Line Drawing in Virtual Reality using a Game Pad

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Abstract

We describe a software interface for drawing in three dimensions using a game pad. The software runs in a walk-in, virtual-reality theatre and has been designed for walk-up usability for a science museum. Usability aspects of the interface are discussed including the mapping of the thumb-joystick controllers and movements of the cursor in three dimensions.

Keywords: virtual reality, drawing, game pad, usability

1 Introduction

Case studies of usability engineering tend to emphasise early contact with a target population, an iterative process of development, significant exploratory design, and regular usability evaluation.

In this paper we describe a quite different case study which has taken place in a university setting. The constraint of having to fit this work into a number of single-semester, individual student projects has meant that the process has been drawn out over more than two years. In spite of the rather ad-hoc nature of this process, the project has been able to maintain a "real life buzz" over all of this time. Although its early stages were principally driven by functionality, usability techniques have played a formative role in the software process. In its latter stages, a formal usability test on users has resulted in an enhanced understanding of the interface and has increased confidence in the ultimate success of the project.

2 Target installation

The Wedge (Gardner & Boswell 2001) is a two wall virtual reality theatre inspired by the CAVE (Cruz-Neira, Sandin & De-Fanti 1993). The first Wedge was built in 1998 as a cost-effective visualisation facility for universities: it comprises two screens which display frame-accurate, stereoscopic images. Participants wear special glasses which filter the images to the left and right eyes. The three-dimensional scene is calculated for the position and orientation of a lead observer. The Powerhouse Museum in Sydney has been featuring a Wedge as part of its "Cyberworlds" exhibition(Powerhouse Museum 2001) since 1999. The exhibit shows an audio-visual real-time animation which gives an introduction to the technology of the spectroscopic theatre as well as displaying a number of 3D visualisations from scientific research. Visitors can interact by moving a joystick which is anchored to a pedestal located in the best viewing position.

As part of an ongoing collaboration with the Powerhouse museum, it was decided to augment the Cyberworlds Wedge with new, more interactive, exhibits. Ideally, these new exhibits needed to give visitors the opportunity to be genuinely creative. As a walk-up-and-enjoy interface, they also needed to conform to the criteria of "immediate engagement" and "immediate learning" (Bill Kules and Hyunmo Kang and Catherine Plaisant and Anne Rose and Ben Shneiderman 2001).

As one of the simplest places to start, we chose to develop an attractive, three-dimensional, line-drawing application.

3 Application description

The `Draw3D` program was initially developed as a prototype by Duan Lifeng in 2002. It was subsequently refined by Guyin Zhou and Qing Wang to incorporate a game pad interface.

This program starts by displaying a "dancing" pencil-shaped cursor which can be moved in each of the 6 coordinate directions. Pushing a "pen-down" control places a "blob" of ink onto the screen. Subsequent movements of the cursor draw a cylinder segment which can be freely moved until the second endpoint is defined (by a pen-up command). Participants can build up a picture which is made up of several, coloured, cylinders – each of which can have any orientation in space.

The two major modes of operation of the program (pen-up and pen-down) are clearly distinguished by having the pencil-shaped cursor dancing in the pen-up case and stationary (with ink) for the pen-down case. The program runs with a 4 minute time-out loop to encourage participants to circulate to other exhibits.

4 Programming the Game Pad

A game pad was chosen as the interface for `Draw3D` because it had enough controls to encourage visitors to move the pen cursor in three-dimensions, to change the pen colour and to rotate the entire object. It was also expected that it would appeal to school-children up to age 15 (one of the main user groups of the museum).

