Coversheet

Team Name : Group 206 (The Katerpillars)

Robot Name: Katerpillar

Team Members:

Mechanical:

Richard Parsons	(rjp204 , Lab group 132 , St. John’s)
Gary Chambers	(gc581 , Lab group 132 , St. John’s)
Keeth Wayne Teo	(kwt29 , Lab group 165 , St Edmund's)

Electrical

Kureha Yamaguchi	(ky295 , Lab group 156 , Clare)
Patrick Nevil	(pn309 , Lab group 156 , Clare)

Software

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Colin Wong	(yhw25 , Lab group 145 , Emmanuel)

Approach for solving the problem

As this is a relatively sophisticated project, it is imperative that we split the problem into groups of sub-problems. As a result, we have divided the project into 3 sub-teams: Mechanical, Electrical and Software. All 3 groups will go through the problem statement as a team, and then come up with integrated solutions that can then be assigned to each designated team. Due to the fact that Mechanical, Electrical and Software are wildly different disciplines, each group would have a different approach to solve the problem.

Mechanical

The first task was to identify exactly what solutions the mechanical team should provide. The key solutions required are the design and manufacture of a locomotion system for the AGV; a mechanism for collecting and depositing the robots; a structural body that accommodates all hardware - in the correct position and orientation - necessary for other aspects of the project; and producing final drawings (CAD or otherwise) of the final design.

The approach for providing these solutions was firstly by liaising with the whole team to have a general idea of what requirements they have from the body of the AGV. This includes sensor positions; space required to fit the breadboard, Arduino, and other elements onto the AGV body; ways to fit wheels that makes movement software easiest.

After having a rough idea of what the size and shape of the AGV needed to be, making a box-like prototype from cardboard was a priority. This enabled us to envision designs and concepts for future iterations of the AGV. This also gave the rest of the team a chance to see approximately what they must fit their systems to.

Attention was then turned to the robot collecting and depositing mechanism (henceforth “grabbing mechanism”), which is one of the most challenging aspects of the design. Concepts were put forward, and advantages/disadvantages were identified for each, a final design was then to be decided after some prototyping using cardboard.

Once designs are decided upon, the process is to prototype, and iterate until happy with the design, and build a final design (with drawings updated as necessary when prototype evolves to final design.

Electrical

On the other hand, the electrical team decided to classify the problem into the 3 categories: Rescue, Navigation & Identification. For each of these functions of the robot, we identified what sensors and components could be useful. For the Navigation, we worked with the software team and presented them with the electrical options that could be used for navigation, such as ultrasonic transducer, and determined the reliability and accuracy of the devices through testing. For the rescue part, this is mainly focused on working with the mechanical team and determining what motors or servos we need. The final task is the identification and this is mainly electrical and has been given a lower priority as to first provide the electronics for the mechanical and software teams.

We have split it up into these three sections, so that we can work in parallel on different parts, which will utilise our strengths more effectively. Additionally, having smaller areas means that we can test and debug the smaller circuits before integrating them together, with the aim of reducing the amount of debugging needed to be done on a larger, more complicated circuit.

Software

The software team has decided to approach this problem by firstly investigating different methods that achieve the same purpose (e.g. Locating robot using distance sensors vs Ultrasonic Transducer). Some research and testing of image and video processing was done as well to determine whether computer vision is feasible in this project. Once the options are identified, the software team will undergo lots of testing in the components relevant to the implementation. We will spend significant time testing measuring the errors, and determining the reliability of the method. Once that is done, we will build a test environment and write test procedures (which could be run to make sure everything is working). We will then split the massive task into various smaller sub-tasks, by implementing and testing each task separately to achieve the desired results. Last but not least, to ensure nothing goes wrong in the competition, it is crucial that we plan sufficient time for debugging and being aware of those edge cases. By finishing all coding for testing stage as soon as possible for hardware testing, we would be making sure that the other teams are able to test the components as soon as possible so that we can further discuss the problem arising from testing stage for further debugging and error reducing.

Robot Concept and Diagram

The robot will be built in a modular design to assist development and repair work with easily interchangeable parts, this also accommodates changes to the vehicle as the design evolves.

The first module to be considered was the chassis as this will be the central module which further systems are added to, and must adhere to the geometry of. The current design is a simple laser cut MDF plate; to which motor brackets, electrical fittings, grabbing mechanism and sensors can be attached through ‘Meccano™-like’ steel or aluminium brackets and bolts. A drawing of the current design is shown in Figure 1 Another important aspect of the chassis design is the arrangement of components on the base. In the beginning, many sub-teams were unsure how much floorspace their implementations would need, to aid with this problem a cardboard prototype chassis was built very early on. This has allowed the design to evolve with the base now set to widen in front of the wheels to allow greater ‘deck space’ while minimising the length of the robot for ease of control.

A major concern is the contention for space from several aspects of the design (grabbing mechanism, sensors, wiring) for floorspace, in particular the front of the AGV which is a hotspot for activity. Current concepts to deal with this problem, should it arise, is the small height of the AGV currently, and the possibility of adding a second level, or including platforms to make more space. Designs for the grabbing mechanism have been made to minimise the space at the front of the AGV used.

