Integrating Wikipedia and Facebook Context into Collaborative E-Brainstorming

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ABSTRACT

This paper presents an application for collaborative brainstorming on shared digital displays that integrates online content to help create new ideas during the brainstorming process. The brainstorming application links ideas under discussion to their best matched Wikipedia pages, suggests related ideas for deeper discussion based on items "pinned" on the whiteboard, and recommends a broader scope of new ideas based on users' experiences and expertise, as derived from their social networking profiles. The software system for this application is described, including its idea recommendation engine and UI component. Experimental tests evaluating the application in the context of real users are presented.

INTRODUCTION

Creative ideas generated during a group brainstorming session typically arise from the interaction and ingenuity of the participants involved, as well as the experiences and expertise that the participants bring into the discussion. A potential limitation to this human creative process is that the participants, even if they have broad and deep knowledge, may "draw a blank" during the brainstorming despite having a wealth of expertise and experiences that could be relevant to the session. This limited ability to recall helpful and relevant ideas at key moments in the session hamstrings the overall creative process's breadth and depth of exploration. This may be one of the reasons that people have such a hard time coming up with good ideas during brainstorming.

To help people think of new ideas during the brainstorming process, we describe a new application for shared digital screens and electronic whiteboards that harnesses the wealth of online content present in Wikipedia [27] and Facebook [1] to (1) link currently discussed concepts on the whiteboard with their closest Wikipedia pages, thus bringing a wealth of new contextually relevant information into the brainstorming process, and (2) proactively recommend new ideas for brainstorming based both on (a) which words/phrases are currently "pinned" as important on the whiteboard as well as on (b) users' experiences and expertise, which are obtained from their online social networking profiles.

The overall intent is to more thoroughly connect collaborative brainstorming software to the Internet so that, rather than being a stand-alone entity, it is deeply interwoven with the richness of information available online in such a way that the creative process of discovery is enhanced. This can be achieved by making the data brought in from the Internet relevant to the topic of discussion as well as to the individuals contributing to the discussion. To ensure that the ideas displayed on the electronic whiteboard are in line with the users' goals, the brainstorming application provides flexible control to the users to dynamically adjust the percentage of ideas brought in based on pinned ideas and percentage of ideas brought in based on users' experiences and expertise. The application can be viewed as a tool for helping brainstormers navigate or walk through the Wikpedia link structure - *Wiki surfing* - in a collaborative search for new ideas and concepts in a manner that enhances both the breadth and depth of the search. Figure 1 demonstrates a group of users conducting a Wiki surfing brainstorming session using the application.

This paper builds upon prior work in single display groupware and electronic whiteboards [16, 6, 14], brainstorming applications [11, 10], and proactive displays [13]. In particular, we observe that research such as IdeaExpander [24] is also pursuing the theme of supplementing idea generation during brainstorming with suggestions, which in the case of IdeaExpander consist of pictures that are designed to help stimulate brainstorming. The pictures chosen to be shown are those whose metadata most closely matches keywords mined from a text chat window of the brainstorming session. The pictures are obtained from a small offline database of annotated images. We extend this idea to recommend not just pictures but entire online Wikipedia Web pages filled with pictures, text, and hyperlinks. Proactive displays support a variety of applications that show content that is aware of the identity and profiles of users near the display, e.g. public information about a user, or a graph showing terms mined from profiles that interconnect nearby users. We leverage this idea of making displays more contextually aware by updating collaborative brainstorming applications to make the recommendation of new ideas, in the form of Wikipedia links, based on both users' social networking profiles as well as current session context. GroupMind allows users to drag and drop images from Web pages into a collaborative whiteboard application to manually generate and organize new ideas [20]. Our brainstorming application makes idea gener-

Figure 1. Users interacting with the group brainstorming application.

ation more automatic by allowing users to request the generation of new Wikipedia concepts at any time.

Our contributions are as follows:

- We build an application for collaborative brainstorming on a shared electronic screen that integrates the brainstorming process into the rich semantic link structure and content of Wikipedia.
- Our application enables building session context or focus through pinning important ideas during brainstorming and appropriately focusing future recommendations on these pinned ideas, so that the brainstormers can drill more deeply into the topics pinned on screen.
- Our application enables recommendation of new brainstorming ideas based on the expertise and experiences of participants by utilizing users' contextual history as obtained from their online social networking profiles, e.g. their favorite films, music, hobbies, etc.
- Our application allows users to broaden or focus how closely recommended ideas relate to those ideas pinned during brainstorming, allowing the recommendation engine to be as useful as possible for different brainstorming scenarios and throughout the different phases of the brainstorming process.
- Evaluations of our application are conducted with different groups of users brainstorming on various topics and using multiple versions of the software.

BACKGROUND & RELATED WORK

Our work of leveraging online, social, and session context to support group-based electronic brainstorming draws upon research from several related fields. In particular, the problems of electronic whiteboard design, interactive/proactive display, group-based brainstorming, mobile-supported collaborative work, as well as group characteristics have been subjected to much research.

