The Use of Hand-held Devices for Search Tasks in Virtual Environments

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Abstract

Interaction through handheld devices is increasingly being used in virtual environments (VEs) for science, engineering, and entertainment applications. Some of the uniqueness of these non-traditional multiplatform user interfaces (MPUI) lies in the division of information between multiple displays and the remote control of information (e.g., using on computer to control a remote display). We performed an exploratory comparative study to understand what an appropriate division is and how people interact in such setting within the context of information-rich virtual environment for biomedical visualization applications. Three conditions studied were a Tablet PC (Tablet) with a traditional desktop, a Tablet with a large screen display combination, and a desktop VE environment. The results reported here are: physical large screen had a noticeable impact on presence; the form factor of Tablet worked both in favor and against the user in different conditions; and context switching was a problem but might be compensated using the mobility of the Tablet.

1. Introduction and related work

The proliferation of different handheld devices (e.g., Tablet PCs, PDAs, and other small devices, like cellphones) and wireless technologies (IR, Bluetooth, and 802.11) is creating research opportunities in the interactive use of these devices. A use afforded by this combination is that of group collaboration, as in [2, 6]. Another use is that of single user interaction but using what amounts to a dual display configuration, where one of the displays is a traditional display used in virtual environments (VEs), as the one shown in Figure 1. This opens up the questions of what information should be displayed in the VE displays and how people will use the combination of the devices to do their tasks.

There are tradeoffs to consider with this configuration. Users may benefit from certain multiplatform user interfaces (MPUI) by doing real world tasks which are heavily dependent on

Top: the environment setup in the CAVE
Bottom: Tablet PC user interfaces

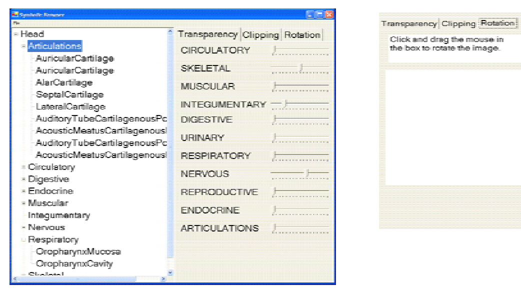

Figure 1. Tablet PC as a control device in a virtual environment

cooperation between platforms. Users may also benefit in tasks that involve multiple sources of information from different technical resources (such as operating systems, toolkits, etc), different screen sizes, and different capabilities (such as visual auditory and touch channels). Also, because the handhelds are computers in their own right, users can carry data with them and collaborate with other people at any time any place [15].

Handhelds also offer a constrained movement in two-dimensional (2D) plane which may result in a better interface than free-space interaction. In particular, handhelds affords WIMP (Windows, Icons, Menus, Pointer) user interfaces and text input [14]. One particular area where this scenario is typical is in information-rich virtual environments (IRVEs) [4]. Such added information can enhance users' performance and promote a semantic directness leading towards more accurate mental models of the spatial objects they perceive, therefore enhance training and teaching [10].

Some of the uniqueness of using handheld in VEs compared to traditional graphical user interfaces lies in the physical division of information between multiple displays and the possibility for the remote control of information. This physical division forms a multiple-view system which can improve the users' task performances, help discover unforeseen relationships, and reduce information cluttering. But it can also increase the time and effort needed to learn the system, increase the load on users' working memory, force the user to divide his or her attention, force context switching, increase system overhead, or cause interruption [1, 5].

Most of the work about using handheld devices to interact with VEs [6, 9, 14] has been done with a focus towards determining the engineering difficulties that a designer would encounter when creating these systems, rather than the human interaction problems that a user of such a system might face. However, many VE interfaces do not work as well as they could because they impose requirements on the human user that may conflict with the way people attend, perceive, think, remember, decide, and act. Our goal in this research is to touch on some of the usability issues that can occur when the Tablet is used as a remote control device. We expand previous work on usability by considering the usability aspects when dealing with a three-dimensional (3D) biological data visualization application, which provides cross-disciplinary issues and information-rich data sets.