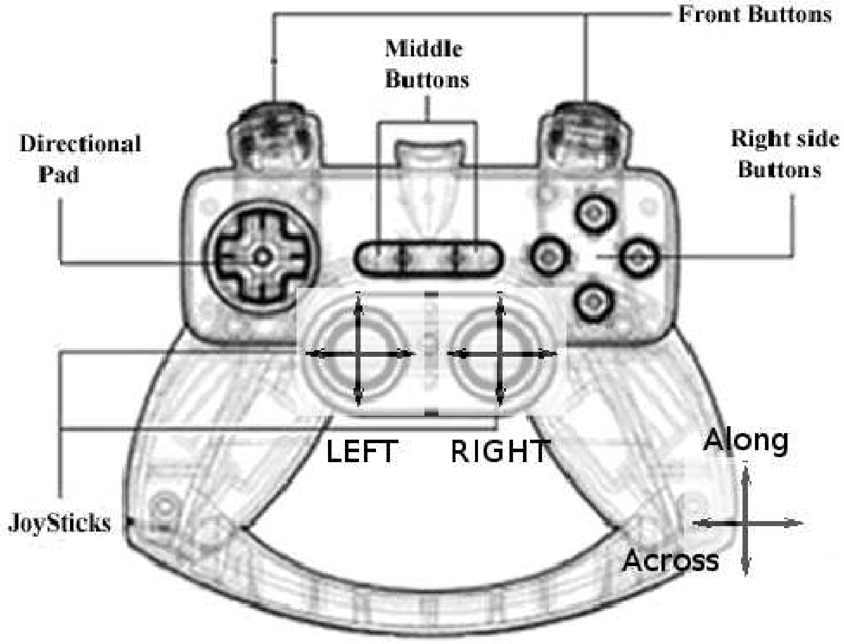

Figure 1: The Nostromo N45 Game Pad

The game pad chosen was a "Nostromo N45" manufactured by Belkin(Belkin Components 2005). The software was written in Java and Java3D using JXInput(Joerg Plewe 2005) to drive the controller.

A picture of the game pad is shown in Fig. 1. Because we wanted to program this interface to have a universal appeal, and not just be dominated by first-shooter-games aficionados, it was decided that it should not be biased in the direction of existing computer games. An additional constraint for our application was that the controls would be operated in semi-darkness, so the mappings between controller and functionality needed to be intuitive and memorable.

The game pad contains 4 distinct groups of controls. Their description and comments on our mapping of them to program functionality follows:

1. Two "thumb" joysticks are arranged symmetrically on the top face of the controller. Each joystick sits on top of a push-down button.

   Each of these joysticks has the same affordance and a natural mapping for each is to the motion of the cursor in the plane. An intriguing problem was how to map cursor movements out of the plane and this became the subject of a usability study described in the next section. The push-down button affordance was felt to be weak and confusing for museum visitors unused to computer games.

2. A diamond-shaped array of 4 "action buttons".

   These right-side buttons have a toggling affordance and can be mapped to a pen-up/pen-down transition. They can be distinguished from each other by assigning a different colour to the pen ink. The problem is seeing which is which in the dark! (This problem was partly addressed by modifying the pen-cursor so that its tip clearly showed the colour that was being selected.)

3. A half-cylindrical array of 3 buttons in the centre of the top face.

   These middle buttons look and feel different to the action buttons but also have a toggling affordance. One is marked with a red stripe which slightly increases its visibility in the darkened theatre. It was decided to map these buttons to the special, "system" operations of "help" and "reset". Because these three buttons are flush-mounted next to each other, only the two outside buttons were programmed to reduce the number of mis-keying errors. The leftmost button toggled a drawing erase and restart. The rightmost button toggled a help screen containing a labelled image of the game pad.

4. Four trigger-finger controls on the front face of the controller.

   These front buttons were felt to be out-of-the-way for visitors without game pad experience. We decided to give them non-essential functionality by assigning them to toggle pen-up and pen-down with more obscure colours than were used for the right-side, action buttons.

5. The directional pad.

   This large button is spring mounted and has a tight, rocking feeling about it. A natural affordance is to associate this rocking with a rocking rotation of the entire drawing about two axes. We extended this to be a smooth rotation if the button was rocked and held down.

