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DDDAS-BASED MULTI-SCALE FRAMEWORK FOR PEDESTRIAN BEHAVIOR MODELING AND INTERACTIONS WITH DRIVERS

Hui Xi

Systems and Industrial Engineering
The University of Arizona
Tucson, AZ 85721, USA

ABSTRACT

A multi-scale simulation framework is proposed to analyze pedestrian delays at signalized crosswalks in large urban areas under different conditions. An aggregated-level model runs in normal conditions, where each crosswalk is represented as an agent. A derived probability function extended from Adams' model is utilized to estimate an average pedestrian delay with corresponding traffic flow rate and traffic light control at each crosswalk. When an abnormality is detected, a detailed-level model with each pedestrian being an agent is executed in the affected subareas. Pedestrian decision-making under abnormal conditions, physical movement, and crowd congestion are explicitly considered in the detailed-level model. In addition, pedestrian-driver interactions under unsignalized condition such as midblock crossing have been modeled as a two-player Pareto game. By mimicking cognitive decision making processes of drivers and pedestrians, we intend to identify the significant variables that help improve comfort and convenience as well as safety of pedestrian crossing.

1 INTRODUCTION

A multi-scale simulation framework is proposed to analyze pedestrian delays at signalized crosswalks in large urban areas under different conditions involving a rich set of human characteristics (e.g. pedestrian types, goal of trip, destination, and group behaviors) and environmental attributes (e.g. dynamically changing traffic control signal and right-turn traffic flow rate). The aggregated-level model runs in normal conditions, where each crosswalk is represented as an agent. Pedestrian counts collected near crosswalks are utilized to derive the binary choice probability from a utility maximization model. The obtained probability provides an insight into pedestrians' choice between waiting for the next green light and changing direction when they run into a red phase at crosswalks. A probability density function extended from Adams' model (Adams 1936) is utilized to estimate an average pedestrian delay with corresponding traffic flow rate and traffic light control at each crosswalk (Xi and Son 2012(b)). When an abnormality (e.g. closure of an area by police) is detected, the detailed-level model with each pedestrian as an agent is running in the affected areas. The detailed-level model contains two sublevels: the tactical sublevel for pedestrian route choice and the operational sublevel for pedestrian physical interactions. The tactical sublevel is based on Extended Decision Field Theory (EDFT) (Busemeyer and Townsend 1993) to represent the psychological preferences of pedestrians with respect to different route choice options during their deliberation process after evaluating current surroundings. At the operational sublevel, physical interactions among pedestrians and consequent congestions are represented using a Cellular Automata model, in which pedestrians are allowed biased random-walking without back step towards their destination that has been given by the tactical sublevel (Xi and Son 2012(a)). Dynamic-Data-Driven Application Systems (DDDAS) (Celik, Lee, Vasudevan, and Son 2010) (architecture has been integrated with the proposed

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multi-scale simulation framework for an abnormality detection and appropriate fidelity selection (between the aggregated level and the detailed level) during the simulation execution process. Various experiments have been conducted under varying conditions with the scenario of a Chicago Loop area to demonstrate the advantage of the proposed framework, balancing between computational efficiency and model accuracy. For example, we have compared the pedestrian delay values obtained from both the aggregated level as well as the detailed level. The results have revealed that with a static low pedestrian volume, there is no significant difference between delays obtained from both levels. However, a high pedestrian volume involving dynamic changes has resulted in significant differences between delays from two levels. In addition, the correlation analysis has been performed among delays in the restricted crosswalks and those in their neighbors (from closer ones to further ones). To the best of our knowledge, this is the first research work on the development of simulation framework that can estimate pedestrian delays in an urban area and adaptively zoom in to individual crosswalks.

In addition to the signalized intersections, pedestrian crossing behavior under unsignalized conditions has also been analyzed. As a major scenario of pedestrian-vehicle crashes, pedestrians' interactions with drivers during mid-block crossing are modeled as a two-player Pareto game. Both players, the pedestrian with crossing attempt and the driver of the oncoming vehicle, play mix strategies. By observing the current environment and estimating each other's strategy, the two players evaluate the strategies from two aspects: delay and risk. The obtained strategy value matrix is provided to the EDFTwhich gives the choice probability of each strategy. For pedestrians whose goal is to complete crossing in an acceptable gap, their decision variables include their own capability (*C*) (e.g. maximum walking speed), value of time (*V*) (e.g. trip purpose and schedule) and environment setting of the specific situation (*E*) (e.g. distance to the oncoming vehicle and width of the road). After the evaluation process, pedestrians have to choose one of the three strategies: accept the gap and cross to a refuge, accept the gap and cross the road, or reject the gap. For drivers, the scenario of interacting with pedestrians at a midblock is analogous to the scenario of driving straight on yellow light (FHWA 2006), because they have options to proceed or to stop depending on the detection time and distance to the intersection/pedestrian. Besides, drivers' behavior is constrained by their vehicles' physical condition, such as maximum deceleration rate, current speed, and vehicle length. Considering all these parameters, drivers also have to choose one from the three strategies: proceed, brake aggressively from a short distance, or brake comfortably from a long distance. By varying the parameter settings, we are able to analyze behaviors of different types of pedestrians and drivers as well as their interactions. For instance, we have tested the impact of drivers' attention allocation on their yielding behavior. In addition, the relationship between pedestrian gap acceptance and the risk of crossing has been demonstrated as well. The analysis results help identify the significant variables that may improve comfort and convenience as well as safety of pedestrian crossing.

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