Engineering Design and Innovation

Robot Sumo Project

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Abstract

This report will outline our team's design process and thought structure into the construction of the robot. The aim of the robot sumo was to be the last robot standing by pushing the opponent out. In order to do this we need to design a robot that could withstand other robots by pushing them out. During the processes of conceptualising the design and implementing them, our team discovered that the implementation is much more difficult than coming up with solid solutions. We concluded that the most important features of the robot includes a ramp, low centre body and wheel location. It is recommended that extensive testing is necessary to improve the robot as just coming up with ideas does not give concrete evidence of the performance.

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1. Introduction

Our challenge was called the Robot Sumo wherein the only objective is to be the only robot left in the sumo ring. The basic idea is to build a robot using the Lego Mindstorm kit and battle other teams by eliminating them from the sumo ring. The first robot to cross the sumo ring loses, but if there is no crossing within three minutes the match is considered a draw. The robot must be completely autonomous, meaning no input from a human while the match running. The rules in the match are stated as follows:

- You may use any components in one EV3 kit.
- Can weigh no more than 800 g. (There will be a weigh in at the start of the tournament).
- The robot must be capable of movement, and try to move at some stage in the bout.
- If a robot is immobilized because it is on its back or side, it loses.
- You are allowed to attempt to pick up or flip over the other robot.
- Intentional damage (e.g. hammers) are not permitted. Pushing and lifting only.
- No projectiles - this is a safety hazard. Any dangerous activity means instant disqualification.

At the start of the match, both robots are parallel to each other but facing opposite sides. When the match starts someone on each team presses the button on the robot to signal the go. After the button press, both robots must hold for three seconds before being allowed to move. During the three seconds, a rotating turret can move around to scan for the opponent.

The design process was met with challenges that caused our team to struggle with the construction of the robot. The initial stage kept us stumped as we failed to solidify the design that we conceptualised in the planning stages. Due to the size and shape of the motors and the brick, it was difficult to attach the three pieces together to adopt a low centred mass and thus resulted in an overhaul of the whole robot and starting from scratch. The second attempt where we met during the weekend happened to be a lot more successful, and after attaching the brick and motors together, the other features slowly banded together to fit the ideas we wanted. Although the mass limit seemed to be a constraint, in the final stages of the completion of our robot it was comfortably under the weight limit.

This report has been mainly split up in two different sections named conceptual design, and implementation and testing. The conceptual design information provides insight as to the team's thought processes into the development of the robot. Ideas and concepts have been identified that we believe carry the heaviest impact when it comes to winning the tournament. The implementation and testing focuses on the building process and highlights some of the struggles we faced throughout our build. Following these two sections, the report covers the team's results of the tournament and analysis of each round, our final thoughts and conclusion of the whole design process and the tournament, acknowledgements, and references.

2. Conceptual Design

Our process for the generating and evaluation of the design solution to the problem involved the division of the initial problem statement into individual functions of our robot and conceptualising the design ideas for the components of the robot system that would achieve each of the defined functions. After several meetings of producing ideas through the use of morph charts (one of which is included in Appendix A), brainstorming and brainwriting, the design proposals were evaluated in regards to expected performance, feasibility, complexity, creativity, cost, and available parts. Through this method of formulating and assessing solutions, a number of suitable design components were selected for implementation of the robot.

2.1 Hardware

2.1.1 Turret-Mounted Ultrasonic Sensor

We conceptualised the approach of the rotating ultrasonic sensor as an innovative and beneficial answer to the sub-problem of locating the opponent robot. This design solution involves the attachment of an ultrasonic sensor to the axle of a motor, which is placed accordingly to body of the robot, such that the ultrasonic is placed as low as possible. This is accompanied with a gyroscope attached directly to the body of the robot. The utilisation of the ultrasonic sensor allows for the measuring of distance of objects facing the sensor, thus allowing for the detection of an opponent, and the motor allows for the rotation of ultrasonic sensor without the need to rotate the whole body of the robot to locate the rival. The use of the gyroscope assists the robot with orienting itself in the direction of the opponent.

This approach to the problem of locating the opponent robot is associated with many advantages. One of these is that the use of the motor to spin the ultrasonic enables the robot to obtain the location of the opponent before the 3 seconds waiting time are up, giving the robot an advantage over the other, as the robot can orient itself to face its opponent with greater certainty as to its location.

2.1.2 Lifting Ramp Wedge

The simple design idea of a ramp connected to the robot was chosen as an intuitive approach to the problem of being the prevailing robot in the ring, by means of rotating itself to face the opponent, and forcing it out. The design concept consisted of a doorstop-like wedge attached to the front of the robot near the base. As the robot applies full power to its wheels, the robot makes contact with the opponent with the intent to push it out. The front of the opponent slides onto and is lifted by the wedge that is near to the ground and comprises an inclined plane. The partial elevation of the opponent on the ramp brings several advantages to our robot:

- The opponent's force against our robot is reduced, so less force is required to counteract the opponent's pushback and drive it out.

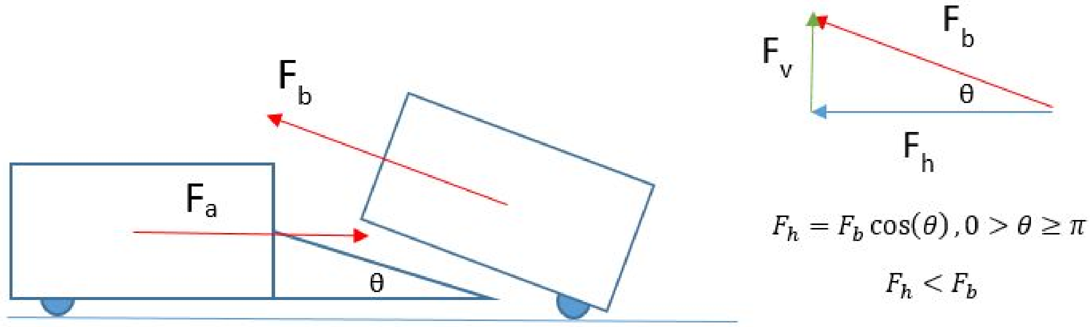


Figure 2.1 Angling the force vector of the opponent reduces the magnitude of its horizontal component

As shown by Figure 2.1, the use of a wedge to lift the front of the opponent tilts it such that its force vector is angled upwards. The horizontal component of the robot is equal to the force vector multiplied by cosine of the angle of elevation. The magnitude of the horizontal force is less than that of the original force, so less force is exerted onto our robot, reducing the force required to overcome it.

