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SUMO ROBOT

INTRODUCTION TO MECHATRONICS

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1.Introduction

1.1 Purpose

At the beginning of the semester, it was requested from each team to create a sumo robot, a sumo robot is a mini robot that mimics the Japanese sport Sumo where two robots are placed in a circular arena called “Dohyo” where they attempt to push each other out of said arena.

The main challenges that face this robot is to detect its opponent and attack it while trying to avoid being pushed out, these tasks are accomplished through a set of proximity sensors and codes to automatically control the robot. All while adhering to the rules set for the competition which include constraints like weight and dimensions.

1.2 Background

During the first phase of the creation of this project, extensive research was conducted alongside brainstorming for ideas to reach the final plan that was included in the first presentation attached in the appendix.

In the second stage, a prototype is put together to test the mechanical design and its stability, to configure all the updates needed for the final robot, to test out the electronic components and connections and to visualize the robot’s movement in the arena to secure the best attack and defense strategy.

For the final stage; after an aluminum sheet of 3mm thickness was cut and folded to create the mechanical parts of the robot, some electrical parts were shipped and delivered and PCBs were designed and printed; the final robot was finally assembled and multiple codes were tried inside an arena resembling the Dohyo to reach the final strategy and code.

2.Scope and Overview

The creation of the sumo robot took part over three phases, each divided to two sections: mechanical which included the design on SOLIDWORKS, the choice of the material and any optimization included such as the ramp and rubber while electrical included the choice of components, actuators, the design and implementation of PCBs and the code used to automatically control the robot.

2.1 Mechanical Overview

The mechanical part of the sumo robot consists mainly of the design for a 20x20 cm sumo-bot which was conducted on SolidWorks by designing each side of the robot then assembling it as shown in Fig.2.1.

