ME400 Capstone Design I, Spring 2018

Hamza Shafique

20140917

Final Report

Submission: June 17th, 2018

Table of Contents

Introduction:

The aim of the course was to design a robot that can identify, sort, collect and deposit particular colored balls within the shortest amount of time. We were supposed to work on different aspects of the robot design, there was the Open CV team that worked on the Vision of the robot, the SolidWorks team that worked on designing and materializing through fabrication the concepts of the robot, the LabView team that had to task to program and operate the actuators onboard the robot and finally the ROS team that integrated all the separate components and used them to program a routine that helps in accomplishing the tasks we wrote earlier that were the aims of the course.

I was assigned into the SolidWorks team, so we naturally contributed the most in the design and fabrication of the robot, I was responsible of the hardware part of the robot. Within our first meeting, after having brainstormed about the ball collection systems we decided to stick to a simple and effective ball collection system that was a sweeping motion. Thus that became the center piece of our design and rest of the robot was designed, fabricated and programed around the sweeping mechanism.

Design Milestones

Conceptual Design:

We started off with a brainstorming session. By listing down the main objectives of the course we tried coming up with different ways to tackle the problems in hand. The most important task was designing the ball collection system. We decided to use a sweeping mechanism to achieve the task. Once we had decided on it we began to design the robot around this basic idea.

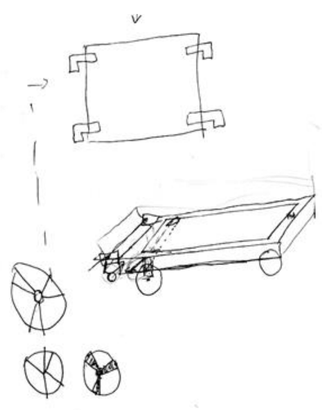

Figure 1: Base frame and sweeper side and top view

We got down and drew all the necessary dimension on a paper and sketched the basic robot. Different parts of the robot were sketched and they are shown in the Figures 1, 2, 3, 4.

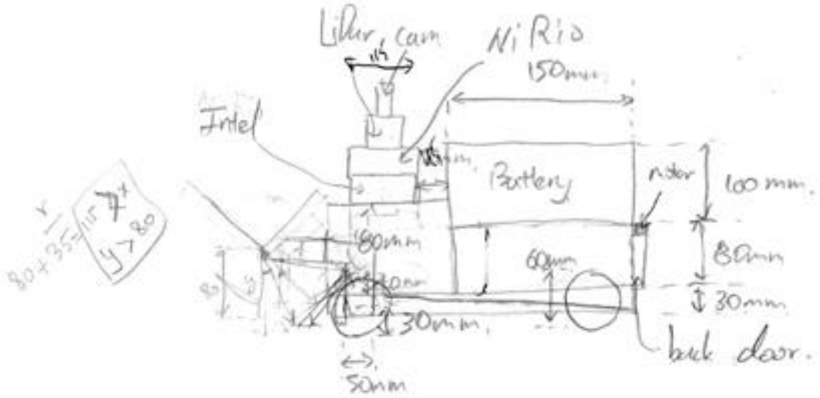

Figure 2: Major dimension definition and assembly of the robot.

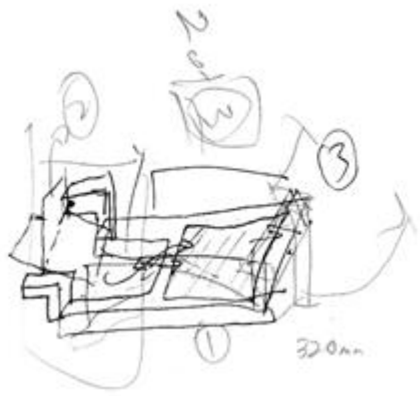

Figure 3: Iteration 2 of the base frame

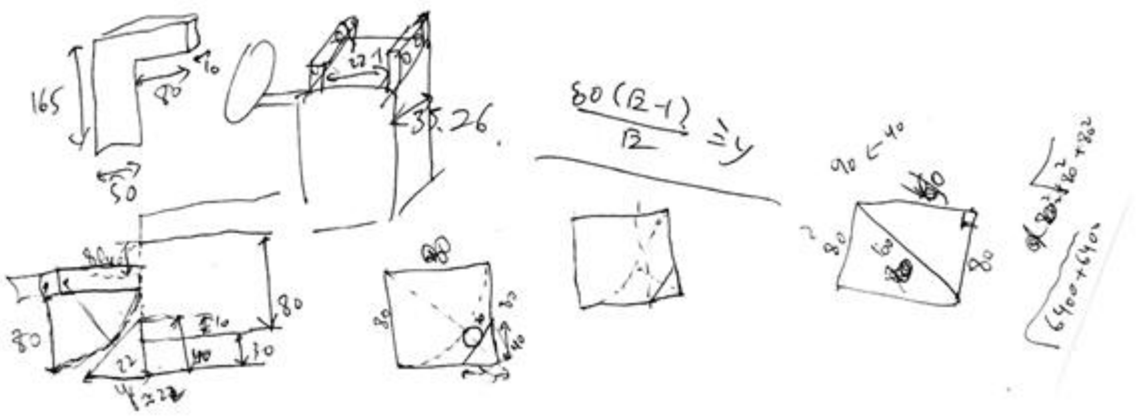

Figure 4: Ramp angle and position calculation and sketch.

Basic 3D CAD Design:

Taking up the basic sketches as outline we got on and drew the 3D CAD model of the robot. We adjusted the design and dimensions as was required for the proper assembly and design of the robot. The first 3D sketch and the 2D line drawing is shown in figure 5 and 6.

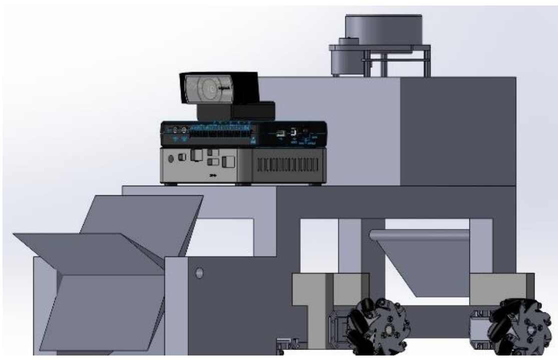

Figure 2: 3D CAD drawing of the Robot.

