Project 2: Management Report

Team 302
Seth Tumlin
[redacted]

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EXECUTIVE SUMMARY

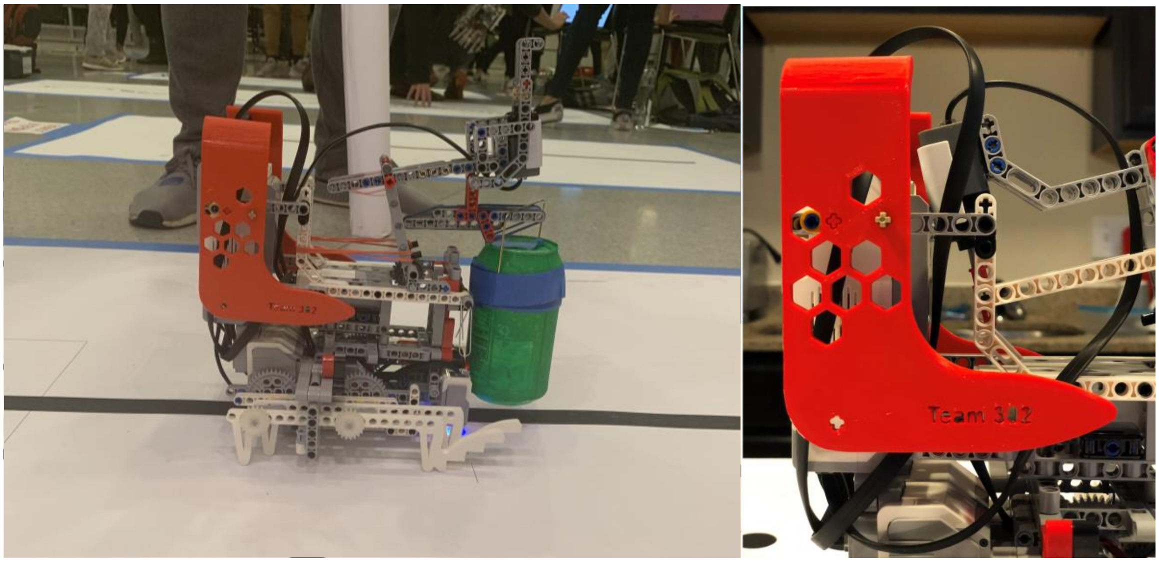
From the beginning of the project, the problem we sought to solve and the task we sought to complete was the request from Dr. Clearit and Dr. Sortit. We created a Prototype Mover Robot (PMR) that fulfilled all requirements set out in their original request for a prototype. A few of the major requirements were moving without rolling to navigate rough terrain, autonomously determining the contents of a bin of recycled material, and taking said bin to a predetermined location to be recycled. Our fulfillment of these requirements and more will allow the company to begin operation of their Thermal Depolymerization (TDP) plant – dependent on the other components – and begin to sustainably clean up in areas affected by natural disasters.

Given the limited resources and sizable task from the company, we were required to engineer some unique and innovative solutions. We are very proud of these designs and were pleased to see them work (sometimes). We have compiled some unique features here.

1) Bin attachment point. Our original bin attachment point was a see-saw-like arm with an upside-down force sensor on the back. This did not work too well because residual force from picking up heavy cans was held on the sensor from the friction on the fulcrum. Our solution to this was a completely new design (Fig. 1). It features a hanging attachment point that is held by the force sensor. This worked better, but was still not perfect. Eventually, we were able to perfect it by making the PMR shake up and down by walking forward one step. This, for some reason, made the force sensor more accurate. We added rubber bands for traction on the handle.

