Diamond's Edge: From Notebook to Table and Back Again

Michael Bernstein, Avi Robinson-Mosher, Ron B. Yeh, Scott R. Klemmer
Stanford University HCI Group
353 Serra Mall, Stanford, CA 94305, USA
{mbernst, avir, ronyeh, srk}@cs.stanford.edu

ABSTRACT

We discuss the interaction benefits derived from combining the collaborative nature of touch-sensitive tabletop interfaces with the paper affordances and personal space of digital pen and paper. The pen may be used as fluid input to create and transform content within the public table space, and the table's top-down projection as a method to augment the physical paper with properties of digital output. Finally, we introduce Diamond's Edge, a design brainstorming tool which incorporates the interaction techniques described.

Author Keywords

Augmented paper notebooks, tabletop interfaces, CSCW.

ACM Classification Keywords

H5.2. User interfaces – *input devices and strategies*.

INTRODUCTION

The field of computer-supported cooperative work has generated a large body of research concerning tabletop groupware [5, 6]. One of interactive tabletops' known strengths is their collaborative capacities, especially large-scale display and multi-user sensing in collocated work.

Augmented paper documents (*e.g.,* [2]) bring their own compelling set of affordances to interaction: for example, they are mobile, personal, have infinite battery life and map well onto existing paper practices. Prior work, beginning with Wellner's DigitalDesk, has explored integrating paper and digital systems in a variety of applications [4, 7].

Though augmented paper and tabletop groupware have generally played independent roles to this point, we suggest that they also exhibit great potential as an ensemble. For instance, the mobile nature of paper documents allows for content creation in a distributed manner, while the tabletop collaborative systems can easily bring this content together for discussion. Haller *et al.* have explored the functional input that paper may provide to a tabletop interface [3]; we build on this work by exploring the interaction benefits to be gained from such a marriage. To this end, we have integrated paper notebooks and interactive tables in a system we call Diamond's Edge, where digital paper may be used as fluid input for the table, and the table may be used to view, transform and re-output the paper's contents.

DIAMOND'S EDGE

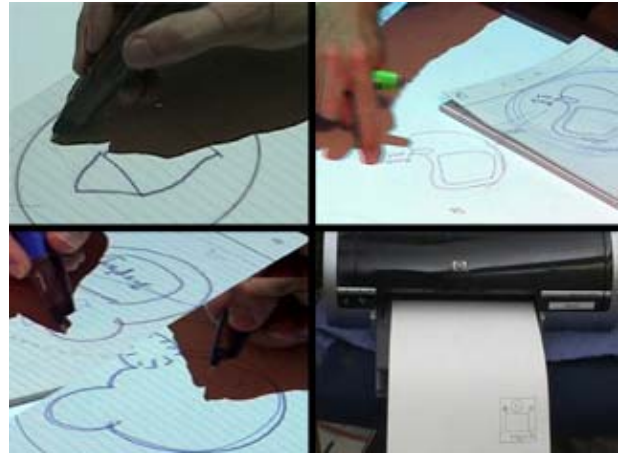We present Diamond's Edge, a prototype tabletop + paper system exploring the space of group collaborative

Figure 1. Using Diamond's Edge, drawings can be (a) created, (b) transferred to the collaborative table surface, (c) placed in another user's notebook, and (d) added to simultaneously by both users.

brainstorming. We suggest that this style of interaction leverages the strengths of pairing pen and table interfaces.

Our envisioned scenario is that of a group of designers working together in a brainstorming session. Each designer brings a personal paper idea log and digital pen, and they gather around the collaborative table to share and refine their thoughts. Diamond's Edge supports their needs through several key interactions: *private sketching*, *rip to share*, and *collaborative editing*.

Private Sketching

Each paper notebook serves as the user's private space: sketches remain in the notebook unless they are purposefully moved to the public area. This functionality is similar to that provided by other systems [2] while in "edit" mode (Figure 1a). In our scenario, users will keep private brainstorms and notes solely in their notebooks.

