- ***Experimental Design and Test Setup:***

During the different experiments realized, we aimed at evaluating the different features of our system which range from detecting obstacles, to detecting gaps, and finally adjusting the motor speed automatically according to the inclination angle.

In order to do so, we realized 2 experiments:

1- In the first one, the inclination angle was set to be equal to 0. In this experiment, we only tested the ability of our system to detect gaps and obstacles. An obstacle is said to be detected if it is within the range of 10 cm whereas a gap is said to be detected if the second ultrasonic sensor reads 50cm. During this experiment, the motor speed was about 70% of its maximum speed in the case when neither obstacles nor gaps are detected. We also wanted to test the time needed for the motor to get to its normal speed (70%) if it was initially 0.

2- In the second experiment, we wanted to check the values of the motor speed according to different inclination angles. These angles can either be positive or negative. We also tested the other features (obstacles and gaps detection) in this case. Again we tested the time needed by the motor to reach the normal speed if it was initially 0.

During these experiments, we also wanted to avoid false alarms as much as possible. Therefore, in both cases, we tested the ultrasonic sensors outside the desired range of detection. For example, our motor should not stop if the obstacle is placed at distance larger than 10 cm or if a gap has a depth less than 50 cm. These values were set according to hardware testing and physical constraints.

- ***Results:***

The below tables summarize the different results of the experiments:

- ***Exp I:***

The inclination angle was 0 in this case.

Feature 1: Obstacle Detection

Distance (cm)	Trial 1	Trial 2	Trial 3	Trial 4
4	✓	✓	✓	✓
6	✓	✓	✓	✓
8	✓	✓	✓	✓
9	✓	✓	✓	✓
10	✓	✓	✓	✓
14	✗	✗	✗	✗
13	✗	✗	✗	✗
3	✓	✓	✓	✓

Motor speed is set to 0: ✓ motor speed remains the same: ✗

As we can see from the above table, an obstacle is always detected whenever the distance is less than 10 cm. No false alarms also happened: if the distance is greater than 10 cm, the motor does not stop.

Feature 2: Gap Detection

Distance (cm)	Trial 1	Trial 2	Trial 3	Trial 4
55	✓	✓	✓	✓
60	✓	✓	✓	✓
80	✓	✓	✓	✓
78	✓	✓	✓	✓
100	✓	✓	✓	✓
40	✗	✗	✗	✗
30	✗	✗	✗	✗
75	✓	✓	✓	✓

Motor speed is set to 0: ✓ motor speed remains the same: ✗

As we can see from the above table, a gap is always detected whenever the distance is greater than 50 cm. No false alarms also happened: if the distance is less than 50 cm, the motor does not stop.

Feature 3: Time

In this section we will be testing the time needed for the motor to get back to its initial speed after begin set to 0.

	Time (sec) Trial 1	Time (sec) Trial 2	Time (sec) Trial 3	Time (sec) Trial 4
Obstacle at 4 cm	3	3	3	3
Obstacle at 6 cm	3	3	3	3
Obstacle at 8 cm	3	3	3	3
Obstacle at 9 cm	3	3	3	3
Gap at 55 cm	3	3	3	3
Gap at 60 cm	3	3	3	3
Gap at 80 cm	3	3	3	3
Gap at 78 cm	3	3	3	3

