Using a Dance Pad to Navigate through the Virtual Heritage Environment of Macquarie Lighthouse, Sydney

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Abstract. In this paper we look at the potential of a novel navigational interface, a dance pad, to allow users to intuitively explore a virtual heritage environment. An immersive Virtual Reality environment has been created to learn about the historical background of the Macquarie lighthouse in Sydney, Australia. Using the dance pad technology, we hoped to allow the users to literally step back in time and walk around the environment in whichever direction they chose. This paper introduces the Macquarie Lighthouse virtual heritage environment and the dance pad technology and describes its usage for navigation. We discuss the outcomes of a pilot study and note a number of current limitations of the technology. Future research directions in the field of intuitive Human-Computer-Interaction devices in virtual heritage projects are also presented.

Keywords: Virtual Heritage, Virtual-Immersive Environments, Virtual Reality, USB Dance Pad, Alternative HCI Input Devices.

1 Introduction

Educationalists have realised that game technology can improve learner engagement and motivation [1]. Also, games have even been employed to teach medical students [2]. In the *VirSchool* research project [3] we are currently focusing on bringing Australian history to life in an immersive Virtual Environment by using game technology. The project aims to take history off the dusty shelf by providing a positive and memorable experience that will encourage our heritage to be valued and thus passed on.

In the highly immersive CAVE-like (Cave Automatic Virtual Environment) environment that we are using in our virtual heritage project (see Figure 8), we wanted the users to be as immersively involved as possible without the restrictions of traditional input devices (i.e. cables or the need of a flat surface to operate a computer mouse, keyboard or joystick). Despite the existence of alternative input methods (e.g. the Footmouse [4] or data-gloves) the predominant navigational input device nowadays continues to be the computer mouse originally invented by Douglas Engelbart [5] back in the 1960s. While this input device certainly has benefits when working on typical office related tasks (word-processing, spreadsheets, etc.) it has

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limitations in regards to intuitiveness and freedom of movement. Hence, for our project, we were looking for a more intuitive navigational input device that allowed a more natural way of Human-Computer-Interaction. Others have pioneered this area of tangible interfaces. For example, Hiroshi Ishii and his tangible media research group at the MIT [6] used the Audiopad [7] or the Topobo [8] system to achieve "seamless interfaces between humans, digital information, and the physical environment" [6]. In this spirit, we investigated the use of human feet to navigate a player character (also called an Avatar) through the aforementioned virtual-immersive environment. A promising technology for this purpose appeared to be a dance pad, which we subsequently connected to a virtual heritage course.

Before describing the dance pad technology and a pilot study we conducted, we give a brief overview of the wider project context and the historical background of the Macquarie Lighthouse and the Virtual Reality technology that has been used to create the virtual heritage environment. We will discuss outcomes and restrictions of what we hoped would be an intuitive Human-Computer-Interaction (HCI) device. Finally, we will look at possible future research directions in the field of intuitive HCI devices in virtual heritage projects.

2 Background

Before we discuss the advantages and disadvantages of using a dance pad for navigational purposes, we will briefly explain the historical and technological backgrounds of our *VirSchool* virtual heritage project.

2.1 Historical Background

The Macquarie Lighthouse (See Figure 1) is the landmark icon of Macquarie University and, more importantly, it is Australia's first lighthouse (some even say it was the first lighthouse in the southern hemisphere [9] in [10]). It is situated on the South Head peninsula of Sydney's Port Jackson harbour entrance and the lighthouse that we are looking at today is the second lighthouse that was built in almost the same spot as the first lighthouse.