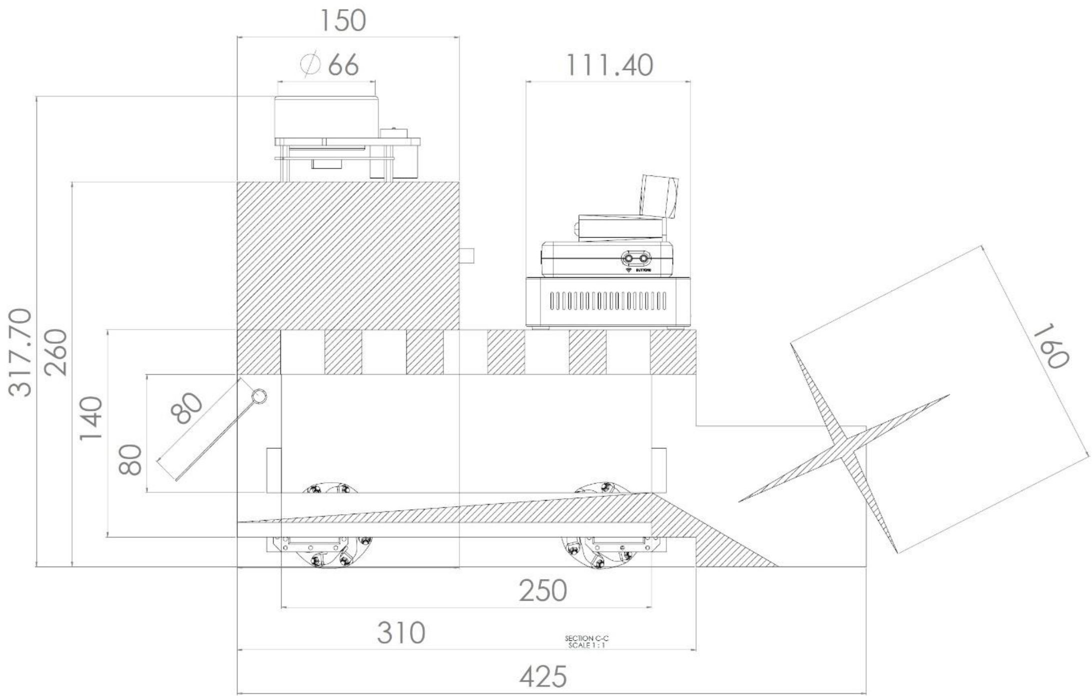

Figure 3: 2D line drawing of the Robot

As can be seen in the cross sectional view from figure 6 we had designed the robot such that the sweeper will sweep the ball into the robot and there will be a ramp to assist the ball movement into the robot and then keeping the ball in until the release from a gate at the rear.

Fabrication Draft:

Once we had the 3D CAD model and we knew that all the set dimensions fit each other in the assembly we started the fabrication process. We had various choices for the build material but we chose to use the aluminum profile for its appropriate strength and flexibility in modification when needed. We thus made the main frame for the robot with space for components to fit in. The frame is shown in figure 7.

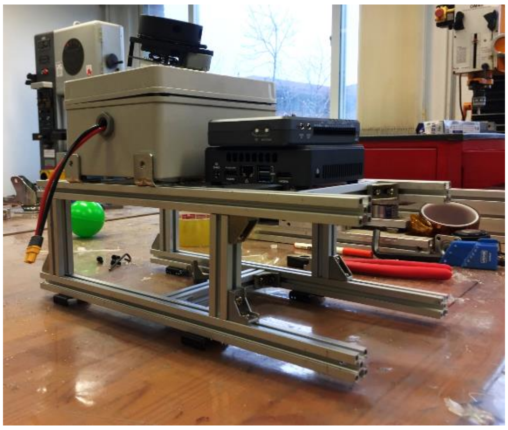

Figure 4: Frame of robot

Model Improvements and Changes:

Initially we had decided to make a four fanned sweeper that runs on a DC motor, but we figured that it might have problems of being energy inefficient and ball capture problems. Thus we replaced this DC motor with a servo motor and instead of having a 360 degree rotation, we restricted the rotation of the sweeper to only the needed angle of sweep. Thus making it more energy efficient. We went through a lot of iterations of the sweeper design to get the final design, all that will be discussed in the next section.

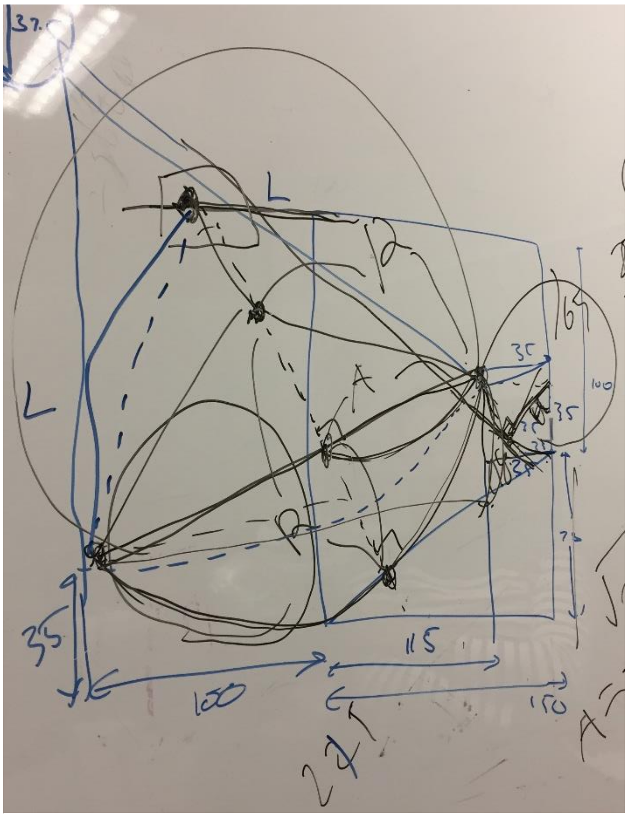

Figure 5: Calculations for defining the position and dimensions of ramp and sweeper.

We did not use the LIDAR as it was only a redundancy and we figured that we can achieve all the tasks without using the LIDAR.

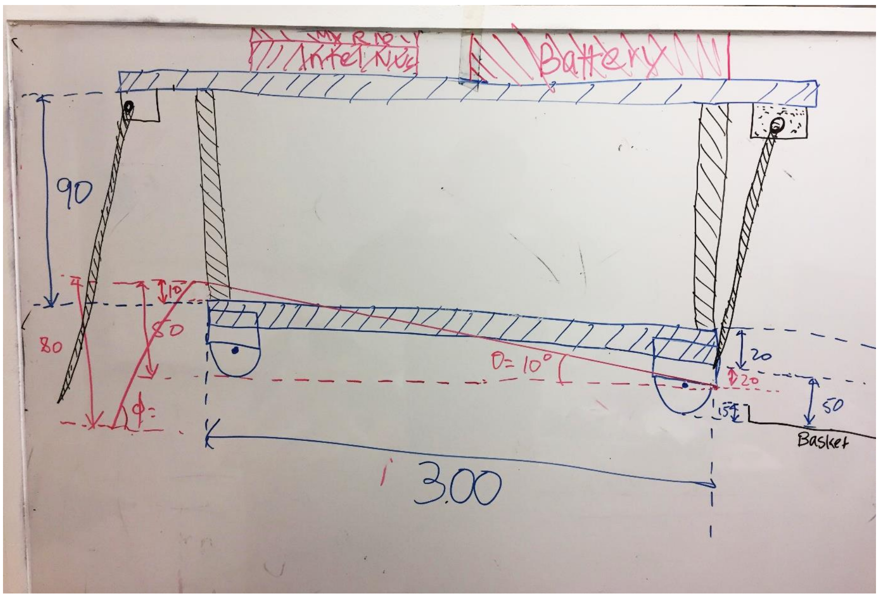

Figure 6: Finalized defining dimensions.

The Sweeper Design:

The sweeper was the most important part of our robot design, therefore we designed, tested and implemented a number of iterations of the sweeper. All the major iterations are described in the figures 10-16.