5 Usability test

At the conclusion of the final developmental stage, a formal usability test was undertaken to evaluate the question of the best mapping of the joysticks to

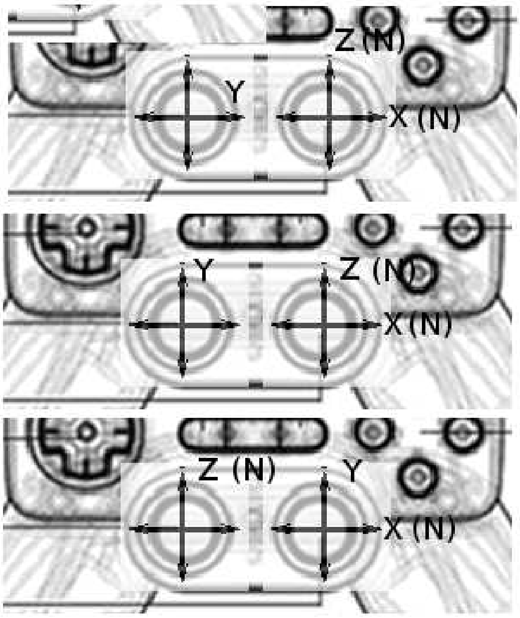

Figure 2: Mapping of the joysticks for Configurations 1 (top) 2 (middle) and 3 (bottom) to cursor movement. The X direction is left-right and the Z direction is in and out of the theatre. As both of these movements are in the same plane as the joysticks they are natural and are tagged with "(N)" in the figures. The Y direction is up-down.

cursor movement as well as to uncover general usability problems prior to installation. As discussed above, both thumb-joysticks have natural mappings to cursor movements in the horizontal plane. A design decision was made that redundant mappings would be avoided, so that the "un-natural" mapping to the "Y", up-down, cursor direction would need to be located on only one of the joysticks. Even having made this design restriction, there were two issues which it would have been good to address:

- whether, in the absence of a natural mapping, there is any preferred mapping of joystick direction to up-down, Y, cursor movement.
- in the case that there is a preferred Y mapping, whether it should be grouped together with another natural mapping or isolated on its own joystick.

5.1 Test design and execution

Eight test participants were selected from volunteers from a senior-level course on the human-computer interface (mostly overseas students in their mid-20's) for a within-subjects comparison of two game pad configurations. Following a 4-minute training session, the participants were asked to pretend that they were museum visitors and they wanted to draw a picture of their own choice (many tried to draw a simple house). During a 4-minute drawing time, they were asked to speak aloud whenever they felt frustrated at the interface. These events were labelled as "frustration errors" and were meant to be distinguished from trivial mistakes that museum visitors would be happy to make when first playing with a new exhibit. The subjectivity of this measure was mitigated by having independent observers who recorded events when they thought the participant seemed to be fumbling repeatedly with the game pad in a frustrated manner. The two measures were compared and the maximum number of frustration errors was used for analysis.

The participants were divided randomly into two groups and the order the two configurations was varied for each group. A break of 48 hours was allowed between tests to decrease carry-over learning and to control for time-of-day effects. For their second test, participants were asked to draw a figure approximately like the one in their first test. The two configurations chosen initially were "Configuration 1" and "Configuration 2" of Fig. 2. Both of these configurations had the Y mapping isolated on one joystick but the directions chosen for this mapping were across the game pad in the case of Configuration 1 and along the game pad in the case of Configuration 2.

Usability tests sometimes need to be redesigned on the fly. In this case, two events caused the testing to be stopped and started again. One was the unexpected observation that the first group of test participants became "obsessed" with the operation of the direction pad. Another was the suggestion from a test observer that Configuration 3 would be a good one to try. For reasons discussed below, there seemed to be powerful rationale for this. Because of the constraint of the order in which results had been collected, it was only possible for the balance of the experiment to compare Configuration 1 with Configuration 3 over the full 8 participants in the restarted test.

