Towards Unobtrusive Obstacle Detection and Notification for VR

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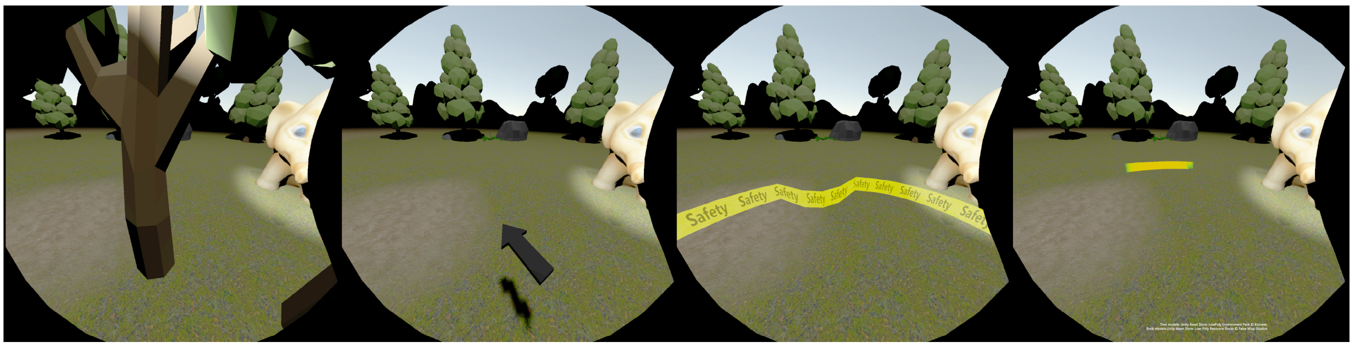

Figure 1: The four metaphors: Placeholder (tree); Arrow; Rubber Band; Color Indicator.

ABSTRACT

We present results of a preliminary study on our planned system for the detection of obstacles in the physical environment by means of an RGB-D sensor and their unobtrusive signalling using metaphors within the virtual environment (VE).

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**; *User studies*; *Laboratory experiments*; *Interaction techniques*; • **Computing methodologies → Virtual reality**; *3D imaging*;

KEYWORDS

Virtual Reality, Notifications, Interaction metaphor, Collision Avoidance, 3D Interaction, Walking Workspace, Range Imaging, RGB-D

ACM Reference Format:
Peter Wozniak, Antonio Capobianco, Nicolas Javahiraly, and Dan Curticapean. 2018. Towards Unobtrusive Obstacle Detection and Notification for VR. In *VRST 2018: 24th ACM Symposium on Virtual Reality Software and Technology (VRST '18), November 28-December 1, 2018, Tokyo, Japan.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3281505.3283391

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VRST '18, November 28-December 1, 2018, Tokyo, Japan

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ACM ISBN 978-1-4503-6086-9/18/11.
https://doi.org/10.1145/3281505.3283391

1 INTRODUCTION

VR systems with 6DOF tracking allow natural locomotion interfaces. These systems require a defined free-of-obstacles area and use visual cues to warn immersed users [5]. While static objects can be easily avoided, this is not so easy with objects that dynamically change their position (e.g. pets). Our work aims at detecting obstacles by an RGB-D sensor and signaling them in the VE. Prior to working on the detection of moving obstacles, it was necessary to evaluate which visual metaphors are suitable to provide a spatial understanding of the obstacles and to enable users to avoid them efficiently. Therefore, only stationary obstacles were used in this study.

2 RELATED WORK

Walking interfaces offer advantages in navigation of VE systems over other types of locomotion [6, 9, 12]. Real walking is a natural form of locomotion, resulting in higher presence than other types of locomotion [11] and reducing the probability of the occurrence of simulator sickness [1, 6]. Real walking locomotion interfaces are based on the acquisition of the user pose and are limited to tracked space, thus raising the problem that users may leave tracked space. Peck et. al. introduced "deterrents" that appeared when the users were close to the edge of tracked space. They used bars as visual cues and that the users were instructed to avoid [5]. The standard technique today is to display a visual cue when the user threatens to leave the previously defined empty and thus obstacle-free area. Scavarelli's et al. compared different collision-avoidance methods between co-located VR users, but didn't used real obstacles [7]. The Magic Barrier Tape by Cirio et al. is a hybrid collision-avoidance and navigation method. A tape represents the walking area and

