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Developing a VR tool for studying pedestrian movement and choice behavior

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ABSTRACT

This paper presents a new VR research tool to systemically study pedestrian movement and choice behavior. This new VR tool, called CivilEvac, features a complex multi-level building that is an exact copy of an existing building. CivilEvac allows participants to freely navigate through the building, records their movements and vision fields at 10 fps, which assist the analysis of pedestrian movement and choice behavior. By showcasing CivilEvac, this paper contributes an example of using VR experiments specifically developed to study pedestrian movement and choice behavior. Thereby adding to the discussion surrounding the usage of VR technologies for studying pedestrian behavior.

Keywords: Virtual reality, virtual environment, pedestrian behavior, wayfinding behavior, multi-story building.

Index Terms: Human-centered computing—Laboratory experiments; Human computer interaction—Virtual reality

1 INTRODUCTION

Different data collection methods have been used to investigate pedestrian behavior in buildings during the last decades. However, pedestrian movement and choice behavior in buildings are complicated and processual; the constraints of these traditional methods often fail to capture in detail all the behavioral data that shape pedestrian behavior. For instance, during field experiments, it is difficult to control external factors.

In order to collect detailed behavior data recording pedestrian movement and choice behavior, Virtual Reality (VR) has been more and more frequently used [1]–[3]. Advances in VR technologies present new opportunities with respect to full experimental control and automatic collection of behavioral data (e.g. route trajectory, orientation, locomotion) featuring all stages of the decision-making process.

This paper presents a VR tool, coined CivilEvac, that can be used to study pedestrian route and exit choice behavior in buildings. The design process of the VR tool and the VR experiment is detailed in this paper. Moreover, this paper showcases how to implement it in an experimental study featuring pedestrian movement and choice behavior. In doing so, we illustrate various possibilities to use this VR tool to collect pedestrian behavior data in complex buildings.

2 RELATED WORK

Historically, two dominant data collection methods have been used to study pedestrian behavior in buildings, namely field experiments and VR laboratory experiments.

Field experiments are the traditional method to study pedestrian route and exit behavior in real life both in normal and emergency conditions [e.g. 4, 5, 13, 14]. The major advantage is that pedestrians walk in a real-life environment and are most likely to behave naturally. However, in field experiments, the external variables are difficult to control. Furthermore, almost all studies have limited themselves to investigate pedestrian movement in the horizontal levels [5].

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Due to the limitations of field experiments, researchers have explored VR as an experimental technique to study pedestrian behavior. Using VR, it is possible to collect detailed behavioral data (e.g. route trajectory, locomotion, gaze points) in an immersive environment. For instance, Tang et al. [8] created a VR emergency escape game to determine if and how various emergency signs help pedestrian in route and exit choice. Van den Berg [9] developed a multi-player VR game to study the impact of herding on the evacuation choice behavior of pedestrians on event terrains, while Kinateder et al.[10], [11] used a 3D CAVE to investigate the effect of social influence on the route and exit choice during evacuations from a tunnel emergency. Kobes et al. [7] studied pedestrian exit and route choice behavior in a virtual and real hotel. However, studies featuring pedestrian route and exit choice behavior in complex buildings are still rare. Existing research predominantly studied simplified environments, mostly in a single level of a building.

3 METHODOLOGY

3.1 Experiment design

The building of CEG Faculty of the Delft University of Technology was chosen as the benchmark of the VE, which is a complex multi-level building. The experiment assignments features route choice across a combination of horizontal and vertical levels. Firstly, pedestrian route choice behavior at the horizontal level is investigated. Participants are asked to find their way from Room 4.02 to Room 4.99. Secondly, pedestrian exit choice behavior at the vertical level is investigated (Room 4.99 to Room 2.01). The third assignment investigates pedestrian route and exit choice in both horizontal and vertical level (Room 2.01 to Room 4.64). The forth assignment is to investigate pedestrian route and exit choice during evacuations (4.64 to an exit).

