Smart Braking Utilising a Control Loop

TEAM 5

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ABSTRACT

Our scope for this project is to create an autonomous control loop system. To complete this we need to research and learn what is an autonomous control loop. Then we must decide what unique control loop we wish to use and the Makeblock equipment needed to carry out this task, we must carry out tests to ensure a project works, all while recording are progress week by week.

This project has a 6-week timeline. Our group consists of 7 members, divided into different roles and jobs. The equipment available to us was a Makeblock kit and the PC's running MakeBlock so that we can finish our project and produce our designs. In addition, we would maintain contact with all team members to make sure we are all in agreement while using the computers to conduct the required research to produce the designs and record our progress.

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1 INTRODUCTION

An autonomous robot is capable of functioning without external aid, regardless of the environment that it is placed in. There are many robotic designs in which control loops are employed, such as walking robots, rovers, and cars. In this project, the assignment was to create an autonomous control loop system. The design settled upon for the robot was based on an autonomous robotic car. This was due to the effectiveness and efficiency of this design. This design took less time to construct than other models, such as walking robots or rovers. This was beneficial to the team, as more time could be spent focusing on the control loop.

This report discusses Smart Braking utilising a control loop. This is a feature that has many real-world applications. It is used in systems such as in smart cars. It detects obstacles in its path and slows down to a halt accordingly. Smart Braking is an aspect of obstacle avoidance. Obstacle avoidance is a necessary part of autonomous navigation. The overall creation process of the MegaPi Robot is presented below in **Figure 1**.

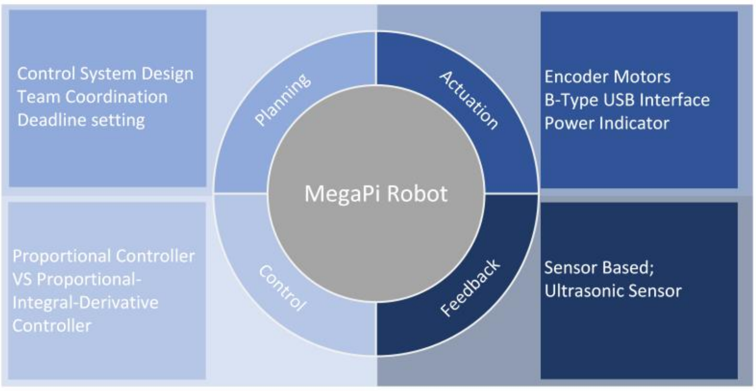

Figure 1: Schematic Illustration of the Creation Process of the MegaPi Robot

The control loop used in this project to achieve this uses a sensor to detect an obstacle and slow down the robot as it approaches the obstacle until the distance between the robot and the obstacle reaches 50cm. The decision to make this a P-controlled (Proportional Controlled) system, instead of a PID-controlled (Proportional-Integral-Derivative Controlled) system, was down to the simpler execution of this system when compared to a PID-controlled system. Proportional control is a form of feedback control. It is the simplest form of continuous control that can be used in a closed-looped system. [1]. A P-controlled system took less time to program, which was vital to the project as the time constraint for the project was limited to 13 weeks. In this control loop, the P-controller was used to control speed by adjusting the gain. The robotic car would respond quickly to changes that occur in the error signal.

1.1 Definition of a Control Loop

A Control Loop is a connection of components which forms a system [2]. These components typically include a controller, a sensor, and a component that is controlled. The sensor returns a measurement that is checked against a desired output. If the measurement and desired output are not the same an error is created. Instructions are sent from the controller to be carried out by the actuator. This causes the process to be adjusted to match the desired output. Control loops can be open or closed. An open loop requires human interaction whilst a closed loop can be fully autonomous due to its inclusion of a feedback loop. **Figure 2** depicts a general closed control loop. **Figure 3** shows the closed feedback control loop used in this project.

