Analysis of Human Behavior During Braking for Autonomous Electric Vehicles

Khairul Ikram, Wan Khairunizam, A. B. Shahriman, D. Hazry, Zuradzman M. Razlan, Hasri Haris, Hafiz Halin and Chin S. Zhe

Abstract Nowadays, the development of modern technologies in the transportation area has increased rapidly. The latest technology is focused on autonomous vehicles. The most important aspect in autonomous vehicle control systems is safety, smooth operation and comfort. It can be provided by the natural element which is from human behavior as a reference to the autonomous control system. This paper is briefly describing the human behavior during braking for autonomous electric vehicle (AEV) control system development. To obtain the human behaviour during accelerating and braking, two units of angle sensors were installed to the accelerator and brake pedal of an electric car to measure the angle of both pedals. Real-time speed is recorded by using a GPS unit. The experiment is focused on braking characteristic of the electric vehicle. It was carried out based on four different distances with fixed initial speed before braking action was recorded. A software interface was designed to display and control real-time speed and pedal angle value during operation.

Keywords Autonomous electric vehicle · Transportation · Autonomous control system · Human behaviour

K. Ikram (✉) · W. Khairunizam · A. B. Shahriman · D. Hazry · Z. M. Razlan · H. Haris · H. Halin · C. S. Zhe
School of Mechatronic Engineering, Universiti Malaysia Perlis UniMAP, Kampus Pauh Putra, 02600 Arau, Perlis, Malaysia
e-mail: iqram832@yahoo.com

W. Khairunizam
e-mail: khairunizam@unimap.edu.my

A. B. Shahriman
e-mail: shariman@unimap.edu.my

H. Haris
e-mail: hasri@unimap.edu.my

H. Halin
e-mail: hafiz@unimap.edu.my

A. Öchsner (ed.), *Engineering Applications for New Materials and Technologies*, Advanced Structured Materials 85, https://doi.org/10.1007/978-3-319-72697-7_37

1 Introduction

In the recent time, the technology in transportation has become more advanced day by day [1]. It has transformed from old internal combustion engines to hybrid systems before the autonomous electric vehicle (AEV) was invented. Longitudinal control becomes the fundamental component in AEV technologies to keep the vehicle moving at the desired speed by controlling throttle and brake precisely. This is to ensure that the driver is safe and comfortable during accelerating and braking. In acceleration control, Bjomberg [2] has proposed an autonomous intelligent cruise control technique to aid the driver to keep the desired speed on the highway.

For braking control, many new research and inventions were developed day by day. In 2003, Emami [3] was proposing an antilock braking system (ABS) using a discrete-time adaptive fuzzy sliding mode controller. The non-linear function of the plant was controlled using two fuzzy approximations. The aim of the project was to reduce the dependence on mathematical models, just assuming on certain upper and lower bound of uncertainties. The development of autonomous control continued using the robotic driver by Nicholas [4] in 2008. PID controllers were used to control both steering and pedal actuator. Input is from a combination between a 6-axis inertial measurement unit and GPS. In 2011, Chang [5] developed an electronic braking system (EBS) to increase the braking performance in standard cars. This system focused on passenger comfort. The main point was to obtain the maximum deceleration based on different road condition.

In 2012, Jonas [6] has introduced a system to avoid collision by automatic control on brake and steering during emergency events. Closed-form expressions were derived based on longitudinal prediction and measurement errors. For autonomous braking, Kopert [7] highlighted the autonomous emergency braking system in 2013 for high safety standard in commercial cars. In 2014, Sachin [8] highlighted the automatic car braking system using a combination between fuzzy logic and PID controller. Responses on both controllers were compared to achieve the best result. By latest, Frederik [9] has introduced driver intention recognition to automatically give warning and braking in emergency situation on safe behavior planning on 2015. The automatic system could be cancelled in case of existing braking intention by the driver.

This paper is organized as follows. Section 1 describes the literature review in development of brake and acceleration control during recent time. The following section introduces hardware configurations, design of experiment and all the methods used to extract data in this paper. Section 3 shows the test result of the experiment and the conclusion.