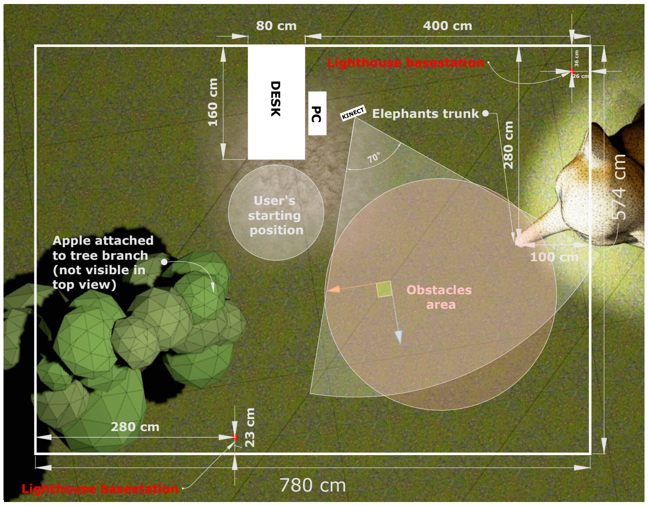

Figure 2: Room setup diagram

allows further navigation in VE [2, 3]. Simeone used a depth sensor to detect people, but did not provide a spatial visual representation within the VE [8]. Similar to Nescher et al. [4], Sra et al. used a depth sensor to 3D reconstruct the physical environment and detect the walkable area. Because this process needed to be performed in advance, the authors outlined the need for additional collision-avoidance methods and the lack of detection of moving obstacles. It was also pointed out that these methods should be evaluated in terms of how much they influence the feeling of presence [10].

3 EXPERIMENTAL PROTOCOL

The space for the experiment consisted of an area of 7.8x5.7 meters (tracking area 5x5 meters). To use the room size effectively and due to the maximum cable length of the HTC Vive of 5m (headset) + 1m (breakout box) the computer was positioned relatively centrally (see Figure 2). A Microsoft Kinect v2 was used to detect obstacles placed within a designated area. Four visual metaphors were introduced to signal obstacles in VE (Figure 1). The **Placeholder** metaphor displays any virtual object. We chose a tree as an unobtrusive representation. The **Arrow** metaphor is based on the principle of a compass pointing towards an obstacle. The **Rubber Band** metaphor floats around the virtual center of the body and deforms when close to an obstacle. It is inspired by the Magic Barrier Tape but offers no navigation [2]. The **Color Indicator** metaphor is a color-coded semitransparent fade-in tape. It first appears green at the position of an obstacle and turns orange and subsequently red when the distance decreases further.

20 participants (13 male, 7 female) aging from 21 to 57 (mean : 34.16, sd : 8.38) took part in the study. Invisible to the participants, two obstacles were placed in the room and detected by our system before the subject had to walk across the tracked area and to solve a simple task in VE. We paid attention for each metaphor if a user collided with an obstacle and determined the spatial understanding by asking participants to indicate the suspected location of the obstacles. Everybody was asked to give their subjective assessment, using a likert scale-based questionnaire.

4 RESULTS AND FUTURE WORK

Our results indicate that the metaphor has a significant influence on spatial comprehension ($\chi^2(3) = 39.88$, $p < 0.001$), presence ($\chi^2(3) = 13.237$, $p = 0.0041$) and subjective preference ($\chi^2(3) = 29.28$, $p < 0.001$). Pairwise comparisons show that Placeholder gets higher ratings than the other techniques for these 3 criteria (with all p-values < 0.05). The Placeholder metaphor is the most efficient and leads to a higher spatial understanding. Subjective evaluation indicate a strong preference of the subjects for this metaphor. Not only was it ranked as the preferred technique. It was also perceived as the most intuitive. It is not surprising that it is the technique with the lowest impact on presence. These results suggest that the subjective ratings of participants may be biased such that users rate the sense of presence higher than the ability of a metaphor to ensure security by attracting the user's attention. We plan to complete this first experiment with a follow-up study that will include the possibility of capturing moving objects in the environment and assessing the metaphor's ability to attract the attention of users when needed.

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