VisuaLift Studio: Study on Motion Platform using Elevator

Masahiro Koge [1] Taku Hachisu [1,2] Hiroyuki Kajimoto [1,3]

[1] The University of Electro-Communications [2] JSPS Research Fellow [3] Japan Science and Technology Agency

ABSTRACT

We present a novel setup called VisuaLift Studio for developing virtual reality content with a motion platform that employs an ordinary elevator and augments the subjective movement of said elevator using sensory illusion of movement induced by vision. A prototype system of VisuaLift Studio consists of an elevator, an acceleration sensor, a microcontroller, a laptop PC, and a head-mounted display (HMD). The experiment demonstrates that it is possible to control the perceived direction of the elevator by providing optical flow through the HMD (visual stimulus), regardless of the real direction of the elevator (physical stimulus). On the other hand, comparing the intensity of subjective movement between the case of visual and physical stimuli and the case of only visual stimulus, the former exhibits significantly stronger sensation of movement, even in the case where the directions of both stimuli are inconsistent.

Keywords: Motion platform, VisuaLift Studio, vection.

Index Terms: H5.2 [Information interfaces and presentation]: User Interfaces—Graphical user interfaces

1 INTRODUCTION

We perceive the movement of our bodies within the surrounding environment through visual and kinesthetic (somatosensory and vestibular) sensations in terms of position, velocity, and acceleration. To simulate this in a virtual reality (VR) environment, motion platforms, such as driving simulators, are used. The motion platform enriches content realism, but it generally requires large space and complex mechanical setup. Cheng et al. developed the Haptic Turk system that employs human power to actuate the cockpit [1]. This system significantly reduces the cost for space and implementation time; however, it requires multiple people and has some limitations because of human error and fatigue.

In this paper, we present a novel setup for motion platform called VisuaLift Studio that employs an elevator as a motion platform and provides infinite elevation and descent using the sensory illusion of movement induced by vision. There are approximately 670,000 elevators in Japan [2]; this means that new space and implementation for mechanical components are not required. Therefore, VisuaLift Studio provides cost-efficient implementation of VR content with motion platform.

On the other hand, using elevator as a motion platform has several limitations, as follows:

1. Distance of continuous movement depends on the height of the building (movable range).
2. Direction of movement is limited to the vertical axis (one degree-of-freedom).
3. Poor variation of movement parameters (duration, displacement, velocity, and acceleration).
4. Poor real-time performance.

This paper resolves the first limitation using the visually induced self-motion sensation known as vection.

2 RELATED WORK

Lishman et al. showed that when sensory conflict between visual and kinesthetic sensations is present, subjects tend to rely on visual cues for controlling body balance [3]. This phenomenon is now commonly known as vection.

Combining an elevator with HMD was first developed by Kume et al. [4]. They conducted experiments to study the influence of visual animation whose direction is the same as or opposite to the direction of an elevator. Their results showed that animation affects the perceived direction. This work is similar to our approach and supports the basic concept. On the other hand, the acceleration provided in the study was around the sensory threshold (approximately 0.1 m/s^2). Acceleration provided by a real elevator is sufficiently large to be perceived (0.8 m/s^2, see section 3). Their work also did not show the subjective intensity of the illusion.

3 SYSTEM PROTOTYPE

We built the VisuaLift Studio system that consists of an elevator, three-axis acceleration sensor, microcontroller, laptop PC, and HMD. The elevator (Mitsubishi Electric) was installed in a five-story building of dimensions 140 cm × 140 cm × 230 cm (width, length, and height). The acceleration sensor (Freescale MMA7361LC, ±1.5G) was attached to the elevator wall, and the microcontroller (NXP Semiconductor, mbedLPC1768) was used to measure vertical acceleration with 12 bit and 1,000 samples per second. The maximum acceleration was approximately 0.8 m/s^2, which is sufficiently large compared to the threshold required for a human to sense acceleration through kinesthetic sensation [5]. The PC received acceleration data from the microcontroller, computed elevator displacement, and rendered a virtual elevator using the Unity3D engine (http://unity3d.com). The virtual environment was presented to the user using an HMD (Oculus VR, Oculus Rift).

4 EXPERIMENT ON PERCEIVED DIRECTION, TENDENCY OF VISUAL DOMINATION, AND INTENSITY OF SUBJECTIVE MOVEMENT

We conducted an experiment to study whether the optical flow presented by the HMD dominates the perceived direction of the subjective movement over the acceleration presented from the elevator. An additional purpose of the experiment is to measure the intensity of subjective movement and to observe the tendency for visual domination to occur more frequently as the trials proceed.

4.1 Setup

We built a virtual elevator (VE) in the virtual environment with dimensions similar to the real elevator (RE), and fixed a virtual stereo camera (with interpupillary distance of 6.4 cm) at the

{koge, hachisu, kajimoto}@kaji-lab.jp

IEEE Symposium on 3D User Interfaces 2015
23 - 24 March, Arles, France
978-1-4673-6886-5/15/$31.00 ©2015 IEEE

position 70 cm × 70 cm × 170 cm. The system simulated the VE displacement y using acceleration a of RE as follows:

$$v = kat + v_0$$
$$y = \frac{1}{2}kat^2 + vt + y_0, \quad (1)$$

where v is velocity, t is time, v_0 is initial velocity, y_0 is initial position, and k is the acceleration coefficient. When $k = 1$ / -1, the VE direction was the same as/opposite to that of RE. When $k = 0$, VE did not move. The refresh rate of the three-dimensional (3D) engine was 60 Hz.

