared directories [48]. A more recent example is provided by systems for collecting and sharing physical trails, such as pedestrian walks, cycling paths, or travel itineraries. While modern online physical trail sharing systems look quite different from the Web trail-sharing systems, the early motivating examples of physical trail sharing systems, such as Salzburg Trail Manager [47] or Cyclopath [95], were developed by teams with solid experience in social navigation and were directly motivated by the earlier research on social navigation in the digital world. This example is especially interesting because it demonstrates how the ideas of social navigation have completed a full circle between the physical and digital worlds. Originally motivated by social navigation in the physical world, work on social navigation has explored the application of these ideas to help users in navigating in various digital environments. After being enriched and expanded, these ideas are now coming back to improve navigation through the physical world.

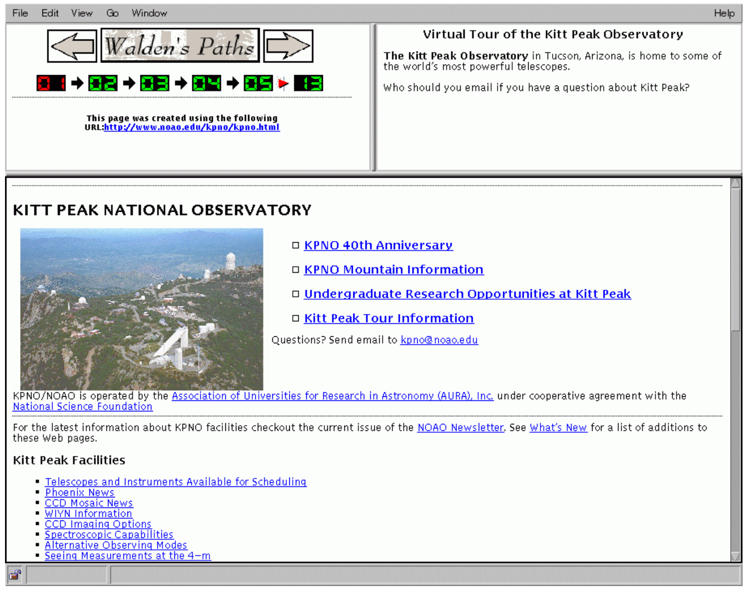

Fig. 6 Following a shared trail in Walden's Paths system

6 Addressing the Challenges of Social Navigation Support

Despite the potential benefits of social navigation support in information spaces as highlighted above, researchers and practitioners faced various challenges in both the design and implementation of those ideas and in enriching users' information navigation experiences. These challenges were gradually identified and have been extensively discussed. The need to address these challenges encouraged a number of projects that could be classified as the third generation of research on social navigation. The majority of these systems were developed between 2005 and 2010 and represent considerably more mature endeavors. Many of these systems have been used in real-life contexts with hundreds and even thousands of users. This section attempts to provide a representative review of this work. We start with discussing major challenges of social navigation support. Following that, we review some of the most representative systems of the third generation and stress specific approaches that these systems have used to address some of these identified challenges. Not all challenges have been addressed in these systems and as a result, some remain as open challenges.

The major challenges in implementation of social navigation support can be categorized as follows:

Tracking Users' Traces: Privacy, Information Efficiency, and Effectiveness: The implementation and evaluation of social navigation mechanisms have included various sources of user traces as a basis for social navigation support, including anonymous individual traces [106], traces of identified individuals, or aggregated traces; however, it remains an open research question as to which navigation trails should be logged and visualized to support effective social navigation. Each approach includes both advantages and disadvantages. On one hand, more information can be provide richer and more accurate social navigation support; however, there are privacy and social representation issues associated with collecting detailed and identifiable information. Being aware that each action is being recorded by the system and is going to be presented can cause users to change their behavior to present their navigation behavior in a more desirable way. At the same time, such use of the system can raise users' concern about their privacy that not only will their navigation in the system be logged by the system, but also that it would be visible to other users' of the system. Moreover, more information is not always more beneficial. At times, an abundance of information can cause information overload for users, especially if it is difficult for users to assess the relevance of information. At the same time, visualizing large amounts of information can introduce technical challenges [116]. Similarly, in terms of information efficiency and effectiveness, trace aggregation faces challenges in terms of the level of aggregation. Aggregation can be done at the group level by defining groups of similar users, collaborating users, or competing users [58, 34]. However, the current research lacks conclusive results on the overall effectiveness of different approaches.

Reliability of User Traces: Snowball Effect and Cognitive Biases

Social navigation relies on recommending the path traveled by others; however, users' reaction to social navigation support can be influenced by different cognitive biases. Several researchers have attempted to experimentally study the significance and degree of such biases. Salganik et al. [99] studied the impact of social influence on user decisions in an artificially created online music market. They showed that social influence, such as the presented and prior number of downloads, can persuade individuals to take action, independent of the actual quality of the songs. Following these experiments, in a series of experiments, Lerman distinguished the position versus social influence cognitive bias in individuals' information accessing behavior [72]. She found that independent of the quality of information and in addition to social influence, the position of information on the screen can significantly influence a user's decision to access it.

As a result of such cognitive biases, social navigation systems often are challenged by a snowball effect: if the first user heads in the wrong direction, all other users of the system enhanced with social navigation can be attracted to the same wrong path. This "snowball effect" is a special concern for systems that rely mostly on implicit feedback that could be frequently unreliable, especially when considered in isolation. For example, a click on a page link might indicate true interest in a page's content, or could be a mistake caused by an unclear link anchor. Therefore, it is important to be able to detect these paths and to prevent the system from directing users to follow them.