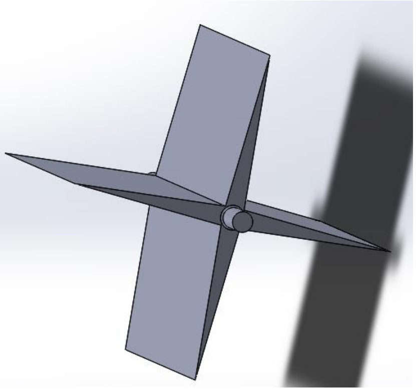

Figure 10: Iteration 1 - Four fanned sweeper

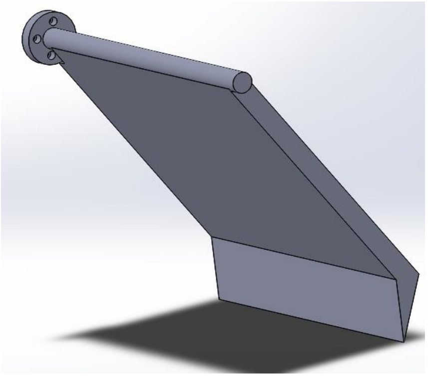

Figure 11: Iteration 2 - Single fanned sweeper

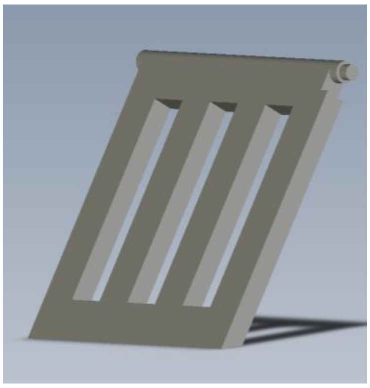

Figure 12: Iteration 3 - Ribbed sweeper with flexible sweeper attachment

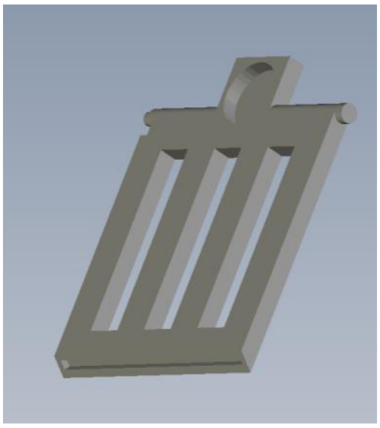

Figure 13: Iteration 4 - Sweeper with counter mass.

Figure 14: Iteration 5 - Side positioned counter mass.

Figure 15: Iteration 6 - Sweeper with side guides.

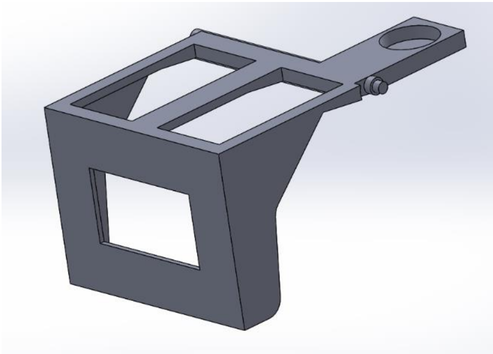

Figure 7: Iteration 7 - Sweeper with side and front guide.

The Ramp Design:

In the robot design, the Ramp design was the second most important design problem thus we also went through multiple iterations of the ramp as well. The major problem was to configure the ramp properly so as to make it fit perfectly and work in synergy with rest of the robot. The ramp length exceeded the maximum size of 200mm that we could 3D print, so we had to come up with assembly ideas so that we could print he ramp in parts and join them together. The major iterations of the ramp design are shown below in figures 17-20.

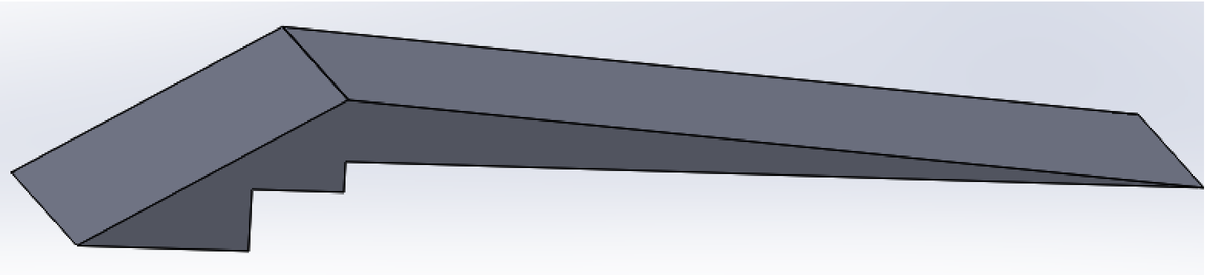

Figure 8: Iteration 1 - Basic Ramp design

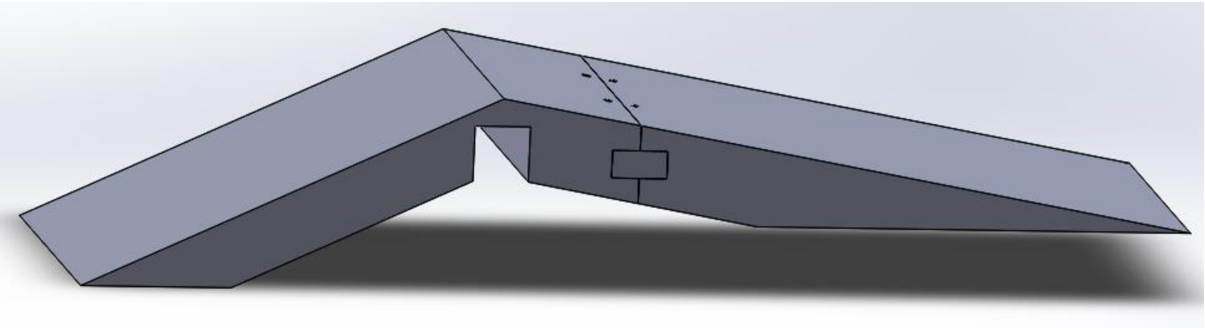

Figure 9: Iteration 2 - Ramp with key and whole fixture

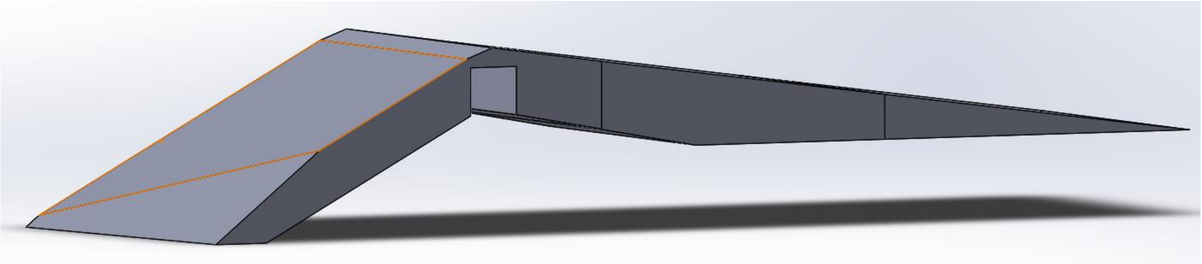

Figure 10: Iteration 3 - Ramp Design with slanted cut to push out the Red ball.

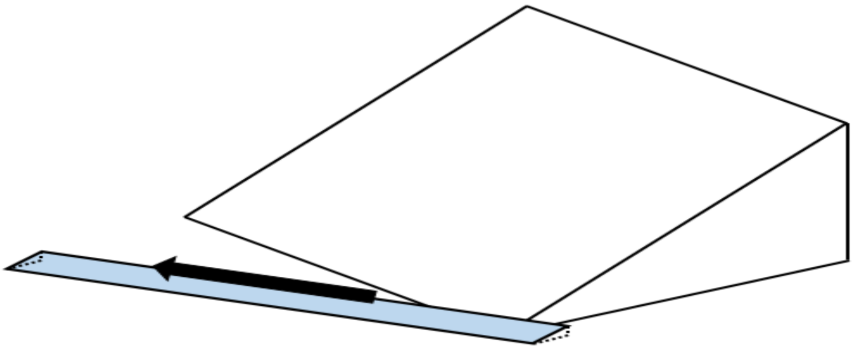

Figure 11: Iteration 4 - Ramp design with plastic strip attached to enhance the ball pushing effect.

