

Designing Tabletop Groupware

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ABSTRACT

Interactive tables are an emerging class of devices that are subject to different design constraints than other types of single display groupware. Through prototype-building and evaluation, we have identified three key design challenges for tabletop groupware: integrating access to public and private information, managing display elements, and mediating group dynamics. We discuss each of these issues and present approaches we have developed to address the challenges they present.

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General terms: Design, Human Factors, Experimentation

Keywords: Tabletop interfaces, CSCW, single display groupware.

INTRODUCTION

Nearly every work environment contains desks and tables, and with good reason: tables are well suited to many kinds of information work. They facilitate face-to-face collaboration and permit the spreading, piling, and management of many documents and objects. Enhancing traditional tables by adding computational functionality combines the collaborative and organizational benefits of horizontal surfaces with the power and adaptability of digital technology, such as the ability to archive, search, and share digital documents. Combining the productivity benefits of computing with the social benefits of around-the-table interaction has applications in business, education, and entertainment. The recent introduction of hardware that detects touch input from multiple, simultaneous users [2] has made computationally-augmented tables, or “interactive tables,” a practical concept.

Interactive tables are a form of single display groupware (SDG) [20]. Most prior research on designing software for SDG has focused on large, interactive whiteboard-style displays, such as [7] and [10]. Around-the-table collaboration has different properties than collaboration around vertical displays, and merits exploration as a design space with distinct issues. For example, shoulder-to-shoulder work at vertical displays tends to promote a single

leader who controls most of the interaction, while face-to-face work around tables results in more turn-taking and participation from all group members [16]. As a consequence of this increased parallelism, certain design issues rise in prominence.

We have explored the properties of group interaction with interactive tables and their associated design challenges by building and evaluating a series of novel prototypes. In the following sections, we discuss systems and studies that address three key design challenges: integrating access to public and private information, managing display elements, and mediating group dynamics.

INTEGRATING PUBLIC AND PRIVATE INFORMATION

Shared display interfaces afford a closely-coupled navigation style – all users view the same information. Integrating sources of private information with an SDG system allows increased parallelization of activity, permits user-specific customization of content, and preserves control over sharing private or sensitive information. Users of traditional, non-augmented tables naturally divide the work surface into distinct regions for personal work and for group objects and activities [17]; we hypothesize that simultaneously supporting both group and personal tasks is key to designing effective tabletop groupware. Shoemaker and Inkpen [19] implemented a single display privacyware system that used shutter-glasses to allow users of a vertical SDG system to simultaneously view user-specific content overlaid on the shared display. However, wearing shutter glasses prevents eye contact between group members, thus impeding a key aspect of face-to-face collaboration. We explore techniques that integrate public and private content in a fluid and non-intrusive manner, such as interactions for sharing digital documents and combining private audio with a shared tabletop.

Document Sharing

Work in the social sciences [4, 11] reveals that co-located group work involves periods of closely-coupled activity combined with more loosely-coupled individual work. We would like to preserve this aspect of traditional face-to-face workflows when creating software for interactive tables. To enable users to transition digital documents between periods of individual and group work, we have developed four interaction techniques (*release*, *relocate*, *reorient*, and *resize*) that allow users to interactively grant or deny document access permissions (i.e., the ability to manipulate or modify a document) to other group members [15]. A formal comparison of these techniques found that the

“relocate” interaction (Figure 1) most efficiently facilitates document transfer and is considered the most natural by users, although all four techniques were quick to learn and had few performance errors.

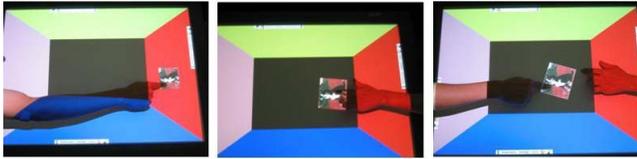


Figure 1. The *relocate* technique is used to transition a document between personal and public accessibility by moving it from a designated private work zone into a centrally-located shared region.

Individually-Targeted Audio

We have explored the use of individually-targeted audio channels to provide private or customized information to tabletop groupware users [13] (Figure 2). We take advantage of the human ability to more easily parse sounds presented to separate ears [5] by presenting system-generated audio to a single ear (thus allowing group conversation to be perceived contralaterally). This avoids the stifled-conversation problems reported by previous attempts at incorporating personal audio with co-located groupware [1]. Allowing uncoupled exploration of content resulted in increased task parallelization and increased involvement from “shy” group members. Audio privacyware facilitates these benefits of integrating private information with SDG while allowing users to maintain eye contact with group members and avoiding the cognitive overhead of switching between a main display and supplementary personal displays (e.g., PDAs).



Figure 2. A group uses SoundTracker, a tabletop application with individually-targeted audio.