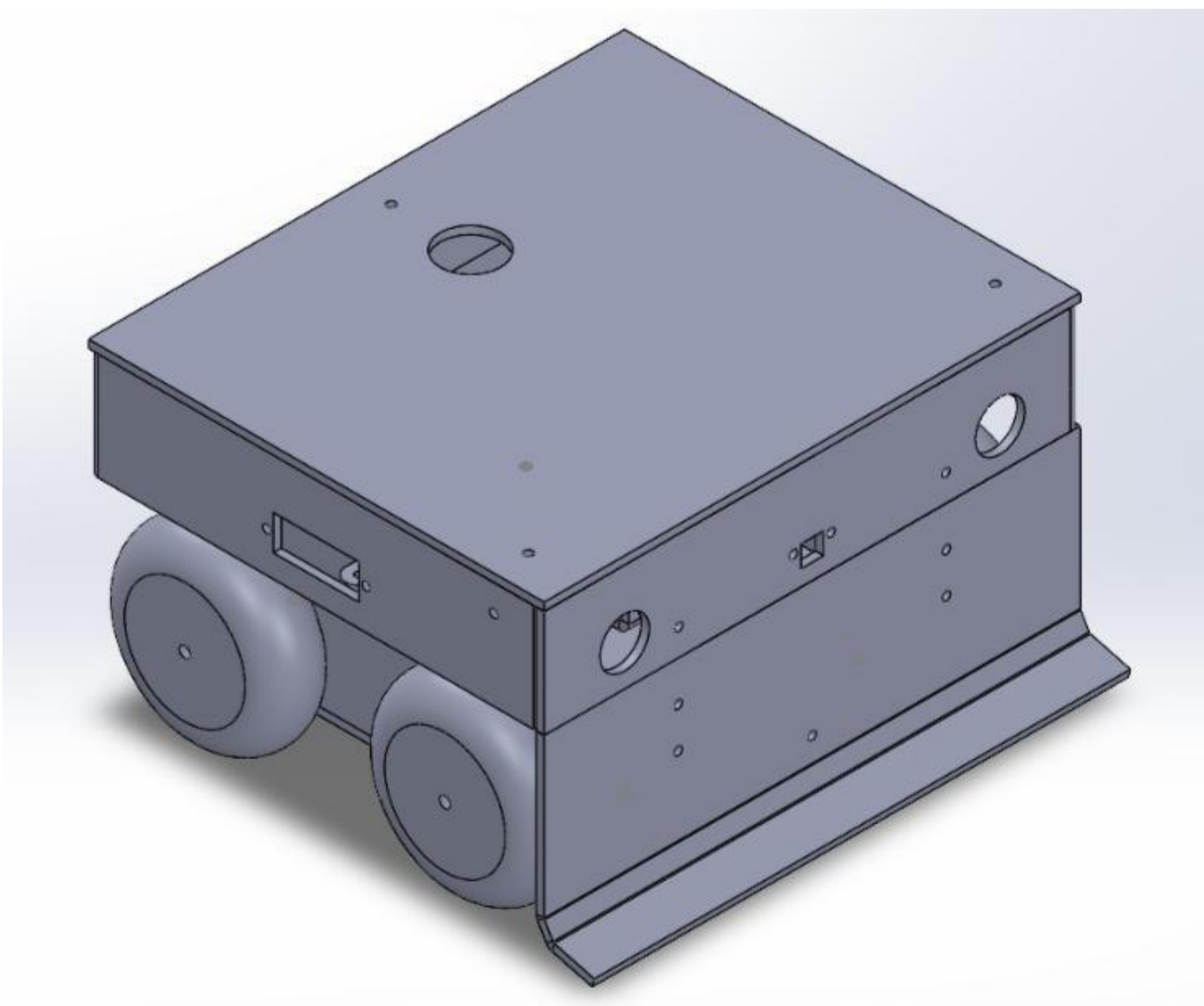

Fig.2.1

The full assembled design of the sumo robot on SOLIDWORKS

2.1.1 The Front

The front part (Fig.2.2) consists of a 20x4 cm upper plate and a 60x150mm lower plate, both with 3 mm thickness made of aluminum.

The 2 upper circular holes are for the photoelectric sensors which are 18 mm in diameter but the hole designed is 18.5 mm diameter for clearance, the sensor is mounted to these holes and fixed by 2 nuts.

The 3 middle holes are for the time-of-flight sensor, the rectangular cut is for the sensing part of the sensor which is 10.60x6 mm while the 2mm circular holes are for the fixation of the sensor to the body of the robot.

A blade was added in the front of the robot to scoop up the opponent attempting to lift its wheels making it easier to attack from the front. This blade was padded with rubber from below to eliminate the risk of any two wheeled robot sliding underneath it.

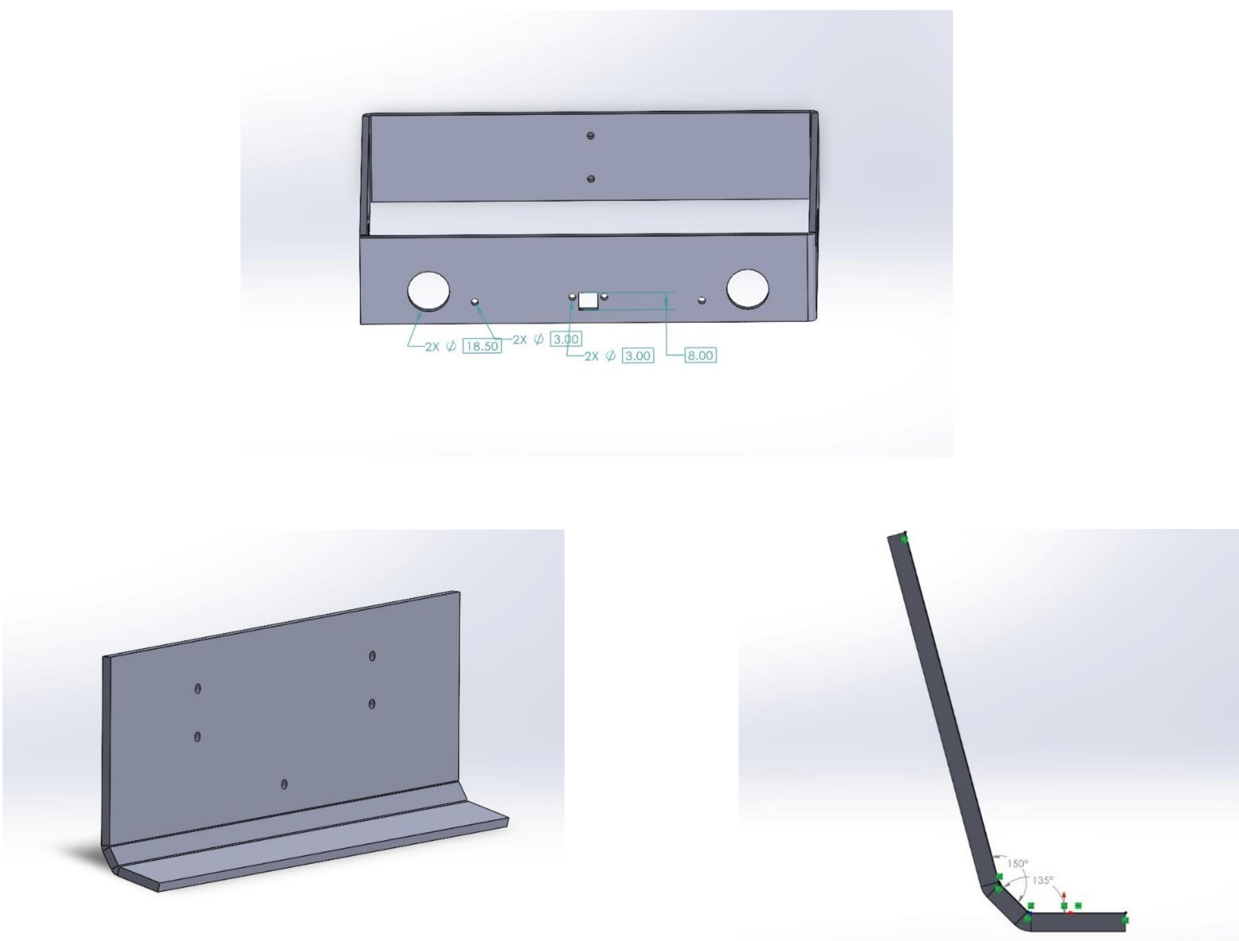

Fig.2.2
The front part

2.1.2 The Sides

The side face (Fig.2.3) consists of a 200x170 mm upper plate and a 60x150 lower plate, both with 3mm in thickness made of aluminum.