2 Methodology

2.1 Flow Chart

The overall process to obtain braking characteristic of human behavior is shown in Fig. 1. The speed control configuration of the electric cars (golf buggy car) is determined before deciding the methods for measuring human characteristic behavior on pedal control. Based on the speed change characteristic, it is proportional to the movement of the accelerator pedal, so we decided to use the pedal angle as the primary measure for the position of the pedal.

As to measure the pedal angle, a pair of the potentiometers (see Fig. 2) was installed into the car for both brake and accelerator pedals. Global Positioning System (GPS) was used to indicate the real time speed (see Fig. 3).

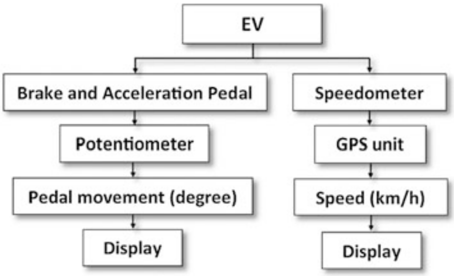

Fig. 1 Flowchart of the buggy car speed control

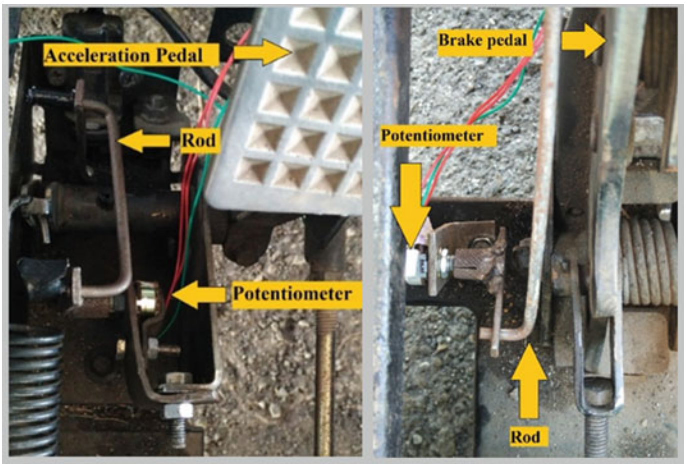

Fig. 2 Potentiometer installation on brake and accelerator pedal

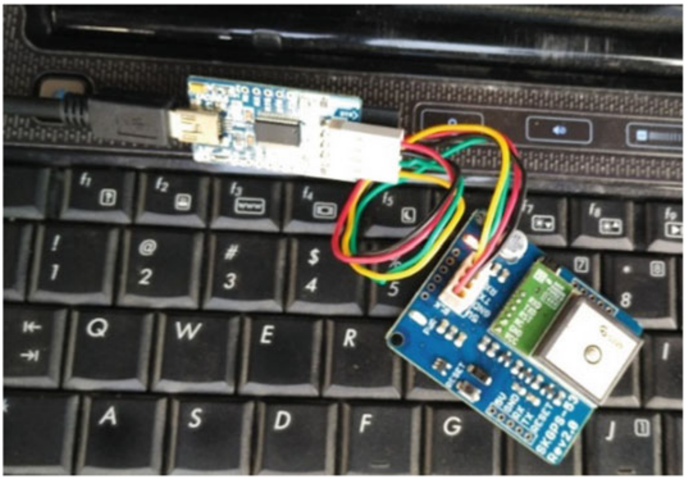

Fig. 3 The GPS unit for speed measurement

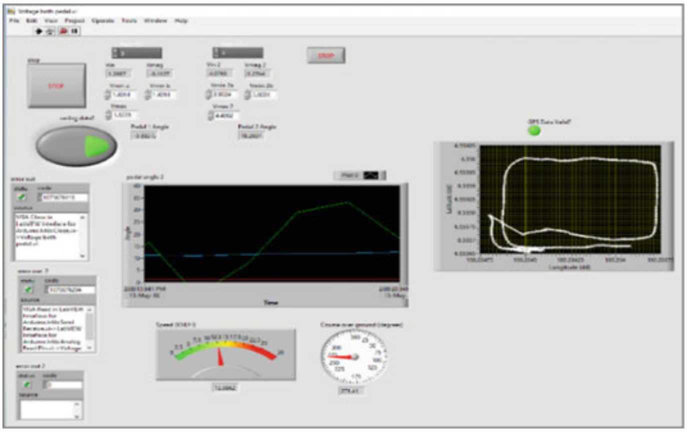

Fig. 4 User interface by using LabVIEW software

During the experiment, all input data will be displayed on a computer by using a pre-designed user interface based on the LabVIEW software as shown in Fig. 4. The real-time data will be recorded before analyzed after the experiment.

2.2 Design of Experiment

The experiment is carried out at the Institut Kemahiran MARA Perlis (IKM). Based on the design of experiment (DOE) as shown in Fig. 5, to obtain appropriate data for braking characteristic, the test is performed in terms of braking distance. Four different distances were chosen which is 5, 8, 10 and 17 m by considering the speed of the car before stopping action. The hallway has 50 m in distance to maintain the car speed at 15 km/h before entering the braking zone. There were five selected subjects as the respondents in this trial of braking [4]. The respondents are males and ages between 19 and 26 years old with driving experience.

