Enhancing Data-Driven Collaboration with Large-Scale Interactive Tabletops

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Abstract

Reality-based interfaces (RBIs) such as tabletop and tangible user interfaces offer unique opportunities for enhancing data-driven collaboration. In this paper, we describe the design and implementation of a large-scale interactive tabletop for augmenting data-driven co-located meetings of larger teams (8-12 participants). We also discuss usability challenges for large-scale tabletop interaction and present a set of design metaphors and interaction techniques for supporting collaboration around large-scale interactive tabletops.

Author Keywords

Tabletop interaction; Multi-touch interaction.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g. HCI): Miscellaneous.

Introduction

Over the past two decades, Human-Computer Interaction (HCI) research has generated a broad range of interaction styles that move beyond the desktop into new physical and social contexts. Key areas of innovation have included multi-touch, tabletop, and tangible user interfaces. These interaction styles share an important commonality: leveraging users' existing knowledge and skills of interaction with the real non-

digital world, thus they are often unified under the umbrella of Reality-Based Interfaces (RBIs) [9]. RBIs leverage users' social, spatial, and kinesthetic skills, thereby supporting collaboration while reducing the mental effort required to learn and operate a computational system.

Numerous research prototypes have explored how these emerging interaction styles impact collaborative work, opening the opportunity to consider reality-based interfaces as a prominent alternative to traditional co-located meeting settings. Within the realm of RBIs, our research has focused on interactive surfaces.

Several studies have investigated the effects of different interactive surface parameters on co-located collaboration e.g. [7][13][14][15]. However, most studies have focused on small groups of 2-4 participants. To date little research has been devoted to investigating the strengths and limitations of interactive surfaces in supporting co-located collaboration in *larger groups* of 8-12 members. We are particularly interested in investigating the application of large-scale multi-touch high-resolution tabletop displays for augmenting data-driven co-located meetings in larger teams.

In this position paper, we describe the design and implementation of a large-scale high-resolution multi-touch tabletop display (81 x 42 inches, 40 ppi) that can accommodate up to 12 users interacting in parallel (see Figure 1). This interactive tabletop, nicknamed "the Beast," takes advantage of the large working surface to offer RBI support for data-driven discussions such as scientific research meetings and curatorial decision-making. We designed the Beast based on observational studies of extended data-driven co-located meetings.

Figure 1: The Beast - a large-scale interactive tabletop.

Following, we describe our design goals for the Beast and its implementation. We also discuss usability challenges for large-scale interactive surfaces and a set of design metaphors and interaction techniques. We begin with a brief survey of related work.

Related Work

Large vertical information displays are common in collaborative settings. The LiveBoard [4] was the first well-developed digital whiteboard system followed by the development of several commercial and research systems. While interactive walls have shown to be successful in facilitating information sharing, they afford side-by-side rather than face-to-face interaction, and thus are less suitable for supporting extended collaborative discussion. Numerous tabletop systems have been developed by research labs and industry including [2][6][8][12][17], demonstrating benefits in augmenting group meetings and supporting co-located face-to-face collaboration in small groups (2-4 users). While most tabletop systems have a diagonal size of 30-80 inches, we present an interactive tabletop display with diagonal length of 91.24 inches designed to support interaction in larger groups and can accommodate up to 12 users.

Collaborative workspaces such as iRoom [10] and WeSpace [18], which integrate personal devices, large wall displays, and a multi-touch table offer additional benefits for data-driven discussion and information visualization. However, the size of the tabletop still limits the interaction to small groups, typically 2-6 participants. uTable [19] is a large-scale interactive tabletop that is more similar to our work. However, to date there are few details of its interface components.

Meetings	Setting	Data
5 research meetings of an MIT Biology lab. 12 students, 5 staff.	Lecture room with shared screen, conference table, and additional chairs.	Graphs, diagrams, images of wet-lab results, lab protocols, Wiki.
8 research meetings of BU Biology lab. 2-6 students, 1-2 graduate students, 1 post-doc.	Meeting with a conference table and white board.	All of the above, as well as, lab notebooks, notes, and journal papers.
Semester long meetings of an HCI studio course. 13 students, 1 instructor.	HCI lab where the Beast table was used as a traditional conference tables. Additional seats were used.	Sketchbooks, notes, paper prototypes, images, carious websites.

