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Observation results on pedestrian-vehicle interactions at non-signalized intersections towards simulation

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ABSTRACT

The modelling and simulation of pedestrian-vehicle interactions is an open challenge for both research and practical computational solutions aiming at supporting urban/traffic decision makers and managers. The social cost of pedestrian-car accidents pushes the development of more effective and expressive computational models and simulation systems, integrating analytical knowledge, data and experience about pedestrian-vehicle interactions. The paper presents the results of a significant data gathering campaign focused on the considered phenomenon and aimed at supporting the extension and calibration of an existing model. A video-recorded naturalistic observation was executed in an area of the City of Milan (Italy) characterized by a significant presence of elderly inhabitants and by a high number of road accidents involving pedestrians in the past years. The achieved results include both macroscopic and microscopic indicators about pedestrian-vehicle interactions at the observed non-signalized intersection, with reference to: (i) traffic volumes; (ii) Level of Service; (iii) drivers compliance to pedestrians right of way on zebra crossing; (iv) age-driven pedestrian crossing behaviour, focusing on motor skills (speeds and trajectories) and decision making (accepted time gap to cross). Since elderlies represent one of the most vulnerable pedestrians in terms of road accidents, data analysis is focused on comparing results among two samples composed of adults and aged pedestrians. Results showed that crossing behaviour is characterized by three main phases: approaching, appraising (evaluation of the distance and speed of oncoming vehicles) and crossing. Moreover, results showed a significant difference in the crossing behaviour of adult and elderly pedestrians. The final objective of the research is to support the development of a microscopic agent-based tool for simulating pedestrian-vehicle interactions at non-signalized crosswalks.

1. Introduction

The role of computer-based systems for the simulation of vehicular traffic is a consolidated field of research and application that produced results whose level of maturity led to a significant impact on the activity of traffic engineers and planners in the design of efficient transportation networks (e.g., transportation planning, design and operations). Several successful models for the simulation of different aspects of vehicular traffic have been developed and applied: see Nagel,

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Wagner, and Woesler (2003) for a review of different approaches, which include both cellular automata discrete models (Wang & Ruskin, 2006) and continuous ones like car-following models (Kesting, Treiber, & Helbing, 2007).

In parallel, the micro-simulation of pedestrian dynamics have also emerged and affirmed as supports to the assessment of the level of comfort and safety of crowded facilities in case of both ordinary and emergency operations. Computer-based simulations allow, in fact, to properly assess pedestrian circulation dynamics in mass transit and gathering spaces, and to support the design and planning of crowded facilities (e.g., effective positioning of entry and exit points). In analogy with vehicular traffic, the simulation of pedestrian behaviour has been tackled by different approaches, considering both continuous models, such as the social force (Helbing & Molnar, 1995), and discrete ones based on the floor field method, such as cellular automata (Burstedde, Klauck, Schadschneider, & Zittartz, 2001).

Whereas separately the above mentioned simulation approaches have produced a significant impact, efforts characterized by an integrated investigation on the simultaneous presence of vehicular traffic and pedestrian dynamics are not as frequent or advanced as isolated vehicular traffic and pedestrian models. With the exception of Helbing, Jiang, and Treiber (2005) and Zeng, Chen, Nakamura, and Iryo-Asano (2014), most efforts in this direction are relatively recent or they just analyse simple scenarios not even validated against real data about human behaviour.

In general, computer-based simulations of pedestrian-vehicle interactions allow to import a digital representation of a determined transportation facility and to populate it with a certain number of heterogeneous agents, which navigate the environment according to a set of behavioural rules and individual goals/preferences. Then, a series of analyses on simulation results can be performed to evaluate key performance indicators in order to test the efficiency and safety of alternative spatial layouts. Of course, to finalize simulations into decisions and operational steps it is necessary to consider the crucial contribution of social science in the definition of theories and empirical methods to study pedestrian-vehicle interactions. This is aimed at defining descriptive sets of metrics and parameters for characterizing the phenomenon and at supporting the development of computational models against real data (i.e. *validation*).

