TEAM 4 IDP L1

Team Name: Porous a Drink
Robot Name: Wall-E 2.0

Jan Derlatka, 86, JN, Info (Team Leader)
Lucca Pereira Martins, 86, JN, Info
Maya Roy Prabhakaran, 99, M, Mech
Jenny Hardwick, 99, M, Mech
Szymon Piatek, 110, PEM, Elec
Noah Barker, 110, PEM, Elec

[Name, Lab Group, College, Sub-team]

Design and Sub-systems:

Approach

We have opted for a general, works for all approach, where we account for all possibilities of where the cube could be by sweeping all possible positions, removing the need for cube detection (ref fig1.). To collect the cubes, we use two large arms which will open when sweeping, drive the vehicle forwards to a maximum value, and close around the cube, but not squeeze it. At this point we will measure porosity by using infrared sensors at one corner of the cube. The robot will rotate and return over the ramp with open arms, pushing the cube forward. When depositing the cube back, the robot will turn into the box, putting the first cube deepest into the area, then reverse out before rotating and continuing.

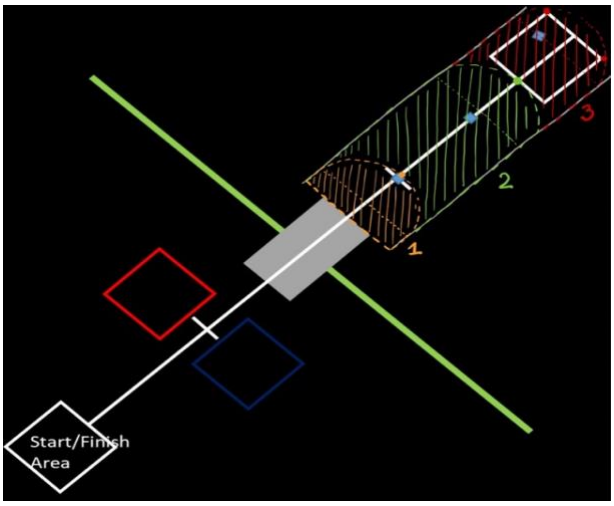


Figure 1 Sweeping Arcs for Each Cube

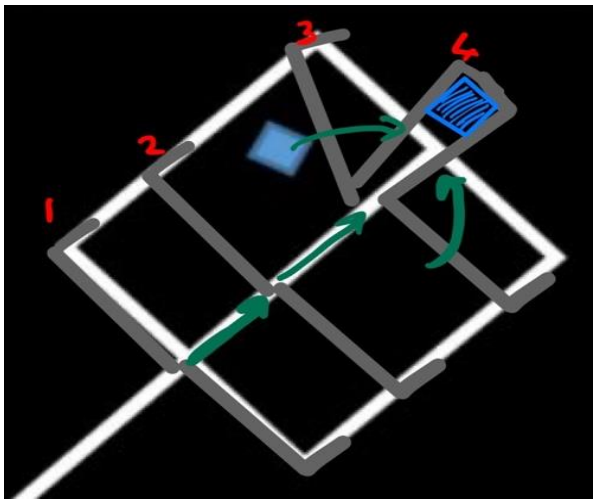


Figure 4 Pincer Motion for Arms

Moving

Keeping robot movement as simple and fundamental as possible and minimising the number of turns it must make (hence reducing the time spent off the central white line), will ensure an accurate and robust result. We decided on 2 rear wheels connected to a motor with 2 ball rollers at the front of the vehicle (ref fig2 & fig3). This would allow us to turn on the spot when delivering the cubes, but also micro adjust to ensure the robot stays on the central white line. The argument against 4 wheels, whether fixed or rotational, was that the requirement for an additional motor would increase the complexity and the weight of the robot, whereas the ball rollers would provide more flexibility in terms of motion and micro adjustments. We explored the possibility of driving backwards over the ramp and into the box, removing the need to turn on the spot, but to implement this we would have had to use a central axle with 4 ball rollers in each corner. Given the robot rotates about the rear axle, when trying to follow the line in reverse, the amplitudes of adjustments were higher, putting it off track. We decided not to pursue this idea given insufficient time to implement such a big design change.

