# Rescue Robot

Report

For

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## EXECUTIVE SUMMARY

This report discusses how a rescue robot aids in the search and rescue of humans in case of disasters and calamities. It does so by the use of searching techniques such as reconnaissance and mapping, aiding by removing debris, delivering supplies and evacuating casualties. In addition to this, it can perform functions like extinguishing fire, marking survivor locations, closing a gas valve or taking care of any leakage. It is of great benefit under situations when human support takes longer to reach or rescuing areas that are too small for humans to reach and provide help. Moreover, the report highlights all the challenges faced by team *D.A.M.M.* over the course of working on the robot and how they were overcome. The report concludes with a suggestion to improve work in the future.

# CONTENTS

# 1 INTRODUCTION

Rescue robotics is a new research field that deals with the phenomenon of saving humans, animals or simply performing rescue operations to save them from a dangerous situation such as a calamity or natural disaster (fire, earthquake, flood, bomb/ gas explosions etc.) In such a situation, a rescue robot can be used to provide insight to collapsed structures, search and locate victims, and perform rescue functions such as extinguishing fire and draining water from any source of water and being able to prevent leakages. Robin Murphy in tedTalk said: “Robots can make a disaster go away faster”. This is a perfect depiction of what the sole purpose of a rescue robot is.

However, there are many engineering challenges involved with the construction of a rescue robot as it not only has to be designed for harsh environmental conditions of disasters, but they also need advanced capabilities like intelligent behaviors to free them from constant supervision by operators. The project assigned to team D.A.M.M in ENES-100 involved the construction of a similar rescue robot, but on a smaller scale. It should be capable of lifting any debris off the ground along with marking location for the survivors. Another feature it must possess is the mechanism that allows it to prevent leakages by closing any valves (gas/water) and draining a specific amount of water with the application of water depth measurement phenomenon. It must be capable of extinguishing fire with an inbuilt feature of being able to measure the room temperature along with possessing a shoring structure that is able to withstand weight to prevent further collapses. Lastly, to test the efficacy of our robot and the functions it performs, it will be run and tested under an environment set up by a team of highly qualified professionals where it will be checked for all the functions mentioned above.

# 2 MAIN BODY

Team D.A.M.M. began with assembling the *Hi-Wonder Le Arm* which was the basic step to initiate the project as the arm is to perform maximum number of functions in our project, including lifting debris, closing valves, moving in order to allow camera to capture maximum vision, place water pump in desired locations to drain water, and to dip the water depth sensor in the drained water to measure its depth. The arm was able to take advantage of the bluetooth module built within it so that a user can send commands to the arm and drive specific motors to do specific actions.

The figure 2.1 shows how the arm looked after the assembly was complete and the wires were grouped together.

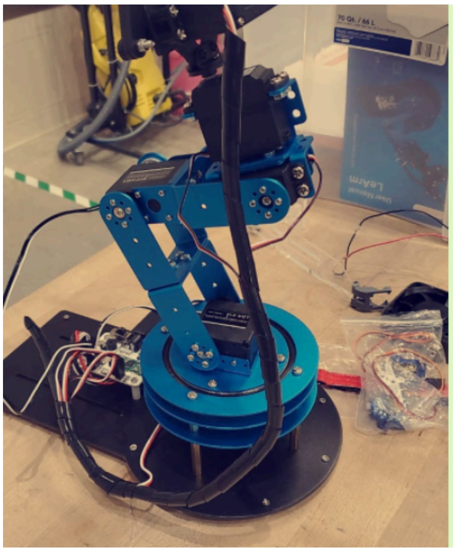

Figure 2.1 Hi-wonder LeArm assembly completed.

The team then began to compile the codes for the arm, the water depth sensor, temperature sensor and the fan onto one single code. The individual codes can be located in the following document. After this, there was a thorough discussion on what type of shoring structure would be best for our robot and the entire argument for that can be found in this document. Next step involved choosing a fan as the one we had available was not efficient enough as depicted in these testing videos. It could either operate on a higher voltage (for which we needed another battery which required another code to compile onto an arduino) and rather preferred to go with this fan. **Figure 2.2** shows the fan and it was excellent in performing the required function.

