

Calibration of car-following model of microsimulation by using Zen Traffic Data

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1. Introduction

Microsimulation is an important tool to evaluate road traffic safety and the effect of transportation policies. To simulate real traffic flows accurately, it is necessary to use field observed data to calibrate the car following model of microsimulation. The Next Generation Simulation (NGSIM) data provided by the U.S. Federal Highway Administration since 2006 is one of the most popular datasets for microsimulation. However, the NGSIM data cannot reflect traffic flows in Japanese highways. Recently, the field observed trajectory data, Zen Traffic Data (ZTD), has been provided by Hanshin Expressway Co. Ltd, Japan. In this study, the vehicle trajectory data of ZTD is utilized to calibrate a car-following model for microsimulation.

2. Data description

The ZTD contains trajectory data developed from the image sensing technology and the loop detectors. The dataset provides vehicle position and speed at every 0.1s with the vehicle length and type. The dataset was collected at two different sites: I) Route 11, Ikeda Line (bound for Osaka), with five different time periods in September 2018; II) Route 4, Wangan line (bound for Osaka), with five different time periods in 2017.

The data from site-I is utilized in this study. This site is 2-km expressway with two lanes. There is a S-shaped curve and an on-ramp entrance at 3.8 kilometer-post (kp). Lane changing is prohibited from 4.2 to 3.5kp. The speed limit is 60 km/h. The map of site I is shown in figure 1.

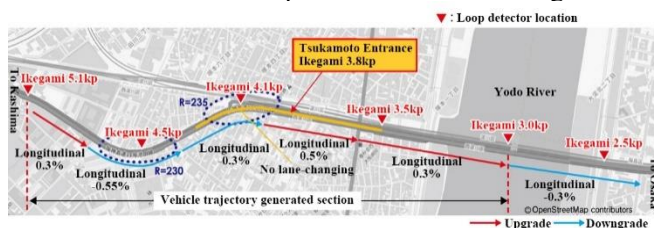


Figure 1 Site I: Ikeda Line

3. Trajectory reconstruction

The provided speed in the trajectory data is calculated and based on the vehicle position data. However, there remains significant inconsistent between the observed speed and calculated speed from the kp data. Figure 2 shows an example of provided speed (referred as observed speed) and calculated speed from kp. This makes it difficult to utilize both position and speed data to calibrate the car following model.

To keep the consistency of speed and position, a workflow to filter the position data is proposed as follows:

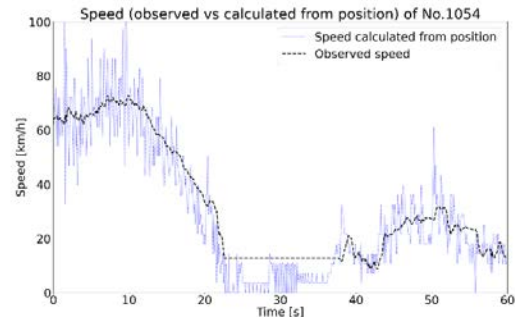


Figure 2 1-minute clip of speed profile of vehicle No.1054 at 7:00-8:00

Table 1. Comparison of observed and calculated speed

	7:00	10:00	15:00
Average Std.dev of observed	10.44	10.15	9.65
Average Std.dev of calculated	17.70	19.47	18.48
MAPE against obs. and cal.	0.217	0.223	0.192

Step1: Remove outliers

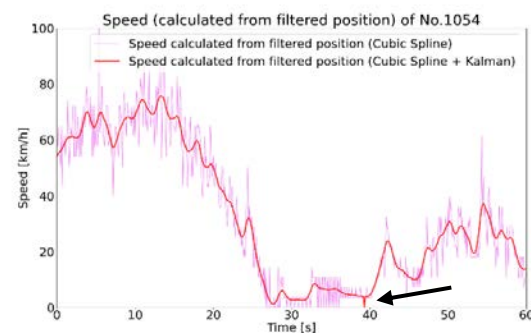
In this step, the outliers with unreliable values of acceleration are removed by locally filtering the trajectory. A threshold of $[-50,30]$ m/s^2 is adopted. The position points with acceleration beyond this threshold is replaced by natural cubic spline interpolation with 10 reference points (1 second data points) before and after the outliers. The average number of outliers is 342 for a trajectory.

Step2: Filter high frequency noise

In this step, Kalman filtering is applied to the trajectory in order to filter high frequency noise.

Step3: Remove residual outliers

After step1 and step2, among several trajectories, there still exist isolated abnormal points which suddenly drop to 0 speed. A natural cubic spline with 5 reference points before and after the outliers is applied to substitute these abnormal points. 1355 out of 10781 trajectories have 1 or 2 outliers removed in this step.