Conclusion

We finalized our robot, adding an imu being used as a compass for better reference. We added heat sinks to lower the temperatue of the motors that were getting a little hot, otherwise we had good control over the temperature regulation. We also added the 배달의민족 Mascot for our robot. We had done multiple runs leading up to the final evaluation run. Most of them were successful in collecting and depositing all the correct balls. On the event day, for some unknown reasons the Wi-Fi signal to the MyRio kept getting disconnect and we were not able to capture all 3 balls, instead we captured and successfully deposited 2 balls. In essence we did achieve all the tasks were asked to accomplish. Thanks to the cooperation of all the team members, TAs, and our advisory professor it was indeed a successful project.

Figure 12: Our final Robot with 배달의민족 Mascot

Appendix I : Weekly Progress Reports

1st Progress Report

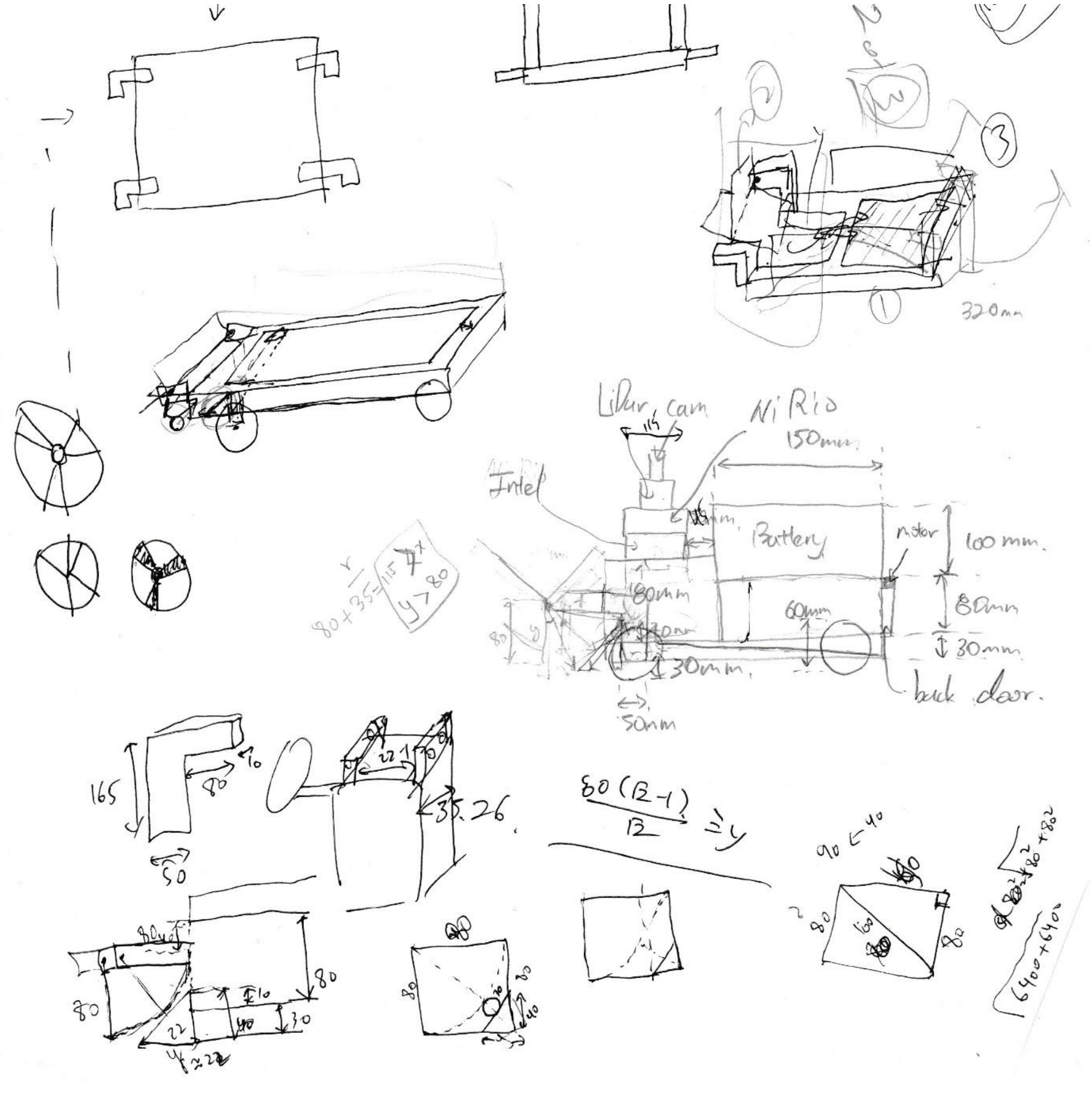

Figure 13: Basic Sketches for the Robot

Huiman and I are responsible for doing SOLIDWORKS for our group. We started off with basic sketches for our robot which is based on the roller-type pick-up method. We assumed some of the dimensions, which we might modify later after considering the whole system, like the thickness of the plates frame.

2nd Progress Report

Based on the sketches that we had made earlier we created the 3D CAD drawing on SolidWorks. Various renders and screenshots of the CAD drawings are put below.