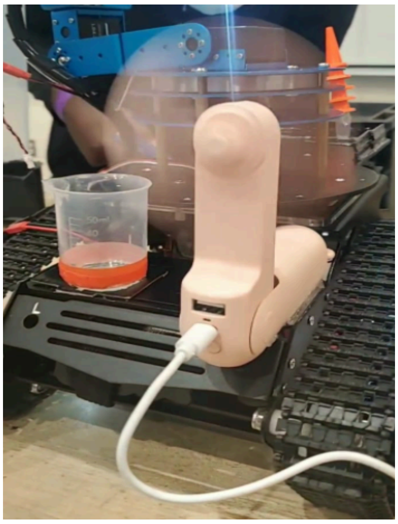

Figure 2.2: The fan

Then we planned to glue a beaker on the tank top that could hold exactly 18 ml of water. The orange line that can be seen from **figure 2.3** marks the exact 18 ml point beyond which the water will stop being pumped.

Figure 2.3: The beaker

Finally towards the end of the project, the group was able to attach a camera to the “wrist” of the robotic arm so that the “hand” could rotate and not interfere with the angle of the camera. The Light Emitting Diodes (LED’s) are attached to the robot in 4 different places, the back, the two sides, and the "hand" of the arm. Which can be seen in the **figure 2.4**;

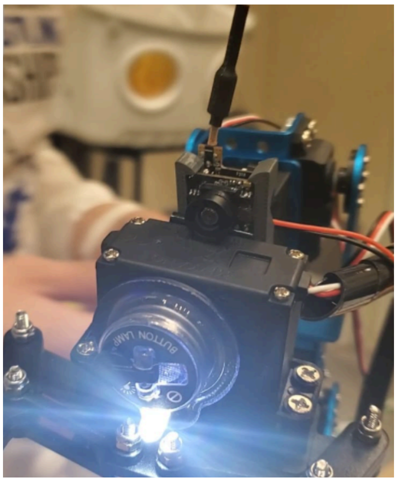

Figure 2.4: The camera and LEDs mounted.

After a series of trials and testing, this is how Robot D.A.M.M. looked. The robot, however, is missing the shoring structure as it wasn't able to be attached at the time the picture was captured.

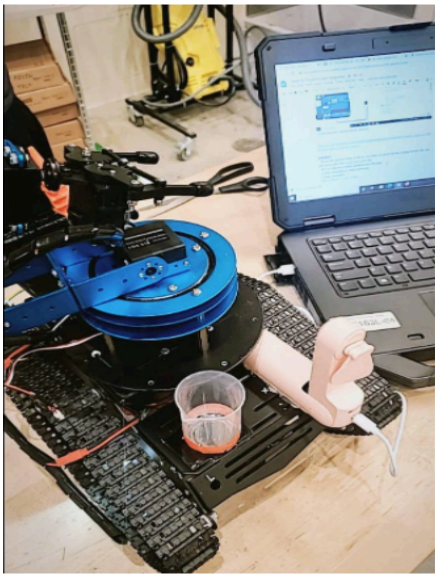

Figure 2.5: Final look of the robot

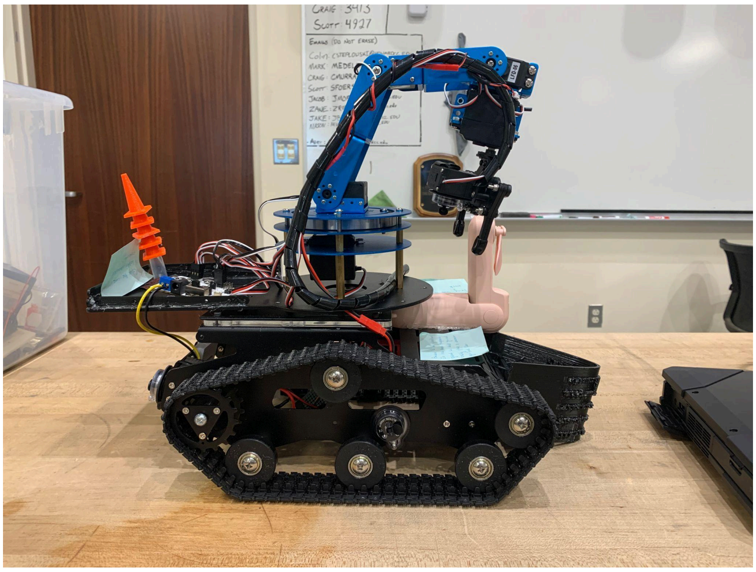

Figure 2.6: Final look of the robot

## 2.1 CONCEIVE

We initially started our project by discussing in class what each of our strong suits were. Then we decided the best possible way to keep track of our ideas was by pitching in some ideas into the google doc. Reconnaissance was something that interested all of us because it was worth the most points. We discussed having a computer cooling fan to extinguish fire as they are compatible with our setup as well as we could use the fans that were available in the lab, a temperature sensor to record the temperature and water depth sensor to be displayed on the LCD screen in order to gage what the surrounding environment was hiding. We also at one point did a brief research on Reconnaissance which we dropped the idea because in order to code the reconnaissance properly it requires an algorithm to measure longitude and latitude or even measure the length of one tank tire revolution and calculate the distance it travels in a certain amount of time which will still require a very specific code. A triangular prism was another idea to clear debris out of the way like snow plowers. A water pump's purpose was to drain out a certain amount of water into an accessible spot to possibly reuse the taken water. Cones were used to mark the location of survivors and were held on their own station designated on the front of the robot.

