Autonomous Vehicle: Introduction and Key-elements

Hafiz Halin, Wan Khairunizam and Hasimah Ali
Advanced Intelligent Computer & Sustainable Research Group (AICoS), Faculty of Electrical Engineering Technology, Universiti Malaysia Perlis, Pauh Putra Campus, 02600 Arau, Perlis
hafizhalin@studentmail.unimap.edu.my, khairunizam@unimap.edu.my

Abstract. The development of autonomous vehicles is undergoing extensive research because the autonomous system must ensure passenger safety. Consumers are concerned about vehicle safety, data privacy, system safety, and the autonomous vehicle's legal liability. Autonomous develop based on several key elements; perception, data processing, path planning, and control system. Comfort and a safe autonomous system can be achieved by creating a controller that can imitate human intelligence and decision-making ability. The proposed controller will be developed from an analysis of the human driving characteristic. The Allied Research Market forecast the autonomous vehicle industries can generate a lot of revenue in the future.

1. Introduction
The autonomous vehicle is ongoing research. Autonomous vehicle researcher aims to develop a usable and reliable autonomous vehicle with the high adaptability to the diverse traffic condition. An autonomous vehicle must capable of recognizing the surrounding vehicle, road sign, pedestrian other unexpected obstacles. Detection accuracy and risk prediction of the autonomous vehicle are crucially related to the passengers’ safety.

Society of Automotive Engineers (SAE) classifies the autonomous system into 6 different levels. Level 0 is for the manual car without any autonomous/automatic system. While level 5 is the fully autonomous vehicle without humans intervention for navigation [1]. Currently, only level 3 autonomous system is used in domestic vehicles. The autonomous system in level 3 vehicle only engages when specific requirements are fulfilled, and the system still needs human/driver intervention. Self-parking, lane departure warning, and cruise control are examples of the system in the level 3 autonomous system.

The idea of the autonomous vehicle existed since 1939 by General Motors. In 1964, the Stanford Artificial Intelligence Laboratory started developing an autonomous cart with an AI system to navigate an unfamiliar environment [2]. The Stanford cart is designed for the Mars exploration project. Since then, the research in autonomous vastly improve. Some companies develop a level 4 autonomous vehicle, but the system still in the testing phase. Past reports indicate the company such as Waymo, GM motor, Grab, and Tesla are examples of several companies that are currently testing autonomous vehicle on the road [3].

The controller used in the autonomous vehicle varies from low-level controller to the Artificial Intelligence (AI) controller. Controllers such as Model Predictive Control [4]-[6], Fuzzy controller [7]-[9], neural network [10], [11], machine learning[12], and many others are widely used in the autonomous vehicle. Certain researcher combines several controllers to improve the performance of the autonomous vehicle. [13] combine Fuzzy and PID controller to drive the mobile robot. The controller can self-tuning
the PID parameter for the motor control of the mobile robot. While [14] use an adaptive Neuro-Fuzzy inference system for environment recognition. Neuro-Fuzzy system by [14] able to avoid the obstacle and then return to the target pathway successfully with tracking error of 8.1%. The hybrid controllers give better performance than the stand-alone controller as the hybrid controller complement both controller weaknesses.

The application of the autonomous varies from a small robot to large vehicles like an airplane. The autopilot system in the airplane is an example of an autonomous system as it maintains the airplane attitude. Grab Holdings Inc also interest in incorporating an autonomous system for their e-hailing services [15]. The autonomous system is not exclusive to the land-based vehicle and includes the drone, blip, ship, quadcopter, and many more.

This paper consists of the introduction, autonomous vehicle fundamental design, proposed autonomous research, and discussion about autonomous vehicles' future. Chapter 1 is the introduction about the autonomous vehicle. Chapter 2 focuses on the general element for the autonomous. Chapter 3 is the proposed research for an autonomous system that will be developed. Lastly, Chapter 4 is a discussion about the future of the autonomous vehicle.

