

Ngoc Thanh Nguyen · Bogdan Trawiński  
Hamido Fujita · Tzung-Pei Hong (Eds.)

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# Intelligent Information and Database Systems

8th Asian Conference, ACIIDS 2016  
Da Nang, Vietnam, March 14–16, 2016  
Proceedings, Part II

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Part II

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# Intelligent Information and Database Systems

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## Preface

ACIIDS 2016 was the eighth event of the series of international scientific conferences for research and applications in the field of intelligent information and database systems. The aim of ACIIDS 2016 was to provide an internationally respected forum for scientific research in the technologies and applications of intelligent information and database systems. ACIIDS 2016 was co-organized by the Vietnam–Korea Friendship Information Technology College (Vietnam) and Wrocław University of Technology (Poland) in co-operation with IEEE SMC Technical Committee on Computational Collective Intelligence, Bina Nusantara University (Indonesia), Ton Duc Thang University (Vietnam), and Quang Binh University (Vietnam). It took place in Da Nang (Vietnam) during March 14–16, 2016.

The ACIIDS conference series is well established. The first two events, ACIIDS 2009 and ACIIDS 2010, took place in Dong Hoi City and Hue City in Vietnam, respectively. The third event, ACIIDS 2011, took place in Daegu (Korea), while the fourth event, ACIIDS 2012, took place in Kaohsiung (Taiwan). The fifth event, ACIIDS 2013, was held in Kuala Lumpur in Malaysia, while the sixth event, ACIIDS 2014, was held in Bangkok, Thailand. The last event, ACIIDS 2015, took place in Bali (Indonesia).

We received papers from 36 countries all over the world. Each paper was peer reviewed by at least two members of the international Program Committee and international reviewer board. Only 153 papers with the highest quality were selected for oral presentation and publication in the two-volume proceedings of ACIIDS 2016.

Papers included in the proceedings cover the following topics: knowledge engineering and the Semantic Web, social networks and recommender systems, text processing and information retrieval, database systems and software engineering, intelligent information systems, decision support and control systems, machine learning and data mining, computer vision techniques, intelligent big data exploitation, cloud and network computing, multiple model approach to machine learning, advanced data mining techniques and applications, computational intelligence in data mining for complex problems, collective intelligence for service innovation, technology opportunity, e-learning and fuzzy intelligent systems, analysis of image, video, and motion data in life sciences, real-world applications in engineering and technology, ontology-based software development, intelligent and context systems, modeling and optimization techniques in information systems, database systems, and industrial systems, smart pattern processing for sports, and intelligent services for smart cities.

Accepted and presented papers highlight the new trends and challenges of intelligent information and database systems. The presenters showed how new research could lead to novel and innovative applications. We hope you will find these results useful and inspiring for your future research.

We would like to extend our heartfelt thanks to Mr. Jarosław Gowin, the Deputy Prime Minister of the Republic of Poland and Minister of Science and Higher Education for his support and honorary patronage over the conference.

We would like to express our sincere thanks to the honorary chairs, Mr. Minh Hong Nguyen (Deputy Minister of Information and Communications, Vietnam), and Prof. Tadeusz Więckowski (Rector of the Wrocław University of Technology, Poland) for their support.

Our special thanks go to the program chairs, special session chairs, organizing chairs, publicity chairs, liaison chairs, and local Organizing Committee for their work for the conference. We sincerely thank all members of the international Program Committee for their valuable efforts in the review process, which helped us to guarantee the highest quality of the selected papers for the conference. We cordially thank the organizers and chairs of special sessions, who essentially contributed to the success of the conference.

We also would like to express our thanks to the keynote speakers (Prof. Tzung-Pei Hong, Prof. Saeid Nahavandi, Prof. Jun Wang, and Prof. Piotr Wierzchoń) for their interesting and informative talks of world-class standard.

