Preliminary Evaluation of a Synchronous Co-located Educational Simulation Framework

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Abstract

We designed the MUSHI (Multi-User Simulation with Handheld Integration) framework to address two educational needs: (1) to help students learn about complex, multi-scalar systems, and (2) to help students collaborate with one another in small groups. The MUSHI system provides each student with a handheld computer that is wirelessly synchronized with a simulation running on a tablet PC computer. A group of students can interact with small-scale elements of the simulation via their personal handhelds, and can observe large-scale elements on the shared computer. Because this is a novel combination of devices, we conducted use trials with middle school students to explore issues surrounding multi-device representations, small-group collaboration, and equitable computing.

Keywords

Single-Display Groupware, Multi-Machine User Interface, educational simulation, complex systems, multi-scalar systems, mobile computing, co-located Computer-Supported Collaborative Learning.

ACM Classification Keywords

K3.1 [Computing Milieux]: Computer Uses in Education --- Collaborative learning, H5.3 [Information interfaces and presentation (e.g., HCI)]: Group and Organization

Interfaces --- Collaborative computing, Synchronous interaction, I6.8 [Simulation and Modeling]: Types of Simulation --- Animation, Continuous, Distributed, Gaming

figure 1. Illustration of the MUSHI system in use.

Introduction

MUSHI was designed to help students (1) understand complex systems, and (2) learn collaboratively. To understand a complex system, a person must understand how the actions of entities at small levels of scale combine to form emergent patterns at larger levels of scale. To collaborate effectively, students must all be able to participate and communicate, among other things. Both of these problems share an underlying challenge: a need for *access*. To understand complex systems, users need to *access* multiple levels of scale. To effectively collaborate, users need equal *access* to the educational application and to each other. Fortunately, both of these problems also potentially share a solution: the use of many wirelessly linked computational devices.

Multiple linked representations (MLR) allow a person to view an aspect of the system simultaneously at different levels of detail. Our approach reifies MLR by displaying each representation on a different computational device. A larger device, like a Tablet PC, is used to depict the larger-scale elements of the simulated complex system (i.e. the “zoomed out” view”). The smaller-scale representations of the complex system (i.e. the “zoomed in” view) appear on handheld computers, which are given to each of the students (see Figure 1). The handhelds magnify regions of the system displayed on the tablet PC, acting like mobile microscopes. Providing each student with his or her own handheld computer allows them all to have equal access to the simulation. Most importantly, the mobile form-factor of the devices allows a group of students to easily see each other, converse, and share results. Members of the group participate in the same simulation by logging into a shared tablet PC via their handhelds. The tablet PC’s large-scale representation is designed to serve as a frame of reference to anchor their collaborative efforts.

The paper proceeds as follows: prior work that influenced our design decisions, the research questions that prior work could not help us answer, followed by our first results and a discussion of future work.

Related Work

Single-Display Groupware (SDG)

In both Computer-Supported Collaborative Learning (CSCL) and Computer-Supported Collaborative Work (CSCW) research, a single, large shared display has often been used to aid collaboration. The most relevant is the Pebbles system, which allowed users to draw on a shared whiteboard via their personal handheld devices [6]. In this, and similar systems [9, 7], users can alter the contents of a public, or shared, display by “pushing” content - via some private device.

Multiple Linked Representations
Some educational software has successfully supported MLR using a single desktop monitor. GenScope and Biologica allow users to switch between windows that depict an organism at different levels of detail: from the DNA, to the alleles in a gene, to the external view of the creature’s traits [4]. Another example, 4M:CHEM, allows users to view a chemical reaction taking place at different levels of scale, displayed simultaneously in several sub-windows [5].

Participatory Simulations
Participatory simulations give students individual access (usually via handheld devices) to a shared simulation. Geney allowed students to use handhelds to collaboratively breed fish [2]. NetHub made use of graphing calculators as input devices, allowing students to control aspects of a shared server-driven projection [10]. Similarly, with Mr. Vetro student-controlled handhelds are used to manipulate the different bodily functions (like heart rate) of a simulated body projected onto a shared screen [8].

