Benefits of Tablet Interfaces for Immersive Visualization in Information Visualization

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ABSTRACT

This paper describes how tablets can be used to increase the interaction possibilities of virtual reality applications running on CAVE-like[1] environments. A use case is presented using the genome comparison software 3DScover. The tablet interface has been introduced in a user-centric development environment. Multiple user studies have guided the evolution of the interface to ensure optimal ease of use. Our results indicate that the tablet provides useful input and output capabilities which are cumbersome to introduce in typical CAVE-like installations. The results should be extrapolable to other information visualization applications using virtual reality technology.

Keywords
Tablet Interface, Immersive Virtual Reality, Information Visualization, User Study, Genomics

1 INTRODUCTION

Virtual reality (VR) devices submerge the user in a virtual world and allow him/her to explore and manipulate the world in an intuitive manner. In the case of information visualization (infovis), the virtual world is composed of two- or three-dimensional objects corresponding to abstract information. The ease of visualization of 3D plots makes the tool quite useful in the study The interaction devices used in VR installations are varied, but often tracked joysticks or wands are used. In some cases, a PDA or tablet has been used to provide a more complex graphical user interface (GUI), but the use of such devices is relatively rare.

In this paper, we present a use case for a VR application which has been augmented with a tablet interface. The application belongs to the genomic comparison field and makes extensive use of information visualization. We claim that the use of a tablet can be of special value for immersive VR applications using semi-immersive CAVE-like[1] or other projection displays in the infor-

mation visualization field, as the interaction with the datasets follows more abstract concepts which are not easily mappable to simple hand gestures. In particular, tablets are ideally suited for complex system control and textual input, while their performance in navigation, 3D manipulation and selection tasks is similar to that of standard wand or joystick devices.

GUI-based interaction, while possible within VR, suffers of quality degradation in the presence of text. The availability of a device which can display high-quality text, menus, graphics or animations (including zooms of the virtual world) greatly enhances the interaction possibilities. A high precision touch interface increases accuracy and speed, and is very useful for text input.

To evaluate this claim, we have performed user studies to compare the ease of use, the performance and the satisfaction of the users with the different input devices and interaction methods. While there is some variability in the responses of the different users, on average users showed that the tablet was a valuable resource.

Section 2 describes related work. Section 3 introduces our prototype, and describes the user studies performed to evaluate it. Finally, conclusions are presented.

2 RELATED WORK

Personal Digital Assistants (PDAs) and tablets have previously been used to help control VR systems, by displaying 2D interfaces in the PDA and 3D ones in the CAVE [Wat99], or for training in industrial settings [Med13]. The medical field also has some applications [Mor14]. A smartphone has been used for e-learning

[1] CAVE[TM] is a registered trademark of the University of Illinois' Board of Trustee. The term is used here to generically refer to CAVEs[TM] and CAVE-like displays.

Figure 1: CAVE application with tablet interface.

[Bed09]. Finally, a library for creating general GUIs in tablets for VR environments has also been developed [Har02].

There is a high quantity of VR applications in information visualization for genomics data. Examples include a dividing road metaphor to symbolize decision taking and a lab bench metaphor for information display, within gene expression studies [Nis04], and Juicebox [Rao14], a commercial software which displays interaction among loci within the human genome.

3DScover is a suite of graphical applications to perform comparative genomic analysis. The desktop version [Tuk14a] shows a 3D data structure which encompasses all the information available in the most often used two dimensional representations, and optionally exposes the previous representations (dot plot, gradient view, and linear representation) as projections. Multiple operations on the genomic datasets are implemented. The CAVE version [Gar16a] displays the 3D data structure and projections in an inmersive environment, and allows basic interaction using a wand.

3 TABLET INTERFACE FOR THE CAVE VERSION OF 3DSCOVER

The early prototype of 3DScover-CAVE used one wall to provide the interface in form of textual information and clickable buttons to control the application (figure 1, top right). This correspondence between the physical and virtual locations allows clear text to be displayed. However, the screen resolution limits text to simple words. Buttons need to be large to be easily clicked by using the wand. Consequently, only a small subset of the desktop functionality was implemented.