As aforementioned, one of the most challenging aspects of the design is the grabbing mechanism, the early stages of design saw several concepts being put forward, from simple designs without redundancies to designs with many redundancies, but very high complexity.

Designs and concepts for the AGV structure and grabbing mechanism are shown in Table 1.

Materials and Fabrication

Final materials chosen for the AGV were laser cut MDF for the chassis. This was chosen because the chassis must be strong and light. Steel and aluminium would be too heavy, and plywood has the tendency to warp, neither of which are suitable for the AGV. Another advantage to MDF is that it can be laser cut whereas metal would need to be cut on the waterjet to accuracy, and/or bent which is more demanding from a design perspective.

The materials for the chosen grabbing mechanism are a combination of steel/aluminium and MDF. The plate onto which the robots will be sweeped should be either steel or aluminium because it must be very thin to allow the robot to be swept on. The choice between the two metals will be a trade off of stiffness and weight. The advantage of steel is the ease of manufacture as it can be spot welded to an axle. The claws are to be manufactured from laser cut MDF due to the complex shapes and the stiffness required.

Brackets for attaching main components (for example, motors, and other main units to be fixed) will be made from cut, drilled, bent and sport welded steel sheets. If weight appears to be an issue, this may be changed to aluminium, but for small bracket components, steel is favoured due to the ease of spot welding components.

Design/ Sketch No.	Functional /10	Complex /10 (10 = low complexity)	Degree of Modular Design/10	Reliable /10	Score /40	Comment
Grabber 1	8	8	7	3	26	Simple and effective. If robot falls flat, difficult to recover
Grabber 2	9	3	6	7	25	More complex, but more reliable, large range, still may not recover from fallen robot
Grabber 3	6	2	6	5	19	Difficult to manufacture, small and impractical range, similar reliability issues to grabber 2
Grabber 4	8	3	6	5	22	Interesting design, would need to twist in one movement, still struggles to cope with fallen robot, small range
Grabber 5	9	5	7	8	29	Fairly simple design, can be made modular. Will be able to cope with fallen robot well, and large range
Chassis 1	9	10	9	9	37	Really simple design of a flat MDF plate, modules can be added or removed as required. This concept was chosen.
Chassis 2	8	7	8	8	31	Slightly more complex design, boxlike structure increases rigidity but also complexity and may be awkward to maneuver around, decreasing modularity

