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Speed Calibration for Mobile Robot As Prototypes to Smart Vehicles

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ABSTRACT

Many studies have been done to find the best formula in building a vehicle with self-driving ability. In order for the vehicle to be smart and able to drive on its own, several factors need to be improved. One of the factors is the ability to make decisions. This research conducted experiments on small-scale mobile robots - also known as robot cars - as prototypes to smart vehicles to find the appropriate value for the driving speed of the vehicle after calibration. The study was conducted using Arduino board hardware, remote robot cars, remote controls for remote robot cars, and rotary encoders. Three main experiments were completed to test the calibrated speed values, namely first test on straight line, test on corner lane, and last test on combination of straight path & corner lane. Simulations for road routes are also made using cardboard, sandpaper and carpet. The results of experimental analysis found that as the speed of a robot car increases, the longer it takes to make a single wheel rotation.

Keywords: *Mobile robot, calibration, Arduino, rotary encoder*

INTRODUCTION

Self-driving vehicles have become one of the most studied topics today. Many studies have been done to find the best formula in building a vehicle with self-driving ability. However, in order for a vehicle to be smart and able to drive on its own, several factors need to be refined. Among them is by looking to identify about the features that should exist for it can be called as a smart vehicle.

One of the main factors of a vehicle to be known as a smart vehicle is, a vehicle must have the ability to make its own decisions. Among them is regulating speed in his movements. The purpose of having the ability to adjust the speed is so that it does not easily experience any accidents. Therefore, this study will seek to find a solution related to the speed of smart vehicles by calibrating the speed that should be used.

For this purpose, experiments on small-scale mobile robots as prototypes to smart vehicles will be performed to find the appropriate value for the driving speed of the vehicle after calibration is performed.

RELATED WORKS

This study was conducted based on the purpose of finding the best velocity values to be referred by smart vehicles or vehicles with self-driving characteristics. For that purpose, several journals have been referenced. The earliest journal to be referenced was one that discussed self-driving vehicles. Badue, Guidolini, Carneiro, Azevedo, Cardoso, Forechi, Jesus, Berriel, Paixao, Mutz, Veronese, Oliveira-Santos, and De Souza (2020) have written about self-driving cars. According to them, there are two systems in the architecture of self-driving vehicles, namely the perception system and the decision-making system.

Among the main statements given by Badue et al is the decision-making system factor that can be done by a smart vehicle. Therefore, the next reference looks at the discussion on studies related to the topic of care from hazards such as accidents due to speed. This is because a smart vehicle must always be able to keep itself from getting involved in problems such as accidents. Costa, Rauen, and Fronza (2020) have conducted studies on vehicle velocities that can cause accidents. Their study used video analysis along with local information to build information on velocity. Speed estimates are based on a combination of velocity calculations on videos obtained through photogrammetry techniques and accident-related information at the scene. Through the study, Costa et al have proposed the use of "pixel scale image factor" as a method of calculating the distance from the vehicle to the camera in different video frames.

Next for the purpose of this project, a discussion that studies velocity using sensors and radar as done by Verma and Tandan (2020) has been seen. In their study, Verma and Tandan have collected information on the condition and velocity of vehicles driven using pre-installed sensors and radar. The purpose is to ensure that the latest information obtained can be used to help drivers make decisions during the driving process. Based on the information gathered regarding the speed and condition of the vehicle after the test drive is completed, Verma and Tandan have proposed to compare it with the existing driverless driving system.

Another method as stated by Wang and Horn (2020) discusses how to avoid accidents by providing time-to-contact (TTC) feedback control. In their study, Wang and Horn used detailed mathematical analysis and algorithm implementation to conduct the study. The result was that Wang and Horn stated the machine for the vision-based TTC Algorithm they had discussed, could be used on Android smartphones running in real time.

