Usability of Tablet PC as a Remote Control Device for Biomedical Data Visualization Applications

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ABSTRACT
Interaction through multi-platform user interfaces (MPUIs), is increasingly being used in battlefield applications, telemedicine, classroom education, and engineering applications. Some of the uniqueness of these non-traditional user interfaces lies in the division of information between multiple displays and the remote control of information (e.g., using one computer to control a remote display). We preformed an exploratory study to compare three different setups: a Tablet PC with a traditional desktop, a Tablet PC with a large screen display (LSD) combination, and a desktop computer. The results showed that many users preferred the familiar Microsoft Windows widgets available on the Tablet PC; users often had difficulty generalizing their experiences' when using the Tablet PC; and the form factor of the Tablet PC worked in favor and against the user in different conditions. Our results indicate that while there are yet problems to overcome, generic handheld devices can make highly effective remote controls for virtual environments.

Author Keywords
Tablet PC, hand-held computing, remote control, multi-platform user interface, biomedical application

ACM Classification Keywords
H5.2.User interfaces: evaluation/methodology, prototyping, user-centered design; H.5.3 Information interfaces and presentation: synchronous interaction, Microsoft .NET

INTRODUCTION

In recent years, the biomedical field has made great strides, many of them tied to the large improvements that have been made in the field of image processing. Doctors can now perform detailed analysis on MRI and CT images via the Internet, which allows them to better manage the health of elderly patients with diabetes [11]. In the biomedical field, the amount of data to be visualized is huge, which may include the electronic medical record of the patient, treatment guidelines, and decision support systems. [5, 10]. Presenting such information on one display can be overwhelming. Dividing information onto different displays may help alleviate this problem.

With wireless mobile devices rapidly becoming ubiquitous, people can now conceivably access information at anytime and anywhere. In this paper we explore the question of how easy is it to access and control such information remotely [6]. At the interface level, certain multiple platform user interfaces generate a multiple view environment. This raises the question of whether it is possible to effectively use a handheld device as a remote control for a multiple view environment and what hurdles we need to overcome in order to make this use a reality.

As the first piece of our research, we address using a Tablet PC as a remote control device to interact with three-dimensional (3D) biomedical data in an information-rich environment, where information about different body parts is presented. Both horizontal and vertical usability issues were investigated with specific regard given to context switching, portability, attentiveness, manageability, and learnability. The investigation was carried out by performing a comparative study of three different interaction paradigms: a desktop, a monitor coupled with a Tablet PC, and a large screen display (LSD) coupled with a Tablet PC, all of which were analyzed with respect to various information search tasks.

These three configurations have different interfaces. We will refer to the different configurations as traditional (desktop), classroom (monitor and Tablet PC), and ubiquitous (large screen and Tablet PC). In the traditional paradigm the interface imitates the type of interaction that is typically found on a desktop computer. The interface of the classroom paradigm has the user using the Tablet PC as a remote control device, but also supports seated and close examination of the onscreen situation. The ubiquitous paradigm is exemplified by interfaces that are inspired by Weiser's vision of the computer for the 21st century, in which the Tablet PC can be carried by a user who can then walk up to a place and use it, in conjunction with a fixed large screen or 3D stereoscopic display device to access the information that he or she is interested in.

RELATED WORK

Oquist and co-authors presented a framework for assessing usability across multi-platform user interfaces. In their framework, usability of mobile devices is divided into four categories: portability, attentiveness, manageability, and learnability. The context of use is divided into four situations, namely stationary, seated, standing and moving. Then the level of attention/interruption, manageability and learnability were evaluated with these four conditions in mind. However, we found this framework to be too constraining to be applied for observing complex scenarios when using a single device. Under different circumstances, for example, visual attention can be limited to a single display even when multiple views are presented [2]. If an interface is well designed, the level of attention can be increased or decreased based on task-requirements.

The usability issues associated with Tablet PCs as remote controls have been researched in the classroom [1] and for home web access [9]. The work from these projects has touched on some of the usability issues that can occur when the Tablet PC is used as a remote control device. We expand upon this work by considering the usability aspects when dealing with a three-dimensional (3D) biomedical data visualization application, which provides cross-disciplinary issues and information-rich data sets. Also, their use does not require context switching. The other display was used for presenting information rather than display information that users have to constantly access.