- Greg Munson (as cited in Paulas 2013) describes how in a similar robotics competition, a robot utilising a wedge would slide under and overturn the opponent, rendering it unable to move. Our team, inspired by this, hypothesised that the use of the ramp on our robot to lift the opponent could raise its centre of gravity, increasing the possibility of falling over and incapacitating it.
- If the opponent's driving wheels are placed at the front, they are lifted off the ground by the wedge, significantly negating resisting forces and decreasing the force required in pushing the opponent back.

2.1.3 Centre of Gravity

With the method of pushing the opponent out of the sumo ring being the main tactic, we initially planned to adopt a low centred robot. A low centred body introduces stability as the mass is focused lower toward the ground minimising the chances of the robot being flipped or the robot itself falling over due to sharp turns. As shown in Figure 2.2 below, a lower centre of gravity creates a larger angle for which it cannot be toppled.

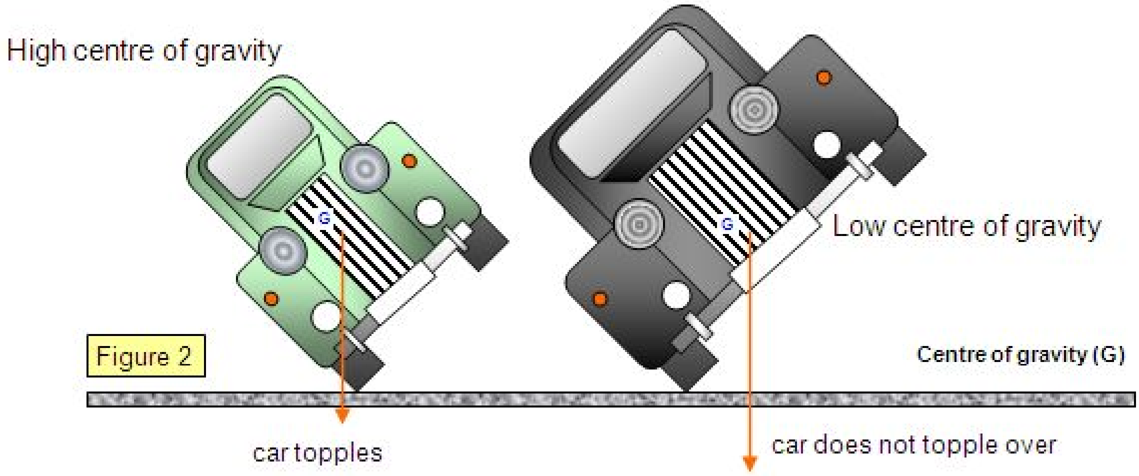


Figure 2.2 Comparison of effects of elevation of centre of gravity on vehicles
Source: Keith Gibbs, 2013 [Demonstration of the effects of a low centre of gravity)

2.1.4 Wheel Placement

The placement of the wheels was a key design decision in improving the robot's ability to force the rival robot out of the ring. Research into the optimal location of the wheels on the robot led to the compilation of Table 2.1 below.

Table 2.1 Benefits and Drawbacks of Front and Rear Wheels on Vehicles

	Pros	**Cons**
Rear Wheel	Offers better weight balance which results in better handling. The larger the load on the rear wheel car, the better its traction	Much easier for it to lose traction if the surface is slippery.
Front Wheel	Better traction due to the fact that the weight is on top of the wheels which increases grip.	Handling is worse. Wheels could possibly jerk to the left and right (torque steer). Towing will reduce traction.

Source: Motorists Magazine 2009, Motoring Australia 2010, Wired Magazine 2014

After discussion amongst the team we decided to make our robot rear wheeled, as the majority of our time in the ring would be spent pushing a load, which would provide us with better traction for the wheels, as seen in the Table 2.1. The board that we would compete on was not too slippery as to require a front wheel drive, and we did not want to risk the chance of torque steer has steering off from the opponent could result in the robot driving or being driven out of the ring.

2.1.5 Gyroscopic Sensor

It was decided, based on the advice of lecturers and 2nd year engineering students that we use a gyroscopic sensor to help the robot understand its position relative to objects surrounding it, thus we planned to include the gyroscope provided in the lego pack on our design. We imagined that the advantage of including this gyroscopic sensor was so that the robot could accurately recognise the position of foreign objects, such as opponents and use this information to move in their direction, thus allowing it to begin pushing them out of the ring.

2.1.6 Gearing

Gearing was discussed extensively by our group as many of us believed that gearing would provide us an advantage in torque, which would allow us to overcome the opponent’s own motors. As a group we discussed and experimented with gearing down to reduce speed while increasing torque, as seen in the formula below. Torque is a rotational force, so a higher torque means that our robot theoretically has a larger force with the same motor. In reality, we knew there would be losses in energy from the movement of the gears, and that it would also depend on whether there would be enough traction between the wheels and the surface to fully utilise this torque. Gearing down would also mean we would be slower than the opposing robot to turn and start attacking, meaning we would always be on the back foot. We also considered gearing up and experimented with it but decided the loss in torque was too great, and that it was too unreliable, leaving us to settle on an ungeared robot, which we believe struck the best balance between speed and torque.

$$RPM_{Out} = \frac{RPM_{IN}}{\text{Gear Ratio}}$$

$$Torque_{Out} = Torque_{IN} \times \text{Gear Ratio}$$

Assuming no losses due to friction.

$$Power_{Out} = Power_{In}$$

Figure 2.3 Mathematical relationship between gear ratio, torque and RPM.

Source: backfire.ca, 2009.