Electronic whiteboards and interactive displays have been an area of active research during the past decades. A number of solutions have been developed, such as Liveboard, Flatland, Interactive Mural, BlueBoard, MERBoard [6, 14, 8, 19], as well as the interactive electronic wall in i-LAND [21] and the recent table-top interface called WordPlay [10]. These solutions can be used in offices or as public displays, supporting individuals and groups for presentations, interactions, and collaborations. Various issues have been explored by researchers, ranging from hardware design, interaction mechanisms, and specific software applications. For instance, Mynatt et al. proposed techniques for space and history management as well as mapping human behavior to application semantics in Flatland [14]. New interaction techniques for the Interactive Mural display have been proposed by Guimbretière et al. and evaluated in a digital brainstorming tool used by groups of professional product designers [8]. Through a multi-touch interface, users of the WordPlay table-top display can generate, organize, and explore ideas. Speech recognition and natural language processing were also used to facilitate input [10]. Research on the use patterns and design of large interactive displays included the case studies of IBM's BlueBoard and NASA's MERBoard by Russel et al. [19] , the survey by Huang et al. [9], and the whiteboard use study by Tang et al. [22]. Researchers also tried to make the displays more *proactive*. Vogel and Balakrishnan studied the problem of transitioning from implicit to explicit, public to personal, and interaction with multiple users [23]. They used simple hand gestures and touch screen input for explicit interaction; and contextual body orientation and position cues for implicit interaction. McDonald et al. studied augmented applications which try to reveal people's backgrounds and interests in three different social settings at an academic conference [13]. Mobile devices have been proposed as controllers that allow users to "pick and drop" objects around the shared whiteboard [17]. Overall, these solutions focus mostly on the interaction mechanisms between the users and display. Our work advances this area by leveraging online, social, and session context information to automatically suggest new and related topics for group-based brainstorming.

Electronic whiteboards serve as a useful shared screen around which people can gather to participate in collaborative activities [16]. A key utility of electronic whiteboards is encouraging brainstorming by the participants, which is also one of the main motivations that groups get together to meet [18]. A number of brainstorming applications have been developed for electronic whiteboards [11, 10, 20, 24]. The authors of Range focused on the implicit techniques of user reflection, system demonstration, and override and how they can be used to improve the whiteboard's proactive behaviors [11]. WordPlay supports voice and touch based idea generation, multi-touch rotation for idea organization, and idea exploration of computational associations [10]. GroupMind supports idea generation through a collaborative mind-mapping tool [20]. Wang et al. have developed a tool called

Idea Expander [24], which supports group brainstorming by selecting pictures based on the keywords identified in the group's conversation (text in a chat window). A 16-user (8 brainstorming pairs) study showed that the tool helped to generate more ideas and more rare ideas. To make suggestions of novel yet related topics, Maguitman et al. have developed an algorithm that works via an iterative process of topic formation, Web-based search of connected topics, and context-based filtering [12].

Another line of related work studies how group brainstorming works and how it may be impacted by various characteristics of groups [2]. Diehl and Stroebe investigated the problem of productivity loss in brainstorming groups [4]. Experimental studies conducted by Gallupe et al. demonstrate that more and better-quality ideas are generated when group size is larger and/or electronic brainstorming is used instead of verbal brainstorming [7]. Other researchers have also tried to model the process of group brainstorming and idea generation, such as the associative memory model proposed by Brown et al. [3], the cognitive model by Nijstad and Stroebe [15], and the neural model by Doboli et al., which represents categories as networks of concepts and ideas as conceptual combinations [5]. Recent studies by Wang et al. has revealed the impact of cultural differences of group members and communication medium (text vs. video) on computer-mediated group brainstorming [26, 25]. These research works offer valuable insights into how group brainstorming can be supported and improved via electronic whiteboard solutions. And our approach of leveraging online, social, and session context information and recommending related topics is a step towards that direction.

THE BRAINSTORMING SYSTEM

This section describes the evaluation prototype. Our brainstorming application consists of four major components:

1. Facebook Data Manager, which retrieves all strings from users' Facebook profile preferences.
2. Wikipedia Mapper, which maps strings to Wikipedia articles using Google search.
3. Wikipedia Surfer, which retrieves all Wikipedia articles linked from a particular Wikipedia article.
4. User Interface, which allows the user to submit ideas as text, pin ideas of interest, link ideas to Wikipedia articles, and request idea recommendations. The User Interface component also manages all interaction with users' mobile devices.

The first three components support the Idea Recommendation Engine, which can integrate Facebook information, user input, and Wikipedia's link structure to provide idea recommendations to the brainstorming session. The Idea Recommendation Engine sends recommended ideas to the User Interface, which in turn allows users to interact through their mobile devices. The general interaction between these system components is depicted in Figure 2. This interaction and the related functions of each component are described in greater detail in this section.

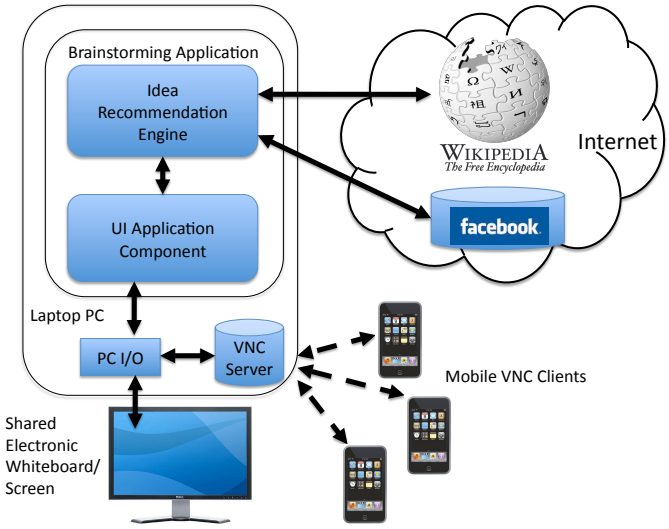

Figure 2. Brainstorming System Components

Idea Recommendation Engine

The goal of the Idea Recommendation Engine is to recommend ideas to the participants for brainstorming. These recommended ideas are displayed on the shared electronic board and can be manipulated by the participants. The idea recommendation engine obtains these ideas by a Google search of Wikipedia articles using a set of text strings, as well as crawling the link structure of different Wikipedia articles.