3.2 Developing of the VR tool

The process of modeling and building the virtual environment is as follows. First, the details of the existing building were logged by means of existing files, photographs and site visits. Afterwards, the building was modelled in 3D using the information featuring the characteristics of the building (Maya). The last step of the process was to translate the 3D model into a VR environment, including functions such as rendering, navigation, soundscapes and triggers (UE4).

3.3 Data collection method

The experiment makes use of two data collection methods. Firstly, participant's positions, head rotations, timestamp are recorded in milliseconds within the UE4. Thus, the system mainly collect four types of behavioral data: (1) travel trajectory and travel distance of the route (2) travel time (3) choice of staircase and exit (4) gaze points.

Secondly, a questionnaire is designed in order to obtain the personal features and experiences regarding the HMD device. The questionnaire contained six sections: (1) participant's information, (2) the face validity questionnaire, which assess the realism of the

VR environment, (3) the Simulation Sickness Questionnaire [12], which determine participant's sickness, (4) the System Usability Scale [13], which assess usability of the VR tool, (5) the Presence Questionnaire [14], which measure experience of presence in the VE, (6) wayfinding strategies, which measure what strategies participants use to find their way in the building.

3.4 Experiment apparatus

In this experiment, participants are immersed in the virtual environment via an HTC Vive HMD, and they use one hand controller to move in the VE. By holding the trackpad on the hand controller, participants can move forward. Meanwhile, the moving direction is controlled by their head orientation. Figure 1 shows one participant using the apparatus during the experiment.

Figure 1: One participant was experiencing the VR experiment

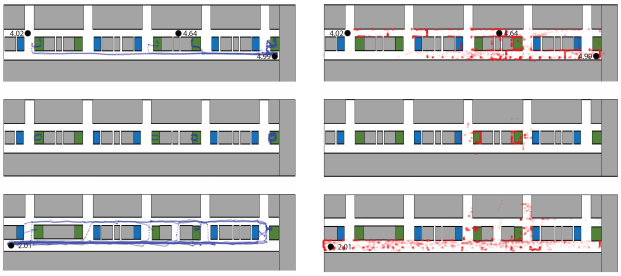
3.5 Experimental procedure

The procedure of the VR experiment included the following parts: 1) participants are introduced to the purpose of the experiment; 2) familiarize themselves with the HMD device; 3) conduct the official experiment; 4) fill in the questionnaire.

4 Findings

In total, sixteen participants joined the experiment: eight females and eight males with average age 28. None of the participants showed any signs of feeling uncomfortable or asked to stop during the experiment. In general, participants stated that the virtual environment was realistic and immersive. Meanwhile, they found the VR devices were easy to use.

The route trajectories were accurately recorded at 10 fps, which means we approximately obtained 5400 data points per participant describing their movements throughout the full experiment. With this data, we can analyze the route choice individually or collectively. Figure 2 (a) shows the aggregation of the trajectories of all participants during the second task. This illustrates that various participants make different choices with respect to their routes both in horizontal and vertical levels.



(a) route choice (b) gaze points

Figure 2: Visualizations of (a) all participants' route choice and (b) one participant's gaze points

While performing the task, participants kept searching for information for their destination. The collected gaze points data make it possible to analyze what objects or information in the virtual environment capture participants' attention. For instance, figure 2 (b) shows the overall gaze points of one participant during the tasks. Here, mainly the fire doors, staircase doors seemed to capture the attention of the participant, which are indicated by the red vertical lines across the main corridors and staircases.

5 Conclusion and Future Research

This paper presents a VR tool call CivilEvac, which is designed to investigate pedestrian movement and choice behavior in complex buildings. The VR tool supports free movement in all directions, collecting of pedestrian behavior throughout the whole virtual environment. The findings showcase the capabilities of CivilEvac using the results of a pilot study. This case study demonstrates that CivilEvac is able to accurately capture pedestrian choice and movement data, including positional data, rotations and time elapsed. Moreover, the results presented in this paper suggest that realistic walking and choice behavior can be captured by means of this tool.

In order to better understand pedestrian movement and choice behavior and validate this VR tool to study pedestrian behavior, the next steps in this research include conduct comprehensive large-scale experiments and analyze the results in detail.

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