A fair amount of work has been done in using MPUIs to interact with VEs [3, 7, 13]. Most of this work has been done with an eye 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. Thus we hope to fill in a gap in this past research by further exploring what problems users might face when interacting with a VE through a smaller, handheld device.

In terms of three-dimensional displays and information visualization techniques, a large amount of research has been done investigating how to effectively display information. In [2], the authors investigate the use of multiple displays for viewing data that has a large number of components, and came to the conclusion that this can help the user understand the information. Bowman and coauthors [4] presented results on the design of 3D information visualization applications, as well as some of the interaction issues that are present when using these applications.

DOMAIN OF USE AND GOAL

The specific application domain that we chose to explore was a biomedical 3D display environment. In this environment there are two main types of information - spatial and symbolic. The spatial information is the 3D rendering of the relevant human anatomy, whereas the symbolic information consists of a number of attributes such as what part of the body to look at and what labels to display.

In order to study the usability issues involved in multi-platform user interfaces we first had to design a multi-platform user interface. We used two main platforms, an SGI workstation which could drive a large screen display being the first, and a Tablet PC as the second. The interface for the large screen display was largely constrained by an existing system developed to allow medical students to study human anatomy. Our goal was to allow the user to be able to interact with the application using the Tablet PC as a type of remote control. We wanted to allow this interaction to take place in much the same way as the user would normally interact with the application if running it on a standard sized display with a mouse and keyboard as input devices.

DESIGN PROCESS AND RATIONALE

We designed our interface in two stages. First, to create an interface that was as realistic as possible, we surveyed domain users to gather information about how they would use a Tablet to control a large display for biomedical visualization. With the findings from the survey, we iteratively designed and evaluated the Tablet PC remote control interface. Our goal in the design was to allow the user to be able to interact with the application using the Tablet PC as a type of remote control in much the same way as the user would normally interact with the application if running it on a standard sized display with a mouse and keyboard as input devices.

During the first stage, we interviewed six medical domain experts, including five faculty members and one graduate student who had extensive clinical experience. This choice of subjects facilitated our goal of assessing the potential use of the Tablet PC and the types of interfaces users preferred to use for a visible human anatomy application, such as the one presented in [8].

Three findings from the survey were: (1) many of the participants mentioned that the Tablet PC 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. (2) 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. (3) 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.

Initially we planned to have the symbolic information displayed on the smaller device, while the spatial information was displayed on the large screen. User surveys, though, exposed this as a poor way to split the information between the two devices. While this break of information is conceptually simple, we discovered that users wanted to have one locus of control, and also that they preferred to see many pieces of the symbolic data in the same place as the spatial data. Thus we changed our breakup of information so all biomedical information (e.g. renderings and labels) were displayed on the large device, while all control information and input was handled on the small device.

SYSTEM DESIGN AND IMPLEMENTATION

With these insights in mind, we designed MoVE, a Multi-platform Visible human Explorer, which supported cross-platform interaction between a Tablet PC and an SGI Origin 10000 workstation (Figure 1). The SGI was used for 3D volume data rendering running on IRIX6.5, and the Tablet PC (a Toshiba Portégé) was used as the remote control device. There was no perceivable delay in communication (less than 1ms.) between them.

