Available online at www.sciencedirect.com
ScienceDirect
IFAC-PapersOnLine 49-19 (2016) 239–244

A Pedestrian Simulator for Urban Crossing Scenarios

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Abstract: In order to evaluate critical urban road crossing scenarios from the point of view of a pedestrian in a safe and reproducible manner, a setup for a pedestrian simulator – analog to a driving simulator – was elaborated using a head-mounted display, a motion capture system and a driving simulator software (for the virtual environment). This paper explains the motivation for such a simulator and delineates the integrated components. Further, a first small-scale study was conducted, delivering insights into the acceptance of the technical setup and the perception of the virtual environment, followed by a larger study evaluating the subjective immersiveness of the simulator using the Presence Questionnaire (PQ) in the case of a gap-acceptance study. The participants were asked to cross the virtual road on two different conditions: an easy and a difficult scenario, varying the density and velocity of passing vehicles. The comparison of the PQ scores of these two conditions revealed no significant difference neither regarding the total PQ score nor its factors, suggesting no influence of the traffic density/velocity on the user's immersive impression. The discussion provides a lookout for possible improvements regarding the setup and further studies.

Keywords: pedestrian simulator; pedestrian crossing; head-mounted display (HMD); motion capture; virtual reality (VR); Presence Questionnaire (PQ), simulator immersion.

1. MOTIVATION

Globally, the number of road users is still consistently rising. While safety measures in cars are being developed to reduce overall accident rates, the fatality of pedestrians is still considerably high, especially in urban environments. In 2013, 22% of fatalities in traffic accidents in Europe consisted of pedestrians. Furthermore, the fatality rate of pedestrians has decreased by only 11% since 2010 compared to the 17.5% decline of traffic participants overall (European Commission, 2015). The occurrence and trend of pedestrian fatalities in the US is somewhat comparable to those of the EU: 14% of all road users subject to a fatal accident were pedestrians in 2013 – a decrease of 9.1% compared to the 2010 statistic (National Center for Statistics and Analysis, 2015). The majority of these deaths occur in locations with higher population density: 69% of all pedestrian fatalities in the EU arise in urban areas, 73% in the US, respectively (European Commission, 2015; National Center for Statistics and Analysis, 2015).

This small introduction into traffic accident statistics underlines that pedestrians are one of the most vulnerable groups of road users in urban traffic. To understand the decision-making process and general pedestrian crossing behavior, previous studies used a variety of methods to generate data. These methods range from field studies (traffic observations, outdoor experiments, and footage analysis) (Koh & Wong, 2014; Sun, Zhuang, Wu, Zhao & Zhang, 2015) to road crossing reconstructions in safe environments (te Velde, van der Kamp, Barela, & Savelsbergh, 2005) up to devices where pedestrians are placed in a virtual traffic simulation.

These setups, often referred to as 'pedestrian simulators', vary in their technical realization. One of the preferred tools designed to visually display a scenario are projections of the virtual environment onto curved or angled surfaces (Feldstein, Lehsing, Dietrich, & Bengler, 2016). Being located within the surrounding screens offers users a high field of view (FOV). This setup can be used to evaluate crossing decisions and distance perception on a busy road (Oxley, Ihsen, Fildes, Charlton, & Day, 2005). Adding a treadmill to the setup enables an actual crossing of a virtual road (Mitobe, Suzuki, & Yoshimura, 2012) without limiting the possible longitudinal walking distance. However, the treadmill prohibits lateral movements and might induce a ramp-up and slow-down time – changing the dynamics of the crossing process. Walking by the projection screens sidewise offers free movement within the spatial limitations and still yields a high field of vision in the area of interest (Lobjois & Cavallo, 2009). As an alternative to projections and screens, head-mounted displays (HMD) offer an all-around view of the surrounding virtual environment and have also been used in previous setups regarding pedestrians in traffic scenarios (Simpson, Johnston, & Richardson, 2003; Maffei, Masullo, Sorrentino, & Di Gabriele, 2014). With the recent advances regarding displays, technical limitations – such as low resolution, motion blur and high latency – are constantly enhanced. Nevertheless, in order to enable the freedom of

10.1016/j.ifacol.2016.10.531

movement and the self-representation (using an avatar), additional complex expansions are necessary when using an HMD.

As part of the project presented below, a pedestrian simulator was developed that offers an immersive experience of different urban traffic situations, combining a head-mounted display, motion capturing of the user's body and a virtual environment as used in driving simulators. This setup enables a reproducible, safe and relatively cost efficient way to evaluate pedestrian behavior in urban environments. Furthermore, connecting the presented simulator to a driving simulator offers a possibility to research pedestrian-driver interaction in a virtual environment.