The lower 3 holes on each side are for the fixation of the motor and the wheels. The 8mm hole is for the motor shaft that is connected with the coupler to connect the wheel. The 3mm holes are for the M3 bolts that fix the motor to the body of the robot.

The upper rectangular cut 31x13.5 mm is for the sharp infrared sensor that is mounted on the side of the robot to detect the opponent when/if being attacked from the sides which enables the robot to counter this attack. These sensors also allow the robot to rotate in the fastest way to face its opponent with the front side instead of having a blind side at the sides.

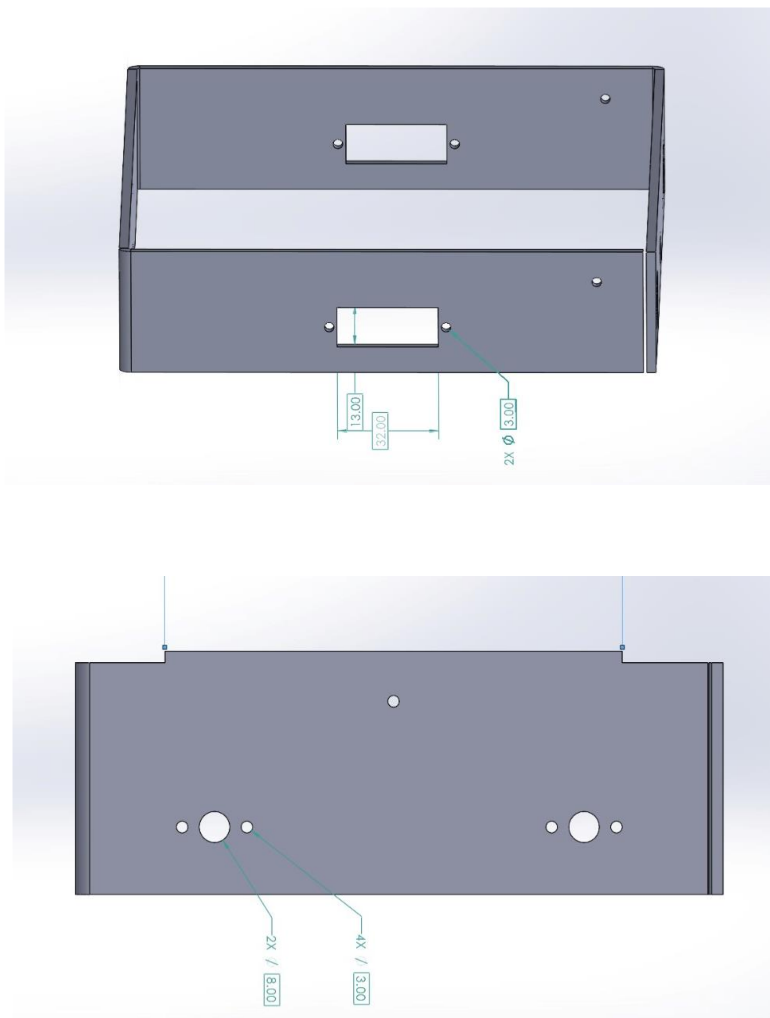

Fig.2.3

The sides

2.1.3 The Bottom

The bottom side (Fig.2.4) consists of a 168x150 mm plate with 3mm thickness made of aluminum. The 4 rectangular cuts at the edges are 14x6.50 mm cut for the line trackers sensors which guarantee the robot stays on the arena.

The bottom has room enough to contain 4 line trackers, 2 H bridge modules (motor drives), the corresponding PCB and 4 motors.