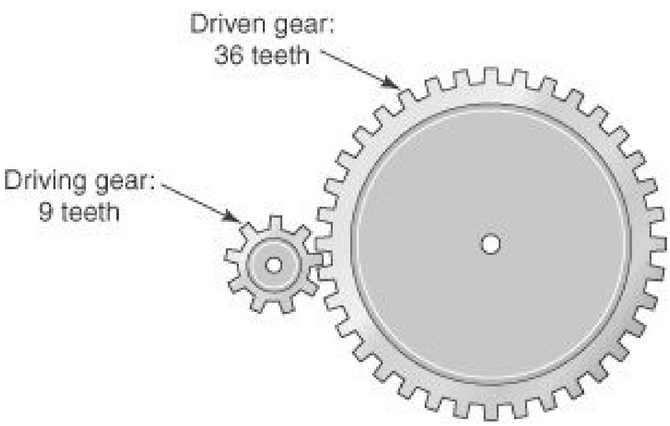


Figure 2.4: Gears and Gear Ratios.

Source: bowlesphysics.com, 2012

2.2 Software

The software written for the robot utilises and operates the hardware in performing the tasks to achieve the goal of being the only remaining competitor in the sumo ring. The software functions that incorporated each of the components of the problem, included in Appendix B1, are:

1. Moving the ultrasonic sensor in order to detect the location of the opponent relative to our robot;
2. Using the information from step 1, along with the gyroscope, to turn the robot to face opponent; and
3. Driving the opponent out of the sumo ring.

In addition to the three tasks, the robot must be programmed to start the competition only after a button press, as well as ending the program upon a button press, as per the rules of the tournament.

2.2.1 Detection of Opponent

Detection of the opposing robot was done through the use of an ultrasonic sensor mounted onto a motor, as described in Section 2.1.1. To achieve this, the sensor is rotated with the motor, while it is scanning for the distance of objects facing it. The motor is then programmed to stop if the ultrasonic motor detects an object with a distance less than a predefined threshold, which would signify the presence of the opponent of that location. This threshold value is a distance that is not too close as to miss detecting the robot, but not too far as to mistakenly identify objects outside of the sumo ring, as the opponent, and aim in the wrong direction. Once the robot has found the opponent, it calculates its position by finding the amount to which the ultrasonic has rotated. The motor on which the ultrasonic motor is attached, has a property for the amount it has rotated in degrees, so the opponent's bearing relative to our robot is easily found through measuring that property. The flowchart for this function is found in Appendix B2.

2.2.2 Rotating the Robot

Once three seconds have passed since the initial button press, the robot is programmed to rotate until it is facing the opponent. Through the above process of scanning with the ultrasonic, the direction of the opponent is known, so the robot now rotates until it is facing its opponent. This is done through applying power to the wheels such that the robot is spinning on the spot. To move clockwise, for instance, the robot moves its left wheels forwards and its right wheels backwards. While it is moving, the robot checks its direction with the use of a gyroscope set to compass mode. The initial bearing value of the gyroscope is 0 and increases or decreases in value as the robot turns on the spot. The gyroscope can therefore find if the robot is facing the opponent, by calculating if the bearing recorded by the ultrasonic is the value currently measured by the gyroscope. Once difference between the two are minimal, the wheel motor stops and the robot is now facing the opponent. The flowchart for this function is found in Appendix B3.

2.2.3 Forcing the Opponent Out

The final task in achieving the goal of driving the opponent robot out of the sumo ring is done through applying full power to the wheels motors to move the robot forward. As the robot moves towards the opponent, the physical properties of the robot, such as its low centre of gravity and front ramp, will aid it in forcing the opponent out the sumo ring and winning. The flowchart for this function is found in Appendix B4.

3. Implementation and Testing

3.1 Hardware

During the implementation and testing phase of our robot we had to expand on a number of our concepts, adding features to ensure that they were successful. Most concepts were implemented in some form and carried through to our final design except for the gearing concept which we decided to cut out entirely as it provided no benefit. Putting the wheels to the back and the centre of gravity close to the ground were easy tasks to complete, and no additional structures needed to be constructed to ensure their implementation. This was our first real construction. Soon after we attached the ramp, which took a little innovation and careful selection of material to build it with. The rotating ultrasonic sensor was extremely difficult to implement and required us to build two additional structures; a stand for the motor and a stand for the sensor. In the end we managed to create our rotating ultrasonic sensor which functioned perfectly but we needed to do additional building that we hadn’t foreseen in our conceptualisation. Next was the gyroscopic sensor which was quite simple to implement based on the existing structured. Our final construction wasn’t planned; the fenders were a last-minute decision. There was a lot of jostling in the implementation/testing phase but ultimately, all structures added to the robot were tested found to give some advantage.

3.1.1 Wheel Location & Lower Centre of Gravity

Our ideas that the robot was to have a low centre of gravity and that its wheels were located at the back were quite easy to implement and were, infact implemented simultaneously. This is because the brick and the two wheel motors formed a majority of the robot’s mass and they could be easily attached to one another with a few very simple joints. The only thing we had to do was flip the motor wheels around so that their rotating axles were sticking out the back of the large mass. In summary, we attached the two motors to the underside of the brick such that they were parallel to one another. The rotating axles of the two motors were distant from the brick and were faced outward of the large mass. Thus, the wheels were distant from the large mass protruded away from the centre mass such that when wheels were attached they were far from the rest of the mass (figure 3.1 and 3.2). Upon building the rest of the robot and testing it against those of other teams, we found this design to be very effective as neither robot could life ours.

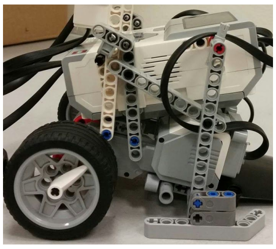


Figure 3.1

Figure 3.2

Figure 3.1 and 3.2 are different views of the connection between the wheel’s motors and the brick. These components make up a majority of the robot’s mass.

3.1.2 Ramp

In order to translate the ground-scraping ramp from concept into reality we needed to use some shapes that provided a very thin plane to create a sharp, inclined plane. Thus, we connected two very thin, wing-like pieces from the box set together into an arrow-like shape which was attached to the front of our robot (figure 3.3). This structure proved to be very effective when it was tested. We aimed the robot at heavy objects placed on a flat surface and in every test the ramp managed to slide inbetween the heavy object and the ground beneath it, allowing it to be moved with ease.