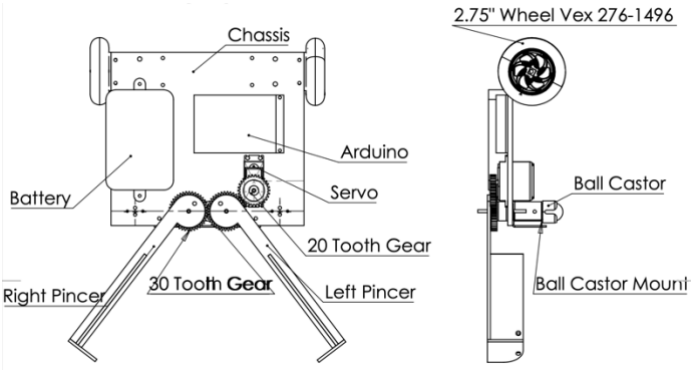


Figure 2 Front, Plan & Side View of Robot

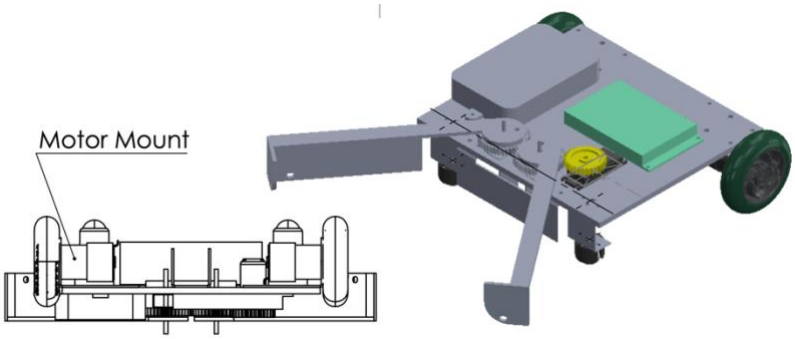


Figure 3 Orthogonal View of Robot

Arms

As mentioned above, the cubes will be collected by two arms in a pincer motion, sweeping a wide arc which covers all possible cube positions (ref fig4.). If the cube is towards the start of the possible locations, the robot will gently push the cube forward, and once the arms are closed and it has detected the cube type, the robot will turn around, open the arms and push the cube into the box. We decided on this approach to entirely remove the need for cube detection, which would have been one of the most complicated steps when finding the third cube. The main risk is knocking other cubes too far out of place, but careful and gentle arm movements will ensure this is not a problem. The arms were operated by a servo which we could adjust the angle of in the code and built from MDF, with a flange a similar height to the cube. The simplicity made the arms robust and easy to implement, giving the robot a certain flexibility regarding the task it approached, meaning it could easily be adapted to carry other objects.

Line following

We used two line-sensors for the robots main steering (ref figs 5a, 5b & 6), placed just either side of the white line and returning a binary output to the Arduino. Once the sensors detected the white colour, the motor would slow down one of the wheels accordingly to turn it back onto course, with a time delay in place to prevent repeated instructions being sent in a short time. When leaving the line to deposit the cubes, the sensors would be ignored, 'deactivated' so to speak, and the motion would be programmed. The robot turns into the box, placing the first cubes further in, before reversing out and rotating as to avoid knocking the cube with its arms. Similarly, when turning on the spot, the robot would turn an angle of 170 degrees before readjusting by detecting the line. This was the best option given the position of the sensors, which meant that if the robot was initially skewed, when using the sensors it would stop at the first detection of the line, which could be in forwards direction.