The history of the Macquarie Lighthouse begins with the colonisation of Australia and the arrival of the First Fleet in 1788. According to Casey and Lowe [10], a flagstaff was erected near the site where the lighthouse is located nowadays as early as 1790. The flagstaff's original purpose was to signal the arrival of a desperately awaited supply ship from England to the colonists, as well as indicating the harbour entrance to the incoming ship. In the years following the erection of the first flagstaff, the flagstaff was upgraded (1792), rebuilt (1797) and extended by a stone column (1790) and a fire beacon (between 1793 and 1805). On the 1st of January 1810 Colonel Lachlan Macquarie started his duty as Governor of New South Wales and in 1818 architect Francis Howard Greenway finished the construction of the first Macquarie Lighthouse. As early as 5 years after the end of the construction, repairs had to be conducted because parts of the building were falling apart. The causes for the decay were mostly attributed to the low quality of the sandstone and mortar.

Fig. 1. The Macquarie Lighthouse in Sydney, Source: [11]

Eventually, the deficiencies in construction were not tolerable any more and from 1880 to 1883 a second lighthouse was built only 4 metres behind the old lighthouse (which was subsequently demolished). After the power supply of the lighthouse had been changed from coal-gas to kerosene in 1909, the lighthouse was connected to the main city electrical power supply in 1933. The lighthouse was automated in 1976 and demanned in 1989. Despite being demanned, it is still operational and is nowadays operated and maintained by the "Australian Maritime Safety Authority"[1]. Public tours are organised by the "Sydney Harbour Federation Trust"[2].

2.2 Technological Background

To bring the history of the Macquarie Lighthouse to life we are creating a computer enhanced virtual reality course. For this purpose the course is set up in a 3-dimensional game-engine, which is run in a virtual-immersive environment. Figure 4 shows the Macquarie Lighthouse game mod (a modification of the original application) developed with 'The Elder Scrolls Construction Set' (TESCS)[3]. TESCS is a modding expansion for the game 'Elder Scrolls 4 – Oblivion'[4] and it allows the creation of complete virtual scenarios and supplies the developer with the necessary tools to design a virtual world in his or her own style.

In a first step, the landscape surrounding the Macquarie Lighthouse was modeled in TESCS. To achieve a high level of authenticity, the landscape was modeled by means of an accurate land survey supplied by the Sydney Harbour Federation Trust (See Figure 2). Afterwards, a 3d model of the Macquarie Lighthouse was created with 3d Studio Max[5] and then imported into TESCS. The 3d model was created based on copies of the original blueprints from 1883 (See Figure 3), also provided by the

1 Australian Maritime Safety Authority: http://www.amsa.gov.au
2 Sydney Harbour Federation Trust: http://www.harbourtrust.gov.au
3 The Elder Scrolls Construction Set: http://www.elderscrolls.com/downloads/updates_utilities.htm
4 Bethesda Softworks: http://www.elderscrolls.com/home/home.htm
5 3D Studio Max by Autodesk: http://www.autodesk.com

Fig. 2. The landscape surrounding the virtual Lighthouse was modeled as closely as possible to a land survey

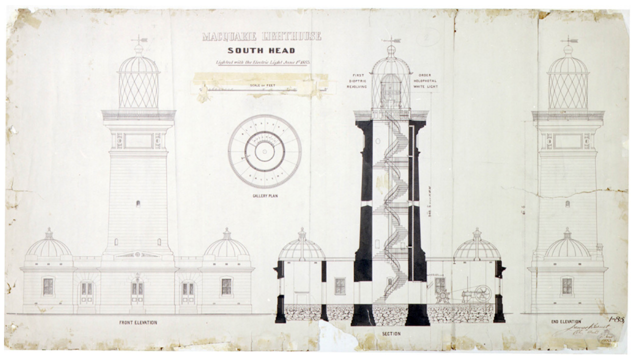

Fig. 3. The 3d model was created based on copies of the original blueprints from 1883

Fig. 4. A 3D Model of the Macquarie Lighthouse together with a virtual Avatar who is explaining the history of the lighthouse to the users

Sydney Harbour Federation Trust. Figure 4 shows the 3d model of the lighthouse on the landscape. The Avatar in the foreground is a fictitious descendant of the first lighthouse keeper, who is delivering the history of the lighthouse to the users.