Figure 3.3
the sharp edged incline on the front of the robot

3.1.3 Rotating Ultrasonic Sensor

Building a rotating, ultrasonic sensor proved to be more difficult than we'd imagined. One major issue we had was finding a way to prop up the motor (on which the sensor would sit) in such a way that it's rotating axle was perpendicular to the flat floor beneath it. After many tested and failed designs we eventually managed to come up with a stand involving two long, upwards pointing bars on which the motor was mounted (figure 3.4). This solution however, gave rise to another big problem. Simply put, there was nothing bracing the horizontal rod, two vertical rods and motor together. This allowed sensor to spin freely around the horizontal bar, which was far from ideal as during testing the sensor would fall completely fall forward and confuse the robot. We managed to solve this problem using numerous braces (figure 3.4).

The next problem which we hadn't foreseen in the planning the rotating sensor, was getting the sensor to sit directly on top of the motor. One solution involved attaching the sensor to the end of a bar that was attached to the rotating axle of the motor at the other end. This proved to be a bad design as not just the view of the sensor rotated but also the sensor itself which led the robot to falsely interpret its position relative to objects. To solve this problem we worked on a stand that perfectly placed the sensor's centre above the rotating axle of the motor (figure 3.5). Subsequently the robot was able to accurately understand its position relative to surrounding objects.

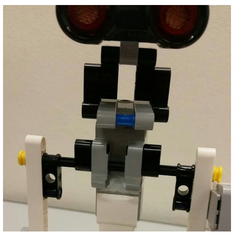


Figure 3.4

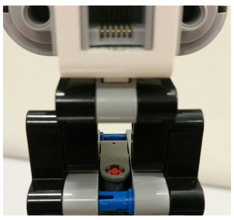


Figure 3.5

Figure 3.4 depicts a part of the final build including the upward-facing motor and the braces that were used to hold all of the pieces together

Figure 3.5 focusses on the stand that was directly beneath the ultrasonic sensor and above the rotating axle of its motor (you can see the axle's red tip pointing upwards)

3.1.4 Location of Gyroscope

When positioning the gyroscope we had to ensure that it was perfectly parallel to the ground to ensure it recieved accurate readings of the robot's bearing. This posed a little bit of a problem as a majority of the parts of the robot were not perfectly horizontal. Thus we had to attach the gyroscope to on the of two vertical rods that formed the stand for the ultrasonic sensor. Once we'd decided to use the vertical as a base for the gyroscope It wasn't difficult to attach it in such a way that it was parallel to the ground (Figure 3.6). Upon subsequent testing of the robot's sense of direction we found that it was able to correctly understand the position of objects that it detected relative to its own when it was able to turn to perfectly face them and charge at them.

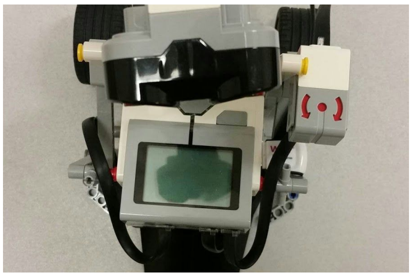


Figure 3.6

Figure 3.6 is a skyview of the robot, including the gyroscopic sensor (with red arrows and a red dot on it) attached to the vertical bars.

3.1.5 Fenders

We hadn't developed any ideas involving a barrier during the conceptualisation process so the decision to add them was a quick last-minute adjustment that we decided on after realising that our wheels stuck out in the open too much and that it could be easy for opponents to get underneath them. It wasn't difficult to add the fenders as there were pieces in an angular shape needed to make a barrier and these were attached to the lower ends of the braces that we had previously built around the robot's large mass (figure 3.7 & 3.8). In testing the effectiveness of the fenders, we found that objects which passed the ramp were in the pathway of the wheel were moved away from the wheel, thus eliminating the risk of our robot being caught on one of its wheels.

Figure 3.7

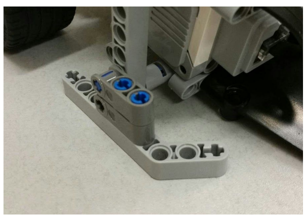


Figure 3.8

Figures 3.5 and 3.6 show the fenders attached to the forward brace of the robot, in front of the wheel and near the frontward ramp

3.1.6 Gearing

We were quite unfamiliar with gears and how they were going to help our strategy, so we decided to make prototypes. First, we built both gear up and gear down 4-gear gear trains and attached it to a wheel (figure 3.9 and 3.10). Then, we attached it to the motors and ran a simple movement program to evaluate their effectiveness.

From our testing, we discovered that gearing down to increase torque significantly decreased our speed. Conversely, gearing up to increase speed wasn't effective as there wasn't a significant improvement to the speed without the use of gearing. However, upon further research, we discovered that there wasn't enough traction between the wheels provided in the kit and the floor for a gearing mechanism to be successful at all. As a result of these observations, we opted to not implement gearing to our wheels.

Figure 3.9

Gearing down (decrease speed)

Figure 3.10

Gearing up (increase speed)

3.2 Software

From the design phase of the project, we decided that we only needed three functions implemented to our robot for success. The first one is a scanning module to find the opposing robot. The second and the most crucial function implemented was the rotating module. If the rotating module wasn't calibrated correctly, the robot will rotate too far or not far enough, resulting in failure for our strategy and our robot. Finally, the third module is the movement module, which was the simplest to implement and enabled our robot to move. Additionally, since most members in the team were not very familiar with code, the programmers made sure to use correct programming convention, such as intrinsic documentation, in the form of meaningful variable names, comments and use of whitespace.

3.2.1 Scanning

```
US_THRESHOLD = 600
us_motor = MediumMotor(OUTPUT_B); assert us_motor.connected
us = UltrasonicSensor(); assert us.connected
detector_count = 0
first_detection_val = 76 # Default detection value
# Set starting point for ultrasonic motor
us_motor.position = 0

# Rotate Ultrasonic motor
us_motor.run_direct(duty_cycle_sp = 40)
while (detector_count < 3 or us_motor.position < 120):
    if us.value() < US_THRESHOLD:
        if detector_count == 0:
            # Get first reading of degrees
            first_detection_val = us_motor.position
            detector_count += 1
            #print "detected, position =", us_motor.position
        else:
            detector_count = 0
            sleep(0.05)
us_motor.stop()
#print first_detection_val

# Move ultrasonic motor back into start position
us_motor.run_direct(duty_cycle_sp = -35)
while us_motor.position > 0:
    time.sleep(0.05)
us_motor.stop(stop_command = 'brake')
```

The purpose of this module is to implement a scanning function to the robot to allow it to detect the opposing robot inside the ring. This is achieved by rotating the ultrasonic sensor attached to the robot and continuously scan for any object until there is something less than 60cm away. The amount the ultrasonic motor rotates is saved, which will correspond to the amount the robot will rotate once the three seconds of sleep time is complete.