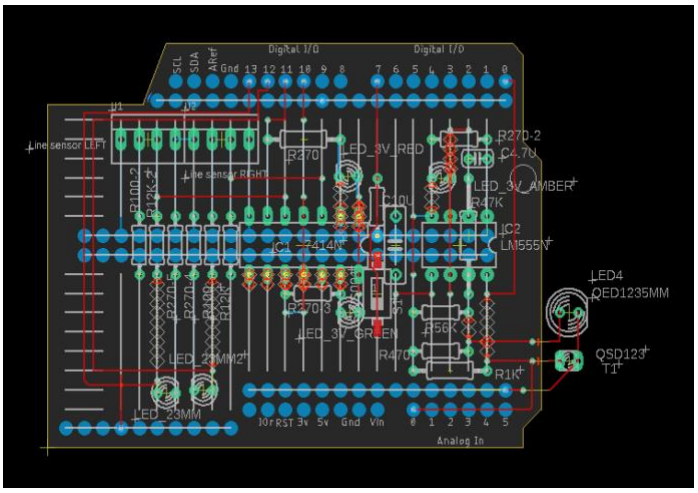


Figure 5a Top Layer of PCB

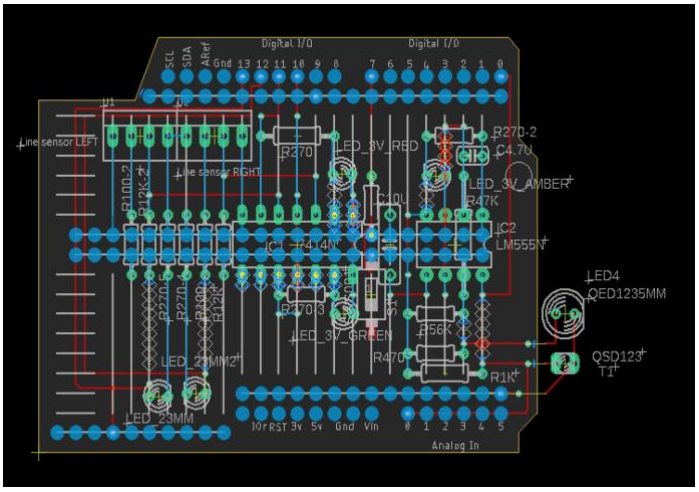


Figure 5b Bottom Layer of PCB

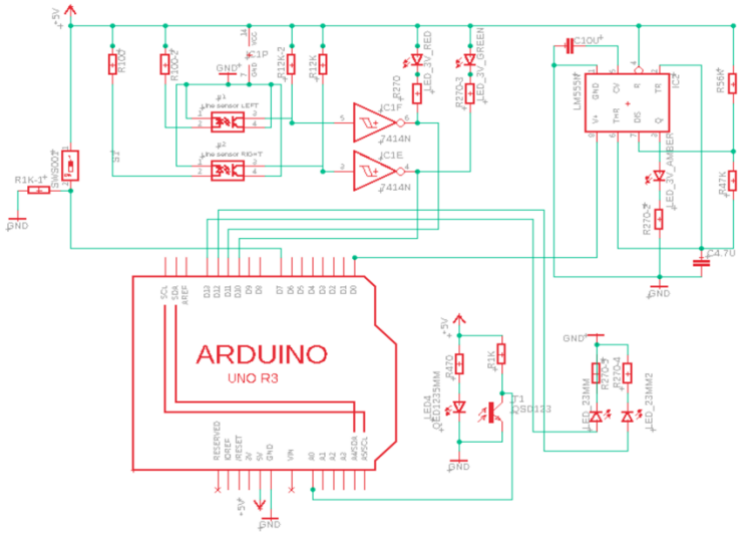


Figure 6 PCB Layout

Determining Cube Porosity

When determining cube porosity, we opted for an infrared sensor placed in the corner of the arm, and hence shining and receiving light through a corner of the cube (ref fig 7). The more porous cubes would return a higher reading, which we could take as an analogue output and have thresholds in the code to determine which type of cube it was. Initially, we tested the sensors at either side of the cube; an emitter in one arm and the receiver in the other but noticed that the difference in measurements between the two cubes was insufficient to be robust, as well as other interfering factors such as cube location.