Combining several types of implicit feedback can partially address this problem; for example, combining time spent reading with clickstream data [21]. If a user has visited a page by mistake, then the chance that they will spend a short amount of time on the page is high. As a result, considering the time a user spends on a page can help to eliminate some of the misleading pitfalls. In addition, different kinds of user traces carry different reliability in registering the user's true interests. While low-commitment actions such as clicking on a link are inherently unreliable, such actions as leaving a comment, downloading, or purchasing indicate a higher commitment and could be used for providing more reliable navigation support and minimizing the snowball effect.

Drift of Interest

A known challenge in implementation of social navigation is the concept of drift of interest [106]. Over time, the interest of people and the importance of information are changing. An item or topic that is important to a community of users today might not have much value in several months. This is especially important for highly dynamic contexts, such as an educational context, in which the interest of students is generally dependent on the specific topic they are studying at the moment.

This problem can be addressed by weighting more recent visits, providing social navigation support based on the data from a specific period of time, or showing the recency of social guidance [104, 27]. Often, it is important to preserve old data in addition to recent data. For example, in educational contexts, students might be interested in current information to work on the latest assignment, and, at the same time, might be interested in previously discussed materials to prepare for the midterm exam.

Bootstrapping and Engaging Users

An important and well-identified challenge in developing social navigation systems is how to get the system started. This is known as the “cold start” problem in collaborative filtering-based recommender systems. Social navigation relies heavily on feedback provided by users, whether implicitly or explicitly. Early users will not have many navigational aids and might get disappointed by the system. On the other hand, as a result of not having navigational aids, they might head in the wrong direction, which will affect the whole functionality of the system by accumulating a trail on the wrong path. Therefore, guiding and motivating early users is a key challenge in determining the effectiveness of social navigation systems.

A study of social navigation in an educational context demonstrated that students with better knowledge of the subject were usually the first to explore “uncharted” territory, in which social navigation support was not yet available [58]. These students have the highest chance to locate the most appropriate resources, thus “blazing trails” for less knowledgeable students to follow. This results suggest that this group of users can be specifically encouraged to bootstrap a new system. However, it is not evident that a situation with the most-prepared users blazing trails for the rest of the community will ensure proper bootstrapping in other contexts. Combining content-based navigation support approaches with social navigation [100] could be recommended as a more general way of addressing the cold-start problem.

At the same time, extrinsic rewards can be introduced to encourage early users to participate, such as gamification approaches in providing points and badges for encouraging contribution, which has been shown to be effective [41]. However, such extrinsic approaches can also face challenges, especially with regards to undermining the quality of contribution and intrinsic motivation in those who have already been motivated to participate [19, 40]. Other studies have investigated approaches in introducing alternative mechanism on the system to allow the users to benefit from their early contributions, when the user cannot yet benefit from the social aspects of the system [37].

6.1 AnnotatEd and KALAS: Exploring More Reliable Traces

The reliability of social traces was among the first challenges addressed by third-generation social navigation systems. Many of these systems tried to avoid a snowball effect by providing more reliable sources of user traces through both implicit and explicit actions. Two good examples of transitioning to more reliable traces can be provided by the AnnotatED and KALAS systems, which were developed as extensions of earlier social navigation projects.

AnnotatEd [34], an educational hypertext reading support system, was designed as an extension of the KnowledgeSea II system [12], which was previously mentioned to address several challenges faced by the classic implementation of social navigation support in KnowledgeSea II. The main focus of this extension was improving the quality of social navigation support by using more reliable evidence of a user's interest in a page (such as leaving an annotation rather than just clicking on a page) or a smarter processing of unreliable click traces. As shown in Figure 7, AnnotatEd allowed users to add public or private comments to the section of online tutorials and textbooks they visited and classify their comments as praise, a problem, or a general note. This information was then used to augment links to reading resources with with social and personal visual cues to represent presence, type, and density of associated student annotations. Annotations are considered to be reliable signs of user interest and page relevance [9] and a study of AnnotatEd [34] confirmed the ability of annotation-based navigation support to direct users to important, relevant pages. Furthermore, AnnotatEd tracked the time that each user spent on each page and determine a "depth" or each "footprint" that accounts for time spent and the length of the text in each page [33]. As a result, a click could be considered as leaving only a half-deep "footprint" or no footprint at all, depending on the time spend reading the page. AnnotatEd also extended the visibility of social navigation support. While KnowledgeSea II focused on social augmentation of Web links on specially created navigation maps, AnnotatEd added social visual cues to all regular within-page links. Note also that both AnnotatEd [34] and the KnowledgeSea II system [12] addressed the global-level aggregation problem, since they used traces of student behavior from the same classes to provide social navigation. This filtered out the behavior of users who might have used the same information with a different need or from a different prospect.

