Pictionaire: Supporting Collaborative Design Work by Integrating Physical and Digital Artifacts

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ABSTRACT

This paper introduces an interactive tabletop system that enhances creative collaboration across physical and digital artifacts. Pictionaire offers capture, retrieval, annotation, and collection of visual material. It enables multiple designers to fluidly move imagery from the physical to the digital realm; work with found, drawn and captured imagery; organize items into functional collections; and record meeting histories. These benefits are made possible by a large interactive table augmented with high-resolution overhead image capture. Summative evaluations with 16 professionals and four student pairs validated discoverability and utility of interactions, uncovered emergent functionality, and suggested opportunities for transitioning content to and from the table.

Author Keywords

Surface computing, design tools, tangible interaction.

ACM Classification Keywords

H5.3. Information interfaces and presentation (*e.g.,* HCI): Group and Organization Interfaces – *Computer-supported cooperative work.*

General Terms

Design, Human Factors

INTRODUCTION

Discussion in design is almost always tied to concrete artifacts: designers use sketches, photographs, and physical prototypes as examples to structure conversation and collaboration [5]. Creative work moves freely across physical and digital boundaries, but today's computing infrastructures are often oblivious to this co-existence [7]. This note hypothesizes that interactive tables are particularly suited to support and enhance group design work when they enable co-habitation of physical and digital artifacts on the table. We contribute Pictionaire, a tabletop system for design teams that introduces interactions for capturing physical artifacts and organizing their digital copies. Pictionaire augments multi-touch input with high-resolution digital still image capture above the table, enabling teams to work with digital images and text, paper-

Figure 1. Pictionaire supports design collaboration across physical and digital artifacts.

based sketches, and physical artifacts (Figure 1). We also contribute an evaluation that highlights tradeoffs between physical and digital interactions for creative group work.

Pictionaire extends related work in computing environments for co-located design teams. The multi-user Shared Design Space [3] focuses on high-resolution digital drawing but does not offer support for capturing images of physical artifacts. PostBrainstorm [2] is an interactive mural that supports image capture on a neighboring table. Pictionaire extends the PostBrainstorm research by merging capture and display space, thereby allowing new interactions. The Designer's Outpost [8] allows co-existence of paper Post-it notes and digital ink on a wall display, but does not offer support for multiple simultaneous users or other materials.

Interactive tabletops have also introduced interactions across bits and atoms outside the design domain. Wellner's Digital Desk [11] targeted the co-existence of paper and digital information for office work. Augmented Surfaces integrated personal computing devices and projected tabletops [9]. Data Tiles [10] introduced referenced projection on top of physical objects, treating these objects as containers for digital content. Pictionaire builds upon this container metaphor and focuses specifically on supporting design team meetings.

In the following scenario enabled by Pictionaire, interaction designers Max and Mia create a UI walkthrough of a touch screen camera during a meeting. Max first searches for images of digital cameras online by typing a query on a wireless keyboard (Figure 2A). He selects a suitable photograph from the search results and passes the image to
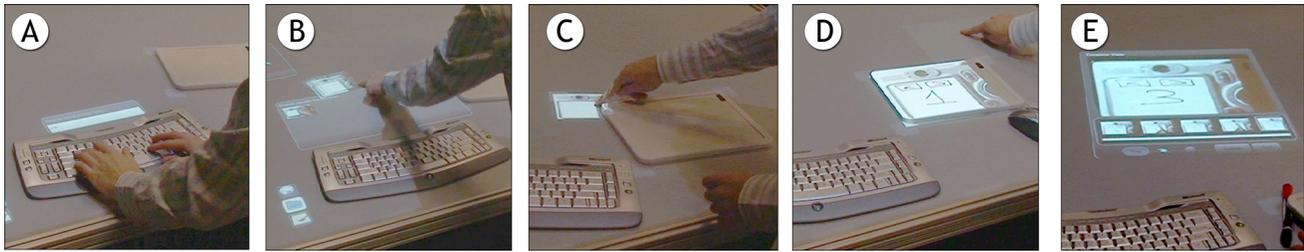
Figure 2. Using Pictionaire to draw a UI walkthrough. A: Search for images. B: Drag result to table. C: Snap image to physical whiteboard. D: Capture copy of annotated image. E: Organize images as a collection.

