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MOTOR SPEED CONTROLLER FOR DIFFERENTIAL WHEELED MOBILE ROBOT

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ABSTRACT
The movement of a wheeled mobile robot (WMR) is provided by motors, however, it is hard to control and predict the motors speed. A cascade Proportional, Integration, and Derivation (PID) controller is presented in this study to achieve the purpose of motors speed controlling. In order to test the controller, a differential drive wheeled mobile robot (DWMR) platform is used. The platform is integrated with decision making algorithm (DMA) for the case of wall-following to test the capability of the controllers in different situations. Through the results illustrated, it shows that the cascade PID controller promises a good performance with low average error in controlling the motors to reach the desired speed.

Keywords: wheeled mobile robot, PID, cascade control, L shape corner avoidance.

INTRODUCTION
A robot is a mechanical device which can execute various tasks, either manually by direct human supervision or autonomously by a predefined program or some guidelines set by human [1], [2]. A mobile robot is a category of robot that is capable to move in a given environment and executes tasks with some degrees of flexibility [3]. It can perform various types of tasks such as inspection, security, and education to serve humans. Among the types of mobile robots developed, a vast majority of mobile robots are wheeled mobile robots (WMRs). The WMRs have the advantages of high energy efficiency, simple mechanics, and well-investigated control systems [4].

One of the fundamental robotic tasks is to navigate a robot from a starting point to a destination point with collision-free motion. Navigation of WMRs normally involves path planning and path tracking. In path planning, the acceleration and deceleration profile of the robot are considered while the path is generated in a Cartesian coordinate. There are some control laws developed in order to track the path.

The controller can be divided into 2 categories, linear controllers and nonlinear controllers. In [5], a linear controller using PID controller was designed to track the heading of a synchronous robot. A Proportional, and Integration (PI) controller with feed forward compensator was presented in [6] to track the desired path.

In nonlinear controllers, system disturbances and unknown dynamic parameters are considered when designing the controllers. In [7], an adaptive sliding-mode dynamic controller was designed. An adaptive tracking controller was presented in [8], which is based on the PID with the control law being developed based on the Lyapunov stability theory.

All of the controllers mentioned above are either done in simulations or implemented with the help of an on-line computer. Moreover, the algorithms require massive computational time and huge memory. Therefore, they will be impractical to implement the algorithms in a microcontroller, which has small memory. To overcome these limitations, a cascade controller was presented in [9] where only the desired position and velocity are fed into the controller.

SYSTEM CONFIGURATION
In this research, the mobile robot platform used is a differential drive wheeled mobile robot platform as shown in Figure-1. The dimension of the mobile robot platform is 160 mm x 160 mm. There are two DC geared motors located each at the center of both left and right side of the bottom layer of the platform to give the WMR motion. The main processing unit used in this WMR system is Arduino MEGA 2560, a microcontroller based on the ATmega2560.

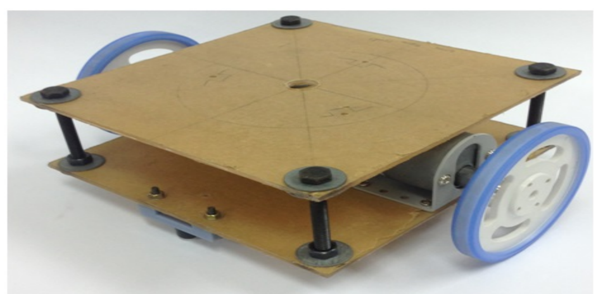

Figure-1. The mobile robot platform without the processing unit.

The controller unit design
Throughout the development history of control system, PID controller is very popular because it is very easy to apply and can work well in a wide range of operating conditions [10]. Besides that, PID controller has clear effects of each proportional, integral, and derivative control [11]. According to [12], cascade control has the benefits of faster response and better disturbance rejection.

The proposed controller for the WMR system consists of a cascade PID controller for each wheel. Each pair consists of a PID controller for position and another PID controller for speed. The master controller in this proposed controller is the position controller, while the speed controller is the slave controller. Through this controller, the wheel will rotate to a desired position with a desired speed. Figure-2 displays the proposed controller for the left side DC motor. Observable from Figure-2, the input of the cascade PID controller developed is the desired step counts of the motor while its output is the actual step travelled by the WMR after every time frame. The desired step count of the motor is obtained from the DMA so that the WMR will move in desired directions.

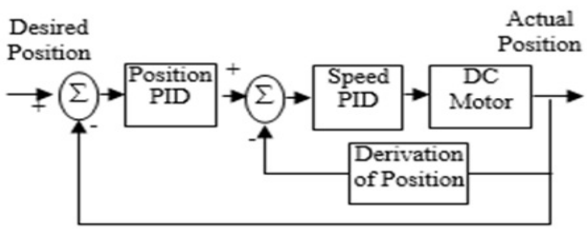

Figure-2. Proposed cascade controller for left side DC motor.

