Design Process Report

TEAM 271

ENED 1120 – 021

Dr. Cedrick Kwuimy

Project 5: Autonomous Record Retriever

Project date: Feb 2, 2020 to April 24, 2020

Team members:

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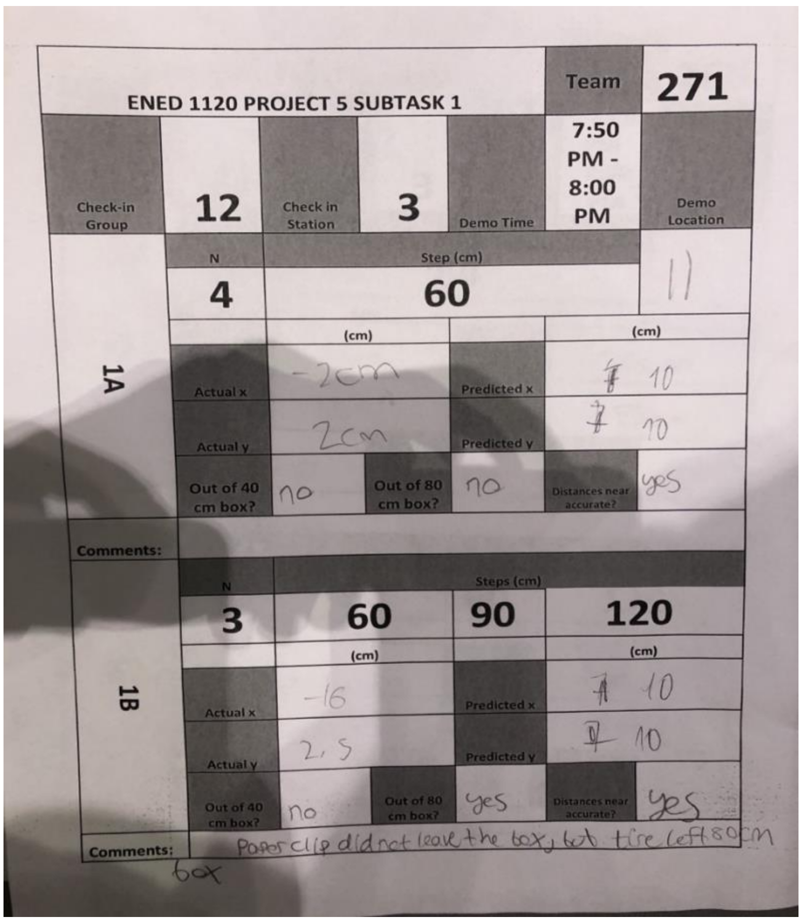
TEAM PERFORMANCE SUMMARY

The purpose of project 5 is to construct an autonomous that can navigate around the field, scan the box's barcode and pick up the box with the correct given barcode. Crucial systems include navigation system, barcode scanner system, collision avoidance system, and IPS.

Due to the breakout of the Covid-19 virus pandemic, the project is transitioned into an online, and many aspects like on-filed prototype testing were lost.

However, prior to the social distancing order, our team has managed to construct the physical outlook of the robot, especially the navigation system, and the robot was tested in the Subtask 1 demonstration:



ENED 1120 PROJECT 5 SUBTASK 1						Team	271
Check-in Group	12	Check in Station	3	Demo Time	7:50 PM - 8:00 PM	Demo Location	
1A	N	Step (cm)					
	4	60					11
		(cm)			(cm)		
	Actual x	-2cm		Predicted x	~~7~~ 10		
	Actual y	2cm		Predicted y	~~7~~ 10		
	Out of 40 cm box?	no	Out of 80 cm box?	no	Distances near accurate?	yes	
Comments:							
1B	N	Steps (cm)					
	3	60	90	120			
		(cm)			(cm)		
	Actual x	-16		Predicted x	~~7~~ 10		
	Actual y	2.5		Predicted y	~~7~~ 10		
	Out of 40 cm box?	no	Out of 80 cm box?	yes	Distances near accurate?	yes	
Comments:	Paper clip did not leave the box, but tire left 80cm box						

Figure 1: Results of team 271 subtask 1 demonstration

As for project management, our team managed to follow our Gantt Chart very well with regular meetings. Thanks to our consistent weekly progress, we fully constructed the physical component of the robot before the face-to-face interaction suspension order. With ample time left for the logical component, we were able to finish the project in time, and in budget.