Below we discuss the three major components that make up the Idea Recommendation Engine. Each component plays an important role in the process of recommended new ideas.

Facebook Data Manager

The Facebook Data Manager takes information from the social networking profiles of the participants. The current implementation focuses only on Facebook, and only on the Facebook "interests" and "movies" fields. However, the particular fields used by the system are configurable within the limitations of Facebook's privacy policies.

Facebook interests do not apply to all situations, and the applicability of using Facebook interests to "prime" a brainstorming application is discussed later. However, once a user's Facebook interests are retrieved, these interests are mapped into the Wikipedia link structure. This is achieved by the Wikipedia Mapper component.

Wikipedia Mapper

The Wikipedia Mapper takes a set of text strings and creates a common bag of ideas, where each idea is a link to a Wikipedia article. This functionality allows text strings to be mapped into the Wikipedia link structure. Many different data sources are supported (e.g., text strings provided by the Facebook Data Manager, or text strings explicitly entered as user input), and the Wikipedia Mapper integrates these sources with the semantics naturally encoded in Wikipedia's link structure. This mapping operation is done using the

Google search engine. Mapping begins with a Google search of Wikipedia performed using the raw text string. The top result from this search, a Wikipedia article, is retrieved and then parsed to extract all links in this article to other Wikipedia articles. This set of Wikipedia article links creates a common bag of ideas. Wikipedia Mapper is used to seed the initial set of recommendations at the start of a brainstorming session, as well as when users input new text strings during a brain storming session.

Wikipedia Surfer

The Wikipedia Surfer drives the system's idea recommendation. It is activated every time a participant refreshes the screen using the idea refresh button (described in the next section). It computes a new set of ideas and displays them on the shared electronic board. Given a set of ideas that map to Wikipedia articles, the Wikipedia Surfer uses user input to drive how the brainstorming application traverses the Wikipedia link structure. This process will be explained in terms of "ideas" displayed as items on the electronic whiteboard, each of which maps to a Wikipedia page. These ideas are divided into two "bags": the "common bag" and the "pinned" bag. The pinned bag consists of all ideas that the participants have "pinned" on the electronic whiteboard, explicitly indicating interest in them. The common bag consists of all other ideas (unpinned items) displayed on the electronic whiteboard.

When a user pushes the idea refresh button, a certain percentage of ideas are taken from the common bag, and the rest of the ideas are taken from the pinned bag. The percentage of ideas taken from the common bag is set by the user via a slider bar UI control, called the "Focus Control". For example, if the Focus Control is set at 50%, then 50% of the ideas selected come from common bag and the remaining 50% come from pinned bag. Once these ideas have been chosen, their related Wikipedia articles are "surfed" to find all Wikipedia articles linked to from them. This new set of ideas becomes the new common bag of ideas. Furthermore, the pinned ideas stay pinned and remain on screen as the pinned bag of ideas.

This process, together with the Focus Control, allows users to specify whether the suggested ideas generated by "Wikisurfing" should be focused around the pinned ideas or more diversely spread across those ideas in the common bag of ideas. Over many iterations with the Focus Control set to a certain level, the ideas will tend to link to the pinned ideas through many hops following some distribution that depends on how the Focus Control is set. For example, after four iterations with the Focus Control set to 50%, the common bag of ideas will tend to contain about 50% ideas one-hop (Wikipedia link) from the pinned ideas, 25% ideas two-hops from the pinned ideas, 12.5% ideas three-hops away, and 6.25% four-hops away, with the rest of the ideas made up of ideas randomly chosen from those un-pinned ideas originally in the common bag. This example illustrates how the Focus Control can be used to narrow or broaden the Wikisurfing process.

The Focus Control can be adjusted dynamically between every screen refresh. For example, in a typical brainstorming session participants will initially set the Focus Control to a low percentage value (e.g., 20%), allowing most of the recommended ideas to come from the common bag, and thus providing scope for a large breadth of ideas on the shared electronic board. When participants feel that they have seen a sufficiently wide variety of ideas, they will start pinning relevant ideas and adjust the Focus Control to a high percentage value (e.g., 90%), resulting in more recommendations from the pinned bag. This will let the participants converge on a smaller number of relevant ideas as the brainstorming session concludes.

Note that our design is flexible enough to permit the idea recommendation engine to be situated on another server, perhaps in the cloud, offered as a Web service. We consider this as future work. For the present, the idea recommendation engine is collocated with the UI component.

THE BRAINSTORMING APPLICATION

In this section, we describe the brainstorming application's UI application component, which controls what items appear on the shared electronic screen, and how users interact with those items.