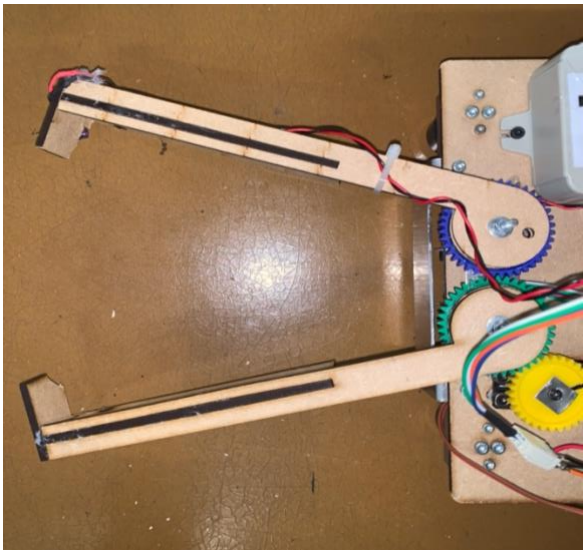


Figure 7a Infrared sensor in corner of arm

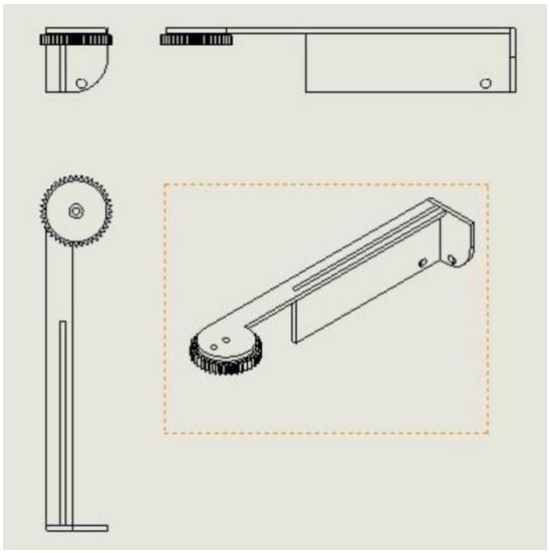


Figure 7b Mechanical drawings of arm

Time-Based Distance Measurement

To keep track of the robot's position and know when to stop sweeping areas, we used a time-based distance measurement. Manually experimenting with the robot's speed on flat ground, rotating on the spot and when crossing the ramp and calibrating it appropriately, we found that our values for the time taken to complete each section were very accurate, translating to errors of only a few millimetres on the table. To further reduce error, given our ability to detect intersections with the line-sensors, we could 'reset' the time at each intersection, breaking it up into smaller tasks rather than one long execution.

Code Structure and System Architecture

The entire code was structured with concurrency in mind. The code within main loop is structured in such a way, that execution of one task does not block the entire program flow, and other tasks can be executed in parallel. The tasks sequence is defined by setting up transitions between phases. For a given phase transition, the next task must be defined along with necessary, task dependent, parameters - most often stop conditions.

Figure 8a Overall system architecture

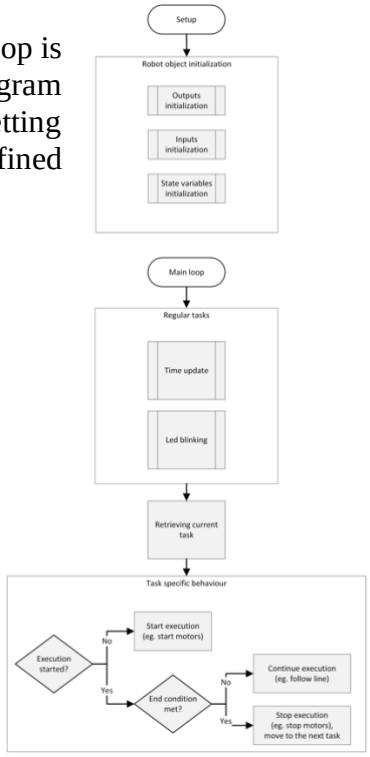


Figure 8b Code Structure

Implementation:

Figure 9 shows how we aim to integrate the three teams, with orange representing mechanical, white: information, and blue: electrical.