Mia on the table (2B). To sketch on top of this photo, Mia drags the image onto a letter-sized whiteboard tablet (2C). The image reorients and resizes to fill the tablet. Mia pulls the tablet toward her and, with a dry-erase marker, sketches a touch screen interface. To capture this first frame of her walkthrough, she makes a digital copy of her drawing with a *drag-off* gesture (2D). As she sketches additional UI screens, Max organizes her captured images by dropping them into a timeline container, which orders the images sequentially (2E). Max plays the walkthrough as an animation, and he and Mia reflect on the design.

We next discuss how Pictionaire enables this scenario.

FORMATIVE DATA AND DESIGN GUIDELINES
Based on interviews with interaction designers and two observations of a product design team, we formed four guidelines that influenced Pictionaire's design: ❶ Offer a large, standing height form factor to approximate designers' workbenches and meeting tables. ❷ Support work with a heterogeneous set of digital and physical artifacts such as web images, sketch books, and form prototypes. ❸ Focus on discussion, ideation, and sketching; detailed design mostly takes place after meetings. ❹ Support input in manners media designers are accustomed to (pens for drawing; standard input devices for application control).

TABLE INFRASTRUCTURE
Pictionaire runs on a custom-built interactive table that measures 120cm × 180cm × 91cm (Figure 3). Graphics are top-projected with two tiled XGA projectors (1024×1536 pixels; 21.3 dpi). Touch input and object location are sensed through diffuse IR illumination with two tiled VGA cameras (640×960 pixels; 13.3 dpi). A high-resolution
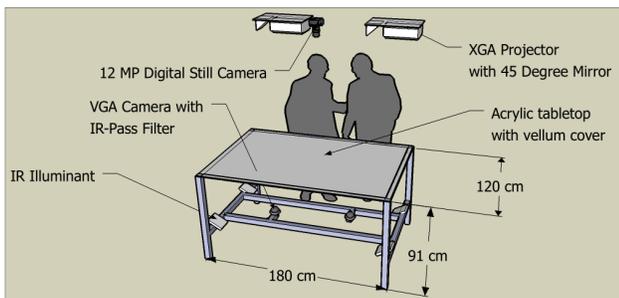
Figure 3. The Pictionaire table offers touch and device input, top projection, and high-resolution image capture.

digital still camera centered above the table captures photos of the entire table on demand (4272×2848 pixels; 59.3 dpi). A Windows Vista workstation runs vision processing and application logic based on a custom version of the Microsoft Surface SDK. To enable efficient text input, precise pointing, and remote interaction, Pictionaire incorporates interaction techniques for mice and keyboards on interactive surfaces [4].

INTERACTION TECHNIQUES
Pictionaire supports group design sessions though interaction techniques for searching & tagging, physical-to-digital transitions, digital-to-physical transitions, remote highlighting, and image organization.

Searching & Tagging
Designers often seek inspiration by searching for example imagery on the web [5]. With Pictionaire, wireless keyboards can be used to initiate such queries, and to enter text annotations. To switch between these functions, soft buttons are projected next to the keyboard when it is placed on the surface. When a user begins to type, a text input box that displays the entered text appears on the table just beyond the top edge of their keyboard (Figure 2A). When a search is executed, the text entry box is replaced with a container showing a grid of images returned by the search (2B). Users can transfer images from this container onto the table through direct touch or mouse input. Typed annotations can be overlaid on any digital item on the table.