User Interface

The user interface supports many user interactions that affect how ideas are recommended by the system. Each of these interactions are discussed below along with a general reasoning for their inclusion in the system. The interface elements discussed in this section can be seen in Figure 3.

Displaying Ideas

Ideas are displayed with their text title enclosed in a rectangular box randomly located on the screen. The box in which the text is located has a pin icon to the top right and turns blue to indicate an item has been "pinned".

Pinning Ideas

An idea is pinned by the user double-clicking on its representative icon. Pinning an idea indicates that this idea is important to the brainstorming session and that it should be persisted between refreshes, as explained below. Pinning an idea causes it to be moved from the common bag of ideas to the "pinned bag" of ideas, so that it can have more influence when ideas are recommended. Also, the pin icon above the related idea changes its background color to blue, and the rectangle encompassing the title of the idea turns from green to red.

Once an icon has been pinned, then a user can click on its Wikipedia link, allowing the user to view the associated Wikipedia page in a browser. An artifact of the current implementation caused by the Java SWT library that we used was that we did not find an easy way to allow UI objects on the screen to be both toggled between pinned/unpinned states and traversed as a hyperlink using a single click, hence our use of double-clicks.

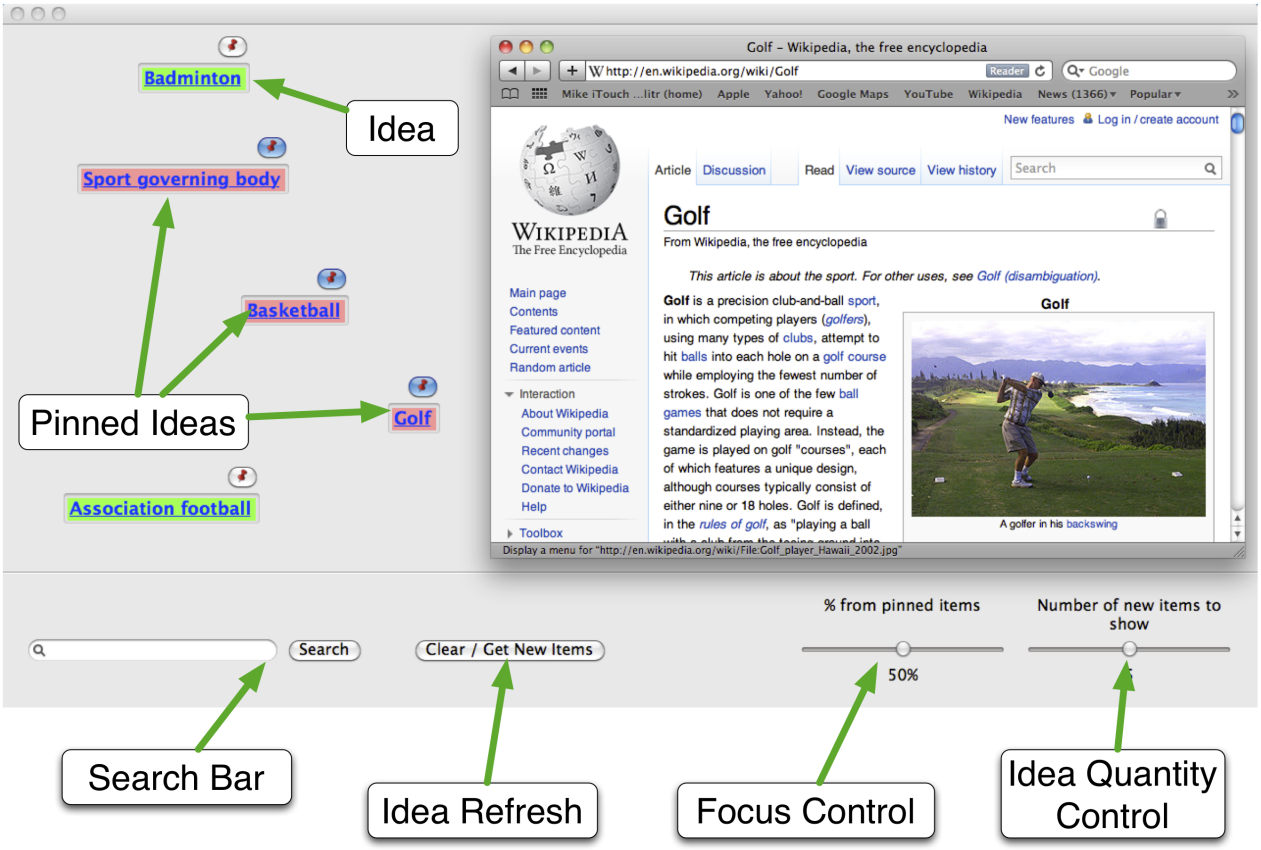

Figure 3. Screenshot of a brainstorming session showing the pinned and unpinned items, search interface, and other control components.

Adding Ideas via the Search Bar

Ideas can be added to the screen by typing them into a text box or Search Bar in the lower left hand corner of the interface. Doing so, maps the entered string to a Wikipedia article and adds the item as a new idea to the common bag of ideas. In this way, users can supply their own ideas, which are then mapped to the nearest Wikipedia page and displayed at a random position on screen.