5.2 Analysis

The number of frustration errors recorded for the three configurations is shown in Table 1. Small data sets such as this one need to be evaluated carefully. In this case, the dependent variable is discrete rather than continuous so the assumption of normality needs to be examined if parametric tests are to be used. Examination of the differences of the error counts for Configurations 1 and 3 show that the data for s8 is an outlier. When this participant is removed from the table, the differences approximate normality. For good measure we applied the, t test and the non-parametric Wilcoxon test both the full data set and the reduced data set. In both cases the t results were significant at the 0.01 level (p=0.00035 for the full data set and p=0.00007 for the reduced data set). Both Wilcoxon results were significant at the 0.05 level (p=0.014 for the full data set and p=0.021 for the reduced data set). Regardless of the exact value for p, it appears that Configuration 3 has a significantly lower number of frustrating errors than Configuration 1.

The differences in the error counts for Configuration 2 and Configuration 3 are approximately normal for this very small data set. A t test of this data gives significance at the 0.05 level (p=0.035) but the corresponding Wilcoxon test was not significant (p=0.098). These results were confounded by the fact that the direction pad was active for Configuration 2 and inactive for Configuration 3. As discussed below, a future experiment is planned to properly compare these two configurations.

	Config1	Config2	Config3
s1	7	3	2
s2	6	4	3
s3	4	3	0
s4	9	7	5
s5	5		1
s6	5		2
s7	4		2
s8	9		1

Table 1: Errors recorded for each of the three configurations over a 4 minute period. Participants s1 to s4 used Configuration 2 followed by Configuration 3 and then Configuration 1. Participants s5 to s8 used Configuration 1 followed by Configuration 3.

5.3 Discussion

From comments made by the test participants, the lower error rate of Configuration 3 as compared with Configuration 1 is probably because Y cursor movements are mapped to the "along" direction of a joystick in Configuration 3 but to an "across" direction in Configuration 1. While not being a natural mapping, a preference for the "along" mapping might have been expected on several grounds including

- There is a lack of orientation for the, alternative, "across" mapping (so that it is difficult to remember whether "right" is "up" or vice versa).
- The game pad affords being held horizontally or at a slight angle to the horizontal so that "along" often has a component in the "up" (or, sometimes "down") direction.
- There is a cultural identification with the movement of the mouse and a cursor on a 2D display. Moving the mouse forward moves the cursor up.

Having verified that an "along" mapping is preferred for Y movements, it is desirable to explore whether the grouping of this control together with the natural X mapping in Configuration 3 is preferable to an isolated Y control as in Configuration 2. There may be cultural aspects to the preference of one over the other: the isolated Y mapping of Configuration 2 is similar to common navigation mappings in 3D computer games whereas the grouped Y mapping of Configuration 3 is analogous to the operation of the mouse in 2D displays. Speculatively, there may also be an innate psychological preference to either group an unnatural mapping with a natural one or to leave them separate.

A future HCI experiment is planned to examine the error rates for walk-up usability of Configuration 2 and Configuration 3. This experiment will control for significant prior experience with 3D computer games. It is also possible to estimate whether there is an influence of 2D mouse mappings by comparing 3D drawings in the distance (which are not very "immersive") with those directly "in the faces" of the participants.

6 Conclusion

A simple drawing application has been developed for walk-up usability in a virtual reality theatre. A usability test of this application has yielded a significant advantage of the "Configuration 3" over the "Configuration 1" mappings of the joystick controllers on the game pad. Participants in this test expressed a preference for a mapping of, Y, out-of-the-plane, cursor motions to control movements "along" the game pad. This test also yielded other information such as a strong enthusiasm for the application itself, and for being able to rotate the drawing using the direction pad. A future HCI test is planned to properly compare Configuration 3 with Configuration 2.

7 Acknowledgements

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