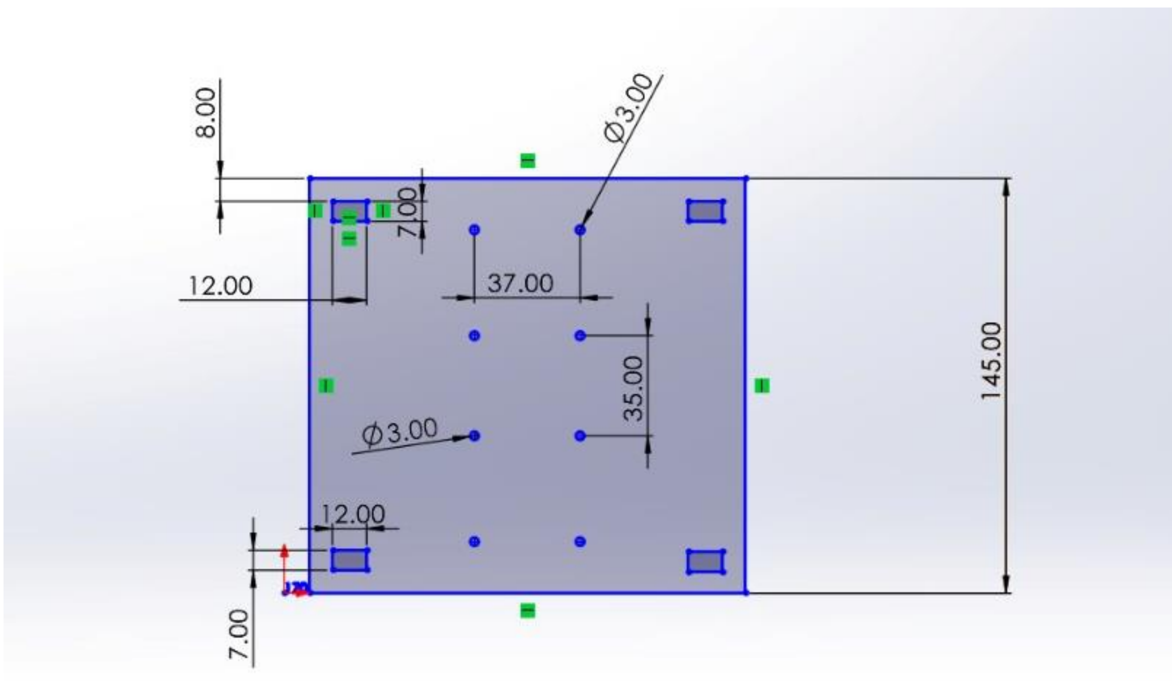

Fig.2.4

The bottom part

2.1.4 The Second Level

The addition of this 2^{nd} level (Fig.2.5) was required as it wasn't efficiently possible to fit all the components on the bottom base only.

Therefore, a 158x140mm with a 3mm thickness rectangular plate is inserted at a height of exactly 40mm measured from the upper surface of the lower plate to split the heigh of the robot to 2 volumes. This additional plate will carry 3 batteries, the corresponding PCB and the Arduino nano.

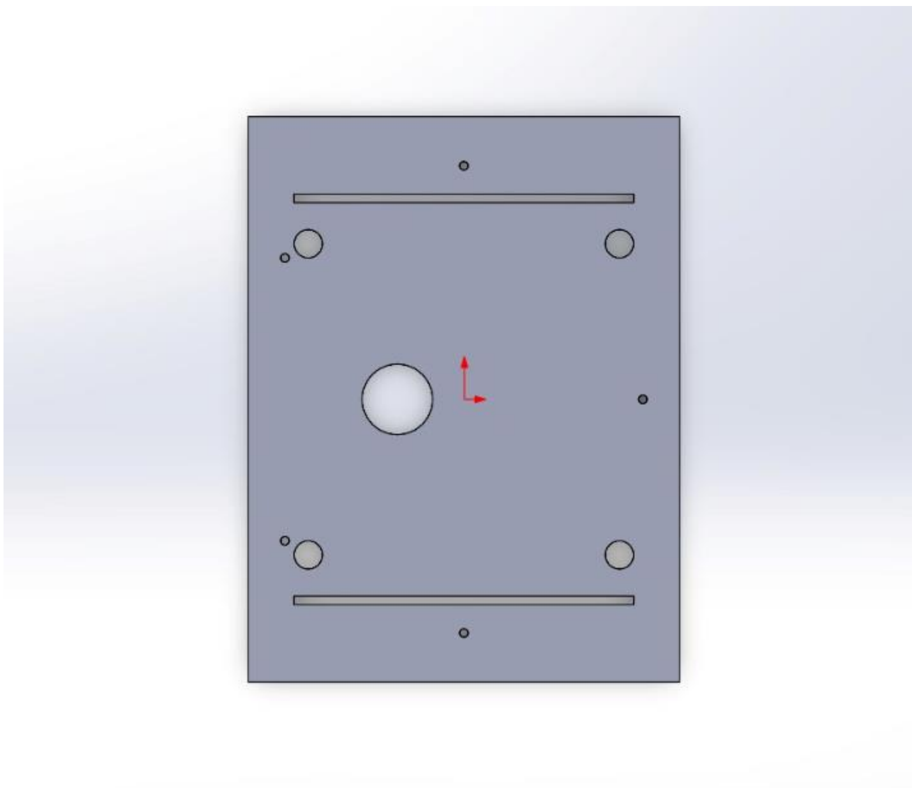

Fig.2.5

The second level

2.2 Electrical Tasks

2.2.1 Sensors

- **For the front:** one time of flight is the main object detection sensor for the front part, the choice of this sensor was based on how it uses laser beams as laser is the most accurate and stable for detection in wide ranges. Unlike infrared light and ultrasonic waves laser is not affected by sunlight, surrounding light or sound, neither the opponent's material and thus is less likely to be distorted during the competition.
  The secondary proximity sensor for the front side is an IR photoelectric, two photoelectric are placed at each side of the time of flight with an acute angle to aid in detecting the opponent when attacking the front with an angle.

