Paper Collaborator: physical interaction with digital documents

Malte Jung + Howard Kao + Ravi Tiruvury + Parul Vora
Stanford University
Human Computer Interaction
{mjung, hkao, raviteja, parutron}@stanford.edu

ABSTRACT
In this paper we address some of the issues faced in collaborative design work. Design project teams share an assortment of documents and files during the course of a project, such as paper sketches, post-its, idea logs, polished presentations, web links, photos and videos. We propose Paper Collaborator which seeks to make document sharing easier and more effective by physically manifesting and integrating the entirety of a design team's documents into an interactive wall in the team's shared workspace. A paper and pen based interface, Paper Collaborator, facilitates the access, sharing, and organization of these documents by offering the benefit of physical affordances to otherwise virtual objects.

Author Keywords
Tangible user interfaces, ubiquitous computing, collaborative computing, computer supported collaborative work.

INTRODUCTION
One of the main challenges in team-based design projects is the collaborative sharing of data. During the course of a project, team members share an assortment of documents and files such as paper-sketches, idea-logs, documents, reports and web-links. Presently these are distributed and discussed over email, while being physically and temporally co-located, online through shared blogs and wikis, or by tacking, taping, and otherwise posting these on common walls in the workplace. These walls are likely appropriated because they are shared, readily available and visible, large in scale and capacity, and serve as a physical location for discussion.

Whittaker and Schwartz [10] compared the performance of two software development teams, one using electronic means to co-ordinate their work and the other using a wall-sized bulletin board in a shared space. They found that the board encouraged discussion, while the emailed documents did not "substantially contribute" to the project. Churchill, Nelson, Denoue and Girgensohn [6] investigated the difference between content sharing online and content sharing by posting to a physical space and found that the content posted to the physical space became topics of conversation and led to increased interaction.

Paper and walls "make information, any kind of information, tangible, easy to manipulate, and easy to organize" [9], but however have a limited capacity and are difficult to distribute, search, update, and archive. The Paper Collaborator seeks to both give digital documents a physical presence, and to integrate some of the benefits of electronic media into the walls of the workplace to make information and idea sharing easy and effective. Presenting all shared documents, sketches, and notes on a shared workspace wall-sized display increases the collective awareness and communication amongst design project team members.

USER GROUP
To design and evaluate Paper Collaborator, we partnered with the "Daikin Personal Climate" team from the ME310 Class at Stanford University. The team is working on increasing the efficiency of personal air-conditioning systems and reducing energy costs. As part of the project, the team members regularly update their project space on the ME310 Wiki, almost on a daily basis. They upload into the Wiki all kinds of documents, pictures, images, videos, research papers and web-links [1].

PROTOTYPES
Our initial design involved a display with a very easy and straightforward interaction for the user. The display had two parts. The first part was a wall-sized arrangement of physical icons, each one representing a different document. The second part was an LCD screen. When the user selected an icon, the corresponding document would be displayed on the screen. To minimize the overhead for the user, our design called for the arrangement of the icons to be automated, presenting them in a way that would help the user discover, locate, and identify documents of interest. We tried two different technologies for enabling the selection of physical icons: initially barcodes and later the Anoto pen (Figure 2).

Figure 1. Elements of Paper Collaborator prototype.

Barcode

To read barcodes, we used a standard Apple iSight web camera and the EvoBarcode software package [4]. We used Barcode Font [2] to print a unique barcode for each document. While the barcode system could be prototyped quickly, we found that the barcodes had to be very carefully oriented to be recognized, creating intolerable latencies as the user waved the camera repeatedly over the barcode. While more robust barcode recognition systems existed, in the interest of time, we moved on to the Anoto pen.

Anoto Pen

The Anoto pen is a ballpoint pen with a built-in camera and Bluetooth connectivity. It is meant to be used with Anoto paper, which contains a light dot pattern that allows the pen to identify its coordinate position on the paper. We adapted some of Ron Yeh's work on ButterflyNet [3] to map patches of Anoto paper to specific documents and display those documents on the shared LCD screen. While the Anoto pen had its own problems with reliability, we saw some major advantages in the pen over the barcode reader, including the affordances of the pen for pointing, marking, and annotating.