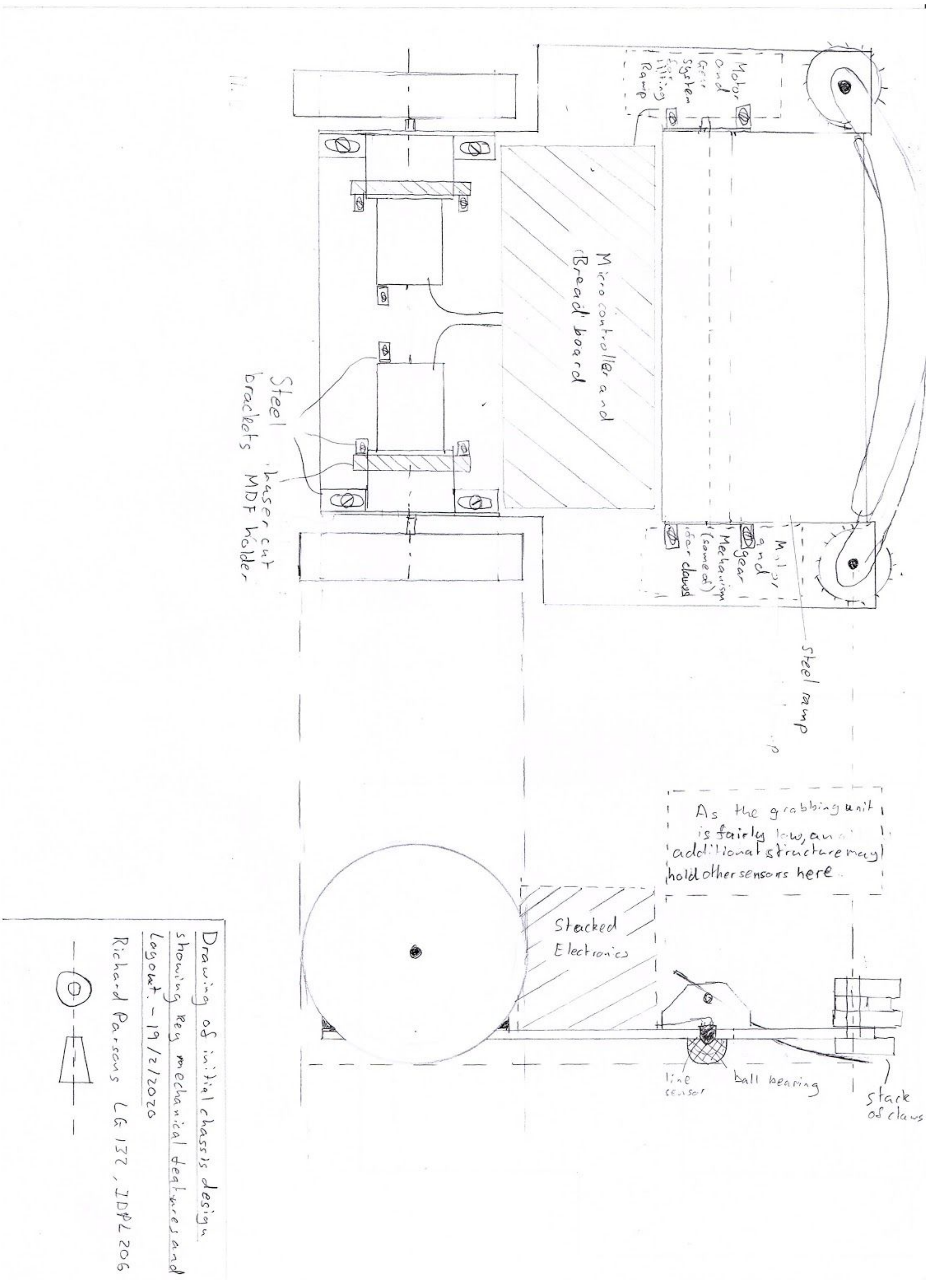

Figure 1: Chassis Design and Layout to Scale, Includes Grabber 5 Concept

The other major module for the mechanical sub-team to produce is the grabbing mechanism. This was approached with three key considerations: tolerance, reliability and awareness. To fulfil each of these criteria, it was decided that simplicity was critical. Many designs were then considered as shown in figures 3 and 4. Initially the favoured designs were concepts 1,2 and 4. The cardboard prototype chassis was then used to test the viability of design 5. Claws for concept 5 were laser cut. While considering the implications of different orientations of the curved plate and ‘pusher’ it was concluded that better tolerance could be achieved if the curved plate faced forwards and instead of a flat plate on a rotating axle pushing the robot in to the AGV, curved claws could gather the robot into the plate from a wider area. Thus the claws being lasercut were incorporated into design. The effectiveness of which will determine whether concept 5 will be explored further.

Electronics/Sensing

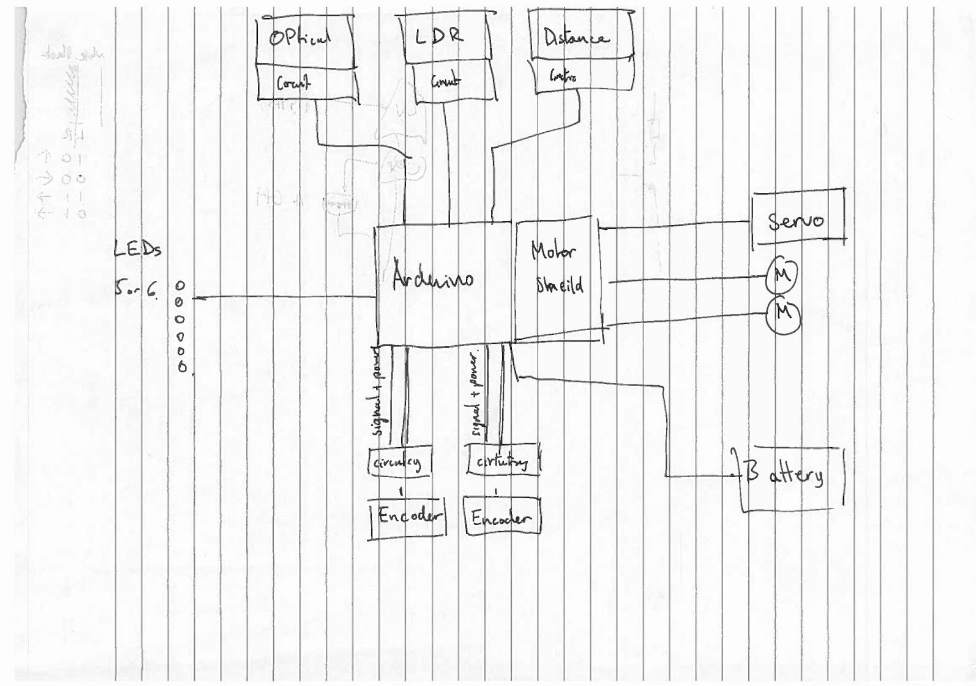

Fig. 8 Electrical design

The figure above shows the electronics block diagram in its current state. The 2 motors are present for the drive, and potentially more motors are needed for the lifting mechanism as well. For the line detection we have decided to use 2 black/white sensors. Despite its role being currently undecided, we have placed the ultrasound sensors in case we need it for future implementations.

Due to the problem statement, we require LEDs to output the status of the robot, however we also chose to add some more LEDs as well as some for debugging purposes. Last but not least, there is the IR detection circuit, which is required to determine whether the targets are emitting 3 pulse or 6 pulses. Using the information given from the IR detector, the AGV can differentiate between the two types of targets, and makes the decision whether or not to pick it up

Exploration and navigation algorithms

The software team identified that there are three main components to the puzzle - finding the target, finding the current location of the AGV, and the one that pieces the two = pathfinding.

