Head-Movement Evaluation for First-Person Games

Paulo G. de Barros
Computer Science Department
Worcester Polytechnic Institute
100 Institute Road.
Worcester, MA 01609 USA
pgb@wpi.edu

Robert W. Lindeman
Computer Science Department
Worcester Polytechnic Institute
100 Institute Road.
Worcester, MA 01609 USA
gogo@wpi.edu

Timothy J. Loughlin
Computer Science Department
Worcester Polytechnic Institute
100 Institute Road.
Worcester, MA 01609 USA
tjloughl@wpi.edu

CHI 2009, April 4–9, 2009, Boston, Massachusetts, USA.
ACM 978-1-60558-247-4/09/04.

Abstract
A first-person view is often used in games to enhance players' sense of presence. Camera movements are added to provide a walking sensation when the player is moving around. Several variations of camera movement are used in current games to simulate head movement. This work aims to evaluate these different types of camera movements by measuring subjective responses of users when exposed to them. In this first stage of research, five important movements were identified, and evaluated in a pair-wise fashion, resulting in subject preferences that contradicted our initial hypothesis.

Keywords
Camera movement, first-person view, games, Virtual Reality.

ACM Classification Keywords
H.5.1. Artificial, augmented and virtual realities; H.5.2. User interfaces evaluation/ methodologies; K.8.0. Games.

Introduction
First-person computer games are designed to provide a higher level of immersion in the virtual world and make players feel they are directly interacting with the game.

However, camera movement in games does not realistically represent the actual head movements of people when they are walking; a simplified movement is utilized instead.

Lécuyer *et al.* [3] conducted a user study comparing different translational first-person camera movements. According to their results, vertical translation was selected by subjects to be closest to natural movement.

We have designed a system that allows the careful control of head translation and rotation in three-dimensional (3D) game-like virtual environments (VEs). Using this system we have created five different types of head movements, including a pseudo-realistic movement. They were compared by subjects using realism as criterion. This work builds on the results obtained by Lécuyer, adding more head movement types.

System

The system consists of a VE and an interface to control the camera movements of the user's graphical representation, the avatar.

The VE was built using the C4 game engine [2], and consists of a corridor with a line of lampposts. Objects were distributed along the corridor to provide additional visual-flow cues to the subject.

The interface for controlling head-movement parameters enables setting up values for head rotation and translation in each of the three spatial axes. The head-movement can be precisely adjusted and viewed in real-time. A snapshot of the interface and the VE is shown in Figure 1.

The interface consists of sliders that control the amplitude, frequency, and phase of independent sinusoidal functions that simulate head translation and rotation along and about each axis. The ranges of values for amplitude are 0 to 4 centimeters for translational oscillation and 0 to 4 degrees for rotational oscillations. Frequency can be varied from 0 to 4 Hz. Phase assumes 5 values that represent percentages of the period of the sine curve: 0, 0.25, 0.5, 0.75 and 1. Notice that phases of 0 and 1 cause the same effect in head movement. Additionally, different sliders for amplitude can be locked to each other for value synchronization. The same is possible for the frequency and phase sliders.

Figure 1: Camera control interface for generating artificial head-movement, and walkway view of the VE used in the head-movement videos.

The system can also load pseudo-realistic head movement behaviors based on the work of Boulic *et al.* [1] and Mulavara *et al.* [4]. The equations presented on both papers were implemented as functions and the movements they represented applied to the user character. Speed control is also provided. The user character moves autonomously along a predefined cyclic spline path.

The user avatar is composed of three interconnected nodes: one located at the bottom of the neck, a second positioned in the center of the head, and a third placed between the virtual eyes. Translational oscillations defined in the interface were applied to the first node, while rotational oscillations were applied to the second node. In addition, the virtual camera representing the user's view of the world was attached to the third node.

User Study

We conducted a study aimed at evaluating different types of camera movements for walking in first-person games. The first step was to identify common techniques used by the video-game industry to simulate walking behaviors in first-person shooter (FPS) games.

Ten leading FPS games published over a 14-year span were selected, and their head movement subjectively evaluated. Table 1 lists information about the selected games.

Movements were categorized according to direction and amplitude. Direction was categorized as oscillating either in horizontal or vertical directions. If oscillations were synchronized, they were categorized as creating an n-like (∩), u-like (∪), or infinity-like (∞) movement. If there were rotational movements, they were described according to the axes of rotation. Intensity of movement was categorized as being slight, moderate or pronounced.