**Figure 2.51** is a screenshot of our budget sheet. The LIDAR sensor idea was scratched because of being inexperienced with that kind of technology. LED lights were purchased and used on the robot and arm. The fan was purchased and used to extinguish fire, it was placed on the front of the tank. A set of beakers was used in order to contain the water and store it for future use. Water pump was used to drain water, the pump was located on the tank and it would be of easy access to the robot arm. Water Depth Sensor was used to measure the level of water and determine if it is high, medium, low, or empty.

**Figure 2.7** and **2.8** is a demonstration of how the team decided to set up the water depth sensor. The sensor seen in **Figure 2.8** contains a code that is able to display on an LCD screen whether water being sensed on the sensor is high, medium, low, or empty.


Figure 2.7: LCD Screen

We then planned to code the water pump and arrange the pipe in a way that one of its ends stayed in the beaker (to drain the water) and the other end inside the water pool (to pump it) with the help of the arm being able to lift and move it and align it correctly to drain.

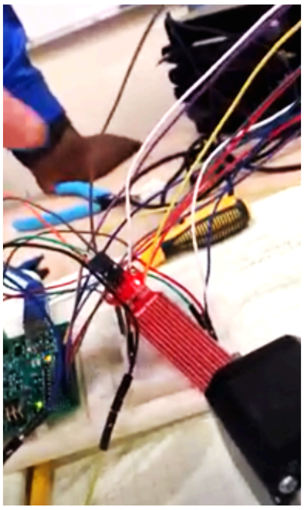

Figure 2.8: Water Depth Sensor & Temperature Sensor

In order to carry out all these aforementioned tasks, we set up a budget sheet to determine how much money we had access to. We researched the things we would need to buy and we discussed where to buy it from. Our options were mainly the lab at HCC, RobotShop and Amazon etc, because those were most reputable vendors.

In order to drain a certain amount of water, our original idea was to develop a pump which was controlled by using a camera to watch the LCD screen. Whenever the depth reaches 18 mL, the water pump would be able to stop manually by a simple "push" button code on the joystick. We did an initial test of a water pump after that we had to code it with Arduino to turn it on when needed and turn it off when depth of the beaker/tank reaches 18 mL. This as well would require voltage taken from an alternative power supply since the power was already being consumed by the tank, arm, and camera.

Figure 2.9: Arduino LIDAR

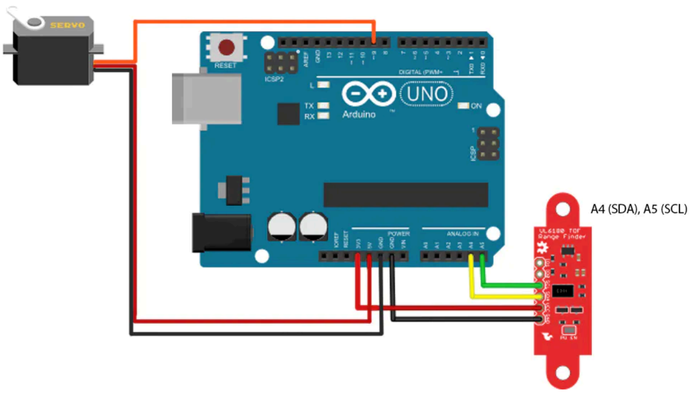


Figure 2.10: Arduino LIDAR Schematics

We looked for some sensors to map the area our Robot is going to work in. Objective is to map the environment for rescuers and specify location of hazards with x and y coordinates, before they begin rescue operations. Sensors or GPS could have helped in that objective, we looked for other peoples work in this objective and found that useful for our objective to carry on that work by giving them due credit. Arduino Light Detection and Ranging (LIDAR) is an optical remote sensing system which can measure distance by shooting a laser to target. Receiver sensors measure distance based on time needed for light to reach the target and return. We can use this technology in our Project by having a SparkFun Range Finder Sensor. LIDAR sensors provide very efficient and precise information of x-y axes but also provide real time mapping of the environment. Mapping the environment is one of its challenges, one of the teams used vSlam technology to map the environment where robots have to mark survivors for rescue teams to specify hazardous areas. Another idea could also work but this is so time consuming.A shown in **Figure 2.9** We can use Range Finder Sensor, Arduino, Servo Motor. We have to program code on Arduino for a servo motor to swivel the servo motor like a CCTV camera while instead of a camera there will be a Range Finder Sensor. We can use schematics for Arduino in **Figure 2.10**.