We cordially thank our main sponsors, Vietnam–Korea Friendship Information Technology College (Vietnam), Wrocław University of Technology (Poland), IEEE SMC Technical Committee on Computational Collective Intelligence, Bina Nusantara University (Indonesia), Ton Duc Thang University (Vietnam), and Quang Binh University (Vietnam). Our special thanks are due to Springer for publishing the proceedings, and all our other sponsors for their kind support.

We wish to thank the members of the Organizing Committee for their very substantial work and the members of the local Organizing Committee for their excellent work.

We cordially thank all the authors for their valuable contributions and other participants of this conference. The conference would not have been possible without their input.

Thanks are also due to many experts who contributed to making the event a success.

March 2016

Ngoc Thanh Nguyen  
Bogdan Trawiński  
Hamido Fujita  
Tzung-Pei Hong

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# A New Method for Calibrating Gazis-Herman-Rothery Car-Following Model

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**Abstract.** Traffic simulation at the microscopic level utilizes car-following model to describe vehicle interactions on a vehicular lane. The most widely used car-following model is the Gazis-Herman-Rothery model, which contains two coefficients:  $m$  and  $l$ . The coefficients should be determined in calibration tests where the involved vehicles are tracked for their positions, velocities, and accelerations. The existing calibration methods are costly. This study proposes a calibration method using computer vision. Two computer vision algorithms are evaluated, namely, multilayer and Eigen background subtraction. The vehicle movement is tracked on a perspective plane and then is projected to an orthogonal plane. From the verification tests, we determine that the multilayer algorithm has 96.6 % accuracy for the vehicle position and 88.9 % for the velocity. The Eigen algorithm has 92.9 % accuracy for the vehicle position and 84.3 % for the velocity. The estimated model coefficients is 0.4 for  $m$  and 1.2 for  $l$ . These values are within the range of the most reliable coefficients according to many literatures.

**Keywords:** Car-following model · Vehicle tracking · Computer vision · Micro-simulation

## 1 Introduction

Traffic congestion is a huge issue faced by many cities including Jakarta, the capital of Republic of Indonesia [1]. Morichi [2] recommends a number of long-term strategic development to overcome the problem including development of well-structure public transportation systems and decentralized urban form. In 2003, Bus-Rapid-Transit-based public transportation system was initiated in Jakarta [3] and the operational efficiency of the system has been the topics of a number of research works [4–6].

Traffic congestion can also be reduced by traffic management. To yield good traffic management, traffic microsimulation is an indispensable tool. Micro simulation shows the movement of every vehicle that is traced through a road network over time at a small time increment of a fraction of a second [7].

Car-following model is at the heart of the traffic microsimulation. The model governs the vehicle movement along a vehicle lane. Essentially, the model is a

mathematical description of the stimulus and response interaction [8]. One of the widely used car-following models is Gazis-Herman-Rothery (GHR) model, which has the following mathematical form [9]:

$$a_n(t) = \alpha \frac{v_n^m(t) \cdot \Delta v_n(t - t_d)}{\Delta x_n^l(t - t_d)}, \quad (1)$$

where  $a_n(t)$  is the vehicle acceleration,  $v_n(t)$  is the vehicle velocity,  $\Delta v_n$  and  $\Delta x$ , respectively, are the relative velocity and the relative position with respect to the leading vehicle. The model has three parameters  $\alpha$ ,  $m$ , and  $l$ , and has a delay of  $t_d$ . The driver delay or response time  $t_d$  is usually about 1 s;  $\alpha$  is the driver sensitivity [9].

The central issue to use the micro-simulation model is finding the model parameters for each type of vehicles, road types, traffic conditions, and environment. The parameters are usually determined via a calibration process. There are few existing calibration methods and they are expensive [10–13].

This study intends to establish a significantly low-cost calibration procedure where the vehicle movements will be recorded digitally, tracked with a computer vision technique, and projected with an orthography projection technique.