Game Name	Year of Release	Camera Movement	Weapon Movement
Doom	1993	Moderate vertical	Pronounced u-like
Dule Nukem 3D	1996	Slight vertical	Slight u-like
Tom Clancy's Rainbow Six	1998	None	None
Unreal Tournament	1999	Slight infinity-like	Slight infinity-like
Halo	2001	None	Slight u-like
Battlefield 1942	2002	Pronounced vertical, slight horizontal	Moderate n-like and rotation around vertical axis
America's Army	2002	None	Slight Infinity-like
Half-life 2	2004	None	Slight Infinity-like
Brothers in Arms: Road to Hill 30	2005	Slight vertical and horizontal	Moderate Infinity-like
Bioshock	2007	Slight vertical and horizontal	Moderate u-like

Table 1: Camera and weapon movements for ten leading FPS games.

Based on the results of this initial review, five types of camera movements were selected to be part of the study and be presented to subjects, as illustrated in Table 2. T_a and R_a represent, respectively, the presence of translational and rotational oscillations in an axis a, where $a = X$, Y, or Z. P indicates the presence of a cyclic or periodic movement. The positive directions of the X, Y and Z axes are right, backward, and upward, respectively, in relation to the camera direction, representing a right-handed coordinate system. Although two possible types of infinity-like movements are possible according to the direction, only one of them was subjectively selected and used in the study. Additionally, the n-like movement was not considered in this initial study. The study included the most-preferred movement from Lécuyer *et al.* [3], which was vertical-only translational oscillation.

Type of movement	P	T_X	T_Y	T_Z	R_X	R_Y	R_Z
⇂↾ Vertical (V)	✓			✓			
U-like (U)	✓	✓		✓			
∞ Infinity-like (I)	✓	✓		✓			
Pseudo-random (R)		✓		✓	✓	✓	✓
Pseudo-realistic (M)	✓	✓	✓	✓	✓	✓	✓

Table 2: Types of walking head movement.

A pseudo-realistic movement pattern was added to our study to measure how subjects perceived authentic movement. Last, a pseudo-random movement pattern was added. This movement had asynchronous cycles for different translations and rotations, and allowed the measurement of how cyclic and acyclic movement would influence user perception.

Our initial hypothesis was that the movement based on realistic equations derived from data collected by bio-physically measured experiments (M) would be the most preferred, followed by pseudo-random (R), u-like (U) and infinity-like (I) movements. The vertical-only type of movement (V) was expected to be the least preferred.

Each of the five camera movements was presented to subjects as a ten-second video that was pre-recorded from our walkway VE at a resolution of 1152x720. With the approval of university's IRB, the study consisted of having subjects view pairs of videos. They were asked to pick one out of the two in each pair that seemed the most realistic to him/her. All pair-wise combinations of the five videos resulted in ten pairs. However, since each pair could be viewed in two different orders, this number was doubled. Additionally, in order to check for consistency of subject responses, each pair was presented three times. Hence, each subject was exposed to a total of 60 trials, with a short rest break after every 20 trials.

Instructions for the experiment were presented on paper together with the consent forms. A brief demographic questionnaire was also administered before the trials, and collected information about age, gender, and how often the subject played first-person games. Questions about study procedure were answered prior to commencement, but answers to questions about the user study in general were delayed until after the subject was done with all stages of the study.

After all trials were run, a final paper questionnaire asked subjects about how many distinct movement types they thought were presented to them during the study, and were asked to describe each of them. They were also asked to indicate which one was the most realistic. Finally, space was provided for any comments on the experiment and/or camera movements.

A total of eight women and 26 men participated in the experiment. The normal distribution model for their ages had a mean of 22 years eight months, and standard deviation of six years five months. It was skewed right and had a median of 20 years. In addition, 20.6% claimed to play first-person games daily, 26.5% weekly, 44.1% seldom, and 8.8% never play.

Results

Figure 2 presents the percentages of choices for each video among all subject trials. Our results indicate that there is a preference for the u-like and infinity-like movements over the other three types of movement as presented in Figure 2. If none of the movement types was preferred, then each would have a response rate of 20%.

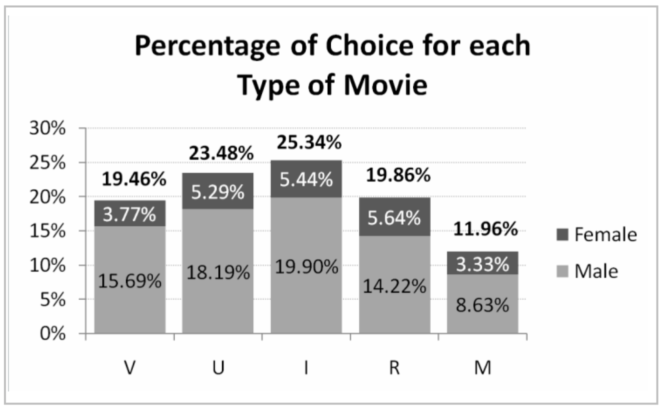

Figure 2: Percentage of choice for each type of movement over the total number of trials.

