Modeling the Trajectories and Trajectory Variation of Left-Turning Vehicles at Signalized Intersections

信号交差点における左折車両の走行軌跡およびそのばらつきのモデリング

東京大学 生産技術研究所 **大口研究室**（交通工学）C. Dias, M. Iryo, M. Abdullah, T. Oguchi
http://www.transport.iis.u-tokyo.ac.jp/

Introduction

Information regarding trajectories of turning vehicles at signalized intersections can be used in many applications such as in microscopic simulation tools developed for safety evaluations, motion planning of autonomous vehicles, and visualization of realistic vehicle movements in driving simulator applications. However, a proper framework to realistically model and estimate trajectories of turning vehicles is currently unavailable. This study explores the applicability of the minimum jerk concept, which has been applied in neuroscience and robotics domains, to model free-flow trajectories of turning vehicles.

Modelling approach

(1) Minimum-jerk concept by ***Flash and Hogan (1985)****:*
When moving a hand to an initial position to a final position within a given time duration t_f , and 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*):

$$x(t) = a_0 + a_1t + a_2t^2 + a_3t^3 + a_4t^4 + a_5t^5$$
$$y(t) = b_0 + b_1t + b_2t^2 + b_3t^3 + b_4t^4 + b_5t^5$$

Where; a_j and b_j (j = {0,…, 5} are constants

This system of equations can be solved with 12 boundary conditions.
→ Location, velocity and acceleration vectors at the initial and final positions can provide 12 boundary conditions. However, t_f is an unknown.

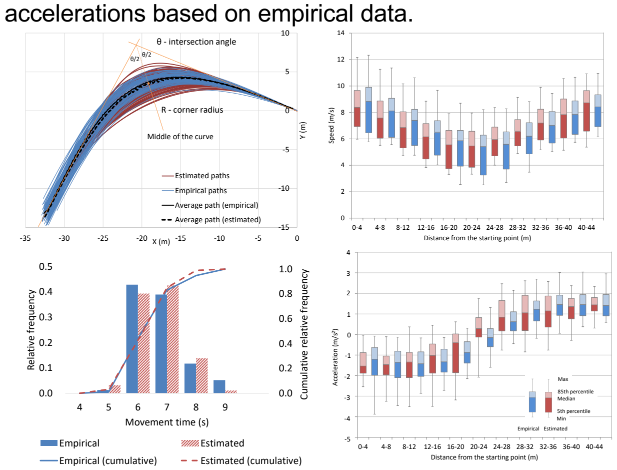
→ Incorporating Minimum speed and location of minimum speed models by Wolfermann et al. (2011) in minimum-jerk solution, an estimate for t_f can be obtained.

(2) Minimum speed (v_{min}) and location of minimum speed (s_{min}) models by ***Wolfermann et al. (2011)****:*

Normal Distribution	Parameters	v_{min} N(μ, σ)	s_{min} N(μ, σ)
μ	Constant	-0.301	1.42
	Entering speed (m/s)	0.0908	-
	Corner radius (m)	0.0607	0.586
	Intersection angle (deg)	0.0387	0.0896
	Lateral exit distance (m)	0.233	0.577
	Heavy vehicle dummy (HV: 1, PC: 0)	-0.496	-
σ	Constant	0.665	0.135
	Corner radius (m)	-	0.144
	Lateral exit distance (m)	0.0419	0.336

Model verification

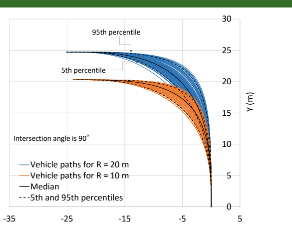
A Monte Carlo simulation with 100 different random seeds was conducted by randomizing entry and exit speeds and accelerations based on empirical data.



»Estimates and observations are well matched

Fig. 1. Comparison of estimated and empirical movement times and trajectories (Suemori-Dori intersection)

Sensitivity analysis



»The larger the curve radius the larger the variation of paths, speed and acceleration profiles

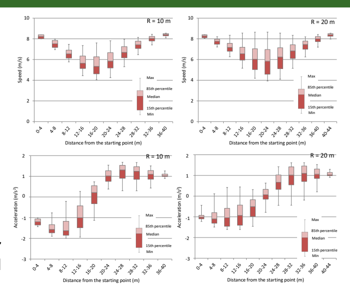
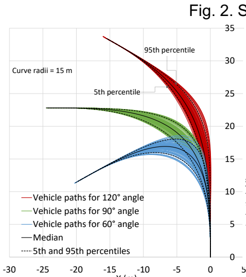
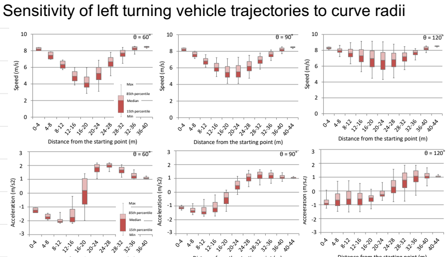


Fig. 2. Sensitivity of left turning vehicle trajectories to curve radii





»The larger the intersection angle the smaller the variation of paths, but larger the variation of speeds and accelerations

Fig. 3. Sensitivity of left turning vehicle trajectories to intersection angle

Conclusions

- ✓ The proposed approach, which is based on minimum-jerk concept, can reproduce free-flow turning trajectories with a good accuracy.
- ✓ Effects of geometric features (curve radii, intersection angle) on trajectories are also realistically captured.