Dragging Ideas

Ideas can be dragged (click-and-drag) to any location within the screen space for ideas. This allows users to emphasize objects by grabbing and moving them or allows the users to group items spatially as they relate to the group brainstorming process.

Idea Refresh Button

Clicking on this button serves two purposes: first, unpinned ideas are cleared from the screen; second, new linked ideas are added to the screen. Thus, when users would like suggestions (through Wiki-surfing), they press the "Idea Refresh" button which erases from the screen any ideas that are not pinned, and further triggers the Idea Recommendation Engine to begin Wiki-surfing according to the users' input and pinned ideas, taking into account the desired focus of the group. When pressed, the previous ideas are removed and new ideas are presented on the screen for further brainstorming.

Focus Control

When the Refresh button is pressed, new ideas are recommended based on the degree of focus desired. The degree of focus is expressed as a percentage signified by the position setting of the leftmost slider bar. When the slider bar is set to the far right at 100%, i.e. most focused, then all of the newly recommended ideas will come from the bag of ideas associated with the pinned items on the screen. This permits brainstorming users to drill down into the set of items already pinned on the screen, and investigate the pinned items in depth. When the slider bar is set to the far left at 0%, i.e. least focused, then none of the new ideas will come from the pinned items, and instead all of the new ideas will be recommended from the common bag, which includes ideas taken from users' social networking profiles for breadth, and previously unpinned ideas.

Idea Quantity Control

When the Refresh button is pressed, a certain number of ideas are retrieved from the common and pinned bags of ideas. The Idea Quantity Control is a slider bar in the bottom right of the screen that controls the number of ideas that are generated with each refresh. Sliding the bar to the right increases the number of ideas shown on the screen, sliding the

	C1	C2	C3	C4
V1	G1,G2,G3		G4	
V2	G4	G1,G2	G1	
V3		G3,G4	G2,G3	
V4				G1,G2,G3,G4

Table 1. Assignments of groups (G) to different brainstorming topics/cases (C) and software versions (V)

bar left decreases this number. The current range of ideas is from 1 to 10. We provide this UI control because in different brainstorming scenarios, groups may either not want to be overwhelmed with too many ideas at once, or may want more ideas than the current setting allows. This slider control gives groups control over adjusting the number of ideas generated at each iteration.

Supporting Mobile and Remote Users via VNC

The prototype runs a Virtual Network Computing (VNC) server, allowing users to login and interface with the system from any device with a VNC client. This makes the application accessible to a group of users, colocated or remote. This approach easily turns our application into groupware, whereby any number of VNC clients, hence users, can connect with and interact with our application. For our tests, we used iPod Touches as local mobile VNC clients to allow users to interact with the brainstorming application on a nearby shared electronic screen, i.e. they could control the mouse cursor's position on the screen by sliding their finger over the iPod Touch's screen. Similarly, text entry was possible via the mobile VNC client. We have designed the application to be flexible enough so that in the future any VNC clients, even remote VNC clients, could participate in networked brainstorming sessions, though we have not tried this scenario yet.

An Example

Figure 3 is a screenshot illustrating an example of a brainstorming session. The pinned items (e.g., "Golf") are shown in light red, and the unpinned items (e.g., "Badminton") are shown in light green. Users can also search for Wikipedia pages, get new recommended items, as well as adjusting the source and number of the new recommended items. A browser window is also opened to the Wikipedia page corresponding to a pinned item.

EVALUATIONS

In this section, we evaluate the effectiveness of the brainstorming application through user studies of real-world group brainstorming scenarios. We are interested in how users respond to the application and to what extent the application enhances group brainstorming experience and outcomes. We first describe the evaluation methodology, followed by detailed analysis of the evaluation results.

Evaluation Methodology

To evaluate our brainstorming system, we conducted a set of brainstorming sessions with different groups of users. An initial twenty-minute training session was provided to each group to explain various aspects of the brainstorming application to the participants, i.e. what are the features of the application, how do you use them for brainstorming, and what kinds of experiments would be conducted. Also during this time, participants were informed that their sessions would be logged, that their Facebook social networking profiles would be accessed, and that following each session their feedback would be requested, namely they would need to fill out survey forms assessing on a scale of 1-10 (1=least favorable, 10=most favorable) how satisfied they were with the group's chosen brainstorming idea (or the progress toward the idea, if no final idea was chosen), how useful were the computer's suggestions, and rate their overall experience with the application. Informed consent forms were then signed.

Each group was given four different topics or cases on which to brainstorm for fifteen minutes each using our application. The cases that we asked the groups to brainstorm on were:

- *C1:* Identify the most promising green energy solution for the next century;
- *C2:* Identify the biggest American cultural change in the past 10 years;
- *C3:* Select an outdoor activity that the whole group would enjoy; and
- *C4:* Decide on a movie for the whole group to watch.

These topics were selected to give a spread of topics, some of which are more general in nature, and others which are more contextual to users' personal experiences.

To explore the various features of the brainstorming application, we created four versions of the application:

- *V1:* Baseline version where ideas are only user-supplied, i.e. users can enter items via the Search bar and click on Wikipedia links, but there is no recommendation of ideas by the application;
- *V2:* Pinned ideas only – the application suggests items related only to pinned ideas using Wikipedia;
- *V3:* All slider bars are enabled, and recommendations can come from both pinned items and unpinned previously entered items, except that Facebook social profiles are not used for seeding ideas in the initial common bag; and
- *V4:* Fully featured with all slider bars enabled, and using Facebook social profiles for seeding ideas in the initial common bag.