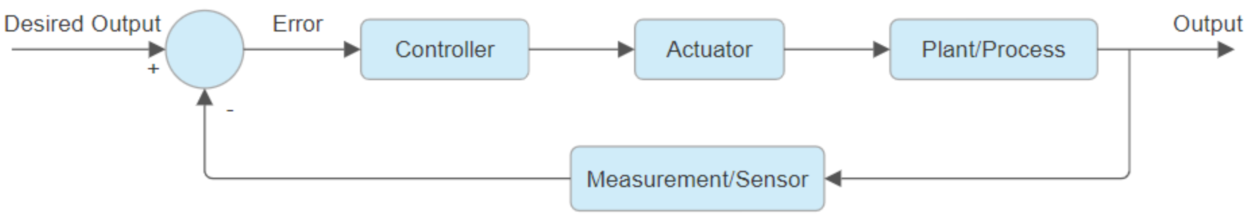

Figure 2: General Closed Control Loop

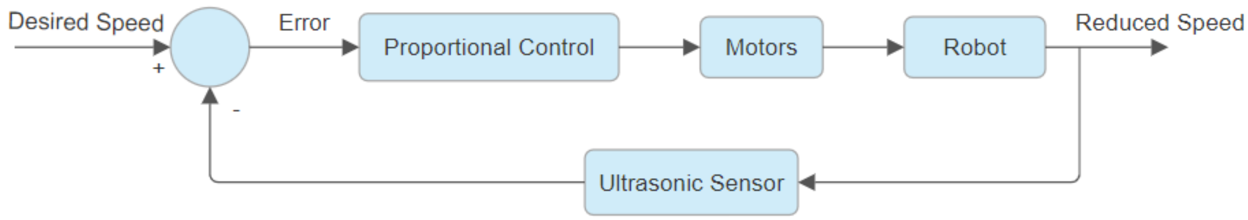

Figure 3: Smart Braking Control Loop

1.2 Proportional Controlled System

Proportional control is a form of feedback control. It provides a faster response than most other controllers [1]. The closed loop P-Controlled system is a static system, resulting in an autonomous driving system which does not record or store data that would run through the equation in the loop and adjust the driving controls accordingly.

$$c(t) = K_c e(t) + b$$

$c(t)$ = controller output

K_c = controller gain

$e(t)$ = error

b = bias

Equation 1: Proportional Control System Formula [1]

The bias (controller output when the error = 0) and the controller gain (change in the output of the controller per change in the input to the controller) are constants specific to each controller. The gain relates the change in the input and output variables. There is a linear relationship between the error of a system and the controller output of the system, which is typical of a P-Controlled system.

1.3 Obstacle Avoidance

Obstacle avoidance is a key feature of autonomous navigation [3]. Implementations of this could involve a sensor detecting an object and stopping the robot in time to avoid collision. Algorithms are designed to allow obstacle avoidance to take place in known and unknown environments. The version used in this project is designed for smart braking in automobiles and assumes that all obstacles can be detected by the sensor (obstacles cannot be above or below the sensor and must be flat surfaces for the sensor to read the outputted ultrasonic waves.

1.4 Report layout

The remainder of this report is structured as follows: In section 2, The Technical Background is discussed. The Literature Survey is detailed in section 3. The apparatus and experimental procedure are then described in section 4. Experiments and their results are presented in section 5. Finally, in section 6, the main conclusions of the work are highlighted.

2 TECHNICAL BACKGROUND

2.1 Hardware / Materials

The hardware used in this project was provided in the Makeblock Ultimate 2.0 Robot Kit [6]. It includes over 550 mechanical parts and electronic modules. All components and modules are connected to the main control board, MegaPi [5].

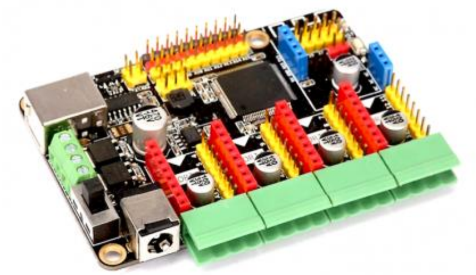

Figure 4: MegaPi Control Board

2.2 Software

The software recommended to use was a block based visual programming language [6]. This software programmes the microcontroller and allows for the user to control the motors and read the sensors. The MegaPi is connected by USB to a computer containing the code. The code is uploaded to the MegaPi and can be ran.

2.3 Sensor

A sensor in a system is used to detect a change in an environment. The data collected by the sensor is used to determine the output of the system. The output changes with respect to the values returned from the sensor. The sensor used in this project was provided in the Makeblock Ultimate 2.0 Robot Kit. It is a Me Ultrasonic Sensor Module. It detects distance within a range of 3 cm – 400 cm, with an error of less than 1 cm [6]. The sensor was used in this project to measure the distance between the robot and an obstacle.