KALAS [106], an extension of the pioneering EFOL food recipe system [107], attempted to address some of the above-mentioned challenges by synthesizing a group of social navigation support features. It provides social navigation support by visualizing the aggregated trail of users through the environment. The trail includes the comments left by the users, as well as information about the number of users who have downloaded a recipe. To provide social navigation support, KALAS collected users' feedback in both an implicit and explicit format. For implicit feedback, KALAS focuses on reliable evidence of interests such as downloading, printing, or saving a recipe. Any of these actions leaves a positive vote for that recipe. Explicit feedback is collected by allowing users to click on a "good recipe" button or to check the thumbs-up/thumbs-down option in the recipe list. This provides an explicit positive or negative vote for the recipe. KALAS also supports synchronous social navigation by displaying currently logged-

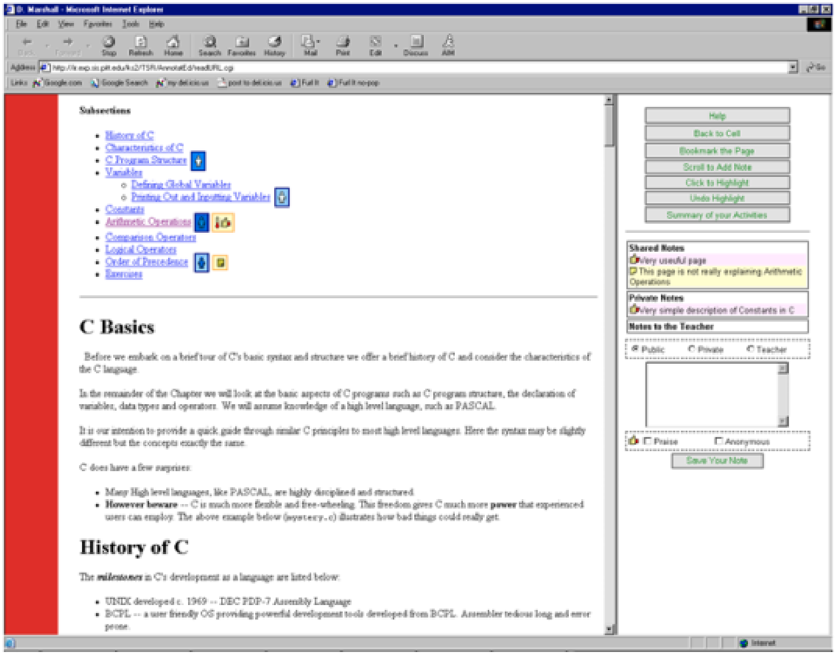

Fig. 7 AnnotatEd: Annotation-based social navigation support with Web page resources

on users in each section of the system and allowing real-time chat to occur among the users. Such implementation of social navigation support can often be observed in large-scale commercial systems, such as in Amazon.com, where aggregate purchasing and browsing information of all customers or specific groups of customers are presented to individuals to assist their shopping decisions.

6.2 Conference Navigator: Reliable Privacy-Protected Traces

Conference Navigator (CN) [35], a community-based conference support system, was designed to explore the value of social navigation in the context of planning a conference attendance. Conference attendees in multiple parallel-session conferences often have a difficult time in deciding which talk to attend. The CN system explored the value of social navigation support to assist the conference attendees with finding the talk in each session of the conference that was most relevant to their research interests. CN system addressed two critical issues in implementation of social navigation support: reliability of traces and users' privacy. To address users' privacy concerns and their concerns about social presentation, the CN system allows users to join sub-communities that are defined in the system. Each sub-community represents a specific research interest. As shown in Figure 8, while the users browse the schedule of the conference, they can look at it from a prospect of their a sub-community (e.g "Social Learning" community in

Figure 8). Each user can belong to as many sub-communities as they desire, but only one sub-community is selected as active at each time. As they browse the conference schedule, they can indicate their interest in a specific talk by "scheduling to attend the talk" or by explicitly up-voting or down-voting the talk as it relates to the interests of their active community. This information is then used to provide social navigation support for the sub-community by guiding users to the talks that are most relevant to the interests of the community. As in many other social navigation systems, the navigation support was implemented by augmenting links to relevant talks with social visual cues.

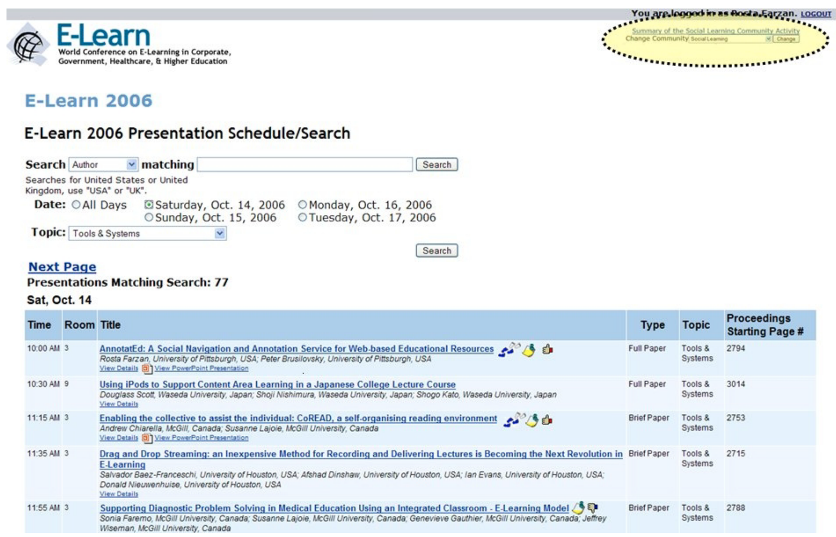

Fig. 8 Conference schedule browser with social visual cues

6.3 Comtella and CourseAgent: Engaging Users

While the reliability of user traces is essential in order to provide meaningful social navigation support, *encouraging* users to leave traces, especially traces based on explicit actions is even more essential to systems that rely on social navigation functionality. Various systems have tried different approaches to increase users' engagement with the system. In this section, we review two examples that show how user engagement can be increased by using two alternative approaches - "intrinsic" and "extrinsic" motivation to participate.