- **For the sides:** one sharp IR proximity sensor will be used per side as this IR produced by Sharp is modified to have a reading range of 20-150 cm. The old choice for the sides was a photoelectric but the sharp IR has proven to be more efficient though both operate through infrared lights but due to adopting the triangulation method this sensor is not easily affected by the reflectivity of the object, the temperature or the operating duration.

- **For the bottom:** the base of the robot contains four line trackers, one at each corner. The sole role of these sensors is to guarantee the robot stays inside the black Dohyo during the competition to adhere to the rules. Lightly colored surfaces will reflect more light than dark surfaces; therefore, lightly colored surfaces will appear brighter to the sensor. This allows the sensor to detect a dark line on a pale surface, or a pale line on a dark surface.

2.2.2 Actuators

- **The motors:** 4 DC motors, 12V, 220 rpm, with 10 kg.cm torque were adequate according to the torque and force calculations as follows:

  F1 = 6 Kg (Mass of 2 Robots)
  F2 (Friction Force) = μs (Coefficient of friction force) x W (Weight of the Robot)= 0.6
  (worst case) x 3 = 1.8 Kg
  Torque (All Motors) = F (Total Forces) x R (Radius of the wheels)
  Torque = (F1+F2) x R = (6 + 1.8) x 3.5 = 27.3 Kg.cm
  Since we are using 4 motors, therefore we will use motors each of torque (27.3/4) =6.825 Kg.cm

- **The motor drives:** 2 L298N dual motor driver modules are used to control the speed and direction of the motors.

- **The wheels:** 4 wheels of 68mm diameter with strong gripping rubber are responsible for the robot's motion.

- **The microcontroller:** Arduino nano as it provides sufficient ports without consuming too much space.

2.2.3 PCBs and Connectivity

Two PCBs are used to facilitate the tracing of wires connections thus allowing enough space inside the robot for the components while providing power to the said electrical components. The alteration between PCB and breadboard has been decided to avoid connectivity errors, the disconnection of jumpers when the two robots clash during the competition and to ensure the electric connections' stability during each round.

A. For the bottom:

Four line trackers and 2 L298N are to be connected in order to control the speed and direction of the motors. Therefore 4 output pins from the Arduino are used as 8 input pins to the modules as each pair of adjacent wheels function simultaneously. For the power supply, a 12V LiPo rechargeable battery is used per module.

As for the line trackers: 4 Arduino IP pins, ground, and Vcc are required. The PCB responsible for the connectivity of the lower part is shown in Fig.2.6.