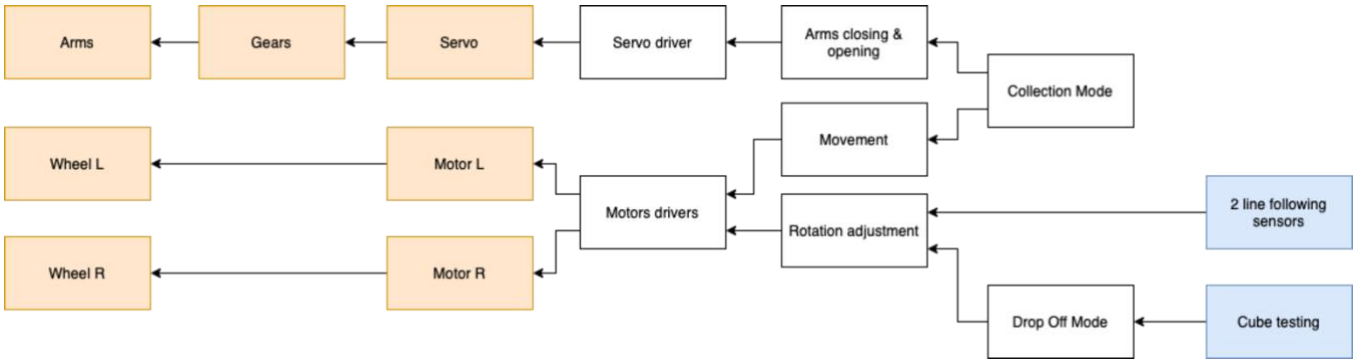


Figure 9 Sub-team Integration

Major Decisions

Although it would be unreasonable to say we made no major decisions, the reality was there were very few. The final product was close to what we had originally designed, and the method was also very similar, but some of the key choices we had to make include:

1. <u>Rotating the robot rather than reversing it</u>
   Initially, we intended on grabbing the cube and reversing over the ramp with the arms closed. This would allow us to reverse up to a point near the starting box and turn a wide arc into the drop-off areas. However, when attempting to follow the line in reverse, we found that given our use of a rear axle, the adjustments the robot would make had much higher amplitudes than when driving forwards. The only solution to this would have been to move the axle to a central location and use 4 ball rollers, one in each corner instead. This meant a complete overhaul of the design and current robot build, which given the time constraints and a lack of necessity, we chose to rotate the robot on the spot instead. The problem of knocking any cubes ahead out of place arose, but this was easily avoided by reversing a little before rotating.
2. <u>Opening the arms when crossing the ramp</u>
   The idea of hinged arms was discussed, where the arms could elevate as they contacted the ramp while crossing over, a concept very much related to reversing with the arms closed. However, this not only proved impossible, but also inefficient. We discovered that by adding a small metal plate to the front body of the robot (ref fig10a&10b), we could safely push the cube along without risking losing it or it lodging under the robot. Given the design of the arms, which covered the span of the ramp, this was very unlikely. This meant that once we had determined cube porosity and turned around, we could leave the arms open for the remainder of the delivery.

