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OPTIMISATION OF THE CONTROL SYSTEM OF A SHELL-ECO MARATHON RACE VEHICLE: WORK IN PROGRESS

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ABSTRACT

A Shell Eco-Marathon is used as a platform for aspiring young engineers to expose and nurture their talent in designing and building energy efficient automobiles. This platform hosts a global competition for science, engineering, technology and maths students around the world. The competition inspires students to work together to test their theories and innovative ideas of energy efficient cars. In this study, we are optimising the control system of an existing prototype car, so as to improve the driving range. Tests on the car's performance were conducted using the default controller settings. New settings on the controller were effected and the performance improvements were noted. The new settings regenerative braking functionality for improved energy conservation, automating cruise control for improved drivability at constant speed. The setting for the best driving speed has been noted as well.

KEYWORDS: *Marathon, Automobiles, Competition, Performance, Optimisation*

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INTRODUCTION

Shell Eco-marathon encourages students to use their innovative ideas to design and build efficient race cars. There are two vehicle categories; urban concept vehicles which have familiar road features (always 4 wheels) and prototype which are ultra-efficient lightweight vehicles (generally 3 wheels). There are different energy categories as well; Internal Combustion engine, Hydrogen Fuel cell and Battery-Electric. The best designs are those that can cover a larger distance with the least amount of energy used. This project focuses on a prototype vehicle which will be competing in the Battery-Electric category. In comparison with internal combustion vehicles, electric vehicles have a significantly short range [2]. The efficiency of an electric car depends on many different factors; the design of the car, driving habits and battery capacity are some examples. To promote fairness, there are competition rules which must be followed by every designer. The weight of the car, its dimensions or size, driver weight and battery voltage are some examples of factors that influence efficiency and were standardised for the competition.

The main aim of the project is to optimise the control system of the prototype electric car in order to improve its performance. To investigate the car's performance, the baseline results were collected prior to any developments made on the vehicle. Automatic cruise control and regenerative braking were implemented in the vehicle. Regenerative braking gives the vehicle the ability to save energy when braking while auto-cruise helps to maintain a constant speed without a driver's intervention. It should be noted that there is an override for which the driver takes full control of the vehicle.

LITERATURE REVIEW

This study is based primarily on the electric car (Shell Eco Marathon's battery electric energy category). A research paper [3], indicates that a greater percentage of greenhouse emissions and other pollutants come from road transport at the United Kingdom. The paper argued that this pollution could reduce significantly provided the Electric vehicles are used on a large scale. The most challenging problem about the electric vehicle was found to be the high cost of replacing the batteries during the vehicle's life. This problem can be mitigated by hybridizing the vehicle with on board super-capacitors. Because of all the advantages of the electric vehicles some countries provide incentives to ownership of the cars and the purchases of them. From [4], we get to understand the role of incentives in promoting Battery electric vehicles and also determines which incentives in particular are vital in deciding to own the vehicle. The paper's research statistics showed that exemption from paying purchase tax and value added tax were the most vital incentives for customers in deciding to own the electric cars. The advantages of electric vehicles over internal combustion mostly concern the environmental friendliness and they offer a secure and balance energy option that is efficient and less harmful to the environment [5]. The electric vehicles also offer a way into the future, in many years to come the population would have multiplied, the number of vehicles increased as well but the fuel (oil) may be little or no more. The most disadvantageous things about electric vehicles is theirs cost of battery packs and the limited driving range as compared to internal combustion vehicles. For this project, cruise control method will be used in improving the driving range of a prototype electric car. The project will be able to demonstrate energy optimisation in electric vehicles. This may bring about change to the car industry and may intrigue electric car manufacturers into building more efficient cars.

The driving range of an electric car is considered to be an important factor for electro mobility [6]. For this reason, the driving range and different methods for improvement is covered by many researchers. Cruise control is one of the mostly researched approaches. From [7] an effective cruise control system is proposed whereby the speed of the electric car will depend on the upcoming traffic signal status. The paper also argues that the car will maintain a safe distance from the preceding vehicle since the inter-vehicular distance will be considered. The system was designed using Model Predictive Control Theory, simulated using a Tesla S vehicle model and it was concluded that the proposed controller improved efficiency and range. A comparison was also made between cruise control in electric vehicles using PI and sliding mode control and it was found that sliding mode controller performs much better [8]. Another paper showed that piece-wise control is better than closed loop control [9]. For cruise driving, it was realised that practical driving motors have nonlinear relationship of voltage to speed therefore performance of nonlinearity can be improved using closed loop control for compensation, but it is difficult to obtain good results when the drive motor has highly nonlinear characteristics.

