International Journal of Mechanical Engineering and Robotics Research Vol. 11, No. 2, February 2022

Investigation of the Advanced Rider-Assistance System of a Personal Electric Vehicle Using Personal Space

Pham Quoc Thai[1*], Chihiro Nakagawa[2], Atsuhiko Shintani[2], and Tomohiro Ito[2]
[1]The University of Danang, University of Science and Technology, Faculty of Transportation Mechanical Engineering, Danang City, Vietnam
[2]Osaka Prefecture University, Department of Mechanical Engineering, Sakai City, Osaka, Japan
*Email: pqthai@dut.udn.vn

Abstract—**Recently, personal mobility vehicles for individual use have attracted tremendous attention as eco-friendly transportation for short-distance trips in urban areas. In this paper, we investigate the advanced rider-assistance system of a four-wheeled personal electric vehicle that supports the rider in recognizing the psychological strain of surrounding pedestrians using the concept of personal space. The proposed system detects nearby pedestrians using range sensors, informs the rider about the invasion of the vehicle via a micro-vibration motor, and cooperates with the rider in avoiding the pedestrian. The experiment was conducted under different conditions of pedestrian densities, and questionnaires were used to evaluate participants' feelings such as discomfort and fear. The findings revealed that the effectiveness of the proposed assistance system was confirmed.**

***Index Terms*—advanced rider-assistance system, psychological factor, personal electric vehicle, personal space, vibration motor**

I. INTRODUCTION

These days, in the context of exhausting fossil fuel and environmental problems, many researchers worldwide have tried to find solutions for transportation, such as developing electric vehicles and hybrid electric vehicles or proposing alternative fuels for vehicles. For short-distance trips, personal mobility vehicles (PMVs), which are suitable for individual use, have been recently offered. Such vehicles are environmentally–friendly, compact, and convenient to use in pedestrian areas such as walkways, pedestrian streets, and shopping malls [1]. As a result, many kinds of PMVs have been recently developed, especially two-wheeled inverted pendulum vehicles [2]–[3]. However, when PMVs are allowed to be used in pedestrian flows, it is essential to consider the psychological factors of nearby pedestrians toward PMVs. There has been growing interest in the safety issues and psychological effects of PMVs on surrounding pedestrians when PMVs move in a flow of pedestrians. Sayed *et al.* investigated automated safety diagnosis of vehicle-bicycle interactions using computer vision analysis [4]. Nishiuchi *et al.* analyzed the behaviors of Segway, focusing on safety distance for pedestrians and the gaze of riders [5]. Xu *et al.* investigated head injures of self-balancing scooter's riders using the virtual vehicle-scooter crash scenarios [6]. Nakagawa *et al.* analyzed avoidance difficulty levels following the type of PMV [7] and examined the effect of the size of a PMV on a pedestrian [8]. Pham *et al.* evaluated the assistance system for a two-wheeled vehicle using personal space (PS) [9] and estimated a semi-active assistance system of PMV's driver [10]. Intelligent wheelchairs that can assist the riders and avoid collisions and with pedestrians have been proposed [11]–[12]. *Dias et al.* analyzed a safe avoidance system for pedestrians in PMVs and mixed pedestrian traffic [13] and investigated pedestrians' danger perception toward PMVs interacting with them in shared space [14].

Generally, a two-wheeled PMV is compact and suitable to use in pedestrian areas; however, this is an unstable and nonlinear system; therefore, for the vehicle to balance by itself, control approaches need to be implemented by using a gyroscope and accelerometer sensors [15]–[16]. In recent years, many researchers have proposed diverse control strategies for such PMVs. Ren *et al.* examined a self-tuning proportional-integral-derivative control strategy based on a deduced model for implementing a motion control system that stabilizes a two-wheeled vehicle and follows desired motion commands [17]. Jung and Kim proposed a control approach for a mobile inverted pendulum using a neural network control combined with a proportional-integral-derivative controller [18].