Table 1: Observations summary of data driven meetings.

Shen et al. [16]discussed challenges and design guidelines for collaborative tabletop applications. Carpendale et al. presented software components designed to support users interacting on large tabletop displays [1]. We draw upon this work but focus on usability challenges distinctive to large-scale tabletops.

Design Goals

Observations of Data-Driven Meetings
To inform our design process, we conducted observations of how groups use space in data-driven meetings. We observed three different groups, Table 1 summarizes our observations. Analyzing our observations, we noted that: (a) the use of personal information devices such as laptops and tablets is ubiquitous in meetings; (b) Physical artifacts are often included in meetings; (c) Participants that are sitting away from the table are often less engaged; (d) Participants often sit next to other participants with whom they work closely and share information on a regular basis with; (e) Throughout a meeting participants were switching between four main work-patterns (See Figure 2): 1) *working individually* - preparing materials, examining artifacts, or taking notes on personal information devices or on paper; 2) *working in sub groups* - consulting with particular group members; 3) *discussing* as a group – participating in a free or moderated discussion; 4) *presenting* - to the group using a shared display. Often transition between work-patterns would have apparent seams such as switching places, sharing a small laptop screen or connecting a computer to a projector. Our observations are also supported in the literature [8][18].

Goals
Based on our observations, we defined four high-level design goals for the Beast:

G1) Facilitating fluid transition between work-patterns;
G2) Integrating various personal input and information devices with a large-scale interactive surface;
G3) Enabling flexible organization of heterogeneous digital and physical information artifacts.
G4) Supporting ergonomic and social aspects of extended data-driven meetings.

Implementation

The Beast is implemented using Diffused Illumination (DI) architecture. We use six modified PlayStation 2 cameras with IR filters replaced by 850 nm visible light filters, arranged in a 3 x 2 grid with some overlap (See Figure 3). We use Community Core Vision (CCV) 1.5 as our tracking solution and EcoTUIO driver [3] to convert the contacts registered from TUIO to Windows Touch pack. The FPS is 60 and processing is about 3 ms.

Two Kinect cameras, mounted above the table each facing a length of the table communicate with the Beast application over a TCP connection. The cameras recognize a new user when approaching the Beast and assign the user an ID that is sent to the Beast. The cameras also track the location of users around the table. We are currently developing various walk-up-and-interact and out-of-reach interaction techniques using information tracked by these cameras. We are also implementing a tracking feature so that a user is "followed" by their artifacts around the table, should they relocate during the meeting. Figure 3 shows the physical components of the Beast.

Integrating personal information and input devices
Personal information devices are ubiquitous in extended meetings. To support the integration of personal devices with the large multi-touch surface, we

Figure 2: Observing data-driven research meetings.

Figure 3: the physical components of the Beast.

developed a TCP client application that allows sending objects to and from pre-registered Windows 8 devices using drag-and-drop. We are currently developing mechanism for device registration on-the-fly.

Usability Challenges of Large-Scale Tabletop Interaction

Supporting extended data-driven meetings using a large-scale interactive tabletop involves several usability challenges beyond those presented by interaction on smaller tabletop interfaces [16]. These include: 1) *Out-of-reach areas* - the large workspace makes many display regions either uncomfortable to work in or completely unreachable. This challenge is amplified by the large workspace; 2) *Coordination and Communication* - the large distance between users makes it difficult to share information and coordinate activities using interactions such as transferring and rotating objects that were found to have major roles in tabletop collaboration [11]; 3) *Visibility* - one of the strengths of tabletop interaction is allowing users to directly observe the content and actions of other users, such visibility contributes to increased group awareness. However, due to the large workspace, visibility of actions and information artifacts is limited in large-scale tabletops; 4) *Various work-patterns* - in extended data-driven meetings users switch between various work-patterns, often multiple times throughout the meeting. Each of these work patterns requires different mechanisms for awareness and control.

Interface Metaphors and Components

To address these challenges, we developed a set of interface metaphors and components (see Figure 4). We used RBI [9] as a design principle, striving to design metaphors that draw upon naïve physics and knowledge from the real non-digital world. We also applied territoriality [15] as an organizing principle by dividing the space on the tabletop into two territories: personal and group.