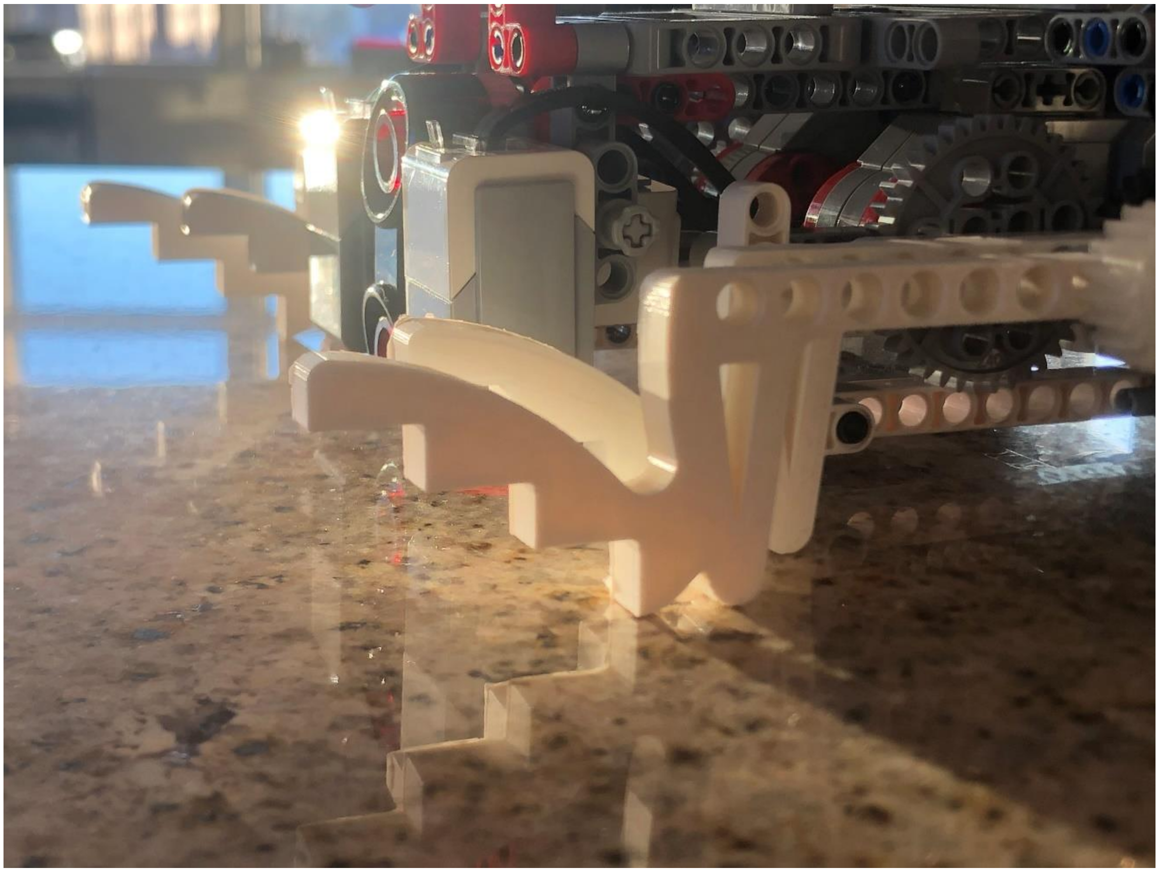
(Fig. 1) Our updated attachment point

2) Aesthetics. Throughout the semester, we made sure to keep the visual appearance of our robot pleasing. Towards the end, we decided to add a 3D printed façade for extra effect (Fig. 2). We sent out a survey asking whether the robot looked better with or without the addition. The averages indicated that it did look better with the façade.



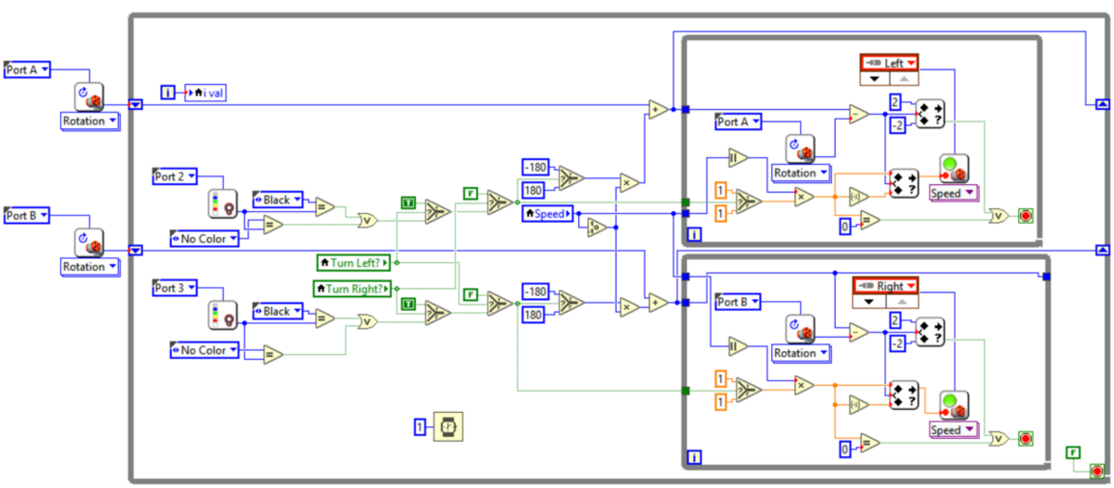
(Fig. 2) Our robot with its aesthetic enhancements