3 Implementation of a USB Dance Pad into the Virtual Heritage Course

The Virtual Heritage environment has been created to narrate the story of the Macquarie Lighthouse and investigate the effect of different musical background stimuli on memory in a virtual-immersive environment. However, in the course of our research we were looking for new input methods to explore the described virtual-immersive environment more intuitively and we thought it would be more natural for users to use their feet to navigate a character through this environment. As a result, we investigated the usability of a dance pad as an input device.

Dance pads are typically used in dancing games, such as Konami's "Dance Dance Revolution"[6] or its open source equivalent "Stepmania"[7]. These games and the associated dance pads have a growing fanbase [12]. However, to the best of our knowledge the dance pads have not been used for much more than the aforementioned dancing games and we were interested to see the potential of such dance pads as input devices to explore virtual heritage environments. For this purpose a 'BNSUSA - Fusion' dance pad was purchased and connected to a PC (Personal Computer) which runs the Macquarie Lighthouse course in the Oblivion game engine. Normally, these dance pads are manufactured for use with XBox or Playstation gaming consoles and they are not suited for use with PC's. The dance pad we used in our tests was especially selected because it includes a USB (Universal Serial Bus) connector which is needed to operate the dance pad on a PC. This dance pad also comes with drivers for Windows XP. However, after connecting the dance pad to the PC it became obvious that the 'Oblivion' computer-game was not capable of being operated with the dance pad 'off-the-shelf'. Since Oblivion (the game engine we used to create and run the virtual heritage course) is designed to be played with either a computer-mouse **or** a gamecontroller (see Figure 5). If using a gamecontroller, the game expects the use of the two joysticks on the gamecontroller for movement and viewing. In our tests, the dance pad was recognized (as a gamecontroller) by the game but could only act as one such joystick, due to the design which basically consists of 4 arrow keys for forward, backward, left and right movement (See Figure 6). With this basic functionality it was possible to move in the respective directions when stepping on the arrow keys. However, the left and right movement was restricted to "strafing" which means side-stepping or shifting to the side with the viewpoint focused on the same view and always facing in the same direction. In contrast to this strafing, we wanted to be able to rotate/turn the character (and the view) when stepping on the left and right arrow keys. As mentioned, this turning command would normally be allocated to the second joystick on a gamecontroller but due to the fact that the dance pad can simulate only one such joystick, this functionality was not available instantaneously.

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[6] http://www.musicineverydirection.com/
[7] http://www.stepmania.com/

Fig. 5. Microsoft Xbox gamecontroller [8] normally used with games such as Oblivion

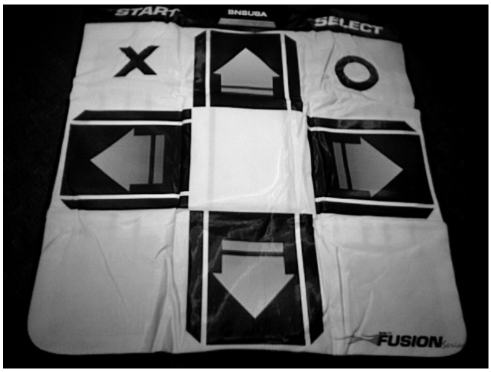

Fig. 6. The USB Dance Pad with the arrow keys for moving the character forward/backward and left/right within the virtual heritage environment

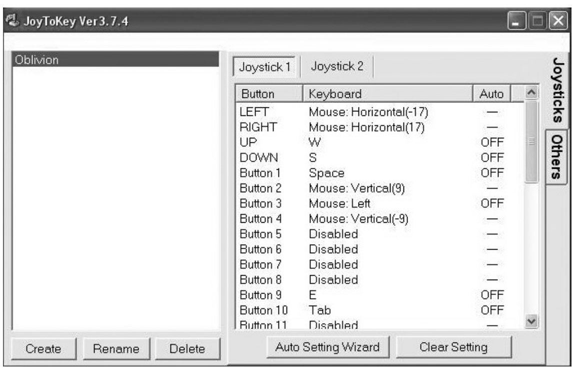

Fig. 7. Joy2Key, a Joystick/Mouse Emulator used to remap the arrow keys on a USB Dance Pad to keystrokes and mouse movements

