








What Is It Like to Be a Virtual Bat?

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Abstract. Virtual Reality (VR) might give us a glimpse of what it feels to have a different from human shaped body and how to orientate ourselves in virtual environment (VE) with it. Bats' wings structure has anatomical similarities to a human hand; yet would it be possible to achieve a compelling illusion of virtual body ownership (VBO) over bat's avatar is questionable. Hence our main aim of research is to imitate bat's sonar system and achieve embodiment of anatomically similar but morphologically different body – a body of a bat. Test results showed a possibility to achieve VBO illusion using bat's avatar. VBO was significantly higher when steering through VE, as opposed to steering without a virtual body and exposing to involuntary movement through VE. With our research prototype, users will be able to navigate with echolocation system and fly through a virtual cave.

Keywords: Virtual Reality · Virtual Body Ownership · Echolocation

1 Introduction

If it would be possible to answer such philosophical question as “What is it like to be a bat” [5] it might be easier to understand and simulate any life form as we would perceive surrounded environment as bats do. In order to elicit objective cognitive embodiment of a bat it will be useful to provide people with the experience of “seeing” the world through bat's eyes and allow them to inhabit a bat's body. As bat's anatomical structure of the wing, for example, is very similar to human's hand, it might give us an opportunity to do so. In attempt to create bat's simulator the following challenges arise: (1) providing users with the sense of ownership of the bat's body; (2) enabling users to control the bat's body in a way that is both intuitive and mimics real bat's behaviour; (3) providing users with impression of how the world “looks” when experienced through bat's senses. In order to imitate bat's basic physiological ability to flight – by inhabiting its body, and orient in the environment – by using echolocation system, we would apply virtual reality (VR) technology to allow users to navigate with a virtual avatar. A commonly held view is that the virtual body should have resemblance

to human morphological structure in order to create a compelling illusion of virtual body ownership (VBO) [4]. Furthermore, VR allows to inhabit not only morphologically modified virtual human bodies [3] but also bodies with additional virtual limbs [7]. This research prototype presents the system intended to produce an illusion of being a bat and navigate inside the virtual environment (VE). The system is a part of ongoing research seeking to address three questions related to this illusion: (1) To which extent can user get the sense of VBO? (2) How can VR be used to replicate the perceptual experience of being a bat? (3) How to navigate with the virtual body using echolocation inside the VE? In order to answer all these questions, the system enables users to control the body of a virtual bat, fly through the VE and simulate the experience of echolocation. The body of the virtual avatar used in the experiments is presented in Fig. 1.



Fig. 1. Virtual bat's position from first person perspective

In the ongoing research, we are exploring the amount of VBO illusion that participants experience over a virtual bat's body through visuo-tactile stimulation of their arm while seeing an object touching their virtual wing [2]. Furthermore, we research agency [1] as voluntary limbs movement and navigation through the environment. The last study indicated a linear relationship between agency and VBO. The higher agency was the more VBO was experienced, which suggests that felt and seen motor activity generated VBO as well as regulated its extent. Asynchronous mapping used for controlled movements produced the illusion of synchronous actions.

Series of pilot tests have been conducted in order to make use of real-time sound spatialization algorithms in VR (see [6] for a recent review on this topic) using appropriate parameters for providing echolocation cues as in a natural environment. The first couple of tests investigated which sound qualities enhance the ability to echolocate. The first experiment included a pre-recorded mouth click 13 ms long [9]. The second one used an expert mouth click [8], generated in Matlab with the length of 2 ms. Both tests involved the following conditions: vision, early reflections without vision, reverberation without vision and finally early reflections together with reverberation but without vision. To measure accuracy and speed performance, time and distance traveled as well as the number of mouth clicks produced by the participants were noted. Test results showed

that musicians were more sensitive to perception of audio stimuli and therefore showed a better performance than non-musicians. Based on the comparison of audio behaviour in the real world through impulse response measurements to the obtained results from the first two experiments we were able to modulate realistic sound behaviour and spatialization when echolocating in the VE. The final study is still currently in progress.

The novel aspect of this research demo is an attempt to simulate echolocation with the help of delay-based effects using expert-generated mouth clicks and navigate through the VE while inhabiting a virtual avatar that is morphologically different from a human shape structure.

2 System Demonstration

Locomotor kinetics (vertical lift to overcome gravity and thrust to overcome drag) and kinematics were considered together with wing size and shape (bat's wing is ideal aerofoil), air density and angle of the attack. Flight locomotion was divided into upstroke and downstroke, which produced one wingbeat cycle.

2.1 Hardware Setup

The system consists of an Oculus Rift head-mounted display (HMD) and two motion Touch controllers, capturing position of the hands in space. Headset resolution is 2160×1200 at refresh rate of 90 Hz. Two cameras are used – one for positional tracking of HMD, another one for touch controllers. For the echolocation system, Oculus left-hand Touch controller (button “X”) is used for generating mouth click and as a result, an output signal is transmitted through Bose AC35 headphones. Overall system setup is presented in Fig. 2.