Figure 2.11 illustrates how a basic shoring structure was recommended by the team however the idea wasn't implemented because this was a very basic approach but it utilized a lot of space on the robot, hence we decided to choose something that is more compact and reflets a greater engineering insight. Figure 2.12 demonstrates the prototype design for the following idea.

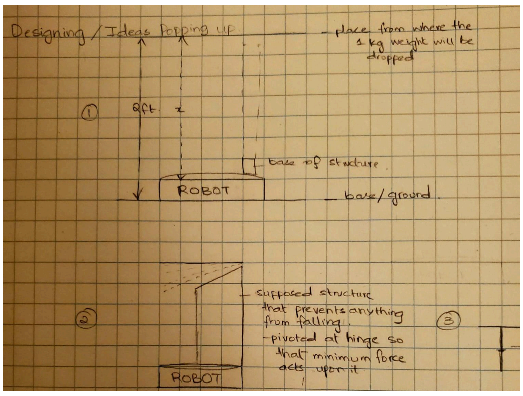


Figure2.11: The initial design team DAMM came up with for the shoring structure.

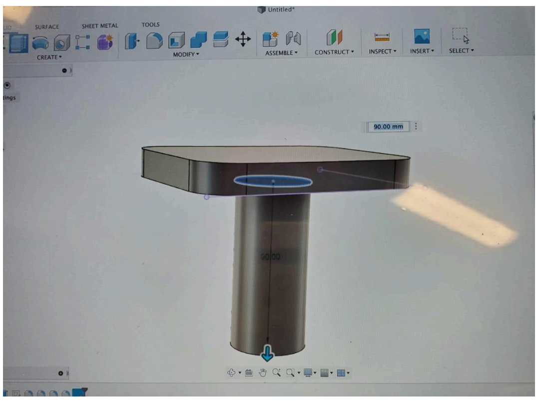

Figure 2.12: Shoring structure prototype.

Figure 2.13 however highlights a more intuitive idea of how the shoring structure could be printed and this required greater use of engineering techniques too. It was supposed to operate on the basis of hinges and open up from beneath allowing it to be more compact, saving space however, like all engineering ideas, it brought with it some concerns such as it involved the toughest coding and assembly. Although it was an idea sufficient in itself, it was far more time consuming to implement.

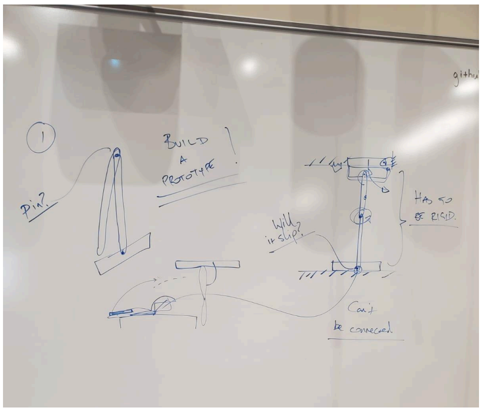


Figure 2.13: A discussion of all the problems involved with another shoring structure idea.

The final idea proposed and accepted by the team is depicted in figure 2.14 which is not only a brilliant idea but also very efficient to implement. Team began with analyzing its prototype followed by taking proper measurements of each piece according to the robot and getting it 3D printed. This was then assembled and coded. The final result is what is shown in figure 2.19.

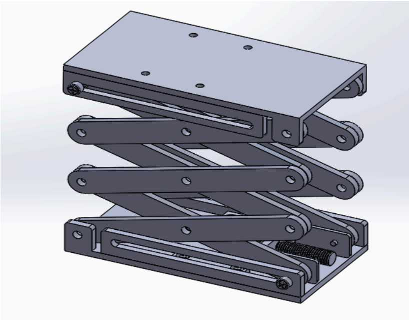

Figure 2.14: Current idea implemented for shoring structure.

In **Figure 2.11**, displayed is the first design that we came up with and discussed as a group. It was a great idea, but it came with difficulties. There were many things that needed to be considered about it, like whether it'd be strong enough to hold up the weight, what would be used so that the concept would hold in place, and how we would get it there.