In order for the WMR to move in a straight path, both left and right DC motors need to work synchronously. Therefore, an additional PID controller is added into the system to compensate the position difference of both DC motors. Figure-3 displays the full cascade PID controller system for both DC motors.

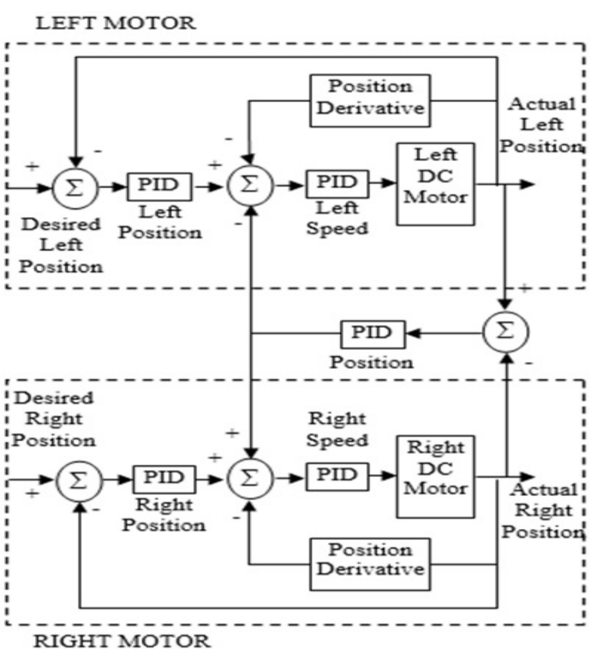

Figure-3. Full cascade PID controller system for the wheeled mobile robot platform.

EXPERIMENTAL DESIGN AND SETUP

In this study, an experiment is setup to test the performance of the motor controller by integrates the motors controllers with a decision making algorithm (DMA) to perform a left wall-following navigation task. The DMA used in this experiment is a wall-follower developed using fuzzy logic.

In this experiment, the WMR is required to move along the wall while maintaining its distance at 50 cm from its left side. Figure-4 illustrates the wall's measurement and the desired path of movement of the WMR for the case of left-wall following and Figure-5 displays the flow of the WMR's movement directions. First, the WMR is required to move in a straight line for 150 cm, then it will turn to its left when the DMA detects a corner, move straight again for 100 cm. After that, the DMA will detects a corner in front which will block its forward path, thus the DMA will order the WMR to move to its right to continue its path.

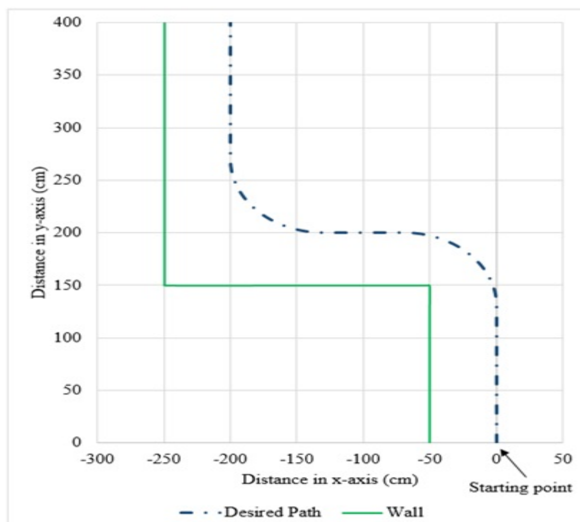

Figure-4. Wall measurements and desired path of movement of the WMR for left-wall following.

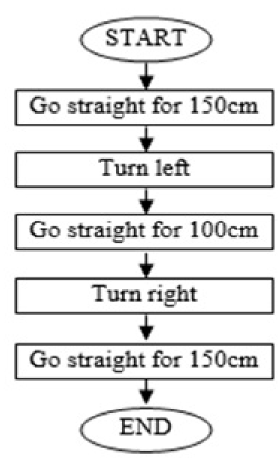

Figure-5. Flow of the WMR movement directions.

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The performances of the integration of PID and DMA are determined by calculate the errors of the actual paths travelled by the WMR, compared with the desired path. A total of 10 points are taken in each path to calculate the errors, as illustrated in Figure-6. It can be seen in Figure-6 that there are 10 guidelines intercept with the WMR's path. The guidelines are used to locate the interception points in order to find the errors of the actual paths, compared to the desired path. 6 of the points are taken in the straight path and the remaining 4 points are taken from the curved path.