Furthermore, driving two-wheeled vehicles is not always an easy task, and it may be difficult for riders to maintain balance while driving the vehicle. Meanwhile, four-wheeled PMVs like Scooter Q3-Chariot [19], which can easily maintain balance, have been introduced in recent years. Nevertheless, such vehicles use a mechanical steering system and are not compact to operate in pedestrian areas. Therefore, this study develops a compact four-wheeled personal electric vehicle (PEV) that uses electric energy, providing green, convenient,

---

Manuscript received August 30, 2021; revised November 19, 2021.
Corresponding author: Pham Quoc Thai.

doi: 10.18178/ijmerr.11.2.92-98

and safe mobility in urban areas. Furthermore, to enhance the safety and comfort of surrounding pedestrians in the presence of the proposed vehicle, a driving assistance system considering pedestrians' psychological factors was investigated.

The remaining sections are structured as follows. In Section II, an advanced rider-assistance system for a four-wheeled PEV is proposed. Section III describes experiments on personal space and participants' feelings of discomfort and avoidance difficulty, experimental analysis results. Finally, Section IV provides conclusions and future work.

II. DEVELOPMENT OF ADVANCED RIDER-ASSISTANCE SYSTEM FOR THE FOUR-WHEELED PEV

Previous studies examined the simulation of personal mobility vehicles based on PS using invasion ratio and crossing time as evaluation indexes [20]–[21]. In addition, a semi-active assistance system was evaluated by riders as the vehicle operated at speeds of 4 km/h and 6 km/h in accordance with low and high steering angle gains [10]. In this study, we develop an advanced rider-assistance system for the four-wheeled PEV considering the psychological factors of surrounding pedestrians. The assistance system detects a nearby pedestrian using range sensors and informs the rider about the invasion of the vehicle using a vibrator. Fig. 1 describes the procedure of the proposed system.

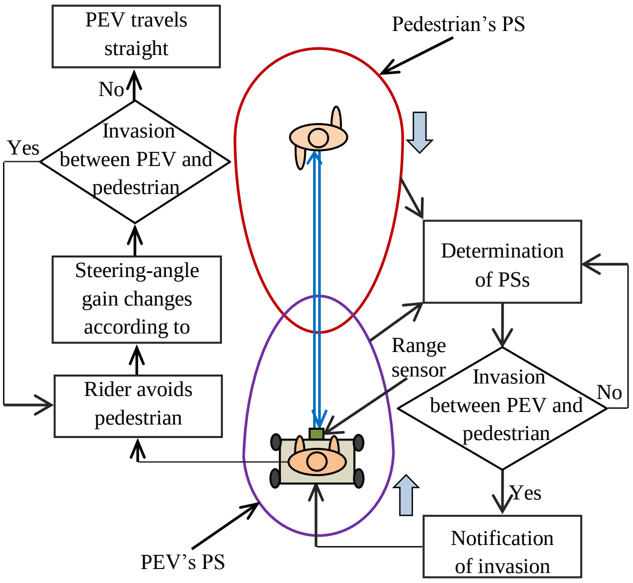

Figure 1. Procedure of advanced rider-assistance system.

Fig. 2 illustrates the control system configuration of the vehicle, which includes three main parts: sensors (inputs), actuators (outputs), and an electronic controller that is responsible for executing the control algorithm for the vehicle.

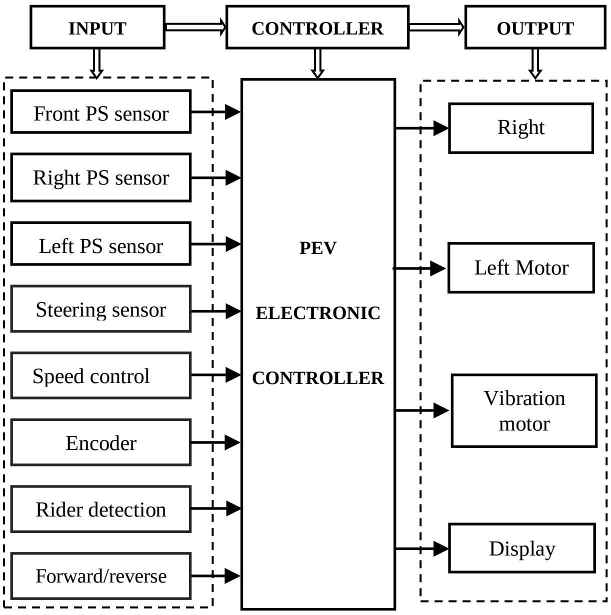

Figure 2. Control block diagram of the PEV with an advanced rider-assistance system

For vehicle motion control, the data from the speed control potentiometer, wheel speed sensors, steering angle sensor, and control switches are fed to the controller. The controller then processes, calculates, and generates signals to control two motors appropriate to the operational mode of the vehicle. For controlling the assistance system, ultrasonic sensors are employed to determine the PS of pedestrians, and a micro-vibration motor and an LED are used to inform the rider about the invasion of the vehicle.