CourseAgent [37] is a course recommendation system that is based on students' explicit feedback about the difficulty level of courses, as well as a course's relevance to specific career goals. The systems uses this feedback to provide social navigation support to future students in making decisions about what courses to take. Encouraging students to provide feedback about courses they have taken is a key challenge for such systems, especially when students who have already taken a number of courses might not directly benefit from the navigation support. To do so, the CourseAgent system transforms the action to provide feedback into an *intrinsically* beneficial action for the users. This was done by introducing a study progress dashboard, where the feedback provided by students about taken courses is used to calculate how far along they are in terms of progress towards each of their career goals. This approach is an example of using intrinsic motivation to increase explicit feedback. A user study demonstrated that this approach was highly efficient [37].

Comtella [19] is a social information system designed for researchers and students to share useful academic and educational resources with a group of users. The success of Comtella as an information system highly relies on the active participation of users in sharing interesting, high-quality resources and voting on resources shared by other users. Comtella employs an adaptive reward system to encourage high-quality participation. The system rewards more cooperative users with various incentives, such as greater bandwidth for download and higher visibility in the community. High-quality participation is ensured through a reputation system that allows the users to rate the contributions of others. The ratings are then aggregated, and negative ratings serve to decrease the rewards given to low-quality contributions. Comtella was one of the first systems to explore engagement based on rewards and reputation that form the foundation of an increasingly more popular extrinsic motivation approach to increase participation. Moreover, as shown in Figure 9, users are visualized as stars in the system, with different sizes and levels of brightness based on their participation in the system. Visualization is also designed as an approach in encouraging participation by increasing users' awareness about their participation, as compared to others, and by enforcing a sense of social responsibility and social comparison.

6.4 Progressor: Social Navigation and Engagement with Social Comparison

An interesting approach that combines the benefits of social navigation support and user engagement is social comparison. Social comparison is known as a strong factor that encourages user participation [18]. KnowledgeSee II [12] mentioned above was the first system to introduce social comparison in the context of social navigation; however, in this system it was based on less reliable navigation footprints and its effect was relatively small. A more elaborate example of extending traditional social navigation with social comparison using more reliable traces of user behavior is provided by Progressor [58], an educational practice system in the domain of computer programming. By its nature, a practice system provides access to various kinds of educational *practice content*. The work with this content is not mandatory and it doesn't carry credit points; however, it is an opportunity to practice knowledge that is gained in a regular class and improve targeted skills. The use of practice content has two known problems. First, good practice systems offer an abundance of practice content of different difficulty levels to address the needs of students with different levels of knowledge - but this

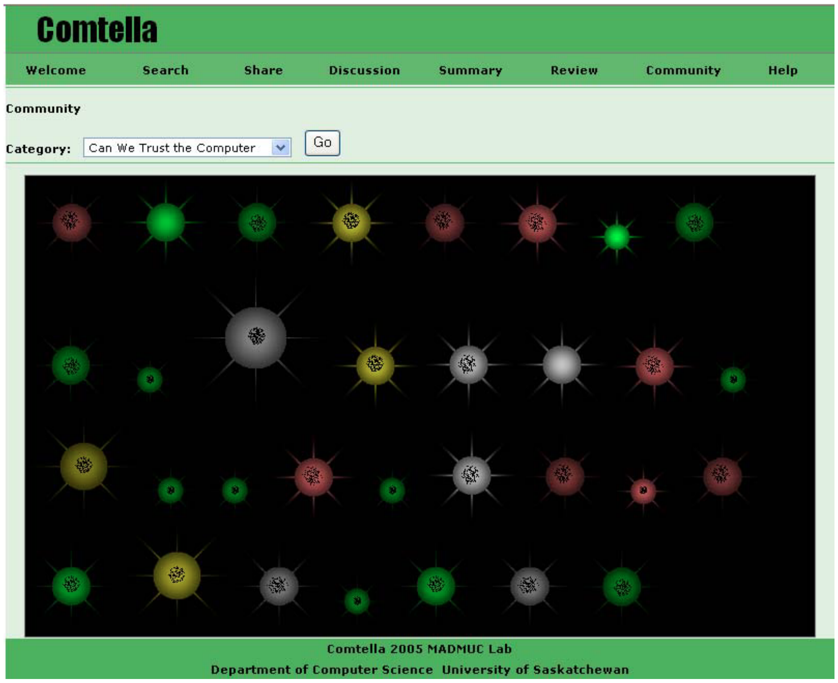

Fig. 9 Visualization of users, according to their level of contribution

abundance makes it hard for students to select the most appropriate content to practice. Second, despite their educational effectiveness, practice systems are usually under-used by students who prefer to focus on credit-bearing activities.

Progressor attempts to address both problems by using a combination of social navigation support and social comparison. The system arranges practice problems into topics that are visualized as segments of a circle, as shown in Figure 10. The color of each segment represents the amount of knowledge gained by a student who works on practice problems for this topic, from red (no knowledge) to green (mastery). This kind of knowledge representation is known as an *open learner model*. The student could view their own model in parallel (left) or a model of class peer or a group knowledge model of the whole class (right). The models shown on the right, especially the cumulative class model, offer social navigation support. Here, students can see the topics that have been already successfully mastered by the whole class, the topics that were only attempted by a few advanced peers, and the topics that have not yet been practiced by anyone. By comparing their current knowledge level against the knowledge of the class or specific peers, the student can easily select the most appropriate topics to practice, while also getting strong motivation to work on bridging the gap between their knowledge and the class's level of knowledge. Clicking on a topic brings a list of practice problems for this topic that uses the same color-coding knowledge representation to help in choosing the most appropriate problems to practice. As a study of Progressor shows [58], both social navigation and social comparison were highly effective: student success rate at practice problems was significantly improved and the amount of student work with non-mandatory content increased by more than 150%. Studies performed on similar systems, like Progressor+ [59] and Mastery Grids [15] confirmed this remarkable double effect of social navigation and social comparison.