2. Interface design and evaluation goal

Particular displays may be better- or worse- suited for different tasks. The task-display dependence has to be considered within a context of an application. We designed the interfaces in this study with the goal of allowing the medical doctors to be able to interact with the application using the Tablet as a type of remote control in an intuitive manner. We surveyed six medical domain experts to gather information about how they would use a Tablet to control another display for bio-medical visualization by extending an existing visible human anatomy application [7].

Three findings were obtained from the survey. First, many of the participants mentioned that the Tablet would be useful for remote control operations, prior to any indication from us that such a use was intended. For example, one participant presented a scenario where a radiologist would access images from a remote site and compared it to receiving images from a server. Second, there are two types of information used in this application, spatial (3D images) and symbolic (text labels of different body parts). All participants preferred the use of a structured hierarchy to present information compared to pure alphabetical order, with the structure following the anatomical structure of the information. Third, participants preferred to have one locus of control rather than controlling the symbolic data in one place and the spatial data in another. Additionally, the users wanted to see many pieces of the symbolic data in the same place as the spatial data. This would suggest that context switching could be a problem and the information should always be displayed at the screen of current focus.

We iteratively design the interface (Figure 1). Within the environment, users could explore and examine the human body through a combination of 2D and 3D interfaces on the two different platforms. An explicit link between the spatial and symbolic data was presented on the display connected to the SGI screen in response to user's clicking on the structure on the Tablet. With our system, users can: 1) switch between the interfaces for transparency, clipping, and rotations were performed by tapping a tab on the Tablet; 2) tapping an item in the hierarchical structure on the Tablet display to visualize the corresponding structure on the SGI display; 3) dragging a slider to change the transparency of a feature (Figure 1, bottom left); 4) use a mouse like gesture with the pen on the Tablet to enable object rotation (Figure 1, bottom right). The WIMP-style interfaces on the Tablet gave users a familiar interaction method.

To gain insight in the use of MPUI in VEs, we performed a usability study to compare three different setups: a Tablet with a traditional desktop using a 21" monitor (Figure 2), a Tablet with a large screen display, and an OSF/Motif style desktop environment. The large screen display was simulated using one wall in the Virginia Tech CAVE (size 10'x10'x10'). The goal lies in observing users' behavior and subjective responses to certain setup while performing search tasks. We tried to avoid the stereo mode in the CAVE

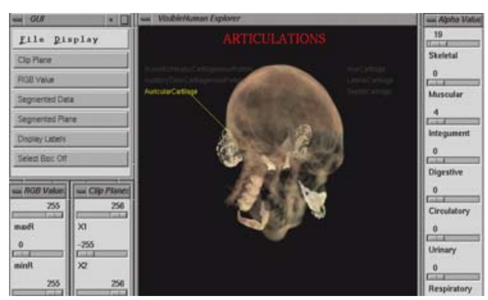

Figure 2. The desktop condition

because we want to control this experiment with the fact that the only difference between interfaces lies in the Tablet as a remote control device.

3. Experimental Design

We designed tasks that required multiple context switches while using the Tablet because we wanted to explore its effects. An example task would be "display the articulations and the skeletal structure so that you can see and differentiate both structures." To finish this task, the user needed to look at both displays, due to the separation of the visualization information and the interface used to control that information.

Additionally, tasks for training involve 'understanding' in contrast to pure navigational or manipulation tasks which is important to most IRVE applications. Such 'understanding' or 'knowledge' of environment is one aspect of situation awareness in UbiComp paradigm [15].

Six participants were recruited and trained for this study including one female and five males aged 22 to 30 from the computer science department. Among them, one was double expert (with both medical and usability engineering background); two were usability experts and happened to user pen-input on a daily basis, and three had certain usability evaluation experiences but no medical knowledge. We ran two trials for each task. The order of execution was counter-balanced. A think aloud protocol was enforced while participants were performing the tasks. Finally, they were asked to fill out a post-questionnaire for subjective assessment.