2.3 Experimental Result

In this section we present the experimental result based the DOE in Fig. 5. An analysis of the experimental graph in Fig. 6 shows the relationship between the accelerator and brake pedal angle with the speed change, especially the effect of braking action in terms of speed drop. The first and second graph from the top, shows the acceleration and braking characteristic based on pedal angle (degree). Maximum pedal angle for accelerator and brake pedal are respectively 40° and 22°. The bottom graph indicates the corresponding speed (km/h). All the graph's *x*-axis represents the time in second (s). Four different color's lines in the graph indicate the four different distances that were tested.

Refer to Fig. 6, the initial condition is maintaining speed at 17 km/h for all distances. When entering the braking zone, volunteers must stop the car before the stop line (based on the given braking range) which is 5, 8, 10 and 15 m. Volunteers were advised to operate the pedals naturally as they drive a normal car. We can observe two main aspects from the graph which is the time taken to brake from zero-degree angle to fully pressed and the time taken for the vehicle start to decelerate until it fully stops. The different distance ranges have different results. During 5 m operation, braking action started on 20th second and the pedal was fully pressed on 22th second. So it takes 2 s to fully press the pedal. The 8 and 10 m braking graph is equally consuming 3 s to before the brake pedal is fully

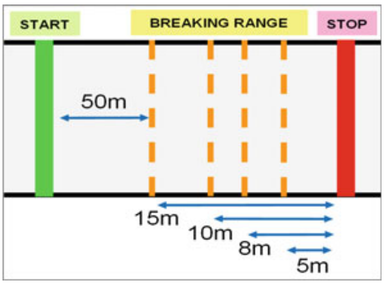

Fig. 5 Design of experiment (DOE)