METHODOLOGY

The main goal of the project is to optimise the prototype electric vehicle for the eco shell marathon completion. The competition requires students to team up and design ultra-energy efficient vehicles. They choose the energy category of their choice. For this project it is required to optimise a Battery Electric vehicle for better performance. The project plan was to test the vehicle for baseline results, make changes to the control system and re-test it to compare the results.

The racetrack used for the competition is called Zwartkops raceway and is 2.40km in length. There are competition rules to be followed, some are about how a successful completion of a track route is made. A car should finish a trial in a given time following all the rules, the energy used for a trial will then be taken from a joule metre that is installed in the car. The calculations for efficiency will then be made in terms of how many kilometres can be covered in one kilowatt-hour using, $Efficiency = \frac{length\ of\ racetrack}{Energy\ used\ \left(\frac{km}{KWh}\right)}$

The project was in two stages, the first stage was conducting tests on the controller to determine its performance prior to implementing proposed settings. After examining the competition rules, it was learnt that to complete the race the car will be timed. It was therefore necessary to test the vehicle's performance with the maximum and minimum allowable time to complete, so that the design plan will produce maximum efficiency. The second stage was conducting tests after the controller settings have been modified for maximum efficiency. Regenerative braking capabilities was integrated, and the controller set for automated driving (auto-cruise).

The racing track used was the driveway in between the University of Botswana's Faculty of Engineering blocks (Block 248,249, 251 and 250). The diagram is shown below labelled, Figure 1.

Figure 1: Racing Track Used to Take Baseline Results.

BASELINE RESULTS

The vehicle was taken for a pre-test before the controller could be re-configured or set differently. The racetrack used was a driveway that is in between the Faculty of Engineering Blocks as shown on Figure 1. Few trials were made before recording the results. Results were recorded after every 5 laps, one trial with high driving speed while the other with relatively low speed. This was based on the theory that driving at high speed wastes energy as compared to lower speeds. After every trial the controller was reset so that we start another trial. The two figures below show the vehicle's display after the controller was reset.

Table 1 shows that for two trials on the same racetrack, with equal number of laps the results for energy efficiency differs significantly given that the driving speeds are far much spaced: high and low speed. Driving at a higher speed uses more energy (27.5 Wh/km) than driving slowly (10.1 Wh/km) but it takes a longer time to reach destination. The results obtained are in line with the theory since they clearly show that more than twice the energy was lost when speeding.

Figure 2: One of the CA Screen after It Was Reset.

Figure 3: One of the CA Screen After It Was Reset.

Table 1: Baseline Test Results

Trial 1 (High Driving Speed)					
No of Laps	**Max Speed**	**Avg Speed**	**Watt-Hours/km**	**Trip (Km)**	**Time**
5	35.2	26.9	27.5	0.80	1min 49sec
Trial 2 (Low Driving Speed)					
5	14.0	11.3	10.1	0.80	4min 10 sec

IMPLEMENTATION AND EXPERIMENTAL RESULTS

Table 2 shows different trial, one with a set driving speed of 26km/h and the other with a cruising speed of 40km/h. For both trials the distance covered is equal, this was to show that high speed driving uses more energy.

Figure 4: CA Screen Showing Regenerative Braking.

Table 2: Experimental Results

Trial 1 (High Driving Speed)					
No of Laps	**Max Speed**	**Avg Speed**	**Watt-Hours/km**	**Trip (Km)**	**Time**
4	42.2	39.4	30.6	0.80	1min 13 sec
Trial 2 (Low Driving Speed)					
4	27.7	26.1	25.3	0.80	1min 50 sec

CONCLUSIONS AND FUTURE WORK

This the project involved data collection, analysis, and research on how to optimise the controller. From the baseline results of table 1, it is conclusive that speeding wastes more energy when compared to low speed driving. At the implementation stage, the controller was optimised to save energy. This involved programming the cruise control function so that the car drives automatically at a constant speed. The controller was also configured and wired for regenerative braking to recover energy that would otherwise be lost when the driver apply the brakes.

As a future development, many functions on the vehicle can be made semi or fully automated using artificial intelligence. For example, communication between the driver and the crew those functions can assist the driver. Already the vehicle can move on its own and it can change speed on its own. It can be easily achieved especially when the driving track has lanes, an algorithm for lane detection can be made. Open Source Computer Visual Library (Open CV) is a computer vision and machine learning software library that can be used to achieve this. It is inexpensive to add this functionality, one needs a raspberry pi board and be knowledge of programming. There are many scholarly articles and resources on neural networks and artificial intelligence online.

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