We have identified two main methods of finding the targets - using the ultrasonic transducer or using computer vision. For the ultrasonic transducer, we run an angle sweep once the robot exits the tunnel , like radar. By getting the real time minimum peak from the output of the transducer, it can be said that the obstacle (robot) is located at a certain angle from datum with distance data collected. The AGV would proceed further by detecting the required pulse and decide whether to move forward and grab the robot. Alternatively, we can choose to locate the targets by using computer vision. By taking the difference between the green and the red, blue channels, the green targets are highlighted for the algorithm to see. Once a bounding box is drawn over the highlights, we can determine the location of the robot

In order to locate AGV, we plan on measuring the distance to the wall using a distance sensor. The data can be further refined by taking into account readings from the Ultrasonic Transducer. We are still considering using the wheel encoder to locate the AGV as we believed that the accuracy of the wheel encoder is not reliable as there might be slipping and other uncertainties which cannot be sensed by the wheel encoder. An alternative to the previous method that we can use is Computer Vision. By placing 2 markers (with bright colours) on the agv, we can apply Computer Vision to locate the markers. Once the location of the markers on the image are known, the real life location of the robot could thus be determined, with high precision and very low uncertainty.

For the pathfinding, there are two options - Rotate and Go, or move like a grid. For the Rotate and Go option, we chose the shortest possible path between the AGV and the target. However, this method is still under consideration as there might be obstacles which are out of range of the transducer, further causing the AGV to collide with other robots which haven't been detected by the ultrasonic transducer. The accurate and precise method for the return journey is still under discussion as it is a more complicated process without any white line to be followed or target to be reached. For the grid movement, we restrict our movement to the directions parallel and perpendicular to the board. This could be used because it would be easier to determine the location of the robot, using the walls as a reference point.

Interface with Software and Electronics

Fortunately for us, the arduino makes the integration between software and electronics quite straightforward. Currently, the main challenge is to ensure the electrical components are predictable and work reliably, such that the components work according to the code that is executed.

Another challenge that we encountered is that we have to ensure the i/o pins are clearly defined. Furthermore, we will need to define the voltage values corresponding to the analog inputs.

Risks and Challenges

There are many risks and challenges that we have identified.

Risks involving the mechanical side mainly relate to a failure for the grabbing mechanism (i.e that it cannot keep grip, or cannot accommodate a fallen robot). Another large mechanical risk is the use of internal space efficiently to fit all components in a tidy and safe manner and could prove to be a notable challenge, a large amount of floorspace should be made in anticipation of this.

It is extremely challenging for the electrical team to make a robot that is modular, has good electrical connections and with a neat design for easy debugging. We also have to worry about placing the sensors in the right place, whilst risking overloading the arduino. Converting signals from analogue to digital for easy software implementation could be an additional challenge we need to overcome.

There are plenty of challenges that the software team has to overcome. One major challenge is that we have to design redundant measures to overcome imperfection or limitations of real life, such as sensors giving nonsensical values. A large risk we have identified is the risk that computer vision may not work properly. In such a case, we can fallback to rely on sensor readings. Another notable risk that we may have to overcome is the communication failure between the arduino and the computer.