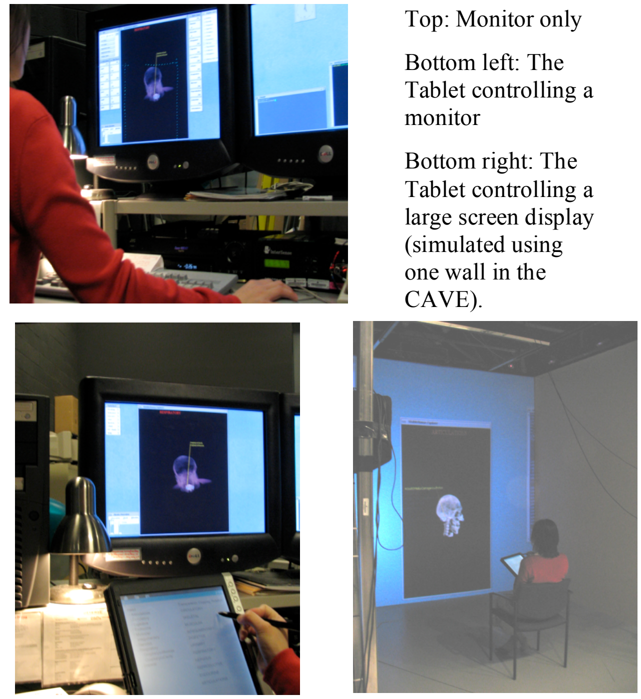
The Interface

The result of our interface design is shown in Figures 2 and 3. Users could explore and examine the human body in a natural and intuitive way 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 in response to user's clicking on the structure on the Tablet PC. With our system, users can: 1) switch between the interfaces for transparency, clipping, and rotation by tapping a tab on the Tablet PC; 2) tap an item in the hierarchical structure on the Tablet PC to display the corresponding structure on the SGI display; 3) drag a slider to change the transparency of a feature; 4) use a mouse like gesture with the pen on the Tablet PC to enable object rotation. The WIMP-style interfaces on the Tablet PC gave users a familiar interaction method.

Software Architecture

On the Tablet PC, socket programming was implemented through Microsoft .NET and C# using a TCP client-sever architecture. The SGI, operating on IRIX, ran multiple threads and used a shared memory architecture. One thread listened to the data sent by the Tablet PC and wrote to the shared memory; the other thread handled data visualization with X Windows and OpenGL Volumizer™ and was updated in real time when the shared memory was updated.

Standard TCP/IP sockets were used to communicate with the SGI workstation. This allowed us to use a standard wireless connection to connect to the workstation, in this case a university-wide wireless connection. While the same



Top: Monitor only

Bottom left: The Tablet controlling a monitor

Bottom right: The Tablet controlling a large screen display (simulated using one wall in the CAVE).

Figure 1. Experiment setup

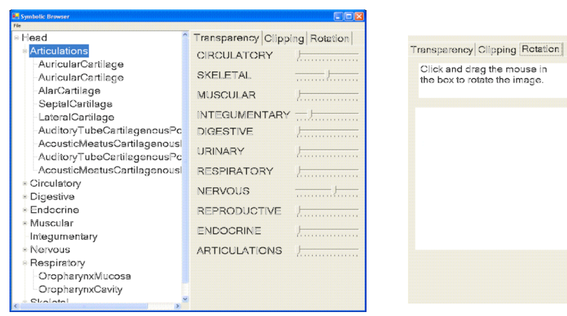


Figure 2. Tablet PC user interface

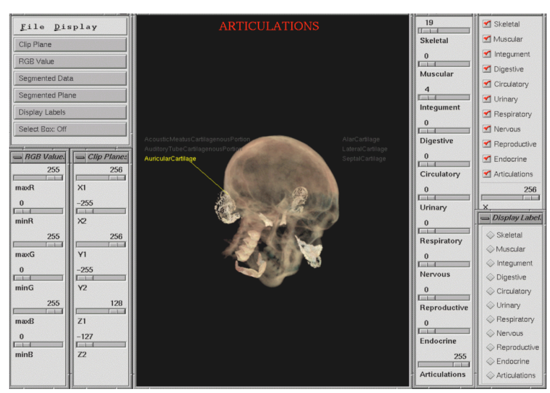


Figure 3. SGI 3D data visualization interface

functionality was maintained across the two platforms, due to the differences between the two operating systems used, the look and feel of the two different applications was substantially different. On the Tablet PC, standard windows widgets were used, including tabbed windows and collapsing menus. On the SGI machine, the interface elements were designed using Motif, and thus the interface on the SGI appears as a set of buttons and sliding bars. In addition to the interface changes mandated by the different platforms, the method for rotating the image was different on the two devices. When interacting with the monitor via the keyboard and mouse, the user could directly click on the 3D rendering, and rotate it by dragging that. Since the user was not directly interacting with the rendering when using the Tablet PC as a remote control, to rotate the image with the Tablet PC, a still capture of the rendering was sent to the Tablet PC. This picture was displayed in a small window which the user could drag on to rotate.

EXPERIMENTAL DESIGN

Two types of displays were used for our experiment. The first was a standard 21 inch monitor and the second was a large screen projection, which was simulated using one wall in a cave automatic virtual environment (CAVE). The software running on the SGI machine was capable of driving a stereoscopic 3D simulation on the CAVE, however, we were unable to make use of this since the stereoscopic goggles used to view the 3D image conflicted with the refresh rate on the Tablet PC, resulting in a disconcerting flickering when viewing the Tablet PC. This issue could be resolved by the passive glasses, though unfortunately these were not available in the VE lab. We did find that viewing the data in a fully 3D manner provided better depth cues, enabling faster performance on the information search tasks.

