Guidance Field: Vector Field for Implicit Guidance in Virtual Environments

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Keywords: User interface, User guidance, 3D navigation.
Concepts: Human-centered computing ~ Interaction design process and methods; Contextual design;

1 Introduction

A 'guidance field' is a kind of a vector field that implicitly guides users to a target point. Users' input for travelling in virtual environments is slightly altered to get closer to the target directions according to the guidance field.

Compared with passive instructional videos, free explorations in virtual environments are efficient to understand the spatial knowledge and the context of the virtual environments. However, in most virtual reality settings, there is so much information and interactive options that users may quit exploring before they experience the whole content of the world. In that case, users cannot recognize the inherent attraction and context of the virtual environments. Therefore, it is necessary to guide users so that they become aware of the important points in the virtual environments.

Galyean guided users by steering them along a pre-defined path while at the same time allowing some extent of free exploring [Galyean, 1995]. However, in their method, the constraint of the user's exploration is so strong that the benefits of the interactive exploration shrink. Thus, there is a trade-off between guiding users and allowing free explorations.

In this research, we propose a new guidance method to implicitly lead users to pre-defined points in the virtual environment while allowing free explorations. This is achieved by altering users' input operations according to a type of vector field, which we refer to as a guidance field (Figure 1 top).

2 Algorithms of Guidance

The guidance field is composed of two independent mechanisms: locomotion guidance and rotation guidance. Locomotion guidance alters the users' velocity by increasing their speed when approaching the target point, but decreasing their speed when moving away from the target point. Rotation guidance alters the users' camera orientation by redirecting their virtual camera to face the route leading to the target point. Figure 1 bottom shows a concept image of input alteration.

2.1 Locomotion guidance

The walking speed increases when users are moving toward the target direction and decreases when they are moving toward the non-target direction. The speed is calculated by the following equation.

$$\mathbf{v}' = (1 \pm h)\mathbf{v} \tag{1}$$

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SIGGRAPH '16 Emerging Technologies, July 24-28, 2016, Anaheim, CA
ISBN: 978-1-4503-4372-5/16/07
DOI: http://doi.acm.org/ 10.1145/2929464.2929468

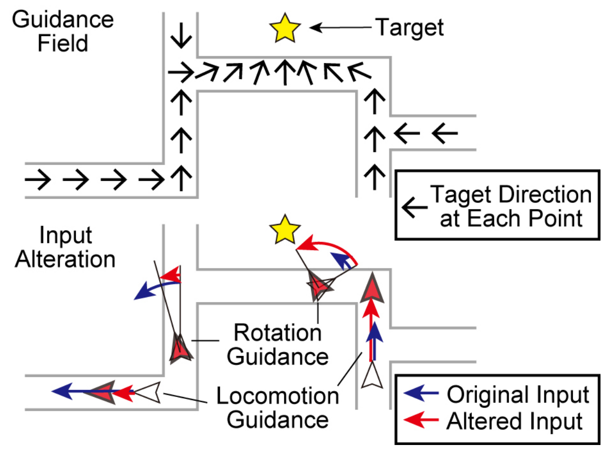

Figure 1: *Example of guidance field (top) and concept of input alteration (bottom).*

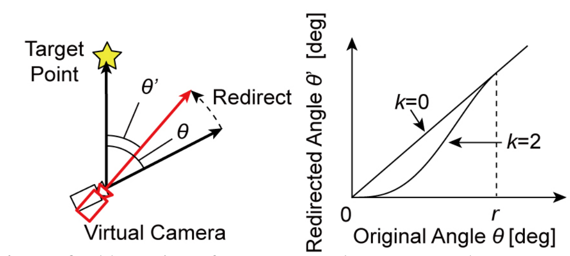

Figure 2: *Algorithm of rotation guidance. Virtual camera is shifted to a target point (left). The amount of shift is determined by the graph (right).*

where v and v' represent the original and altered velocity, respectively, and h is a constant value between 0 and 1, which controls the alteration strength. The sign of the second member is plus when users are moving toward the target direction and minus when they are moving toward the non-target direction. The most important consideration is that the target direction fixes the input alteration function. In other words, setting the target direction of each point sets the guidance field.

Locomotion guidance is expected to have the effect of making users feel that they can move smoothly and comfortably when they are moving toward the target direction, but they cannot when moving toward the non-target direction. Ideally, when users are moving toward the non-target direction, they may feel annoyed and change their moving direction toward the target direction by their own intention. Consequently, there may be more of a chance of arriving at the target point.