Fig. 10 Social navigation support and social comparison in Progressor

The systems presented have been successful at addressing some of the identified challenges at various levels; however, researchers and practitioners are still attempting to find ways of improving social navigation support by tackling these challenges and some of these challenges such as "drift of interest" or concerns with "social presentation of users' activities" are less frequently addressed within the existing implementations.

7 Social Navigation Beyond Hypertext and Hyperlinks

Early research on social navigation focused on assisting users in hypertext-style browsing; namely, users would traverse the hyperlink space and identify links to desirable resources. However, challenges in information access do not stop at the link level, and a vast amount of information continues to challenge users once they arrive at a specific resource. As a result, social navigation support needs to also consider levels of internal resource support; namely, tracking users' traces as they navigate through a particular page. For example, a system might allow users to highlight specific parts of text within a page or to associate comments with specific section of the page. Within-resource social navigation support becomes more challenging when considering the large number of resources on the Web that exist in multimedia and other continuous media formats that contain temporal dimensions. However, a range of recent projects have demonstrated that the ideas of social navigation could be creatively applied to help users find the right place within a page or in continuous media. Moreover, several innovative projects have demonstrated that social navigation could be used to enhance other kinds of information access beyond its original focus on “browsing”. In this section, we review a sample of projects that explored social navigation ideas beyond hypertext and hyperlinks.

7.1 Spatial Social Navigation

While most implementation approaches of Web-based social navigation support have focused on facilitating navigation between Web pages, the original idea of social navigation support as it was imagined by the Edit Wear and Read Wear systems focused on helping a user to navigate within a single document space. Unfortunately, the idea of fine-grained tracing of user behavior that Edit Wear and Read Wear implemented in the context of a text editor was not easy to replicate in either a hypertext or a Web context. In a regular hypertext or Web systems, users leave nothing but page-level clicks behind them. However, a Web system enhanced with annotation functionality opens opportunities for within-page social navigation based on user annotation behavior.

Web annotation technology became quite popular, with various Web annotation systems created at the peak of its work between 1995 and 2005 [98, 63, 105, 24]. While many of these systems supported only page-level annotations (just like AnnotatEd system reviewed above), several systems, including the popular Annotea project from WWW Consortium [63] allowed for the addition of comments to any HTML fragment or allowed a user to simply mark-up the most valuable fragments. Some of these systems limited access to this information to the original users, while others allowed for the sharing of annotations (this stream of work contributed to modern social tagging systems). The majority of these annotation systems also allowed users to share their annotations with all users of the system, which offered some kind of within-page social navigation.

In parallel to this research on Web-based annotation systems, Schilit et al. [101] explored the use of annotations in the context of a tablet-based reading tool named XLibris. Unlike Web annotation tools, which focused on page-level and “linear” within-page text annotations, XLibris pioneered spatial annotation, which enables XLibris users to manipulate the position of the annotation in addition to the text of the annotation. XLibris offered a pen-based, free-form annotation tool that supports highlighting, underlining, and commenting. XLibris also pioneered some forms of annotation-based social navigation, such as a skimming mode, which highlights only the most important parts of a document, based on other users’ annotations.

The ideas of Web page annotation and spatial document annotations were integrated in a Spatial Annotation system developed by Kim et al. [66]. The system was designed as an extension of AnnotatEd [34] to support Web-based access to digitized scanned books produced by large-scale book digitization projects, such as the Carnegie Mellon Million Book project [22]. Unlike the original AnnotatEd that supported only page-level annotations, the Spatial Annotation system allowed users to mark any rectangular page fragment (that might include a figure, a paragraph, or just a few words) and add any kind of comments. Spacial marks and comments might be visible to other users of the system, who might add their own comments to any annotation to create a localized discussion. Further, to guide the readers to the most commented and appreciated fragments, the Spatial Annotation system provided within-page social navigation support based on prior users' annotations through visualizing traces of users' activities related to page fragments. To represent prior users' activities, the system extensively used various visual cues. As shown in Figure 11, the thickness of the border of an annotated fragment indicates the volume of associated annotations, while the color of the border and the background color indicates whether an annotation was created by the target users or by someone else, as well as if it is public or private, or positive or neutral.

A more recent example of spatial social navigation support within a Web-based document space was provided by Wong et al. [116], who focused on supporting sense-making and exploration of visual information. They implemented social navigation support as annotations to online maps, such as Bing Maps, by adding information about which parts of the map users had explored in response to a particular geo-location search task.

