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Exploring Body Gestures as Natural User Interface for Flying in a Virtual Reality Game with Kinect

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Abstract

In immersive Virtual Reality (VR), computationally-mediated worlds allow participants to immersively experience virtual environments, to alter physics in a way that it is not possible in the real world, and to move their body and control their virtual movements in innovative and novel ways. Being able to fly is an experience that humans have long dreamed of achieving. In this paper, we introduce a VR game where participants can use their body gestures as a Natural User Interface (NUI) to control flying movements via a Microsoft Kinect. Furthermore, we conducted a mixed-methods study to explore the ways in which people want to control their flying movements in VR through physical gestures, and we evaluated the ease of use of the flying movement controls. The results revealed that when people map their physical gestures to flying movements in VR, certain gestures are easier to control and interact with.

Keywords

Natural user interface; flying experience; Virtual Reality; body gestures; Kinect.

Introduction

Immersive Virtual Reality (VR) provides six degrees of freedom while the user is navigating, which in turn allows the subject to experience a three-dimensional (3D) virtual environment. VR applications can provide immersive worlds that allow participants to experience places that exist nowhere else, to use physics that are otherwise impossible in the real world, and to move their body and control their movements in innovative ways. Interactivity remains as a significant property, and numerous input devices have been developed for human-computer interaction and navigation in VR. With respect to computational constraints, the requirements for VR interaction include speed, purposefulness, and especially intuitive handling, which means ease of interaction with the system input.

When immersive VEs are not designed as “photorealistic” — that is, when they are not intended to replicate “reality” — but are instead designed as alternatives to reality, different operating metaphors are necessary. An example is a virtual world that enables users to feel as if they are able to fly in first-person ways that are more akin to what we imagine it might feel like to fly as a bird, vs. what it feels like to “fly” as a passive passenger in a commercial airplane. In terms of how one might fly in VR, a metaphor is necessary for how actions and gestures, translated by input devices, are converted to movements and actions in novel VEs. The operating metaphor for flying as a bird, therefore, is based on the logic of how human body movements can be used to control movement in an alternate virtual reality. The way human movements are translated in VR such that they help users to navigate in virtual environments is an open-ended subject that needs both investigation and exploration.

Being able to fly is an experience that humans have long dreamed of achieving. Human beings have attempted to fly via various means in reality with apparatuses including but not limited to helium balloons, hang gliders, airplanes and rockets. Humans have also long expressed the desire to fly in media that ranges from movies and novels to immersive virtual reality. However, the human body does not support the functionality nor affordance of flying like a bird, nor does anyone use their bare hands or arms to fly. Thus, mental effort, reasoning and imagination are required to map human gestures to the movements in a VE to achieve a sense of flying. Researchers have found that users associate and relate their body (as a human interface) to VR, which indicates that they use their body during spatial reasoning [3]. Associating and relating their bodies to VR have been argued to enhance human spatial perception. However, so far few researchers have examined natural user interfaces for flying in VR. One exception is *Birdly*, which offers a bird’s-eye view experience and mechanical navigation of flying via an input chair the player lies down on. *Birdly* is a commercial solution that requires purchase of a standalone system. In contrast, we aimed for a distinct body gesture interface that creates very specific experience “gliding like a ghost” rather than a bird.

The aim of this paper is to explore the navigational experiences of FLYING in a VR environment via body gestures. We conducted two rounds of studies that focused on participants’ experience of gesture control and the mappings between their navigation in the real world and VR. Thus, the specific research question is: how can people control flying movements easily in VR using their body gestures as the natural user interface? Results found that for participants to control and map their physical gestures to flying movements (yaw, pitch, roll—the three dimensions of movement), leaning forward/backward to control forward/backward movement and moving arms up/down to go up/down were gestures that were easy. However, out of three possible rotational approaches, our results revealed that “airplane mode” (extending both arms and swinging them up and down) was perceived to be the easiest among all proposed rotational gesture designs.