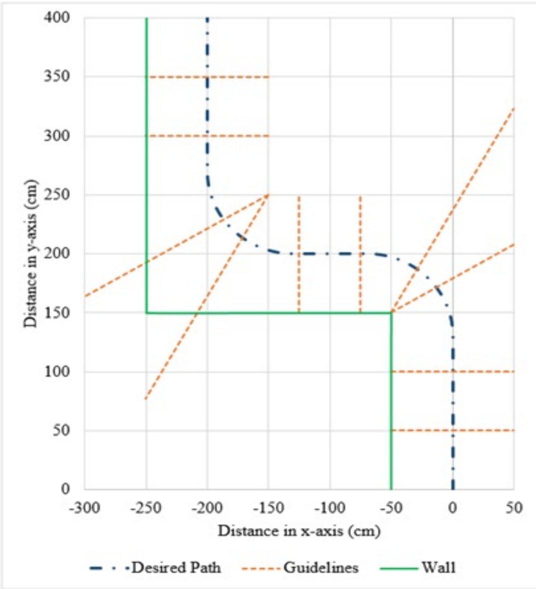

Figure-6. Guidelines to calculate the error of the paths.

RESULT AND DISCUSSION

Figure-7 and Figure-8 displays the step counts recorded by both left motor and right motor in every time frame after the cascade controller in Figure-2 is applied. The desired step counts are 9 steps for both motors.

Based on Figure-7 and Figure-8, the cascade controllers are able to control both DC motors to move in the desired step counts, which is 9 steps. From Figure-7, at the starting point, the motors are not running in the desired steps, this is because the PID controllers need some time to adapt the error between the actual and desired step counts into the controller. After that, the controllers managed to control the motors to move in the desired step counts. Noticeable in Figure-7, the controller for left DC motor takes 13 seconds to reach steady state while the right DC motor in Figure-8 uses 11 seconds to reach the steady state. Furthermore, both Figure-7 and Figure-8 shows that the cascade controllers are capable to make sure both motors move in the same speed although left DC motor is lagging 2 seconds from right DC motor.

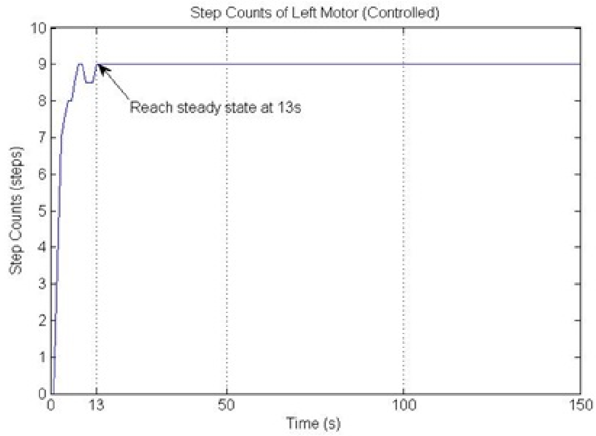

Figure-7. Step counts recorded by left DC motors.

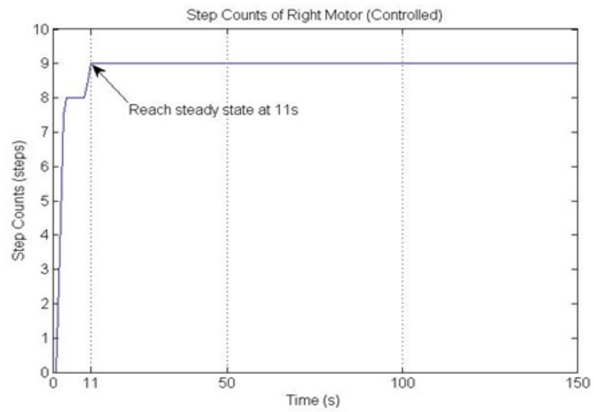

Figure-8. Step counts recorded by right DC motors.

Figure-9 illustrates the robot's movement in a straight path using the cascade PID controller of Figure.3, while Figure-10 shows the error of the path, which is compared with the assumption that straight line is equal to 0 along the y-axis. In Figure-9, it can be seen that, overall, the WMR is moving in a straight path. From Figure-10, it shows that the errors of the path are less than 2 mm, which is negligible.