The wand used in our installation has four digital buttons and an analog joystick. Although in principle it is easy to map the different interaction modes to the different options, the users found it too complex to remember which button mapped to which action. The possibility to create virtual buttons on the tablet screen was very welcome by final users.

We used the tablet capabilities to create a new high-precision selection method, although we also provide the wand-like selection method by attaching a tracker to

the tablet. We also added advanced functionality which can be easily accessed by using the tablet features. The development of this improved version of the software was guided by a set of user studies to ensure usability. A final study studied the satisfaction of users with the software. Figure 1 shows our final system.

The tablet interface is composed of a series of clickable tabs. The visualization tab helps the users familiarize themselves with the 3D representation and its three 2D projections. The selection tab (figure 3) controls which of the genome is the reference. The other genomes are pairwise compared to it. Subsets of the genomes can be selected here based on their position in the genome, and the application will show the relevant subsets in the rest of the genomes. The edit tab allows the user to perform rigid transformations on the 3D object, allowing them to focus on the relevant parts of the object they want to study. The search tab allows the user to search the genomes by gene name or function. Additional tabs to control connection settings and file loadings also exist.

4 EVALUATION

A description of the user studies performed to validate the interface follows (participants were new to VR).

4.1 Interface Design Questionaire

The first user study took care of choosing easy-to-understand names and icons for the different possible actions and the navigation across the different modes of the application. The users were shown different possibilities and chose the ones they found best. The most commonly chosen sets of icons and names were used in the following prototypes. In particular, most users were keen on having textual description in addition to icons. The navigation was also tailored to the responses of the users (two thirds of the users preferred tabs versus one third which preferred a slide-in interface).

This user study used a web-based questionnaire. 35 participants took part, 22 (63%) of them male and 13 (37%) female. The average age was 25.

4.2 Mock-up analysis

A mock-up was created which allowed users to test the interaction possibilities The second user study used a tablet with this mock-up application to verify the usability of the interface.

10 users took part in the mock-up analysis, Four (40%) of them male and six (60%) of them female. The average age was 29,3. Since we were targeting an android tablet, we used when possible the native icons for standard actions. A minority of users (who use IOS or windows phone) had issues with the menu icon.

The users provided comments on possible improvements in most of the interaction modes, which were
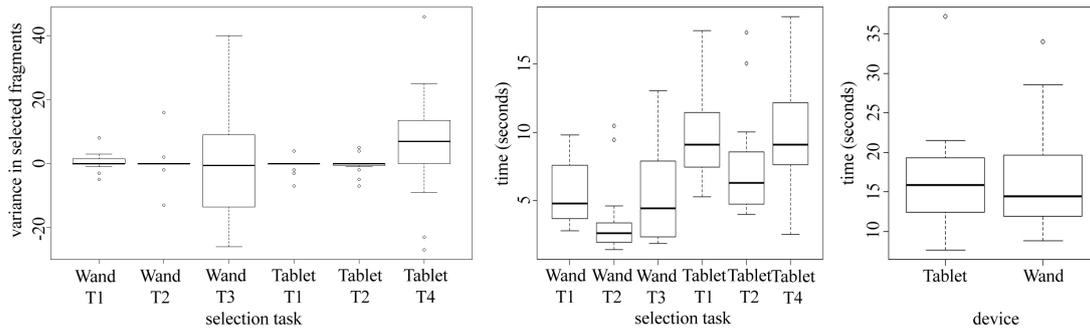
Figure 2: Time (left) and accuracy (center) for tasks 1-3. Time for task 4.

taken into account in the final version of the software. In particular, most of the comments regarded adding additional information to the search, sliders and data input fields. The users were asked to evaluate the interface in a 5 point Likert scale. The mean score was 4.1, validating our design. See figure 3 for the resulting design.

4.3 Final User Study

The final user study aimed to validate whether the use of a tablet would improve accuracy and user satisfaction with the software. 20 participants took part, 17 (85%) of them male and three (15%) female, with an age average of 28. The following hypothesis were tested:

H1 The selection task with the wand is performed faster than with the tablet.

H2 The selection with the tablet is more precise than with the wand.