The Tablet PC, which was used as a remote control for the SGI workstation, was a Toshiba Portégé 3505 running Windows XP Tablet PC edition with a 1.33 GHz Pentium III and a 12.1 inch display. The user interacted with the Tablet PC by means of the stylus, thus allowing him or her to hold the Tablet PC like a normal pad of paper. The primary design goal for using the Tablet PC in this manner was to allow the users to interact with the device while standing.

We performed the experiment in two stages. In the first stage, we performed qualitative analysis with respect to the specific domain of our application (i.e. biomedical visualization). For this stage, we utilized six domain experts, five faculty members from the medical school and one graduate student (who had 2 years of clinical experience before joining the medical school). For this stage we employed a think-out-loud protocol in order to gauge the users' reactions to the interface design, as well as to determine what improvements that the users felt would help the application. During this stage, we allowed the users to explore the application in whatever manner they chose. Our purpose for this stage was primarily to determine what realistic usage would consist of. We did this in order to ensure that we did not create an application that was specifically geared towards MPUI usage at the expense of specific domain usage.

In the second stage, we concentrated primarily on the multi-platform user interface dimensions of the application. Six participants were recruited for this stage including one female and five males aged 22 to 30. Among them, five were graduate students from the Computer Science department and one from the Industrial and Systems Engineering department. We had the subjects try all three different interaction methods (i.e. traditional, classroom, and ubiquitous), varying the order in which the subjects saw these methods. The subjects were each given approximately five minutes to familiarize themselves with each interface, after which they were given two information finding tasks that required them to use the full set of the features in the application. We observed the subjects while they were performing these tasks as well as when they were exploring the interfaces. After they were done with all of the configurations, we asked them to fill out a short questionnaire, as well as give us any thoughts that they had on the interfaces.

EXPERIMENTAL RESULTS

During the first stage of experimentation, we found one interesting result with an implication toward MPUIs. Many of the domain users preferred to interact with the Tablet PC rather than through the normal GUI because they felt more familiar with the interface on the Tablet PC. This is undoubtedly due to the fact that the interface on the Tablet PC used the familiar Microsoft Windows type widgets that the users where familiar with, rather then the more exotic ones used on the UNIX system.

The first stage was primarily designed to ensure that the experiment represented a real world task, so before proceeding to the second stage we tailored our interface based upon what the users with domain knowledge said would be required in this type of application. This allowed us to focus exclusively on the MPUI aspect of the application during the second stage of experimentation, thus allowing us to obtain a number of interesting results.

Interaction Issues

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

The users' frustration with interaction could be explained by the fact that most participants had no previous experience with pen-input, and thus had trouble dealing with the mismatch of tapping and the cursor location. This result suggests that the Tablet PC is not suitable for novice users for this type of application. This has an impact on conditions where the Tablet PC might be available for loan at a library or other common work area.

Our observations showed that most participants did not have trouble when interacting with the "touch-pad" interface to control rotation. They did not put their attention

	PC (mouse as input)	Tablet PC coupled with a monitor (stylus as input)	Tablet PC coupled with one wall in the CAVE (stylus as input)
Is the setup useful?	Yes	Yes (domain users) No (regular users)	Yes
Is the setup comfortable?	Yes	No	Divided
Was context switching an issue?	No context switches	Too many context switches caused fatigue	Lots of context switches but users were not uncomfortable
Favorite position	Seated posture	Seated posture	Divided
Is it easy to manipulate the interface elements?	Yes	No	No

Table 1. Summary of questionnaire results

on the Tablet PC (it essentially became invisible to them) but rather on the image displayed on the primary display. On the other hand, most users put their full attention on the Tablet PC when using the other interface elements. The user's attention was provided to the device that contained the feedback for the manipulation being done. We presume that interactions where the feedback is split between the two devices would have poor usability, as it would increase context switching.

Context switching issues

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

When using the Tablet PC and monitor, one user moved the Tablet PC next to the regular monitor to avoid switching views. The mobility of the Tablet PC served to ameliorate the cost of context switching.

