Evaluation of Two Leaning-Based Control Methods in a Dragon Riding Interface

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Abstract: In this paper we present a dragon rider 3D flight interface which allows users to intuitively control the movement of a fantasy dragon in a virtual world by leaning their body in a seated position. We introduce two different approaches to measure the user’s leaning state in the real world, one using a Wii Balance Board to measure the distribution of the user’s weight on the seat and the other using a Kinect to track the user’s upper body skeleton. We compared the two methods in an experiment focusing on the usability, sense of presence and efficiency in a 3D flight task in a virtual environment presented on a head-mounted display. While both approaches were considered as intuitive by our participants, our results indicate that tracking the user’s upper body with a Kinect was preferred by the participants and estimated as more usable than via shifts in the user’s weight.

Keywords: 3D Navigation, Virtual Environment, Wii Balance Board, Kinect

1 Introduction

Head-mounted displays (HMDs) and tracking sensors provide a way for the user to freely look around and navigate through virtual environments (VEs) via movements in the real world, in particular during walking in the tracking space or using redirected walking for larger VEs [SVCL13]. Moreover, different setups and techniques have been inspired by the science fiction literature and proposed for flying through VEs to cover longer distances, e.g., based on metaphors of flight vehicles such as airplanes [KLB+87] or rockets [SBH07] and hands-free 3D traveling approaches [ZHF+16]. However, while most of these were presented as general-purpose 3D navigation methods, their usability often depends on the virtual reality (VR) context in which they are applied. For instance, while virtual airplane metaphors are well suited for navigation in virtual worlds inspired by the real world, their applicability in virtual fantasy environments in which magic and dragons exist remains in question.

In this paper, we introduce a virtual flight interface which allows the user to travel through a virtual fantasy world by riding on a dragon controlled by leaning one’s upper body while seated. In this context, we present and evaluate two approaches to track and map the leaning state of the user’s upper body to steer the flight of the virtual dragon.
The paper is structured as follows: Section 2 provides an overview of related work. Section 3 describes the dragon riding interface and two control methods. Section 4 presents an experiment in which we evaluated and compared the approaches and we discuss the results. Section 5 concludes the paper and discusses future work.

2 Related Work

2.1 Leaning

Inspired by the fact that humans often intuitively shift their weight or lean in the direction of expected opposing forces, e.g., during acceleration or while running, different researchers have evaluated the effects of leaning on the perception and usability of traveling in VR. In particular, Kruijff et al. [KRTK15] have found in experiments that leaning forward with the upper body while seated can have a positive effect on the perception of forward self-movement in virtual worlds. This advantage has also been utilized while standing in walking-in-place interfaces, such as introduced by Langbehn et al. [LEK15], which use the forward leaning angle of a user wearing an HMD to control the speed of their movements in a virtual world. Other interfaces are based on leaning of the entire body in the real world for the control of movements in VEs. Notable in this instance are the Joyman [MPL11] and the Silver Surfer [WL11] interfaces.

2.2 Wii Balance Board

The Wii Balance Board provides a way to gain data on the distribution of weights of a user’s body standing or seated on the board. Wii Balance Boards have already been used by several interfaces in the field of virtual traveling, such as the Silver Surfer [WL11] interface which treats shifts in weight as on a surfboard in the real world and extended it to 3D traveling. Other approaches such as an interface proposed by Hilsendeger et al. [HBTF09] use a Wii Balance Board to approximate the user’s leaning direction. Other ways to use the weight distribution provided by the Wii Balance Board are proposed by Valkov et al. [VSBH10] who use them to recognize foot gestures for an implementation of a human-transporter and Williams et al. [WBN11] who use it to track the user’s steps in a walking-in-place implementation.

3 Dragon Rider User Interface

3.1 Physical Setup

The physical setup of our dragon rider interface (shown in Figure 1) consists of a seat with a Wii Balance Board mounted on top as well as a Microsoft Kinect 2 facing the seat from ahead that allowed us to track the upper body of a seated user at different leaning angles. In our current implementation, users are wearing an Oculus Rift DK2 HMD which is connected
to a graphics workstation running the Unity3D game engine for rendering and movement control in the VE. Additionally, we use wireless headphones to provide audio feedback from the VE. In the experiment described in Section 4 the Wii Balance Board and the underlying seat were covered by a blanket hiding the board from the user’s view.