We tested four different groups of three users each. Groups 1 and 3 consisted of entering graduate students, Group 2 consisted of advanced doctoral-level students, and Group 4 was comprised of second-year business graduate students.

The groups were assigned to test the different cases and different software versions according to the matrix of assignments shown in Table 1. Our goal was to spread the assignment of groups across different cases and versions while still having some overlap among the groups. While it was feasible to test a given group more than once on the same version

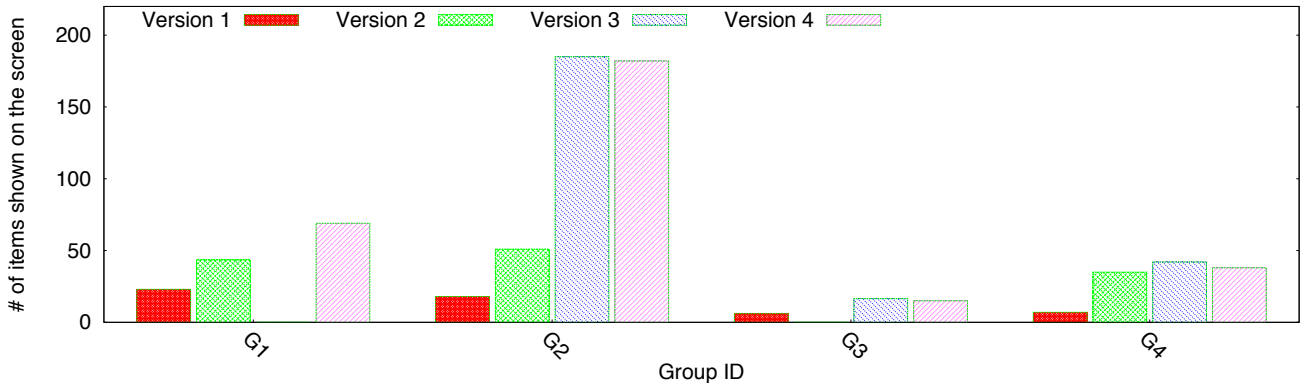

Figure 4. Number of items shown on the screen vs. application version.

of software, one constraint that we faced was that it did not make sense to have the same group brainstorm on the same case more than once, as the second time brainstorming on the same topic would bias the result, since the group could use the results of their first session to inform the second one. As a result, each group brainstorms on a different topic for each session, even though they may use the same software version.

Besides evaluating the application using the user survey forms collected after the brainstorming sessions, we also instrumented our software to collect logging information. Every time the refresh button was pressed we logged the event, as well as the parameters surrounding each refresh, namely what was the % setting of the Focus control slider bar and how many recommended items were being requested as set by the Idea Quantity Control slider bar. Every time an item was pinned or unpinned, we logged the event. We also logged clicks on hyperlinks that invoked the browser, and text entered into the Search Bar. With this type of logging, we were able to measure metrics such as the number of new items recommended, and the number of pinned and unpinned items per session.

Facebook profile information was obtained in the current implementation by having each of the group members friend one of our co-authors on Facebook. Once they had friended us, then their Facebook information could be accessed. We plan to improve this mechanism in future versions of the software by allowing independent login by the users, without requiring any involvement by the authors.

Analysis of Evaluation Results

We collected data for all of our user study sessions. The data we collected include logs of user activity automatically recorded by the brainstorming application, post-session surveys, and comments from the users that we noted over the course of each brainstorming session.

Data from the log files we have collected indicate that pinning items allows users to obtain more recommended ideas during the brainstorming session, which helps to increase the breadth and depth of ideas generated while brainstorming. Figures 4 and 5 present data on how many ideas were shown

Group	V1	V2	V3	V4
G1	0	10, 10	NA	19
G2	0	9	30	31
G3	0	NA	3 | 1	2
G4	0	7	11	5

Table 2. Number of refresh button clicks

and pinned during the user study sessions. The application version and group number of each session are specified in these figures. When one group tested the same version more than once, the results of these sessions were averaged. In the case that a group did not test a particular version of the application there is no data shown. Figure 4 shows that, as compared to version one, versions two, three, and four of the application generated more items on the screen over the course of a session. Figure 5 shows that users pin more items over the duration of a session for application versions two, three, and four. Recall that the only functional difference between version one and version two is version two's addition of recommending new items related to currently pinned items. Therefore, together these results show that item recommendation is effective in terms of generating more ideas during brainstorming than could be generated solely through a process of users manually supplying new ideas.