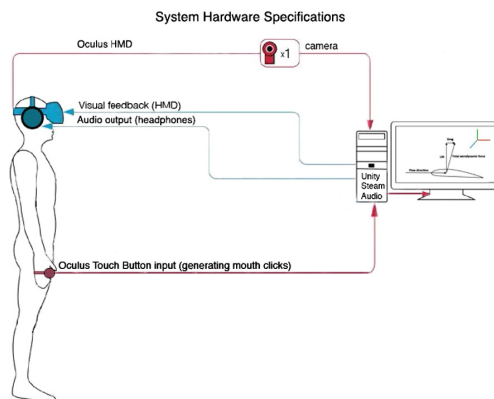


Fig. 2. System set-up

2.2 User Interaction

Users will be able to control their flight with their hands through Oculus Touch controllers. Before users would be able to proceed with the system, calibration is applied. During the calibration phase that lasts for 5 s, users have to keep their hands in T-pose (or in front and slightly to the sides for convenience), and press down PrimaryThumbstick button of the left-hand Touch controller. The users are notified about application start through a screen message when calibration is done. Navigation requires the constant unified hand movements (up and down passing the “zero” angle acquired from the T-pose) to generate physical forces and to avoid falling down, since if the attack angle would be negative (hands down) gravity and drag forces would eventually make the virtual body to fall. Direction of the flight is computed in the direction of the hands. Users will be able to experience echolocation by pressing the button generating expert mouth clicks and listening to the audio feedback from the virtual space through their headphones. The duration and volume of the feedbacks will allow users to determine primarily the distance to the objects in virtual space, the size of the VE and, theoretically, provide additional information on the shape, size and material of the objects.

2.3 Software Architecture

To meet the requirements for natural sound propagation in VR, Steam Audio engine was used. As soon as the users’ press “X” button generated mouth click audio sample is processed through Steam Audio in real-time. Steam Audio casts multiple rays from the sound source within the defined radius (radius = 7 m) that imitate sound propagation as in the real world with multiple real-time reflections that could be controlled in the program, and finally level and decay time of reverberation is also calculated by Steam Audio in real-time. User’s movements are mapped to the virtual avatar also in real time. Linear mapping is used for this purpose, tracking one “hand beat” cycle (hands up and hands down) in a virtual representation of one wingbeat cycle (upstroke and downstroke) through animation.

Gesture Detection. Bat’s animation is synchronized with real-time data acquisition from users’ input gestures imitating bat’s locomotive cycle. The system would register hands movements, following along Y-axis: positive α , when hands go up above “zero” angle, and negative α , when hands go down below “zero” angle, equivalent to upstroke and downstroke of bat’s biological locomotive cycle. A certain position on the Yaxis is capturing a specific α . Finally “zero” angle interval passes highest/lowest positional values of α into the system.

Velocity Estimation. The faster the users imitate flying movements (passing “zero” angle) the faster bat flies through VE. Stroke duration computes the amount of time passed, depending on the up- or down stroke of the cycle. It keeps

track of the stroke speed allowing to control the speed of the bat, depending on the positive or negative α , which in its turn differs depending on the calculated aerodynamic forces.

Heading Direction. Touch controllers (hands) position are responsible for the direction of movement through the environment. This is done in order to “free” HMD from being responsible for the direction of the flight and give users full control over the bat’s body. Direction of the flight is calculated in the direction of the unified movement of the hand controllers. E.g. if the users would want to change direction they would need to rotate/move their body to the desired direction and new direction for the virtual body will be calculated. It is realized by creating a forward directional vector, using position of the Touch controllers in space.

Echolocation. In order to properly simulate echolocation, raycasting is used to calculate distances from the virtual bat to virtual objects in the VE space. This information provides the proper delays parameters for input clicks as it would occur in real life taking into consideration sound speed. Head-Related Transfer Function (HRTF) provides further spatial information about the direction of arrivals of echoes reflecting from objects (azimuth and elevation). For stimulating more realistic reverberation succeeding parameters are adapted: bilinear HRTF interpolation, physics-based attenuation, air absorption, direct mix level = 1.0 (where minimum is 0 and maximum is 1), frequency dependent transmission occlusions using partial method, e.g. casting multiple rays from the sound source within the radius of 7 m, real-time reflections with indirect mix level = 1.0 (where minimum is 0 and maximum is 16). The system is able to perform real-time calculations of sound impulse reflections and reverberations depending on the user position and head rotation. The following audio shaders are applied to the objects in the VE: “Rock” for the walls, “Wood” for the trees, roots and vegetation and “Glass” for crystals.

3 Conclusion

The discussed system is built to support learning echolocation during flight locomotion. In the ongoing research, we create a new compelling illusion of VBO over anatomically similar but morphologically different virtual body of a bat, which can be achieved during navigation and orientation through VE. Navigation is performed by specific gestural inputs imitating flight in combination with echolocation using expert-generated mouth clicks, imitating sonar signals in the VE. Flying algorithm was computed using bat’s locomotor kinetics and kinematics.

4 Video

Video is hosted by Youtube and could be seen on the following url: <https://youtu.be/uB2ApqoNzzU>.

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