# E190Q Lab 1 - Closed Loop Control to Maintain Constant Wall Proximity


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***Abstract*—The purpose of this lab was to design a closed loop control system to maintain a mobile robot's position with respect to its surroundings. A laser range finder output a distance value between the robot and a wall, which was used to proportionally control the angular velocity of the motors. The Jaguar Robot was able to reach the desired position with 14% error when decreasing the distance between itself and the wall and with 8% error when increasing the distance between itself and the wall.**


## I. Introduction

One method of maintaining a mobile robot's position relative to its environment is to implement a control system that uses a sensor to measure distance. The goal of this lab is to design a closed loop control system to maintain a constant distance between the wall and Jaguar Lite mobile robotic platform. A laser range finder was used to measure distance.

## II. Problem Definition

The Jaguar robot was tasked with driving to a wall and positioning itself 1.0 m from the wall. The robot starts facing the wall and must position itself somewhere between 0.5 m and 3.0 m from the wall using a closed-loop control algorithm.

## III. Background

The Jaguar Lite is a mobile robot platform developed by Dr Robot Inc. It is a differential drive ground robot platform with a drive track on each side. The sensor package on the robot includes a $270^o$ laser scanner, GPS, camera, and 9 degree-of-freedom IMU (gyroscope, accelerometer, and compass). Figure 1 shows the platform and where each of its sensors are located.

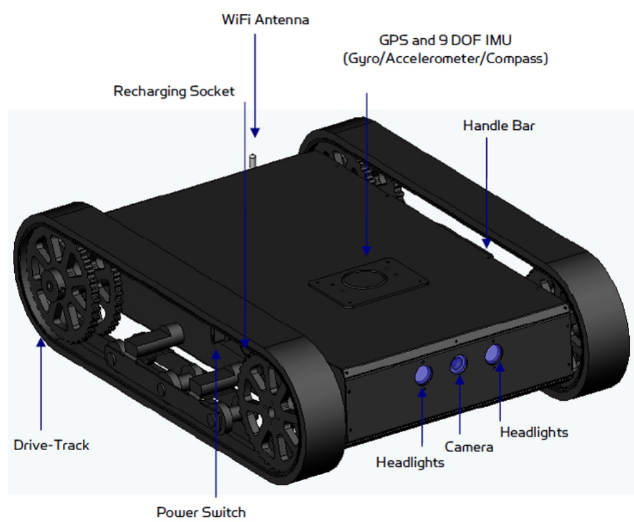


Fig. 1. The Dr Robot Jaguar Lite Robotics Platform[2]

## IV. Control Design

The closed loop control system was designed with proportional control. The angular velocity of the motors were set to be proportional to the distance that it was away from the wall.

$$motorVelocity = maxVelocity(D - d) \tag{1}$$

Where *D* is the desired distance from the wall and *d* is the measured distance between the robot and the wall. The sign of *motorVelocity* changes when the distance measured by the laser range finder shifts from a value smaller to larger than the desired distance or vice versa. This change in sign shifts the rotational direction of the motor, allowing the robot to slow down to an equilibrium point. Only the central laser scan point is used to measure distance from the wall, as it is assumed the robot only moves forward and backward without rotation.

$maxVelocity$ was given in the provided code as 0.1 m/s, and this was used as the proportional gain value. This turned out to be an appropriate value to prevent overshoot of the robot.

## V. Experimental Setup

The Jaguar robot was set on the floor with the laser scanner and cameras facing the wall (this direction will be designated as the forward direction) at different distances. Time and position data was taken in order to determine the effectiveness of the control algorithm. Figure 2 shows the experimental setup.

## VI. Results

When placed at different starting positions, the robot was able to drive forward or backward to readjust its position relative to the wall and stop within the required 0.5-3.0 m distance without overshoot.

The Jaguar Robot was able to reach the desired position with 14% error when decreasing the distance between itself

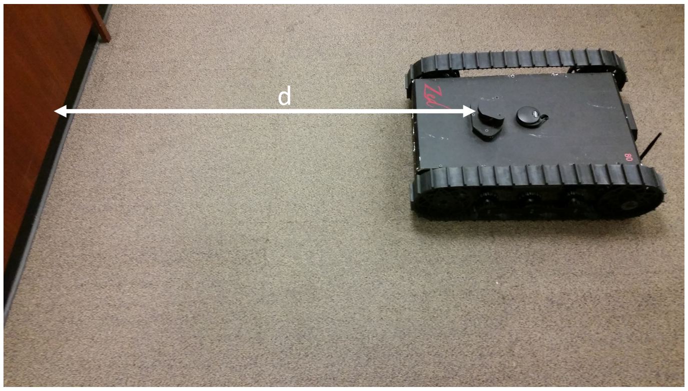


Fig. 2. Experimental Setup: The Jaguar was placed such that the robot's laser scanner was facing the wall. All distances $d$ were taken from the wall to the robot's central laser scan.