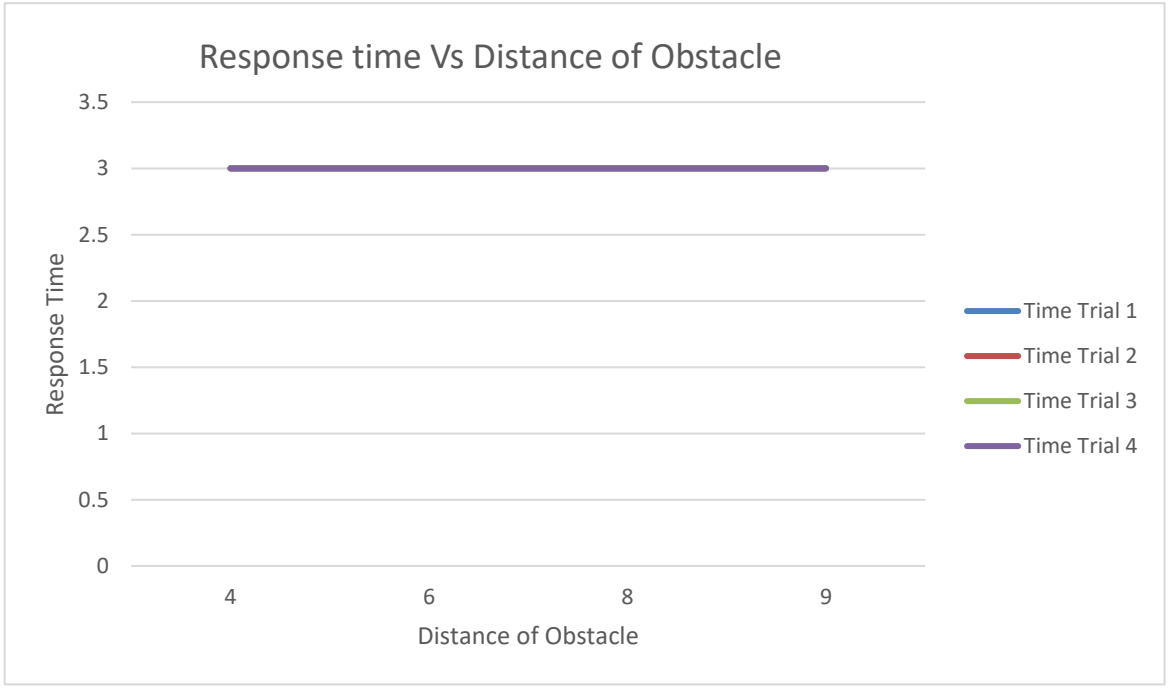

Figure 1 Response time w.r.t. the distance of the obstacle.