By observing the difference between the number of choices of a movie y in the pairs (x, y) and (y, x), it was noticed that this difference would not follow a normal distribution centered at 0. The result indicates that the error in the choice of videos varies from pair to pair, which was to be expected. This variation is illustrated in Figure 3 , which presents data for all pairs of videos when one of the videos of each pair was selected. A total of 2,040 data points (34 subjects times 60 trials) were collected across all subjects, with each of the 20 ordered pairs accounting for 102. Notice the larger variation in the pair U-I, followed by the pairs V-I, V-M, U-M and R-I.

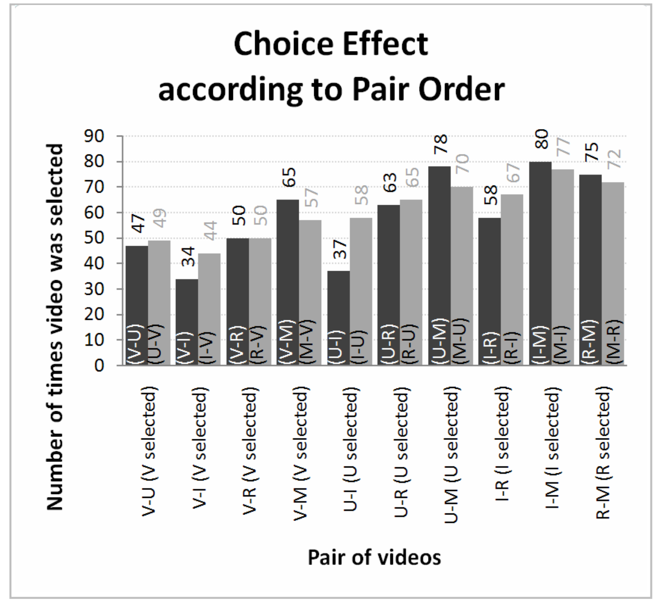

Figure 3: Difference between the number of choices of a movie y in the pairs (x, y) and (y, x).

Discussion

This research has measured how subjects perceive and prefer different camera movements. Our conclusions are based on the results of subjective evaluation for five types of camera movement.

Our initial hypothesis that the M movement would be preferred was contradicted. The lack of preference for

M may be because the movement values we chose for M seemed exaggerated, due to a lack of inertial movement cues for the brain. This may be corrected by adjusting how we merge the two sets of equations used to generate the pseudo-realistic movement [1], [4]. It may also be that with time, subjects would get used to this movement, and prefer it more.

The pseudo-random camera movement R, with smaller rotations than M, was not subjects' first choice either. This indicates the choice by subjects of periodicity over movement variety.

By analyzing the bar chart in Figure 3, we notice that subjects had a hard time choosing a video for the pair U-I. This may indicate that these movements are very similar and hard to distinguish visually. The pair V-I also contains some error in choice, which may confirm the results of Lécuyer that vertical movement affects perception of realistic movement more than horizontal movement, and makes the choice between these videos difficult. Interestingly, the same variation was not present for the U-I pair. The reason for this absence of variation is not yet understood. The variation in the V-M pair only seems to indicate that both camera movements are poor in terms of realism. For this pair, the decision seems to be more about deciding which one is the worst video instead of which one is best. The results for the pair U-M may indicate that slight rotations still provide realism when compared to some types of translational-only movements such as U. This is confirmed by the I-R pair variation. Although not containing an easily perceptible cyclic behavior, but with slighter rotations than M, the R type of movement provided a reasonably realistic type of movement. When paired with I, it was difficult for subjects to decide which one to choose.

Conclusions

We believe that in a long-term study, a better calibrated realistic movement camera should be the first choice for most subjects as initially hypothesized. As future work, we will attempt to validate this claim. Other research extensions would be testing the effect of camera movements on avatar control, that is, running the above experiment and allowing the user to actively control the avatar and camera movement. Another extension is to relate different walking configurations to game character types, sizes, and even the character's mood.

References

[1] Boulic, R., Thalmann, N. M., Thalmann, D. Human free-walking model for a real-time interactive design of gaits. *In Computer Animation 1990,* N. M. Thalmann and D. Thalmann, Ed., Springer-Verlag, 61-79., 1990.

[2] C4 Engine. Terathon software. http://www.terathon.com

[3] Lécuyer, A., Burkhardt, J.M., Henaff, J.M., Donikian, S. Camera Motions Improve Sensation of Walking in Virtual Environments, *Proc.s of IEEE VR 2006*, 11-18.

[4] Mulavara, A.P., Verstraete, M.C., Bloomberg Modulation of head movement control in humans during treadmill walking, *Gait and Posture*, 16, 3 (2002), 271-282.