As a more direct approach to this study, the allocation for the velocity movement of the robot to be implemented is on a small scale. On this factor, discussions by Censi, Franchi, Marchionni, & Oriolo, (2013) have been referred to. In their paper, Censi et al have studied velocity movements on robots using mobile phones equipped with sensors and odometers. Basically, odometry and sensors have been used by Censi et al to estimate the movement of robots. This project has been undertaken to calibrate odometry and sensors simultaneously. The calibration performed on the robot involves an estimate of six parameters: three for odometry for the fingers and the distance between the wheels. While the other three are for the position of the sensor placed on the robot. As a result of experiments, Censi et al found that the calibration of each parameter can be done simultaneously by measuring the wheel velocity and data from the exteroceptive sensor. This can be achieved provided; such methods do not require robots to move along a specific path, and the simultaneous calibration methods performed should be formulated as maximum problems and solutions that can be found in closed form.

Finally, a study on risk in odometer measurement errors such as the discussion conducted by Borenstein & Feng (1996) is referred to. In their study, Borenstein and Feng proposed a reduction in odometric measurement errors in measurements on mobile robots. To this end, Borenstein and Feng have identified major errors that can occur during odometry measurements. To avoid repeated mistakes, Borenstein and Feng suggested that the calibration be done occasionally. The main result obtained with the implementation of occasional calibration is to reduce errors in finding accuracy in odometry.

METHODS

This study was conducted using Arduino Board hardware, remote robot car, remote controller for the remote robot car, and rotary encoder. In addition, Arduino Software (IDE) has been used for program encoding on the Arduino Uno board.

Mobile Robot Programming

A robot car needs travel guidance to allow it to move in an environment. We can provide this guidance through built-in programs. To measure velocity, a rotary encoder will be used to measure the speed limit of the robot car movement.

An algorithm is a sequence of programs that apply a step-by-step solution to solve a problem. Programs written in the Arduino programming language are referred to as sketches. For this project, only one sketch is required. The sketch used is for rotary encoder and LCD display. The sketch will receive the input signal from the rotary encoder, the program will calculate the speed from the input signal and display it on the LCD.