ME310 Loft Version #1

Our first prototype consisted of an acrylic board mounted to a storage rack in the workspace of the ME310 project team who agreed to test out our prototype. Attached to the board was a laptop that served as a screen and the Anoto pen. To the right of the laptop was a large, open area where we arranged the icons representing documents. Each icon consisted of a thumbnail and a patch of Anoto paper glued to a small Post-It. They were arranged from top-to-bottom, left-to-right in reverse chronological order of when the document was made available to the project team. The use of Post-Its was chosen because they allowed for rapid updating of the display and enabled the user to rearrange the display as they saw fit.

Figure 2. Initial Anoto Pen based interface installed in the ME 310 Daikan Teams workspace.

Current Prototype

As the ME310 project team members used the prototype, we observed some shortcomings that persuaded us to make some changes. We tripled the size of the icons based on two observations: one, that the small size of the original icons made it difficult to identify the documents that they were supposed to represent, and two, that the project team was not taking advantage of the opportunity to reorder the icons; we hypothesized that an icon that the user could grasp in his hand versus plucking with his fingers would encourage greater interaction. To support the larger and growing number of icons, we doubled the size of the display. We also repositioned the icons along the edge of the display area, creating a clear, "scratch" space in the center where they could move icons to and work freely in.

Icon Experiment

Based on our general observations we designed a short experiment to get further insight into the effect of different representations of the paper icons. Our motivation during the experiment was to observe how our users would represent their ideas on post-its, and how they would organize it on a large-sized display. For this, we collected various data samples related to their Daikin Project – text documents, pictures, images, photographs, PowerPoint presentations and videos. We manually created various representations for each data sample. For Word documents, we chose representations that involved one or more of the following: filename, title, keywords, initial text, text with highlighted keywords, the MS Word Icon. For PowerPoint files, we chose combinations of: filename, first slide, first few slides and the PowerPoint icon. For Videos, we included filenames, video title, and some video screenshots. For Images (with and without text), we used the filename, image thumbnail, image with part of the text.

We chose 30 representative document samples and created multiple representations for each of them, as shown in fig 1.

Each of our users was then asked to pick one representation from each stack, and arrange them on a whiteboard as per their preference. The idea was to see what kind of representations are most-used, and how people would arrange the content on a shared workspace. We asked the users to talk through their task, and we obtained some really interesting patterns in selecting an organization and representing it.

EVALUATION

General qualitative observations: The Cost vs. benefit ratio was too high. The display usage was heavily influenced by the reliability of the Anoto pen system. After an initial higher usage due to excitement about the new technology the observed team used the system more and more sparsely. Several students reported that after trying to get the system to run for several seconds without success they felt it was faster to access the data in the standard way.

No effect on re-use: The display did not affect re-use as intended within the observed team. It is assumed that the main reason for this is that the content of the display is focused on publishing-items rather than items the team was working with such as word or excel documents.

Presentations as preferred usage scenario: The team reported to have used the display mainly to present their project ideas to people outside their team. One student explained that the system was very helpful for ad-hoc presentations since the content was always present and readily available. This observation is also heavily linked to the intent the team had when uploading content to the wiki as most of this content is meant for presentation rather than collaboration

Evaluation of usage log: To evaluate display usage in detail every interaction was logged. Precise time-stamps of the interactions could not be recorded due to technical reasons. The following graph gives some insight into which items were accessed.

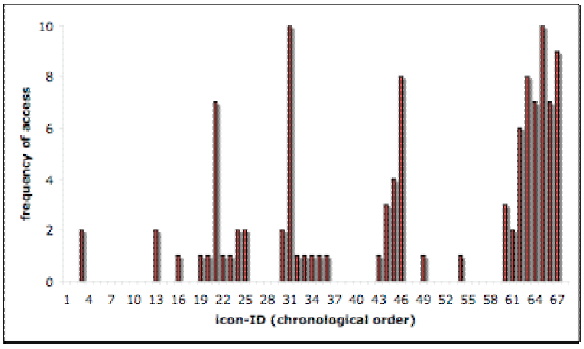

Figure3. Number of individual accesses for each document over the 2 week evaluation period.

The Graphs shows the ID-number of each icon in chronological order on the horizontal axis. The vertical axis represents the number a specific item was accessed. The graph shows a more frequent usage towards the more recent additions to the display. Since the display was only introduced at a later stage of the project, this could mean that the team accessed preferably items that were close to their current state of the project.

When looking at the icons that were accessed most (6 or more hits) no clear preference pattern can be found. There might be a slight preference towards pictures regarding the presentation style and a preference towards benchmarking items regarding content. However the sparse data set doesn't allow for more than just preliminary notions.