Research Questions

Educational software should strive to be usable, lest some students become disenfranchised. Although prior work has touched on many pertinent issues, we still needed to answer some basic usability questions before developing the MUSHI framework in earnest.

Relating Personal and Shared Views
Prior work has not looked at the effect of separating dynamic, multi-scalar MLRs onto distinct devices. We were concerned that this reification could place a high cognitive load on students, exacerbating problems students might have with integrating multiple dynamic displays [3]. In our prior work we explored this question, but our experimental design suffered from a ceiling effect: all users of MUSHI-Life, a simulated ecology, successfully accomplished the tasks given to them. While this demonstrated that negotiating the MLRs poses no *serious* difficulties to students, it didn’t provide much insight into where problems might arise.

We decided to revisit this question by videotaping students while they accomplished a more stringent task. They were asked to conduct a four-minute survey of available food sources in the simulated environment. The distribution of the food sources could be seen on the large shared display, but the *identity* of the food sources could only be determined by inspecting them with a handheld. We structured this scenario to encourage the use of both displays: the handheld is necessary to identify the food sources, but the large display is strategically useful (to choose target areas to inspect with their handhelds). We used video recordings to identify the moment-to-moment target of their gaze. (We used a grain size of one second for target identification, which was appropriate for most glances. The few second-long intervals with multiple targets were labeled with the target that dominated the interval). We were looking to see what types of viewing behaviors would correlate with the task performance (i.e. the number of food sources correctly identified).

Coordinating Tasks
Most of the SDG systems and participatory simulations involve users “pushing” data onto the shared display. Our system is the reverse: users “pull” data from the

shared display onto their personal devices. “Pulling” does not leave visible traces, like whiteboard markings, so we were concerned that this would adversely affect the users’ coordination. To assess this, we engaged pairs of users in a food source survey task similar to the one described above. We tailored it to be too difficult to be finished within the time limit, so task performance would be a measure of the degree to which pairs of users were able to maximize the territory covered. (Pairs were used to maximize the number of trials we could conduct, and to vary the gender distribution, because gender can affect collaboration in this age group). We transcribed the videotaped dialogue and coded it for explicit task coordination [1], and recorded the areas of the screen inspected by the partners to detect implicit coordination.

Classroom Evaluation

Since MUSHI is designed for educational purposes, in addition to context-free lab trials, we conducted several trials within a classroom context. The goal of these trials is to compare MUSHI-augmented instruction to traditional lab methods, to reveal major gaps in user support, idiosyncrasies in usage patterns, and unanticipated collaborative difficulties. Identifying such problems can be informative when developing generic scaffolding strategies applicable to MUSHI-style systems.

Testing in a classroom setting requires the alignment of experimental learning goals and curricular content. In an attempt to obtain the most authentic classroom trial possible, a new MUSHI simulation, MUSHI-Wiggle, was developed to fit in with a 6th grade curriculum on Light & Sound. It was designed to be a close parallel to an existing hands-on activity based on slinkies, ropes, and rulers that explored the relationship between wavelength, frequency, and amplitude. MUSHI-Wiggle differed from previous versions of the MUSHI framework by allowing groups of users to adjust the large-scale sound-wave simulation on the tablet PC with the tablet’s digital pen. Students could then make detailed observations of the wave simulation with their individual handhelds. We compared pre- and post-test performance across groups of 4-5 students who used MUSHI-Wiggle and groups who used the hands-on activity, to see how MUSHI would impact learning.

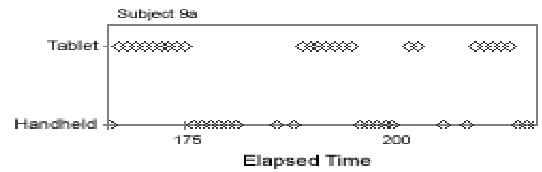

figure 2. Snippet of a second-by-second encoding of a participant’s gaze target. This pattern of longer continuous gazes and small fusillades of glances is typical of most users.

Results

Relating Personal and Shared Views

As in our prior work (which had a very different task), we found that all participants switched their gaze frequently between their handheld and the shared display, an average of 17.7 times per minute (SD = 4.3, N = 8), looking at the handheld a few more times (M = 44.0, SD = 9.5) than at the tablet (M = 30.9, SD = 10.5), but lingering about the same length of time. This seems to indicate an active attempt to relate the images represented on the two displays (see Figure 2).