MANAGING DISPLAY ELEMENTS

Efficient use of screen real-estate is a challenge for all SDG systems, but this is particularly true for tabletop systems where all group members are likely to participate in interactions. Displaying items of group interest and items relevant only to individual users, as well as displaying multiple copies of basic GUI widgets (i.e., a copy of a menu in reach of each user) can lead to cluttered displays. Horizontal displays further complicate matters by

introducing the need to orient information to maximize readability by users on different sides of the display [18]. We explore clutter-reduction and widget placement techniques for tabletop displays.

Multi-Modality for Clutter Reduction

Conveying small chunks of textual content (e.g., photo captions, tooltips, etc.) through private audio channels, rather than visually, mediates several tabletop display challenges. Foremost, offloading non-critical or peripheral content to audio reduces visual clutter on the display. Audio presentation also avoids the orientation problem – users sitting on opposite sides of a table can simultaneously hear an audio caption, but would have difficulty simultaneously reading text with a single orientation. Our work on supplementing tabletop displays with individually-targeted audio presents an initial exploration of these benefits [13], and we are currently developing prototypes to explore the advantages and limitations of this technique.

Widget Placement

When designing tabletop groupware, the layout of basic GUI widgets (e.g., menus, buttons, etc.) becomes complicated: replicating GUI controls for each user improves reachability and avoids orientation-based legibility problems, but wastes valuable screen real-estate and potentially detracts from having a centralized, team-focused feel to an application. Tabletop interface toolkits such as DiamondSpin [18] facilitate making either single or multiple copies of controls, but offer no guidance regarding the consequences of this design decision. We compared two alternative widget layouts at opposite ends of this design spectrum (“replicated controls” and “shared controls”) in the context of TeamTag, a cooperative tabletop digital photo management application (Figure 3). Although replicating GUI widgets for each group member consumes more screen real-estate than providing a single, centrally-located set of controls, we found that replication avoided two pitfalls of the “shared controls” design. With the shared controls, parallelism was greatly reduced as users were uncomfortable manipulating the controls at the same time as other group members for fear of violating proxemic [8] norms (e.g., accidentally touching a co-worker’s hand). Another drawback of the shared design was that subjects wanted to use the group-reachable areas of the table (e.g., the center) for organizing documents essential to their activity. Thus, even though the shared controls occupied fewer pixels than the replicated ones, the space they occupied was more valuable to the groups.

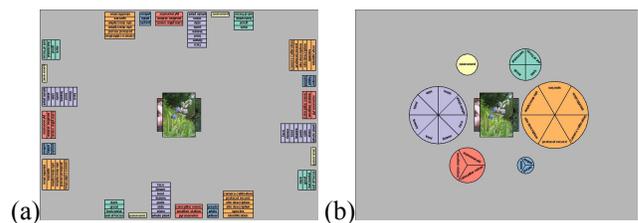


Figure 3. (a) Replicated, individually-oriented widgets. (b) Shared, universally-oriented widgets.

MEDIATING GROUP DYNAMICS

Social interactions are an important aspect of face-to-face meetings. Consequently, we hypothesize that groupware that facilitates social processes will increase productivity and subjective satisfaction. Good software design can help coordinate group actions, encourage equitable participation in group activities, and increase awareness of important events. We address these issues through our work on coordination policies, the free-rider problem, and cooperative gestures.

Coordination Policies

Prior work has observed that social protocols are not always sufficient to avoid conflict among groupware users [6]. Our observations of interactions with tabletop applications such as Table-for-N and Magnetic Poetry [18] provided further evidence that social protocols are not sufficient to avoid many types of breakdowns, such as when one person takes a digital document away from another group member who was actively using it, or when one person changes an application setting that negatively impacts the rest of the group (e.g., clearing the screen while others are working). To mediate these breakdowns, we introduced *multi-user coordination policies*, software-level mechanisms to provide deterministic outcomes to element- and application-level conflicts in co-located groupware [14]. The design of these policies was based on surveys of users' expectations regarding outcomes to sample conflict scenarios [12]. We introduced a framework for coordination policies based on *conflict type* (global, whole-element, or sub-element) and *initiative* (proactive, mixed-initiative, or reactive), and implemented an initial set of these policies as an extension to the DiamondSpin toolkit. Example policies include requiring group members to vote on major state-changes (e.g., clearing the screen or quitting the application), and creating duplicate copies of a digital document when more than one user simultaneously tries to access it (Figure 4). Coordination policies can minimize the confusion associated with breakdowns, allowing groups to focus their attention on their main task.



Figure 4. The *duplicate* coordination policy: when more than one user simultaneously grabs a document, a copy is automatically produced.