DESIGN PROCESS FOLLOWED:

1. **Empathize**

In this stage, we spent time discussing the requirements for project 5 through the Request for Proposal to identify the main objectives and main functions/components our robot should have. After understanding about the robot's purpose, we decided the robot should have the following four components:

A. Navigation system: The robot must first the able to move smoothly in the arena, so a navigation with wheels or treads is necessary
B. Barcode scanning system: The robot must be able to read the barcode correctly to get the right box
C. Pick up system: A good pick up system helps the robot retrieve a box surely (not dropping the box half-way) and in a timely manner. The system also manages dropping off the box when going back to the HOME location
D. Storage system: A storage system is necessary to ensure that the box is safe when transporting between location no matter how far. The system also ensures if anything happens, the box's content shall remain intact
E. Localization system: A localization system with Bluetooth receiver help the robot triangulate its position to navigate the arena.

2. **Define**

In this stage, we spent time to clearly define how to turn the functions and components we decided into concrete numbers that we can verify. Therefore, we developed a general testing plan for our robot:

A. Navigation system

- Minimum speed: 1 ft/s
- Be able to go forward perfectly straight – for 5 times in a row; will test with different distances from 1 to 10ft
- Be able to go backward perfectly straight – for 5 times in a row; will test with different distances from 1 to 10ft

- Be able to turn precisely with a displacement less than 3 inches – for 5 times in a row; will test with different angle from 45 to 270 degrees
- Each test above will be replicated on difference surface: carpet, paper, and tile

B. Barcode scanning system

- Barcode scanning maximum speed: less than 10s
- Be able to determine the right barcode type out of the 4 types – for 15 times in a row
- Be able to determine additional made-up barcodes as INVALID – for 15 times in a row

C. Pick up system:

- Be able to pick up maximum of 250g
- Be able to pick up boxes without dropping half-way successfully – for 10 times in a row, with boxes of different weights
- Be able to pick up boxes and put correctly in storage system and still able to move a small distance after that successfully – for 10 times in row; maximum time for this test must be less 10s for each repetition

D. Storage system

- Be able to carry object of maximum 250g without making the robot malfunction
- Be able to carry the object safely through a minimum distance 5 ft successfully – for 10 times in a row; will test for different speed: 1ft/s to 3 ft/s
- Be able to keep the object safe while robot spins at high speed for 10s

E. Localization

- Be able to display the correct (x, y) position of the robot – for 20 times in a row
- Be able to navigate between two coordinates precisely (with error < 5%) – for 15 times in a row; will test for different distances, including edge cases

3. Ideate:

In this stage, we started brainstorming ideas and concept designs for each of the system in our robot:

- For navigation system:

We decided to use **wheels** as the mean of transportation, which is both easy to implement and control, while also agile enough to allow robot to dodge obstacles in the arena. We went with 2 wheels because having 4 wheels would mean gears are needed to connect the front and back part, but gears have big variability due to popping in and out.

We also added a metal ball at the back to balance out the two wheels at the front, creating a strong triangular structure.

The concept design of our robot navigation system is described in the images below:

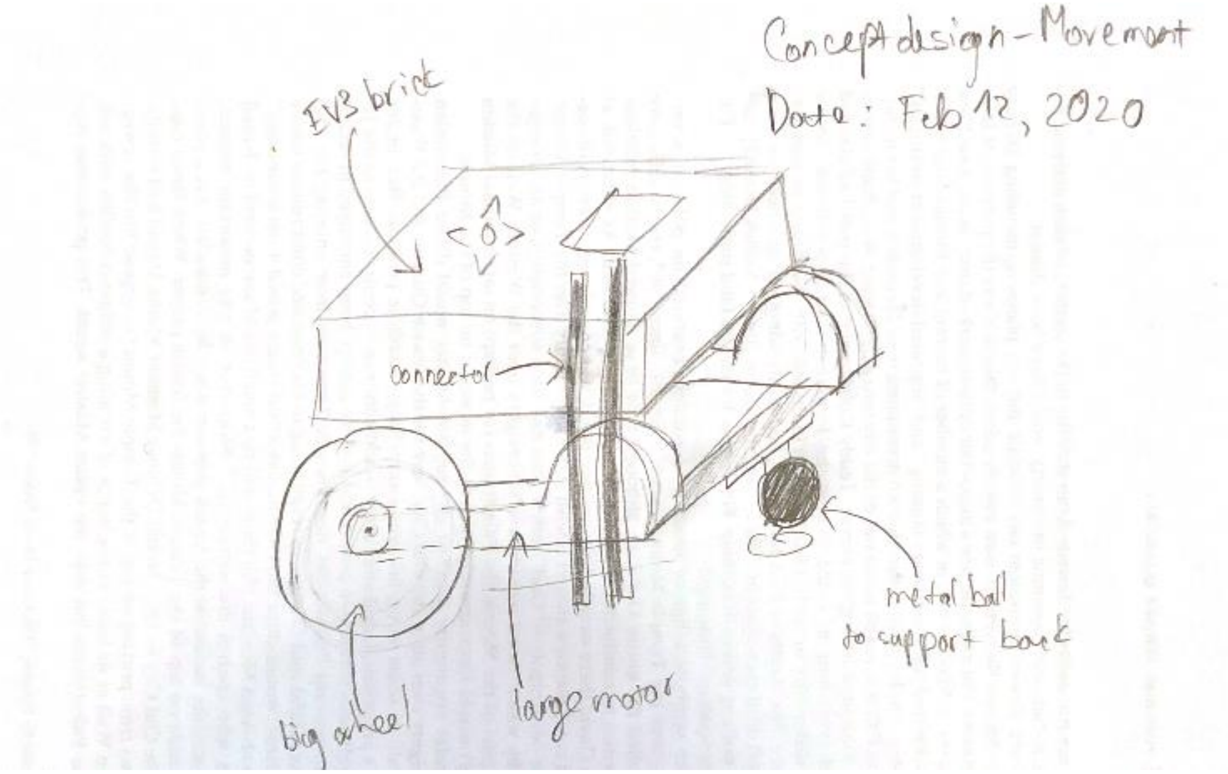


Figure 2: Concept design of team 271's navigation system

- For pick and storage system:

We brainstormed some possible ideas for this lift system and came up with decision matrix followed:

Table 1: Team 271's Decision matrix for Lift system

Criteria (higher point is more important)	Hydraulic forklift (higher point is better)	Hook and lift (higher point is better)	Claw mechanism (higher point is better)
Weight power (5 points)	5	2	4
Ease of building (3 points)	1	5	3
Ease of coding (1 points)	1	5	3
Use less resources (2 points)	1	5	4
Ease of transportation after picking up box (4 points)	4	3	1
TOTAL =	47	52	44

According to our decision matrix, we built the hook and lift system first, with a protruding arm to “piece” into the box’s handle and lift it up using the medium motor.

The claw mechanism has more lifting power than a hook, but for it to be viable, it needs at least 2 medium motors, one for grabbing the box and another for lifting the box up, which we didn’t have. The hydraulic forklift also has strong lifting power but is also the most difficult to implement because it would be very hard to “sneak” the forklift under the box to lift it up, and the positioning would have to be very precise or the box would fall instead of being picked up.

Therefore, we went with the hook and lift system, which, albeit does not have the most lifting power, has its advantages in ease of implementation and ease of transportation after picking up the box.

- For barcode scanning system:

We decided to scan the barcode using color sensor. Placement of the color sensor is **precisely at 6 inches** from the ground because that is also the height of the box where the barcodes are attached, since we have no way to move the color sensor around. To scan the barcodes, we discussed that, since we have no more motors to move the color sensor, we will let the robot turn gradually, and read each color section individually (there are 4 black-white sections that make up the barcodes). The reading results can then be combined into the corresponding type of box.

- Ideate process revisited in our logical coding progress

The ideate process is also revisited by us later as we discussed ideas for our simulation algorithms. From our brainstorming, we decided to implement a backtrack scanning algorithm for our barcode scanning system, and a “roundway” circumvention algorithm for our collision avoidance system

4. Prototype:

After deciding on the ideas, we began to slow build up our robots. The following are images of our robot physical prototypes:

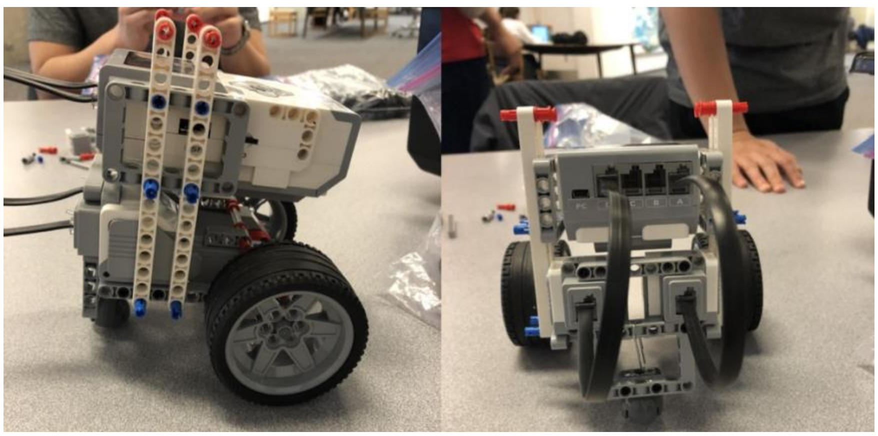


Figure 3: Prototype of Team 271's navigation system

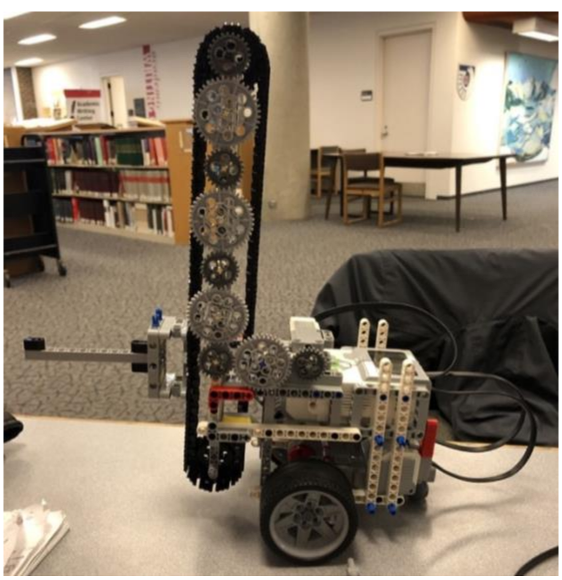


Figure 4: Prototype of Team 271's Lift system

Testing:*Table 2: Team 271's test data for navigation system*

For our navigation system, we did repetition test on various surfaces to determine the robot's speed:

	On floor			On paper	
	Time	Distance		Time	Distance
FORWARD	5	59		10	109
	5	60		10	113
	10	106		12	125
	10	107.5		12	133
	12	124		18.86	192
	12	124		13	133
	18.86	189		13	135
	Average =	10.5613505		Average =	10.578438
BACKWARD	27	-265		20	-200
	20	-201		20	-199
	18	-179		18	-181
	9	-96		11	-115
	13	-134		15	-154
	Average =	-10.057471		Average =	-10.107143

Later, as face-to-face meetings are prohibited and the project transitioned to online, we could not, and did not have to, come together for testing of the robot. Instead, the testing was on our codes and algorithm where had to run the codes multiple times with random variable each time to make sure our codes cover all the cases. In some cases, the code tests revealed critical bugs that we needed to go back to the ideate stage to brainstorm solutions.

CONTINUOUS IMPROVEMENT

Upon reflecting on our team's design process, we recognized one of our strong points was that we were able to make weekly consistent progress, which significantly quickened our progress to the final deadlines.

However, one of the weak points we found was our lack of proper testing for our prototypes. We were quick to build, but often neglected the testing phase. Therefore, some of our prototypes needed some rebuild or extra reinforcements. We believed that was because we did not test the robot under a diverse range of situation and therefore, was not able to control the variability.

Another thing we want to improve in the future is our far-vision which will help us develop prototypes that not only works well for its own functionality but also integrates with future systems yet to be built. Often, we found ourselves extending all the spaces available to build one system, and then when the next system was needed to be built, we had to revamp the robot in order the leave more spaces or wires or sensors to fit in. Therefore, from the experiences of project 5, we think that in the future, when we ideate one system, we should brainstorm about how a particular design will integrate with other components better as well.

APPENDIX A

Reporting of Personnel Cost

1. Bao Huynh

- Roles: Team leader, Timekeeper, Quality control, Notebook editor, Main programmer
- Hours spent: 50 hours
- Personnel cost: $40 / hour * 50 hours = $2000

2. Triet Pham

- Roles: Assistant builder, Assistant programmer, Notebook editor
- Hours spent: 40 hours
- Personnel cost: $40 / hour * 40 hours = $1600

3. Nathan Damas:

- Roles: Main builder, Notebook editor
- Hours spent: 40 hours
- Personnel cost: $40 / hour * 40 hours = $1600

4. John Cummings:

- Roles: Assistant builder, Main engineering notebook recorder
- Hours spent: 40 hours
- Personnel cost: $40 / hour * 40 hours = $1600

➔ **Total project cost: $2000 + $1600 + $1600 + $1600 = $6800**