(a)

Keywords: Microsimulation, Car following model, Intelligent Driver Model, Zen traffic data

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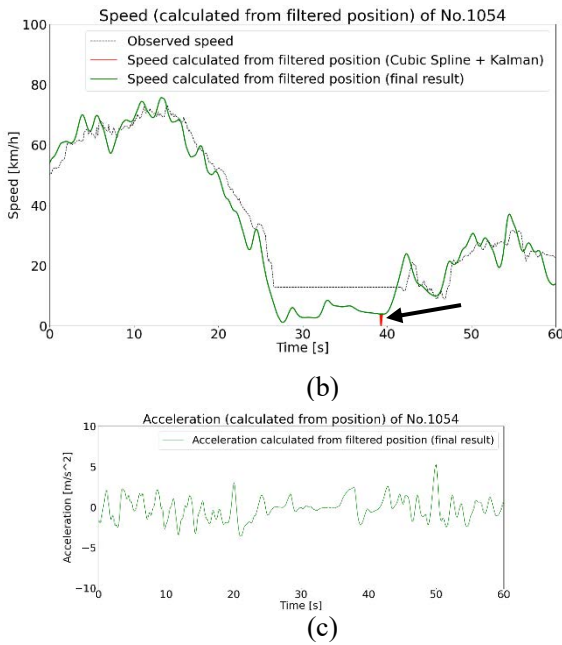


Figure 3 1-minute clip of vehicle No.1054 after reconstruction: (a) Speed profile after step 1 and 2, the arrow indicates the isolated outlier; (b) speed profile after step 3; (c) acceleration profile after step 3

Table 2 MAPE between calculated speed and observed speed

Average MAPE	7:00	10:00	15:00
calculated speed from observed position	0.217	0.223	0.192
calculated speed from filtered position	0.101	0.114	0.098

Figure 3 shows an example of the improvement in the calculated speed after each step. Table 1 shows the improvement of mean absolute percentage error (MAPE) comparing calculated speed and observed speed.

4. Calibration of car-following model

Leading-following pairs on inner lane are extracted to calibrate a car following model for microsimulation. If the leading car changes, a new pair is recorded. The total numbers of pairs extracted from the dataset of the three time periods, 7:00-8:00, 10:00-11:00, and 15:00-16:00, are 1492, 1342, and 1370 respectively.

4.1. Intelligent Driver Model

IDM is calibrated for the car-following model in this study. IDM uses few parameters which are well-defined, and it can describe different states from free flow to fully congested flow with a unified form. In IDM, the acceleration is determined by the desired speed considering spacing and speed difference defined as follows:

$$\frac{dv}{dt} = a \left(1 - \left(\frac{v}{v_0} \right)^4 - \left(\frac{s^*(v, \Delta v)}{s} \right)^2 \right)$$

where

$$s^*(v, \Delta v) = s_0 + vT + \frac{v\Delta v}{2\sqrt{ab}} \quad (1)$$

in which v_0 : desired velocity, T : minimum headway, a : maximum acceleration, b : comfortable deceleration, s_0 : standstill distance.

4.2. Calibration method

Genetic algorithm is adopted in this study for the calibration. The measure of performance (MoP) is calculated from the normalized root-mean-square deviation (NRMSE) of speed and spacing as follows:

$$MoP = 0.5 * \sqrt{\left(\sum (v_{calculated} - v_{real})^2 \right) / n} + \sqrt{\left(\sum (s_{calculated} - s_{real})^2 \right) / n} \quad (2)$$

The optimization of the calibration is to minimize MoP. Both the population size and iteration times of the genetic algorithm are set as 100. To avoid over fitting, 150 leading-following pairs are randomly selected for each iteration.

4.3 Calibration result

The calibration results show that parameters except standstill distance were stable among three time periods. It is reasonable because there are no standstill situations in the dataset. After conducting sensitivity analysis, 2.5 is adopted for the standstill distance. Table 2 shows the result of calibration. 10 random samples are used for cross-validation. Compared to the reference values by Treiber et al., the calibrated results perform better for all validation samples.

Table 3 Calibration result of IDM parameters

	v_0 [m/s]	T [s]	a [m/s ²]	b [m/s ²]	s_0 [m]
7:00	25.16	0.78	0.78	2.67	2.5
10:00	27.14	0.87	0.80	2.85	2.5
15:00	27.42	0.86	0.77	2.84	2.5
Reference	30	1.5	0.73	1.67	2.0

5. Conclusion

In this study, the vehicle trajectory data of Hanshin Expressway, Zen Traffic Data is utilized. The proposed method is feasible to filter the observed data and reconstruct trajectories with consistent speed and position information. Using the reconstructed trajectories, an IDM car following model is estimated. The calibrated result performs better and shows different values for each parameter compared to the reference values indicating the characteristics of the traffic flow in Hanshin expressway differs from US highways.

Reference

- 1) Hanshin Expressway Co. Ltd., Zen Traffic Data, <https://zen-trafficdata.net/>
- 2) Kurtc, V., & Treiber, M. (2016). Calibrating the Local and Platoon Dynamics of Car-Following Models on the Reconstructed NGSIM Data. arXiv: Physics and Society, 515-522.
- 3) Treiber, M.; Hennecke, A.; Helbing, D. (2000), Congested traffic states in empirical observations and microscopic simulations, Physical Review E, 62 (2): 1805-1824