<u>**Gantt Chart**</u>

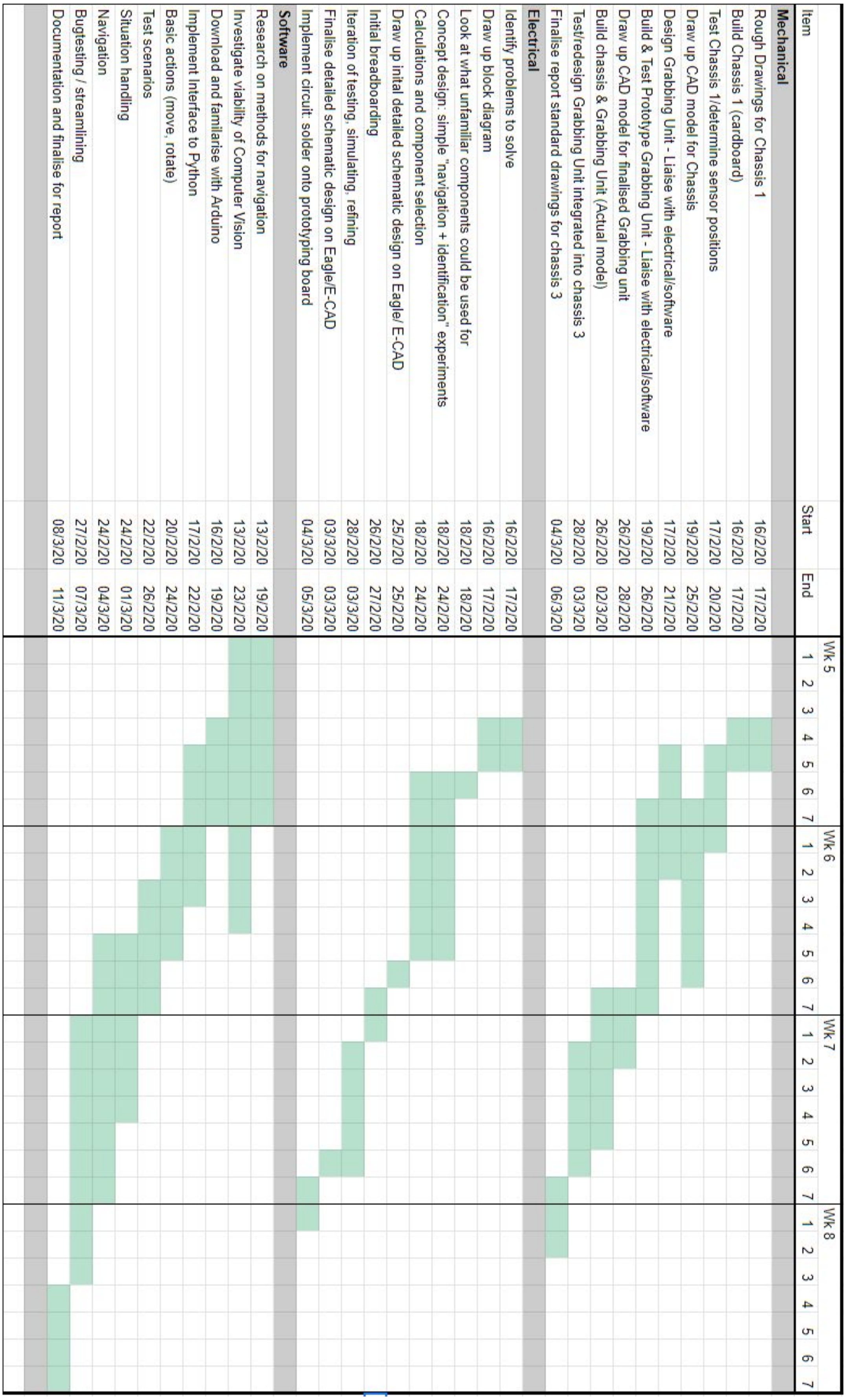

Figure 2: Gantt Chart

Appendix

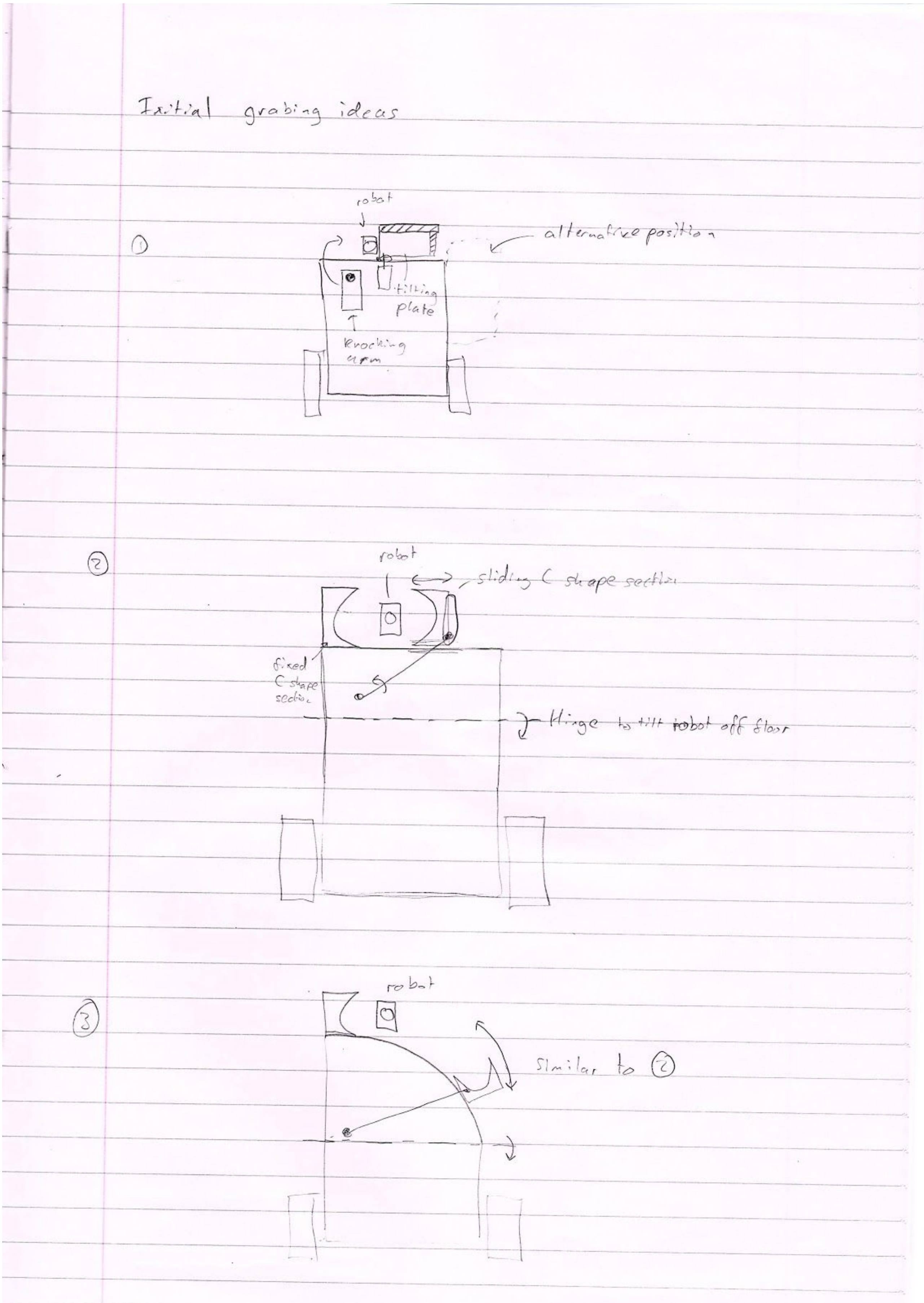

Figure 3: Grabber Concepts

Instead of tilting a, twisting mechanism could take robot off the ground:

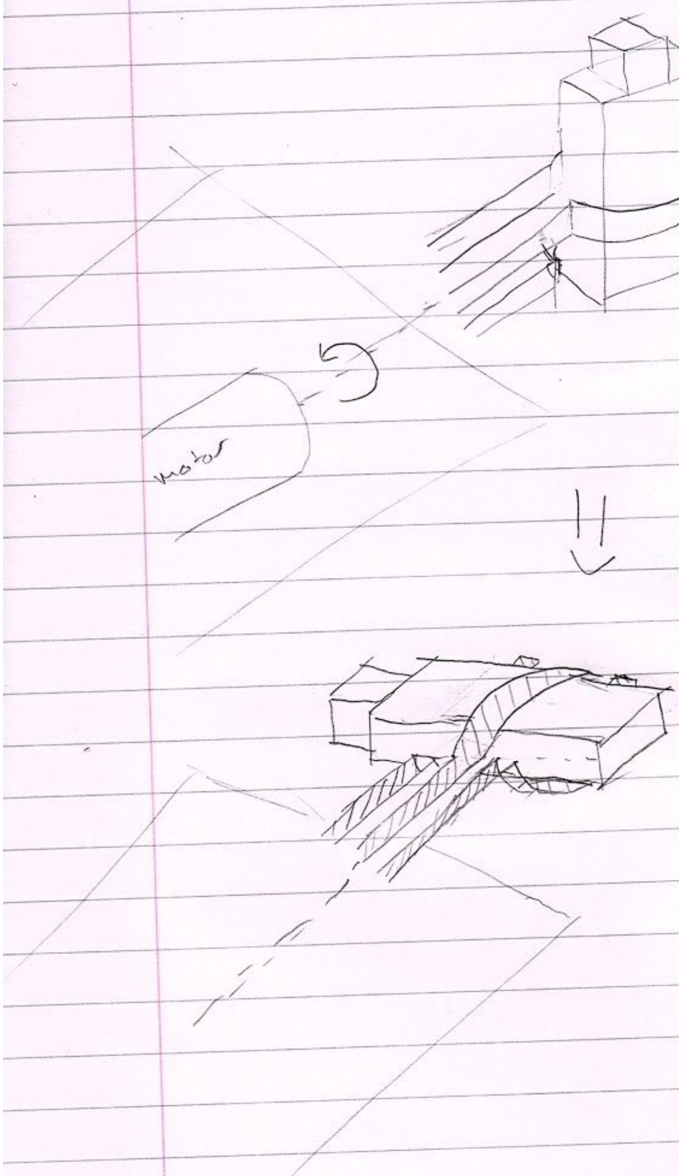

Figure 4: Grabber Concept Number 4