Observations made from the experiment: The experiment was conducted at the Center for Design Research with each of the four team members individually. Each session including exit interview took 40 to 60 minutes and was videotaped for further reference. After a thorough evaluation, we make the following qualitative observations about the Paper Collaborator:

Display layout based on individual preferences. The designed layout of the icons differed between all four subjects (see figure below). One Subject preferred to categorize the items based on the milestones of the teams project whereas another subject chose a more “item type” based categorization. However all subjects grouped icons that referred to a similar file type. Although not emphasized by all subjects, a clear preference towards representations with file-type icons was observable.

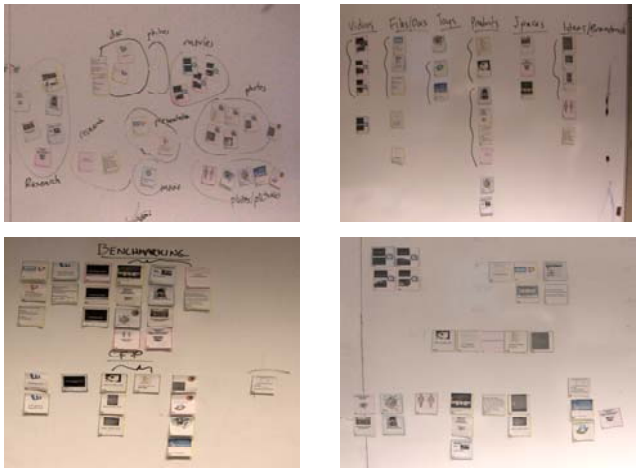

Figure 4. Different icon arrangements created by 4 users in our design exercise.

FUTURE DIRECTIONS

To be able to focus on improvements and more detailed evaluation the generation of icons has to be automated. Having a database as storage that can be updated through

various sources such as email or mobile devices makes it possible to enlarge and broaden the data set. The data set should be extended to contain working items such as research documents, excel files, and ideas in progress rather than just finished and refined content meant for presentation. To achieve this better information input paradigms have to be found. A capture function that retrieves content right off the display or from the workspace might be useful to achieve this. To reduce the effort to re-use the speed of the interaction can be increased further. One possibility would be to use an offset screen that displays the digital content of icons in an x-ray type fashion as they are moved behind the screen. Given that extended interaction a detailed evaluation framework has to be developed to study the effect of the display on sharing and re-use in and outside the observed design team. Further the display can be tested in the setting of a globally distributed team. Here the impact of presence and awareness on reuse might be more easily observable.

Additionally, in the course of our Icon Experiment, we noted that the choice of representations for documents was inconsistent both for different documents of the same type for a particular user as well as between different users. In retrospect, this inconsistency isn't surprising because each user has an individual experience with the documents, and this should be taken into consideration.

Had time and technical limitations not been there, we would have liked to further develop the Paper Collaborator system to automatically updated the content of the physical wall display, allow two way symmetric communication between the physical display and digital documents such that physical manipulations could result in a reordering or rearrangement of electronic files, such as the wiki, experiment with touch interactions, and provide different information visualizations for the physical icons by perhaps allowing for informal categorizing and tagging that could be made appropriately visible.

CONCLUSION

Giving the ME310 Daikan teams' digital documents a physical presence with the manipulability, organizability, and visibility that affords proved useful more as an archive than as a tool for collaboration. The cost/benefit ratio did not fit for the intended use. The system was intended to add presence to items that are otherwise hidden. However the display content was based almost exclusively on content from the team's wiki which was meant for publishing rather than an active exchange or collaboration. Our display thus competed directly with the wiki. The reliability of both the barcode and Anoto pen interfaces also negatively affected the cost-benefit relationship more than expected in our intended scenario.

We believe the limited success of the Paper Collaborator in the Daikan Team's design process was more due to the fact that it contained information and documents that the members no longer needed to interact with than its interaction.

The addition of the virtual to the physical workspace did result in some degree of increased awareness and interaction, but the benefits of physical form – namely its pliability and readiness for the display to evolve alongside the project – were underutilized. This is could be improved with an interface that was better suited to accommodate for the subject choices of file representation.

ACKNOWLEDGMENTS

We thank Ron Yeh, Scott Klemmer, and the Human Computer Interaction Research Group at Stanford.

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