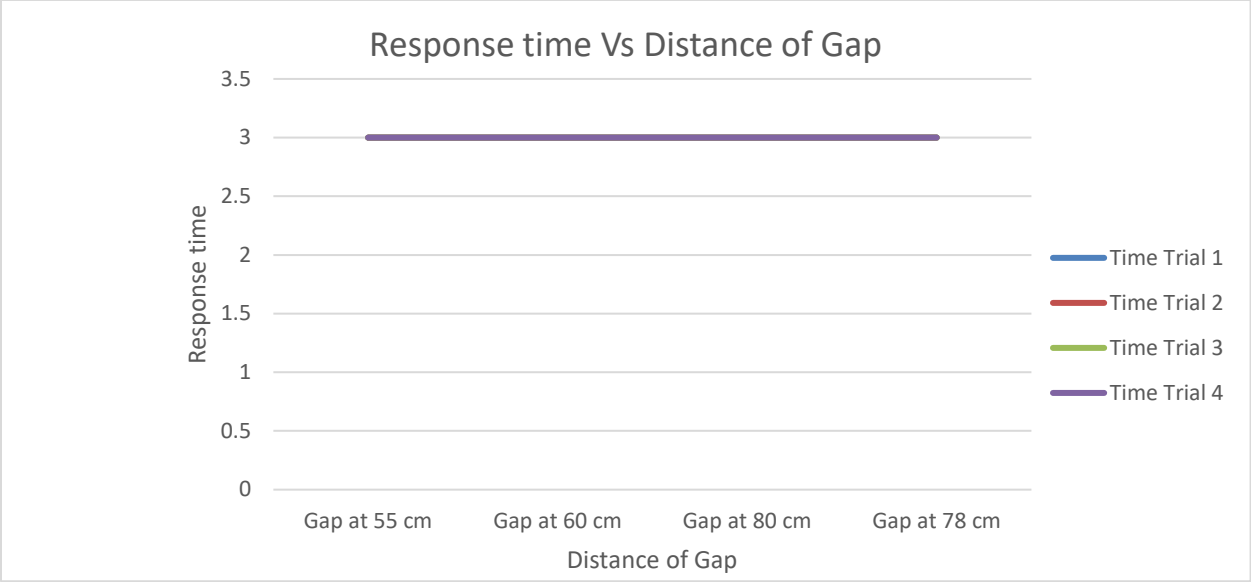

Figure 2Response time w.r.t. distance of gap

From the previous table it can be seen clearly that the time needed by the motor to get back to its initial speed (70% of the max value) is 3 seconds.

- ***Exp II:***

In this experiment we have to vary the inclination angle and measure the motor speed accordingly. Kindly note that in our design, the motor reaches its max speed at 60^{o} and then the speed stabilizes. The value of the motor speed is indicated relative to 255(which represents the max speed: 0 represents a 0% duty cycle and 255 represents 100%).

inclination	Speed Trial 1	Speed Trial 2	speed Trial 3	speed Trial 4	Average speed
0 ^{o}	180	180	180	180	180
10 ^{o}	192	192	192	192	192
20 ^{o}	204	204	204	204	204
60 ^{o}	255	255	255	255	255
80 ^{o}	255	255	255	255	255
90 ^{o}	255	255	255	255	255
-10 ^{o}	168	168	168	168	168
-20 ^{o}	156	156	156	156	156

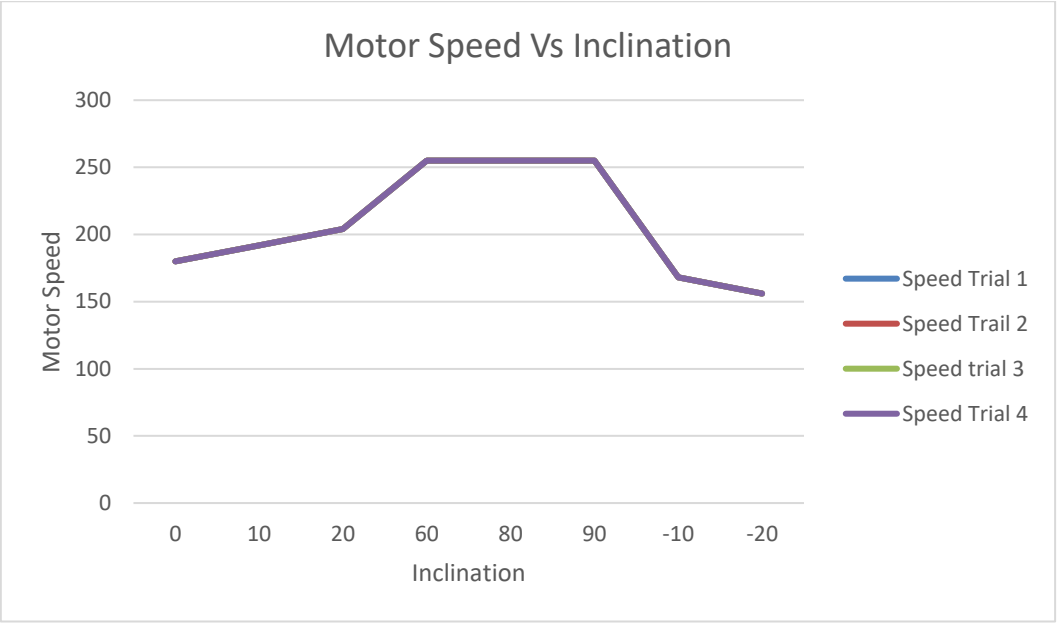

Figure 3 Graph Showing the different motor speeds Vs. Inclination