H3 The user will be satisfied with both devices.

H4 The user will be satisfied with the additional functions provided by the tablet.

4.3.1 Functionalities and tasks

14 basic functions compose the building blocks for all the functionality of the software. Each of the functions corresponds to a primitive interface action. We classified the functions depending on whether the wand could be used to perform the task (testing hypothesis 1-3) or not (testing hypothesis 4). The functions were used to define higher level tasks, which were evaluated empirically to test for accuracy and speed.

T1 First the user has to scale the visualization to the side and select a defined huge area on the front wall. After the selection he has to activate the default view.

T2 Next the user has to move the visualization on the front wall and select a small area on the side wall. The default view has to be activated afterwards.

T3 In the last selection task the user has to deactivate the 3D view and select a square area on the floor. After the selection return to the default view.

T4 In the final task the user has to scale the visualization. The small cube has to be scaled to it's maximum size. Then, the cube has to be grabbed and placed on the top right corner of the front wall.

Figure 3: Wand vs tracked Tablet. For the users view, the pointer is aligned with the left side of the tablet

Figure 2 shows the accuracy and speed for the first three tasks, and the speed for the last task. Mean, standard deviation and outliers are displayed. Interested readers can find detailed statistical information in the additional material. The distribution of responses was examined using the Quantile-Quantile-plot [Wil68], the Shapiro-Wilk-Test [Sha65] and a histogram. All distributions were found to be non-normal and independent, so the Wilcoxon-Mann-Whitney-Test (WMWT) [Man47] was used to measure the significance, with values under 5% considered statistically significant.

The WMWT showed statistical significance for the time difference in tasks 1-3 (with values 6e-4, 6e-6 and 6e-4, respectively), while there was no statistical significance in the difference in accuracy in tasks 1-3 or in the time for task 4 (values were 12%, 39%, 12%, 70%). From this data, we must consider that the new selection method is not useful, and the old one should probably be used. Fortunately, the tablet can use the old method when a tracker is attached to it (figure 3).

4.3.2 Post-questionnaire

This section deals with the subjective evaluation of the differences between wand and tablet by the users. When evaluating the intuitiveness, satisfaction, comprehension and speed of using the tablet interface to do control and selection tasks which could be done previously with the wand, a preference for the tablet appears. The wand is preferred for moving the 3D object and for its smaller weight.

With respect to the evaluation of the tablet interface to do things which could not be done using only the wand, which included load, search, setting the main genome, reordering, visualization selection, etc: except for the

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changing of the order of the genomes, all the tasks were found easy to perform.

Users mostly preferred using the tablet, even though they were slower while performing the tasks. For typical information visualization applications such as this one, where we are interested in obtaining insights about the data, user satisfaction is more important than speed, as content users are more likely to spend the needed time within the system to obtain valuable discoveries.

4.3.3 Hypothesis evaluation

In accordance with section 4.3.1, H1 (wand selection faster than new tablet interface) is true. H2 (tablet selection more precise) could not be proven, as the tests show no statistical difference between the two. Since the tablet also allows the use of the wand selection method, by the use of an attached tracking device, it may be possible to obtain high speed selection using the alternative interface. As we saw in the previous section, the questionnaire shows that H3 and H4 are true.

The tablet can thus be used as an alternative to traditional wand interfaces, allowing new tasks to be performed easily and to the user's satisfaction.

5 CONCLUSIONS

We have used an android tablet to enhance the interaction possibilities of an immersive VR installation in the field of information visualization. The screen allowed us to provide an easier to use menu interface, and to increase the online help available during the use of the software. The touch interface in the tablet is higher precision than commonly used wand interfaces. There was no statistically significant difference between the accuracy of tasks when using tablet versus wand, but the tablet allowed symbolic input and enhanced system control.

It is worth noting, though, that the tablet is no panacea: the biggest remark is often that tablets are heavier and more fragile than joysticks or wands. We expect that in the future, these limitations will be reduced. Even now, the use of a mobile phone can alleviate the weight considerations, and phone covers can also be useful in the case of an accident.

6 ACKNOWLEDGMENTS

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