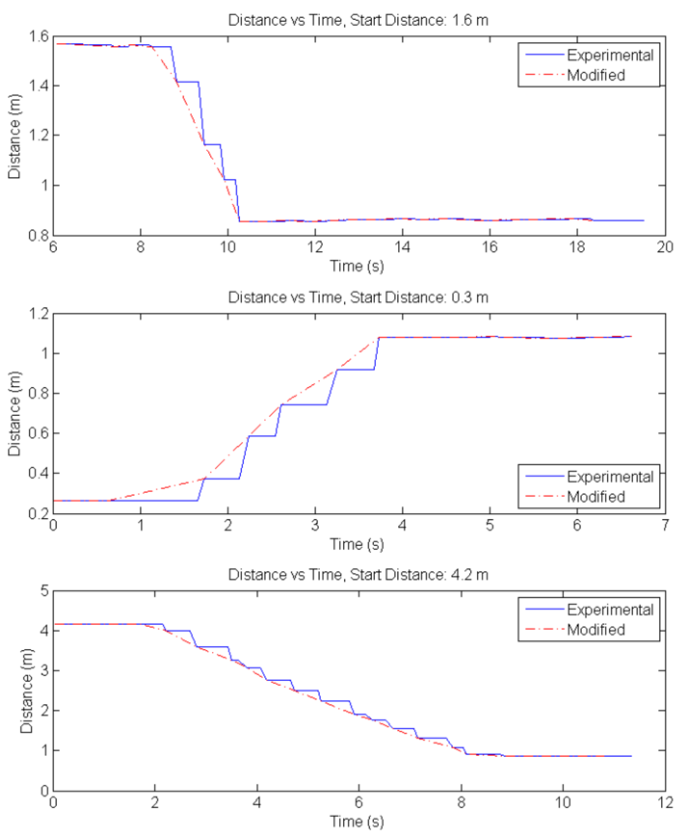


Fig. 3. Distance vs Time Plot. The Jaguar robot was placed at three different starting points of 1.6 m, 0.3 m, and 4.2 m. The final position of the robot was dependent on the direction of approach to the desired goal of 1 m.

and the wall and with 8% error when increasing the distance between itself and the wall.

Figure 3 shows experimental data from different starting distances. The experimental data shows sections in which the position of the robot seems to be constant for specific lengths of time, leading to a plot that looks like a staircase. Observation of the robot during testing does not support the plot that was collected as the robot was seen to smoothly approach the desired distance from the wall. The laser scanner is rated to scan at 10 Hz[3], however the collected data is updated at much slower intervals. A potential explanation for this data is slow update speed for the array that holds the data from the laser range finder. Because the log rate at which the most recent value from the array is recorded is faster than the update speed for the array, the log shows moments in which position seems to be constant for sections of time. The data was processed to take data points once they change in value, leading to the "modified" line that approximates the actual position of the robot as a function of time. The laser range finder seems to update every 2 Hz and data seems to log at around 10 Hz.

It should be noted that the robot does not stop at exactly 1.0 m. This is because a certain threshold velocity must be applied to the wheels, otherwise the motors will stall. Since proportional control is used, the system will reach this threshold before it reaches the desired 1.0 m distance from the wall. This does not explain why the distance at which the robot stops from the desired distance is dependent on the direction of approach. It may be that the threshold velocity before stall is dependent on the direction of rotation for the motors.

## VII. Conclusion

One mistake that was made in the software to control motor velocity was that the angular velocity of the motor would exceed the desired maximum angular velocity. The constant *D-d* would become a value greater than 1 or less than -1, driving the angular velocity of the motor to values greater than the maximum angular velocity. One method of resolving this would be to define the angular motor velocity so that:

$$motorVelocity = maxVelocity\left(\frac{D-d}{D}\right) \tag{2}$$

This would limit the *motorVelocity* to values between the desired bounds of positive and negative *maxVelocity*.

## Acknowledgment

The authors would like to thank Jerry Hsiung, Sean Messenger, Katherine Yang, and Professor Christopher Clark who gave excellent advice.

## References

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