Towards Contextual Design Requirements for MDEs

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ABSTRACT
Multi-display research has evolved to date as a consequence of Moore's law, developments in display technology and wireless networking, and of the significant strides taken in groupware research. Devices ranging from laptops to smart phones, when combined with a shared workspace, should in theory enable new forms of collaboration, yet in practice these MDEs have been slow to materialize. Our community, at heart, is interested in building the holy grail of CSCW research; discovering how to support and design for collaborative work with small groups and a variety of technology.

This position paper will first discuss some of the origins of MDE research, and relate these origins to issues that are of interest to this workshop and the most immediate obstacles to completing MDE research. We will then describe our previous and on-going work in the area, along with our intended strategies for moving MDE research forward.

ORIGINS OF MDE RESEARCH
MDE research can trace its origins to two specific branches of Human-Computer Interaction: ubiquitous computing and groupware. As a consequence of MDE's technological roots in ubiquitous computing, initial projects have focused on the development of MDEs using a bottom-up approach, and focused on taking a collection of heterogeneous computing devices and developing technologies that facilitate their collective use. For example, many projects have enabled a room full of laptops to share mouse-input with a set of shared displays [1-4], known as input redirection.

However, one of the most significant issues with this approach is that research is implicitly restricted by the available devices. One issue in particular is that researchers have had to work with devices that are explicitly designed for individual work; group work has not been a strong consideration in either commercial hardware or software design. As a consequence, initial MDE research has focused on overcoming technical restrictions at the hardware and software level; research has developed numerous projects which have enabled network discovery [5], input redirection [1-4], content redirection [1, 6], and overcoming fundamental limitations of underlying operating systems, such as multi-mouse input [7, 8].

As a consequence of these fundamental issues in building groupware, many problems have been addressed by research. A common problem with this approach, however, is that often much of the work in overcoming fundamental restrictions in the hardware and software used is repeated. For example, a number of projects have enabled input redirection including PointRight [3], Mighty Mouse [2], ARIS/SEAPORT [9] and our own framework called Swordfish [10]. This replication of work has significantly increased the "cost of entry" into MDE research, and provided little additional insight into the problems it addressed; a potentially significant contribution to the community would be to create a shared, expandable framework for common use.

Multi-display research also has roots in the social sciences and computer-supported collaboration, which embodies a top down, task-driven approach to research, in which task requirements are used to derive design considerations, and eventually software and hardware requirements. This approach is attractive because it promises to facilitate the design of MDEs which better support collaborative tasks – to fulfill the original goal of using mobile devices in concert to optimally support collaboration. However, to successfully develop MDEs with this approach, a better understanding of task requirements is required. Once attained, a more malleable canvas is also required; hardware and software need to be designed with these goals in mind.

This research has illustrated tensions in groupware such as those between supporting the individual and supporting the group [11], and has helped to understand the social impacts of display use [12], resulting in design considerations and guidelines for designing groupware [13-16]. Where these approaches are currently stalled is in determining common tasks that are performed with MDEs, who will be using them, and how to measure whether or not these tasks are being supported.

OUR RESEARCH

Our research is concerned with both the technical aspects of supporting group work and with theoretical approaches to deriving design requirements and considerations; thus, it related to both ubiquitous computing and groupware areas of research. Specifically, it has focused on developing environments which support co-located collaboration, involving both static and mobile devices. Five such projects will now be described.

Swordfish

Swordfish is a framework developed with the intent of supporting MDE research, particularly research involving mobile devices such as laptops and smart phones. What differentiates Swordfish from other projects is that, in addition to enabling input redirection, it was designed to also support content redirection, or duplicating content on multiple displays, and to provide the groundwork for rapid development of MDE interfaces via an integrated GUI toolkit.

As MDEs that include mobile devices was a primary design target, Swordfish was engineered from the ground up to support *dynamic bindings* between displays, or connections between displays which could change based on location, time, or even which users were interacting with a display.