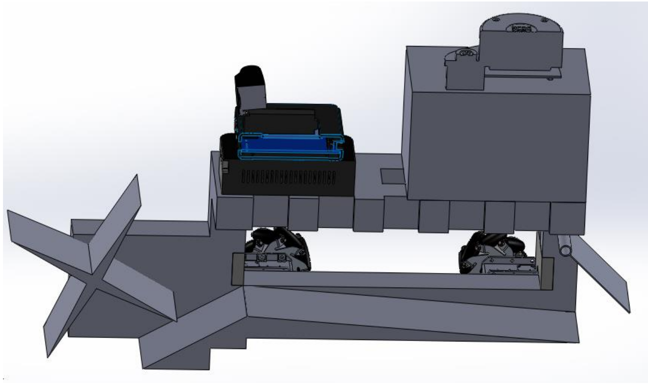

Figure 23: Cross-sectional view

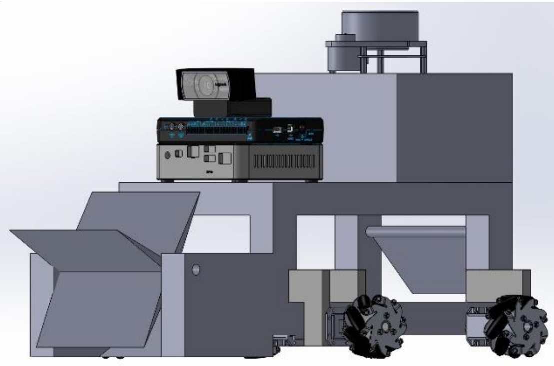

Figure 24: 3D view

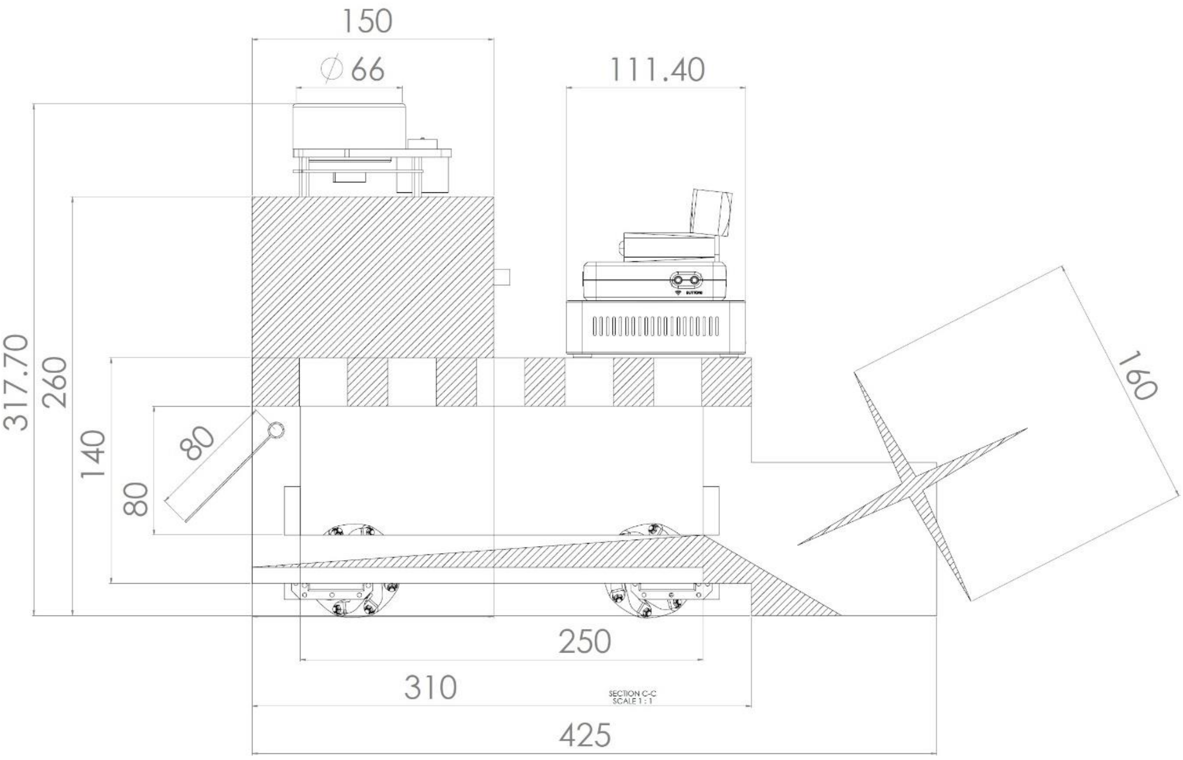

Figure 25: 2D Drawing of Robot

3rd Progress Report

After the basic sketches and the SolidWorks CAD drawing, we took upon the task of actually starting to fabricate the robot frame. We discussed and assessed different materials for our robot frame. We finally decided to use a 20mm x 20mm Aluminum Profile for the purpose. It was easy to handle, cut and join. The biggest benefit of using the Aluminum Profile was that we were able to modify the frame very easily to any change in the requirements from other team members. This gives us flexibility in manufacturing and eases the design process. Having had the feedback from the Professors during our 1st Presentation and our team members we finalized the principal dimensions of our frame shown in Figure 1 below.

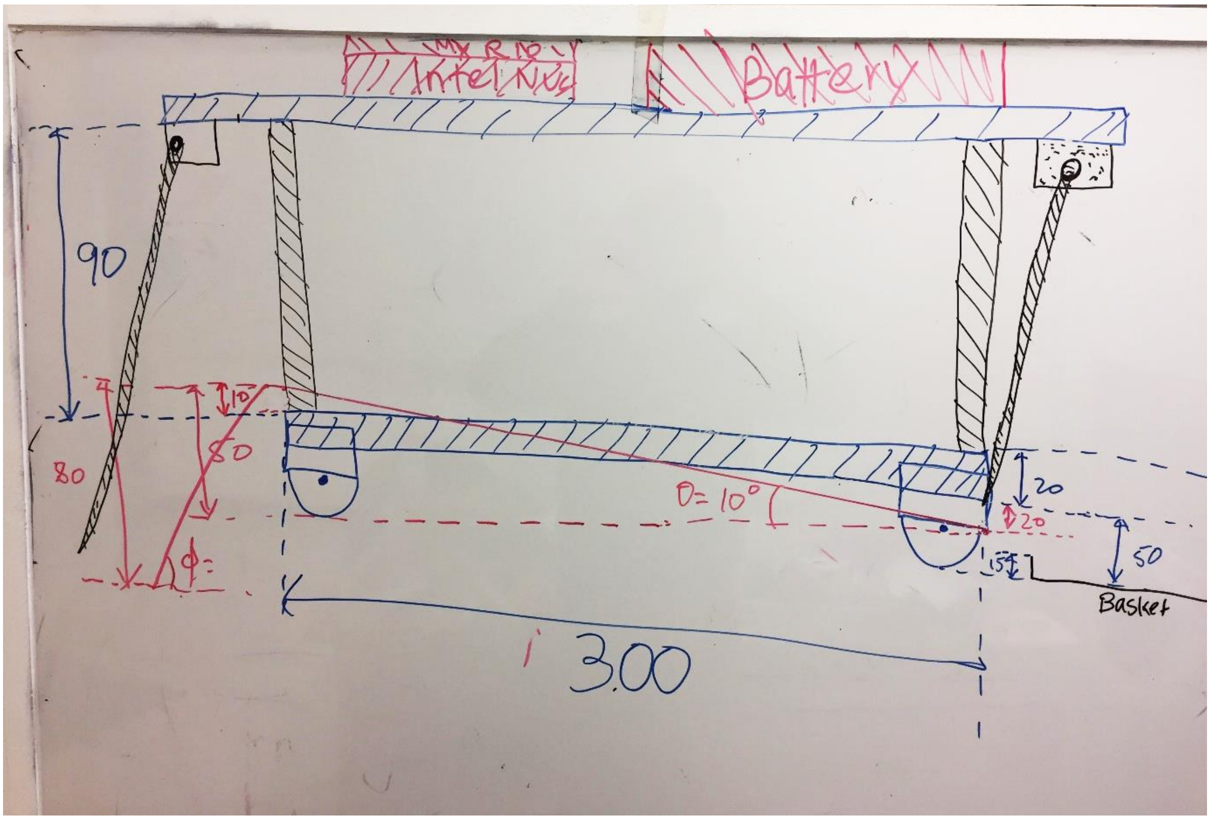

Figure 26: Finalized sketch of major dimensions

4th Progress Report

Moving on from the determination of the principle dimensions we actually took upon the task of making the robot frame using the 20x20 Aluminum Profiles. We cut, filed and assembled the different pieces together with nut and bolts to finally get the robot frame shown in Figure 2 below.