We chose a threshold of 600 from testing. First, we started with a threshold with 800 but that value could detect objects that were outside the ring consistently. Then, we lowered the threshold by 100 until 400, which couldn't detect objects from the edge of the ring, so we decided to use the middle value of 600 which worked consistently. The first detection value was set to 76 and not 0 because if the robot did not detect any object, it would default to turn 90 degrees instead of go straight ahead. This would work well against low lying robots as they would usually be wide, so turning 90 degrees would be effective enough. It is set to 76 and not 90 because of the delay between reaching 90 degrees and stopping since the robot is not able to stop straight away after reaching 90 degrees. As a result, a value slightly less than 90 was chosen as the default value, which was retrieved from rigorous testing. We decided to rotate the ultrasonic sensor at only 40% power since any quicker and the ultrasonic might miss the opponents, and any slower and the motor would not have enough power to rotate the sensor at all. Additionally, our while loop stops once the ultrasonic detects an object less than 60cm away 2 times. This is due to the inaccuracy of the ultrasonic that would sometimes throw a random value, such as 200, for no apparent reason. Furthermore, debugging output statements were used throughout testing to observe what values the ultrasonic sensor motor and ultrasonic sensor outputted to debug and test if our program was working as intended.

3.2.2 Rotating (talk about left)

```
def rotate (opponent_initial):
    # Rotate robot to position
    gyro.mode = 'GYRO-RATE'  # Reset gyro and
    gyro.mode = 'GYRO-ANG'  # Set to return compass angle
    # Spin wheels to rotate robot to opponent
    right_motor.run_direct(duty_cycle_sp=-80)
    left_motor.run_direct(duty_cycle_sp=80)
    while abs(gyro.value()) < abs(opponent_initial) - 50:
        time.sleep(0.05)
    #print gyro.value()
    right_motor.stop(stop_command='brake')
    left_motor.stop(stop_command='brake')
```

This module was the most important in the entire program and was paramount to achieve success with our strategy. The most difficult part of implementing this module was the calibration required to get it right every time. Various elements altered this module throughout testing. The main issue was the inaccuracy of the gyro. On some rare occasions the gyro would lag and cause the robot to over-rotate. However, it also did not give consistent readings. Repeated tests with the same conditions yielded different results many times. Despite this, due to the time constraints, we persevered with the gyro and kept calibrating and recalibrating until it gave somewhat accurate outputs. Additionally, our robot was not on the same charge throughout testing. Some days, we would have enough time beforehand to fully charge the brick, which made the motors more powerful and some days, our brick would be half charged, which decreased the output power of the motors. This severely altered the amount the robot rotated every time. As a result, we

endeavoured to keep the robot fully charged to negate this issue.
We subtracted the ultrasonic motor value by 50 due to the fact that the robot can not stop immediately after reaching the ultrasonic motor value. So we needed to start braking from a point before the motors reached this value. We got this number from vigorous testing. First we started with 30 and worked our way up until the robot consistently rotated the correct amount. However, this value needs to be recalibrate due to the various issues outlined above.

3.2.3 Movement

```
def charge():
    right_motor.run_direct(duty_cycle_sp = -100)
    left_motor.run_direct(duty_cycle_sp = -100)
    while not btn.any():
        time.sleep(0.1)

def stop():
    right_motor.stop(stop_command = 'brake')
    left_motor.stop(stop_command = 'brake')
    us_motor.stop()
```

Our movement modules were simple to implement. The only issue was that our motors were upside down, so we had to apply -100 power rather than +100 power. Additionally, we decided to use the ‘brake’ command instead of setting the power of the motors to 0 to allow it to stop immediately, rather than continue even after power has been cut from the motor.

4. Results and Analysis

We went into the competition quietly confident with our design, as we had performed well in practice matches with other teams. We expected to be able to win 3 games of the 5, but unfortunately, mainly due to random errors in the sensors and our calibration errors, we only managed to win and draw one game each. Analysis of these matches provided some crucial insight into the weaknesses of our design and many improvements that could be made.

Round	Win	Loss	Draw
1			
2			
3			
4			
5			

<u>1st Round:</u>
The opponent robot was extremely wide (giving it a large turning radius) and was geared. As a result, it was very slow to start moving, in comparison to our robot which was not geared and had a much smaller turning arc. We got to the other robot extremely quickly, and got under it easily as the opponent robot had quite a large gap from floor to undercarriage. Our robot then pushed it out quickly and easily. This can be seen in figure 4.1.

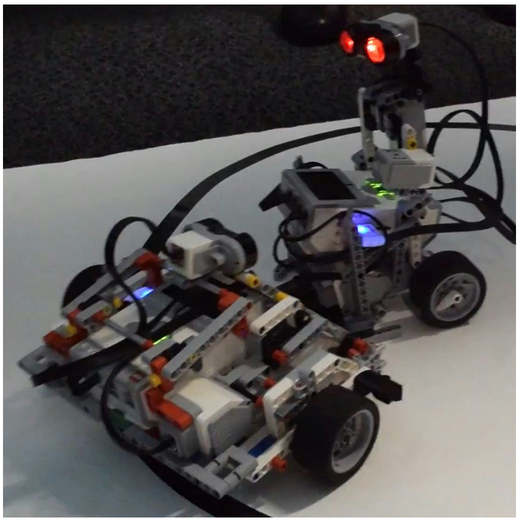
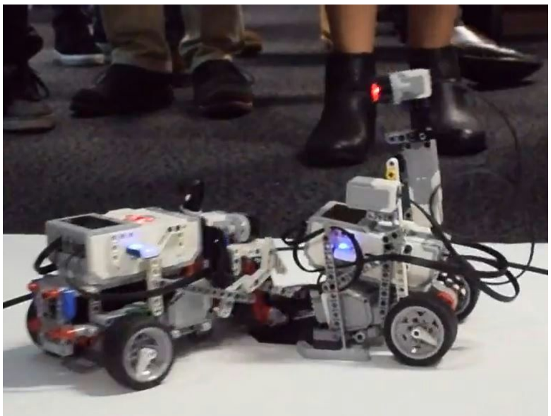