The appearance of a PEV prototype is shown in Figure 3. The prototype has rear-wheel drive using two electric motors, and the front wheels were equipped with Omni-directional wheels, which can roll freely in two directions, helping the PEV turn smoothly. Moreover, the designed vehicle can move forward and backward via acting control switch 11, turn via turning handlebar 10, and change the velocity via adjusting velocity rotary switch 9. The designed vehicle is controlled by an electronic controller 3, put under platform 4, as shown in Fig. 3.

The electronic controller for the vehicle consists of an LPC 1768 microcontroller, with a 32-bit ARM Cortex M3 processor and a diversity of input/output interfaces, including pulse-width modulation, an analog-to-digital converter, and an inter-integrated circuit. Moreover, three ultrasonic XL-MaxSonar-EZ1 range finders were employed to determine the front and side distances between the PEV and nearby pedestrians. Additionally, a light-emitting diode (LED) and a micro-vibration motor were mounted on the handle of the PEV to inform the rider about the invasion of the PEV. The coin-type vibration motor was attached to the handlebar, which can generate vibration amplitude large enough so that the driver can recognize PS invasion status [22]. The vibration amplitude of the motor was controlled in accordance with the level of PS invasion of the vehicle. Increasing the PS invasion increases the vibration amplitude, helping the PEV rider recognize the invasion level of the PEV. Table I shows the parameter of the vibration motor.

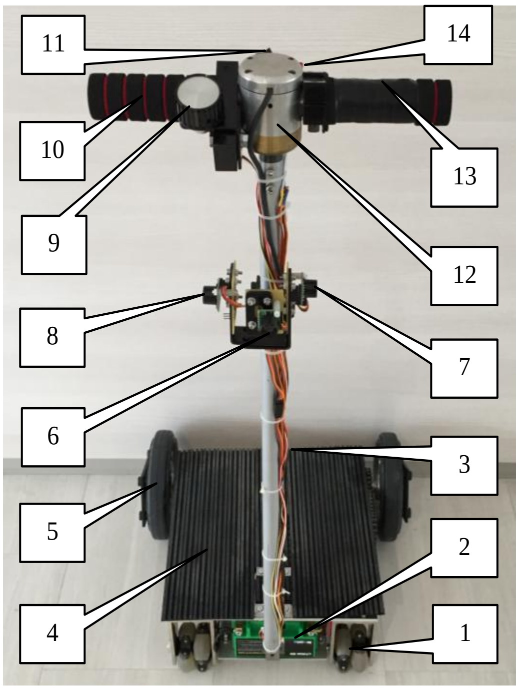

Figure 3. PEV with advanced driver-assistance system
1. Front wheel; 2. Battery; 3. Electronic controller; 4. Platform; 5. Rear wheel; 6, 7, 8. Range sensors; 9. Velocity control; 10. Handlebar; 11. Control switch; 12. Steering angle sensor; 13. Vibration motor; 14. LED.

TABLE I. PARAMETERS OF VIBRATION MOTOR FOR EXPERIMENT

Specification	Value
Body diameter (mm)	10
Body thickness (mm)	3
Voltage range (V)	1.6–3.5
Rated vibration speed (rpm)	12500 ± 2500
Rated current (mA)	65

Furthermore, the advanced rider-assistance system cooperates with the rider in avoiding the PS of a pedestrian when the PS invasion arises to get out of the PS of a pedestrian faster. In this study, the steering is performed by controlling the difference between the angular speeds of the left and right rear wheels. When the rider of the PEV applies a steering angle on the handlebar, the controller acts immediately on the two motors, reducing the speed of the inner wheel and increasing the speed of the outer wheel. Steering angle gain (K_S) is defined as the ratio between the turning angular velocity of the vehicle ($d\varphi_V/dt$) and turning angle of the handle (φ_H), which is expressed as

$$K_s = \frac{\frac{d\varphi_V}{dt}}{\varphi_H}. \tag{1}$$

The steering angle gain increases with an increase in the invasion ratio of pedestrians, as shown in Fig. 4. This helps the PEV evade the PS of a pedestrian faster while invading the PS of a pedestrian.