Related Work

Various types of NUI have been developed and implemented for navigating VR environments in research prototypes. Recently, LaViola et al. [3] explored how people could use wearable shoes to navigate an immersive VR environment, whereas, in Tollmar et al.’s work [7], researchers analyzed the space of perceptual interface abstractions for full-body navigation in a screen specifically through pointing gestures. Although researchers [1] [2] [4] [6] [5] have explored the design space of body gestures, they primarily pre-defined and implemented the control gestures and navigation mapping in VR limited only to hands or arms. It is important, however, to remember the importance of mapping physical-to-virtual movements rather than to assume that what researchers perceive as "natural" and "intuitive" works for all others.

In a more recent study by Sikstrom et al. [5], researchers designed flying in a CAVE-like virtual environment where participants use only their arms to control flying movement. Nevertheless, it was still viewed by participants from a third-person view, and their input control was limited to shoulders instead of arms and hands. Similarly in [2] participants can see the real world from the camera of a drone through the Oculus Rift HMD by using body gesture to control the drone's direction, while in [1] participants could use their arms to control rotation in VR. However, it is important to note that both the VR content and gesture controls were defined by the researchers rather than emerging from participants.

Therefore, in this research, instead of using the game prototype as a means or apparatus to study the matter further — such as exploring embodiment or immersion in VR—we focused on players' navigational experiences through their body gestures and focused on the ease of use of the VR system. We believe that smooth, natural, intuitive navigation and user interaction play critical roles in constructing an immersive virtual environment for participants, and that these aspects are particularly important when the VEs are not based on photorealism, and that offer novel experiences and bodily sensations.

Further, this research is based on the theoretical framework of embodied cognition, which stipulates a close connection between sensorimotor experiences of the body and mental schemas (that is, some experiences are considered to precede cognition), this research examines participants' subjective experiences of flying in VR games. We focused on (1) what subjects wanted to be and to do; (2) and how they wanted to control their movements of flying via body gestures. Even though the participant's subjective experience in VR might not be the same, our assumption is that participants will borrow flying movement metaphors from what they are familiar with, e.g., birds, butterflies, airplanes, dreams and media. We assumed this experiential type of body-mind mapping might be more natural and easy to learn and control in VR.

Kinect VR Game Overview – *Beyond*

In order to test the strong candidate for most natural interaction in a flying-as-navigation experience in VR, we developed a VR game called *Beyond*. In the game, players wear an Oculus Rift DK2 HMD with headphones, and controls their flying movements using pre-defined body gestures captured by a Kinect tracking sensor. Players can fly above a forest, as well as complete tasks such as (1) finding and collecting five hidden items in the forest and (2) handing them over to the final Gate Tree to finish (fig 1 and 2).

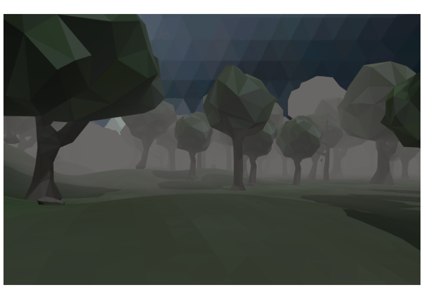

Figure 1: Screenshots from the Kinect VR game, *Beyond*.

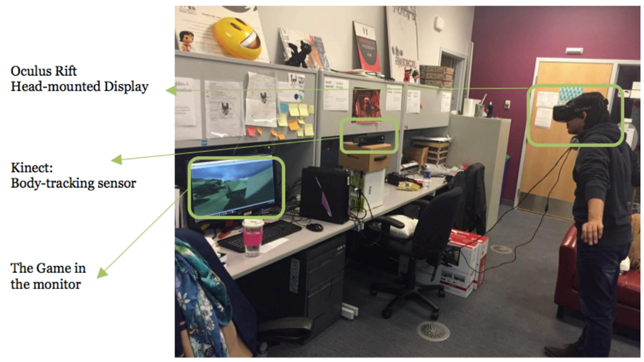

Figure 2: Experiment Setting: a participant wearing Oculus HMD interacting with Kinect to fly in the game.

