A Fusion Of Sensors Information On Path Tracking For Autonomous Driving Control Of An Electric Vehicle (EV)

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Abstract. Depending on an intellectual level and experience, each human may make judgments and respond to situations autonomously. The driver is alerted and knows what to do in a specific circumstance while driving. This research aims to see how individuals act when driving an electric car down a predetermined path. An electric buggy car is built with equipment and sensors called an Electric Vehicle (EV) in experiments. Individuals who meet specified requirements are chosen to analyse their driving behaviours, and data is collected using various sensors. The speed, steering wheel angle, heading, and position of the buggy car are recorded throughout the human navigation trials. After the tests, data on human behaviour while driving straight and turning left and right are collected.

1. Introduction

Decision-making is crucial in an autonomous car because the passenger's safety and comfort are at stake. In Malaysia, human error is to blame for 80.6 per cent of fatal road accidents [6]. The figures continue to grow year after year. Lin Li et al. aimed to develop a self-driving system that could emulate human driving behaviours like acceleration and overtaking [11]. After analysing the human drivers' multiple variables like gender, age, driving experience, personality, and mood, they build a personalised system. To provide ideal passenger comfort, the developing controller must use a human-like control mechanism. Artificial intelligence controllers were able to make decisions that were comparable to human choices. The data will be analysed and used to create a Fuzzy controller in the future.

Steering wheel control is required for autonomous cars to follow the chosen path [7] – [9]. This study aims to design a fuzzy controller for an electric surrey automobile based on the study's findings. Human route knowledge minimises the automated and artificial propensity as passengers use autonomous vehicles. The human route trial is an experiment in which data is collected from human drivers as they travel along specified routes. After the studies, data on human behaviour while driving straight, turning left, and turning right will be collected.
Because sensors are an essential part of autonomous vehicles, creating a sensor fusion algorithm that combines them is a popular topic. Sensor fusion is a method of merging data from several sensors to get more precise and concise results. Recent sensor fusion research has focused on filtering techniques. Particle filters, for example, are the subject of a lot of research [1] and could be useful for identifying dynamic impediments [2]. Some research has utilised an extended Kalman filter in non-linear circumstances and found it beneficial [3,4].

The following is a breakdown of the paper's structure: The examination technique is examined in the System Description. The Investigation Setup depicts the investigation's human examination structure. The findings and discussions are introduced in the section Results and Discussion. Finally, the document comes to a close.

2. System Description

2.1. Electric Buggy Car

![Figure 1: Lvtong Electric Buggy Car](image)

The Lvtong electric buggy car (Figure 1) has chosen to develop Autonomous Electric Vehicles for this project. This electric buggy car was easier to modify and equip with several sensors. It was propelled by a 4 kW DC motor, which was fueled by 48V batteries. Table 1 shows the specifications of the electric buggy car that was used.

| Parameter          | Dimension         |
|--------------------|-------------------|
| Model              | LT-A827.2+2       |
| Motor              | 48V;4KW           |
| Battery            | 48VDC             |
| Transaxle          | 12.31:1           |
| Overall Size       | 2785*1210*1910mm  |
| Ground Clearance   | 120mm             |
| Braking Distance   | < 6m              |
| Turning Radius     | 3.2m              |
| Maximum Mileage    | 100km (flat road) |
| Maximum Speed      | 25-40 km/h        |
2.2. Encoder B106

Encoder B106 (Figure 2) was used to identify the buggy car's speed, steering wheel angle, and heading. The encoder B106 is an industrial-grade rotary encoder and is suitable for many positioning applications. It is usually connected to a rotating unit or shaft. Rotation on the encoder will lead to a square wave pulse. The user can identify the speed of the cycle, angle of rotation, the direction of rotation, or even position of the shaft from the pulses. It can be applied on a robot arm's collaborative, mobile robot, conveyor system or even a printing machine. Encoder B106 has been installed at the steering shaft of the buggy car and connected with Arduino and Laptop (for display and monitoring system). Table 2 shows the technical specifications of the rotary encoder B106 that was used.