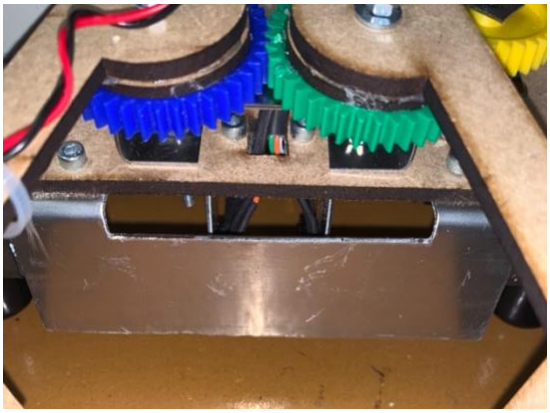


Figure 10a Metal Plate at Front Body of Robot

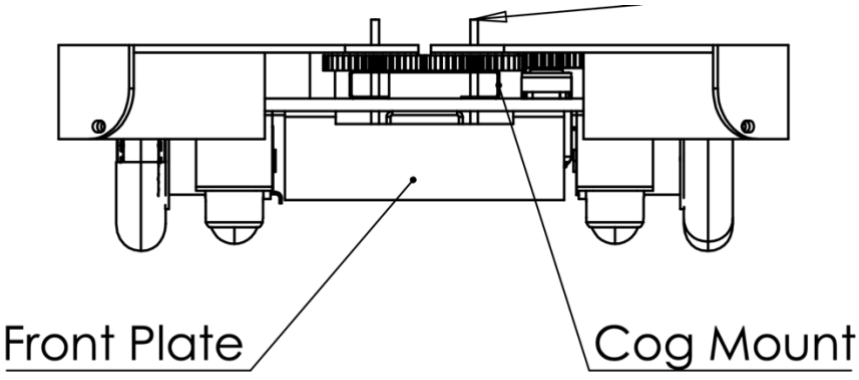


Figure 10b Construction drawings of front plate

Risks:

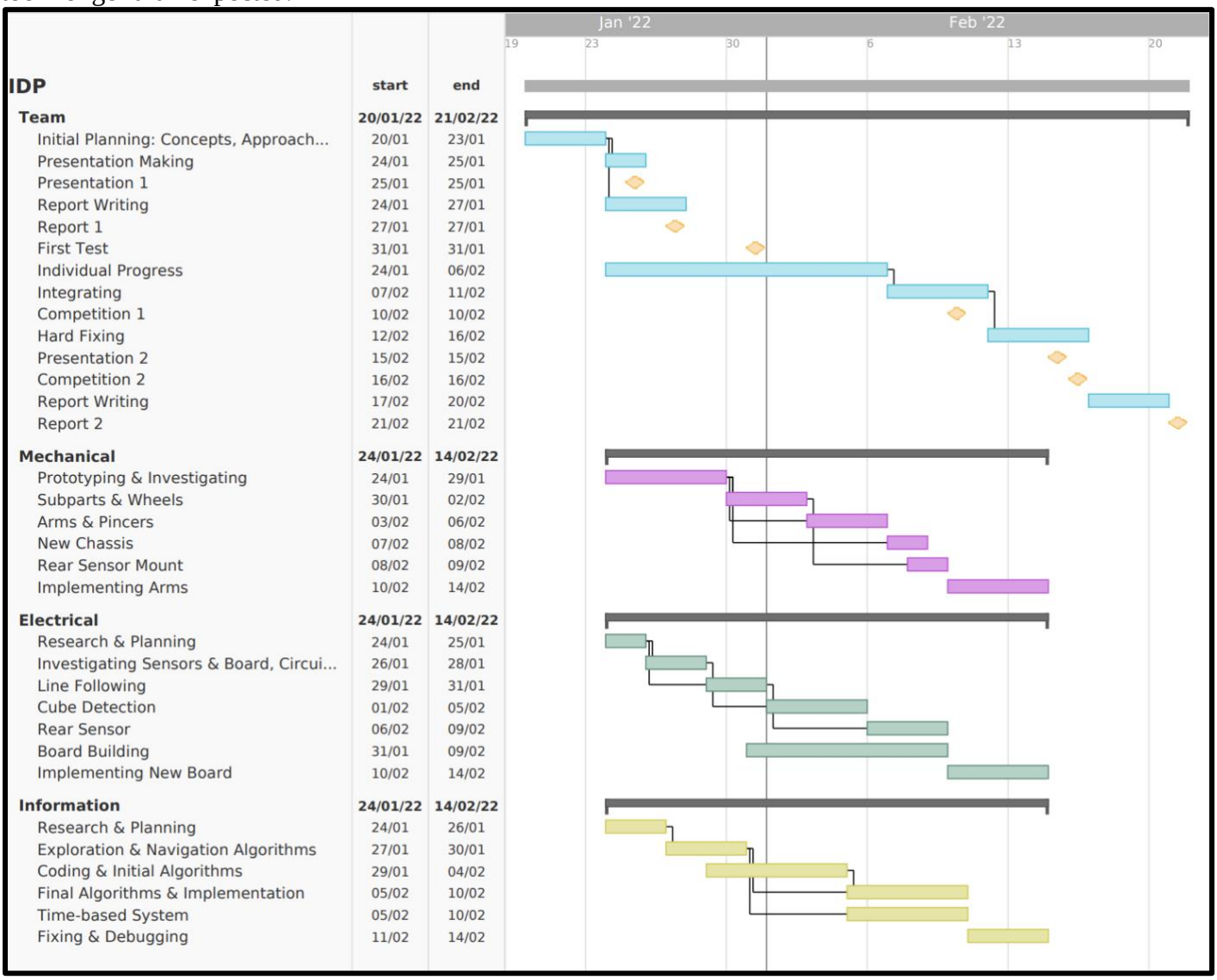
[RISK, LIKELIHOOD, MINIMISING]