While both the LSD and monitor based interfaces required the same number of context switches when a Tablet PC was used as a control, users had fewer problems with the LSD, which could be explained by *peripheral computing*, where an interface attempts to provide peripheral awareness of people and events, as suggested by Ullmer and Ishii [12]. The peripheral computing offered by the LSD allowed the user to divert his or her attention without a change in direction of his or her gaze [14]. For the monitor based interface, most of the time the user had to move his or her head when performing a context switch, with the exception of the user who moved the Tablet PC next to the monitor: a strategy that effectively reduced the cost of context switching. We believe that this result suggests that studying visual scanning behavior would be an interesting future direction.

Large screen display issues

The human dataset displayed on the LSD is about the same size as a real human. When using the LSD, a common user comment was "it is scary". 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 large screen displays for non-office use. The size of the display might make some information seem more real, causing possible emotional effects.

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

Cognitive Issues

From observing the subjects while they were becoming acclimated to the interfaces, we observed that those who used the Tablet PC as an interface first, learned the system as quickly as those who first used the mouse and keyboard for input. They were also able to perform the first task in approximately the same time. What was interesting, however, was that despite the fact that the second task was functionally identical to the first, those who used the Tablet PC as an interaction device first, often took just as long with the second task as they did with the first task. This behavior persisted even when they switched to the mouse and keyboard interface. Those who used the mouse and keyboard as an input device first usually took about forty seconds to perform the first task, and then about ten seconds to perform the second task. Those who used the Tablet PC as an interface device took forty seconds on both of these tasks. Given the small numbers in our experiments, it is impossible to determine whether or not this represents a valid general observation, or is just an artifact of the specific subjects who participated in the experiments. We believe, though, that this phenomenon might result from users having a hard time relating their actions on the remote to the action's effect on the main display, when performing multiple step processes. While users can easily figure out how to manipulate a slider to increase or decrease the transparency, when the user must switch back and forth between views he or she can lose the trail of actions that resulted in the current state. Without this trail, the user may have difficulty learning from what he or she did to reach the current (goal) state, and is thus unable to learn from the process. This difficulty may arise from the increased mental load that the user is under due to using two devices, or, it may be due to an inherent human difficulty when tracking state across more than one device.

Form Factor Issues

While many users felt that the Tablet PC 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 PC. Perhaps the most interesting use of the portability aspect occurred when one of the users positioned the Tablet PC underneath the monitor, thus enlarging the monitor. This allowed the user to interact with the interface as if it was a Tablet PC 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 PC presents an interesting extension to the customizability of an application, which we feel merits further investigation.

As noted previously, most users strongly preferred to use the Tablet PC while sitting. While one of them said that they would have no problem using it while standing, the others all felt that it was too heavy to be held in one hand effectively. Given that the Tablet PC is extremely light for a device it's size, this would seem to indicate that many users would prefer not to use moderately sized device while standing. It should be noted though that none of the users who made this observation had any experience with using handheld devices, so it is possible that they just were not familiar with the appropriate ways to hold such a device.

On the question of their preferred size for the handheld device, none of the users thought that the device should be bigger, though there was some moderate to strong preference for a smaller device. The users tended to feel that a smaller device would be easier to hold, and that there was already more than enough room to display all the information necessary on the Tablet PC. If a larger amount of information needed to be displayed, the users might not have been as willing to accept a smaller device. Given their complaints on the weight of the Tablet PC, it is unlikely that very many would be willing to accept a larger device, regardless of the amount of information that needed to be displayed.

Initially we thought that some users might be tempted to hold the Tablet PC in such a way that it blocked their view of the screen, however, we found that this was not the case. Users tended to automatically hold the Tablet PC in such a way that it did not interfere with their vision. This did not mean that they did not have any problems with the positioning of the Tablet PC, as half the users felt that it was extremely uncomfortable to hold the Tablet PC in the position that they used. Interestingly, the other half of the users found that they could hold the Tablet PC with perfect comfort; this question invoked answers at either extreme, with no apparent middle ground. This may be an indication that there are some users who would not find the use of such a handheld device at all acceptable, or it may mean that some users just are not familiar enough with these devices to be able to use them comfortably.