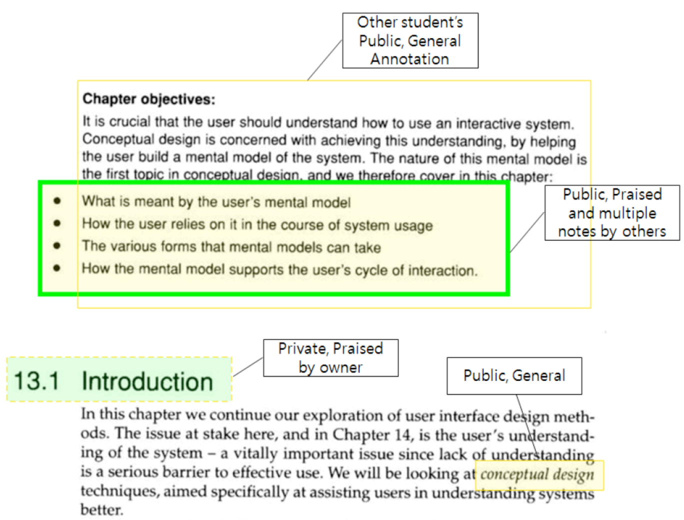

Fig. 11 Visual cues based on spatial annotations provide within-page social navigation support

7.2 Social Navigation in Continuous Media

Social navigation in continuous media, such as video, is similar in several aspects to within-page social navigation, as reviewed above. While the visionary Edit Wear and Read Wear interface offered some ideas of continuous social navigation, this topic was not substantively addressed in early social navigation research. However, the increasing popularity of online video, and especially video-based Web lectures [11], encourages the application of social navigation ideas in this context. A traditional (1-3 hours) Web lecture contains many mundane parts, such as course logistics, but also many important fragments that explain core domain concepts. However, a regular Web lecture interface, even if it is extended with special video navigation tools such as sliders and scrolling, provides no guidance as to the importance of various fragments. Mertens et al. [83, 84] described a VirtPresenter system that attempts to address this problem using an extension of a classic footprint-based approach to continuous media. VirtPresenter considered each viewing of one video frame by a user as a social footprint that indicates the possible importance of this frame and displays a cumulative history of frame-level lecture viewing in a graphic form next to the video scrolling bar (see Figure 12). This approach made it easy to identify (and not to miss) the most-watched parts of the lecture. To address students' drift of interest, which is natural in a semester-long course, VirtPresenter introduced week-based filtering: the students were able to choose which social data are used to construct the social viewing graph: the amount of data gathered during the whole term or just the interaction recorded during specific weeks. VirtPresenter also enabled explicit social navigation to allow students to bookmark specific parts of the video and send these bookmarks as Web links by e-mail to their friends and peers.

It is important to observe that through its use of less reliable implicit "footprint" data, VirtPresenter was similar to the first generation of "click-based" social navigation for the Web. While the simple approach pioneered by VirtPresenter has been later used in other systems with slight variations [65, 67], several follow-up projects focused on improving the reliability of social navigation for Web lectures. The set of explored ideas was mostly similar to those explored in research on Web-based social navigation, as reviewed above. For example, the CLAS system [97] attempted to use explicit vs. implicit footprints to identify most important lecture fragments. The idea of the CLAS approach is simple: it encourages students to mark important parts of the lecture while watching, by simply pressing the spacebar. In return, all watched lectures are enhanced with the visually annotated timeline showing important spots. Another project [49] explored a smarter use of several kinds of of implicit social feedback (such as the use of pause, play, skip, and rewind) to identify most important fragments. The DIVER platform [92] offered students the ability to create "dives" by marking and commenting video fragments, as well as the ability to share these dives with other students. This approach enabled annotation-based social navigation in video context. The Video Colaboratory [103] made annotation-based social navigation more transparent by visualizing comments and marks of participating students as *signposts* attached to the video navigation bar.

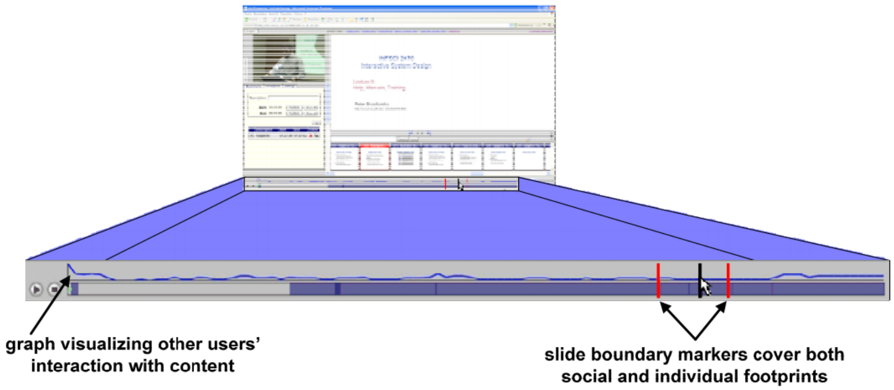

Fig. 12 Social navigation interface for a video lecture in VirtPresenter

7.3 Integrating Social Navigation with other Social Information Access Approaches

Social navigation could be naturally combined with other approaches to information access. Wherever the link to an information object is displayed, be it among other links on a Web page, in the list of search results, or in the information visualization space, it could be augmented with visual cues that express various kinds of socially-produced information associated with an object. In fact, KnowledgeSea (Figure 4), Educo (Figure 5), Comtella (Figure 9), and Progressor (Figure 10) reviewed in this chapter present social navigation in the context of different information visualizations that correspondingly display the volume of traffic and annotations, co-presence, activity, and performance associated with elements of visualization. Two other examples of more advanced "social visualization" that display both traffic and annotations associated with information items can be found in [79, 3]. Similarly, a typical example of using social navigation in search context is the social annotation of search results in the ranked list with associated traffic [2] and social linking information [87]. These examples are reviewed in more detail in the Social Search chapter of this book [14]. A study presented in [13] has shown that it is more influential to provide social navigation support across multiple information-access pathways, including search, browsing, and information visualization.

Despite their demonstrated value, the examples reviewed above present a rather simple integration of social navigation into other information access approaches such as search and visualization. In all these cases, the social data (i.e., clicks or annotations) are collected and processed in the same way as for the traditional social navigation; only the context for presenting social visual cues is different. More interesting are cases of more tight integration where social data and their processing approach traditionally used for one type of access (i.e., search) are used for social navigation.