Physical to Digital: Drag-Off
Paper-based sketches were frequently used alongside digital images in our formative studies. To capture such sketches, users can place sheets or notebooks anywhere on the table. Objects are distinguished from finger touches by their size and shape. When an object is recognized, digital handles are projected around the corners of the object (Figure 4, left). Users can then *drag-off* from the projected handle onto the table area to create a digital copy: the item is photographed by the overhead camera, and a digital image at 1:1 scale is created. Copies can be manipulated in usual multi-touch fashion (via multi-point translate, rotate, and scale). When the user executes a drag-off gesture, the camera takes an image of the entire table and crops that image using a rotated bounding box calculated from the ellipse model of the object's contact area supplied by our input SDK (Figure 4, right).
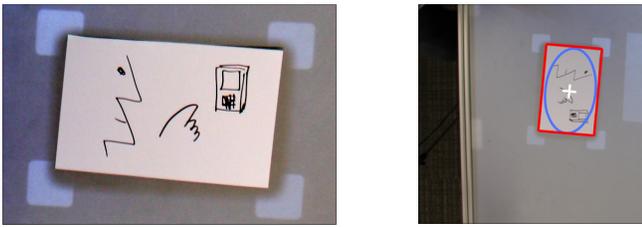
Figure 4. Recognizing a paper drawing. Left: Virtual handles projected around a sheet of paper. Right: Ellipse (blue) and bounding box (red) of paper as calculated by our vision system.

### Digital to Physical: Copy-and-Annotate

Sketches are not only brought to meetings, they are also produced during meetings to illustrate ideas on the fly, and are then taken from meetings for later review as graphical "to do" lists. To support composing digital and physical imagery, digital images can be snapped to drawing surfaces on Pictionaire. To preserve the analog feel and resolution of pens, Pictionaire uses letter-sized dry-erase whiteboards for this function. Designers drag a digital image onto one of the virtual handles of such a tablet (Figure 2C). The projected image is resized and reoriented to fill the tablet (preserving aspect ratio). After sketching on the image, designers then drag out a new digital copy which contains both the original graphic and the added annotation. To capture the composition, Pictionaire currently takes a single photo. To increase fidelity, one could photograph only the marks on the tablet and digitally compose this image with the sketched-upon image, or use digital pen technology [3]. Digital pens provide high-resolution input but constrain the choice of drawing instrument and surface. Using paper notebooks instead of whiteboards enables use of Pictionaire as a light table to create hand-traced copies of digital images (Figure 5).

Remote Highlighting

During discussion it is beneficial to direct group attention to details of an artifact. The Spotlight technique [6] achieves this function on digital images by projecting a circular highlight on demand. Pictionaire extends Spotlight into the

Figure 5. Using Pictionaire to trace images in sketchbooks.
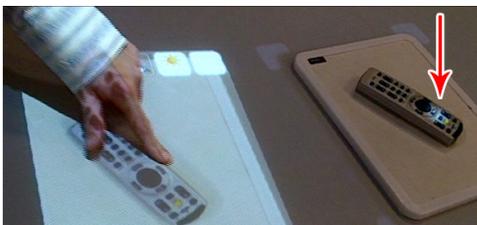
Figure 6. Projecting light onto a physical object by pointing on its digital copy. Red arrow indicates highlight.

physical realm. Users place an object, *e.g.*, a form prototype, on the table and capture a digital copy. After activating highlighting mode, pointing to features on the digital copy creates a projected highlight on the corresponding location on the physical artifact (Figure 6). This technique enables designers to direct attention without obscuring the view for others.

Organizing Digital Material

To organize visual material into meaningful aggregates, Pictionaire offers collection containers that hold multiple images. These containers enable grouping, sorting, and animation of image sets through three views: ❶ a freeform layout, where individual images can be freely moved, scaled, and rotated; ❷ a grid view where images are tiled to maximize table real estate; ❸ a flipbook view that offers a timeline and playback of images as an animation (Figure 2E). The flipbook view supports the practice of presenting interface walkthroughs of UI prototypes and enables stop-motion animation.

Capture and later replay of table sessions can help attendees recall meetings and report them to others. Pictionaire offers a capture function that photographs the entire table. Histories can be assembled by manually triggering capture or by setting an automatic interval. A special flipbook container is dedicated to browsing these session histories.

USER EXPERIENCES

How well does Pictionaire support the needs of real design teams? 16 design professionals evaluated our table in open-ended sessions. Five tested individually; others in groups of two to four. The professionals tried out Pictionaire's features and were asked to relate how it could be used in their work. In addition, eight graduate students completed a 30-minute brainstorming task in pairs. The student pairs were asked to brainstorm ways to re-design a handheld game controller. All participants were invited to complete an online survey — 13 responded.