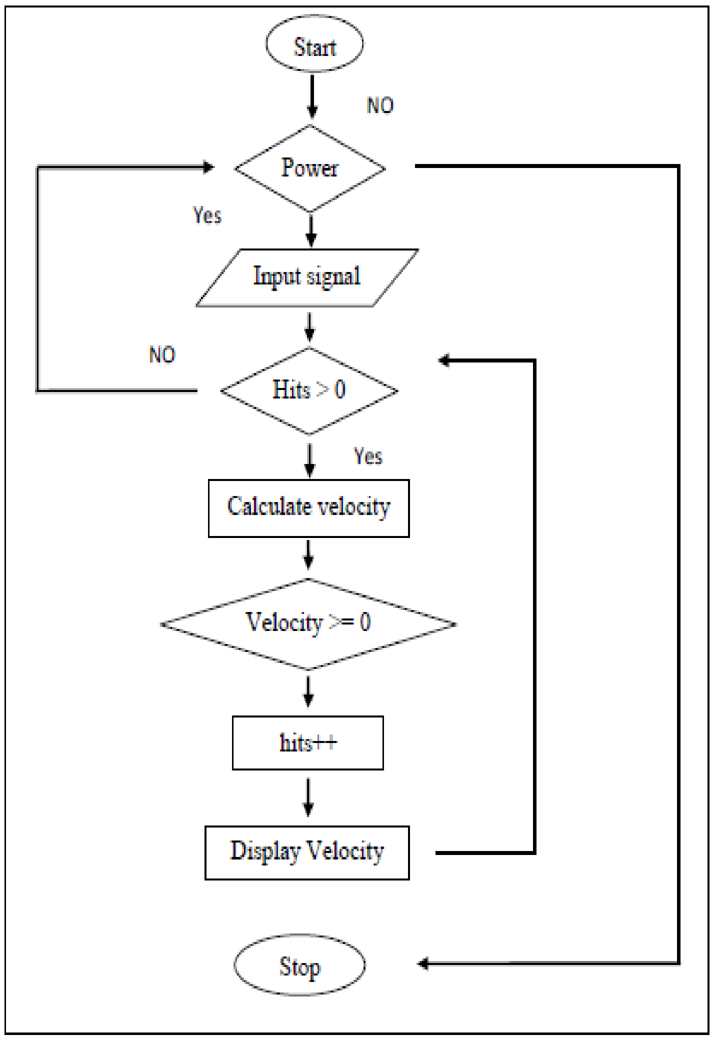

Figure 1: Rotary encoder with LCD flowchart

Environmental Preparation for Speed Calibration

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The environment that normally exists during a moving car will be created as a simulation for the purpose of this study. Among such environments is to create different types of road surfaces for the movement of robot cars. The first environmental situation created was by using cardboard. Cardboard is used in experiments as a simulation of a normal road surface. The second environmental situation created was using sandpaper. Sandpaper is used as a simulation of a road with a rough surface full of rocks. This rough surface is also used to measure the rate of decrease in velocity that occurs due to friction. A third environmental situation was created using a carpet. Carpets are used as a simulation of a road full of long grass for the movement of a car. This grassy surface is also used to measure the rate of velocity that may decrease due to friction or rise due to sliding.

Preparation of Experiments

We have prepared three environmental preparations for the experiments to be carried out with three different road structures. Prior to that, we have also provided a preliminary experiment to determine the time taken by a complete cycle taken by a rotary encoder, and the maximum value of the speed limit that can be detected by a rotary encoder.

i) Preliminary 1: Experiment on Rotary Encoder Rotation

This experiment was performed to see the time taken in one rotation using a rotary encoder. The value obtained will be the benchmark for the next experiment.

ii) Preliminary 2: Experiment on Rotary Encoder Detector

This experiment was performed to see the usability of the rotary encoder detector to be used, up to a maximum velocity level.

iii) Road Structure 1: Experiment with Straight Line Motion

In this experiment, the mobile robot will move for 100 cm in straight line motion as seen in the figure below. Robot mobile will move in different type of surface. Observation is needed when the experiment conducted. The speed of the mobile robot is taken as a result for every experiment conducted.

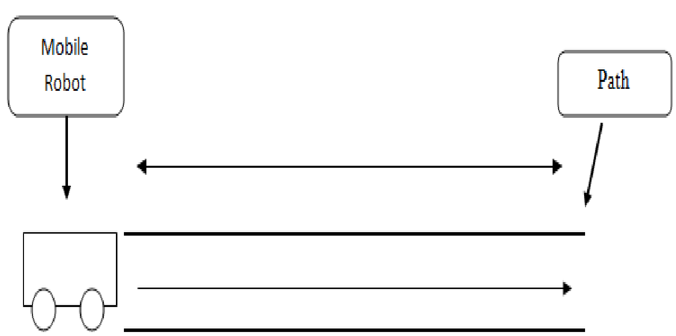

Figure 2: straight line motion

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iv) Road Structure 2: Experiment with Corner Path Motion

In this experiment, the mobile robot will move for 50 cm in corner as soon as started as seen in the figure below. Robot mobile will move in different type of surface. Observation is needed when the experiment conducted. The speed of the mobile robot is taken as a result for every experiment conducted. To calculate the rotation for every experiment, the equation below has been used:

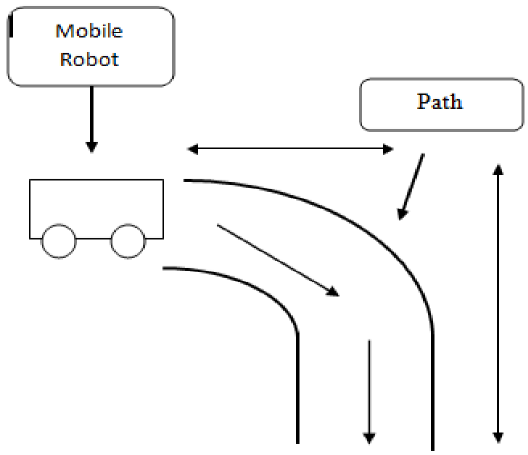

Figure 3: Corner path motion

v) Road Structure 3: Experiment with Straight Line and Corner Path Motion

In this experiment, the mobile robot will move for 50 cm in straight line motion before move in corner path as seen in the figure below. Robot mobile will move in different type of surface. Observation is needed when the experiment conducted. The speed of the mobile robot is taken as a result for every experiment conducted. To calculate the rotation for every experiment, the equation below has been used:

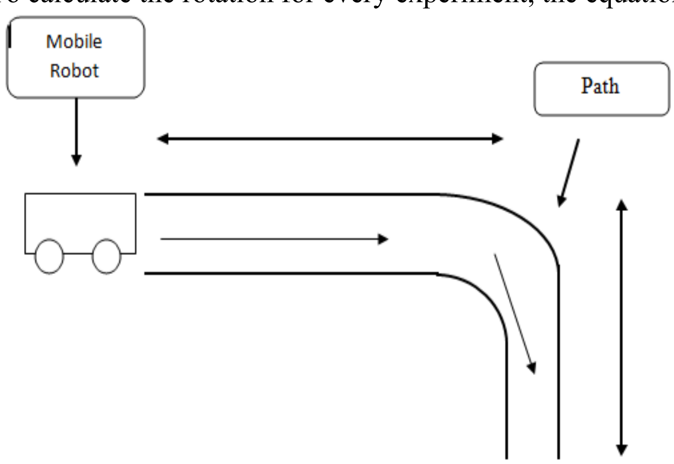

Figure 4: Straight line and corner path motion

We will use the Equation 1 and Equation 2 to calculate the rotation for each experiment happens in Figure 2, Figure 3, and Figure 4.

$$N\ (total\ number\ of\ rotation) = \frac{total\ distance\ travel}{circumference} \quad \text{Equation 1}$$

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$$A\ (time\ taken\ for\ one\ rotation) = \frac{N\ (total\ no\ of\ rotation)}{time\ taken}$$ Equation 2

RESULTS AND DISCUSSION

The results achieved for the preliminary experiments can be concluded as follows:

Preliminary 1 and 2: Experiment on Rotary Encoder Rotation and Rotary Encoder Detector

Table 1: Rotation time

Number of Rotation	Time taken (s)
1	1.5

Table 2: Detection test

Velocity (mm/ms)	Detection (Y/N)
0.00	Y
1.57	Y
4.71	Y
6.28	Y
14.14	Y
15.00	N
15.56	N

The first analysis is the rotary encoder rotation and the detection on the rotary encoder. Based on the experiment in Table 1, it shows that one full rotation of slotted disk take 1.5 second. Based on the experiment in Table 2, rotary encoder only detected small speed than a fast and powerful speed. The encoder only detect speed until 14.14 mm/ms which small and cause the limitation to the research project since it cannot fully utilized it in the experiment. From the experiment, it can be concluded that the higher the speed the higher chances the encoder not to detect the rotation.

The results of experiments related to different road structures can be established as follows:

Road Structure 1: Experiment with Straight Line Motion

In the first structure related to the use of straight roads, two tables namely Table 3 and Table 4 have been formed.

Table 3: straight line motion

Type of Surface	Speed taken (cm/s)	Time taken (s)	Smooth movement (Y, N)
Cardboard	125	0.8	Y
Sandpaper	90.9	1.1	Y
Carpet	83.4	1.2	Y

Table 3 compares the journey made by robot cars on the surface of cardboard, sandpaper, and carpet. The speed on each route is recorded along with the travel time period along the 100cm travel distance. By comparison, it is found that the path on the cardboard is the fastest at 125 cm/s with the shortest duration of 0.8 s. While the carpeted path gives the slowest speed of 83.4 cm/s with time taken for 1.2 s to complete the journey.