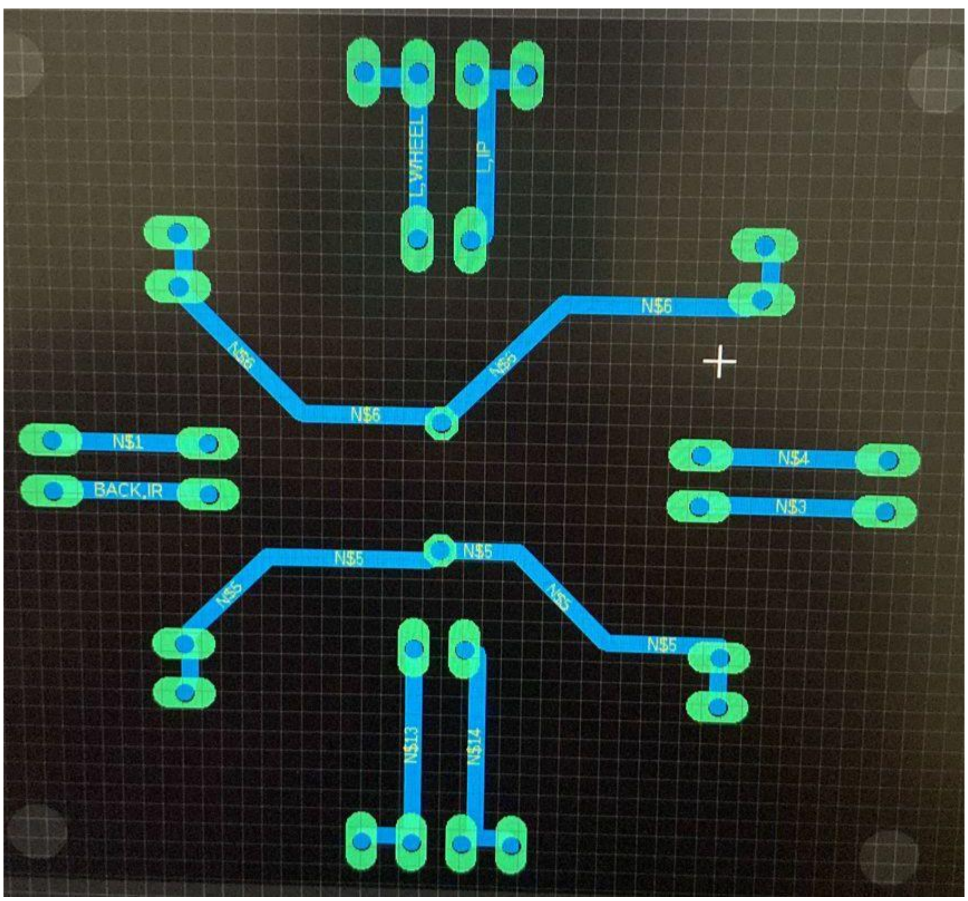

Fig.2.6
PCB of bottom part

B. For the second level:

Since 5 sensors are used in the top level, it's required to have on the PCB (Fig.2.7) 5 Arduino IP pins, 5V as the Vcc for both PCBs, and a ground. Connecting a Vcc and ground is necessary for the function of all electrical components.

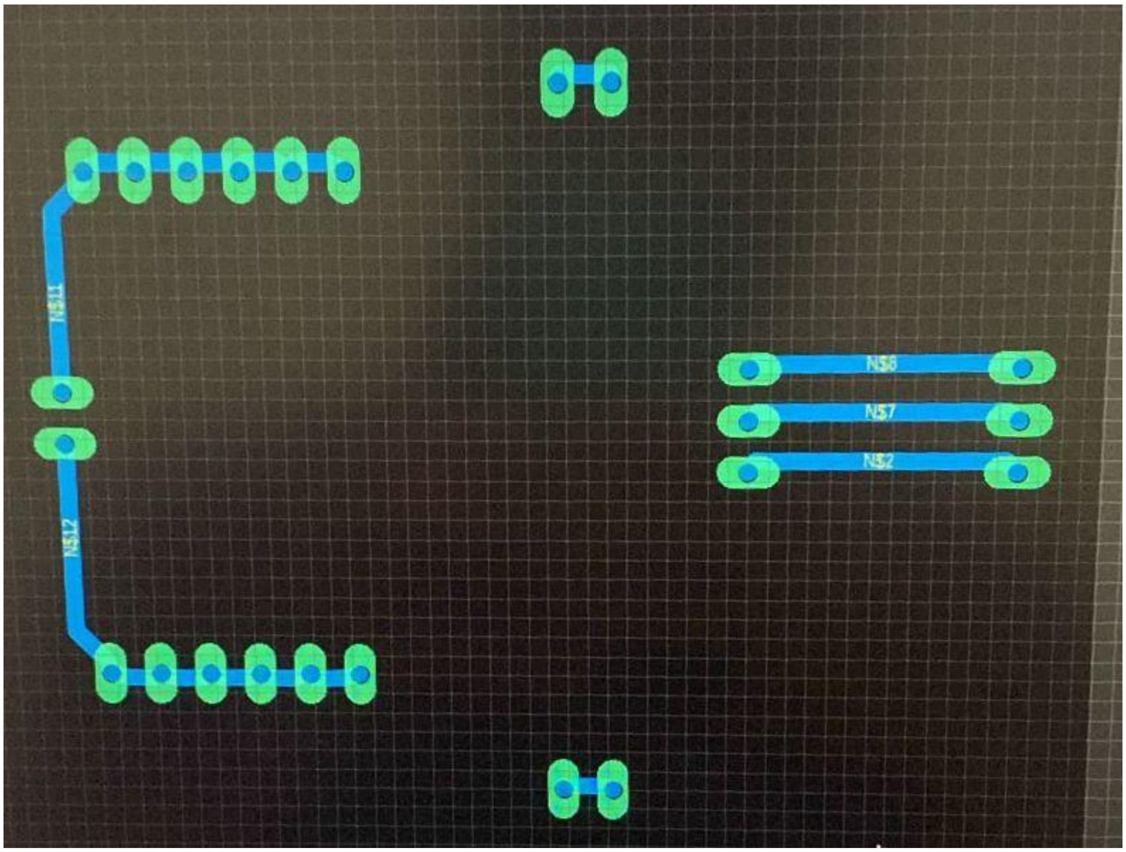

Fig.2.7

The PCB of the second level

2.2.4 Code and Control

Attached in the appendix is the full Arduino ide code and below in Fig.2.8 is the flowchart used to derive and write the code

