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"Technical Research and Development for Road Policy Quality Improvement" Study Summary

No.	Title	Principal Researcher
No.24-6	Development of a Microscopic Traffic Simulator for Assessing Safety Improvement Strategies at Signalized Intersections	Prof. Hideki Nakamura Nagoya University

This study developed a microscopic traffic simulator which can represent stochastic behavior of vehicles and pedestrians based on empirical models of their paths, speeds and reactions to the traffic lights and other road users considering the impact of geometric design as well as signal control policy. By using the simulation output, temporal and spatial distribution of conflict risk inside an intersection space became possible to obtain and to use for assessing safety improvement strategies prior to their implementation.

1. Background and Objectives

This research focuses on the stochastic behavior of road users at signalized intersections (e.g., path and speed choice, reaction to traffic lights, etc.), which would be strongly related to collision, by considering the impact of intersection geometry, signal control, and so forth. The objective of this study is to develop a microscopic traffic simulator for quantitatively assessing safety improvement strategies through modifications of geometric design and/or signal timing and prior to their implementation by representing the sensitivity of road users to them.

2. Contents of the Research

(1) Video surveys at signalized intersections and data processing
(2) Analysis and modeling of left-turn vehicle behavior (speed, trajectory and reaction to pedestrians)
(3) Analysis and modeling of right-turn vehicle behavior (speed, trajectory, stop/go decision, start-up at the onset of protected right-turn phase, and gap acceptance to opposing through traffics during permissive phase)
(4) Analysis and modeling of pedestrian behavior at crosswalks (crossing speed, path, stop/go decision at the onset of pedestrian flashing green phase, reaction to other pedestrians and change of traffic lights, etc.)
(5) Development of traffic simulator and visualization of the output for the safety assessment
(6) Study on surrogate safety measures (SSMs) and case study using the developed traffic simulator

3. Study Results

(1) Video surveys were carried out at twelve signalized intersections, and the position and timing of individual vehicles and pedestrians were extracted from the recorded videos by using an image processing software.
(2) With regards to left-turn vehicle behavior, (i) speed profile inside an intersection space was modeled as a function of entering speed and crossing angle, (ii) turning path was approximated by three types of segment (i.e., straight lines, circular curves and clothoid spirals) and estimated by intersection design as well as entering and exiting speeds, and (iii) reaction to crossing pedestrian was estimated by incorporating lag/gap acceptance model.
(3) With regards to right-turn vehicle behavior, (i) turning path (Fig.1) and speed-profile were modeled by the similar method with left-turn vehicles, (ii) the probability that drivers stop at the onset of yellow after protected right-turn phase was modeled as a function of the time needed to reach the stop line with constant speed and setback distance of the stop line, (iii) start-up response time was estimated considering vehicle type, intersection design and red clearance intervals, and (iv) gap acceptance to the opposing through and left-turn traffic was explained by gap size and cumulative waiting time of the subjective right-turn vehicle.

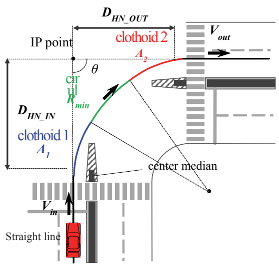

Fig.1 Right-turn trajectory model

(4) With respect to pedestrian behavior, (i) crossing path and average speed were modeled by assuming that pedestrians change their walking direction only at the beginning, the middle and the end of a crosswalk and follow the shortest-distance path between them, (ii) the probability that pedestrians stop at the onset of pedestrian flushing green phase was modeled as a function of distance to the crosswalk edge and walking speed, (iii) microscopic pedestrian behavior considering the reaction to other pedestrians, change of traffic lights, and so on were represented by applying the social force model (Fig.2).

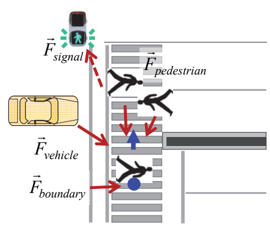

Fig.2 Social force model for pedestrian behavior

(5) The two-dimensional microscopic traffic simulator was developed by integrating all the empirical models established in (2)~(4) (Fig.3). The

simulated output was validated against the observed data. In addition, temporal and spatial distributions of conflict risk were visualized by computing the surrogate safety measures from the simulation output.

(6) Applicability of various surrogate safety measures in the previous studies were examined with the purpose of evaluating “safety at intersections” through analyzing the relationship with the accident records.

(7) A case study demonstrated the impact of intersection angle on the safety performance focusing on pedestrian versus left-turn vehicle conflict.