2. PROJECT ENVIRONMENT

The development of the pedestrian simulator was carried out within the scope of the German funded project UR:BAN (Urban Space: User oriented assistance systems and network management). The project thematic target area "Human Factors in Traffic" focuses on increasing traffic safety in urban areas (Manstetten et al., 2013). The sub-project "Simulation and Behavior Modeling" deals with the descriptive modeling of human behavior in urban traffic based on microscopic behaviour studies and therefore also with pedestrians. In order to enable studies on pedestrian behavior in specific traffic conflict situations as well as their interaction with other traffic participants (e.g. drivers), the decision was made to develop a pedestrian simulator for experiments with human participants. A specification for this development was the ability to connect the pedestrian simulator virtually to existing driving simulators investigating urban scenarios.

3. TECHNICAL SETUP

To meet the aforementioned requirements for reproducible pedestrian studies in urban areas, a new setup for a pedestrian simulator was created at the Technical University of Munich. Therefore, modifications on the approved driving simulator software, Silab, were undertaken in cooperation with its producer, the Würzburg Institute for Traffic Sciences. In a first step, a controllable pedestrian avatar was implemented in the software, making it possible to steer the avatar through the simulated environment using a keyboard (Fig. 1). This setup allowed for some first interaction attempts with the chair's driving simulator connected to the same network so that both road users met in the same simulation, solving occurring conflicts (Lehsing, Kracke, & Bengler, 2015).

After diverse pretests with the keyboard setup, the technical enhancement of the pedestrian simulator was pushed forward (Fig. 2). In order to obtain participants' real body movements and transform them into machine readable values, a motion tracking system was needed. Therefore, the visual marker-based infrared system Vicon was implemented. In order to allow the users to interact with the virtual environment, the real-time exchange of measured data is indispensable.

Fig. 1. First setup of the pedestrian simulator (keyboard edition).

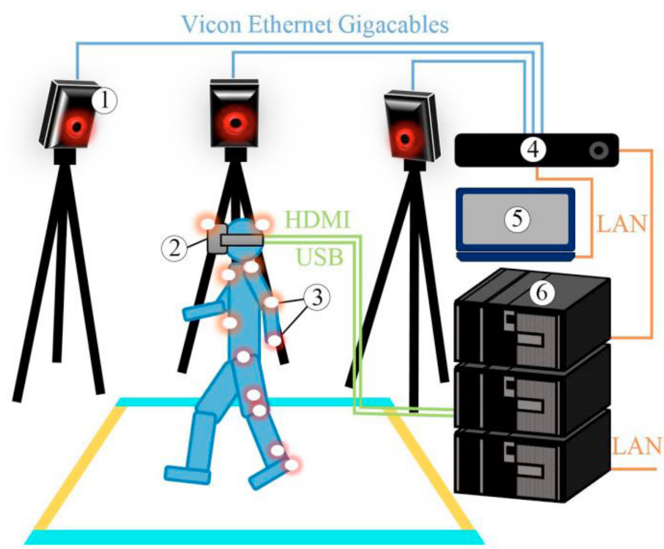

Fig. 2. Second setup of the pedestrian simulator (stage 2014): (1) Vicon camera, (2) Oculus Rift, (3) reflective marker, (4) Vicon Giganet, (5) notebook running Vicon Nexus, (6) control center.

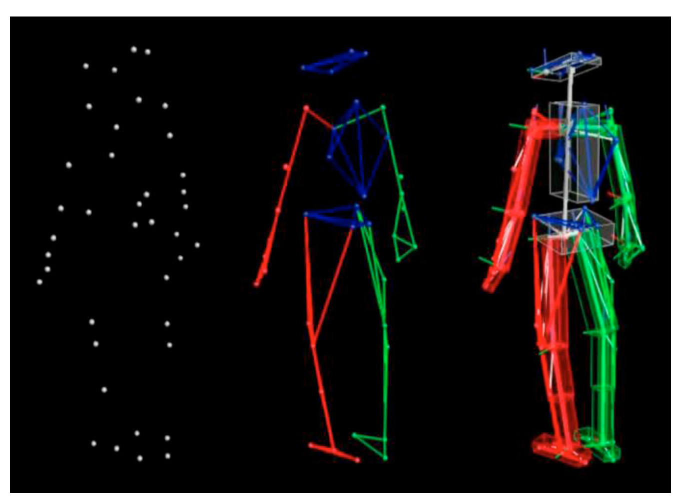

Fig. 3. Creation of the marker-based human model.