Risk	Likelihood (1:least -5:most)	Risk Reduction
Failing to collect cube or slipping out in transit	**1**	Ensure arms sweep the entire area gently and arms are similar height to cube
Knocking into other cubes	**3**	Best avoided through trial and error, with careful consideration of all possibilities
Failing to cross ramp	**5**	Adjustments have been considered should this happen, ie. raising arms
Failing to determine porosity	**4**	Ensure sensors are accurate and well-placed, and code is robust at evaluating
Losing track of white line	**2**	Sufficient testing and robust code to ensure adjustments are smooth & correct

Project Management:

Gantt Chart

The Gantt Chart (ref. chart 1) helped keep all team members on track and aware of upcoming deadlines. We updated it frequently and kept track of deadlines and expected milestones, allowing some leeway for each task to ensure punctuality. The initial estimates for time were accurate, although integrating new parts together took longer than expected.



IDP	start	end
Team	**20/01/22**	**21/02/22**
Initial Planning: Concepts, Approach...	20/01	23/01
Presentation Making	24/01	25/01
Presentation 1	25/01	25/01
Report Writing	24/01	27/01
Report 1	27/01	27/01
First Test	31/01	31/01
Individual Progress	24/01	06/02
Integrating	07/02	11/02
Competition 1	10/02	10/02
Hard Fixing	12/02	16/02
Presentation 2	15/02	15/02
Competition 2	16/02	16/02
Report Writing	17/02	20/02
Report 2	21/02	21/02
Mechanical	**24/01/22**	**14/02/22**
Prototyping & Investigating	24/01	29/01
Subparts & Wheels	30/01	02/02
Arms & Pincers	03/02	06/02
New Chassis	07/02	08/02
Rear Sensor Mount	08/02	09/02
Implementing Arms	10/02	14/02
Electrical	**24/01/22**	**14/02/22**
Research & Planning	24/01	25/01
Investigating Sensors & Board, Circui...	26/01	28/01
Line Following	29/01	31/01
Cube Detection	01/02	05/02
Rear Sensor	06/02	09/02
Board Building	31/01	09/02
Implementing New Board	10/02	14/02
Information	**24/01/22**	**14/02/22**
Research & Planning	24/01	26/01
Exploration & Navigation Algorithms	27/01	30/01
Coding & Initial Algorithms	29/01	04/02
Final Algorithms & Implementation	05/02	10/02
Time-based System	05/02	10/02
Fixing & Debugging	11/02	14/02

Chart 1 Gantt Chart

GitHub Repository

Using a single repository to share and store all files such as code, CAD models, sketches and graphs, helped simplify distribution and version control across teams, maximising coordination and communication.