2. Autonomous Vehicle Fundamental design

The autonomous vehicle is design based on four fundamental elements as shown in Figure 1. Perception, data processing, path planning and control are the fundamental aspect of design an autonomous vehicle. Perception uses the sensors to gather information from the surrounding. The sensors (perception) gather appropriate data for data processing. The path planning executes from the process data. Several techniques are used for path planning, such as Stanley [16] and pure pursuit[16]. Then, path planning is used to navigate the autonomous vehicle to follow the desire/planned. The controller is used to control the vehicle steering angle, speed, and heading of the autonomous vehicle. PID, sliding control, Fuzzy controller, NMPC, and pure pursuit are examples of the autonomous vehicle's controller. The autonomous vehicle's orientation and vehicle direction are monitored continuously during navigation to reduce path tracking errors. Path tracking error is the distance between the Centre of Vehicle (CG) to the desired path.

![Figure 1. Autonomous vehicle architecture](image)

3. Propose an autonomous system

The proposed system consists of two parts, which is the data collection and the simulation design. The system is designed by analyzing data from the Human Navigation Experiments [17]. The subject instructs to drive an electric vehicle with sensors attached to it for the data collection. Data such as vehicles' orientation (from IMU), GPS coordinate, speed, steering wheel angle, steering angle are collected during Human Navigation experiments. These data then use to develop the controllers. In order to develop a controller with human characteristic embedded is the reason why human navigation experiments are done. There are three controllers that will be developed: Fuzzy controller, Nonlinear
Model Predictive Control (NMPC), and Neural network. The simulation will be conducted to compare the performance of the three controllers. The overall flow chart shows in Figure 2.

![Figure 2. Research flow chart](image)

4. Future of the Autonomous vehicle

The number of vehicles on the road increases each year. With this, the progress of autonomous vehicles is not impossible. Each year, automotive companies try to produce an advanced vehicle with new technology. The automotive industry's current trend is more skewed to the development of smart vehicles, for example, the automatic parking system, lane-keeping, cruise control, and collision avoidance system. This trend shows the consumer slowly accept the autonomous system in their vehicle.

Tesla is the leading automotive company that produces a vehicle with an embedded autopilot system. The autopilot system in the Tesla needs to be activated manually, and the autopilot system still requires the driver to input every 10-15 minutes. The autopilot sometimes cannot detect specific obstacles on the road. In this situation, the driver needs to take control of the vehicle [18]. This situation shows the available autonomous vehicles still need further studies and improvements.

The demand for the vehicle with autonomous system increases each year [15], [19], [20]. The Allied Research Market estimates the autonomous vehicles industries projected $556.67 billion market size in 2026. In 2019, the market size for the autonomous vehicle was $54.23 billion [20].

The autonomous system researcher aims to develop a Level 5 autonomous vehicle, which is a fully autonomous system without human intervention. The autonomous vehicle can obey the law whereas, the human driver deliberately speeding, uses the emergency lane, does not use indicator light when needed, and others misconduct. The autonomous vehicle will revolutionize public transport, health, and the environment [21].