Table 2: Encoder B106 Technical Specification

| Parameter                  | Value                                      |
|----------------------------|--------------------------------------------|
| Operating Voltage          | DC + 5V to 24V                             |
| Output Voltage             | NPN open collector (require pull-up)       |
| Current consumption        | ~120 mA                                    |
| Maximum Pulse              | 100 kHz                                    |
| Output waveform            | Square wave                                |
| Starting torque            | $1.5 \times 10^{-3}$ Nm (at 25°C)          |
| Moment of inertia          | $3.5 \times 10^{-6}$ kgm$^2$               |
| Max allowable load         | Radial direction = 20N, Axial direction = 10N |
| Maximum shaft speed        | 6000 rpm                                   |
| Vibration resistance       | 50m/s$^2$ 10-200Hz, X, Y, Z directions 2H |
| Shock resistance           | 980m/s$^2$ 6ms, X, Y, Z directions twice   |
| Protection                 | IP54                                        |
| Life span                  | MYBF>10000 hours (25°C, 2000 rpm)          |
| Operating temperature      | -10°C to +70°C                             |
| Storage temperature        | -30°C to +85°C                             |
| Operating humidity         | 30 to 85% without frost                     |
| Mass                       | ~ 100 grams                                |
2.3. **SKM53 GPS**

![Image of Cytron SKM53 GPS](image)

A GPS module (Figure 3) was used to navigate the AEV. The GPS module Cytron SKM53 was selected for navigation. The longitude, latitude, speed, and heading information were extracted for path tracking. The GPS module is installed at the front bonnet of the vehicle to get a clear view of the sky for better accuracy. The PC was used to gather data and process data from the controller. The steering wheel angle, speed, position, and heading are shown on the monitor. Table 3 shows the technical specifications of the Cytron SKM53 GPS that was used.

**Figure 3:** Cytron SKM53 GPS

| Parameter                  | Specification                      |
|----------------------------|------------------------------------|
| Receiver Type              | L1 frequency band, C/A code, 22    |
|                            | Tracking / 66 Acquisition-Channel  |
| Sensitivity                | Tracking -165dBm                   |
|                            | Acquisition -148dBm                |
| Accuracy                   | Position 3.0m CEP without SA       |
|                            | Velocity 0.1m/s without SA         |
|                            | Timing (PPS) 60ns RMS              |
| Acquisition Time           | Cold Start 36s                      |
|                            | Warm Start 33s                     |
|                            | Hot Start 1s                       |
|                            | Re-Acquisition <1s                 |
| Power Consumption          | Tracking <35mA @ 3.3V              |
|                            | Acquisition 45mA @ 3.3V            |
|                            | Sleep/Standby TBD                  |
| Navigation Data Update Rate| 1Hz                                |
| Operational Limits         | Altitude Max 18,000m               |
|                            | Velocity Max 515m/s                |
|                            | Acceleration Less than 4g          |

3. **Experiments And Path Selection**

Human navigation tests were conducted to gather data for the Fuzzy controller's development. The human navigation paths were chosen based on findings from prior research with self-driving automobiles. As previously stated, the researcher chose a path that includes a straight, left, and right curve. Several researchers chose a road with a mix of straight, left, and right turns to test their autonomous systems (Bae et al., 2013; Jo et al., 2014; Perez et al., 2012; Wu, Lee, & Chang, 2007).
Andersen, Chong, Eng, Pendleton, and Ang (2016) tested their autonomous automobile at Singapore University on a constructed track. Among the paths were bezier curves and straight routes.

The paths were selected because they were close to the Automotive Engineering and Electronic Engineering buildings at Institut Kemahiran MARA (IKM) in Beseri, Perlis, Malaysia. The walkway is a complete circle around the building and includes a straight path and left and right turns. The goal of the human navigation testing was to collect data for the development of the Fuzzy controller. Preliminary data was gathered to create a supervised controller. The data that had been evaluated was used to develop the rule-base for the Fuzzy controller.