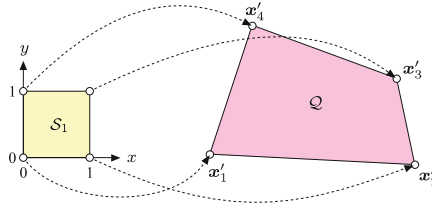
## 2 Research Methods

The current proposal is only suitable for vehicle moving along a straight lane. The lane should be marked at four corners. The vehicle position is obtained with the following procedure.

Firstly, a camera is positioned at an elevation and angle from the lane to capture the vehicle movement in the perspective view. The camera is used to produce images of the vehicle movement. Secondly, computer vision is used to obtain the vehicle position in the images [14]. Two algorithms are evaluated in this study: multilayer background subtraction [15] and Eigen background subtraction [16]. Thirdly, the vehicle position is projected from the perspective view to an orthographic view using an orthorectification projection.

The following transformation is used to map the data from the perspective plane to the road/orthographic plane [17]. We consider a unit square  $S_1$  and an arbitrary quadrilateral  $Q$ , which is governed by four corner points:  $x'_1$ ,  $x'_2$ ,  $x'_3$ , and  $x'_4$ . These four points have one-to-one relations with those four points in the unit square, see Fig. 1. The following matrix  $\mathbf{T}$  projects any point on the unit square to a point on the quadrilateral, or mathematically:  $S_1 \xrightarrow{\mathbf{T}} Q$ , where the transformation  $\mathbf{T}$  is

$$\mathbf{T} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}, \quad (2)$$

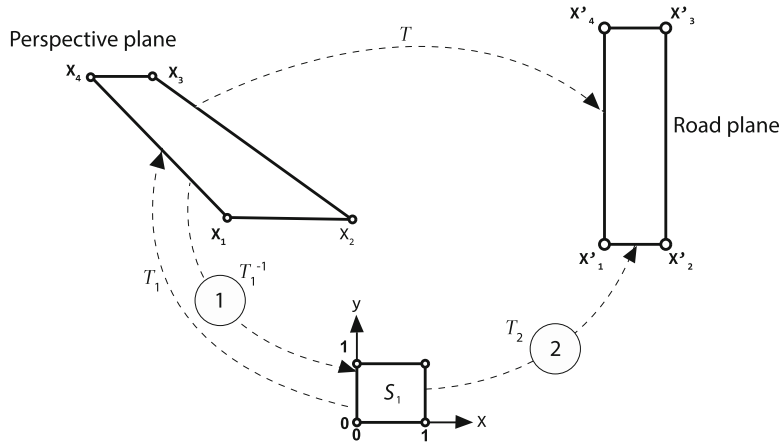


**Fig. 1.** Projective mapping from the unit square  $S_1$  to an arbitrary quadrilateral  $Q$  [17].

where

$$\begin{aligned}
 a_{31} &= \frac{(x'_1 - x'_2 + x'_3 - x'_4)(y'_4 - y'_3) - (y'_1 - y'_2 + y'_3 - y'_4)(x'_4 - x'_3)}{(x'_2 - x'_3) \cdot (y'_4 - y'_3) - (x'_4 - x'_3) \cdot (y'_2 - y'_3)}, \\
 a_{32} &= \frac{(y'_1 - y'_2 + y'_3 - y'_4)(x'_2 - x'_3) - (x'_1 - x'_2 + x'_3 - x'_4)(y'_2 - y'_3)}{(x'_2 - x'_3) \cdot (y'_4 - y'_3) - (x'_4 - x'_3) \cdot (y'_2 - y'_3)}, \\
 a_{11} &= x'_2 - x'_1 + a_{31}x'_2 & a_{12} &= x'_4 - x'_1 + a_{32}x'_4 & a_{13} &= x'_1, \\
 a_{21} &= y'_2 - y'_1 + a_{31}y'_2 & a_{22} &= y'_3 - y'_1 + a_{32}y'_4 & a_{23} &= y'_1.
 \end{aligned}$$

Inversely, we can project any point on the  $Q$  plane to the  $S_1$  plane by the inverse of the transformation matrix  $\mathbf{T}^{-1}$ .