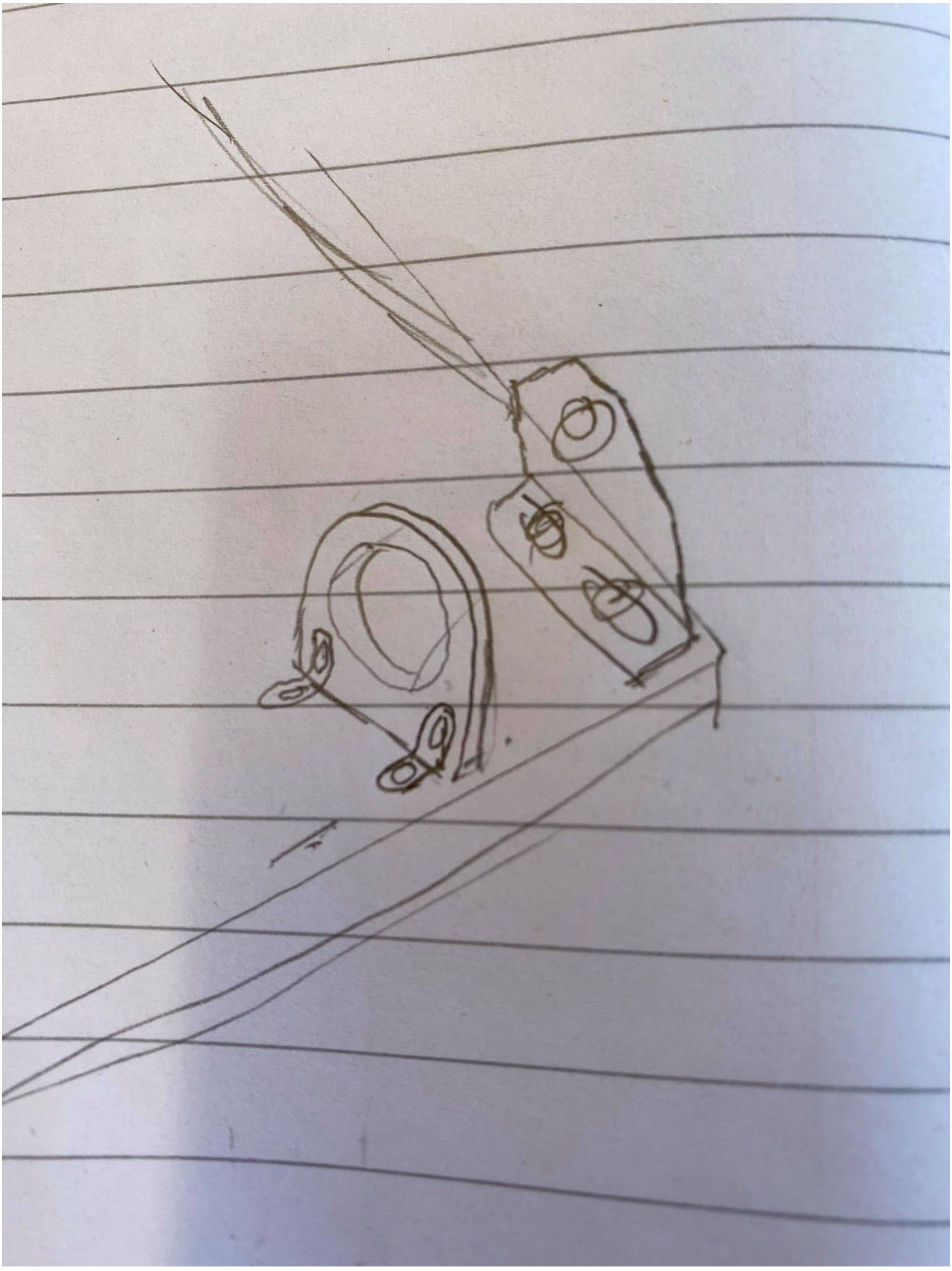

Figure 5: Motor bracket concept

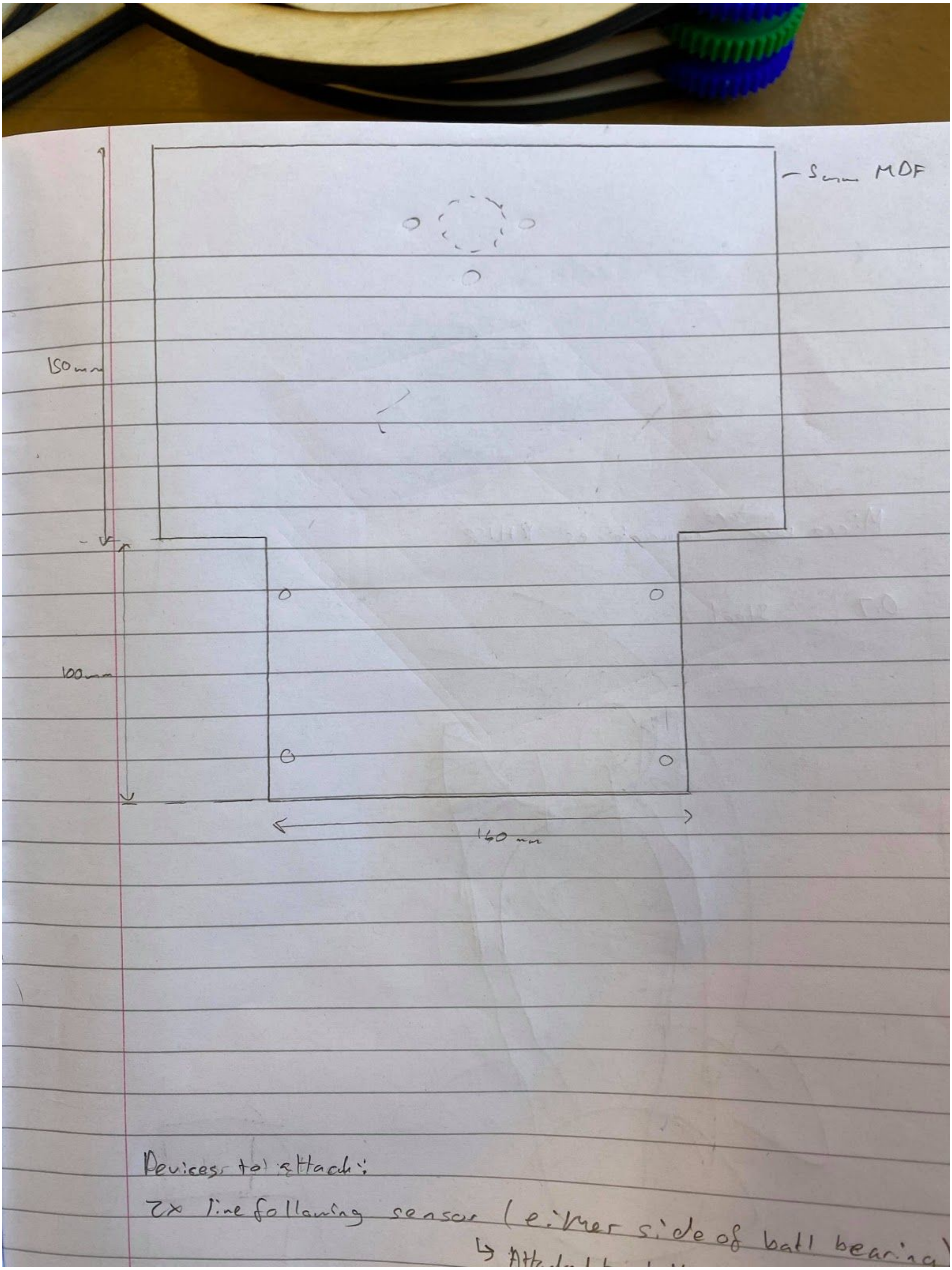