Rip to Share

A fundamental interaction in Diamond's Edge lies in selecting an area of the private notebook to "rip" to the public space. By tapping a special area of the page (analogous to pressing the top of a typical pen to retract the head), users can treat the pen as a stylus and circle an area of the notebook to copy. The "digital ink" of the image will then be top-projected onto the notebook and the pen may be used to drag the sketch onto the table (Figure 1b). There are now two copies of the drawing — the private, physical one
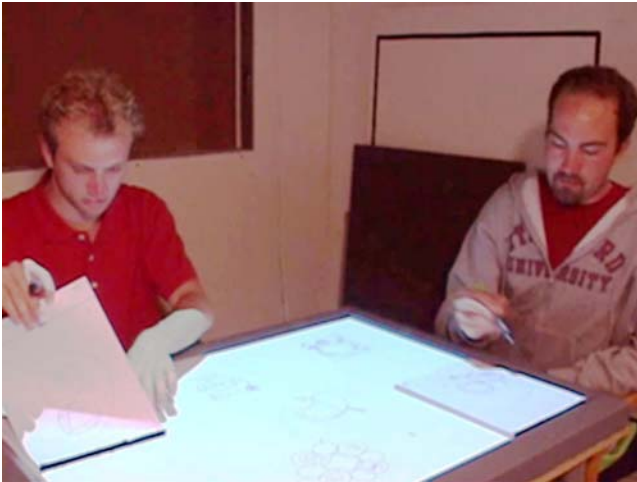
Figure 2. Two participants in our informal study brainstorm designs for a handheld media player using Diamond's Edge. Each has his own notebook and digital pen, and they use the tabletop space collaboratively to share and refine ideas.

in the book, and the public digital one on the table. The public copy may be viewed and moved around the table by any participant. As the author continues to add to the drawing, the public copy mirrors the additions.

Collaborative Editing

A second user who drags the public copy into her notebook (achieved by top-projecting the image onto the notebook) and "pins" it by pressing down may now use her pen to add to the image. The images are linked together – as the second user adds to the drawing, her pen strokes appear in the original author's notebook via overlaid projection (Figure 1c). The two users may now add to the sketch simultaneously and see each others' work immediately reflected in the collaborative sketch. In this way we support "leapfrogging" off each others' designs. In addition, a "pinned" sketch become part of the notebook in which it is placed, tracking with it as it moves around the table.

The paper and digital worlds will continue to exist in sync throughout the session; however, we provide a printing facility for users who wish to bring the digital ink immediately into their physical notebooks. Printing will output the entire sketch onto an adhesive label to be affixed into the design notebook (Figure 1d). These labels may be affixed to the users' notebook pages and added to immediately, or in another session. Diamond's Edge users may also print at the end of brainstorming sessions to capture their final work into their design notebooks.

SYSTEM IMPLEMENTATION

Diamond's Edge is built using Java on the DiamondTouch collaborative tabletop and Anoto digital pen platforms. The DiamondTouch is a touch-sensitive input device supporting up to four users through capacitive coupling to the tabletop surface and visual feedback via top-projection. We use Bluetooth-enabled Anoto pens to acquire streaming pen data. The visualization is managed by the Piccolo ZUI

system. The ARTag 2D barcode system is used to track and identify notebooks [1].

USER FEEDBACK

To evaluate our work, we conducted an informal study with three teams of two undergraduate students. Each team was informed they had been brought in as design consultants for a fictitious electronics company which wanted to design a video and music player tailored for 7 to 9 year old girls. They were then asked to collaboratively brainstorm a series of designs for the product. At the conclusion of the study, their attitudes were gauged by a survey consisting of Likert-scale and open-ended questions about Diamond's Edge.

Results and Discussion

Users rated their collaborative performance using the Diamond's Edge system highly (mean 5.8/7) and commented positively on the program's collaboration support. Since we could not actually retract the pen heads, stylus-type gestures left marks on the paper; users maintained that this sometimes made the physical paper more of a hindrance than a help.

Future directions based on this feedback include the ability to track the position of the paper notebooks, create "branching" copies of images and potentially erase. Experienced product design students generally wished for greater leverage of the private (incomplete sketches) vs. public (sharing with the group) distinction in the system.

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