Pilot Study One: "Flying" Body Gestures Exploration in General

The goal of the first pilot study was to figure out participants' experience with the fundamental navigation elements—forward/backward, up/down, and rotation. Overall, each session lasted 15 to 25 minutes. Seven participants joined and each participant was informed about the main idea as well as the objectives of the game (i.e., to explore the environment while flying in VR). They were told the control mapping gestures (i.e., lean forward and backward to move forward and backward, rotate body to the left and right to rotate the game's view, and raise both hands/arms above the waist to fly up or down). Next, the participant was asked to play the game for 10 minutes. Finally, the participant was asked to fill out a quantitative questionnaire that implements a Visual Analog Scale.

The questionnaire asked participants' for their feedback from four of the most significant aspects: (1) *Demographic Information & Prior Technology Experience*; (2) ***Movement (self-motion) & Gesture Control***: such as "how does movement feel"? The questionnaire was constructed in a manner that made it is possible to investigate how the gesture mapping felt to players, and if they felt like they were flying more like a "ghost" or more like a bird. The objective while designing the controlling scheme was to make the gestures easy to control without feeling disoriented or nauseated, i.e., to give the player the feeling of flight without providing the often-jarring real experience of flight.

Pilot Study Two: "Flying" Body Gestures for Rotations – Shoulder rotations, Twisting arms or Airplane

The aim of the second pilot study was to explore the ease of use of three different rotational gestures as well as participants' subjective experience of flying in VR and their preferred natural interactions. In general, the second study had a similar study procedure as the first one, and another entirely different group of seven participants took part in the study. The first difference between the first study and the second is that this test was conducted as a within-subjects study: each person played the game three times with each of the three rotational gestures – rotating shoulders, twisting arms, or in airplane mode. Further, in addition to quantitative questions, we added qualitative interviews after the test in order to understand participants' flying preferences and experiences in VR.

Open qualitative questions in the semi-structured interview mainly included the following: (1) What would you want to do (in the virtual environment) if you could fly? (2) Who or what would you want to be if you could fly? (3) What was your flying experience like in this VR? (4) How would you control your body movement if you could fly? Did you feel you are flying in VR? If so, what did you feel while experiencing the flying movement in VR?

Results and Discussions

Movement (self-motion) & Gesture Control

In the first study, generally, participants felt it was easy to move forward and backward (M = 66.1, SD = 17.15) and move up and down (M = 64.1, SD = 31.28) without motion sickness or nausea (M = 47.7, SD = 37.39). However, the rotational movement was rated as more difficult than the other two movements (M = 42.6, SD = 23.86) (fig. 3, 100 means very easy to control, and 0 means very difficult).

In the second study, among three rotational movements, the shoulder rotation (M = 42.6, SD = 23.86) was rated as more difficult than the other two rotation movements (fig. 4). Airplane mode was rated to be the easiest control (M = 16.0, SD = 8.94) over all three approaches, whereas the rotate with shoulders (M = 62.8, SD = 33.26) and arm twist (M = 54.8, SD = 24.34) ranked second (100 means very difficult, and 0 means very easy). For the "flying" experience, participants could almost control the movement to the extent they wanted (M = 47.7, SD = 19.43). The data also revealed participants did not have a problem understanding or using the movement gestures (M = 24.7, SD = 27.58).

Responses to Interview Questions from the second study

(a) What do participants want to DO while flying in VR?

Participants reported that they wanted to **explore their residential areas and nature scenery OR enjoy simple flying navigation and flight control**, e.g., P01 "I want to fly across the forest like a bird and stay at a branch of a tree. Also, I probably would fly from one building to another building, patio to patio."

(b) What do participants want to BE while flying in VR?

Maintain human character, with body parts like hands that can control flying movement; **OR have a body extension like wings**. Seeing one's virtual body, or even part of the body from first person point-of-view allowed the participants to sense their existence of the very moment in the virtual world. E.g., P01 "I would add a little nose to the avatar in front of the camera, because that is the what I see in the real world."

(c) How do participants want to control their flying movement in a natural and comfort way?