With respect to task performance, however, we noticed a significant trend: the performance was higher amongst those students who allocated more time to viewing the tablet, and lower amongst those students who viewed the handheld proportionally more, $r(6) = .80$, $p < 0.05$. This implies that some students may "get lost" in the handheld display, and suggests that through explicit instruction, prompts, or other means, we should periodically encourage them to use the shared display. Further work needs to determine exactly how successful students use the large display, but it is likely for planning purposes. We found no correlation between gender and task performance..

Coordinating Tasks

When investigating coordination between participants in prior work, we were surprised by how little explicit coordination was observed (as gestures, like pointing, or dialogue, as in "I'll take the left side"). Even so, pairs of students were able to perform tasks successfully..

Curious to see if the students were implicitly coordinating their actions, in this experiment we assigned pairs a task (surveying the food sources) and recorded which regions of the larger simulations were inspected in greater detail with the handheld devices. Dialogue coding indicated that students made very few (M = 4.3, SD = 2.5) coordination utterances (i.e. statements that suggest a task allocation, or indicate intent to perform a task). We found that even in the absence of explicit coordination, the students still managed to implicitly divide up the work (see Figure 3). Amongst the 4 pairs of participants, we found that all pairs (regardless of gender composition) coordinated their actions – the regions inspected by both pairs overlapped by an average of only 10% (SD = .07, or 7%). There was no correlation between the degree of overlap and the number of coordination utterances. The only explanation for the coordination is that the students must note their partner's location when he or she views the shared display (the extents of the partners' handheld views are displayed as uniquely-colored rectangles on the shared display). This implies that on-screen indicators of a collaborator's current (and previous) activities assist in the collaborative process.

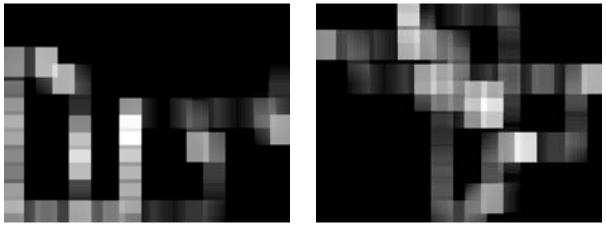

figure 3. These two images show the inspection patterns of two partners. The two images represent the regions of the large, shared screen inspected in detail with the participants' handheld views. The lighter the color, the longer the user let his or her detailed view linger in that spot.

Classroom Evaluation

Classroom work revealed that students using MUSHI-Wiggle learned about as much as students working on a traditional laboratory task, scoring 30% (N = 12, SD =12%) to 31% (N = 49, SD =13%) respectively on fairly challenging posttests, with very similar achievement gains (~3.5%) compared to pretests. This is very promising, because untried technology usually performs far *worse* than traditional methods in initial classroom trials, because so many other elements (like instruction, technological readiness, etc.) are not aligned. A detailed analysis of students' in-lab work *does* reveal a troubling gender difference in performance with MUSHI-Wiggle, however. Female students out-performed male students in the control group by ~3%, but in our test group females performed a full 20% worse than the males. One explanation is that intermittent technical problems may have to occurred more frequently with the female participants, but we should remain vigilant for gender disparities in future trials. We also discovered a variety of new usage patterns, such as “Tablet Hogging” (fighting over control of the shared pen), and “Virtual Slowdown” (pausing and unpausing the simulation rapidly) which will inform further MUSHI designs.

Discussion

Thus far, our results have been promising, even with more stringent performance tests. Students were able to integrate the small- and large-scale displays, coordinate their actions, and use MUSHI to learn concepts in an authentic classroom setting. This shows that our framework is indeed viable, and we can move on to studying how it can help complex system learning. Some of our observations will guide future design: students need help navigating MLRs, indicators of partners’ actions should be depicted on the shared display, and shared resource use must be investigated. We also plan to study how groups with 3-5 members do (or do not) coordinate their actions while using MUSHI.

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