To date, a number of existing interface techniques have been developed using Swordfish GUI toolkit, including Multiple-Monitor Mouse [17], Extended Desktop [3], and Edit Blind [6]. In addition to these established techniques, a number of novel interfaces have also been developed including a network view of the workspace, palette-based binding creation, and simple techniques for creating bindings based on screen borders (see Figure 1).

Swordfish is implemented in C#/.NET and can draw on any of the tools designed within the .NET framework. Swordfish has been used to support MDE studies which will be described below, and continues to evolve, primarily as a research support tool. It has been used in our own research for rapidly developing prototype interfaces. As a continued effort to more fully develop research software, Swordfish has continued to incorporate new features, such as logging software, into its core library, and continues to evolve with each new project.

MyMDE

The MyMDE project [18] evolved from a desire to explore how participants view differing display configurations, and in turn, how displays are perceived by users to form workspaces. A user study was conducted involving individual participants and low-fidelity MDE settings consisting of cardboard mock-ups (see Figure 2). Participants were shown a total of 10 different MDE configurations, and in each asked how they would traverse the displays using a mouse attached to a laptop placed on a table in front of them.

The results of the study revealed that participants' traversal preferences tended to fall into two groups; user- and environment-centric traversals. User-centric traversals tended to connect all displays in the environment to their laptop, using the personal display as a "hub" for the rest of the environment. Environment-centric traversals tended to use a centralized display (i.e. tabletop or shared vertical display) as the hub, with only a single connection bridging back to a person's personal display.

These results suggest that individual preference may impact the effectiveness of a display configuration, and that interaction techniques should take the users' view of the workspace into account. These studies were conducted at a preliminary level, and further research is needed to refine the results based on factors such as display type, number of users and user orientation.

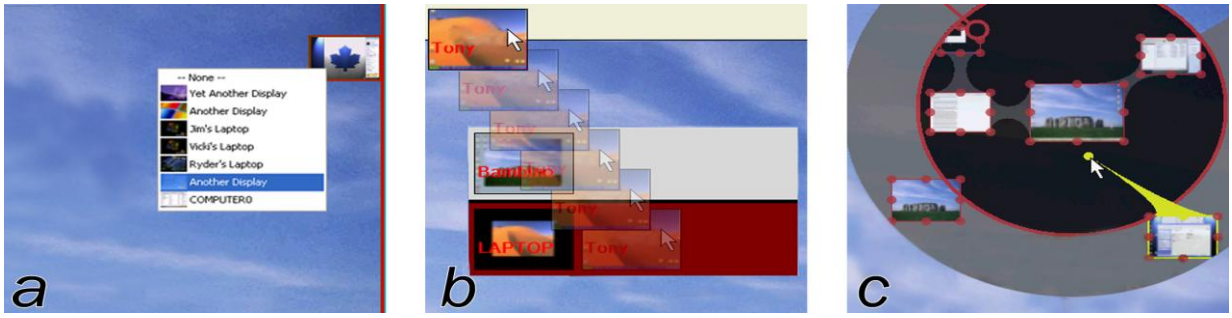

Figure 1. Interfaces developed for Swordfish. a) A context menu accessed near the edge of the display b) a floating palette containing iconic representations of alternate displays c) A floating map in which users "glue" together displays.

Figure 2. Low-fidelity displays used in the MyMDE study.

Content vs Input Redirection in MDEs

More recently, our research has focused on deriving design requirements and considerations for MDEs. Specifically, we have investigated how interfaces impact a user's ability to interact with personal and shared displays, and how a group's ability to perform a task (*taskwork*) and to coordinate itself (*teamwork*) are impacted by introducing multiple displays to an environment.

In recent work [6], we compared input and content redirection interface techniques in suboptimal seating positions. This study was motivated by our desire to develop techniques that enable users to interact with shared content regardless of where they are seated in a MDE. This aspect of MDE design is important, as many interfaces are optimized for users seated directly in front of the display, however in reality only a few users in a group setting are likely to be in such an ideal position. In the study, we aimed to understand how users who may not be positioned optimally within the environment perceive and interact with shared data.

