Study on the Mobility Performance of Wheelchair Using Smartphone Accelerometer

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Abstract. Wheelchair is very important as a means of transport by a person who is unable to walk as a result of illness or injury. On the other hand, smartphones have become common device that allow users to remotely control many electrical and electronic appliances. This paper presents a study on the mobility performance of wheelchair using smartphone accelerometer. The powered wheelchair is presented by a two-wheeled robot car which emphasized on the control layout platform for the smartphone’s tilting directions with suitable tolerance values. A basic motion’s algorithms for the movement of robot car have been developed, and its mobility performances on the cornering and straight-line direction are analysed.

1. Introduction
A wheelchair is a crucial modality for rehabilitation of people with mobility impairments. Two common wheelchairs implemented in industries are manual self-propelled and powered wheelchair. Jorge L. Candiotti et al. [1] proposed in designing their powered wheelchair namely Mobility Enhancement roBotic (MEBot) wheelchairs to enhance the navigation skills of the users in common terrains. V. Santhanam et al [2] had designed an automated wheelchair controlled by tilting smartphone with 3 axis accelerometer inbuilt and Bluetooth connection.

Some studies involved experiment with such applications to test mobility performance of wheelchair. N. Viswanath et al [3] proposed experiment with operation of four-wheel drive wheelchair that done by tilting the smartphone. It considered with maneuverability for the performances moving in different directions and also the optimization of ergonomics in designing a better wheelchair. R.M.A. van der Slikke et al [4] proposed to measure wheelchair sports kinematics based on inertial sensors with wheel skid correction. Furthermore, there are some studies using human manually test on wheelchair such as C. Usma-alvarez et al and David S. Haydon et al [5,6] who proposed an Illinois agility test and sprinting test. They mentioned that tangential velocity and turning radius were the factors that affect performance of rugby athletes where it only involved with skilful sportsmen that trained for competition manually control the wheelchairs.

However, to the best of our knowledge the study on mobility performance has not been reported in any literature to date. Therefore, the main objective of this project is to create a two-wheeled robot car chassis that represents wheelchair using smartphone accelerometer controlled to study on its mobility performance.
The structure of this paper starts in section 2 which provides brief description prototype’s implementations. Section 3 presents the methods in conducting experiments for cornering and straight line performances. Section 4 discusses the results obtained and analysis for both experiments conducted. Finally, the conclusion of this project is given at the end of this paper.

2. Prototype Implementations

2.1. Developing Hardware

For the hardware section, the Arduino microcontroller is connected with a motor driver, L298N which allows speed and direction control for the two DC motors and a Bluetooth module, HC-05 for Bluetooth communication with smartphone. The electric voltage supply is from the lithium polymer battery that has capacity of 11.1V and 1100mAh.

![Figure 1. Hardware Connection on Robot Car.](image)

2.2. Developing Software

This control layout design implemented using MIT App Inventor for the smartphone tilting that sends command to the robot car. A series of building block designed for the tilting algorithms in this section. Furthermore, Bluetooth connection is involved for the communication between smartphone and Arduino microcontroller implanted in robot car.

![Figure 2. Control Layout Designed for Smartphone Tilting.](image)

3. Experiment on Mobility Performance

3.1. Cornering Performance

Different PWM signals input among both wheels for different configurations. A pencil attached behind the robot car will draw out different sizes of circles due to different configurations when the robot car moves. Since, the pencil and unsteady small front wheel can affect the size of circles drawn, each measurement for the circle’s radius will be repeated for 3 times to obtain the average value.
3.2. Straight Line Performance
A test with different recorded time for robot car to reach a distance of 150cm has been conducted. Both wheels are set with same PWM signal to give forward motion and the PWM signal has been increased constantly to obtain the recorded time taken.

4. Results and Discussion

4.1. Results on Cornering Performance
The configurations with increment in PWM signals of 10 (30, 40, 50 and 60) implemented on left wheels, radii measured become shorter in left turning. Regarding to similar configurations, radii measured become longer for right turning.
After all, it clearly shows that huge difference in PWM signal values between left and right wheels provide the robot car to draw shorter radius of circle which indicates better cornering performance. In order to perform left turning of robot car, the PWM signal on right wheel must always higher than that on the left wheel or vice versa. The zero measurement in each configuration will be carried out for the following straight line experiment.

4.2. Results on Straight Line Performance

Robot car with similar PWM signal inputs in both wheels but has the highest inputs values compared to other configurations can reach the distance of 150cm in the shortest time. The line graph inclined downwards and almost inversely proportional. This has proved that robot car with higher PWM signal inputs can move in a faster pace to reach its destination.
Due to light weight of robot car that will make it turn over, an estimated equation has been derived with $y=mx+c$ as following:
To obtain gradient using points $(X_1, Y_1) = (30, 5.24)$ and $(X_2, Y_2) = (50, 1.87)$:
Gradient, $m = \frac{(5.24-1.87)}{(30-60)}$

$m = -0.1123$

Hence,

$$y = -0.1123x + c$$  

Using the point estimated points $(80, -0.4)$, substitute into equation (1):

$$-0.4 = - 0.1123 (80) + c$$

Then, get $c = 8.584$

Substitute again $c = 8.584$ into equation (1) to get:

$$y = -0.1123x + 8.584$$  

After inserting zero time taken ($y=0$) into equation (2), the PWM signal value is approximately 76 which means the implemented robot car in this project will immediately turn over or collapsed at this PWM signal inputs on both wheels.

5. Conclusions
In cornering experiment, it implied that huge difference in PWM signal values between both wheels provide a sharp cornering for robot car. Different PWM signals input on both wheels with different speed rotations determine the direction of turning in robot car. Meanwhile, the straight line experiment shows robot car with same higher PWM signals input on both wheels allows the robot car to move faster in forward motion. A limitation due to light weight of robot car is determined with estimated equation derived to indicate the maximum PWM signal it can afford with.

6. References
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