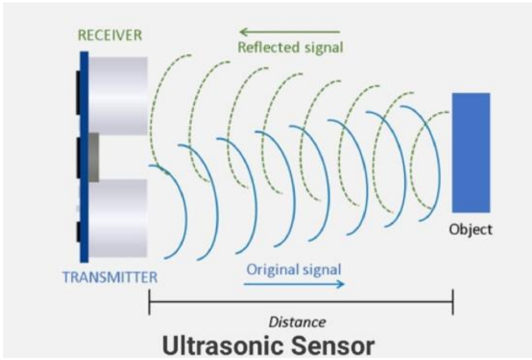

Figure (a): Me Ultrasonic Sensor Module **Figure (b): Ultrasonic Sensor Working Process**

Figure 5: Ultrasonic Sensor

2.4 Driving Controls

The system is programmed to move forward if there are no obstacles sensed within 50 cm. If an obstacle is detected within this range, the robot slows down proportionally to the distance from the obstacle. The robot stops when it is exactly 50cm from the obstacle.

The sensor is located on the front of the robot, are used to determine if the robot is within 50 cm of an obstacle. If the robot is placed within 50cm of an obstacle, it will not move at all.

From testing different versions of code, it was found that the lowest speed that the motors could run at is 10 RPM (*Revolutions Per Minute*). The test was done by setting the velocity to different values until a value was found that the motors did not run at. At a velocity less than 10 RPM the motors did not run. This led to the derivation of the equation for the velocity (in RPM) of the robot, as shown in below in **Equation 2**.

$$Velocity\ (RPM)\ =\ \frac{Displacement}{10} + 5$$

Equation 2: Velocity of Robot (in RPM)

As the robot only runs when it senses a distance greater than 50cm, the minimum velocity is determined by the minimum distance of 50cm. This results in an equation for the minimum velocity as shown below in **Equation 3**.

$$Min\ Velocity\ (RPM) = \frac{50}{10} + 5 = 10$$

Equation 3: Min Velocity of Robot (in RPM)

The ultrasonic sensor provided in the Makeblock Kit has a set max range of 400cm. Any distance outside of this value would still return 400cm. This limit on the distance means the max velocity of the robot can be figured out using **Equation 4** below.

$$Max\ Velocity\ (RPM)\ =\ \frac{400}{10} + 5\ =\ 45$$

Equation 4: Max Velocity of Robot (in RPM)

2.5 Light Module

The LED (Light Emitting Diode) module is programmed to change colour depending on the status of the robot. When moving the LED module is green, and whilst stationary it is red. Occasionally, when the robot is stopped 50cm from an obstacle, the light will flash from red to green. This shows that the sensor is continuously checking for an error to ensure the robot is exactly 50cm from an obstacle.

Figure 6: LED Module

3 LITERATURE SURVEY

Through research, we found a similar project submitted by IEEE to IEEE Xplore in 2015 titled "An ultrasonic sensor distance induced automatic breaking automobile collision avoidance system" [7].

The solution detailed in the report used different components to achieve the same result. For example, two sensors were used instead of one. This allowed them to reverse as well as move forward. While our solution focused solely on forward motion. There was also a difference in the type of sensor used. Laser Beams were used in their report. We had to use an ultrasonic sensor as it was part of the equipment, and we had access to in the Makeblock Kit. Laser beams can provide more accurate readings compared to ultrasonic sensors. Ultrasonic sensors have an error of +/- 1cm [12]. However, this has a minimal impact on the overall system.

One similarity we had was the approach we used to achieve object detection. It detects obstacles when a minimum distance separation is reached. We decided on a minimum distance of 50cm from an object. Comparatively, we used an LED component as a warning signal.

4 ETHICAL CONSIDERATIONS

Ethical considerations are crucial in the research of projects, to learn the positive and negative effects of the object you wish to learn or write about. Ethical considerations are crucial in many aspects like business, healthcare, research, and social interactions. In research it is a set of principles that guides your design and practice.

Ethical considerations in PCB circuit manufacturing are complex [10]. They embrace environmental stewardship, labour right, product lifecycle management and national security.

The biggest ethical concerns of manufacturing these circuits are the environmental impact. Production of these circuits requires a lot of hazardous chemicals, like toxic gases and heavy metal, which if not disposed of correctly can cause serious threats to the environment. In manufacturing these circuits, the energy consumed contributes to mass global emissions.

Materials required to make these circuits often are gained from mining, which can cause serious environmental degradation. The environmental damage from mining are soil erosion, deforestation, and water pollution.

E-waste is one of the biggest growing concerns [11]. As technology is growing and improving constantly, this results in older devices being discarded. These old, discarded devices are often thrown away into landfills which play a huge role in environmental pollution.

