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The Assessment of Pedestrian-Vehicle Conflicts at Crosswalks Considering Sudden Pedestrian Speed Change Events

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Introduction

Pedestrians are vulnerable road users. In Japan, more than one-third of the fatalities in traffic crashes are pedestrians and most accidents occur as the pedestrians cross a road. To evaluate alternative countermeasures effectively, recently traffic simulation is considered as one of the powerful decision support tools (Shahdah et al. 2015). A very important requirement for a reliable utilization of traffic simulations for the safety assessments is the proper representation of road user behaviors at potential conflict areas. Severe conflicts usually occur when road users fail to predict other users' decisions and properly react to it. The widely varying behaviors and maneuvers of vehicles and pedestrians may lead to misunderstanding their decisions, which can result in severe conflicts. So far, most existing studies assume constant walk speeds for pedestrians and complete obedience to traffic rules when crossing roads as if they are at walkways. However, it is known that pedestrian behave differently at crosswalks compared to other walking facilities such as sidewalks and walkways. Pedestrians tend to walk faster at crosswalks (Montufar et al. 2007). Furthermore, their compliance to traffic signals vary by traffic conditions and other factors (Wang et al. 2011). Although many studies have analyzed pedestrian behavior including speed at crosswalks, most of them are based on the average crossing speed without considering the speed profile of the crossing process and the variations within. Iryo-Asano et al. (2015) observed from empirical data that pedestrians may suddenly and significantly change their speed on crosswalks as a reaction to surrounding conditions. Such speed changes cannot be predicted by drivers, which can lead to safety hazards. A study of the speed change maneuvers is critical for representing the potential collisions in the simulation systems and evaluating the probability and severity of collisions reasonably. The objective of this study is to quantitatively model the pedestrian speed change maneuvers and integrate the model into traffic simulation for assessing traffic safety.

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Pedestrian speed change events as critical maneuver

Figure 1 shows an observed pedestrian trajectory with sudden speed change. If there is a turning vehicle approaching the conflict area, the driver may behave based on his expectation of pedestrian arrival time to the conflict area. If the pedestrian suddenly changes his/her speed close to the conflict area, drivers will not be able to predict the new arrival time, which might lead to severe conflicts. Figure 1 demonstrates a real observed example of such speed change. The pedestrian suddenly increased his speed at the beginning of the conflict area, which yielded to the early arrival to the conflict area by 2.0 seconds (Tdif) than expected time assuming that the pedestrian will continue with his/her speed. A turning vehicle cannot predict this early arrival if it exists at the same time. Furthermore, these 2 seconds are large in terms of collision avoidance Iryo-Asano et al. (2015) showed that timings and locations of pedestrians speed changes mainly occur 1) at the entrance to the pedestrian-vehicle conflict area and 2) when there is a large gap between pedestrian's current speed and his/her necessary speed to complete crossing before the end of pedestrian flashing green interval. In this study, further in-depth analysis is conducted by combining the pedestrian data and the information of approaching vehicle trajectories to identify the influencing factors on pedestrians' sudden speed change events. The probability of speed change is quantitatively modeled as functions of the remaining green time, the remaining length to cross, the current walking speed and other related variables.

Simulation integration for safety assessment

The proposed pedestrian maneuver model is implemented into an integrated simulation model by combining it with a comprehensive turning vehicle maneuver model (Dang et al. 2012). The vehicle maneuver model is dedicated to represent probabilistic nature of drivers' reaction to road geometry and surrounding road users in order to evaluate user behavior upon traffic safety. It produces speed profiles of turning vehicles considering the impacts of geometry (i.e. intersection angles, setback distance of the crosswalks) and the gap between the expected arrival time of the vehicle and that of the pedestrians at the conflict area. The proposed model allows us to study the dependencies and the interactions between pedestrians and turning vehicle s at crosswalks. Using the integrated traffic simulation, pedestrian-vehicle conflicts are generated and surrogate safety measures, such as Post Encroachment Time and the vehicle speeds at conflict points, are estimated. These measures are used to evaluate the probability and severity of pedestrian-vehicle conflicts. To verify the characteristics of the simulated conflicts, estimated and observed surrogate safety measures at a selected signalized crosswalk are compared through statistical tests.

Conclusions

The consideration of sudden speed change behavior of pedestrians in the simulation environment generates more reliable and realistic pedestrian maneuvers and turning vehicle trajectories, which enables more accurate assessment of pedestrian-vehicle conflicts. This enables the assessment of improvements in the signal control settings and the geometric layout of crosswalks towards safer and more efficient operations. Furthermore, the model is useful for the real-time hazardous conflict event detection, which can be applied to the vehicle safety assistance systems.

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