An example of a tight integration of *social search and social navigation* technologies is provided by the ASSIST system [38, 42]. This integrative system has been designed to exploit the pools of wisdom from users' traces collected through both social search and social navigation. The system collected users' searching traces, such as the search queries and clicks on search results, as well users' browsing traces, such as time spent on each page, page annotations, and navigation from search results to other Web pages. Both kinds of traces were then used to augment user search and browsing interfaces with social visual cues (Figure 13). An evaluation of the integrative system in the context of research paper access in the ACM digital library suggested the potential for integration to provide information access support beyond just the sum of two approaches [42]. A similar attempt to use traces of both search and navigation behavior in a context of supporting user access to YouTube videos is presented in [23].

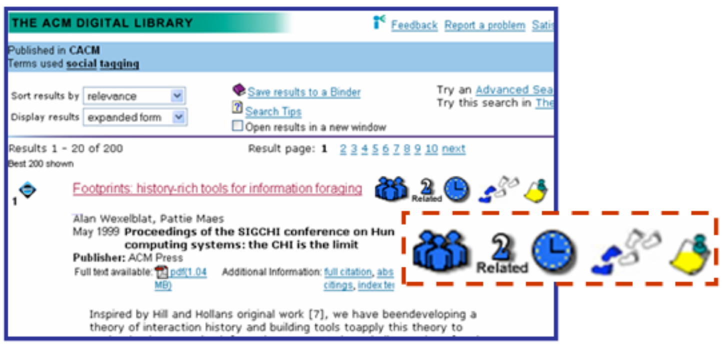

Fig. 13 An integration of social navigation and social search in ASSIST

As an example of integration of *social navigation and collaborative recommendation* approaches, we can consider social link generation based on a broader picture of navigation behavior. Link generation is considered to be one of the major types of adaptive navigation support [**?**], yet almost all social navigation approaches focus on the social augmentation of links that are already present on a page, rather than on generating additional links that would benefit users who are browsing this page. This helps the users to select what is possibly the best navigation step, but doesn't bring them sufficiently close to their possible navigation destination. By accounting for user navigation behavior beyond this single page, it might be possible to deduce more distant or even the ultimate destinations of user navigation and generate links to these destinations. This idea was first implemented by Bollen and Heylighen [6] who demonstrated how multi-step social navigation links could be generated by a transitive closure approach (i.e., $A \rightarrow B$ & $B \rightarrow C \implies A \rightarrow C$). The result of this "distant links" generation – a list of recommended links added to the page – combines the features of social navigation and collaborative filtering and can be generated using data collection and processing technologies from either area. Indeed, one stream of work on "distant link" generation, including that of Bollen and Heylighen, was motivated by swarm intelligence ideas and used social navigation approaches [117, 109] while another stream was associated with the field of recommender systems and used item-to-item [75, 76], graph-based [61], and contextual recommendation approaches [1]. Probably the best known example of generated social navigation linking is provided by Amazon.com recommendations *"Customers Who Bought This Item Also Bought..."* or *"What Other Items Do Customers Buy After Viewing This Item?"* on a specific product page.

8 Evaluation Methods

The evaluation of social navigation technology is particularly challenging. On one hand, to accurately evaluate the impact of social navigation support, it is necessary to study a natural system with a large number of users who can generate data as sources of social navigation support and to allow users to perform information-seeking tasks and navigate through the information space as naturally as possible. However, there is little that can be controlled in these field studies with natural settings, and as a result, only the overall impact of social navigation can be observed in these kinds of studies. Details about how various aspects influence the impact of social navigation support cannot be studied in such settings. On the other hand, the manipulated nature of controlled lab studies can be obvious to study participants, and as a result, their behavior can be significantly altered, as compared to natural or organic conditions. Therefore, researchers in this area have been employing mixed methodologies and pseudo-experiments in an attempt to evaluate the different aspects of social navigation support. The evaluation of social navigation technology has been focused on the following aspects: the overall impact of social navigation support, presentation of social navigation, and circumstances under which social navigation support is positively effective.

8.1 Overall Impact of Social Navigation on Users' Behavior

Studies that examine the overall impact of social navigation use both natural settings and experimental conditions to understand how social navigation support changes user behavior, as well as what kind of "additional value" can be brought by affecting this behavior. The studies that focus on behavioral changes compare user behavior with social navigation enabled or disabled, as well as access to information items that are either enhanced or not enhanced with different social visual cues. In particular, studies evaluating aforementioned systems such as KnowledgeSea II, CourseAgent, Progressor, and Educo show that user behavior is significantly influenced by social navigation cues. Users frequently notice the navigation cues and use the cues to more effectively access the information that they seek. The results of such evaluations showed that resources with navigation cues were accessed at significantly higher rates and that users of the systems followed the footprints of each other, which created a clear path across resources. The studies that focused on "additional value" attempted to register the various kind of benefits that the presence of social interaction could deliver. For example, a study of

Progressor [58] demonstrated that social navigation significantly increases user motivation to work with practice problems while also improving user success rates. KALAS [106] has been evaluated by 302 users. The result of this evaluation shows that users frequently make use of the recommendation feature and are likely to be attracted to the most populated sections of the system; however, they were less influenced by the implicit trail left by other users and left few comments.