Figure 4: Flow Chart for Human Navigation Experiments

Figure 4 depicts the flow chart for human navigation experiments. The 15 people were picked based on their prior driving experience. A valid driver's license and no more than ten years of driving experience are required (Hong et al., 2009). The path taken for human research at IKM Beseri in Perlis, Malaysia, is depicted in Figure 5. This study included fifteen volunteers, each of whom had to complete five trials. Each issue must bring the allocated path's cycle to a close. It will take about 700 metres to complete the operation. The circuit is a full circle with a mix of straight path, left turn and right turn that take about 240 seconds to complete.

Figure 5: Selected path for the experiment

Table 4: Straight, Right and Left Turn Remarks for Given Paths

| Point | Remarks          |
|-------|------------------|
| A     | Right Turn       |
| B     | Straight         |
| C     | Right to Left Turn |
| D     | Straight         |
| E     | Left turn        |
| F     | Straight         |
| G     | Left to Right Turn |
4. Results And Discussion

The human navigation studies show each individual's wheel angle and speed characteristics while navigating across the prescribed paths. For straight, left, and right turns, all of the topics provide the same driving characteristic. This section discusses the outcomes for straight, right, and left pathways.

![Graph showing speed vs. subject](image)

**Figure 6:** Result for Min, Max, Average Speed Of All Subject

Figure 6 shows the minimum, maximum, and average speed of all the participants in this experiment. The results show the behaviour of all subjects during controlling EV in the straight path, right turn and left turn. The speed result is from all issues that completed 700 meters of distance and took about 240 seconds to complete a circle.

![Graph showing steering angle vs. time](image)

**Figure 7:** Result for Right Turn

For right and left turns results, a positive sign angle means turning to the left side, while a negative sign angle means turning to the right side. Figure 7 shows the steering wheel angle results during the right turn for the selected subject. The subject has driven an electric buggy car following the path and turns A (displayed at seconds 15) to point B (displayed at seconds 37). Data from the suitable turn experiments have been collected and converted to the graph. The graph shows a different pattern of steering wheel angles between trial two, trial three, trial four and trial five. But different speed characteristics, which trial three early than others. Trial four and trial five look similar, and trial two is a little bit late. The minimum steering wheel angle on a left turn is positive 0 degrees, and the maximum steering wheel angle on a left turn is negative 225 degrees.
Figure 8: Result for Left Turn

Figure 8 shows the steering wheel angle results during the left turn for the selected subject. The subject has driven an electric buggy car following the path given and makes the left turn at point E (displayed at seconds 104) to point F (displayed at seconds 122). Data from the left turn experiments have been collected and converted to the graph. The graph shows a similar pattern of steering wheel angles between trial two, trial three, trial four and trial five. But different speed characteristics, which trial four early than others. Trial two and trial three look similar, and trial five is a little bit late. The minimum steering wheel angle on a left turn is negative 0 degrees, and the maximum steering wheel angle on a left turn is positive 230 degrees.

Figure 9: Result for Straight Path

Figure 9 shows the steering wheel angle results for the straight-line paths for one subject with four trials. The subject has driven an electric buggy car on the straight track. Data from the straight-line experiments have been collected and convert to the graph. The graph shows different steering wheel angle characteristics on a straight path starting from point F (stated at seconds 123) to point G (stated at seconds 158). The steering angle varies because of the roughness of the road conditions. While moving in the straight line, the small changes in steering angle are using the rack and pinion steering systems on the buggy car. The maximum steering wheel angle at the straight path is positive 20 degrees, and the minimum steering wheel angle is negative 10 degrees.

The overall result shows the difference in human behaviour in driving at a straight path, left turn, and right turn based on steering wheel angle and speed results.
5. Conclusion

Creating a fuzzy controller determines the relevance of each action and decision based on human behaviour during fundamental leadership capacity. The driving experiences of the chosen subject's drivers provide a similar driving example for straight, right, and left turns. The conventional base was designed to rely on the human drive for input. The goal of developing a controller that mimics human behaviour is to make passengers of self-driving vehicles feel more secure and comfortable. The exhibition of the fuzzy controller is still being tested. The fuzzy controller constructed in the previous stage will test the autonomous car in a planned manner.

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