

## Development of mobile robot for measuring distance using optical quadrature encoder

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### ABSTRACT

This paper describes the design and development of a measuring tool using a mobile robot. At present, contractors are measuring distances using measuring tape which has few limitations. This includes using of another manpower or a marking flag. The Robot Measuring System is designed to measure distances at multiple conditions such as smooth and rough surface. An optical quadrature encoder is used as a sensor to measure the distances while a program is installed in Arduino Uno for reading and data collection. Graphical User Interface (GUI) was created using Android software so that the movement of the robot can be controlled using a smartphone within a Bluetooth range. An experiment was conducted to test the reliability in terms of accuracy and precision. The best accuracy and precision were obtained when the robot speed is at 90 cm/s on the plain tiles, 80 cm/s on the tar road and 90 cm/s on the grass surface. The robot speed needs to be adjusted accordingly based on the surfaces in order to get an accurate result. This paper proved that the robot measuring system was successfully designed, implemented and analyzed.

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## 1. INTRODUCTION

In recent year, developments of mobile robot have been popular in research field. The authors in [1-3] have been developed mobile robot for various applications. Measuring of distance between one point to another point still using conventional measuring method which still using of measuring tape. Conventional measuring tool is produced using a metal strip with straight estimation markings. This type of measuring tool is often stiff, and require extra manpower or a marking flag to complete the measuring tasks especially for long distances. This paper focused on the design and development of a measuring tool using a wheel robot. The designed wheel robot is able to improve the existing conventional measuring tool. It capable to measure displacement which is length and width using a microcontroller and to provide an accurate measurement.

The author in [4] had developed an omni-directional distance sensors and mecanum wheels. The robot measures environment situation such as distance between the side walls and mobile robots. Data National Instrument (DaNI) mobile robot was developed by [5] where this robot consists of three flat wheel terrains for localizations. The localizations were used to associate environment data captured by the robot with the location where this data is captured, or to issue robot commands depending on location and remaining battery energy. A new algorithm proposed in [6] for improving estimation accuracy of travel

distance of a mobile robot by estimating the slanted angle of the road. They used six wheels with encoder to estimate the travel distance while gyroscopic sensor is used to estimate the slope of travelling road.

A mobile robot needs to be equipped with appropriate and suitable sensors so that a safe and effective path can be found. Kuester [7] are using laser displacement sensor while modelling the wind tunnel position measurement and conclude that the length output from the lasers was found to drift slightly with temperature. Laser displacement sensor has been used in [8-11] which conclude that the measurement using this method provide more convenient operation and ease to be used. A study conducted in [12] proposed to use light emitting diode reflective distance sensors (LED-RDS) for displacement measurement which is cheaper and inherently safe alternative to sensors using lasers and optical fibers. According to [13-15], by applying multiple sensor in measuring system, high precision and more accurate distance information is obtained. Work in [16] mentioned many indoor robotics systems utilize laser rangefinders as their essential sensor for mapping, localization, and obstacle avoidance. However the cost and power energy of such systems is a major roadblock to the deployment mobile robot.

An odometer or encoder is one of the oldest and basic techniques. The optical quadrature encoders are connected to the shaft between the motors and the wheels [2]. According to [17-19], the encoder is the most fundamental method used for localization of mobile robots using wheel encoders. It uses periodic information on velocity and distance travelled to estimate the current robot pose. There are several advantages of optical quadrature encoder which is good for frequency monitoring applications and also for speed, bearing and position observing. Brugnano [20] proposed to use encoder in measuring speed since this method is cost effective and However, the issues of ensuring of mobile robot control systems to have an effective control and security, require further research and development [21]. Previous work by [22-23] controlled their mobile robot using internet of things which able to monitor the robot in real time. However, this method is more complex which is not suitable to use in measuring system. Study by [24-25] reported that by control of mobile robot through Bluetooth using Arduino platform is much cheaper and more convenient to be commercialized. Compared to the previous work, this paper presents the design and development of a robot measuring system controlled by a smartphone using two optical quadrature encoders attached to the front wheels.

## 2. RESEARCH METHOD

In order to choose the wheel of the robot, the size & tread of the wheel, the sensor and the direct current (DC) motor must be chosen correctly in order to make sure the robot is able to perform it tasks. Figure 1 shows the wheel, sensor and DC motor used in this work. The chosen wheel is capable to run on smooth or rough surface area. The size of the chosen wheel robot is 65 mm x 27 mm while the encoder has twenty holes with size 26 mm.

DC gear motor is used as mechanical gears to reduce the speed or increase the torque of the motor. L298 Dual Motor Controller Module enables to control the speed and direction of two DC motor easily. It has the operating voltages between 5 to 35 Volts. This motor driver is used with motors that have a voltage of between 5 and 35V DC.

An Inertial Measurement Unit (IMU) is an electronic that combine with several sensor which is accelerometer, gyroscope and magnetometer that measure and report specific force, angular rate and sometimes the magnetic field surrounding the body. Figure 2 shows the block diagram of the system designed. The designed robot has four wheels as mobility but only two front wheels are attached to DC motor and optical quadrature encoder module.

On the software development part, the Arduino Uno board has been chosen because it is more practical and able to sense environment surrounding by using different transducers. The coding was drafted using C language before being combined with the designed hardware. The connections between sensor and motor with Arduino were established. A GUI was created in Android smartphone so that users can easily control all the movement of the mobile robot. Users can easily explore the system without knowing the complexity of software actions behind it.