Ease of Use

When comparing the ease of use of the three different configurations, we found that users found it easiest to use the mouse and keyboard, and hardest to use the Tablet PC to interact with the standard size monitor. It should be noted that all of these test subjects had well above average experience using a computer, and thus a mouse and keyboard, and so might prefer this method more than a less computer savvy group would. Additionally, while the users did feel more comfortable with the mouse and keyboard, they reported no particular hardship when using the Tablet PC.

IMPLICATIONS OF RESULTS

The results of our experiments have suggested a number of design implications when creating an MPUI for a virtual environment. One of the first things we noticed was that inexperienced users found it easier to use the standard widgets from Microsoft Windows that they were familiar with. While it is possible to build more familiar widgets in other systems, it is often much more difficult, and thus using a platform that the users are familiar with can greatly increase the ability of the user to effectively and comfortably interact with the application. Additionally, we found that users who were not particularly computer savvy were much more likely to feel comfortable using the Tablet PC than those who were more computer savvy, though the users who were most comfortable were those who had experience using other handheld devices. From this we can gather that if the users of an application are primarily users who are intimately familiar with a keyboard and mouse style of input they might not be as willing to switch to some other less comfortable input method as users who are not quite as tied to the keyboard and mouse input method.

As we noted earlier, it seemed that users had trouble developing an effective mental model for the application when using the two devices in combination. While they were able to learn simple tasks with no difficulty, and had little trouble performing exploratory tasks, tasks which required a succession of actions often seemed to be difficult for them to effectively generalize. This problem seems to be a particularly important one to solve, though we do not know just how best this could be done. One possible solution would be to limit the number of multi-step tasks that a user might need to perform. Alternatively the user could use a standard keyboard and mouse combination when first using the application in order to develop an effective mental model of the application, and then progress to a 3D display once the user was more familiar with the capabilities of the application.

We also found that many users found the Tablet PC to be either too heavy or too cumbersome to use in a standing position. This would seem to indicate that many users would prefer smaller devices for this type of application. While a PDA might be too small to effectively display a reasonable amount of information, a smaller Tablet PC might work very well. Additionally, it seems that a number of people found using the Tablet PC to be fairly uncomfortable, and thus it might take a nontrivial amount of time to acclimatize users to the use of any such handheld device.

Finally we found that the attribute that users most admired about the Tablet PC was its portability. This would seemingly conflict with some of the users' reluctance to use the device in a standing context, however, those who were either more comfortable or at least moderately comfortable using the Tablet PC while standing found the ability to move around of great benefit. One user pointed out that by using it in such a manner, it would be possible to move among a number of displays, controlling them all with the same device. This mobility being one of the main points that users found likable about the device, a designer would be well advised to allow the users to take advantage of this ability in an effective manner if designing such a MPUI system.

FUTURE RESEARCH

Our study identified a number of interesting research paths that we are interested in pursuing further. The most interesting of these would be a further exploration into the learning difficulties that we found when users where using the Tablet PC as a remote control. We would like to establish that these learning difficulties where, in fact, actually caused by the use of the Tablet PC as a remote control, rather than just an anomalous result brought about by the different learning strategies of the test subjects. If these learning difficulties are a result of the use of a remote control, it would be interesting to attempt to determine why this problem comes about, and what could be done to solve it. We would also like to further investigate how well a remote control would work in a stereoscopic three dimensional environment. As mentioned earlier, we had problems with conflicting refresh rates on the Tablet PC and the alternating images used by the stereoscopic projection system. We hope that by experimenting with the various refresh rates, we could attempt to eliminate this conflict, and thus gain information on using a Tablet PC as a remote control in a truly 3D environment.

CONCLUSION

With this paper we have explored some of the usability issues that face a designer of a multi-platform user interface application when applied to a three dimensional display. In order to explore these issues, we created an MPUI using a SGI workstation and a Tablet PC. We explored this integration on a biomedical based application, which we tested on typical domain users in order to ensure that the application remained a valid and realistic example, rather than simply a toy application suitable only for MPUI use. We then tested this interface on non-domain experts in order to obtain information focused directly on the MPUI aspects of the interface rather than simply on the domain specific aspects. We found a number of interesting implications for the design of MPUI interfaces to VEs, as well as a number of different areas to explore. We believe that using handheld devices as remote controls for large screen displays and virtual environments is an eminently feasible proposition. While we have identified a few problems with this usage, we hope that these can be overcome in the future, and allow us to make use of the many advantages that we identified when using a handheld device as a remote control.

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