3) The legs. Early in the project, we realized it would be better to 3D print our legs. We did this and went through most of the project with these legs. At some point, the only requirement we couldn’t fulfill was the 3/4” obstacle one. Our robot only stepped 3/8” high and we could not change this. Instead we designed and printed new legs with serrations (Fig 3.). These allowed the robot to climb up the obstacle and slide down the other side.



(Fig. 3) Our legs that allowed us to step over the obstacles

4) The programming. Our programming used many control techniques including a proportional loop control with a virtual setpoint for our walking. This allowed our legs to stay in sync. (Fig. 4) shows our walking loop.



(Fig. 4) The closed-loop walking control for our PMR

Our PMR performed outstandingly. At the demo, we completed every single task (including in the final demo) except we missed the last part of subtask 2. We were all thrilled with the performance and many of the TAs liked the looks and designs.

The project was completed on-time and under-budget. We fulfilled all requirements by the demo and our original budget estimate was $15,308 – we ended up using $7,547 (additional breakdowns can be found in the Appendix).

DESIGN PROCESS FOLLOWED

Throughout the project, our team followed the design process. We began by **empathizing**. To understand the problem on a deeper level, we read the entire document including the introduction, which may seem irrelevant, but in the end, was helpful to understanding the background of our problem. This was helpful to understand the challenge deeply but abstractly. To understand the problem more specifically, we next moved on to the define stage.

In the **define** stage, we broke down the requirements into a simpler form. This allowed us to breakdown the work into stages. (Fig. 5) shows our work-breakdown diagram. Originally, we planned on breaking up work between members by subsystem, but we soon realized that this would not work with the subtasks. The following is our early subsystem description table (Tab. 1).

Drive Train – The drive train will be used to move the robot around to its required locations (bins, shipping container, etc.). The drive train must not use wheels or treads, so it is able to move around on uneven terrain. **Line Follower –** The line follower will guide the robot as it moves around to its specified locations. The follower must be able to decipher different lines and reliably navigate curved lines. **Bin Identifier –** This device must be able to distinguish what type of refuse a bin contains by picking it up. It must do this through weight. The shape of the bins is unknown. ***BREAK***

Aesthetics – The robot must look good in order to be more marketable to future customers. The embellishments must not affect the performance of the robot.

(Tab. 1) Early subsystem descriptions

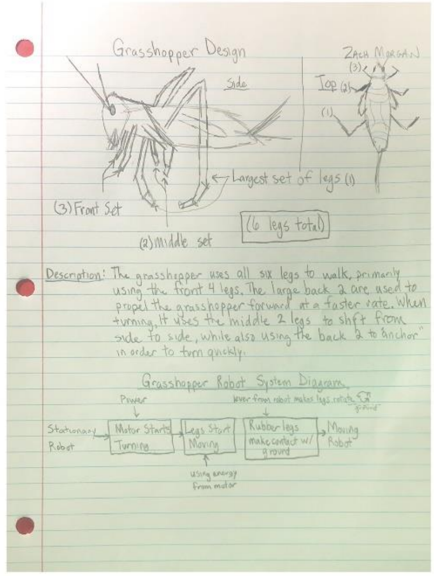
The other major part of the define stage was to determine what criteria our robot must meet to be considered to be successful. We decided that this would be mainly through a testing bed that we would develop once we had more information. Our criteria is shown in (Tab. 2).

Drive Train – The drive train must always be able to 1) keep the robot upright at all times and 2) move over obstacles up to ¾" tall. **Line Follower –** The line follower must be able to 1) follow all given types of paths and 2) not leave a circular test track more than once every 50 revolutions. **Bin Identifier –** The bin identifier must be able to 1) pick up all types of bins and 2) correctly determine the contents at least 90% of the time. **Aesthetics –** The aesthetic improvements must 1) convince the majority of a small focus group that the robot looks more marketable than it did prior to its alterations.

(Tab. 2) Test criteria

The criteria laid out above would come in great use for the testing part of our design process.