Use hands, arms, and upper limb to navigate flying movement as a creature's wings, borrowing the flying gesture from birds, e.g., P02 "lean body back to go up, forward to go down, that is like how the gravity works if you face down, that you are falling, right? " **Leaning forward/backward** to control forward/backward movement **matches people's perception of flying movement** control. **Moving arms & hands up/down** to control flying up/down **felt intuitive and easy to control**. These body movement metaphors made sense to participants while they were controlling the flying movements. **Airplane mode** to control flying rotations was **the most intuitive and easy** way for people to control rotation, e.g., P03 "I like the airplane one because it gives me the feeling of body extension and it helps me more with the real experience of flying. "

Also, some participants mentioned they felt **fatigue while having their hands raised or leaning forward without moving their body for extended periods of time.** This is a limitation of the prototype that requires future refinement; potentially, it needs to be solved by implementing an alternative gesture control or body orientation. P01 and P05 both said, "it is tiring to hold arms at a particular position for an extended amount of time."

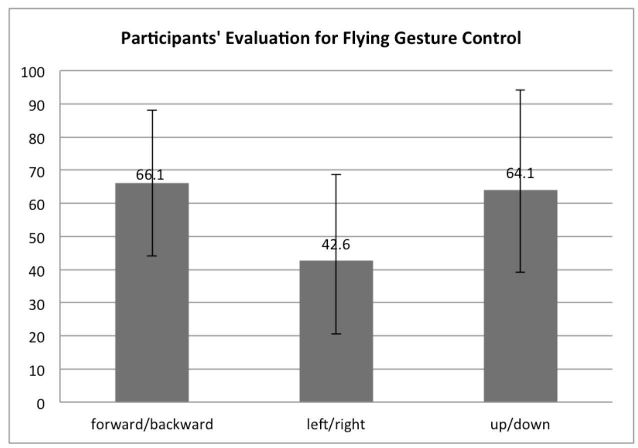

Figure 3: Pilot Study One: Study Results – participants' experiences of using gestures to control flying forward/backward, left/right, and up/down.

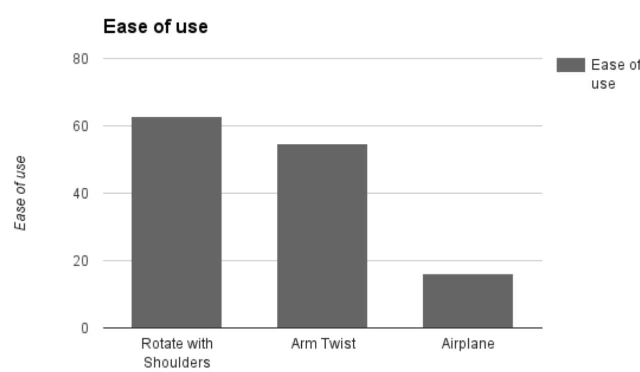

Figure 4: Pilot Study Two: Study Results – Comparing three types of rotation gestures: shoulder rotations, twisting arms and airplane mode.

Conclusions

In this paper, we studied the experiences of participants in a VR game where they could use their body gestures as a Natural User Interface (NUI) to control flying movement via Microsoft Kinect. The gestures that proved to be the most intuitive and easy to control when participants mapped their physical gestures to the flying movements were leaning forward/backward to control forward/backward movement, and moving their arms up/down to go up/down in the VE. The findings of this research provide insights for future VR-human interface designers to construct a natural approach for body-gesture controlled movement in navigating-as-flying scenarios.

The suitability study and results of flying gestures are sufficed in this context for this experience – flying and gliding in the environment like a ghost. For other VR environments and controls, designers are advised to implement gesture mappings within the framework of the specific VR application. Moreover, although the application of Kinect offers novel interface for human-computer interaction through a NUI, its limitations also restrict the way people can interact with the VR system. From an ergonomic aspect, human beings are not made for moving a long time with outstretched arms, because they become heavy and start hurting. This mainly happens during longer navigation and application sessions. However, for the **short** VR sessions, this problem has not been a limitation so far. Further, Kinect does not supply haptic feedback to the users. Those should also be concerns addressed in future research.

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