Graphical Manipulation of Human's Walking Direction with Visual Illusion

Akira Ishii* Ippei Suzuki Shinji Sakamoto Keita Kanai Kazuki Takazawa Hiraku Doi Yoichi Ochiai

University of Tsukuba

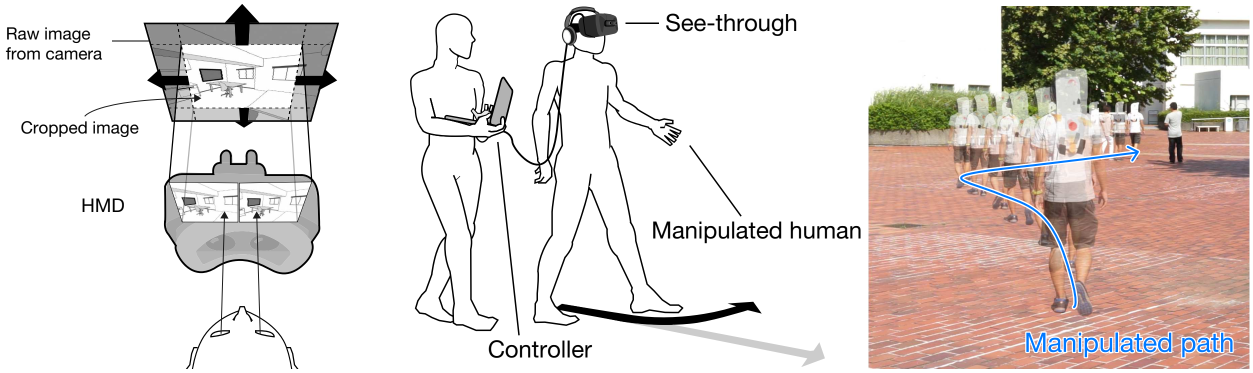

Figure 1: *Outline of the changing focal region method for manipulating a pedestrian's walking direction with visual illusion (left). Concept application of the remote-controlled human (middle). Result of the user study using the changing focal region method (right).*

Keywords: Pedestrian navigation, head mounted display (HMD), stereo camera, wearable devices, visual illusion, optical illusion, augmented reality (AR).

Concepts: •**Human-centered computing** → *Mixed / augmented reality;*

1 Overview

Conventional research on pedestrian navigation systems has explored the possibilities of presenting information to users both visually and aurally. Existing navigation systems require users to recognize information, and then to follow directions as separate, conscious processes, which inevitably require attention to the system. This study proposes a novel method that enables pedestrians to be guided without conscious interaction with a navigational system.

Several studies have reported on how pedestrians could be guided without paying attention to their navigation systems. These studies propose methods that directly affect a user's body so that the navigation system can physically control the pedestrian. These *subconscious* navigation methods require various hardware setups, such as an electronic muscle stimulator [Pfeiffer et al. 2015], a head-mounted vection display [Tanikawa et al. 2012], and vection fields on the ground [Furukawa et al. 2011]. Some studies employed a system that forced a heavy load on either the user or the hardware. To realize pedestrian control methods with a light load on users, our study focused on visual control achieved by wearable equipment. In the virtual reality research field, the visual approach has achieved success in reorienting mobile users [Razzaque et al. 2001], and a visual optic flow technique that affects self-motion has been evaluated in an augmented reality context [Bruder et al. 2013]. These earlier studies, however, did not test a navigation system in a real world environment, and in addition, the manipulation mechanisms have not been formalized experimentally.

Our study employs a combination of an HMD (head-mounted display; Oculus Rift Development Kit 2; Oculus VR, LLC) and a stereo camera (Ovrvision; Shinobiya.com Co., Ltd.) for pedestrian control. This system, displaying images as if the HMD were transparent, controls the pedestrian's direction by superimposing a visual illusion onto the raw images. This study was initiated with the hypothesis that pedestrian movement can be controlled with appropriate visual programming, and that a subconscious navigation system not requiring a user's attention can be realized.

We evaluated and compared two image processing methods for manipulation. The *moving stripe pattern method* superimposes a moving stripe pattern on a real-world image to induce vection. The stripe pattern always stays on the real-world image, which keeps shifting to the right or left. In the *changing focal region method*, the image provided by the camera is magnified, cropped along the focal plane, and then resized to the original size. The HMD displays only the cropped image. The magnified image makes it possible for the center position of the cropped image to be modified. Once modified, the focal plane that the user focuses on also changes, as shown in Figure 1 (left). This method provides a virtual optic flow to the users by scrolling the center position of the cropped image.

A pilot study was conducted to determine how to control pedestrian direction from a hallway to an outside using the image processing method. We recruited 11 participants (two females). We examined four image processing types: without processing, the moving stripe pattern method (slow/fast), magnification, and the changing focal region method (slow/fast). Image magnification was added to each of the image processing types for comparison, because it is used in the changing focal region method. Each participant walked along a straight path for 25 m. While the participants were walking, we operated a computer and controlled the walking direction. At a point 4 m from the starting point, the participants were guided to the left, and at the 14 m point, they were guided to the right.