4. Results and discussion

4.1 Presence effects produced by physically large displays

Slater et al. [11] defined the sense of presence as "a state of consciousness, the (psychological) sense of being in the virtual environment."

Five out of six participants reported "it is scary" and did not want to stay long in the CAVE. No such comments were made when the users were interacting with the desktop. This result suggests that the level of presence of the information displayed increases with the increase in the size of the display given that all other factors are the same.

This is an important consideration for the design of VEs with realistic rendering. The size of the display might make some information seem more real, causing possible emotional effects. Users had about the same field of view as they looked at the monitor. Large size leads to better visual search task performance [3], better navigation performance [12] and higher retention [8] while used in a single display mode.

We would expect performance to increase on search tasks across displays without context switching. We made an informal comparison of task performance. However, users did not present any patterns of increasing performance while switching from any of the three conditions to another. The decrease in performance across displays can be caused attributed to context switching, but we cannot decide given the small sample size, training or instruction given to participants. Further investigation of these issues is needed.

Participants also preferred the large display over the desktop monitor and commented that the large display could present more information as well as a more clear view of the data. This would suggest that the visual realism setup afforded by large size can offer more peripheral stimuli sources (i.e., stimuli that are not in the center of conscious attention) compared to a regular monitor.

4.2 Context switching can be resolved through mobility and peripheral display

Participants ranked the desktop interface as the interface with most ease-of-use (the mean is 6.2 on a 7 scale). This interface required no context switch since display and control were both on the same computer and interface.

Interestingly, participants commented that the peripheral vision provided by the large screen display caused fewer problems with context switching than the monitor with a Tablet as a remote control. However, both the large display and monitor based interfaces required the same number of context switching. This result could be explained by peripheral computing, where an interface attempts to provide peripheral awareness of people and events [13]. The peripheral computing offered by the large display allowed the user to divert his or her attention without a change in direction of his or her gaze.

Perhaps the most interesting use of the portability aspect occurred when one of the users positioned the Tablet underneath the monitor, thus enlarging the monitor. This allowed the user to interact with the interface as if it was a Tablet with a dual display and also allowed the user to place the control information in the position that the user considered most convenient. By enabling the user to customize not only how the information is displayed, but also the display itself, the Tablet presents an interesting extension to the customizability of an application, which we feel merits further investigation.

4.3 Interaction with the Tablet PC was difficult for novices

Participants ranked the interaction with the Tablet (3.7) as the worst factor by comparing the mean, context switching the next (3.8), and the remote control the best (5.2 for the large display and 4 for the monitor) on a scale of 7 where 1 meant strongly disagree, 4 meant neutral, and 7 meant strongly agree.

From our observation, novice users had trouble dragging or tapping a slider but found it is easier to interact with the "touch-pad" interface to control rotation since no explicit numerical input was required. Expert users did not have such complaints. Users did not put their attention on the Tablet (it essentially became invisible to them) but rather on the image displayed on the primary display when doing rotation.

While many users felt that the Tablet was too heavy to be used in a standing context, even these users often found interesting ways to take advantage of the portability of the Tablet.

5. Conclusion

We performed a behavioral observation of the usage pattern by comparing three usage scenarios. Our findings and contributions follow: certain amount of training is needed for novices to interact with VEs using a Tablet. A large screen display might have an effect that goes beyond the resolution as it increases the user's sense of presence, as seen with the groups that saw the human-body in the application at real-life scale. The Tablet's mobility can help solve context-switching problems. It would be interesting to further investigate the cost and cognitive load on the user when using systems that involve multiple displays controlled by different computers.

Our initial study suggests numerous future directions for us to pursue:

- Due to the form factor of the Tablet (e.g., heavy, difficult to carry), PDAs might be a device that are more suitable to be used in VEs. Usability studies are needed to measure subjective and objective responses.
- Formal usability studies are needed to compare the effects of different handheld devices on task performance in both collaborative and single user environments.
- We need to investigate what information visualization method to use for text labels presentation and assess the level of detail needed to make the information legible.
- We need to identify other applications that could use high resolution display and rich information presentation on hand-held devices.

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