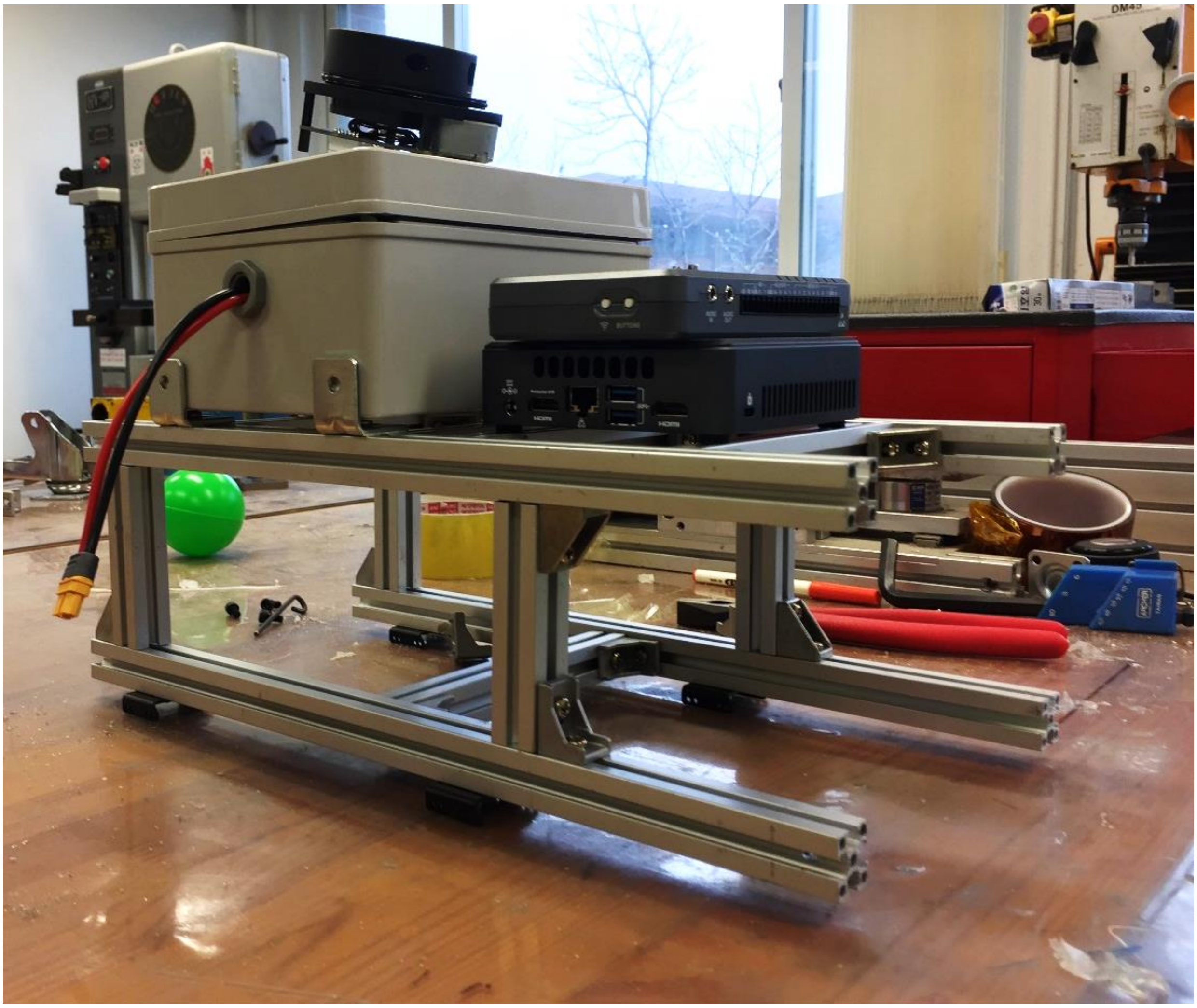

Figure 27: Robot frame with Battery, Intel NUC and NI MyRio placed on it.

It should also be noted that we have also fixed the mounting plates for the actuators attached to the wheels.

5th Progress Report

With the help of LABVIEW coworkers we attached the wheels and checked if they work alright. To our relief the robot works well and without any major vibrations. So we finally finished making and manufacturing our robot's driving system. This is the final frame design. Unless any major problems are encountered in the future we are not going to change the frame design. And this will be the final shape of our robot.

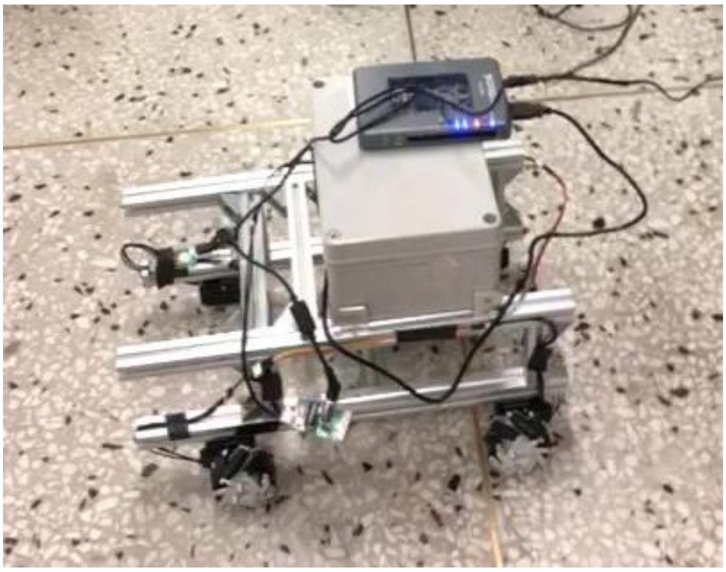

Figure 28: Functioning motors attached to the robot with the actuators.

We also finalized the design of the ball ramp of our robot over which the ball will move into the ball collection region of the robot, the picture of the ramp is shown below.

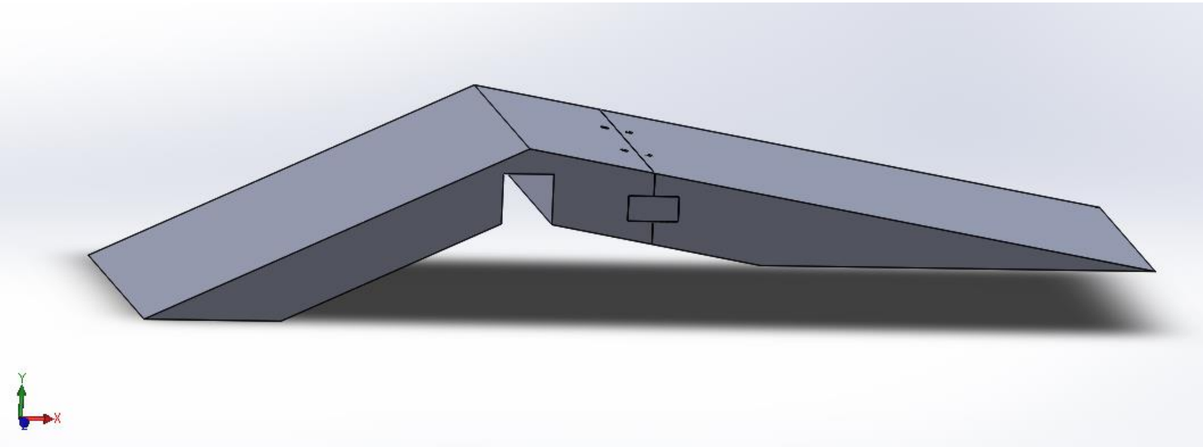

Figure 29: Ramp CAD design

The total length of the ramp is 400mm, but we can only 3D print a maximum of 200mm long component in the 3D printers. Therefore we used a key and hole system to print the ramp in two parts and then join them together later.

6th Progress Report

With the SOLIDWORKS TAs' advice, we decided to make our sweeper design more robust. Previously, we were just considering the case when the ball is at the edge of front ramp. But the ball in some case can be anywhere near the front ramp. Even if we tune and configure the motion algoritim, there will always remain an error of the position of the ball in a position where the sweeper can sweep the ball into the robot. Hence to give more room to ROS coworkers we redesigned the front sweeper in a way where the ball can easily be trapped between the sweeper and the robot. Now we finished drawing to print the sweeper by 3D printer. We also switched from a DC motor powered 4 winged sweeper to a single wing Servo motor controlled sweeper for better control.