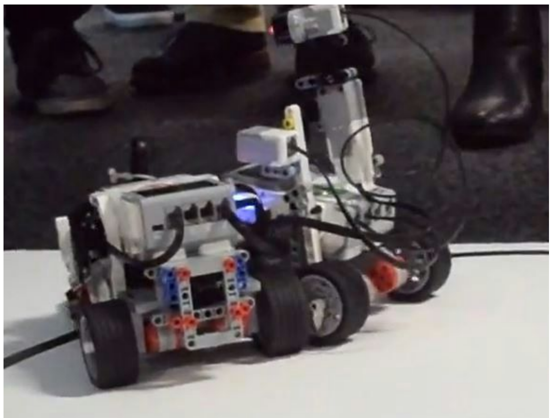
Figure 4.1 The opponent robot was geared and had a wide base, meaning we reached it and pushed it out early.

<u>2nd Round:</u>
The opponent robot in this round was extremely similar in design to our own, with the same ramp and size. Due to our ultrasonic turret, we located them before they did us. Due to our small turning arc, we also reached them before they reached us. Due to the unreliability of the gyro

sensor, we contacted on the side of the opponent. As a result, when we were pushing out the opponent robot, we ourselves left the ring at the same time, resulting in a draw. Our initial contact happens at figure 4.2, and our end position in figure 4.3.



(Figure 4.2)



(Figure 4.3)

While we initiated contact (4.2), our misjudgement of position led to both robots exiting the ring at the same time (4.3).

<u>3rd Round:</u>
In the 3 seconds waiting period, our ultrasonic sensor seemed to not detect the opponent robot but rather something past it. This meant that we overshot the other robot by at least 20 degrees and exited the ring of our own accord. This was a disappointing result for us, as we had failsafe code in the case that the ultrasonic sensor didn't pick up any robot, which was to default to a 90 degree turn and spin. However, in this case the ultrasonic sensor received a false positive, which we did not account for in our code, and we lost without a fight. Figure 4.4 clearly shows the result of this with us running ourselves out of the ring.

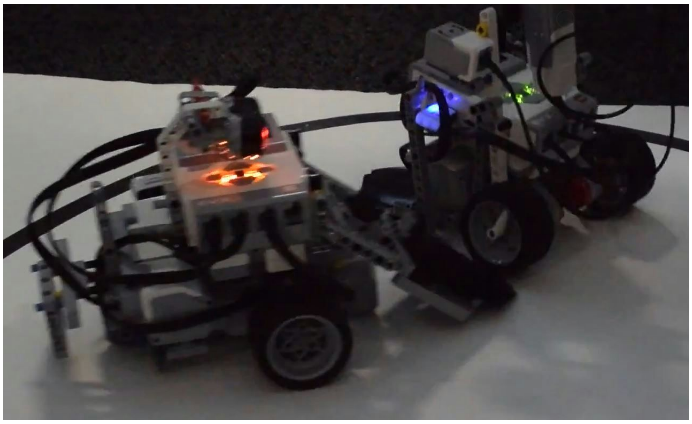


Figure 4.4 We didn't detect the opponent AND the sensor had a false positive reading which led us to run ourselves out of the ring.

<u>4th Round:</u>
Our ultrasonic sensor picked up the robot properly, and reached the opponent robot before they begun moving. However, due to the imprecision of the gyro and likely poor calibration of our values before the competition, we overshot the robot's centre making contact with the end of the opponent. Due to this, we exited the ring before the opponent as seen in figure 4.5.

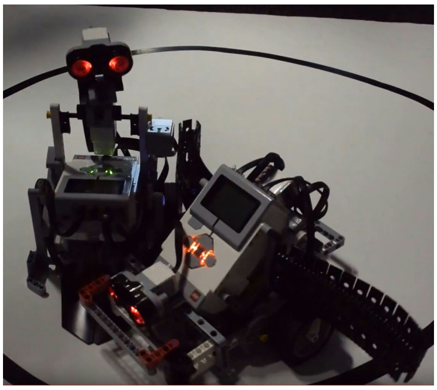
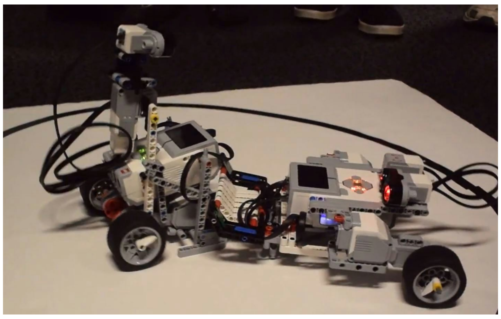


Figure 4.5 Here again, we slightly overshot our target and glanced off the robot, resulting in us exiting the ring.

5th Round:

Our ultrasonic and gyro worked well this round, meaning we were aimed essentially at the centre of the opponent when it was sideways. Since the opponent robot was extremely long, when it turned to face us, the centre of their robot had changed position, meaning we were aimed slightly to the left side of the robot, seen in figure 4.6. They also had large leverage due to its front prongs being a large distance away from their rear wheels. Due to this design, our robot was veered off course, and pushed off to the side and out of the ring, seen in figure 4.7.



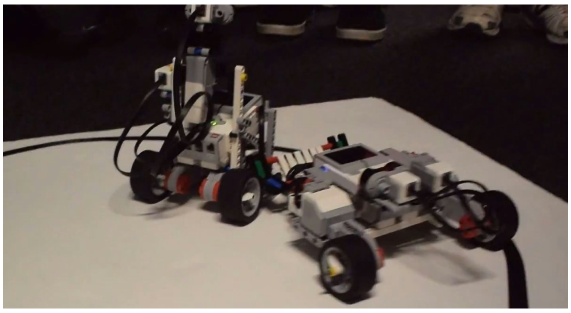


Figure 4.6

Figure 4.7

Due to the opponent robot's large amount of leverage and small nature of our robot, we were veered off course and outside of the ring.

