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Modeling Driving Distraction Considering Psychological-Physical Constraints

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Abstract : Modeling driving distraction in microscopic traffic simulation is crucial for enhancing simulation accuracy. Current driving distraction models are mainly derived from physical motion constraints under distracted states, in which distraction-related error terms are added to existing microscopic driver models. However, the model accuracy is not very satisfying, due to a lack of modeling the cognitive mechanism underlying the distraction. This study models driving distraction based on the Queueing Network Human Processor model (QN-MHP). This study utilizes the queuing structure of the model to perform task invocation and switching for distracted operation and control of the vehicle under driver distraction. Based on the assumption of the QN-MHP model about the cognitive sub-network, server F is a structural bottleneck. The latter information must wait for the previous information to leave server F before it can be processed in server F. Therefore, the waiting time for task switching needs to be calculated. Since the QN-MHP model has different information processing paths for auditory information and visual information, this study divides driving distraction into two types: auditory distraction and visual distraction. For visual distraction, both the visual distraction task and the driving task need to go through the visual perception sub-network, and the stimuli of the two are asynchronous, which is called stimulus on asynchrony (SOA), so when calculating the waiting time for switching tasks, it is necessary to consider it. In the case of auditory distraction, the auditory distraction task and the driving task do not need to compete for the server resources of the perceptual sub-network, and their stimuli can be synchronized without considering the time difference in receiving the stimuli. According to the Theory of Planned Behavior for drivers (TPB), this study uses risk entropy as the decision criterion for driver task switching. A logistic regression model is used with risk entropy as the independent variable to determine whether the driver performs a distraction task, to explain the relationship between perceived risk and distraction. Furthermore, to model a driver's perception characteristics, a neurophysiological model of visual distraction tasks is incorporated into the QN-MHP, and executes the classical Intelligent Driver Model. The proposed driving distraction model integrates the psychological cognitive process of a driver with the physical motion characteristics, resulting in both high accuracy and interpretability. This paper uses 773 segments of distracted car-following in Shanghai Naturalistic Driving Study data (SH-NDS) to classify the patterns of distracted behavior on different road facilities and obtains three types of distraction patterns: numbness, delay, and aggressiveness. The model was calibrated and verified by simulation. The results indicate that the model can effectively simulate the distracted car-following behavior of different patterns on various roadway facilities, and its performance is better than the traditional IDM model with distraction-related error terms. The proposed model overcomes the limitations of physical-constraints-based models in replicating dangerous driving behaviors, and internal characteristics of an individual. Moreover, the model is demonstrated to effectively generate more dangerous distracted driving scenarios, which can be used to construct high-value automated driving test scenarios.

Keywords : computational cognitive model, driving distraction, microscopic traffic simulation, psychological-physical constraints
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