Fortunately, Oblivion allows a mix of input devices to be used for interaction. For example, a computer mouse and a keyboard, or a keyboard and a joystick can be used simultaneously to execute commands in the game. Thus, the solution for the problem was to make the dance pad appear as two such input devices to Oblivion. The Y-axis

[8] http://www.xbox.com

would still be used as a joystick (for forward/backward movement) and the X-axis would be used as a computer mouse (rotation/turning of the character). For this purpose, a software program was used to remap the left and right arrow keys in order to emulate left and right mouse movements. In Figure 7 we can see the configuration screen of this software and in the right column we can see that the left and right button (the arrow keys on the dance pad) are allocated to negative and positive values of horizontal mouse movement. The software we used is called Joy2Key and for our tests, version 3.7.4 was used. The software can be downloaded and used free of charge [9].

4 A Dance Pad as a Navigational Input Device: A Pilot Test

Once the remapping of the arrow keys on the USB dance pad was completed, the feasibility of the dance pad as a navigational input device for our virtual heritage environment could be investigated. For this purpose, a pilot-test was conducted with 5 participants. Although the results reported here are of an empirical and experiential nature, we found that the reactions of the participants were overwhelmingly consistent and the results we found were quite unexpected. We further note that the number of participants involved in our pilot did not permit meaningful quantitative statistical analysis.

In Figure 8 we can see a user who is utilising the dance pad to navigate through the virtual-immersive environment and interact with the Avatar. When users first stepped on the dance pad the navigation through the environment was intuitively easy – a step forward/backward made the character walk forward/backward, a step to the left and right resulted in the first person character turning left and right. Unfortunately, this first impression of the intuitive use seemed to be the only beneficial aspect of the dance pad. Negative aspects were clearly showing the limits of the feasibility of this setup for virtual-immersive environments. The most obvious disadvantage was that people using this form of HCI (Human Computer Interaction) tend to be disoriented and their balance is affected by the virtual-immersive display system. The vertigo experienced in this virtual-immersive setup is sufficient to put users so much out of balance that they sway to the side. They have to put one of their feet out and step off the dance pad to avoid falling over. Even one long-time user of dance pads - with many months of experience with dancing games and dance pads as HCI input devices - stepped off the dance pad unintentionally in order to correct his position and regain his balance. The reason for this vertigo is very likely to be the result of a conflict between vision and our balance system. As Redfern *et al.* say in their article:

> *"Visual conflicts can have powerful effects on balance. Moving visual environments can cause postural changes, disequilibrium, and motion sickness in healthy adults."*[13]

We found that the vertigo could be partially overcome if a table to hold on to was placed in front of the participant, as shown in Figure 9. Chairs put to the left and right of the dance pad worked as stabilisers as well when held on to.

However, after the vertigo and balance issues were temporarily 'resolved' with a table or chairs, another problem became obvious. Although the basic functionality of

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[9] http://www.electracode.com/4/joy2key/JoyToKey%20English%20Version.htm

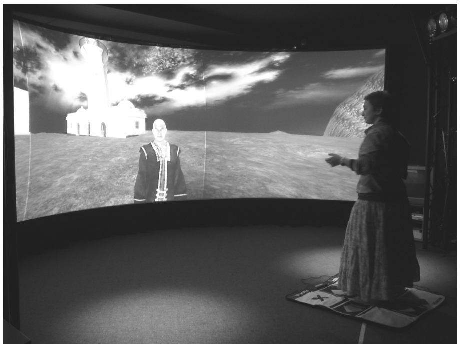

Fig. 8. A user utilising a USB Dance Pad to steer towards an avatar (from first-person viewpoint) who explains the history of the Macquarie Lighthouse

