Evaluation of Guidance Systems in Public Infrastructures Using Eye Tracking in an Immersive Virtual Environment

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Abstract. In this paper we present a novel method to evaluate guidance systems and navigation solutions for public infrastructures based on an immersive virtual environment in combination with a mobile eye tracking system. It opens new opportunities for wayfinding studies in public infrastructures already during the planning phase. Our approach embeds an interface for natural locomotion in the virtual environment offering significant advantages related to the user's spatial perception as well as physical and cognitive demands. Accurate measurements of position, locomotion and gaze within the virtual environment enable a great simplification for the analysis of eye tracking data. We conducted a study with participants that included virtual and real world scenarios within a train station. First results exhibit similar behaviour of participants in the real and virtual environment, confirming the comparability and applicability of our method.

Keywords: Wayfinding, Immersive Virtual Environment, Eye Tracking, Gaze Analysis, Visual Attention.

1 Introduction

Public transport infrastructures are becoming more multi-functional by serving as a short or long distance transportation hub and, for instance, as a shopping mall at the same time. For passengers and visitors, the increasing complexity of such infrastructures can lead to disorientation or subjective uncertainties. These aspects need to be fully taken into account already in the planning phase to prevent wrong design decisions which might result in higher costs in case they have to be changed later. To this end, it is important to understand how people interact with their environment and how different visual information sources influence the orientation and navigation behaviour.

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For such questions, eye tracking has become a popular method to investigate human wayfinding and to gain insights into perception and processing of visual information. Research on wayfinding has been conducted within lab and field studies, which has provided evidence for comparable eye-movements in experimental and real world scenarios [2]. This study also revealed that the freedom of immersed participants to move their head and body is of high importance.

This paper presents our approach of combining an immersive virtual environment with an embedded interface for natural locomotion together with a mobile eye tracking system and demonstrates its applicability for wayfinding studies.

2 Immersive Virtual Environment

The immersive virtual environment DAVE [4], as shown in Figure 1, allows to efficiently perform wayfinding studies with enhanced comparability of the results due to controlling and reproducing the testing conditions (e.g. time, passers-by, train and bus schedule, etc.) for each participant. By extending the functionality of this test environment with a mobile eye tracking system from SMI, we are able to test different scenarios with alternating visual information within complex infrastructures.

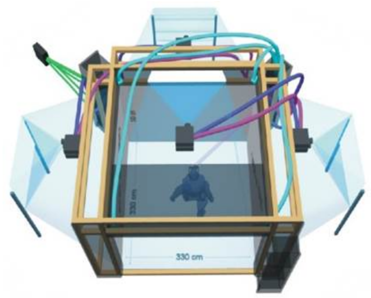

Fig. 1. The DAVE, a four-sided immersive stereoscopic projection environment.

Results in [7] show that body orientation and movement have a strong impact on the results of eye tracking studies in spatial navigation tasks. To enhance the awareness of movement and body perception within the virtual environment, it has been equipped with a Microsoft Kinect sensor for tracking the user's motion. The user has to walk in place to move forward and to turn the shoulders to invoke rotations in the virtual world. The outcome of [3] revealed the importance between head alignment and heading. In our observations, the head was consistently aligned with the current walking direction because the participants not only turned the shoulder but rather changed the complete body orientation into the walking direction.

In [6] a survey of empirical studies on the perception of egocentric distances in virtual environments is made and the egocentric distance is reported to be shorter with a mean about 74% of the modelled distances. The main influencing factors to facilitate a veridical spatial perception are binocular disparity, high quality graphics, a rich environment and an enhanced user's sense of presence. Of great importance is the participants' feeling of their own body in the virtual environment. These requirements are fulfilled by the immersive virtual environment DAVE.

The validity of our hands-free steering approach has been explored in [1] by conducting a case study with parallel test groups, exposing individuals to wayfinding exercises in the real world and the corresponding virtual world. The validation results showed that the perceived durations, egocentric distances and directions do not differ statistically significantly between the real and the virtual world.

Maybe the use of stereoscopic shutter glasses instead of head mounted devices providing the perception of the own body in the virtual scene, instead of a virtual avatar, provides an enhanced sense of presence and therefore a better metric in the virtual environment leading to better results in the estimation of egocentric distances and directions. But there is still much unknown about presence and a promising field for further research on spatial perception in virtual environments.

3 Analysis Method

Within the virtual environment DAVE all activities, movements and user interactions are recorded to be available for detailed analysis. Figure 2 shows a participant performing an experiment in the virtual environment as well as the corresponding eye tracking video indicating the gaze point with an orange circle.