Analysis:

- Our speed was significantly better than all other robots we faced. This is due in part to our smaller robot design, our small turning radius, and rotating ultrasonic sensor which allows us to turn quickly as we have already located the robot before movement is allowed.
- Our extremely low ramp was effective as it allowed us to get underneath 1 robot, and made sure nothing could get under us.
- The high position of our ultrasonic sensor lost us one game, as we didn't locate a robot which was particularly low to the ground.
- While our rotating ultrasonic sensor allowed us to detect the opposition robots very quickly, it meant we had to resort to positioning our robot based solely on our gyroscopic sensor, which itself is not very accurate and is prone to random errors, and interferences from the environment. Our reliance on this sensor lost us a few games.
- Our calibration was done slightly incorrectly, as in 3 of the matches we slightly overshot the centre of our target.
- Our robot's narrow width meant it was easier for it to glance off the other robots prongs etc, and go off track.

- Our robot, once finding a target in the pre-movement phase would just charge straight at where the ultrasonic sensor picked up a value. However, in this time, the opponent robot can move a lot, meaning their centre of mass can change significantly. Our robot didn’t account for this, meaning in the majority of matches we were not pushing at the optimal positions.

5. Improvements

Our teams design will have to be improved and modified in order to counter its vulnerabilities. Our robot had both strengths and weaknesses as it was seen in the course of the tournament. We were able to pick up the both the subtle and the major flaws in our robot, by comparing our robot to our peers. This was a helpful method of seeing where our robot stands among all the other ones and what functions they have invested time in in order to make their robot stand out. While assessing our robot in the competition we found that there were restrictions to the robot which deviated the robot from reaching its optimum.

We found that throughout the tournament there was a lot of teams using gearing which was concept our team had discussed before. But we decided in going against it as it looked like it would improve the robot, but as pointed out by Hayden since there isn't really anything to keep the wheels intact to the ground the robot would just slide making the gearing ineffective.

The ultrasonic sensor:
Our design lacked the awareness of the environment even though we had an ultrasonic sensor, this is due to the inaccuracy of the sensor. This lack consciousness of awareness for the robot was frustrating and probably the biggest flaw as we were not able to detect the other robot. The teams ultrasonic was mounted on the brick which gave it a lot of leverage and allowed it rotate smoothly. But this put the team on a significant disadvantage as the other robots that we went against were very low which meant that our robot couldn't detect them. On the other hand, the downside to having the sensor lower is that it can detect other things other than the opponent's robot, which would make it go off track and even out of the ring. We were able to experience this as our robot detected something that was not there and hence it went off course.

The mass:
Our team could have maximised the pushing power by utilising the mass amount given to us. When we were designing and building our robot we didn't take mass into too much consideration as we know that we would be under and we didn't weigh the robot until the day of the competition and we were shocked to find out that the robot only weighed 697g which was a lot below the maximum limit. We could have added additional features to the robot and also increasing the mass which would make our robot harder to push out of the ring.

The programing:
Some minor improvements that could our group work on for next time is when the programmers in our team were writing the program, they weren't saving the code as they went along. This was particularly annoying as at this one particular moment, the code was changed and the robot stopped working. We had no way of retrieving the code and hence time was wasted in order to write the code again.

A side ramp:
Our robot can also be improved through adding some features that would allow our robot to resist the pushing of the opponent. This new improvement would be particularly helpful as our robot was mainly pushed from the side and had no counter method to the pushing. An improvement that would help catalyse this process is through the adding of a side ramp that could prevent the robot from being lifted from the side, as in one of one the matches we were lifted from the side and we had no contact to the ground which allowed the other robot to push our robot out smoothly.

The structure:
Our robot was not very sturdy and stable, the structure of the robot could have been reinforced by attaching some more Lego pieces in the core of the structure. Our team's robot lacked the pushing strength and the stability that we were aiming for and because of this we were not able to come up with the results that we had hoped for. This was mainly due to finishing our design last minute, which caused us to overlook some factors and hence we weren't able to test our robot out as much as we would have like. Next time we should test the robot as much as possible as the lecturer said that the best way to win the competition is to test your robot as much as possible.

Research:
During this course of the project our group has not done enough research or has the depth of knowledge to fully understand what we are doing and what we are implementing into our project. Most of our research was done at the last second which meant that we only had the surface facts, this was evident when we tried to implement gearing into our project but couldn't do implement it effectively, as we couldn't integrate the gears into the wheels. More research has to be done in advance in order to maximise results and enhance our robots functions.

Through analysing and reflecting our design and the performance of our robot, we have been able to come up with a more efficient and succinct design.

6. Conclusion

Given what occurred throughout our project, including the translation from concept into reality, testing, the results that our completed design produced and the teamwork that generated all of these things, it can be said that we've encountered both success in achieving the goals of the project and some areas of teamwork but we have also found ourselves lacking in each of these areas. These successes and shortcomings have given our team valuable lessons about the project-based engineering design process and teamwork.

Ultimately we were able to achieve all objectives defined in our problem statement through collective team conceptualisation and the combined efforts involved in translating our visions into tangible results that were more than capable of achieving results. However, on the day of competition, our robot's performance was far from satisfactory, losing a majority of its fights, for various reasons. Our team faced great disappointment as our design was proven, yet we have been able to learn from the entire experience. We now understand more about the engineering process; in particular, testing ideas and continuously returning to set points in our process to alter/remove concepts/implemented features of current designs to generate improved concepts/designs that will, themselves be assessed and subject to improvement.

On the grounds of teamwork we've all learned of the vitality of communication between every member in allowing members to contribute to the success of the project. Throughout every stage of our process we found that some members were not completely up to date on the group's activity and this ofcourse led to confusion and inevitably, a lacking in contribution from those team members. We believe that, had every individual attempted to engage in better communication with every member we could have worked better as a team, all simultaneously thinking about an overall problem, or all tackling different problems which contributed to the overall completion of our project.