Table 4: straight line motion rotation

Type of Surface	Number of rotation	Time taken (s)	Time taken for one rotation (ms)
Cardboard	314	0.8	0.3925
Sandpaper	314	1.1	0.2855
Carpet	314	1.2	0.2617

Table 4 compares the same road structure, but focuses more on the number of turns made. Based on Table 4, we can see that the time taken in one rotation is preceded by a carpeted surface with a duration of 0.2617 ms compared to sandpaper with a duration of 0.2855 ms and cardboard for 0.3925 ms.

Road Structure 2: Experiment with Corner Path Motion

On the second road structure through the corner lane, two tables namely Table 5 and Table 6 were recorded.

Table 5: Corner path motion

Type of Surface	Speed taken (cm/s)	Time taken (s)	Smooth movement (Y, N)
Cardboard	25	1.0	Y
Sandpaper	17.9	1.4	Y
Carpet	19.2	1.3	Y

Again like Table 3, Table 5 also compares three surfaces as paths yet using different road structures. The results of the comparison in Table 5, found that the cardboard again gave the highest velocity of 25 cm/s with a time taken of 1.0 s. However, in contrast to Table 3, in Table 5 it is found that sandpaper gives the slowest velocity value of 17.9 cm/s with a duration of 1.4 s compared to carpets that only take 1.3 s with a velocity of 19.2 cm/s.

Table 6: Corner path motion rotation

Type of Surface	Number of rotation	Time taken (s)	Time taken for one rotation (ms)
Cardboard	63	1.0	0.0630
Sandpaper	63	1.4	0.0450
Carpet	63	1.3	0.0485

Table 6 displays the results for the amount of time made in one rotation. The results obtained show that the surface of sandpaper gives the shortest time for one round which is 0.0450 ms compared to the carpet which is 0.0485 ms, and cardboard which is 0.0630 ms.

Road Structure 3: Experiment with Straight Line and Corner Path Motion

The last road structure to be experimented with is to use a straight road before moving towards the corner lane. The results obtained for this experiment are recorded in Table 7 and Table 8.

Table 7: Straight line and corner path motion

Type of Surface	Smooth movement (Y, N)	Smooth movement During turning (Y, N)	Speed taken (cm/s)	Time taken (s)
Cardboard	Y	Y	38.5	1.3
Sandpaper	Y	Y	35.7	1.4
Carpet	Y	Y	41.7	1.2

Unlike Table 3 and Table 5, the results in Table 7 show the carpeted surface giving the highest velocity of 41.7 cm/s over a period of 1.2 s compared to the velocity of cardboard which is only 38.5 cm/s with a time period of 1.3 s, and sandpaper 35.7 cm/s within a period of 1.4 s.

Table 8: Straight line and corner path motion rotation

Type of Surface	Number of rotation	Time taken (s)	Time taken for one rotation (ms)
Cardboard	157	1.3	0.1208
Sandpaper	157	1.4	0.1121
Carpet	157	1.2	0.1308

Table 8 shows the surface with sandpaper giving the shortest time in one rotation which is 0.1121 ms compared to cardboard with 0.1208 ms and carpet with 0.1308 ms.

Each time taken for one rotation as shown in Tables 4, 6 and Table 8 above uses mathematical formulas as found in Equation 1 and Equation 2 in 3.3. These values will then be converted to line graphs as in Figure 5.