The manufacturing of these' circuit requires a lot of labour. Being so labour-intensive results in many of the workers being in developing countries, where labour laws would be less strict compared to first world countries. Many reports about long hours, poor conditions and inadequate pay are quite common. This raises many questions about the responsibility of manufacturers to ensure fair labour work.

In conclusion, as the demand for electronics grows even further, it is crucial for manufacturers to address these ethical considerations quickly. This will require a commitment to sustainable practices, fair labour work and a better approach to product management.

While manufacturing these circuits its crucial to follow health and safety regulations. Make sure to wear the correct PPE, like masks to prevent inhaling toxic gases and gloves to prevent damage to your hands. There is an extremely low injury rate when it comes to PCB circuit manufacturing. A low injury rate shows a good set of rules to follow health and safety regulations.

5 EXPERIMENTS

5.1 Investigating the Accuracy of the Sensor

Apparatus: Ultrasonic sensor, MakeBlock Software, Obstacles

Procedure:

1. Connect the robot to a computer and ensure that Live Mode is selected on MakeBlock.
2. Measure the distance from the sensor to an obstacle.
3. Read the measurement the sensor reads back using live mode.
4. Check if the measured distance is within 1cm of the actual distance [12].
5. Repeat the above step 5 times.
6. Records results.

Actual distance	Measured distance	Within Range
5cm	5.1cm	Yes
50cm	49.81	Yes
1m	99.86	Yes
2m	199.57	Yes
3m	292.72	No

The results show the sensor is within the range of error for the values around our stopping distance. However, the results show that the sensor becomes less accurate as the distance increases.

5.2 Investigating the change in Velocity as the Robot Approaches an Obstacle

Apparatus: Measuring tape, Robot, Obstacle, Stopwatch.

Procedure:

1. Place the measuring tape along a straight for 3m from an obstacle (Range of our measuring tape is 3m).
2. Place down and activate the robot.
3. Making use of a stopwatch measure the distance from the object over 5 second intervals until the robot reaches its stopping point (50cm).
4. Graph distance over time.

Note: Suitable obstacles are obstacle that can be detected by the sensor. An obstacle raised slightly above the sensor but still able to obstruct the robot is not suitable.