Testing

Some of the problems which arose during testing and prior to the competitions were:

1. Scrapping of the arms against the ramp
   Some of the ramps were slightly different across the different tables, meaning on some of them the open arms would scrape against the ramp, and almost prevent the robot from crossing it entirely. We solved this by filing down and curving the corners of the arms, which although didn't completely remove the scrapping, it decreased it significantly.
2. Increased sensitivity of line-sensors when using circuit board
   For the first competition, the electronics were on a breadboard before we transferred them to a soldered circuit board ahead of the final competition. We noticed the line-sensors became much more sensitive after doing so and would detect intersections at places which there weren't any, such as going up or coming off the ramp. This was detrimental as our time-based system relied on correctly detecting the intersections to move the robot onto the next phase. There wasn't an easy solution to this and would require rewriting the intersection detection code to include some form of verification.
3. Calibration of infrared sensors
   Setting up the emitter and receiver at such an angle and position as to get consistent results proved much harder than expected. A slot was cut into the arm, allowing the sensor to be adjusted and moved around before ultimately being glued in place. However, we struggled to find said position and because of this, the cube detection was largely inconsistent and incorrect.

Specification

Robot Specification Criteria	**Criteria Met (Y/N)**	**Comments**
No sharp edges and safe around humans	Y	Any edges considered sharp were filed down before competition
Displays a flashing amber light when moving	Y	Use of a 555 timer circuit to generate flashing behaviour
Modular construction & standard components	Y	Each component was easily removable and interchangeable
Robot started in a controlled manner	Y	Started using a physical button
Neatly installed colour-conforming cabling	Y	Refer to figure 11
Robot must fit entirely in start area	Y	Robot was relatively small so this was never an issue
Task Specification Criteria	**Criteria Met (Y/N)**	**Comments**
Robot reaches alternate side of table	Y	Easily completed
Block transported to opposite side	Y	The arms functioned correctly and were able to transport the blocks, although occasionally the cube could get jammed under the arm
Correct LED displayed when transporting the block	Y & N	As discussed above, the cube detection lacked the robustness we desired, meaning it could only correctly detect the cube 50% of the time, which is what happened in the final competition, once correctly and once incorrectly.

Delivering block to correct area	Y & N	Similar to above, this meant some of the cubes were in the right boxes and some were not, however all were within the area limits and the robot did not push any cubes out when manoeuvring out of the box.
Robot returns to start area	Y	Although complicated by the intersection detection, we could manually experiment and calibrate the robot to return to the start area

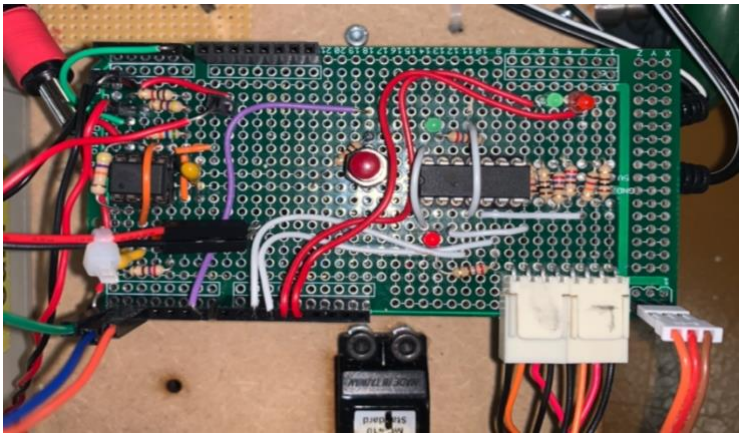


Figure 11 Physical PCB Board with Correct Cabling

Competition Performance

The issues that prevailed in the competition were the incorrect detection of intersections and the inconsistent use of the infrared sensors to determine cube porosity. We could consider two solutions for the increased sensitivity in the line-sensors, causing the robot to move onto movement stages ahead of time and even miss out cubes entirely. A physical adjustment would be to alter the resistors and circuit in a way that the signal threshold would be higher, meaning there would be no output on the fringes of the line, only when the sensor was entirely on or off, providing a sort of buffer. The other alternative, which is software based and the more likely one, would be to include this buffer in the code, which could be done by requiring repeated inputs indicating an intersection before an output was provided, or by an overhaul of the distancing process.