Acknowledgement

The author would like to acknowledge the financial support from Universiti Malaysia Perlis under Publication Scheme UNIMAP.
References
[1] Shuttleworth J 2019 SAE J3016 automated-driving graphic SAE International [Internet] Retrieved from: https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic. [Accessed: 24-Dec-2019]
[2] Weber M 2014 Where to? A History of Autonomous Vehicles CHM BLOG [Internet] Retrieved from: https://computerhistory.org/blog/where-to-a-history-of-autonomous-vehicles/?key=where-to-a-history-of-autonomous-vehicles [Accessed: 10-Feb-2020]
[3] Lee Waymo T B 2017 Makes History Testing on Public Roads With No One At The Wheel ars technica
[4] Yu R Guo H Sun Z and Chen H 2015 MPC-Based Regional Path Tracking Controller Design for Autonomous Ground Vehicles in 2015 IEEE International Conference on Systems, Man, and Cybernetics pp. 2510–2515
[5] Zhou H Guvenc L and Liu Z 2017 Design and evaluation of path following controller based on MPC for autonomous vehicle in 2017 36th Chinese Control Conference (CCC) pp. 9934–9939
[6] Batkovic I Rosolia U Zanon M and Falcone P 2021 A Robust Scenario MPC Approach for Uncertain Multi-Modal Obstacles IEEE Control Syst. Lett. 5 3 pp. 947–952
[7] Haris H Wan K Hazry D and Razlan Z M 2013 A fusion of sensors information for autonomous driving control of an electric vehicle (EV) IOP Conf. Ser. Mater. Sci. Eng. 53 1 p. 012025
[8] Fernandez Llorca D et al. 2011 Autonomous pedestrian collision avoidance using a fuzzy steering controller in IEEE Transactions on Intelligent Transportation Systems 12 2 pp. 390–401
[9] Nguyen A T Sentouh C Zhang H and Popiel J C 2019 Fuzzy Static Output Feedback Control for Path Following of Autonomous Vehicles With Transient Performance Improvements IEEE Trans. Intell. Transp. Syst. pp. 1–11
[10] Ambarak J M Ying H Syed F and Filev D 2017 A neural network for predicting unintentional lane departures in 2017 IEEE International Conference on Industrial Technology (ICIT) pp. 492–497
[11] Wang X, Xu Y, Jia P, Peng Y, and Li W 2010 Study on intelligent vehicle’s steering control system using BP neural networks in 2010 3rd International Conference on Computer Science and Information Technology 8 pp. 185–189
[12] De Morais G A P et al. 2020 Control Engineering Practice Vision-based robust control framework based on deep reinforcement learning applied to autonomous ground vehicles Control Eng. Pract. 104 p. 104630
[13] Heikkinen J Minav T and Stotckaia A D 2017 Self-tuning parameter fuzzy PID controller for autonomous differential drive mobile robot in 2017 XX IEEE International Conference on Soft Computing and Measurements (SCM) pp. 382–385
[14] Xue H Zhang Z Wu M and Chen P 2019 Fuzzy Controller for Autonomous Vehicle Based on Rough Sets IEEE Access 7 pp. 147350–147361
[15] Grab the Right Angles on Autonomous Vehicle Investing with ARKQ | Nasdaq. [Internet] Retrieved from: https://www.nasdaq.com/articles/grab-the-right-angles-on-autonomous-vehicle-investing-with-arkq-2021-02-08. [Accessed: 14-Feb-2021]
[16] Domina A and Tihanyi V 2019 Path following controller for autonomous vehicles 2019 8th IEEE Int. Conf. Connect. Veh. Expo ICCVE 2019 - Proc.
[17] Halin H et al. 2019 Analysis of Human Behaviour while Controlling the Steering Wheel of a Buggy Electric Vehicle (EV) IOP Conf. Ser. Mater. Sci. Eng. 557 p. 012011
[18] Tesla Crash Investigators Slam Autopilot Deficiencies, Lack Of U.S. Rules For ‘Partially Automated’ Cars. [Internet] Retrieved from: https://www.forbes.com/sites/alanohnsman/2020/02/25/tesla-crash-investigators-slam-autopilot-deficiencies-lack-of-us-rules-for-partially-automated-cars/?sh=28777f6b2255. [Accessed: 15-Mar-2021].
[19] I. Grand View Research 2020 Autonomous Vehicle Market Demand to Reach 4.2 Million Units by 2030 https://www.bloomberg.com/. [Internet] Retrieved from: https://www.bloomberg.com/press-releases/2020-04-06/autonomous-vehicle-market-demand-to-
reach-4-2-million-units-by-2030-grand-view-research-inc. [Accessed: 13-Feb-2021].

[20] JadHAV A 2018 Autonomous Vehicle Market Size, Share and Analysis | Forecast 2026 AT: Electric and Hybrid Vehicles, 2018. [Internet] Retrieved from: https://www.alliedmarketresearch.com/autonomous-vehicle-market

[21] Crayton T J and Meier B M 2017 Autonomous vehicles: Developing a public health research agenda to frame the future of transportation policy J. Transp. Heal. 6 pp. 245–252