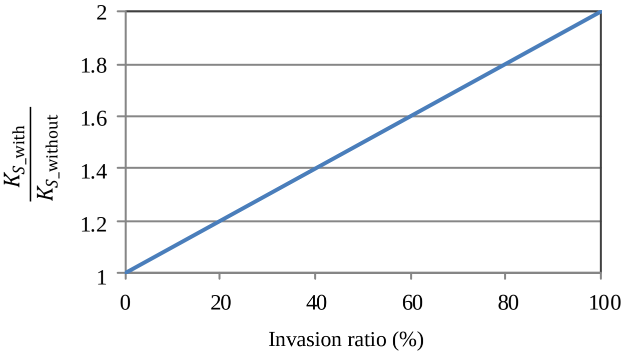

Figure 4. Steering angle gain according to invasion ratio.

where K_{S_with} and $K_{S\_without}$ are steering angle gains of the vehicle with and without assistance system, respectively.

III. EXPERIMENT AND RESULTS

A. Experimental Measurement of PSs

In previous studies, Nakagawa *et al.* measured the static and dynamic PSs of pedestrians encountering PMVs [23]. Pham *et al.* investigated the PS of pedestrian and a two-wheeled inverted pendulum vehicle [24]. In this study, we continued determining the PSs of a pedestrian and a four-wheeled electric vehicle.

The experiment was conducted under the condition that a four-wheeled PEV encountered 15 subjects one by one. The pedestrians consisted of 15 people (sex: 13 male/2 female, average age: 24.7 years old, range: 22–31 years old), and safety in the experiments was explained to participants. In this experiment, we assumed that the PEV travels in a pedestrian area at a low velocity of about 4 km/h (the same pedestrian velocity).

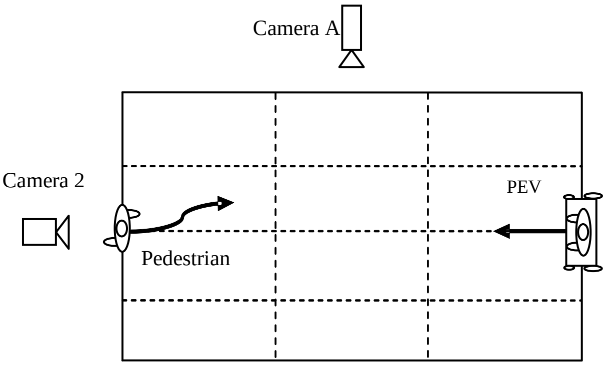

Figure 5. Measurement of pedestrian's PS.

The experimental area was over 10 m long in the traveling direction and wide enough to allow avoidance. In this experiment, we used two cameras to measure the PSs of a pedestrian and the vehicle. The PS of a pedestrian and the PEV were distances that caused discomfort when a pedestrian and a PMV were traveling toward each other, as described in Figs. 5 and 6.

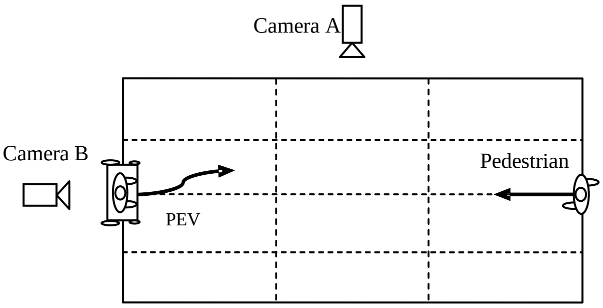

Figure 6. Measurement of PEV's PS.