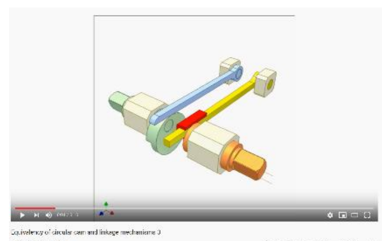
The next step in our design process was **ideate**. This is where our normal meetings were the most useful. We were able to bounce ideas off of each other and research. Some sample work from the ideate step are shown in (Fig. 6), (Fig. 7), and (Fig. 8).



(Fig. 5) An idea for a biobot design

Subtask 1 Decision Matrix			
Criteria	**Nara Cricket**	**Turtle**	**Grasshopper**
Speed	4	1	5
Stableness	4	5	2
Easy to mechanize	3	4	3
Ease of turning	4	4	2
Total:	3.75	3.5	3

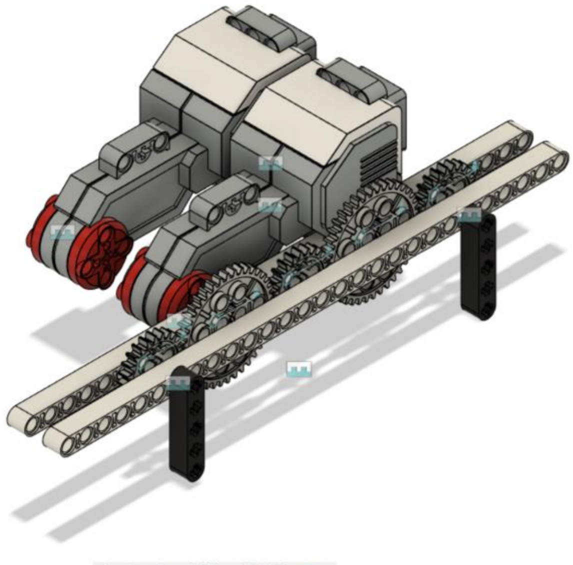
(Fig. 6) A design matrix for the biobot



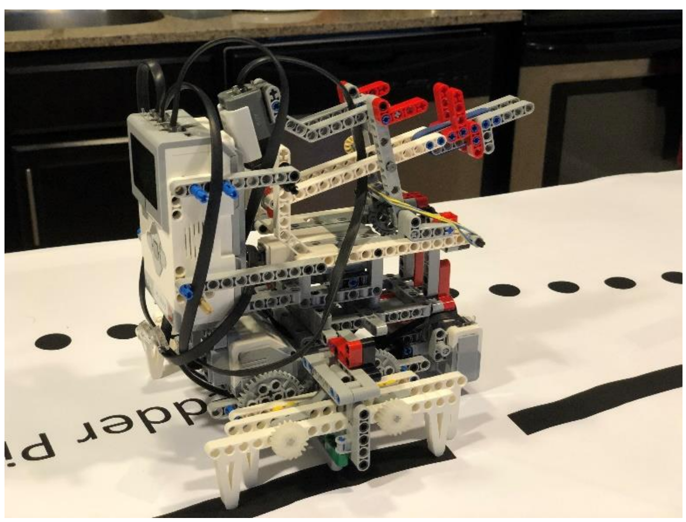
(Fig. 7) A video that inspired our walking mechanism later in the project [1]

The ideate step was helpful to generate many ideas for our design; however, sorting through and deciding on one of the ideas was another problem. This is why our next step was prototype.

For the **prototype** section (this was the majority of our time) we got to get down to the hands-on work and build our concepts in real life. This step was tightly interlaced with our testing step. Some examples of our work from the prototype section are shown in (Fig. 9) and (Fig. 10).