**Figure 2.12** was a prototype that was modeled in Fusion 360, it was a very simple concept, but it was likely to have failed because there was not enough support for a weight to be dropped on it from an elevated height, and then have to stay up for the remainder of the course. It would likely have tipped over.

**Figure 2.13** displays another brilliant design, something that had potential. However, the amount of support that a life model would have provided would have been little to none. Coding the concept to flip open and stay in place would have been a difficult task, adding to that, we needed to think about what would be needed that would keep that lever type concept latched.

Finally, **in Figure 2.14**, we searched for a good concept that looked like it would support the most weight. This design was acquired from Grabcad, so we used this idea, and started to design based off of that. The final model can be found in **Figure 2.19**.

## 2.2 DESIGN

In the design of the robot, we bought certain items. We got a 12 voltage computer fan from the lab because we wanted to save time that would have been wasted waiting on the delivery. However, this was not the final fan used because the fan required another power supply and an individual code to allow it to function properly. The 12 volt computer fan was later replaced with a portable fan with a higher "wind" blow. Figure 2.15 shows a 12 voltage computer fan close to a fire and being unable to extinguish it.

Figure 2.15: Testing Fan Series 1.

In deciding the final type of fan to be used, we explore the market and by doing market research, where we weighed the costs of the fan, the delivery time, the size of the fan and the ability of the fan. The fan we decided to buy is shown in **Figure 2.2**, this fan also did not complete our desired requirements because when we were driving our robot in the environment, whenever the robot hit the wall, the fan stopped working and we needed to power it back on manually. This particularly happened because the wings were hitting each other and each time they clashed, its speed decreased and it ultimately stopped. Another reason the fan powered off is because the arm would come in range of the wings. A video of which can be found here.

For the purpose of clearing obstacles from the way, we utilized a 3D printed Debris Remover which was intended to be installed in front of the tank. This was the only part we modeled and it had some issues when it was being printed. This impeded us from being able to successfully mount it on the tank. Due to mishap, we used sandpaper to grit the excess material in part to make it even and smooth from the sides. When it was attached it would scrape along the ground in the environment and hinder the ability to provide a "smooth ride." We then tried to add fish wire to suspend the debris remover.

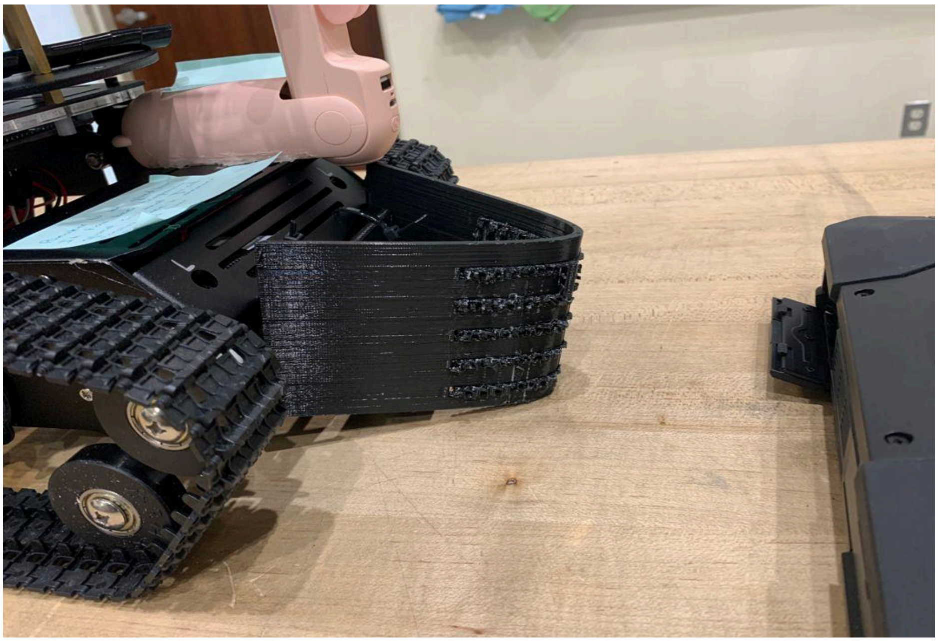

Figure 2.16: Disaster Robot Debris Remover

For the purpose of measuring depth of water of about 18 mL we used a water depth sensor with this code, with LCD screen. When we examined the LCD screen, there were not any pins that we could use for jumper wires, so we solder the wires on the LCD screen that were used as jumper wires to breadboard in a circuit. Then compiled the temperature sensor on the same code as the water depth sensor.