After conducting the experiment, by analyzing the data from the cameras, the PSs of a pedestrian and the PEV were determined. Table II shows the experimental results of the PSs of a pedestrian and the PEV (N = 15), which were used as input parameters for the advanced rider-assistance system for the vehicle. The results reveal that the PSs of a pedestrian were larger than those of the PEV, respectively. This means that the discomfort level generated by the PEV rider was higher than that caused by the pedestrian when a pedestrian traveled toward the PEV. Besides, there was a statistically significant difference between the PS of a pedestrian and the PS of the PEV (Wilcoxon test $N = 15$, $p < 0.05$).

TABLE II. EXPERIMENTAL RESULTS ON PS OF PEDESTRIAN AND PEV (MEAN AND STANDARD DEVIATION)

Parameters	Pedestrian	PEV
Front PS (m)	4.8 (0.84)	4.4 (0.72)
Side PS (m)	0.82 (0.18)	0.75 (0.24)

B. Experiment on Participants' Feelings

The previous study [10] evaluated the effectiveness of a semi-active assistance system by experiment when the vehicle operated at speeds of 4 km/h and 6 km/h in accordance with low steering gain (K_{S1}) and high steering gain (K_{S2}). The results revealed that the effectiveness of the semi-active assistance system had been confirmed by the driver. However, the experiment was conducted in the condition that the vehicle encountered pedestrians one by one.

To confirm the effectiveness of the proposed assistance system in more realistic scenarios, we continue conducting experiments in the measurement of feelings of pedestrians and PEV riders with the advanced rider-assistance system. In the experiment, we assumed that the PEV travels at low velocity in a pedestrian area of a Japanese road pedestrian area, and we constructed an experimental scenarios model with a PEV traveling toward ten pedestrians for different pedestrian densities of 0.1, 0.2, and 0.3 people/m^2. The experiment was conducted at Osaka Prefecture University under the condition that the PEV encountered a flow of pedestrians. The experimental area was 20 m long in the traveling direction and wide enough to allow the PMV to avoid pedestrians, as shown in Fig. 7. This figure is admitted to use by the experimental participants.

Figure 7. Picture of the experiment.

Fig. 8 describes the layout of the experiment, such as the positions of pedestrians and the PEV. The experimental area has length l and width w. The pedestrian density in the experiment was varied following the values of l and w, as shown in Table III.

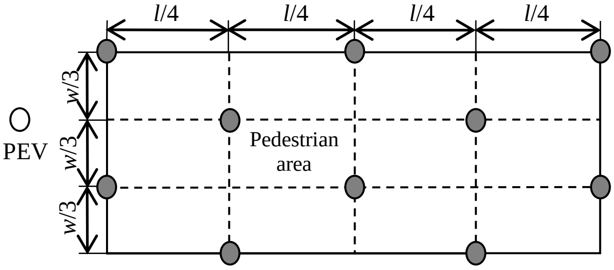

Figure 8. Layout of the experiment.

TABLE III. PEDESTRIAN DENSITY ACCORDING TO THE SIZE OF EXPERIMENTAL AREA

Density (people/m^2)	l (m)	w (m)
0.1	20	5
0.2	12.5	4
0.3	10	3

During the experiment, the PEV riders avoided pedestrians when recognizing the invasion via the advanced driver-assistance system. Meanwhile, the pedestrians traveled in straight lines from their initial positions toward the PEV and evaded the PEV when they felt uncomfortable or fearful. After conducting the experiment, participants were asked to complete the questionnaire sheets in two different modes of the vehicle operating with and without the assistance system, as shown in Table IV.

TABLE IV. QUESTIONNAIRES

No.	Participants	Questions
Q1	Riders	How uncomfortable do you feel when driving the PEV in the pedestrian flow? (1-comfortable, 2-slightly uncomfortable, 3-somewhat uncomfortable, 4-mostly uncomfortable, and 5-very uncomfortable)
Q2		How difficult did you feel when avoiding pedestrians? (1-normal, 2-slightly difficult, 3-somewhat difficult, 4-mostly difficult, and 5-very difficult)
Q3	Pedestrians	How uncomfortable do you feel when sharing the space with a PEV? (1-comfortable, 2-slightly uncomfortable, 3-somewhat uncomfortable, 4-mostly uncomfortable, and 5-very uncomfortable)
Q4		How fearful do you feel when sharing the space with a PEV? (1-normal, 2-slightly fearful, 3-somewhat fearful, 4-mostly fearful, and 5-very fearful)