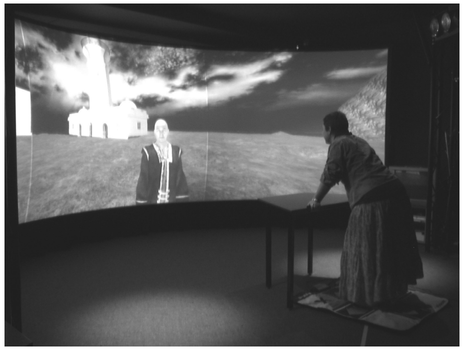

Fig. 9. The same user, holding on to a table to avoid vertigo in the virtual-immersive environment

moving forward/backward and left/right could be realised with the dance pad, this form of navigation is not responsive enough (in terms of time needed to press buttons/keys) to maneuver comfortably in a virtual heritage environment. If for example, a user approached an avatar or an object and the user accidentally over-steered because the arrow key was activated for too long, then they had to change from one foot to the other in order to use the opposite arrow key with the other foot and reverse into the other direction to correct the previous over-steering. This change of direction takes a considerable amount of time and is not practical for extended use in virtual-immersive environments. As an example, in Figure 10 we can see the steps that are necessary to steer the virtual character. The black footprint represents the right foot and the checkered footprint represents the left foot. Pictures a-d in Figure 10 show the final position of the feet which navigate the character forward and left (Picture d). Pictures e and f-g show two alternative step sequences to change from the previous movement (forward and left indicated in Picture d) to forward and right (Picture h). While one might think that this change of direction would be a rather simple task, we were astonished at how complicated this was, at least over an extended period of time. The reason for this feeling of complexity is the amount of movement that is necessary to enter/transfer the movement commands into the system. When we compare the sequences to change the direction (Pictures a-h) to a gamecontroller (Figure 5) then we can see that the distance to get from one arrow to the opposite (e.g. left to right) is much higher for the legs and feet on a dance pad than for a thumb on a gamecontroller. Also, the momentum necessary to shift the weight from one side of the body to the other - in order to change feet - takes a considerable amount of time. Thus, the reaction time of the dance pad is rather slow when compared to traditional input devices (i.e. computer mouse, keyboard and joystick). To make up for this slow reaction time the users often ended up using the solution displayed in Pictures i-j, where the right foot would remain on the forward arrow and the left foot would press the right arrow key by moving it behind the right foot. Although this solution might improve reaction time, it is a rather awkward position, because one ends up with crossed-over legs. Understandably, this is not a very stable

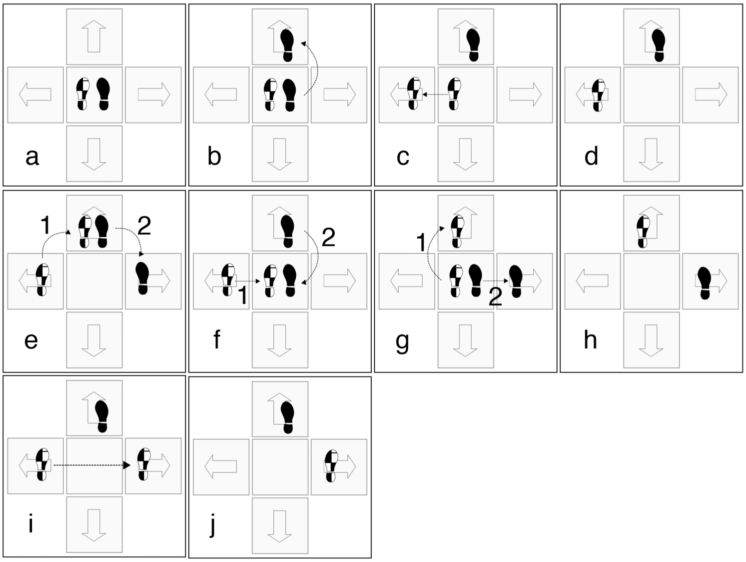

Fig. 10. The necessary steps to change from a forward and left movement (a-d) to a forward and right movement (e and f-h). Many steps are needed or one can end up in an unnatural position.

position, especially with the (albeit reduced) problem of vertigo in mind. A further problem with this form of navigation is that it lacks accuracy.