Since each brainstorming session is limited to 15 minutes, it is possible that the group may not have converged (i.e., decided on a particular idea) by the time the session ends. During each session, when the current brainstorming ideas do not converge, users tend to request more suggestions by using the application rather than manually coming up with new ideas directly from their own minds. As shown in Table 2, the pink cells represent the brainstorming sessions that did not converge within 15 minutes, and the number in each cell represents the number of times that the refresh ("Clear / Get New Items") button has been clicked by users in each particular session. An interesting observation from the table is that the non-converged sessions (7 out of 16 sessions in total) usually have a higher number of refresh button clicks than that of the converged sessions. According to our statistics, the non-converged sessions have on average 14.4 refresh button clicks, compared with 4.1 clicks on average for the converged sessions. As one of our participants has commented:

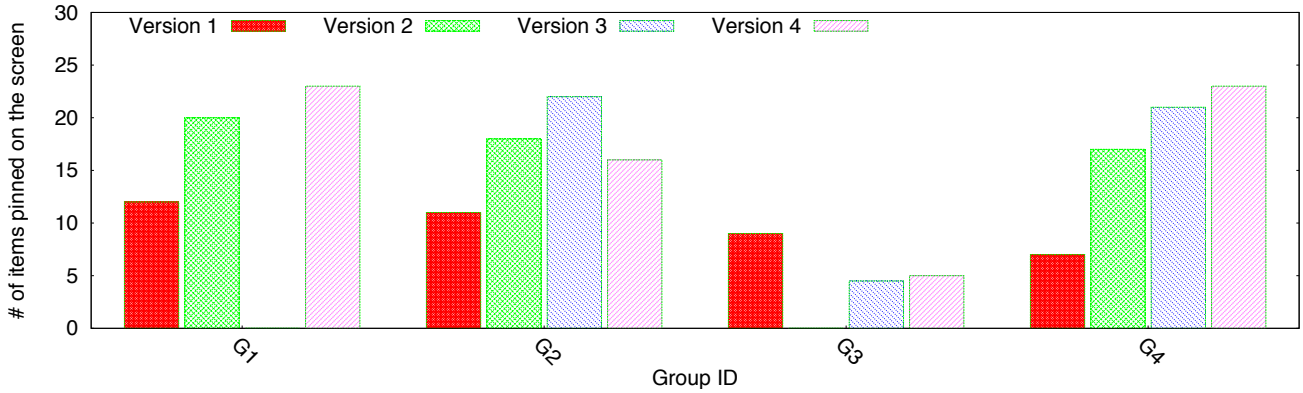

Figure 5. Number of items pinned on the screen vs. application version.

"Coming up with a new idea concerning a topic which I am not familiar with is fairly difficult. I am more than happy to obtain the assistance from the application."

As the number of refresh button clicks increases, users request more idea recommendations from the system. Good recommendations are then identified by the users and "pinned" on the screen. As a result, more ideas are generated and pinned in each session, representing a larger and broader scope of brainstorming ideas. Such broadening effect is desirable in group brainstorming sessions, and in particular, non-converged sessions. As one of the participants has commented:

"Bringing in other search engines like Google search would be helpful for us to drill deeper and may help us converge our idea faster; however, the application does provide us with very broad ideas. Especially when we discuss American culture changes over the past 10 years, the application makes us open our mind to a wide world ..."

Consider the following example in our user study, where we study the relationship between the number of refresh button clicks and the number of pinned items (Figure 6). We can clearly see the trend that more clicks of the refresh button lead to more pinned items on the screen. This is consistent with our participants' comments. Specifically, when a brainstorming session does not have a converged idea, the number of items that are pinned on screen continue increasing, resulting in a broader scope of useful ideas recommended to users.

We observed several instances where users started the user study session with the brainstorming application focus control set to a lower value, between 0 to 50%, with one to four items pinned. In one instance, the group increased the focus control to 76% and clicked the refresh button several times. After eight refresh iterations, this group pinned two more new items and moved the focus control to 100%. This behavior indicates that the group was initially exploring a breadth of ideas, and then decided to explore more focused ideas related only to pinned items. This example demonstrates the utility of the focus control in the brainstorming process.

In our post-session surveys, we asked users to rate the different application versions using a scale of 1–10, where 1 means least favorable and 10 means most favorable. Overall, our users tend to give higher ratings to application versions two and three than the other versions in terms of satisfaction with the group's chosen idea (or progress toward the idea), usefulness of the computer's suggestions, and the overall experience with the application. Several user comments indicated that the recommended items were useful in bringing up ideas that the group members were not aware of or would not have thought of without assistance. Three of the four groups rated version four of the application lower than the other versions. Based on user feedback, it appears that the primary issue was that the application did not allow the groups to drill as deeply as they wanted, i.e. the way we implemented recommendations did not intersect the pinned items, so that for example when "comedy films" and "2010" were pinned, we did not automatically recommend pages that had both of the terms. The topic of choosing a movie to watch together may have exacerbated this issue. Another observation was that users tended to keep the application focus control set to 100 percent for this version, indicating that they generally wanted to keep recommended ideas more focused on the pinned items. Based on these results, the intersection capability for drilling even more deeply will be added to a future version of the brainstorming application.

Analysis of User Comments

The first group that evaluated the brainstorming application remarked: *"The experience with the system was good as we were able to converge down to an idea , but the application can produce more related searches."* This group found the idea of pinning an item and fetching related items to the item being pinned quite useful, as it helped them to brainstorm and converge on the C2 topic ("Identify the most promising Green Energy Solution for the next century"). After looking through various ideas, they were able to decide on "sustainable energy" as their probable solution. The group suggested and desired the idea of having more related search results, similar to the presentation of search results on the Google search engine.