C. *Rider's Evaluation*

The evaluation results for the feelings of discomfort and avoidance difficulty by five riders (mean and standard deviation) are shown in Table V. The results show that the rider's levels of discomfort and pedestrian avoidance difficulty when the PEV equipped with the assistance system were lower than those for the case of the PEV without the assistance system. This could be because the assistance system helps the rider recognize invading the PS of nearby pedestrians and assists the rider in avoiding the pedestrians.

TABLE V. EXPERIMENTAL RESULTS EVALUATED BY RIDERS

Feeling / Density	Discomfort level		Avoidance difficulty	
	Without assistance system	With assistance system	Without assistance system	With assistance system
0.1	1.3 (0.48)	1.1 (0.32)	1.3 (0.48)	1 (0.00)
0.2	2.2 (0.42)	1.6 (0.52)	2.2 (0.42)	1.8 (0.63)
0.3	3.2 (0.42)	2.7 (0.67)	3.2 (0.63)	2.5 (0.53)

D. *Pedestrians' Evaluation*

Table VI presents the results for the levels of discomfort and fear felt by ten pedestrians toward the PEV when operating with and without the assistance system. The pedestrians reported that their levels of discomfort and fear felt toward the PEV with the assistance system were lower than those felt toward the PEV without the assistance system. This may be because the assistance system helps the PEV avoid the PS of a pedestrian faster while invading the PS of a pedestrian.

TABLE VI. EXPERIMENTAL RESULTS EVALUATED BY PEDESTRIANS

Feeling / Density	Discomfort level		Fear level	
	Without assistance system	With assistance system	Without assistance system	With assistance system
0.1	1.42 (0.67)	1.33 (0.65)	1.08 (0.29)	1 (0.00)
0.2	2.17 (0.83)	1.75 (0.97)	1.33 (0.49)	1.17 (0.39)
0.3	2.58 (1.00)	2.33 (0.78)	1.75 (0.75)	1.58 (0.51)

IV. CONCLUSIONS

In this paper, we have investigated an advanced rider-assistance system for a four–wheeled PEV considering the psychological factors of pedestrians. The following findings were obtained.

- The PSs of a pedestrian and the PEV were determined by experiment. It was found that the PSs of the PEV were smaller than those of a pedestrian. The data PSs were used as inputs of the proposed assistance system.
- The proposed assistance system was evaluated by the riders and pedestrians under different conditions of pedestrian density. Experimental results reveal that the assistance system was effective at the pedestrian densities of 0.1, 0.2, and 0.3 people/m^2.

As future works, we will optimize the controller of the driving assistance system that will improve the efficiency of the proposed system. Furthermore, we will consider conducting experiments in higher pedestrian densities and actual scenarios.

CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

AUTHOR CONTRIBUTIONS

Chihiro Nakagawa, Atsuhiko Shintani, and Tomohiro Ito were in charge of conceptualization, methodology, formal analysis, writing—review and editing, project administration. Pham Quoc Thai is the corresponding author of this research work. He was in charge of conceptual generation, software, validation, formal analysis, writing—original draft preparation, and editing. All authors have read and agreed to the published version of the manuscript.

ACKNOWLEDGMENT

This research is funded by Funds for Science and Technology Development of the University of Danang under project number B2019-DN02-60.

REFERENCES

[1] K. T. Ulrich, "Estimating the technology frontier for personal electric vehicles," *Transp. Res. Part C Emerg. Technol.*, vol. 13, no. 5–6, pp. 448–462, Oct. 2005.

[2] Segway-The leader in personal, green transportation. [Online]. Available: http://www.segway.com/.

[3] yooPT your personal transporter. [Online]. Available: http://www.ewee-pt.com/.

[4] T. Sayed, M. H. Zaki, and J. Autey, "Automated safety diagnosis of vehicle-bicycle interactions using computer vision analysis," *Saf. Sci.*, vol. 59, pp. 163–172, 2013.