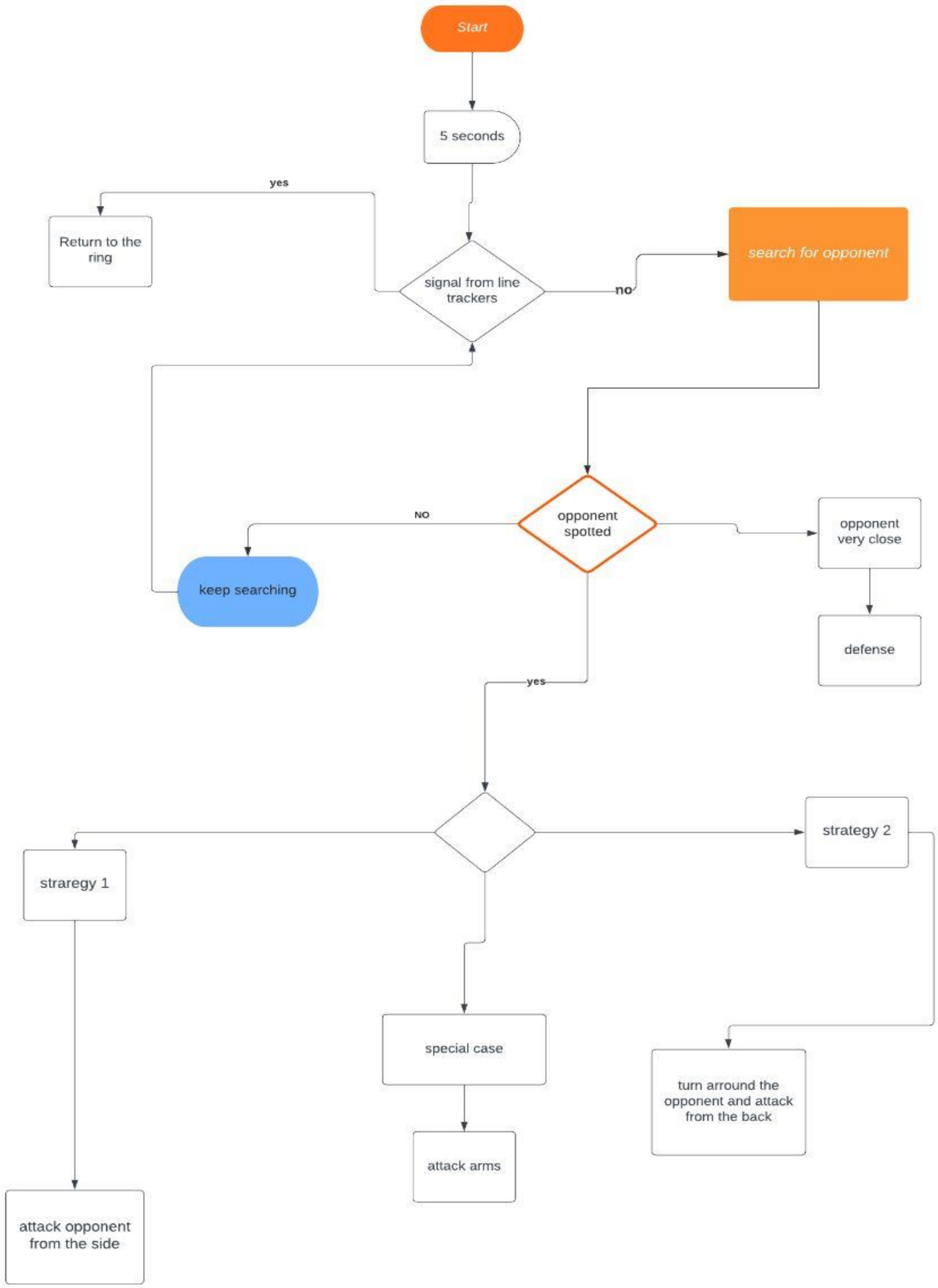

Fig.2.8

The flowchart of the operation

2.2.5 Attack and Defense Strategy

Finding the opponent is dependent on multiple start patterns, good object detection sensors, and sufficient speed to attack before the opponent has a chance to escape or take evasive action.

- **Start:** The robot starts automatically after 5 seconds of turning the switch on, all along the competition the robot checks the signal from the line trackers to ensure it stays on the arena, in the same manner the robot checks the line tracking sensors after completing each action or combination of orders.

- **Search:** The searching regime is accomplished primarily via the front sensors. The robot first checks if any reading is incoming from these sensors: if yes it proceeds to attack using one of the decided strategies, else it takes a step forward in case the opponent is farther than the reading range of the sensor. If no reading is taken in both cases, it rotates a bit and repeats the same process. This searching regime is repeated until the opponent is spotted.

- **Attack:** The attack consists of two main strategies and one special case strategy. The main goal of the attack is that contact is made in an advantageous location such as pushing on the opponent's rear or side rather that the opponent's front.

  Strategy 1: is the main attacking strategy as it's the most reliable in many cases considering differently built opponents. It consists mainly of making the robot make a couple of turns to face the opponent's side and proceed to push it. The side is usually a blind spot where most sumo robots have no proximity sensors.

  Strategy 2: is another indirect attack configuration where the robot makes a 180˚ turn and pushes the opponent from its behind. This strategy works in the case the opponent does have any proximity sensors in the sides and vice versa for this method but it's contingent on the speed of the robot.