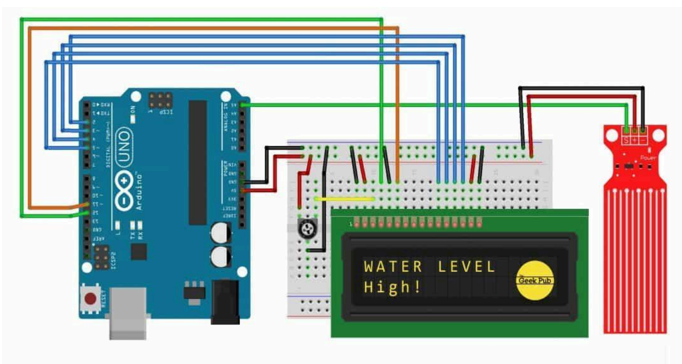


Figure 2.17: Disaster Robot Water Depth Sensor

While testing our Arm at one point servo 4 stopped working so by doing some troubleshooting on mobile app first and then on computer app. We then tested the individual function of the motor with "sweep" code. We came to the conclusion that Servo 4 is broken and we have to replace it. We were going to order it online but we were provided with one extra servo motor from the lab of another arm and we tested it and came to the conclusion that our servo motor was fixed now. We figured that out by uploading servo motor code on the arduino "sweep" and then we tried to run that motor on the arduino to test it. We replaced the new servo motor just in case it stopped working again in the process. We then added it onto the arm and came to realize that we installed it wrong because the range of rotation was only 90 degrees from the initial start point when it should be 180 degrees. We then took it back apart and adjusted the servo motor accordingly.

Final Temperature and Water Sensor Code (Fully Functional)

Functionality test

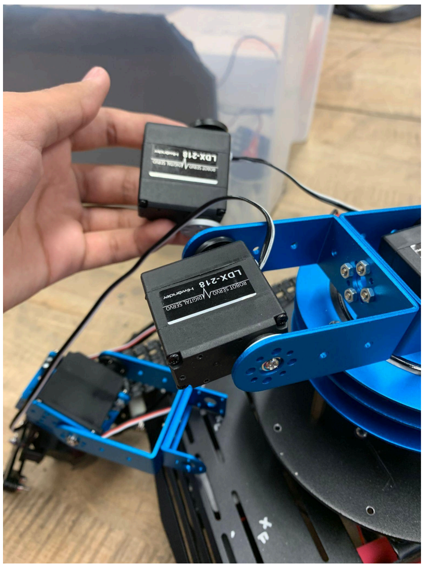

Figure 2.18: Servo Motor

We started designing our shoring structure a bit later than what would have been convenient as we had just come up with the idea. We began by researching ideas on the structure and eventually came across Grabcad, which is a website where CAD designers can share their ideas. This is the design that we borrowed from the website. Using fusion 360, we proceeded to create our own version of the design in a way that was most convenient for us given the time we had left. At first, we got the measurements wrong and the 3D printer printed out a miniature version of what was needed. With a little fixing up and editing though, we were soon able to print the correct measurements. After all the pieces were printed, we immediately began the assembly process. We wanted to use a stepper motor, but unfortunately there was not enough time to get it coded. It was all assembled and the mechanics were up to par, but ultimately, we were unable to run it through the course. This video displays the mechanics of the structure.

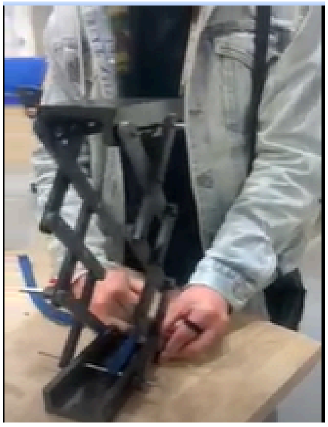

Figure 2.19: The shoring structure

The video depicts our efforts to test how the arm would be able to take care of closing the gas valves. This is when we realized that one of our servo motors is not working properly and that the arm doesn't catch the signal from an ios derived Le Arm application, it needs an android one. Hence we shifted to controlling the arm with an android phone (for the app).

## 2.3 IMPLEMENT

The most important factor this project included was the power source. The entire functionality of the project was dependent on the power source as it had to supply energy to the servo motors, to arm, to get the fan working, for the camera, to enable the water pump and to light up the lights. Our robot was supplied with a 12-Volt Battery and when we tested the fan, the battery was not sufficient to get it functioning. From this point on, we had two options, either to add another battery and adjust code to it, followed by coding the fan, or to use a fan with its own power source operated through a switch. The discussion of this can be found in this document under 3/2/2021. We then decided to go with this as it reduced the work of coding again and getting another battery.

