Concurrent Prediction of Location, Velocity and Acceleration Profiles for Left Turning Vehicles at Signalized Intersections

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Introduction

Microscopic simulation based methods provide a promising approach to evaluate conflicts between turning vehicles and road crossing pedestrians or cyclists. In order to enhance the reliability of such microscopic simulation models, characteristics of turning vehicle trajectories should be realistically captured. In this study, a method that is based on ***Minimum-Jerk Theory*** is explored to model left turning vehicle trajectories at signalized intersections.

Modelling approach

*Minimum-jerk theory by **Flash and Hogan (1985)**:*
When moving a hand to an initial position to a final position within a given time duration t_f the cost to be minimized in order to maximize the smoothness of the trajectory is:

$$J = \frac{1}{2}\int_0^{t_f}\left(\left(\frac{d^3x}{dt^3}\right)^2 + \left(\frac{d^3y}{dt^3}\right)^2\right)dt$$

Solution (*Flash and Hogan 1985*):

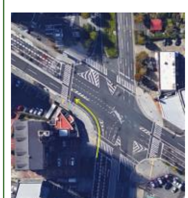
$$x(t) = a_0 + a_1 t + a_2 t^2 + a_3 t^3 + a_4 t^4 + a_5 t^5$$
$$y(t) = b_0 + b_1 t + b_2 t^2 + b_3 t^3 + b_4 t^4 + b_5 t^5$$

Where; a_j and b_j ($j = \{0,\ldots, 5\}$) are constants

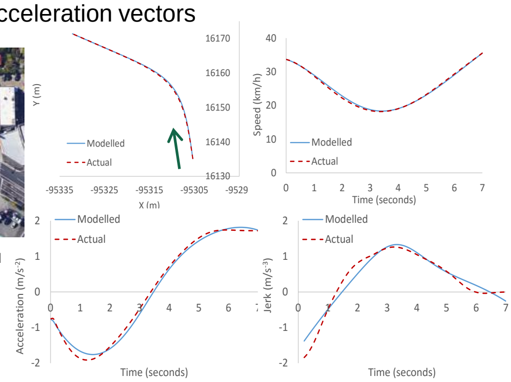
This system of equations can be solved with 12 boundary conditions.

Estimating trajectories with complete information

Model inputs: Movement time (t_f), initial and final location, speed and acceleration vectors



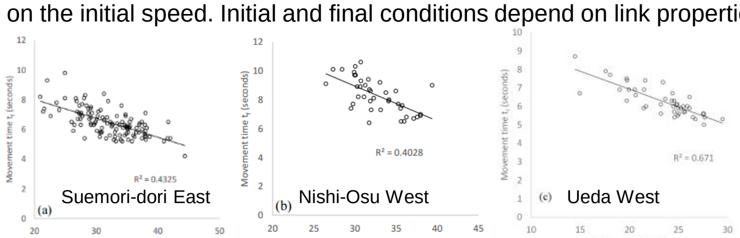
Ueda Ipponmatsu intersection



Trajectories are accurately predicted when boundary conditions and t_f are known
→ Free-flow turning maneuvers are actually smooth (or jerk-minimized)

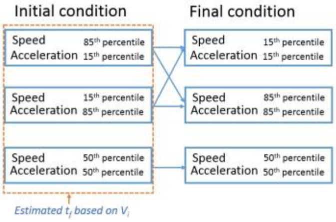
Variation of turning trajectories

Generally, t_f and exit conditions are unknown. The value of t_f primarily depends on the initial speed. Initial and final conditions depend on link properties.

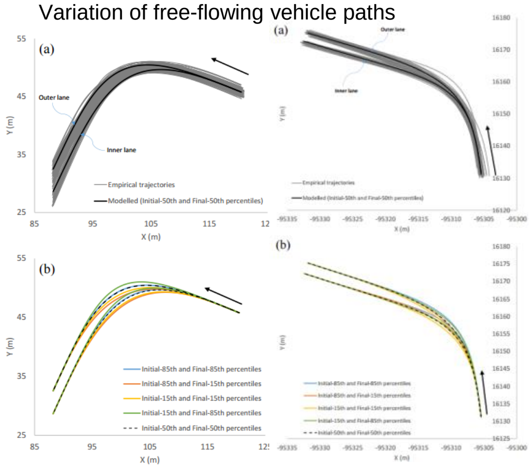


Suemori Dori 2 intersection

Combinations of initial and final conditions as model inputs to check the trajectory variations

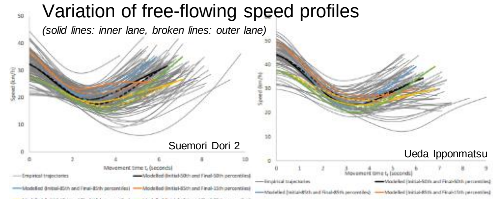


Variation of free-flowing vehicle paths

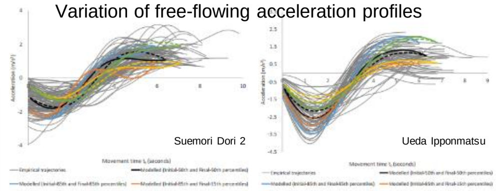


Suemori Dori 2 intersection   Ueda Ipponmatsu intersection

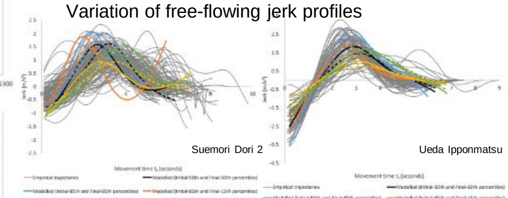
Variation of free-flowing speed profiles
(solid lines: inner lane, broken lines: outer lane)



Variation of free-flowing acceleration profiles



Variation of free-flowing jerk profiles



→ Modelled profiles are within the range of observed profiles
→ Minimum-jerk theory provides a promising platform for modelling trajectories of turning vehicles at signalized intersections