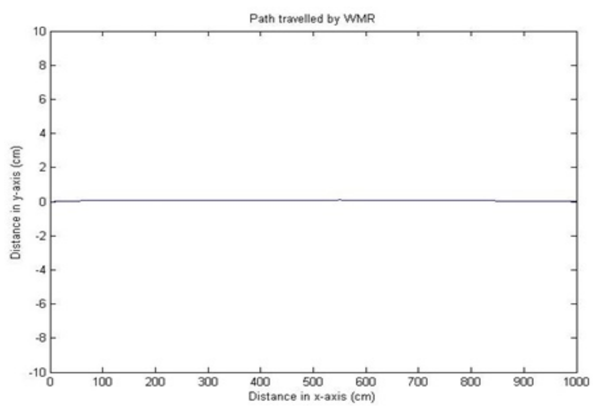

Figure-9. Robot movement plotted in MATLAB.

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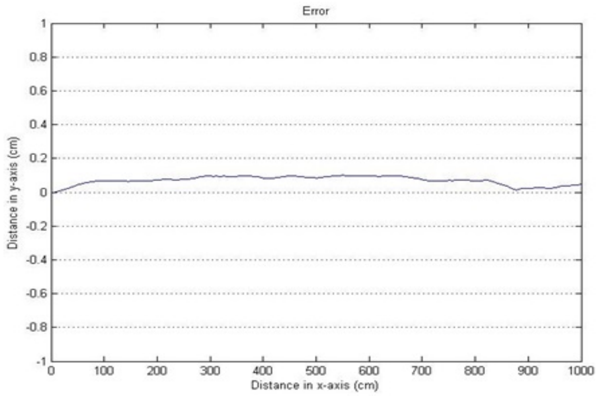

Figure-10. Errors of the path.

Figure-11 illustrates 4 trials of the paths travelled by the WMR with left-wall following DMA. From 4 trials in Figure-11, it can be observed that all 4 trials have the same pattern of paths, which is going straight for about 150 cm, then turn left around a corner, and continue moving straight for 100 cm. After that, turn right when the WMR detected a corner on its left. Lastly, the WMR moves straight for about 150 cm before it comes to a stop.

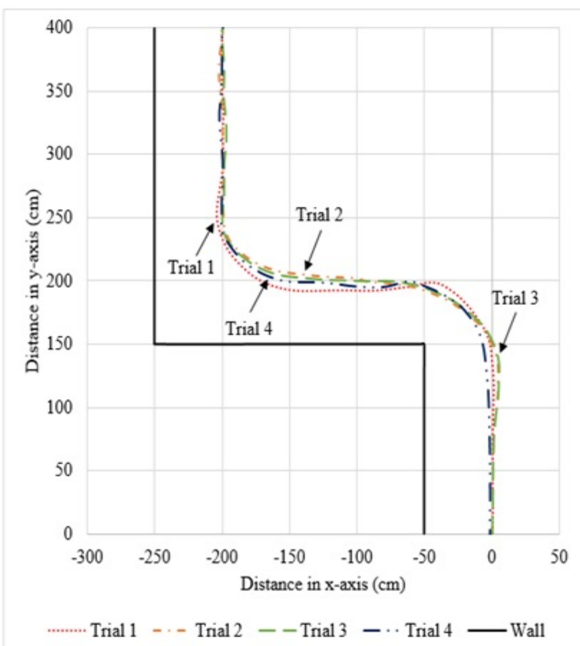

Figure-11. Four trial paths of the WMR.

Table-1 tabularizes the errors of the 4 trials calculated after using the guidelines displayed in Figure-6. From Table-1, it is observable that all the 4 trials have the average errors under 4 cm. The largest average error is Trial 1, 3.74 cm while Trial 3 has the lowest average error, 2.15 cm, which is the best result among the 4 trials. This shows that the motor controller is working well with the DMA to control the WMR to move in desired path.

Table-1. Summary of the 4 trials' errors.

	Errors (cm)			
	Trial 1	Trial 2	Trial 3	Trial 4
Point 1	0.48	0.88	0.88	1.27
Point 2	0.89	3.23	3.50	2.25
Point 3	0.89	2.44	0.89	3.51
Point 4	1.85	5.07	3.36	3.22
Point 5	6.20	2.70	1.50	3.50
Point 6	7.80	3.50	0.90	2.20
Point 7	10.03	0.00	2.47	5.33
Point 8	8.65	2.69	4.17	5.92
Point 9	0.40	0.40	2.20	0.60
Point 10	0.20	1.30	1.60	1.40
Average	3.74	2.22	2.15	2.92

CONCLUSIONS

In conclusion, the results of the two cascade PID controllers in controlling the motors are presented. From the results displayed, it can be concluded that the cascade PID controllers promise good result with low average errors in controlling the motors speed with the desired conditions accordingly. With these two PID controllers, the motors on the WMR can run in the desired speed when commanded and the WMR can also move in an almost perfect straight line without the help from any external sensors.

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