Strategy 3: is a special case strategy of attack in case the opponent has arms or flags that intend to push and/or distort our robot. In this method, the robot rotates to face the arm and attempt to push with its full power before facing the robot and pushing its main body once more out of the ring.

- **Defense:** Whenever the robot is being pushed from the front it takes a small step backwards, repositions itself with an angle before coming in contact with the other robot again. While if it's being pushed from the sides it goes with the full speed on two wheels on the farther side to evade the attack.

3.Cost Analysis

The total cost of the implementation and creation of this sumo robot including all the previously mentioned components and specs is 5,500 egp and this sum includes:

- Aluminum sheet with 3mm thickness 1,300 egp.
- Cutting, folding and welding of parts 700 egp.
- Electrical components including instruments such as jumpers..etc 3,500 egp.

4.Conclusion

After several months of planning, creating and optimizing this project, our sumo robot has passed through a couple of stages and variation from the choice of sensors to the final strategies and code. As well as some mechanical design modifications from the prototype to the final output robot as can be viewed in Fig.3.1.

This robot is designed to adhere by all the rules set by the competition supervisors and should be able to withhold during the rounds to be played. It displays an extensive mechanical and electrical knowledge and an application of sensors and control methods taught in this course.

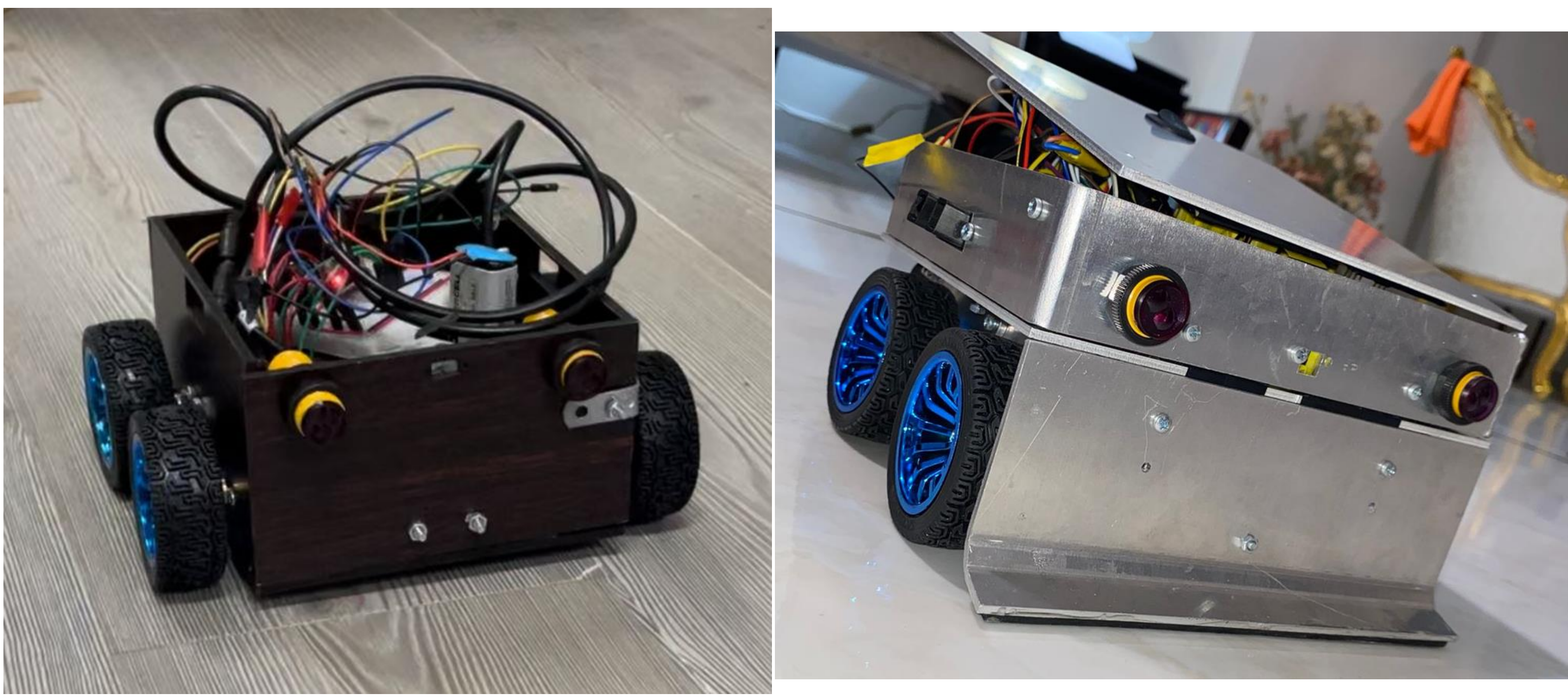

Fig.3.1

HDF prototype on the left, final aluminum robot on the right