Another group remarked *"The idea of extracting Facebook interests from our profile seems to be a good idea, but more*

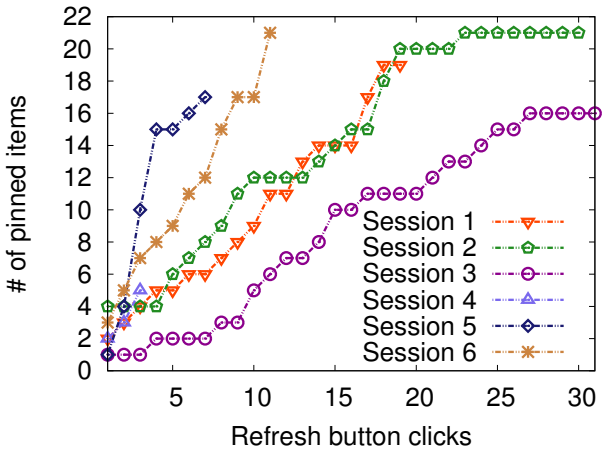

Figure 6. More pinned items lead to more refresh button clicks and broader scope of brainstorming ideas.

items from the Facebook account can be extracted which might be useful." This group was excited with the fact that they could use to their interests, with the help of brainstorming application, to decide on a movie for the entire group to watch. The group found it easy to decide on a movie to watch by using their movie interests from Facebook, but they suggested that more details be extracted from Facebook to help them converge on other ideas apart from movies.

The third and fourth group provided another important insight on the brainstorming application. The third group found the idea of system recommendations quite useful. The group was brainstorming to converge on an outdoor activity for the whole group. While pinning items and fetching their related items are useful, when they decreased the "Focus control" bar to 50%, they found that 50% of the ideas were based on the pinned items and 50% were new and related ideas automatically recommended by the application. One of those recommendations, "paintball", seemed to be exactly what they were looking for. The group also wanted a way to have a search feature that can provide them with results based on the intersection of a subset of displayed "pinned" items. For example, the group wanted to have a list of comedy films produced in 2010 if they had pinned "2010" and "comedy film".

The fourth group was not familiar with the brainstorming topic assigned to their group. This group was composed of Chinese students and they were asked to brainstorm on "The biggest cultural change in US in the last ten years." They did not know where to begin. But with the help of application-generated recommendations they were able to make good progress and identify a set of broader yet useful ideas. They particularly liked the fact that the application was able to help them arrive at a broader perspective on a topic alien to them. The group also suggested that the ideas provided by the application are broad in nature and would like to have more depth in the search results. A Google-like search mechanism would be a good addition to the brainstorming application and very useful for the group.

From the user studies it was clear that the users liked the idea of pinning items and getting related searches iteratively until they could converge on an idea. The brainstorming application seems to provide the capability of helping users to arrive at a broader perspective on ideas. The fact that users are able to converge on a broader idea for an unfamiliar brainstorming topic was one of the motivations behind our application. Nevertheless, there is opportunity for reasonable enhancements as suggested by the user groups, which we discuss next.

IMPLICATIONS FOR FUTURE RESEARCH

We have identified a plethora of future research directions, the sheer volume of which indicates that our brainstorming application's theme of integrating online content and user context into the collaborative brainstorming experience is ripe for much deeper exploration. The algorithm for recommending new ideas from pinned and unpinned items deserves more research. We plan to add the ability to recommend new ideas based on combinations of intersections of pinned ideas, and will conduct further user studies. Also, we plan to explore other mechanisms to improve the breadth and depth of idea recommendation, like (selectively) expanding the search radius to two or three Wikipedia link-hops.

We seek to add functionality so that users can group ideas together and label them as a single integrated idea, and then create hierarchies of grouped ideas to better organize ideas. We will also consider updating the recommendation engine to account for the physical distance between ideas on screen, which may be an important indicator of the perceived semantic proximity of ideas. We intend to experiment with pushing new ideas to users periodically, in addition to having users request/pull new ideas via the refresh button. We hope to update t so that it shows recommended multimedia images and video in addition to text links, allows easier login to social networks, and can save user sessions for later replay. We would like to expand our binding to online resources by integrating more information sources, such as LinkedIn, Google, etc, and widen our willingness to consider Web pages beyond Wikipedia as potential links.

Privacy needs to be considered more fully, especially if more data sources are integrated. We have assumed that participants voluntarily contribute personal information such as their social networking profiles because they want to brainstorm together using our application. Ours is an opt-in policy, so users can still participate in the application without divulging their personal information, though this handicaps the breadth of idea recommendation.

Ultimately, our goal is to release our brainstorming application as open source to the community, so other researchers can use the application as a platform to explore some of the research issues mentioned above and innovate in their own novel directions.

CONCLUSIONS

This paper has presented a new application for collaborative brainstorming on shared digital screens that links ideas

to Wikipedia pages, and recommends new ideas for discussion based both on the session context of "pinned" items on the whiteboard as well as the social context obtained from Facebook. We show through user studies that our application allows users to obtain more ideas during the brainstorming session. Recommending ideas is effective in generating more ideas during brainstorming than could be generated solely through a process of users manually supplying new ideas. We also present anecdotal results that show in different scenarios for different groups how our application was able to suggest ideas to groups that were appreciated as helpful and were not previously considered during the brainstorming session. The application opens the door to a new generation of collaborative electronic brainstorming applications that are more comprehensively tied in with online content and social and session context in order to suggest new ideas for brainstorming and thereby enhance the overall brainstorming experience.

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