2.2 Rotation guidance

The extent of redirection is determined by the following equations (Figure 2)

$$f(\theta) = \theta \sin^k \frac{\pi\theta}{2r} \qquad \text{(if } \theta < r\text{)} \tag{3}$$

$$f(\theta) = \theta \qquad \text{(if } \theta \geq r\text{)} \tag{4}$$

where θ represents the original angle between the directional vector of the target point and that of the virtual camera, r determines the angular range in which the angular shift occurs, and k is a constant value that determines the strength of the angular shift. In

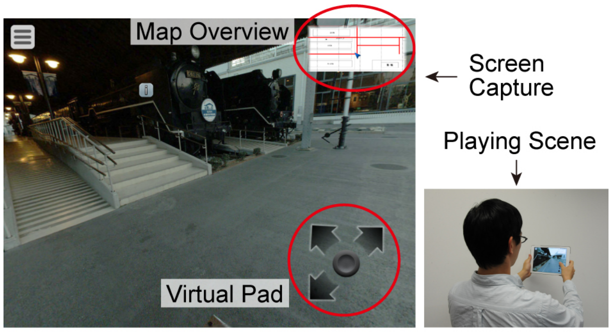

Figure 3: *Screen capture and playing scene of "Window to the Past"*

Figure 2, θ' represents a shifted angle ($\theta' = f(\theta)$). In this work, the value of r is 180° and that of k is 2. The target direction fixes the input alteration function at a node in the virtual environment. Therefore, the target directions determine the guidance field.

Around the target point, the rotation guidance method entices users to gaze at the target. When users are far away from the target and there is occlusion between the users and the target, our aim is to make users approach the target. The inducement to move toward the target is based on the assumption that users are more likely to move toward the direction they are facing. As the result of rotation guidance, users become more likely to look in the target direction. Thus, the chance of the user arriving at the target location improves.

3 Virtual Environment Exploring Application

Virtual environments constructed with a sequence of spherical images are becoming popular because they are more realistic, immersive, and easy to construct compared to virtual environments constructed with computer graphic models [Chen *et al*, 1995].

We developed an application that enables virtual environments to be explored and named it the "Window to the Past." This application depicts a virtual museum space constructed with a large sequence of spherical images. The application uses images of the Modern Transportation Museum in Osaka, Japan, with an area of 10,000 m^2. We archived the museum as 7,096 spherical images and developed a node-edge based walk-through system. The distance between nodes was approximately 0.15 m, and the normal walking speed was set at 160 m/min. Thus, approximately 18 spherical images were seamlessly shown in 1 s.

The direction of the virtual camera is linked with the orientation of the tablet device. Therefore, when the user moves the device in a specific direction, the virtual camera moves in the same direction. A virtual pad is adopted as an input interface for locomotion (Figure 3 (left)). In addition, to inform users of the direction in which they can move from their node, arrows are shown around the virtual pad.

Part of the overview map, including the camera paths, user's position, and user's orientation, is displayed in the upper-right corner of the screen (Figure 3 (left)). Figure 3 right shows a playing scene of Window to the Past. The user is holding an iPad.

A guidance field can also be applied to virtual environments constructed with computer graphic models. In addition, it is also possible to apply it to other input interfaces such as HMDs and real walking.

4 Evaluation in Demonstration Experiment

The basic algorithms and their evaluation are already reported as a paper [Tanaka *et al*, 2016]. In this paper, we introduce a summary of our evaluation results.

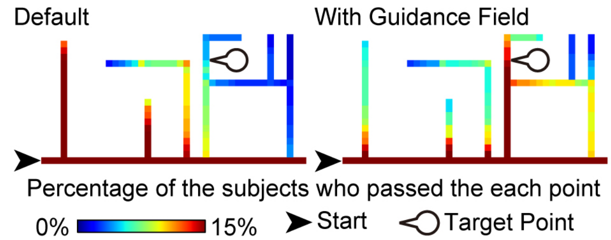

Figure 4: *Heat map of the percentage of the subjects who passed each point.*

We evaluated our method by conducting a large-scale experiment in a real exhibition at KNOWLEDGE CAPITAL The Lab. The subjects were people who visited the exhibition and experienced the "Window to the Past". The visitors varied from children to seniors. They could play the application until they were satisfied.

We selected three exhibits as the targets and compared each subject's behavior with and without the guidance field for each target. The number of subjects was 729 without the guidance field and 703 with the guidance field.

Figure 4 shows heat maps of the percentage of subjects who passed each point when the target point was one of the three target exhibits. More subjects visited the red area than the blue area. The heat maps indicate that more subjects approached the target exhibit with the guidance field than without it. Quantitatively, the percentage of subjects who arrived at the target point increased from 2.1% to 7.3% ($p < 0.01$) and the percentage of subjects who gazed at the target exhibit increased from 7.7% to 15.8% ($p < 0.01$) with the guidance field.

Because of the input alterations, the guidance may harm users' operational feeling. We compared the experience time when subjects are using the application. In our experiment settings, subjects could quit the experience whenever they wanted. Therefore, if they felt stressful or annoyed by the input alterations causing a bad operational feeling, there may be fewer subjects that continue their explorations. However, the median of the experiment time increased from 46.0 s to 48.9 s ($p < 0.05$). Therefore, it can be said that the guidance method does not interfere with users' free explorations.

5 Demonstration in SIGGRAPH 2016

In SIGGRAPH 2016, we implement the guidance field to "Window to the Past" on tablet devices and HMDs. Visitors can enjoy the free explorations in the virtual environments. Actually, they are implicitly led to a pre-defined exhibit. Our work is expected to clarify the context of virtual environments and contribute to the spread of the interactive navigation in virtual environments.

Acknowledgements

This work was partially supported by the MEXT, Grant-in-Aid for Scientific Research (A), 16H01762, and Hoso Bunka Foundation.

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