[5] H. Nishiuchi, T. Sato, T. Aratani, and T. Todoroki, "An analysis of Segway behavior focusing on safety distance for pedestrians and gaze of riders," in *Proc. 17th ITS World Congress*, 2010, 01368768.

[6] J. Xu, S. Shang, H. Qi, G. Yu, Y. Wang, and P. Chen, "Simulative investigation on head injuries of electric self-balancing scooter riders subject to ground impact," *Accid. Anal. Prev.*, vol. 89, pp. 128–141, 2016.

[7] C. Nakagawa, K. Nakano, Y. Suda, and Y. Kawarasaki, "Experiment on the safety and comfort of personal mobility vehicles in pedestrian flows," *Trans. Soc. Automot. Eng. Japan*, vol. 41, no. 10, pp. 941–946, 2010.

[8] C. Nakagawa, K. Imamura, A. Shintani, and T. Ito, "Influence of the size of a personal mobility vehicle on the affinity with a pedestrian," in *Proc. ASME 2012 5th Annu Dyn Syst Control Conf Jt with JSME 2012 11th Motion Vib Conf DSCC 2012-MOVIC 2012*, 2012, pp. 1–8.

[9] Q. T. Pham, C. Nakagawa, A. Shintani, and T. Ito, "Experimental evaluation of an assistance system for the driver of a personal mobility vehicle," *Adv. Sci. Lett*, vol. 22, no. 9, pp. 2077–2081, 2016.

[10] Q. T. Pham, C. Nakagawa, A. Shintani, and T. Ito, "The effect of a semi-active driving assistance system on the driver of a four-wheeled personal mobility vehicle," *Int. J. Mech. Eng. Robot. Res.*, vol. 6, no. 4, pp. 322–326, 2017.

[11] Y. Murakami, Y. Kuno, N. Shimada, and Y. Shirai, "Intelligent wheelchair moving among people based on their observations," in *Proc. IEEE Syst. Man Cyber.*, 2000, vol. 2, pp. 1466–1471.

[12] T. Q. Pham, C. T. Van, and M. T. Le, "Design and implementation of an electric wheelchair operating in different terrains," *Int. J. Mech. Eng. Robot. Res.*, vol. 6, no. 9, pp. 797–802, 2020.

[13] C. Dias, M. Iryo, and H. Nishiuchi, "Evaluation of safe avoidance distance for pedestriansin personal mobility vehicles and pedestrian mixed traffic: A simulation-based study," *J. East Asia Soc. Transp. Stud.*, vol. 12, pp. 1994–2005, 2017.

[14] Y. Hasegawa, C. Dias, M. Iryo-Asano, and H. Nishiuchi, "Modeling pedestrians' subjective danger perception toward personal mobility vehicles," *Transp Res Part F Traffic Psychol Behav.*, vol.56, pp. 256–267, 2018.

[15] L. Shui-Chun and T. Ching-Chih, "Development of a self-balancing human transportation vehicle for the teaching of feedback control," *IEEE Trans Educ*., vol. 52, no.1, pp. 157–168, 2009.

[16] M. U. Draz, M. S. Ali, M. Majeed, U. Ejaz, U. Izhar, "Segway electric vehicle," in *Proc. International Conference on Robotics and Artificial Intelligence*, 2012, pp. 34–39.

[17] T. J. Ren, T. C. Chen, C. J. Chen, "Motion control for a two-wheeled vehicle using a self-tuning PID controller," *Control Eng. Pract.*, vol. 16, no. 3, pp. 365–375, 2008.

[18] S. Jung, S. S. Kim, "Control experiment of a wheel-driven mobile inverted pendulum using neural network," *IEEE Trans. Control Syst. Technol.*, vol. 16, no. 2, pp. 297–303, 2008.

[19] Q3 Chariot - Stand & Ride Electric Personal Transporter. [Online]. Available: http://www.scootercatalog.com/q3-chariot-snr-electric-scooter.html.

[20] T. Q. Pham, C. Nakagawa, A. Shintani, T. Ito, "Modeling and simulation of multiple personal mobility vehicles in pedestrian flows using personal space," *J. Adv Simul Sci Eng*., vol. 2, no. 2, pp. 255–270, 2015.