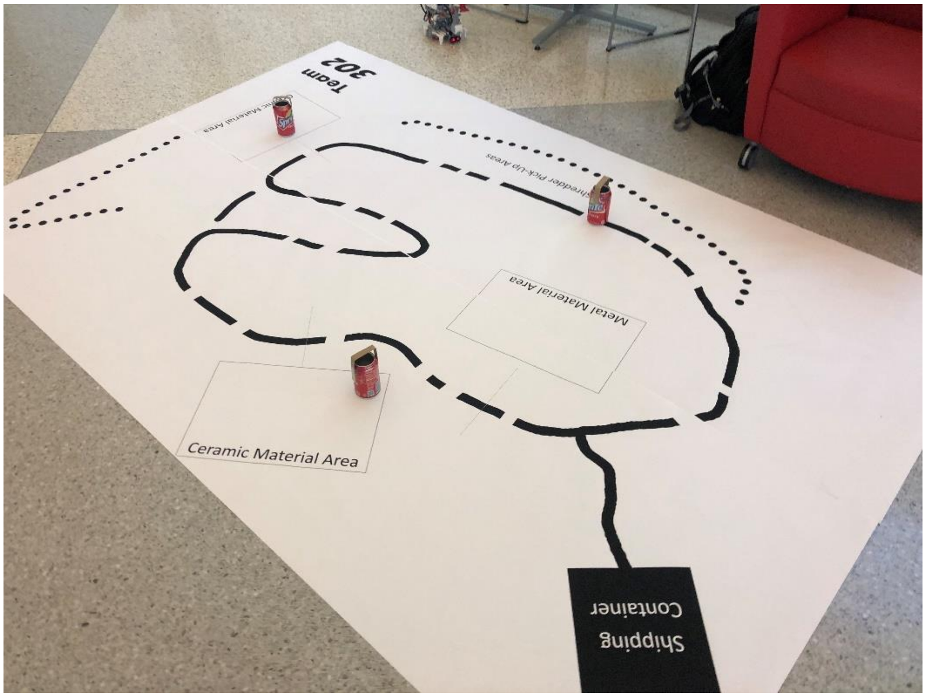


(Fig. 9) An early CAD prototype



(Fig. 10) A prototype used in Subtask 2

The next step was to **test**. This step usually involved 1) setting up a test rig, then 2) the prototype would typically fail (but sometimes work) and, 3) we would go back to the ideate step and repeat or move on – this depended on the level of success. We used our earlier criteria for success to produce a testing rig and run trials. We printed a full-size testing map (Fig. 11) and used cans with weights to simulate bins. This meant we could use the iterative design process to land on a final design that we would then implement.



(Fig. 11) Our full-scale testing map

The final step in the design process is the **Implement**. Implementing consists of cleaning up odds and ends to make the product a great experience for the user. For this reason, we added aesthetics to our robot. Throughout the entire process, we kept looks in mind. However, we decided to add something to really tie together the entire theme. That is why we added the red accent façade on both sides. They are shown above in (Fig. 2). They really put the finishing touch on the robot and people at the demo loved the extra touch as well.

Our design process as a whole consisted of a frequent repetition of the ideate, prototype, and testing steps. For example, we originally had a design with two separate large motors driving the legs. We then switched to one large motor for driving and the medium motor for steering because we believed this would be better for the straightness of the robot's walking. However, after about a week, we switched back to the dual motor and used the medium motor for the arm. Another example is when we decided to move the ultrasonic sensor to make room for the light sensors. There were many other instances similar to this, all are outlined in our notebook.

CONTINUOUS IMPROVEMENT

We did our best to utilize the design process the entire time; and this was to excellent result. However, we did not receive the point for the curved dotted line in the demo, so obviously there are things we want to improve. If we were to do the entire project over again, there are changes that we would make to our process.

One of the main problems with our process was that a lack of communication and coordination meant that the work was not evenly distributed among the members. If we were to start again, we would probably share our schedules with each other and have set dates for build sessions that everyone could attend. This would mean that all members could work on the robot in a more fairly distributed fashion.

Another improvement could be having the CAD work designated to a person with less work. If more time was spent on the CAD, we would have had a more complete model and we could have made integration plans earlier.

As for the timing of our design process, it would have been helpful for us to start on the testing phase earlier. We spent quite a bit of time testing, and we also believe this was the most helpful stage of the process, as it gives real-life results.

It also might be helpful to, when in the define stage, find subsystems that the individual members have prior knowledge in. For example, it can be helpful to know that one member is fluent in CAD and 3D printing, rather than assigning this task to a member that does not have prior experience and would take a significant amount of time to become familiar with the area.

A final improvement that would be helpful to the group's design process would be to establish team norms that are specific to the project. We had team norms that were made for our team before we received the project; however, these were too abstract to be applied directly to the project – each member could have a different interpretation of how a team norm applies to the project.

All of these improvements would have made the project flow more smoothly and achieve a greater level of success. These improvements can also be applied to future teams that the individuals of this current team will work in. Overall, we were very happy with our process, and believe that we learned a lot from the experience.

References

[1] thang010146, *Mechanisms Playlist*. [Online]. Available: https://www.youtube.com/channel/UCli_RJkGWfZvw4IlDLHNCQg. [Accessed: 06-Dec-2019]