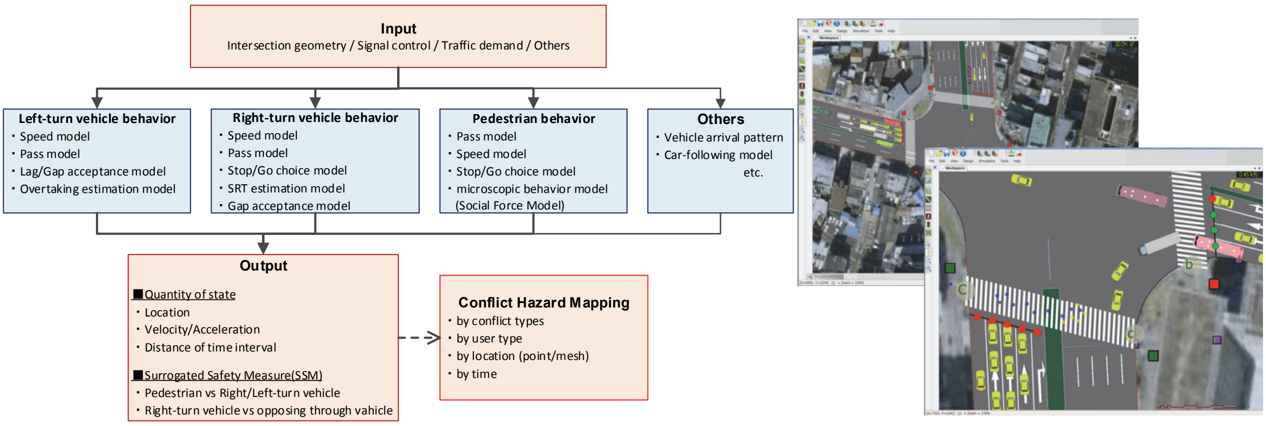

Fig.3 A framework of the developed simulator (left) and snapshots of the simulation display (right)

4. Publications (major ones only)

1) Chen, P., **Nakamura, H.**, Asano, M. and Zeng, W.: A Microscopic Traffic Simulation Model for Safety Assessment of Left-turning Vehicle versus Pedestrian Conflict at Signalized Intersections, Proceedings of Infrastructure Planning, No.47, 8 pages, 2013.

2) Ito, H. and Suzuki, K. Analysis on the Relationship between the Risk of Pedestrian versus Left-turn Vehicle Conflict and Intersection Geometry, Proceedings of Infrastructure Planning, Japan Society of Civil Engineers, No.47, 6 pages, 2013. (in Japanese)

3) Zhang, X., Chen, P., **Nakamura, H.** and Asano, M.: Modeling Pedestrian Walking Speed at Signalized Crosswalks Considering Crosswalk Length and Signal Timing, Proceedings of the 10th International Conference of the Eastern Asia Society for Transportation Studies, 15 pages, Taipei, Taiwan, 2013.

4) Chen, P., **Nakamura, H.** and Asano, M.: Application of surrogate safety measures for assessment of pedestrian versus left-turning vehicle conflict at signalized crosswalks, Advances in Transportation Studies, Vol. 1, Special Issue, pp.37-50, 2014.

5) Zeng, W., Chen, P., **Nakamura, H.** and Asano, M.: Application of social force model to pedestrian behavior analysis at signalized crosswalk, Transportation Research Part C: Emerging Technologies, Vol.40, pp.143-159, 2014.

6) Watanabe, K., **Nakamura, H**. and Iryo-Asano, M.: Analysis of Right-turn Vehicle Behavior in Protected Right-turn Phase for Planning Signalized Intersection Improvement, Journal of the Japan Society of Civil Engineers D3(Infrastructure Planning and Management), Vol.70, No.5, I_1013-I_1022, 2014. (in Japanese)

7) Zhang, X., **Nakamura, H**. Iryo-Asano, M and Chen, P: Modeling Pedestrian Speed at Signalized Crosswalks Considering Crosswalk Length and Pedestrian Signal Timing, Journal of the Japan Society of Civil Engineers D3(Infrastructure Planning and Management), Vol.70, No.5, I_1031-I_1040, 2014. (in Japanese)

5. Study Development and Future Issues

Applicability of the study results

・Geometric design and operational control policies of signalized intersections became possible to quantitatively assess for the purpose of safety improvement,

・Applicability and drawbacks of the developed simulator can be further investigated by using it for estimating the safety performance of an actual intersection before and after implementing the safety improvement strategy.

Future works

・Further study on the appropriate surrogate safety measures and their incorporation into the simulation output,

・Development and integration of the empirical models missing in the current simulator (e.g., cyclist behavior, motorcyclists, users with some specific characteristics such as elderly people, etc.),

・Expansion of the applicable intersection design (e.g., three-leg intersection) and control type (e.g., unsignalized stop-controlled intersection or roundabout) in the developed simulator.

6. Contribution to the Quality Improvement of Road Policy

・The results of the empirical analysis and the case study give a significant consideration to the design and operational policies of signalized intersections particularly from the viewpoint of safety,

・The developed simulator enables to assess safety improvement strategies more efficiently without collecting the accident records for a long period,

・The developed simulator may be useful for getting consensus of local authorities and citizens by providing some visualized images of the expected traffic situation after implementing the strategy.

7. References, Websites, etc.

・Website of H. Nakamura Lab., Nagoya University: http://www.genv.nagoya-u.ac.jp/ge1/nakamura/research/index-en.html