Another very important part of the project was to include the phenomenon of reconnaissance in the robot so that we could determine the exact location of survivors and catch signals. For this, after doing a thorough market research, we decided to get a Navigation Chip. It operates on the phenomenon similar to a GPS module receiver in most mapping apps however we couldn't make use of it because where the robot had to be run, that place didn't catch much signals so getting this was not on our list consequently. We then took a break from thinking about it and focused on other portions that seemed more do-able.

Along with this, making a shoring structure was another portion of focus as it held a lot of points. For this particularly, we had a greater influx of ideas compared to all other parts of the project as this was one thing we could keep experimenting with. However, it was very challenging. Initially a group member decided to build a prototype that some what operates on a phenomenon similar to that of a nail cutter with hinges and rotating pivot points, but that not only included a lot of precision, but also it had to be very rigid and we had to make sure it doesn't slip as we didn't know if the material with which we D3 print it, will be strong enough to allow it to sustain the additional weight dropped on it.

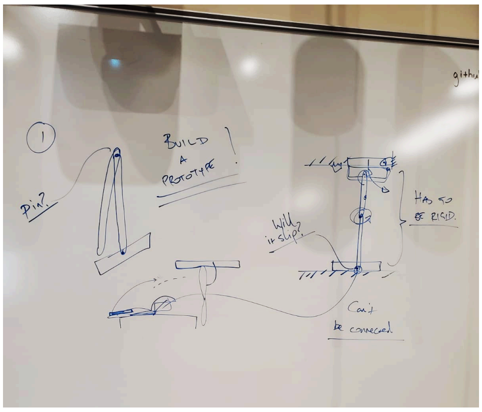


Figure 2.20: Discussing the problems involved with this prototype

## 2.4 OPERATE

There are a number of factors one must consider before beginning an engineering project, one being efficiency of the power source and division of power according to the number of devices used that will draw energy from that. For example, the fan we initially had planned to use, could not perform its function to the fullest because the battery was draining if it supplied power to the fan along with other devices. Not only this but our battery also exploded on 03/02/2021 because unfortunately the battery was not securely locked in place, so we added a velcro strap.and since at that point of time, our battery wasn’t tied up properly with the tank, it fell off. This caused it to heat up eventually, leading to it catching fire and exploding. For future work, it is recommended to make sure the battery is constrained in its place and the robot lifted gently considering all the wiring.

**3/2/2021**
- **Michael** working on the code.
- New link for reconnaissance added because the previous one wasn't sufficient. Have a look. Navigation Chip
- Fun Fact: Our battery exploded today! And Daniel's flesh was *cooked*!! :D
- Further market research for reconnaissance.
- Daniel and **Michael** discussed controller functions , specifically the function of each button performing a given function.
- Next assignment is due three weeks from now.

GOAL: Complete one timed run of environment.
Have working solutions for 50% of missions.

Plan for the fan?
- **Ayesha** came up with an alternate to the fan, Hiwonder fan.
- **Michael** helped us test our preexisting fan to check the minimum voltage it needs to extinguish the fire and perform its function to the best of its ability. Because the one mentioned above has the max of 5V. (can look for more than that.)

Figure 2.21: A track of our documents and the day the battery exploded

Another problem we faced was controlling the arm with the app and with the controller therefore it is suggested for future working members to make sure, they test rotating the arm with both, an android and ios (app) and keep a check on the controller battery as that was another issue we faced towards the end, our controller wasn't working properly due to a low battery life.

In addition, to avoid any sort of smoking, make sure all your wires are wrapped properly and not tangled as later when you need to fix any issue, it gets really frustrating to sort the wires. Also making sure that any DC motors are being run through a shield to prevent coils from being damaged. As well as making sure your robot arm is receiving DC power instead of AC power.