3.1.1 Wii Balance Board

The Wii Balance Board consists of a rectangular plastic plane standing on four feet which are positioned in the corners of the board and each contain a pressure sensor. By using the values determined by the sensors it is possible to gain information on the weight distribution on the board. The Wii Balance Board can be connected to a computer via Bluetooth. To gain the sensor data provided by the sensors in the board we used an adapted version of the Wii Balance Walker software. When seated on the board and leaning forward, backward or sideways, the sensor data reflects this change by a shift of weight in the corresponding direction.

3.1.2 Microsoft Kinect 2

To track the user’s upper body skeleton we used a Microsoft Kinect 2, connecting it to Unity3D via the Unity Plugin in the Kinect SDK. To detect changes in the leaning angle we evaluated the tracked position of the user’s “spine shoulder” joint in the Kinect’s skeleton model, comparing them to the user’s initialized upright position. We also used the Kinect to detect an additional gesture in our dragon rider interface: When performing a fast up and down movement of the hands similar to the gesture one would use to spur on a horse using reigns, we map this to the acceleration of the dragon which then leaps forward. For detecting the gesture, we used Microsoft’s Visual Gesture Builder, tagging several videos of the gesture recorded with the Kinect Studio. Additionally, we used the postural data received from the Kinect to move the joints of the upper body of an avatar displayed in the VE matching the user’s seated body pose in the real world.
3.2 Calibration

In order to compare the two different forms of input from shifts in weight and leaning, we mapped the raw values we gained from them on a scale from -1 to 1 for the transverse axis and the sagittal axis of the user’s body. For the balance board, we achieved this by looking at the distribution of the user’s weight on the four sensors such that a shift of the entire weight to one side of the board corresponded to a value of -1 or 1 depending on the side of the board that the weight was shifted to. For the Kinect, further calibration was necessary to determine the individual maximums of the user’s possible leaning angles. In the beginning of the flight, we asked the users to lean once as far as comfortably possible in each direction and saved the leaning angles. After doing that, the maximum value reached in calibration corresponded to a value of 1 or -1, again depending on the side.

3.3 Steering Methods

Our approach to steering the dragon’s movement direction while flying through the VE is based on the leaning direction of the user’s upper body. The user leaning to the left and right in the real world leads to the dragon flying in the same direction in the virtual world. In doing so, a leaning value of -1 or 1 corresponds to an angular velocity of $75^\circ$/sec, the values between are linearly interpolated. We combine a yaw and roll movement to make it appear as if the dragon is leaning into the turn. As the dragon in our implementation has a constant flying speed, we differ from the joystick metaphor and use leaning forward and backward to control the dragon’s upward and downward movement via a pitch rotation in the corresponding direction. In addition to the leaning controls, the user can speed up the dragon’s flight by using the speed-up gesture described above, which leads to the dragon tripling its speed for three seconds and then slowly decelerating back to a comfortable traveling speed.

4 Experiment

In this section we describe the experiment in which we evaluated the dragon rider interface and compared the two control methods.

4.1 Participants

After removing 13 participants from further analysis who quit the experiment prematurely due to simulator sickness, the sample for our study consisted of 17 participants, 11 male and 6 female (age from 18 to 37 years, average 27.5 years). Participants were students or professionals in the fields of human-computer interaction or computer science. Two of our participants reported color blindness, the others had normal or corrected-to-normal vision. 6 participants wore glasses and 1 wore contact lenses during the experiment. None of the participants suffered from a known disorder of equilibrium or binocular vision disorders. 11 participants had already participated in other studies using an HMD. Half of the users started
with the Kinect condition and the other half started with the Balance Board condition, not being informed which control mechanism would be used. Participants wore the HMD for approximately 20 minutes. They were allowed to take breaks or terminate the experiment at any time.