For the *group territory*, we utilized an area in the center of the table that is easily reachable but is uncomfortable to work in for all users. In this area we display a *River* - a container that supports the sharing of information artifacts across the workspace characterized by an on-going flow. Artifacts that are added to the River flow smoothly within the River. Users can add objects to the River or drag objects from the River to their personal territory. When dragging an object out, a copy of the object is created and oriented towards the user. River objects that are not accessed for a certain time period will slowly fade. Our River component draws upon Interface Currents [1]. However, unlike Interface Currents, we expect users to only have lightweight interactions with a single river component that is rarely customized.

For the *personal territory*, we designed a *Drawer* component - a resizable container that is fixed to the edge of the table. Similar to interacting with a real-world drawer, users can open or close their drawer and can add or remove objects from the drawer, which is used both as personal storage and a workspace. A drawer is created when a user approaches the table and is registered by an overhead Kinect camera. Users can then login to retrieve their drawer content from previous sessions. A drawer is removed when a user leaves the table. Drawers are resized according to the number of users per side of the table (tracked by the Kinect cameras) to improve workspace management.
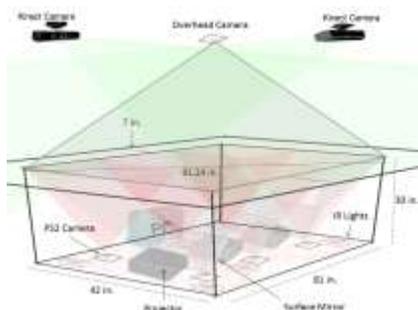
Figure 4: Interface components: a curatorial decision-making application with open drawers and a river.

Objects that are added to the drawer are automatically resized to a miniature representation, but can be resized and manipulated within the drawer. users can arrange objects in meaningful configurations as well as annotate them. Users can choose to use a personal device as their personal drawer (by dragging their drawer into a registered device). This is particularly useful when a higher resolution is required in order to examine particular information artifacts. This is often the case when scientific information is examined and discussed. Users can drag objects into and out of their device to add and remove objects from their drawer.

The use of drawers in tabletop applications was also explored by Hancock et al [5]. However, while they utilize drawers as expandable palettes for virtual objects and tools our design focuses on the use of drawers as persistent personal workspace.

The area outside of the drawer is a *group territory*. Users can manipulate objects in this area, annotate, resize, and arrange artifacts. However, items in this area will not be saved when the mode of the interfaces is changed unless saved in the drawer.

To facilitate mode changes a *control panel* with three switches is attached to the top of the drawer. Each switch represents one of three modes: *Browse* – where the River flows in the center of the table and users can interact freely with information artifacts; *Discuss* – where a *tile* display covers the River in an area of the table, creating a sub-group to engage in discussion; and *Present* – where 6 identical tiles controlled by the user that initiated the mode change request cover the River. In all three modes users can access their drawers and revisit their saved objects. Switching

between modes requires all affected users to adjust their switches. Pending mode-change requests are indicated to users through color change in the relevant switch.

To increase *visibility* and group awareness users can present in their drawers a video feed from an overhead camera that show the artifacts manipulated by other users. While the resolution is not sufficient for noticing details, it is sufficient for providing a notion regarding the artifacts manipulated by others and the status of other group members.

Conclusions and Future Work

RBIs such as tabletop and tangible user interfaces offer unique opportunities for enhancing data-driven collaboration. Our focus is on investigating how large-scale interactive tabletops can augment data-driven co-located meetings of larger teams (8-12 participants). We described the design and implementation of a large-scale high-resolution interactive tabletop that offer RBI support for data-driven discussions in larger groups. We also discussed usability challenges for large-scale interactive tabletops and a set of design metaphors and software components.

So far, our investigation has focused on design, implementation and *usability*. Throughout the design process we tested the Beast with 21 users. Our finding informed the design of hardware and software aspects, leading to the prototype we described here. Our next steps focus on the *impact* of large-scale tabletop interaction on collaboration within groups of 8-12 participants. We developed two applications for supporting curatorial decision-making and for supporting phenology research, and are currently

conducting a series of user studies to understand collaboration patterns around large-scale tabletops.

Acknowledgements

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