Patterns of Use

Brainstorm pairs alternated between individual work (generating ideas independently; one person sketches while the other conducts a web search) and shared work (discussing an issue together). By providing multiple independent sets of input devices and tablets, Pictionaire supports switching between these two work styles well. One designer commented that placing tablets and keyboards onto a shared display prevents individuals from "hiding" behind opaque laptop screens, a common meeting problem.

In the brainstorming task, the most frequently performed operations were capture of whiteboard sketches (22 occurrences in 4 sessions) and web search for images (20 occurrences), corroborating our motivation that work across both digital and physical artifacts should be supported. An example of a team photographing a physical controller, then annotating the resulting photo is shown in Figure 7.

Our professional participants imagined a range of different uses for Pictionaire that leveraged image capture,
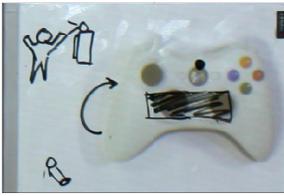
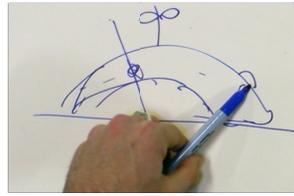**Figure 7. Annotations on a photo of a game controller.**

Figure 8. Hand included in photo points out a feature.

Figure 9. Impromptu image capture of a laptop screen.

sometimes in unforeseen ways. Three participants included their hands in the images taken — to point out important parts of a drawing, or to demonstrate a grip on an object (Figure 8). One participant photographed his laptop screen using Pictionaire as a fast method of sharing an image with a teammate (Figure 9). Having sharing technology available instantly was more important to him than quality of reproduction. Two participants in separate sessions created stop-motion animations by first drawing on pieces of paper, then rearranging these pieces between image captures.

The post-use survey elicited advantages of Pictionaire over current analog and digital practices. Most frequent responses were that Pictionaire promotes collaborative work (7x); it offers a form factor large enough for a variety of work materials (6x); it enables rapid capture & annotation (5x); and allows projecting light onto physical objects (3x). Participants provided free-form answers, which we categorized. Lower counts may not mean that participants found fault with an aspect, only that they chose to focus their comments elsewhere.

Navigating the Boundary Between Bits and Atoms
While the general flow of sketching with physical tools and then capturing digital copies was well understood, the division between bits and atoms was not always clear to our participants. Our participants' mental model appeared to be "projected light can be manipulated by touch." However, Pictionaire can only sense touch on the table surface itself, not on objects. Thus, drag-off gesture can only be initiated from digital handles on corners of whiteboards. In the study, some participants attempted (unsuccessfully) to initiate drag-off gestures on the whiteboard tablet.

Another limitation of capturing drawings through photography is that annotating a whiteboard with a dark marker or drawing on white paper can only make the inked parts of the captured image darker. Thus it is not possible to

erase or lighten parts of a projected image, as some participants attempted.

All groups in the brainstorm task faced overly cluttered tables at some point. Physical objects can be shuffled, stacked, and pushed out of the way. When physical objects touch digital objects during clean up on Pictionaire, those move as well. But digital objects cannot not influence physical objects, nor can they move each other. It thus took participants longer to clean up digital messes than physical messes. This issue could be addressed by mimicking the real world through simulated collisions or through an automatic cleanup function. To avoid interference between digital and physical objects, techniques for obstacle-aware projection [1] could be applied to Pictionaire.

FUTURE WORK: WORK PROCESS INTEGRATION
Pictionaire introduces a set of techniques that, taken together, enable and encourage co-habitation of digital and physical artifacts to facilitate collaborative creative work. The most frequently mentioned suggestion for improvement was to integrate Pictionaire into larger work processes. Participants appreciated that the table specifically supports co-located meetings. This focus also implies the need for individual preparation and follow-up away from the table. Efficient import and export of content is therefore required.

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