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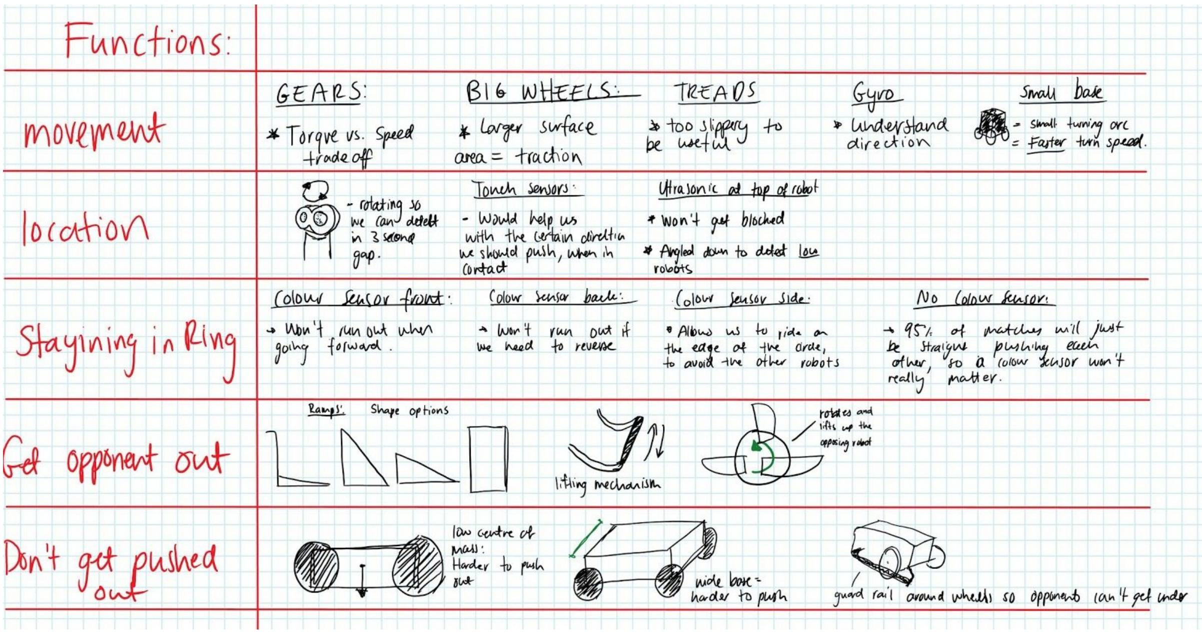
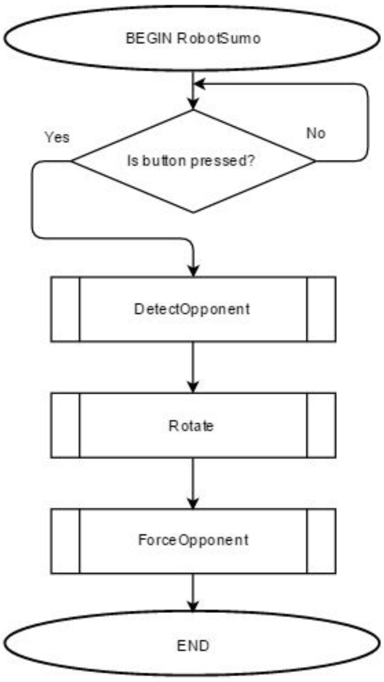
8. Appendices

Appendix A: Design Morphological Chart

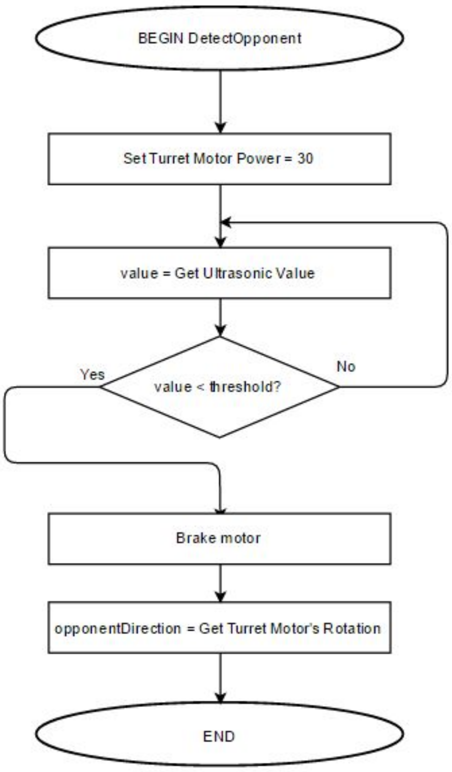


Appendix B: Conceptual Design (Software)

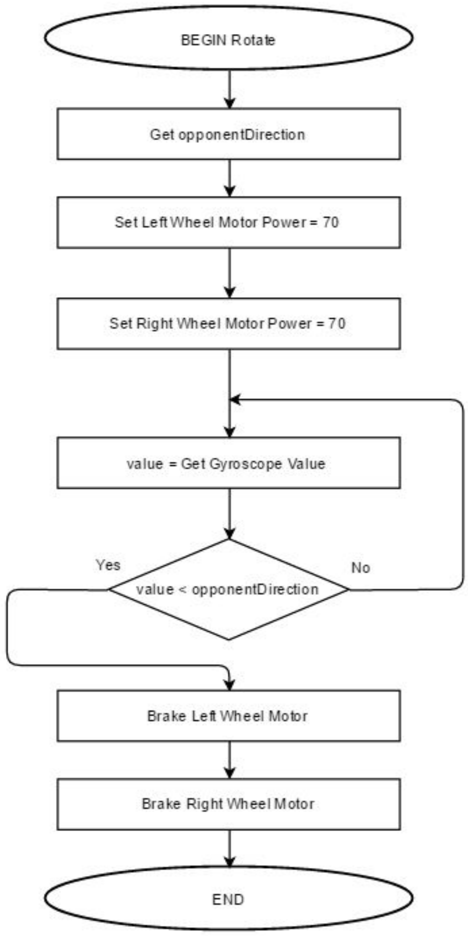
Appendix B1: Flowchart - Main Program



Appendix B2: Flowchart - Detecting the Opponent



Appendix B3: Flowchart - Rotating the Robot



Appendix B4: Flowchart - Forcing the Opponent Out