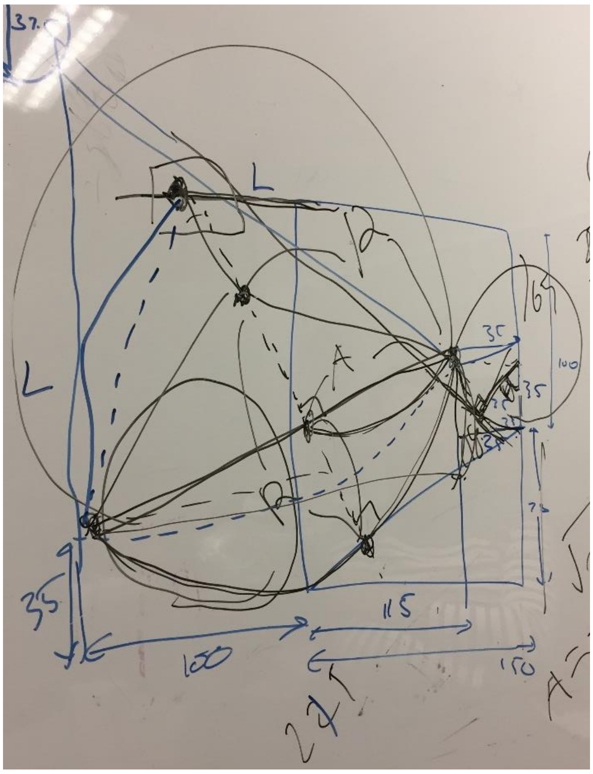

Figure 30: Calculation for sweeper positioning and length

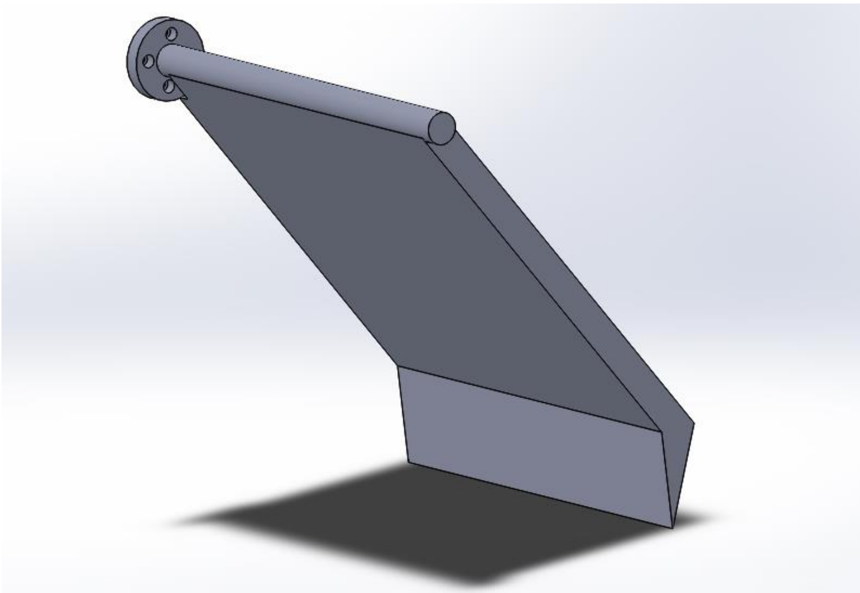

Figure 31: Design of the front sweeper with the motor mount attached.

7th Progress Report

As we had mentioned in the earlier that we had revamped the sweeper design. We encountered another problem that we had to solve. Because we had to start our sweeping algorithm at a position where the center of mass was not in line with the axis of rotation, it was producing a lot of static torque. This has been contributing to two major problems, one was that the motors kept working thus were consuming a lot of power even when we did not use them. Second was that this power consumption was creating a lot heat, a thing that we really do not want. So by consulting other team members and Professor, we decided to add a counter weight to the front sweeper so that the sweeper will maintain the initial position we want and the torque generated will be countered by the counter weight. We initially decided on putting the counter weight at the center of the sweeper, but we had to add other components for vision part so we moved it to one end, as seen the figure below.

Figure 3214: redesigned sweeper with the counter weight.

We have also decided to add brush at the end of the sweeper. We were encountering a problem, where the ball kept getting stuck under the sweeper, so the servo motor kept shifting its zero position due to the extra torque. So we added a brush, so that the extra torque is not exerted and the sweeper can sweep the ball properly. As the ball will not get stuck under the brushed sweeper.

8^{th} Progress Report

This week we made the encasing for the electronics and the camera mount. We tried to tidy up the design so we decided on the proper configuration of all the components that will go on the robot. We decided that we will put the mount for the Intel NUC and NI My Rio on top of the battery. The mount is shown in the figure below.

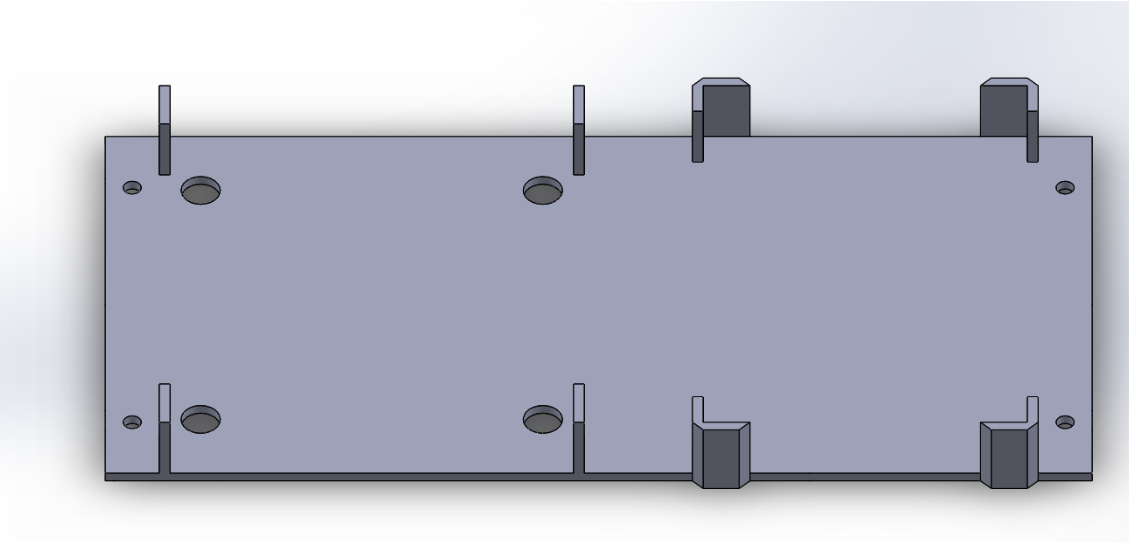

Figure 33: Mount for Inter NUC and NI MyRio

We tried to keep the design minimalistic and neat. We have a separation between the two mounts for the heat to be easily removed. We have put side scaffoldings for t the NI My Rio and holes to fix the Inter NUC using its tiny legs.

We also made the mount for the camera that we are going to put on the aluminum profile. The camera fixes on the mount through a screw. It can be seen in the figure below.

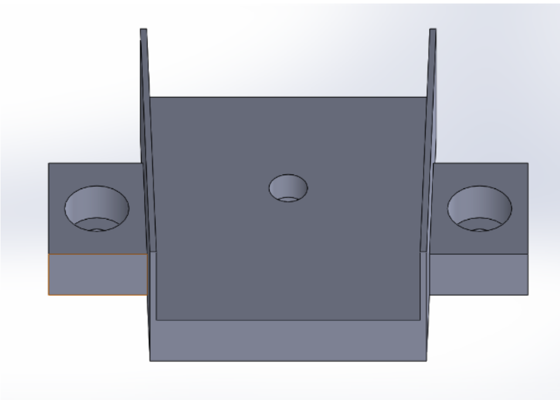

Figure 34: Mount for Camera

9th Progress Report

To arrange our robots electronics at desired positions, we created and modified to further improve the electronic mounts for NUC, MY RIO, Web cam, ISO, and bread board. The picture on the right shows the modified mount for MY RIO and bearing bracket. For other devices we chose similar strategy to fix the position of electronics. The complete fixture for My Rio and Intel NUC is shown in the CAD drawing below.