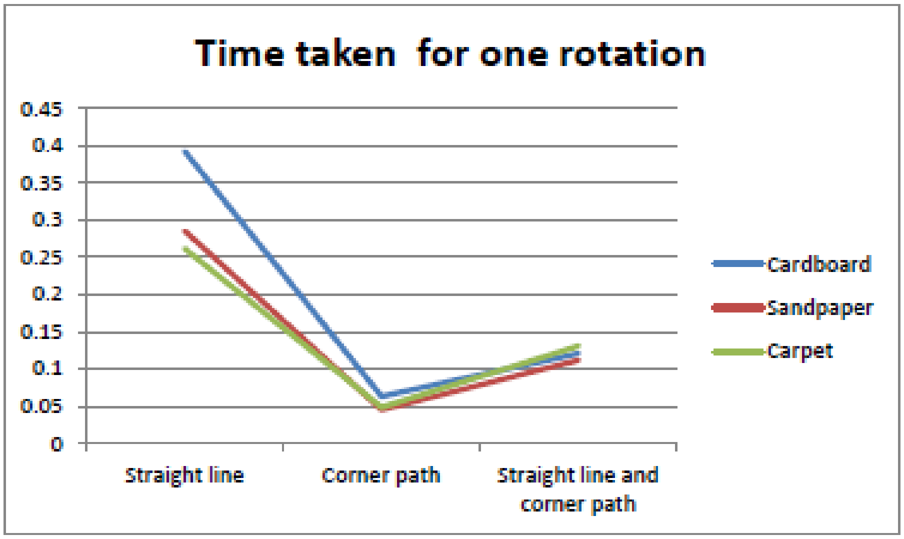

Figure 5: Time taken in one rotation for each straight line, corner path, and straight line & corner path.

Figure 5 shows the relationship of time taken in one round with the type of road structure. On a road structure with a straight line, the maximum speed is taken from the surface of the cardboard which is 125 cm / s but the time required for one rotation for the highest speed is the longest of the other surfaces which is 0.3925 ms. On road structures with corner lanes, the maximum speed is taken from the surface of the cardboard which is 25 cm / s but the time required for one rotation for the highest speed is the longest from the other surface which is 0.0630 ms. While on a road structure with straight strips & corner lanes, the highest speed is taken from the surface of the sandpaper which is 35.7 cm / s but the longest time taken for one rotation is carpet from another surface which is 0.1308 ms.

From these experiments it is shown that robot cars can move at high speeds on straight road structures and corner lanes when passing through sandpaper. This is an indication that compared to the flat and smooth surface, the movement of the robot car is smoother when going through rough roads. However, on straight road structures & corner lanes it is found that robot cars will experience a decrease in rough road velocity. This happens because when approaching a corner lane, it will slow down the speed of the robot car before it can accelerate back after passing it.

The results of the experimental analysis, it is found that as the speed of the moving object increases, the longer it takes for one wheel to rotate.

CONCLUSION AND RECOMMENDATION

The research project objective is fully achieved. The research project objective are to design and develop speed calibration model for moving object and to analyze and create a model on a speed calibration based on the data collected. During this project, a speed calibration model for moving object is design and develops. From the data collected on the experiment, a model needed to be created to calculate the speed and develop a model on speed calibration. To create the model, rotary encoder is used to calculate the speed on the mobile robot. However, there are several limitation in the encoder that made the encoder only can encode a small speed than a high power speed. To analyze the experimentation, data that has been collected is tabulate. Based on the tabulated data, one by one of the analysis is made. Rotary encoder that has been used has disadvantage since it cannot calculate speed from a powerful and high speed motor. However, it can give accurate speed even to a small speed that can be collected. Based on this project and the experiment done, it can be concluded that as the speed increase the encoder cannot detected it. From the project result, it can be concluded that as the speed increase, the longer time taken for one rotation to complete.

Future studies were suggested for this research project to improve since several recommendations can be made. Recommendations are may use to improving the performance and the ability of the research project in the future. First recommendation that can be used to improve the ability and performance of the research project is use another type of encoder and another recommendation is increase test plan. Taken from the result in the experiment of the research project, rotary encoder is not powerful enough to detect the high speed of dc motor. Therefore, using different type of encoder may increase the detection in the encoder. Increase test plan of the research project is the second recommendation for future study. By increasing the test plan, there are several limitation that arise from the research project can be understand and can be improve. Moreover, increasing test plan may avoid result unreliability.

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CONFLICT OF INTERESTS DECLARATION

The authors declare no conflict of interests regarding the publication of this article.

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