**Fig. 2.** Two-step projective transformation between perspective plane and road plane. In the first step, the perspective plane  $Q_1$  is transformed to the unit square  $S_1$  by the inverse mapping function  $\mathbf{T}_1^{-1}$ . In the second step,  $\mathbf{T}_2$  transforms the square  $S_1$  to the road plane  $Q_2$ . Transformation from the perspective plane  $Q_1$  to the road plane  $Q_2$  can be direct by  $\mathbf{T} = \mathbf{T}_1^{-1}\mathbf{T}_2$  [17].

Now, we consider three planes, the perspective plane  $Q_1$ , the unit plane  $S_1$ , and the road plane  $Q_2$ , depicted in Fig. 2. We can map points on the perspective plane  $Q_1$  to points on the road plane  $Q_2$  in two steps:  $Q_1 \xrightarrow{\mathbf{T}_1^{-1}} S_1$ , and followed by  $S_1 \xrightarrow{\mathbf{T}_2} Q_2$ . The transformation can be directed from the perspective plane  $Q_1$  to the road plane  $Q_2$  by:

$$\mathbf{T} = \mathbf{T}_2^{-1}\mathbf{T}_1. \tag{3}$$

In the current work, the vehicle movement is also recorded using an accelerometer, which is placed inside the test vehicle. These data are later compared to the data obtained from the above procedure to evaluate the accuracy of the proposed method. The recorded acceleration data are numerically integrated to provide the vehicle velocity and position. The level of accuracy is simply  $1 - \text{Relative Error}$ , where the error is defined by

$$\text{Relative Error} = \frac{\|\hat{\mathbf{x}} - \mathbf{x}\|_2}{\|\mathbf{x}\|_2} \times 100\%, \quad (4)$$

where  $\hat{\mathbf{x}}$  is the vector of the estimated position or velocity and  $\mathbf{x}$  is the true value, that is obtained from the accelerometer.

### Experimental Procedures

The proposed method was evaluated with a simple experiment described following. The experiment only involved a vehicle. The vehicle was set to travel along a straight trajectory for a distance around 23 m. It was difficult to control the vehicle exact position. Figure 3 respectively show the vehicle initial and final positions. Four cones were placed on the four corners of the vehicle trajectory; see Fig. 3. These four cones were separated by 22.9 m distance longitudinally and 3.5 m distance laterally.



**Fig. 3.** The test vehicle initial and final positions and the four cones used for orthorectification.

The vehicle movement was recorded by two means: a video camera and an accelerometer. The video camera recorded the vehicle movement at the rate of 25 fps and image size of  $720 \times 576$  pixels. The accelerometer recorded at the sampling time of 0.1 s.

In addition, we also compute the vehicle coefficient  $m$  and  $l$  by minimizing

$$\text{Error}(t) = a_n(t) - \alpha \frac{v_n^m(t) \cdot \Delta v_n(t - t_d)}{\Delta x_n^l(t - t_d)}. \quad (5)$$

All data  $a_n$ ,  $\Delta v_n$ ,  $\Delta x_n$  are from the current proposed method.

### 3 Results

Two sets of data are necessary for this study. The first set is obtained from the deployed computer-vision-based vehicle tracking methods. The second set is from the accelerometer.

Two different background subtractions in computer vision will be used separately: multilayer and Eigen background subtractions. The computer vision vehicle tracking provides the data of: frame number, blob number, blob area,  $x$  blob-centroid,  $y$  blob-centroid, and the position of the bottom-right corner of the blob. The frame number and the frame rate data are used to calculate the time associated with the frame number by:

$$\text{Frame Time } t = \frac{\text{Frame Number}}{\text{Frame Rate}}.$$

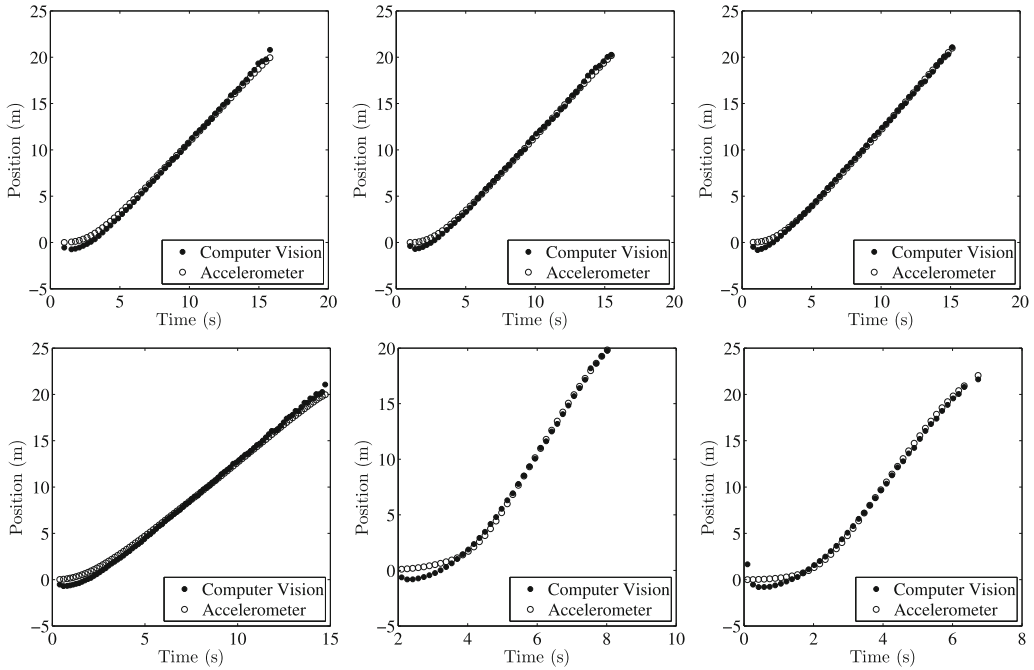
The frame rate is fixed at 25 fps. Only one vehicle is used in the experiment and it has dimensions of 4.7 m long, 1.8 m wide, and 1.8 m high.

The results of the current study are shown in Fig. 4 for multilayer algorithm and Fig. 5 for Eigen subtraction algorithm. The relative error, absolute error, and accuracy have been computed for every experiments; see Table 1. The results show that the tracking accuracy using multilayer background subtraction is better than that of Eigen background subtraction. Multilayer method has 96.6 % position accuracy and 88.9 % velocity accuracy; meanwhile Eigen method has 92.9 % position accuracy and 84.3 % velocity accuracy.

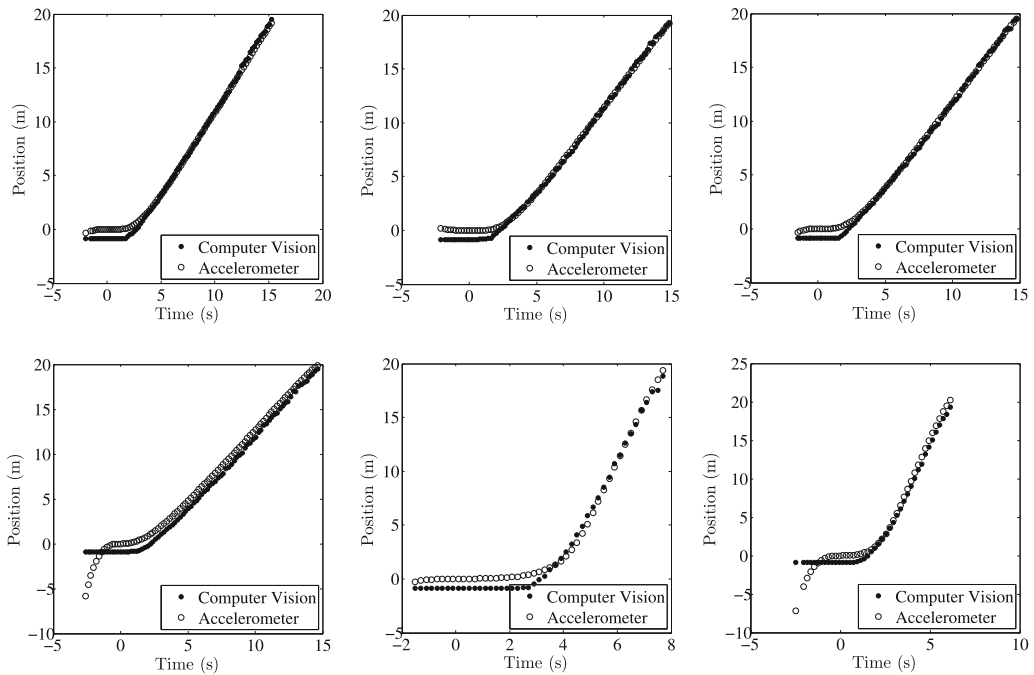
In Fig. 6, we compare the vehicle acceleration computed the GHR model and the measured one. The estimated GHR car-following parameters are  $m = 0.4$  and  $l = 1.2$  at 3.2 % of relative error. These estimated parameters are within the range of most reliable estimated parameters according to findings of other researchers for GHR model [18].