[21] T. Q. Pham, "Investigation of avoidance assistance system for the driver of a personal transporter using personal space: A simulation-based study," *Int. J. Mech. Eng. Robot. Res.*, vol. 8, no. 2, pp. 254–259.

[22] Brushless vibration motor - product catalog. [Online]. Available: https://www.precisionmicrodrives.com/.

[23] C. Nakagawa, K. Nakano, T. Koga, Y. Suda, Y. Kawarasaki, Y. Kosaka, "Evaluation of Personal space for pedestrians encountering personal mobility vehicles," in *Proc. 20th Intelligent Transport Systems World Congress*, Tokyo, Japan, 2013, pp. 1–10.

[24] T. Q. Pham, C. Nakagawa, A. Shintani, T. Ito, "Evaluation of the effects of a personal mobility vehicle on multiple pedestrians using personal space," *IEEE Trans. Intell. Transp. Syst.*, vol. 16, no. 4, pp. 2028-2037, 2015.

Pham Quoc Thai received the B.S. and M.S. degrees in control engineering and automation from University of Science and Technology, the University of Danang, Danang, Vietnam, in 2005 and 2009, respectively, and the Ph.D. degree in mechanical engineering from Osaka Prefecture University, Japan in 2017.

Since 2006, he has been a Lecturer with the Faculty of Transportation Mechanical Engineering, University of Science and Technology, the University of Danang. Since 2020, he has been an Associate Professor with University of Science and Technology, the University of Danang. He was the Vice Dean in 2017 and has been Dean of the Faculty of Transportation Mechanical Engineering since 2018. His study interests include modeling, simulation, control of vehicles, automotive electronics and electrical systems, and intelligent transportation systems.

Dr. Pham has been a recipient of the Japanese Government (MEXT) Scholarship for his study in Japan. Since December 2015, he has served as the Reviewer of IEEE Transactions on Intelligent Transportation Systems, International Journal of Intelligent Transportation Systems Research, and International Journal of Sustainable Transportation. He also served as the Section Co-Chair of the 2015 International Conference on Integrated and Sustainable Transportation, and the Chair Program of the 5th International Conference on Control, Robotics and Informatics.

Chihiro Nakagawa received M.S. and Ph.D. degrees in mechanical engineering from the University of Tokyo, Tokyo, Japan, in 2007 and 2010, respectively.

From 2010 to 2018, she was an Assistant Professor at the Mechanical Engineering Department, Osaka Prefecture University. Since 2018, she has been an Associate Professor with the Graduate School of Engineering, Osaka Prefecture University. Her research interests include mechanical dynamics, vehicle dynamics, multibody dynamics, and intelligent transportation systems.

Atsuhiko Shintani received the B.S. degree in mechanical engineering, the M.S. degree in mechanical and system engineering, and the Ph.D. degree in information and production science from the Kyoto Institute of Technology, Kyoto, Japan, in 1992, 1994, and 1997, respectively.

From 1997 to 2007, he was a Research Associate with the College of Engineering, Osaka Prefecture University. From 2007 to 2018, he was an Associate Professor with the College of Engineering, Osaka Prefecture University. Since 2018, he has been a Professor with the Graduate School of Engineering, Osaka Prefecture University. His study interests include fluid/structure interaction, flow-induced vibration, vibration control, human engineering, and intelligent transportation systems.

Tomohiro Ito received the B.S. and the M.S. degrees in industrial mechanical engineering from Osaka University, Osaka, Japan, in 1975 and 1977, respectively, and a Ph.D. degree in mechanical engineering from Tokyo Metropolitan University, Tokyo, Japan, in 1995.

From 2002 to 2005, he was an Associate Professor with the Graduate School of Engineering, Osaka Prefecture University. Since 2005, he has been a Professor with the Graduate School of Engineering, Osaka Prefecture University. He is the author of three books, more than 100 articles, and more than 70 inventions. His research interests include fluid/structure interaction, flow-induced vibration, seismic design, vibration control and reduction, base isolation, noise control and reduction, human dynamics, and intelligent transportation systems.

Dr. Ito received the Outstanding Technical Paper Award of the Pressure Vessels and Piping Division of the American Society of Mechanical Engineers in 2004 and 2009.