The On/Off characteristic of a digital signal (putting a foot Down/Up) makes it hard to steer precisely. For this reason it was often necessary to cautiously and repeatedly tap on the respective arrow key just very briefly, so that the digital signal was only activated for very short intervals. By using this tapping method the users were able to slowly approach the desired avatar/object, but it seems that this form of navigation would be ineffective for long-term use because it is too time-consuming and users get frustrated with the inaccuracy of this input method. An analog signal, which allows more precise steering, would be more beneficial for this purpose.

5 Conclusion

For our project we were looking at novel ways of navigating through virtual-immersive environments. After overcoming initial problems with the connection of the dance pad to the Macquarie Lighthouse virtual heritage course, we conducted tests to evaluate the usefulness of such a dance pad for navigational purposes. A pilot test was designed and conducted to give an initial indication of the feasibility of further experiments. The tests showed that the dance pad allowed movement and navigation within the environment, however, it was not the intuitive input device that we hoped it would be. During our tests we consistently encountered various problems, which included vertigo and balance issues, which forced participants to step off the dance pad. The tests also showed that a dance pad lags behind in regards to response time and steering accuracy compared to more traditional input devices like computer mouse, keyboard and joystick. The empirical evidence from this project shows that the possibilities for dance pads as navigational input devices are limited for the exploration of virtual heritage environments in a virtual-immersive environment.

Despite the appeal to engage our feet and thereby better utilize our body, as we do in driving a car or operating a sewing machine, it is interesting to consider past experiences with the footmouse or footmole [4], so named due to its larger size. In the footmouse the cursor can move left, right, up or down depending on which corner of the rubberized surface is depressed. Movement can be continued in this direction by continuing the pressure [14]. Dix et al [15] describe the footmouse more as a "isometric joystick" perhaps due to its limited method and range of movement. The limited information that can be found regarding its evaluation, usage and limitations are summed up as follows: "a rare device, the footmouse has not found common acceptance for obvious reasons" [15 p.65]. Unfortunately, the reasons are not given. We assume potentially having to remove one’s shoes may have been an issue, however inaccuracy, lack of agility and familiarity of our feet with the required movements, are suspected to be the main reasons. We note that even though we use our feet to drive cars and operate sewing machines, they are used for stopping and starting, not for navigating.

From our tests we conclude, that in its current form a dance pad as an input device is more of a hindrance than an improvement in Human-Computer-Interaction. In order to foster learning in virtual heritage environments and improve intuitive interaction with a virtual environment, further tests and use-case scenarios of dance pads (i.e. how can they be used otherwise) would be beneficial. Also, it would be valuable to investigate the usefulness of additional input devices, like data gloves and 3d pointing devices in conjunction with foot-operated input devices.

6 Future Outlook

One such alternative use-case could be to use a gamecontroller for moving around in the environment and instead use the feet for other commands, which are not used as

Fig. 11. A Dance Pad with handle bars behind the users - as used in game parlours. Source[10] (Advertising removed)

[10] http://www.ddrgame.com/dance-dance-reovlution-am-energy-extreme2.html

frequently (e.g. to bring up menus, and inventory and maps). This is similar to the use of dedicated/preprogrammed buttons on a gamecontroller, which allow the gamer to shoot or jump, for example. Furthermore, to improve the usability of dance pads as input devices, it would be possible to use a handle bar behind the users like they are being used in game parlours (See Figure 11). This would greatly increase the stability of the users.

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