Other studies have documented mixed results on the impact of social navigation support on user performance. While a group of users have seemed to benefit from social navigation cues to more effectively access relevant information, others, and especially those with a high level of interpersonal trust, were likely to be led to less relevant resources as a result of being highly influenced by social navigation cues [36]. Another study that evaluated social navigation cues on geographical maps [116] confirms similar results, in that user performance in finding geographical spaces can be improved with social navigation cues only if the cues have come from users who have also been guided and who are reliable sources of cues; otherwise, the presence of social navigation cues does not affect users' performance. Connected to these results, a study in the context of news search has shown that users are highly persuaded by navigation cues on which news article to read, as well as more satisfied with their choice, as long as such cues are generated by others they know and are not persuaded by navigation cues produced by strangers [70].

8.2 Presentation of Social Navigation

The evaluation of the presentation of social navigation has focused on studying ways to visualize and highlight social navigation support. It is vital to understand how different presentation approaches of social navigation support affect user decisions in adherence to the cues. Similarly, it is important to understand how different presentation approaches vary in terms of attracting users' attention to social navigation cues. When evaluating social navigation presentation, researchers most often employed log analysis, which has been complemented by eye-tracking and qualitative evaluations, as well as conducting controlled lab experiments [38]. Their results show that the location of social navigation cues influences how much users notice those cues. These results suggest that the visibility of social cues significantly interacts with users' visual parsing behavior. Social annotations draw more attention when placed on top of search result snippets, especially when the snippets are shorter.

8.3 Circumstances under which Social Navigation Support is Effective

The majority of studies of social navigation have focused on field studies; however, there have been a few studies that attempted to assess the impact of social navigation on information-seeking behavior in lab experiments under controlled settings. One such study was done in the context of fact-finding and generating informational reports [36]. The participants in that study were required to find factual information in response to a set of questions from a large corpus of both relevant and irrelevant news articles. The experiment was conducted as a within-subject experiment by manipulating the task's difficulty and the amount of time available to complete the task, along with the availability of social navigation support. The experiment interface followed a typical search engine look and feel. However, as shown in Figure 14, in the conditions with social navigation support, the search results were augmented by two kinds of social navigation support that were presented to participants as other participants' footprints, but that, in reality, were pre-planned by the study and were the same for all the participants. The results of the study indicated that participants are more likely to make use of social navigation cues when they are under time pressure.

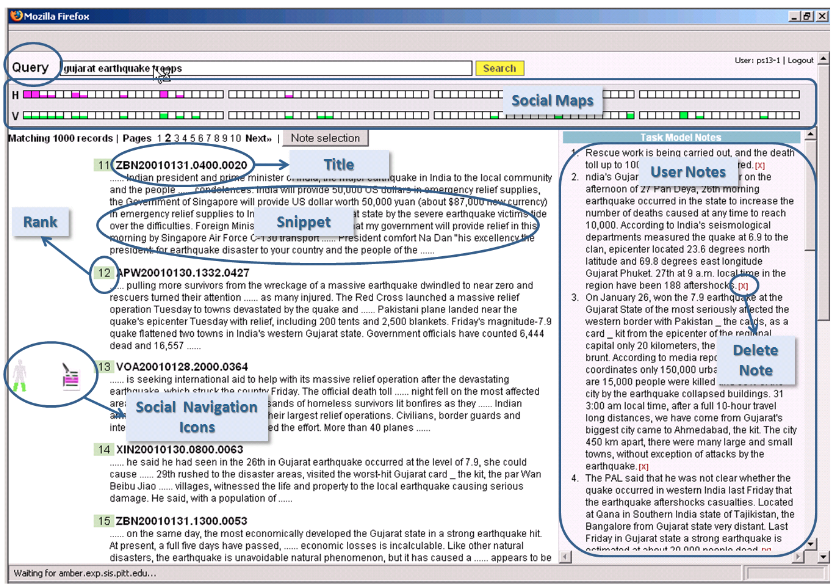

Fig. 14 Social navigation support for fact finding in a large corpus of news articles

9 Concluding Remarks

As a field of research, social navigation is now 20 years old. Over these 20 years, the field has made a significant transition from a narrow topic investigated by a a few like-minded researchers to a relatively large field of work that has influenced many kinds of interactive systems and has affected all kinds of information access. Most importantly, with the growing popularity of social Web applications, there has been a large adoption of the ideas of social navigation support through real-world systems. Many Web applications, such as news websites, integrate social information about how many other people have read a news article or have liked it, and some even extract information from users' social networks about the articles. This information often appears on the sites as "most read", "most forwarded", or "most downloaded" items. Many Web-based information-oriented systems have been transformed into "populated places", as imagined by the early research on KALAT. In these systems, users become first-class citizens that can leave feedback, reviews, and communicate with each other. It is now also a standard practice to engage users in rating products and information items and to display the overall rating alongside the product in every context where it is being displayed. Moreover, social navigation, which was originally motivated by real-world navigation and later enriched by the experience of information navigation, was brought back to help us navigate the real world through location-based systems (such as *Yelp.com* or *Foursquare.com*) and trail-sharing systems (such as *Cyclopath.org* or *trailrunproject.com*).

With all that real-world success, it is important to note that the majority of practical applications of social navigation use it in its simplest form, most often with asynchronous and indirect navigation cues that can be implemented as an overlay of social information on the existing interface. In some senses, we can say that the majority of practical applications of social navigation use techniques that are about ten years old. While most of these applications are affected by the social navigation problems that have been reviewed in this chapter, few applications apply more recent and more advanced techniques that allow users to handle these problems. We think that more research on advanced social navigation is required, as well as more work on integrating the results of new research into practical systems. We hope that this chapter will help both researchers and practitioners in their work on social navigation.

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