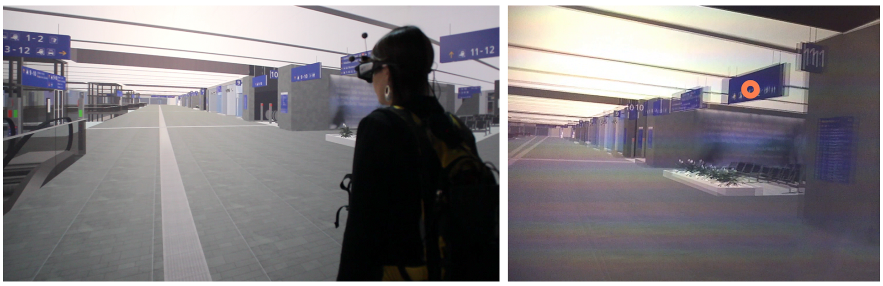

Fig. 2. Participant in the virtual environment (*left*) and the gaze point as an overlay in the eye tracking video (*right*).

Given the highly accurate data on position, body alignment and viewing direction of the participant in the virtual environment together with the gaze point from the eye tracking system, it is possible to compute the intersection between the viewing ray and the triangle mesh of the 3D model for each frame. The overall accuracy is a combination of the eye tracking glasses (according to the manufacturer: 0.5°) and the optical tracking. This enables to project an attention map onto the virtual 3D environment and furthermore to create saliency maps for visualizing the distribution of fixation in the environment as well as the amount of time one particular object was fixated. The aggregated intersections between the viewing rays of participants and the 3D mesh of the environment are shown in Figure 3.

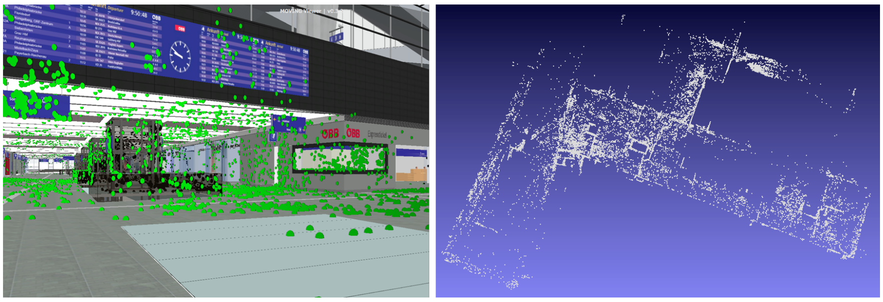

Fig. 3. Fixation points in the 3D model (*left*) and projected onto the ground plane (*right*).

The evaluations are carried out according to the three levels of metric from [5] which are defined as follows: *user task performance* (time required, distance travelled, number of wrong decisions), *physical behaviour* (characteristics of locomotion, looking around, shape of trajectory) and *decision making* (viewed objects and signs identified via attention maps, thinking aloud, interviews).

4 Findings and Outlook

The applicability of the method crucially relies on the similarity between the spatial perception in the virtual and in the real environment. In order to demonstrate the comparability and applicability of the method, we conducted a wayfinding study with two scenarios within the virtual and real world setting of the main train station in Vienna. We recruited different public transport users with specific demographic behaviour and experience. Each participant started on platform 12 and was assigned to walk first to the departure location of the tram line D (scenario 1) and afterwards to the location of the local bus line 13A (scenario 2). Both scenarios are aided wayfinding scenarios, classified after the taxonomy in [8], using external aids like signage and maps. Aided wayfinding using signs is considered to be rather simple since it does not require considerable cognitive effort from the user. Therefore it is important to provide all the relevant information at every decision point. Large public infrastructures such as the main train station in Vienna are very complex which makes the planning of the guidance system more difficult and error-prone.

The proposed method represents a new approach to support an effective evaluation of guidance systems in a goal oriented manner. The main advantage of this method lies in evaluating a multitude of different scenarios already in the planning phase avoiding costly mistakes. It greatly simplifies the data analysis, also reducing time and costs to reveal fixation, attention, saliency maps, objects of interest and route choices based on eye tracking measurements. Our approach provides a basis for an efficient evaluation of guidance systems and navigation solutions in public infrastructures and many additional application areas.

The analysis of the recorded data from the virtual and the real environment is still ongoing. First results of the field studies already exhibit similar critical areas within the real and virtual world where participants showed similar behaviour facing the same challenges like insufficient signposting or misunderstanding of signs. The final results will provide unique insights into task based visual attention and wayfinding behaviour and will reveal the full potential of the method.

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The study was performed using SMI Eye Tracking devices.

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