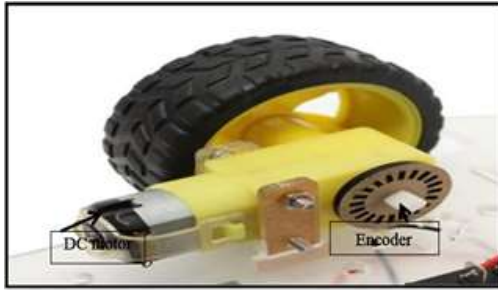


Figure 1. Robot wheel, DC motor and encoder

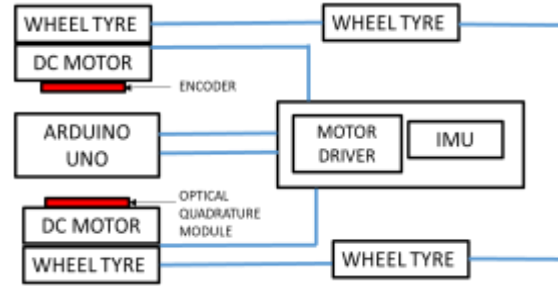


Figure 2. System block diagram of measuring robot

**3. RESULTS AND ANALYSIS**

In The overall view of the designed robot shows in Figure 3. The body of the robot was made from solid transparent plastic known as Perspex and the hardware includes motor driver L298N for the movement of the robot, optical encoder module for counting the distances, two DC Gear Motor, four wheel robot, two encoders, LCD display, two battery holders with 9 Volts battery each, on and off switch, Bluetooth transmitter HS-05 and Arduino Uno module.

The encoder will start to count when the right side of the wheel with the encoder rotates on the optical encoder module. The distance will depend on the how many encoder rotates on the optical encoder module. When the sensor detects black and white encoder, it will count one centimeter (1cm). After that, the value will convert and display on the LCD display.

Figure 4 shows the Graphical User Interface (GUI) display in Android smartphone. Massachusetts Institute of Technology (MIT) App Inventor is used to create the GUI for Android working framework. MIT Application Inventor for Android is an open-source web application initially gave by Google, and now kept up by the Massachusetts Institute of Technology (MIT). By using the GUI, user able to control the movement of the robot using Android smartphone within Bluetooth range. There are five buttons to control the movement of the mobile robot, one button to scan for Bluetooth range and another button to disconnect from the Bluetooth connection.



Figure 3. Top view of robot measuring system



Figure 4. GUI in Android smartphone

An experiment was conducted to test the reliability of the system designed in terms of accuracy and precision. The measuring mobile robot has been tested for three different condition surfaces. The three surfaces are plain tiles, tar and grass with three different speeds which are 70, 80 and 90 cm/s. Testing has been done for 30 times in order to get average (mean), minimum and maximum for the value of distance. Table 1 shows the average value for distance measured using the mobile robot. Then, accuracy and precision will be calculated. Figure 5 shows the percentage of accuracy of mobile robot in three different speed. From Figure 5 it shows that the best accuracy was obtained when the robot speed is at 80 cm/s at tar surface, 90 cm/s on the plain tiles and grass surface. With the results, it can be concluded that the robot speed needs to be adjusted accordingly based on the surfaces in order to get accurate reading. However, to optimize the usage of the mobile robot, 90 cm/s is the best speed setting in all surface.

Table 1. Average value for Distance Measured using Mobile Robot

Surface Types	Speed (cm/sec)	Data Measured using Robot (m)		
		1 meter	2 meter	3 meter
TILE	70	0.968	1.968	2.943
	80	0.989	1.856	2.767
	90	0.994	1.968	2.994
TAR	70	1.083	2.015	3.01
	80	1.011	2.01	3.005
	90	1.018	2.02	3.015
GRASS	70	0.963	1.978	2.97
	80	0.971	1.972	2.967
	90	0.98	1.995	2.975

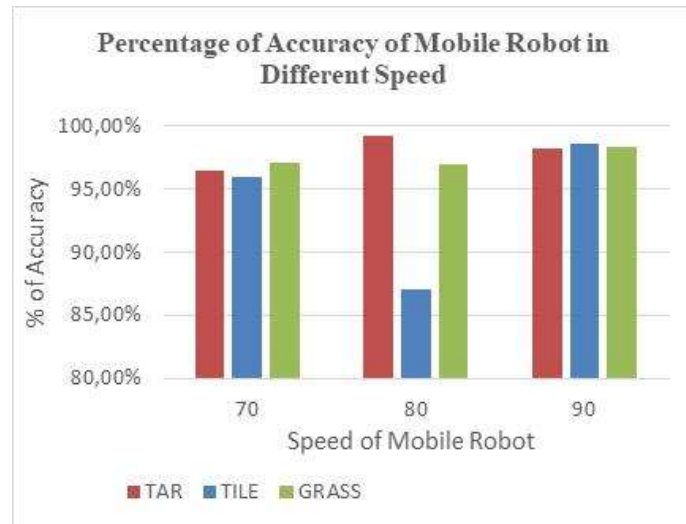


Figure 5. Percentage of accuracy for different speed and different surface

#### 4. CONCLUSION

A robot measuring system has been designed, developed and tested successfully. Through this study, the designed system were tested at three different areas. Robot measuring system is ready to be used to replace the conventional measuring system. In the future, the Bluetooth system can be replaced with Wireless Fidelity (WiFi) system to increase the measuring coverage.

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