Figure 6: Chassis Concept 1

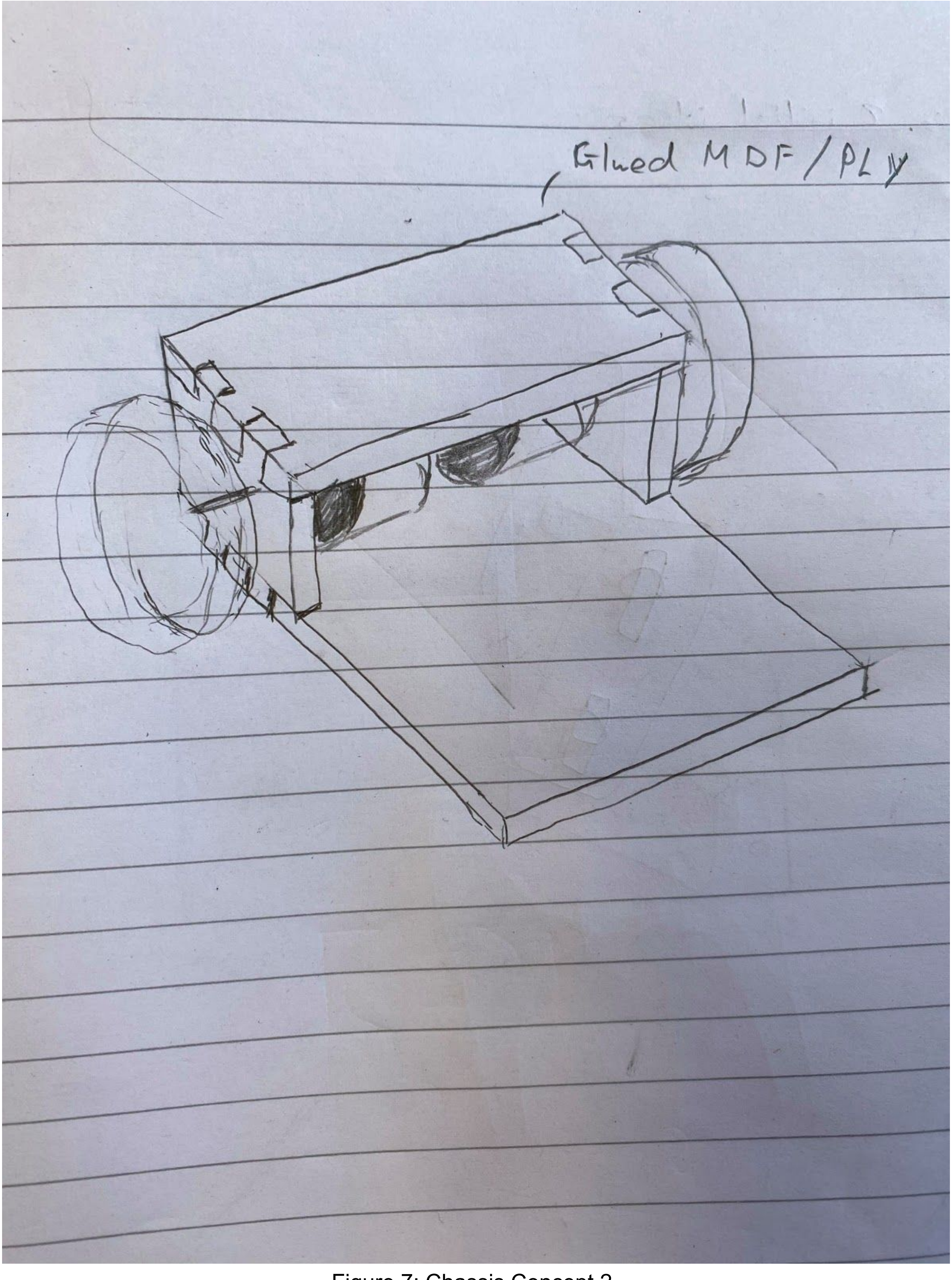

Figure 7: Chassis Concept 2