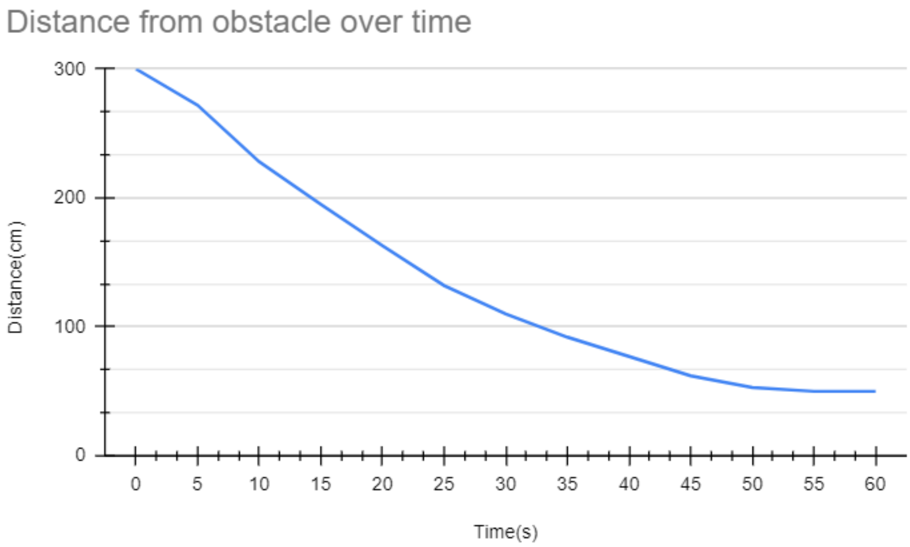

Figure 7: Plot of distance travelled by robot against time

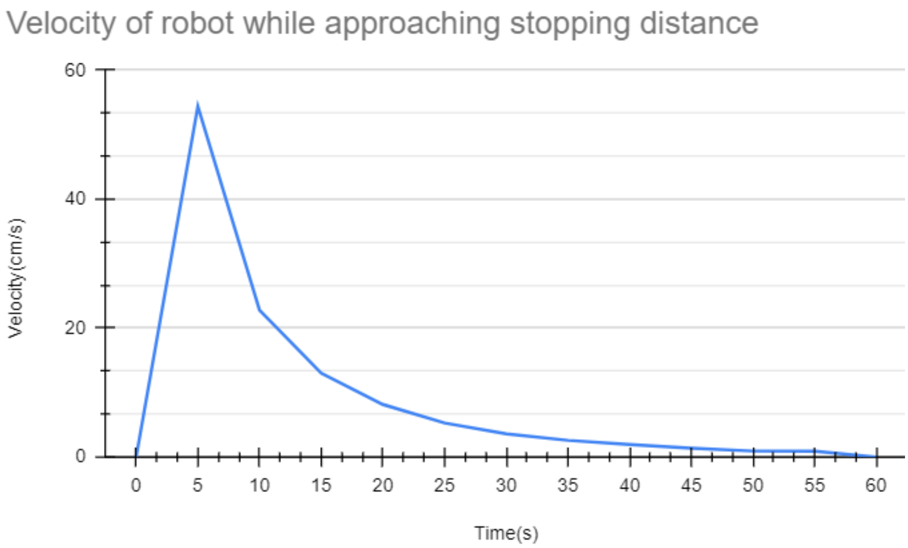

Figure 8: Plot of Velocity of robot against time

The results show the robots steady decline in speed as the robot approaches the stopping distance. Verifying the formula implemented in the code.

6 CONCLUSIONS

The purpose of the project was to design and make an autonomous system featuring a feedback control loop. We were successful in achieving this through the production of a smart braking robot. The robot can accurately read the distance between it and an obstacle placed within a range of 400cm. It reduces its speed as it approaches the obstacle and stops 50cm from the obstacle. It was manufactured using the MakeBlock components and software provided to us by our facilitator. The project was also completed within the given period of 6 weeks. This exactly fits the aim we set out to accomplish, as the robot works as expected and fits the given brief.

Applications of this system could be integrated into more complex systems, such as autonomous vehicles. The larger scale would need components of greater capabilities, such as a sensor that can read above 400cm. Overall, the project has been a remarkable success, shown through its completion and expected outcomes.

Future work to be done on this project include incorporating the idea into an automobile for further testing. Further investigation into applying the project to account for different problems can be done. A possible issue is the limitation of the sensor when faced with differently shaped backs of cars. A laser beam can be used instead of an ultrasonic sensor as a solution to this issue. Further investigation can be done to find the optimal stopping distance from the obstacle as 50cm was used for this project.

7 REFERENCES

[1] P, I, D, PI, PD, and PID control - Engineering LibreTexts

[2] Definition of a Control Loop

[3] Real-Time Obstacle Avoidance for Fast Mobile Robots

[4] Ultimate 2.0 | Makeblock Education

[5] About MegaPi – Makeblock Help Center

[6] MakeBlock - About (mit.edu)

[7] Me Ultrasonic Sensor | Makeblock Education

[8] An Ultrasonic Sensor Distance Induced Automatic Braking Automobile Collision Avoidance System