Addressing the Free-Rider Problem

During group activities, it is often the case that some group members contribute less to the activity than others, perhaps because they are shy or under-prepared, or perhaps because another group member excessively dominates the interaction. In education, this phenomenon is referred to as the “free-rider problem” [9]. We have been collaborating with members of Stanford’s School of Education and with instructors from Stanford’s foreign language departments

to develop La Mesa de Clasificación (LMC), a tabletop application that supports foreign-language learning activities (Figure 5). To address the free-rider problem, we have been exploring how subtle changes in interface design can impact individual group members’ participation in a tabletop activity. We are experimenting with altering the manner in which LMC provides feedback to students regarding their progress in the activity (i.e., whether each answer they provide is correct or incorrect). We hypothesize that providing this information through private, rather than public, channels will encourage increased participation by shy and underperforming group members, and that providing this information through audio, rather than visually, will “break the ice” and result in an increase in conversational activity by all participants. We are conducting ongoing experiments comparing these feedback-privacy and feedback-modality variants in LMC’s design (no feedback, visual feedback, public audio feedback, private audio feedback), and are planning to introduce further design variants intended to facilitate equitable task participation, such as extending the work of DiMicco et al. [3] by showing each user visualizations of their contributions (total interactions, correct answers contributed, amount of speaking in the foreign language) in comparison to the rest of the group. We will also be incorporating LMC into the curriculum of one of Stanford’s introductory language courses in order to observe how long-term use of the system impacts learning.

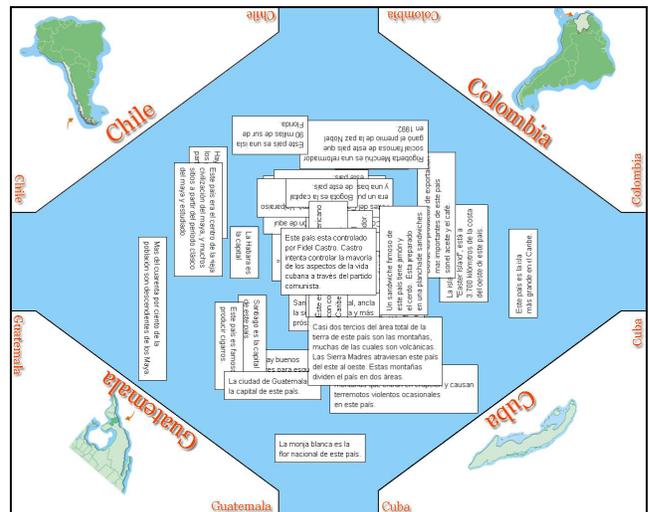


Figure 5. La Mesa de Clasificación is a tabletop application that supports foreign-language education. Subtle interface variations explore ways to mediate the free-rider problem.

Cooperative Gestures

We are currently exploring gestural interaction techniques for interactive tables that fundamentally require the participation of more than one group member. We use the term *cooperative gesture* to refer to cases where the system interprets the input of two or more users as a single gestural command. This cooperative gesture produces a different result than interpreting each user’s gestures independently,

and the individual users' sub-gestures may or may not have valid independent interpretations. There are several reasons why system designers may want to incorporate cooperative gestures into a groupware system, including:

- Forcing cooperation among group members. This can be useful for educational activities for children and for special-needs individuals. For example, therapeutic activities for people with Asperger's syndrome who are trying to overcome socialization and communication impairments can benefit from technologically encouraged collaboration.
- Coordinating multi-user actions, such as interactively transferring access privileges for specific documents.
- Facilitating interactions with out-of-reach items.
- Increasing group awareness about important or potentially disruptive actions.
- Creating a unique entertainment-oriented activity.

We are developing a taxonomy of qualities to consider when designing cooperative gestures. We plan to implement and evaluate a set of gestures that covers this taxonomy in order to better understand what design dimensions influence the learnability, performance, and comprehension of this class of interactions.

CONCLUSION

Interactive tables combine the advantages of computation with the benefits of face-to-face collaborative activity. Our experiences with early interactive table prototypes have allowed us to identify and address several design challenges associated with this emerging class of technologies.

Our techniques for interactively altering document access rights and for incorporating private information with SDG address the challenge of balancing access to personal and public content in tabletop groupware design. Offloading non-critical content to audio reduces tabletop clutter and circumvents orientation-based legibility issues, and our comparison of widget-placement strategies can inform other tabletop designers with regards to managing display elements. Finally, we have addressed the issue of how groupware interfaces can mediate group dynamics by introducing coordination policies, exploring how interface design can impact the free-rider problem, and proposing cooperative gesture interactions. Identifying and addressing the design challenges posed by tabletop interfaces is a key step toward creating interactive tables that can support traditional collaborative workflows and add value by incorporating the benefits of digital media.

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