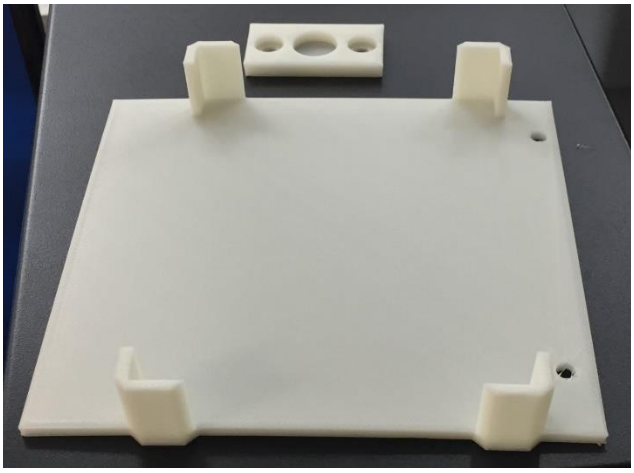

Figure 35: Mount for MY Rio and Bearing Bracket

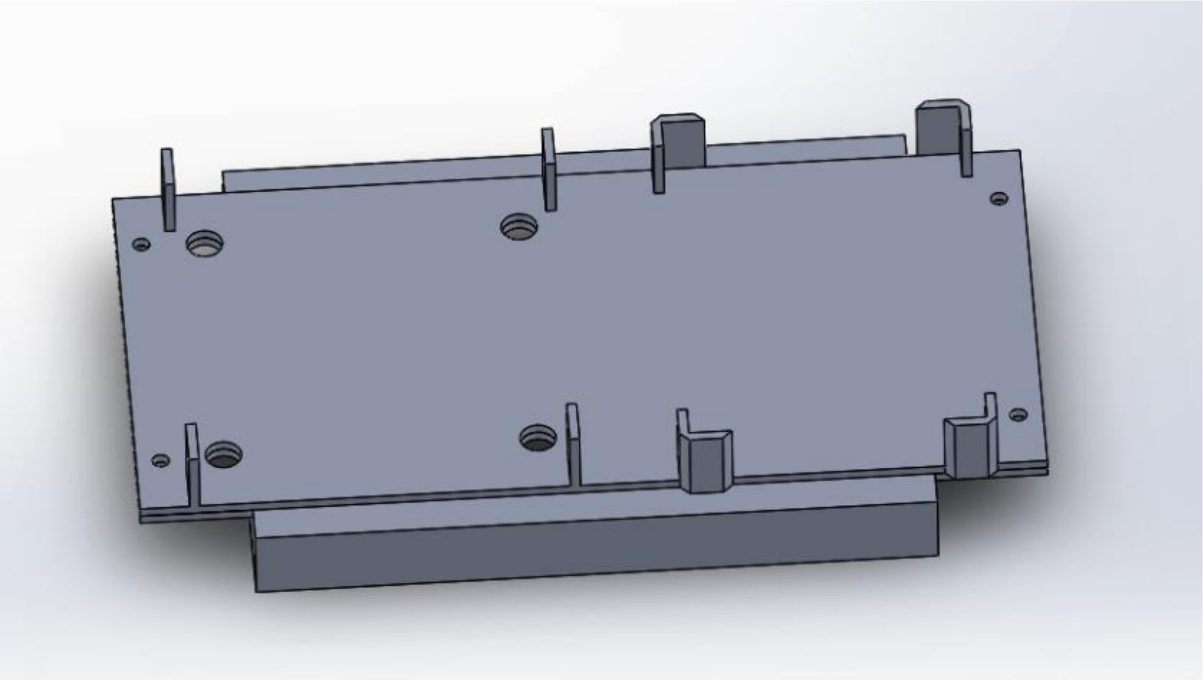

Figure 36: Mount for CPUs that latches onto the Battery

10th Progress Report

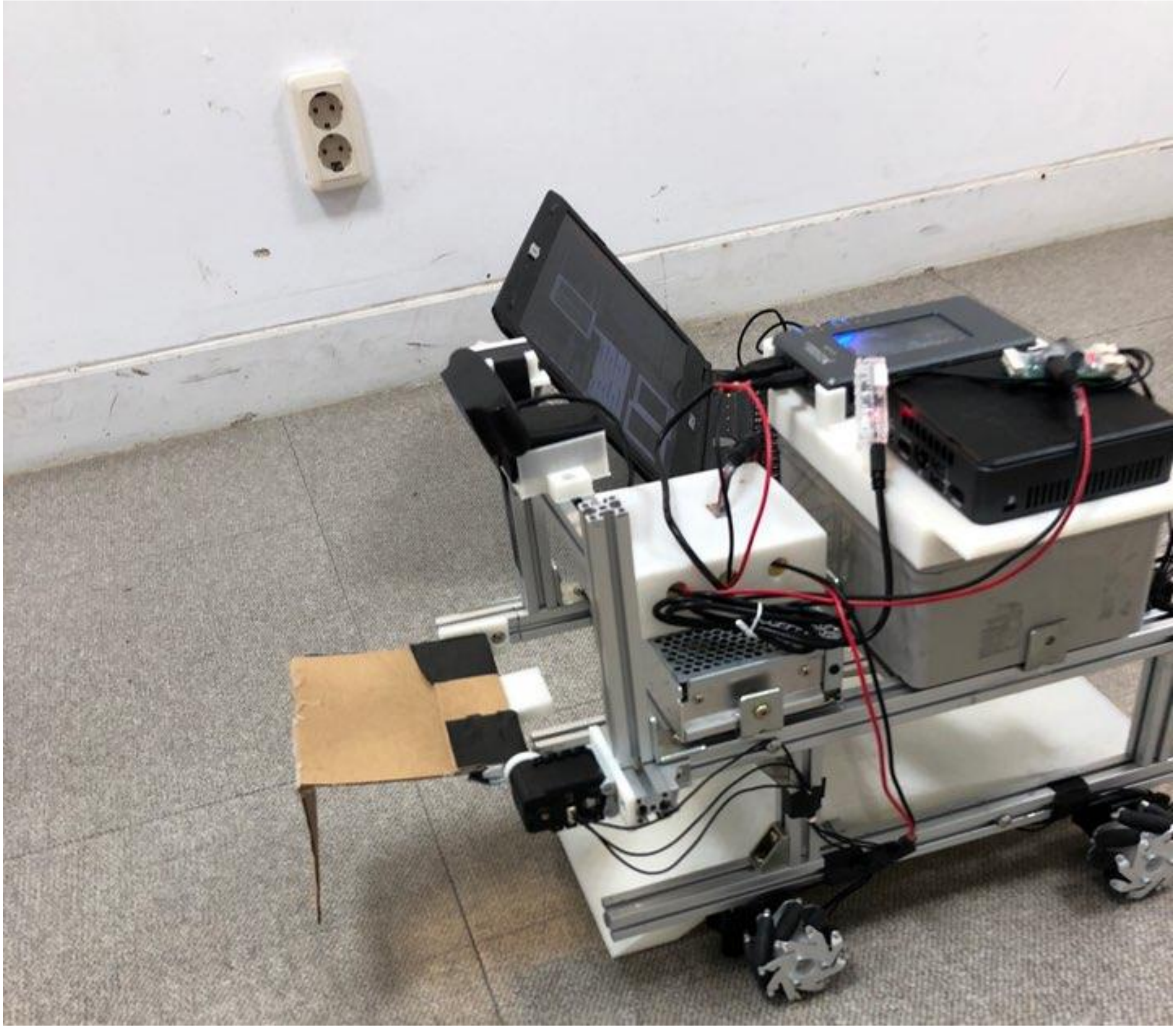

Figure 37: Mockup of modified sweeper

A very critical problem was encountered in our trial runs. Our previous sweeper design was not working properly under certain conditions. In fact, we tried to design the sweeper and ramp make obtuse angle when the sweeper sweeps the ball at the tip position of ramp. But, we gave to small angled tip to previous sweeper, so we couldn't achieve our purpose. So we tried rapidly to make the system work in desired fashion. We will 3D print the front sweeper shown above picture. Now at the point of initiation the sweeper is vertically tangent to the ball, therefore there should be no problem in sweeping the ball.