[9] Control and Autonomy of Microbots: Recent Progress and Perspective

[10] Ethical considerations of PCB manufacturing

[11] Ethical Manufacturing and its importance

[12] Me Ultrasonic Sensor

Appendix 1: Details of Apparatus

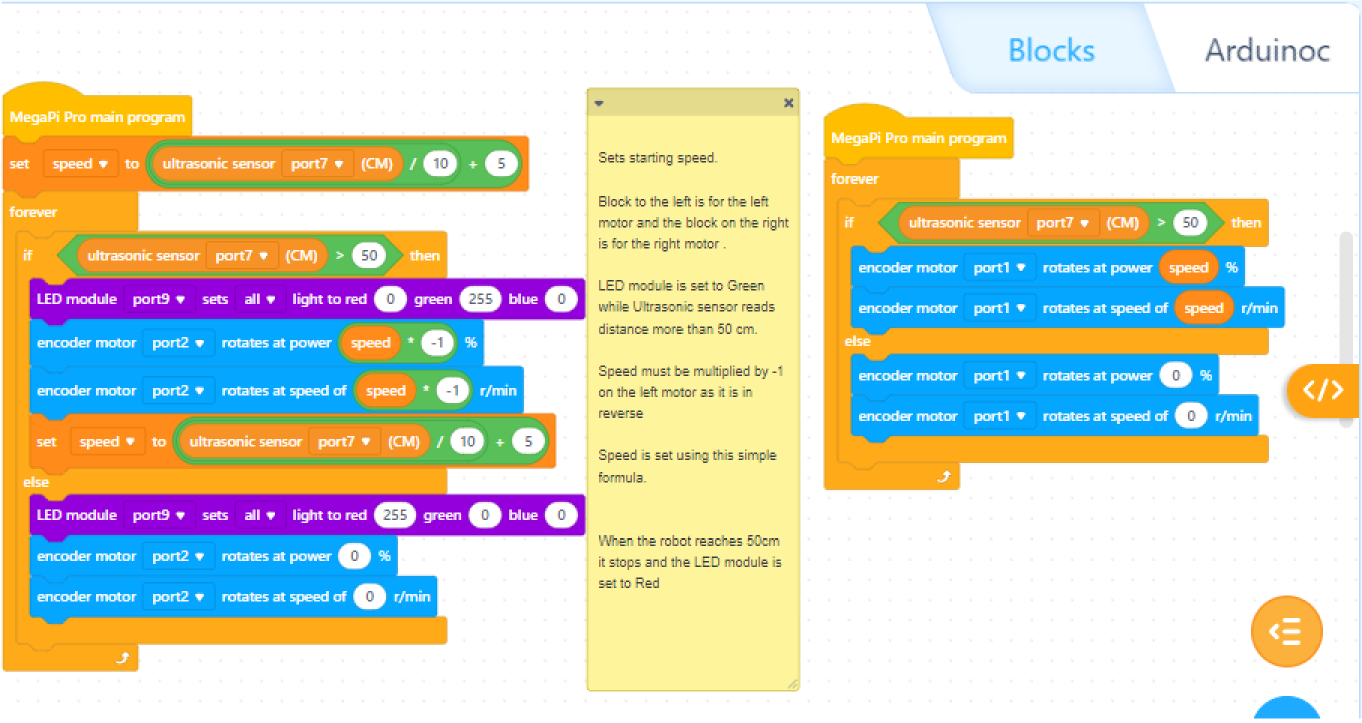

Figure 9: Makeblock Code

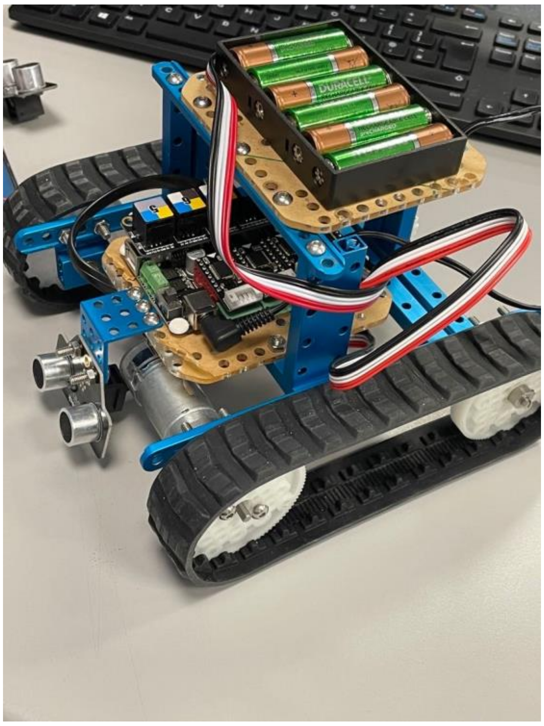

Figure 10: Final robot design

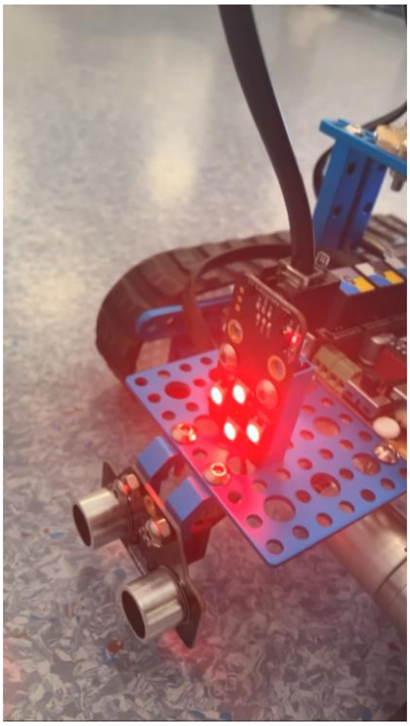

Figure 11: Robot upon reaching stopping distance shown by the LED module turning red

Figure 12: Approaching stopping distance shown by the LED module turning green