The most consolidated methodology to empirically study pedestrian-vehicle interactions is represented by the execution of unobtrusive naturalistic observations at urban intersections (the execution of controlled experiments is limited indeed by practical and ethical issues). The Highway Capacity Manual (HCM, 2010), for example, presents a series of results achieved through the systematic observation of traffic networks, describing general design standards for enhancing the efficiency of transportation facilities and the safety of road users. Other studies highlighted the impact of traffic volumes and quality of infrastructures on drivers compliance with crossing pedestrians (Varhelyi, 1998), as well as on pedestrians crossing decisions (Perumal, 2014). Several contributions coming from traffic psychology and safety science showed that crossing behaviour is determined by locomotion capability (Sisiopiku & Akin, 2003), perceptive and attentional skills in evaluating the distance away and the speed of approaching vehicles (Hamed, 2001; Sun, Zhuang, Wu, Zhao, & Zhang, 2015) and individual attitude towards hazardous situations (Evans & Norman, 1998). In this framework, an innovative methodology is based on the possibility to use immersive virtual reality technologies (e.g., image-generation and projection system, virtual reality head-mounted displays) to systematically measure pedestrian/vehicle interactions in a controlled and safe environment (Cavallo et al., 2016; Dommes, Cavallo, Dubuisson, Tournier, & Vienne, 2014; Lehsing, Kracke, & Bengler, 2015).

All these research efforts are driven by the necessity to develop advanced transportation strategies and safe infrastructure to contrast the social costs of pedestrian-car accidents. As highlighted by World Health Organization (2015), road accidents represent the eighth leading cause of death in the world population: 1.2 million people are killed on roads every year. Despite recent efforts, the measures currently in place to reduce the phenomenon are mainly aimed at protecting car occupants. However, pedestrians are some of the most vulnerable road users, with a percentage of fatalities corresponding to 22% of the overall victims (26% in EU, 14% in USA).

Within vulnerable road users, we focused on the need to take into account the specific needs of elderly pedestrians. Aged pedestrians are indeed more likely to die or be seriously injured in road traffic collisions than adult people (Asher, Aresu, Falaschetti, & Mindell, 2012) due to: (i) locomotion limitations (Oxley, Fildes, Ihsen, Charlton, & Day, 1997; Winogrond, 1981) (e.g., reduced range of motion, loss of muscle strength and coordination, changes in posture, decreased walking speed) and (ii) perceptual-cognitive decline (Dommes, Cavallo, & Oxley, 2013; Lobjois & Cavallo, 2007; Webb & Weber, 2003) (e.g., limited perception of light and colours, inability to tune out background noise, diminished attention and reaction time, spatial disorientation, slower decision-making). Previous works on the analysis and characterisation of age-driven pedestrian behaviour (Gorrini, Vizzari, & Bandini, 2016) highlighted statistically significant differences between adult and elderly pedestrians, which might have an even greater importance within this context.

The rich and composite scenario depicted by the above considerations about pedestrian-vehicle interactions, led us to consider that additional empirical evidences could help the overall understanding of the phenomenon, and of the behavioural aspects of the involved stakeholders, towards the improvement of the results of initial experiences and explorations on its simulation. Earlier works on this line of research (Bandini et al., 2016; Crociani et al., 2014; Feliciani et al., 2017) represent, in fact, an attempt to define a baseline model, deliberately simplified, to evaluate its adequacy to reproduce the coordination between vehicles and pedestrians while, at the same time, successfully generate dynamics respecting stylized facts (e.g. increased pedestrian arrival rates reduce vehicular flow) and within plausible ranges when compared to empirical measurements available in the literature. Results of the present work represent a way to increase the expressiveness of such model and improve the quality of achieved simulation results.

Starting from these preliminary research efforts, the paper presents the results of an unobtrusive video-recorded observation focused on the direct interactions between crossing pedestrians and vehicles at a non-signalized intersection