4.2 Material and Methods

The visual stimulus of the experiment was rendered using the VR mode of the Unity3D game engine and consisted of a wide landscape with tree-covered mountains. 29 waypoints consisting of an egg that we used as a target and a tower underneath for better orientation were placed in the landscape. The waypoints were placed on a roughly circular path spanning across the map. Distances as well as differences in height and amount of curve between waypoints varied. This way, participants were required to apply different degrees of steering in every direction to reach each waypoint without backtracking. The eggs were lit one at a time to indicate which one should be aimed for next and are removed from the landscape when they were flown trough. The user’s representation in the VE was a 3D model of a human moving according to the postural data received from the Kinect, placed on the animated model of a 3D fantasy dragon in flight. Looking forward in an upright sitting pose, participants could see the back of the dragon’s head, as shown in Figure 2. With head movements tracked by the Oculus Rift DK2, users were able to look around in the VE without changing the direction of their flight. The audio feedback that was played through the headphones consisted of a steady wind sound and a sound of flapping wings, which grew faster when the dragon flew with increased speed and stopped when the dragon was gliding. A sound similar to a dragon roaring was played at random times and flying through a checkpoint was confirmed by a popping sound.

![Figure 2: The user’s viewpoint during the experiment](image)

4.3 Procedure

We used a within-subject design in which we compared both control methods: Kinect and Balance Board. Following pre-questionnaires, a short explanation of the controls as well as the calibration process, the participants got accustomed to the controls in a short phase of flying without any given task. After this training stage was over, they were asked to collect all eggs in the landscape by flying through them as fast as they were able to, using the speed
gesture at any time they wanted. To control the dragon in the Balance Board condition it is not necessary to lean the whole upper body. Since the Balance Board detects weight distribution, the user can achieve full results by slight movement of the lower body. To avoid this method and testing both conditions as leaning-based control methods, we did not inform the user about the used measuring condition. Before and after the experiment we asked participants to fill out different questionnaires, which are explained below.

4.4 Results and Discussion

Comparing the time used to complete our task we found a significant difference between Balance Board ($M = 592.57$ sec, $SD = 173.58$ sec) and Kinect ($M = 417.32$ sec, $SD = 114.39$ sec) with $t(16) = 4.623, p < .001$. Looking at the routes of the flights in the different conditions (see Figure 3) one can see that the participants missed the waypoints more often in the Balance Board conditions, losing time by having to reverse.

![Figure 3: The routes flown in the different conditions (top-down perspective)](image)

When asked to comment on the different conditions, many participants felt that the right and left turns in the Balance Board condition felt almost binary while some also had difficulties in achieving the change of altitude needed to complete the route, which they stated were major factors inducing simulator sickness. We measured symptoms of simulator sickness before the experiment and after each of the conditions using the Kennedy Simulator Sickness Questionnaire (SSQ). Computing the differences in the increase of simulator sickness in both conditions we found a similar increase for the Balance Board condition ($M = 22.66, SD = 26.69$) and the Kinect condition ($M = 26.62, SD = 25.94$). A Wilcoxon Signed Rank Test showed no significant differences between Balance Board and Kinect conditions ($Z = -.189, p = .85$). As most participants seemed to prefer the comfort levels of the Kinect condition in their informal statements and in additional questions during debriefing we also looked at the data we gathered from the participants that were unable to finish the flights. Apart from the informal comments mentioned above we did not find clear correlations between simulator sickness and the types of control movements in the dragon rider interface, but we plan to address these points and reevaluate them for the next iteration in the human-centered design process of the interface.

We performed a Wilcoxon Signed Ranks Test to compare the NASA Task Load Index (TLX) scores between the Kinect and Balance Board conditions (Table 1).
The varying levels of both effort and comfort fit our previous observation of the usability in the different conditions. Nonetheless, the perceived presence in the conditions showed no significant difference. The most obvious reason for that is that both environments and control methods used the same visual and auditory stimuli in the fantasy world.

5 Conclusion

In this paper we presented a novel dragon rider interface and described two methods to measure the leaning state of the user’s upper body, which we used to control the movement direction of a virtual fantasy dragon. We compared the two conditions which revealed that using the Kinect to measure the leaning angles of the upper body shows more promising results than using a Wii Balance Board to measure shifts in weight. This is shown not only in the speed at which participants were able to complete a 3D navigation task but also in the overall comfort levels of our participants during the different stages of the experiment. However, our results also show that such leaning-based interfaces in VR, when used for 3D flying, can induce very high levels of simulator sickness. This has to be considered in future research by focusing on approaches to reduce the conflicting motion cues, e.g., by including stationary reference frames for the users to rest their eyes upon. An example could be a fixed cockpit around the user, which does not move by itself as the breathing and flying dragon in our implementation did.
References