**Table 1.** The relative error of the tracked vehicle position by the computer vision technique with respect to the vehicle position obtained by integrating by the accelerometer data. The relative error is defined by Eq. 4.

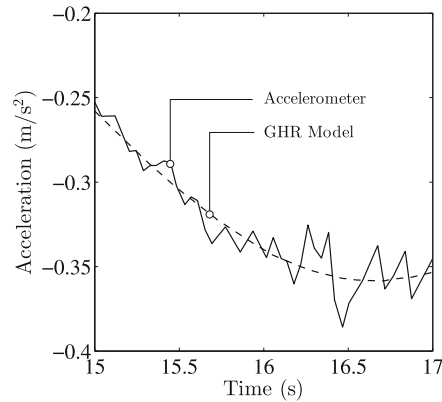
Experiment no.	Relative error (%)			
	Position (m)		Velocity (m/s)	
	MultiLayer BGS	Eigen BGS	MultiLayer BGS	Eigen BGS
1	3.41	2.9	13.1	6.9
2	2.49	4.6	6.5	9.1
3	2.40	4.4	8.4	4.0
4	3.84	10.5	12.5	26.3
5	4.37	9.4	10.9	13.1
6	4.30	12.7	12.5	39.3
7	3.07	5.2	13.5	11.2



**Fig. 4.** Comparison of the space-time diagram obtained from computer vision (multi-layer algorithm) and from accelerometer for six experimental replications.



**Fig. 5.** Comparison of the space-time diagram obtained from computer vision (Eigen background subtraction algorithm) and from accelerometer for six experimental replications.



**Fig. 6.** Comparison of the Vehicle Acceleration between Accelerometer Data and GHR Model Prediction

## 4 Conclusions

The car-following model has important application in traffic and safety engineering. Unfortunately, finding the model parameters are often costly. For the reason, this research proposed a significantly low-cost method to determine the model coefficients. In the current method, the vehicle movement are recorded digitally and tracked by a computer vision technique. The obtained vehicle position is projected to the road plane with an orthographic projection technique. In the current experiment, to evaluate its accuracy, the method is used to track trajectory of a vehicle moving in a short-straight lane. From comparisons to the data obtained from an accelerometer, it is concluded that the current method is reasonably accurate. The results show that the tracking accuracy of multilayer background subtraction is better than that of Eigen background subtraction. The multilayer method has 96.6% position accuracy and 88.9% velocity accuracy; meanwhile, the Eigen method has 92.9% position accuracy and 84.3% velocity accuracy. The method estimates the car-following parameters to be  $m = 0.4$  and  $l = 1.2$  with 3.2% relative error. These estimated parameters are within the range of the most reliable GHR model parameters according to many references.

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