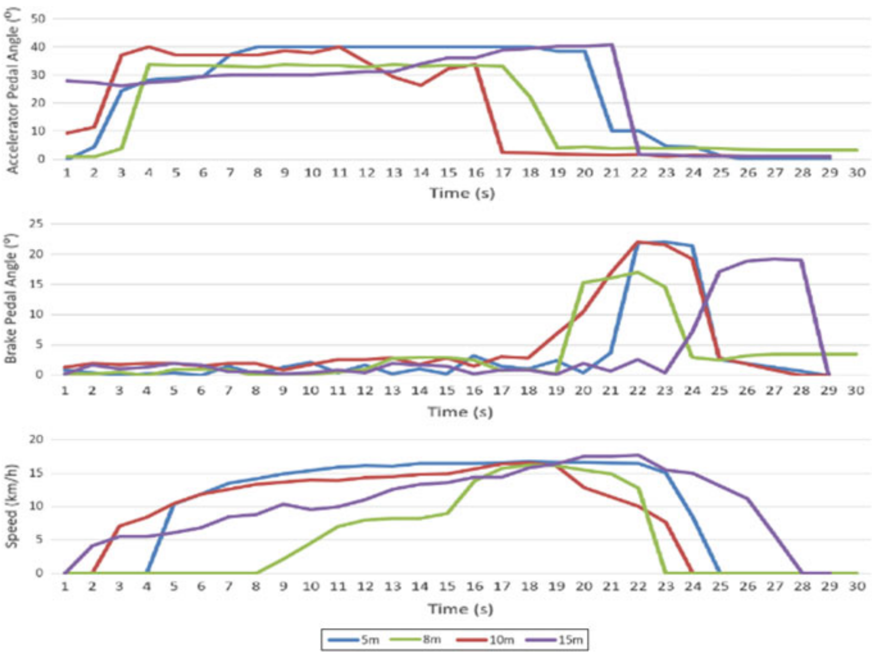

Fig. 6 Experimental results for 5, 8, 10 and 15 m braking range

pressed. The 15 m braking graph is taking brake action from 23rd second to 20th second, which is used the 5 s to perform the braking.

On the speed changes, for 5 m stop range, the speed starts to decrease on 22th second and the vehicle fully stops at 25th second. So its only take 3 s to reduce the speed from 17 to 0 km/h. On 8 and 10 m distance, the speed starts dropping equally at 19th second, but both are fully stopped at one second time interval, which is 23rd second and 24th second. So it takes 4 s in 8 m, and 5 s in 10 m to stop the vehicle. For 15 m, it is required 6 s to fully stop which is the speed start to drop at 22th second before fully stop at the 28th second. The graph pattern is similar generally, the only difference is the time taken for braking. So, the 15 m graph has a bigger curve than the 5 m graph.

As the conclusion, the closer the distance for braking, the shorter the time required to press the brake pedal from zero-degree angle until maximum degree. Moreover, its also means that the vehicle speed is falling faster from 17 to 0 km/h when compared to a longer braking distance. The shorter braking distance shows that in the emergency situation, human is in panic and will press the braking more harshly than usual. A longer braking distance gives more space to slowly perform the braking. This is normal to the human behavior, as we are not a computer programmed machine.

Acknowledgements I would like to thank all team members of the UniMAP Advanced Intelligent Computing and Sustainability Research Group (AICoS), School of Mechatronics Engineering, University Malaysia Perlis (UniMAP), Unit Penyelidikan Teknologi Sukan Permotoran UniMAP (MOTECH) and Centre of Excellence For Unmanned Aerial Systems (COEUAS) for their work and their help in this research.

References

1. Li, L., Wang, F.: Advanced Motion Control and Sensing for Intelligent Vehicles, Tucson AZ85721. Springer, Berlin (2007)
2. Bjomberg, A.: Autonomous Intelligent Cruise Control, Gothenburg (1994)
3. Akbarzadeh, R.: Adaptive Discrete-Time Fuzzy Sliding Mode Control for Anti-Lock Braking Systems, pp. 335–340 (2003)
4. Wong, N., Chambers, C., Stol, K., Halkyard, R.: Autonomous Vehicle Following Using a Robotic Driver, pp. 2–4 (2008)
5. Chang-fu, Z.: A Control Strategy of Electronic Braking System based on Brake Comfort, pp. 1265–1268 (2011)
6. Nilsson, J., Odblom, A.C.E., Fredriksson, J.: Worst Case Analysis of Automotive Collision Avoidance Systems, vol. 11, no. 4 (2015)
7. Kopetz, H., Poledna, S.: Autonomous Emergency Braking: a System-of-Systems Perspective, Vienna (2013)
8. Hirulkar, S., Damle, M., Rathee, V., Hardas, B.: Design of Automatic Car Braking System Using Fuzzy Logic and PID controller, pp. 413–418 (2014)
9. Diederichs, F., Spath, D.: Driver Intention Algorithm for Pedestrian Protection and Automated Emergency Braking Systems, pp. 1049–1054 (2015)
10. Schmitz, M., Hanig, M., Jagiellowicz, M., Maag, C.: Impact of a combined accelerator–brake pedal solution on efficient driving. IET Intell. Transp. Syst. **7**(2), 203–209 (2013)