To present vection, we displayed black and white stripes with 23 cm intervals on the VE wall. The stripes were moved in association with displacement y.

4.2 Design

We presented three conditions (up, down, and stop) for RE and one condition (up) for VE. Thus, there were three conditions. The small number of conditions allowed participants to stably answer perceived direction without confusion.

4.3 Procedure

A total of 12 participants (nine males and three females aged between 18 and 30 years) were selected for the experiment. An experimenter and participant rode the elevator, the participants were instructed on the experiment, and they wore the HMD and headphones with white noise.

First, the experimenter provided a standard condition (REstop-VEup). Next, he provided a comparison condition selected randomly from the three conditions. Then, the participants answered the subjective perceived direction of the elevator from the three conditions (up, down, and stop), and evaluated the intensity of the subjective movement relative to a standard condition using a seven-grade Likert scale (1: very weak, 4: same as standard condition, 7: very strong). One block of trials consisted of three trials with three comparison conditions. The order within a block was randomized. Each participant performed three blocks, which allowed us to observe whether visual domination occurred more frequently as the experiment proceeded. A total of 10 min was required per participant.

4.4 Results and Discussion

Table 1 shows the response rate of the perceived direction for three conditions. When only VE moved (REstop-VEup), the participants stably answered "up," which indicates that vection was induced by our setup. When the directions of RE and VE were consistent (REup-VEup), the participants answered "up." As shown in the inconsistent condition (REdown-VEup) highlighted in yellow in Table 1, the response ratio (up:down:stop) is 66%:33%:0%, which indicates that VE dominates RE over the perceived direction. The result shows the transition of the rates for the "up" answer in the inconsistent condition,for the third block, the rate reaches 75%, which indicates that VE domination occurred more frequently as the experiment proceeded.

Figure 1 shows the intensity of the subjective movement for the three conditions. We performed a Steel-Dwass test and found the intensity in the consistent (REup-VEup) and inconsistent (REdown-VEup) conditions significantly higher than for the VE condition only (RE stop-VEup) (consistent versus VE only: $t = 3.41$, $p < 0.05$; inconsistent versus VE only: $t = 4.60$, $p < 0.05$). On the other hand, there is no significant difference between the consistent and inconsistent conditions ($t = 0.275$, n.s.). The result indicates that the intensity of the subjective movement is enhanced by both visual and physical stimuli from RE and VE, regardless of their consistency or inconsistency.

Table 1: Response rate of perceived direction for three conditions (three conditions for RE (up, down, stop) × one condition for VE (up))

		VE		
		Up		
Answer Direction		Up	Down	Stop
RE	Up	97.2%	2.7%	0%
	Down	66.6%	33.3%	0%
	Stop	100%	0%	0%

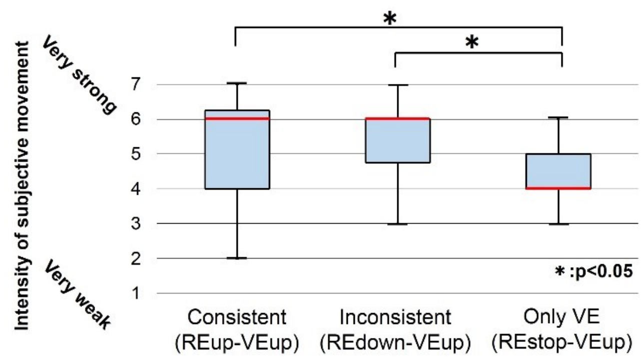

Figure 1: Intensity of subjective movement for three comparison conditions: intensity in the consistent (REup-VEup) and inconsistent (REdown-VEup) conditions are significantly higher than for VE only condition (REstop-VEup)

5 Conclusion

In this paper, we presented VisuaLift Studio, which employs an elevator as a motion platform and augments the physical movement of the elevator using sensory illusion of movement induced by vision. We implemented a prototype system that consisted of an elevator, acceleration sensor, microcontroller, laptop PC, and HMD. Then, we conducted the experiment that demonstrated that it is possible to control the perceived direction of the elevator by providing optical flow through the HMD. Intensity of the subjective movement was found to be significantly stronger when the movement was presented through both the HMD and elevator, even if the directions were inconsistent, than when the optical flow only was presented. Therefore, the result indicates that our approach resolves the first limitation.

We will conduct experiments to validate the implementation with modulated k to overcome the other limitations. Furthermore, we will develop VR applications using VisuaLift Studio.

References

[1] L. P. Cheng et al. Haptic Turk: A motion platform based on people. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pages 3463-3472, 2014.

[2] Japan Elevator Association. http://www.n-elekyo.or.jp/contact/index.html

[3] J. R. Lishman and D. N. Lee. The autonomy of visual kinaesthesis. Perception, 2, pages 287-294, 1973.

[4] Y. Kume and D. Hasegawa. Self-motion sensation affected by vertical acceleration and visual stimulation. The Journal of the Institute of Image Information and Television Engineers, 58(5), pages 727-730, 2004 (in Japanese).

[5] A. J. Gundry. Thresholds of perception for periodic linear motion. Aviation, Space, and Environmental Medicine, 49:679-686, 1978.