---

*ishii@iplab.cs.tsukuba.ac.jp

SIGGRAPH '16 Emerging Technologies, July 24-28, 2016, Anaheim, CA.
ISBN: 978-1-4503-4372-5/16/07
DOI: http://dx.doi.org/10.1145/2929464.2967926

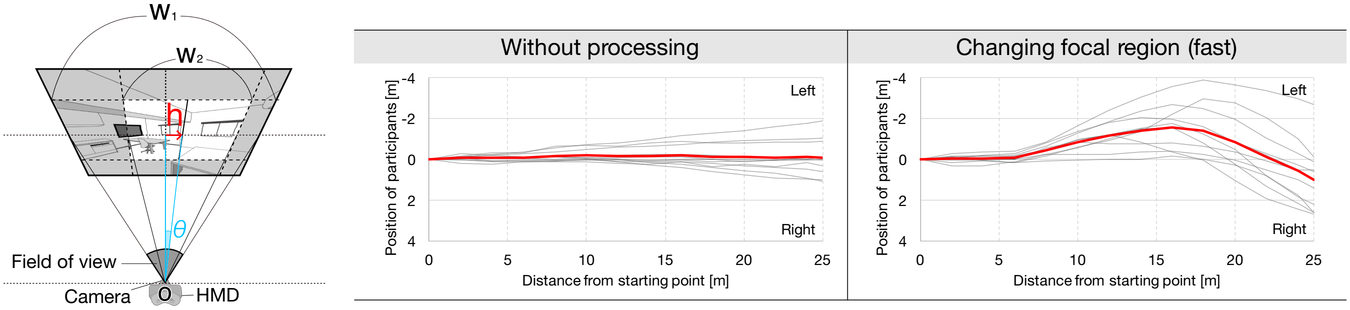

Figure 2: *Relationship between scroll amount from origin and angle of the focal plane (left). Walking path of all participants in the outdoor study (right). The path for each participant is shown as a gray line. The path that combines all the participant paths is shown as a red line.*

The results showed that there was a significant difference between without processing and the changing focal region method ($p < 0.01$) when outside condition. The changing focal region method worked most effectively for pedestrian movement control (Figure 2 (right)), and changed the pedestrian's path by about 190 mm/m on average.

We derived a relationship between the scroll amount from the origin and the angle of the focal plane. As shown in Figure 2 (left), the angle θ of the focal plane to the value of scroll h can be calculated as follows:

$$\theta = \arctan\left(\frac{1}{\frac{w_1}{2\ \tan\frac{fov}{2}}}h\right) \qquad (1)$$

$$\text{subject to } w_1 \geq w_2, \frac{(w_1 - w_2)}{2} \geq h$$

where w_1 denotes the horizontal resolution of the camera, w_2 denotes the horizontal resolution of the cropped image that users see, and fov denotes the field of view of the camera. Let v be walking speed, t be elapsed time, and α be the amount of movement per degree. We can express the position of the user (x: distance from the starting point, y: horizontal position) by:

$$x = vt \qquad (2)$$

$$y = \alpha x \theta \qquad (3)$$

From Formulas (1) and (3), we can get:

$$y = \alpha x \arctan\left(\frac{1}{\frac{w_1}{2\ \tan\frac{fov}{2}}}h\right) \qquad (4)$$

The experiment resulted in α:

$$\alpha = \begin{cases} -5.93 & (\theta \geq 0, \text{guide to left}) \\ -10.26 & (\theta < 0, \text{guide to right}) \end{cases} \qquad (5)$$

Using these results, we were able to formulate a model for our method.

2 Application

Pedestrian navigation system: Using this technique, it is possible to design a system that automatically navigates pedestrians. Because the users are subconscious of the system working, it can be used more intuitively. Furthermore, navigation feedback is expendable to the user, thus, misunderstanding or oversight of information is eliminated. We used the same formula that were derived from the experiment result for estimating manipulated pedestrian's walking path, and implemented a prototype of a navigation system. We performed an experiment to examine how to work our navigation system in a real world environment. We invited four male participants. We adopted the Wizard-of-Oz study to observe how participants are guided and are able to prevent accidents during the experiment. The experimenter followed the participant, and manually operated the navigation system to guide him to the destination. According to the results, three participants were guided to the destination successfully, and overall feedback on the navigation system was positive. Some of the feedback received was, "*this system is enjoyable for me*," and "*I felt relaxed because I just walked casually*." We also obtained some negative feedback, for example, "*I had a concern about motion sickness while using this system*" and "*it is harder to perceive space*."

User interaction: Our system can control walking direction; therefore, we can manipulate a human via a remote control, as shown in Figure 1 (middle). Users can manipulate a pedestrian using the control UI on a laptop or a wireless controller. This interactive technique is also applicable for entertainment activities. We obtained some feedback that the manipulated experience is enjoyable. Furthermore, we asked participants in the pilot study to use our system and to manipulate other people, and they also mentioned that human manipulation is enjoyable. This is a unique experience that has never been accomplished before.

References

BRUDER, G., WIELAND, P., BOLTE, B., LAPPE, M., AND STEINICKE, F. 2013. Going with the flow: Modifying self-motion perception with computer-mediated optic flow. In *Proc. ISMAR '13*, IEEE, 1–8.

FURUKAWA, M., YOSHIKAWA, H., HACHISU, T., FUKUSHIMA, S., AND KAJIMOTO, H. 2011. "Vection Field" for pedestrian traffic control. In *Proc. AH '11*, ACM, 19:1–19:8.

PFEIFFER, M., DÜNTE, T., SCHNEEGASS, S., ALT, F., AND ROHS, M. 2015. Cruise control for pedestrians: Controlling walking direction using electrical muscle stimulation. In *Proc. CHI '15*, ACM, 2505–2514.

RAZZAQUE, S., KOHN, Z., AND WHITTON, M. C. 2001. Redirected Walking. In *Proc. Eurographics '01*, Eurographics Association.

TANIKAWA, T., MUROYA, Y., NARUMI, T., AND HIROSE, M. 2012. Reflex-based navigation by inducing self-motion perception with head-mounted vection display. In *Proc. ACE '12*, Springer-Verlag, 398–405.