Moreover, operating this vehicle could become very tricky for several reasons. First, we used a PlayStation controller to drive the finished robot. However, we only used two joysticks to drive it. Here are the basic commands:

- Both joysticks push upward → robot moves forward
- Both joysticks push downward → robot moves backwards
- Left joystick pushed upward and right joystick pushed downward → robot turns to right in a 360° manner

- Left joystick pushed upwards fully and right joystick pushed upwards with less than full pressure → robot turns to right
- Left joystick pushed downwards fully and right joystick pushed downwards with less than full pressure → robot backs up to the right
- Left Joystick pushed downwards and right joystick pushed upwards → robot turns to left in a 360° manner
- Left joystick pushed downwards with less than full pressure and right joystick pushed downward fully → robot backs up to left

Figure 2.22: A glimpse of the PS4 Controller

These were the basic commands that we were able to do in our final test drive. But our robot stopped working on a ramp due to low battery in the remote control the reason we know this is because if it were to be battery problem for the tank then the camera, tank, and arm will not be functional, but they all were except for the motors, SO it is a possible motor function problem but we realized that the problem was the controller and as soon as we changed out the controller, the reaction time of the tank was significantly increased.

We also used zip-ties to attach our Debris Remover, which was semi-effective at pushing blocks out of the way of the robot's front. In a test run, the debris remover ended up getting caught on the floor as it was touching the ground continuously which eventually loosened our fan and we lost the fan in one of the test runs. Thus, when zip-tying ( or connecting it with another source) make sure to have the tip of the part parallel to ground to possibly avoid that trouble which proved to be effective.

Be careful of the wiring. We have several times where our robot battery starts smoking. One was this time when the battery exploded and one of our team members got hurt as mentioned earlier.

## 3 CONCLUSIONS AND FUTURE WORK

Ultimately, if given the opportunity and more time to work on our project, we would ensure that our tank could run through the course smoothly and in a timely manner. For this a mistake our team recognized was that we didn’t pay much attention to running the robot inside the environment as doing so would've given us more time to analyze the space and see where we need more practice to resolve issues in less time. This would also enable us to check the timely mistakes we were experiencing while controlling the arm through the app, well before time.

In addition, there were a few things that we did not complete, work on, or even get started on like reconnaissance for example. Although the team had shown great enthusiasm towards that initially, but considering the amount of time and available resources, we dropped the idea for the time being. We also ran into some complications like our controller losing connection to the tank in the middle of a course run, or the claw from our robot arm not functioning properly. These were some crucial issues that definitely would have been addressed, given more time. There were a lot of upsides though that we are proud of and cherish, for example, the entire assembly as a whole. It was a great feeling getting our arm assembled and attached to our tank. We were also proud of the assembly of the secondary collapse structure, and working codes that were written to enhance the functionality of our tank. We could not have achieved what we have, had we not worked as one. Our recommendation to future students taking this course is to manage their time in the most efficient way possible. Future working teams should ensure that they have their plans ready, but also consider that each plan could be edited numerous times because with time, ideas and new strategies keep flowing in. For this, what helped team D.A.M.M. The best was an ideas document that helped us keep a track of our entire journey with the robot along with a gantt chart that enabled us to work on each assigned task, considering the given time. Time management is very important when it comes to working together to meet goals and deadlines. We unfortunately fell short of time, but one thing is for certain, we did not fail. Even if we were to completely fail, we learn more from failure than success.

## REFERENCES

1. Reconnaissance Video Example
2. GPS Module with Arduino
3. Arduino Water depth Sensor
4. Robo cup video for reconnaissance
5. Grabcad Design
6. Controller

## APPENDIX

Engineering is a discipline that involves so many failures but only trial and error makes human effort perfect. There were many instances during our project when we failed, failed as an individual, failed as a team, but we didn't lose hope. As previously mentioned, our first attempt to 3D print the shoring structure was a failure as a result of improper measurements, but we only learnt from the mistake and strived to make it better. Hence, the original 3D printed pieces were used to create a barrier for the cones so that they would not fall off as the tank went through the course. The failed pieces turned out to be quite useful and we did not need to discard them. Below is what the barrier looked like.

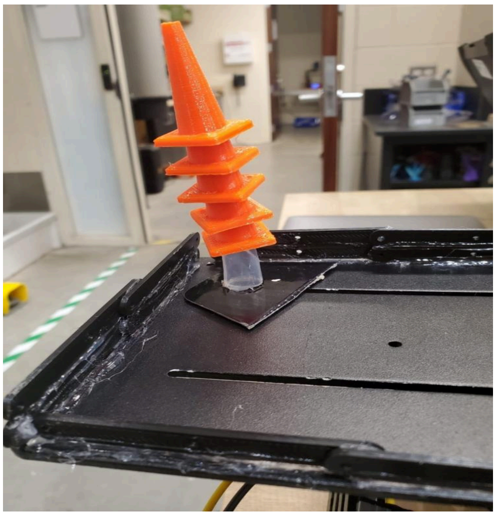

Figure 2.23: The wall