One design approach to support users' seated in non-optimal positions is to duplicate shared content onto a personal display, which we refer to as *content redirection*. Our study findings suggest that content redirection should be considered in cases where participants need to interact with shared content located behind them, or in cases where shared content is situated to their right. In other positions, both content and input redirection techniques provided similar performance.

A limitation of this work is that it was conducted with individual users instead of groups. While it enabled us to more accurately evaluate fundamental interactions within the MDE, it did not provide insight into factors related to teamwork. Our ongoing work aims to address these issues.

Taskwork and Teamwork in MDEs

Currently, we are studying how display configuration can impact the teamwork and taskwork performed by groups working in single-display groupware (SDG) (e.g., shared wall display) environments and MDEs. We have conducted, and are currently analyzing, a study in which groups of three performed the Job Shop Scheduling (JSS) Task [19, 20] in single and multi-display configurations. Additional constraints were placed on task allocations with the intention of simulating a variety of groupware environments. Participants worked in conditions with shared access to all task resources, with negotiated access to resources with their peers, and with computer-assigned access to task resources.

Our preliminary analysis suggests that no differences in solution quality or task time were present, however MDEs better supported taskwork, as the personal displays provided a "sheltered" environment for individual work, resulting in a reduced error rate in MDE conditions. However, by distributing the shared workspace amongst separate displays, teamwork demands appear to increase, as evidenced by increased communication difficulties in the MDE conditions.

SDG environments, on the other hand, provided a unified shared workspace which enabled deixis (i.e. communication efficiency enable by the use of reference terms such as "that one") via telepointers on the shared display, resulting in fewer conflicts between participants when moving job components. However, participants did find the shared workspace distracting since mouse cursors were displayed for all participants simultaneously.

Our initial analyses also indicate that MDEs were perceived as better at supporting communication, and participants reported being more comfortable in the MDE conditions. These findings appear to correspond to the participant's orientation while completing the task. In the SDG conditions, participants adjacent to the shared display tended to sit awkwardly in order to both face the shared display (and thus away from the other group members) and to operate their mice on a shared table. In the MDE conditions in contrast, all participants were able to sit comfortably while facing each other and their personal displays, which were situated in front of each respective group member on the shared table.

Ecologically Valid Analyses

Finally, we are also making an effort to consolidate research from the community which can help elicit design requirements based on the context of use of computational devices. We have recently conducted a literature review [21] which analyses the use of tabletop displays, and discusses contextual design factors revolving around the social and cultural, activity, ecological, motivational and temporal contexts of use (the who, what, where, why and when). We believe that applying this form of analysis would also be beneficial in deriving design requirements for

MDEs, as it leverages information relating to the context of use rather than focusing on technological restrictions in design.

MOVING FORWARD

MDE research is in the precarious situation of pushing the limits of existing technology, while simultaneously developing theory explaining group behavior and communication during collaboration.

In pushing technology forward, there are strategies that we as a community can leverage to facilitate research collectively. For example, open source, or shared source software has already tackled many of the difficult problems faced by MDE research, and has often supplied tested and optimized code for issues such as network configuration [5] and content redirection [22]. For example, work by Hutterer [7] has enhanced the functionality of existing open source projects to include features such as multiple mouse support at the window manager level, which has in turn has been adopted by mainstream open source projects available to the general public. Given our communities' reliance on commercially available projects, one of the most effective tools in enabling more flexible and powerful devices is in contributing to those projects, and encouraging adoption of these ideas.

In terms of theory, many fundamental questions about collaboration and perception remain unaddressed. For example, what tasks will be performed in MDEs? Who will use MDEs? and how do we tell if they are working? We believe that an ecologically valid approach to groupware research can help answer these questions. And perhaps most importantly, determining factors such as the social and cultural relationships between users, what task is being addressed, where collaboration is taking place, and for how long will significantly impact how to measure success and what the "right" MDE design is.

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