Deliverable F: Prototype I and Customer Feedback

Yamam Alsaadi

Jacob Leeson

Xiaoyi Fu

Leah Meerveld

Elizabeth Johnson

2022-11-06

Abstract

The following report outlines the prototypes and client feedback for a raft cleaner machine for group A11 of GNG 1103. In this report,we have collected the feedback from the client meeting and made some improvements to the concept based on the feedback. This document presents the objectives and test plan, critical components and results for the first prototype using pictures and descriptions, followed by a discussion of the second prototype test plan.

Table of Contents

1. Introduction

The purpose of this document is to review client feedback and state the changes made to the concept resulting from the feedback. Additionally, this document will also discuss the first two prototypes, which included a scaled down cardboard version of the machine, and a medium fidelity prototype of the circuit, and the results of the prototypes. The next portion of the document will access the critical components of the concept which will help to identify the important components to prototype. Once prototypes have been selected we can run tests on them and reduce the risk and uncertainty associated with those components. The final portion of the document will cover the plan for the second prototyping test plan. This test plan will include the objective of the test, the prototype being used, the test method, the expected results, how the results should be used, and when the prototyping should be done.

2. Feedback and Design Changes

In the second client meeting the group presented a concept to the client. The proposed concept in the client meeting was a wall mounted machine that cleans one board per cycle and uses a chain belt, stack and push loading method (pushes a board out from the bottom of the stack), water jets, sensor to activate system, and spring stack collection method. The client expressed a desire to have a button to power the machine on and off. Additionally the client wanted a less complex system. The client also brought up a point about how the boards interlock when stacked and the original loading mechanism we had would have trouble working because of that. From the client's feedback the group decided to make some changes to the concept. The new method uses a stepper motor in both the loading and collecting sides of the machine. When the machine first turns on and or when it is started both of the stacks go as low as they can. There are limit switches at the bottom so that when the platform reaches the bottom they stop and the machine knows the location of both the platforms. This process is commonly referred to in similar machines such as 3d printers and cnc machines as homing. Once the platforms have been homed the motors are precise enough that the circuit board will always know the location of the platform based on how much it has been moved by the motors. Once the platforms have been homed both platforms will move upwards until a contactless infrared sensor detects the board on the top of each stack. This will inform the machine how many boards are present based on the height of the stack and it will correctly position the platforms. The loading platform should have the first board so that the bottom of the board aligns with the top of the rollers such that they can be pushed onto the rollers. The unloading side should be aligned such that the top of the top board is aligned with the top of the rollers so that the board being washed can slide on top of it as it finishes. There will be sensors at the top of both the loading and collecting stacks. The sensor on the collecting side also informs the machine when the collection stack is too full and causes the machine to pause until the collection stack has been emptied. The machine will also have an on/off button. When the machine is powered on, a solenoid valve will open and allow water into the machine. Water will be pumped into the pressure washer which leads to a ring of piping containing nozzles which the board will pass though. The water in the machine will be reused for a predetermined number of cycles before the waste water is pumped out and new water is allowed into the machine. If the water gets too dirty during testing the reusing functionality may be removed or modified.These changes reflect the clients feedback as we added the on/off button, and changed the loading mechanism to take the boards off the top of the stack instead of the bottom to reduce the force required and prevent jamming.

For a more in depth description of the current concept look to deliverable E.

3. Prototypes

3.1 Objectives and Test Plan

We devised a plan to create two prototypes that cover multiple purposes. For our first prototype, we created a low fidelity, comprehensive and physical prototype for understanding and communication purposes between the group, where we built a scaled down, cardboard model of our design concept. We also created a medium fidelity, focused and physical prototype to test and reduce risks concerning the circuitry behind the solenoid valve, stepper motors and sensors. Our solution is very automation-based, ensuring we meet our design criteria that the solution requires limited to no supervision and is safe to be left unattended, so the circuitry that runs the machine is very important.

For the cardboard model, our test plan was to communicate the function and appearance of the product. By creating a physical model, we were going to be able to visualize our concept more clearly and use it to clarify some key points concerning the loading and running mechanisms. This was the best prototype to start our prototyping stages with to ensure all teammates are on the same page moving forward and understand the concept as a whole. While this was a comprehensive model describing the entire system, the circuitry was a more focused test plan. We devised a plan to test the functionality of the solenoid valve, stepper motors, and sensors that are key in our design concept. The sensors activate the loading mechanism, so we wanted to discover to what extent we could control the distance between the sensors and the boards. We also wanted to find out how the circuits could be used to control the sensors, motor, and solenoid valve.

3.2 Critical Components

The critical components of our prototype are the circuit, loading/unloading mechanisms, the pressure jet system and the doors to prevent water leaking. The circuit controls sensors, solenoids etc. In other words, the operation of our machines is controlled by the circuit, so it is very important for our prototypes. If the circuit set-up in the prototype is faulty or of low quality, then our machines may not run successfully or may not run smoothly enough to meet the client's requirements. The pressure jet system is the system that cleans the rafts in our prototype. The ultimate goal of our prototype is to clean the raft, so the pressure jet system is a very important part and we need to calculate the jet angle and water pressure and make several attempts to ensure that every corner of the raft is cleaned. When our machines are powered on, the solenoid valve opens and allows water to enter the machine, which circulates through the machine until it is pumped out. So it is very important to ensure that our prototypes do not leak during our use. The loading and unloading mechanisms are the largest parts of the machine which involve most of the machine's structure as well as its most mechanically and electrically complex parts. There are 3 different movement mechanisms which all need to be in sync. It is very important that these parts are mechanically, electrically, and structurally sound, or the entire machine won't work.

3.3 Results

As predicted, the cardboard model served its purpose and increased our team's confidence in our design concept.

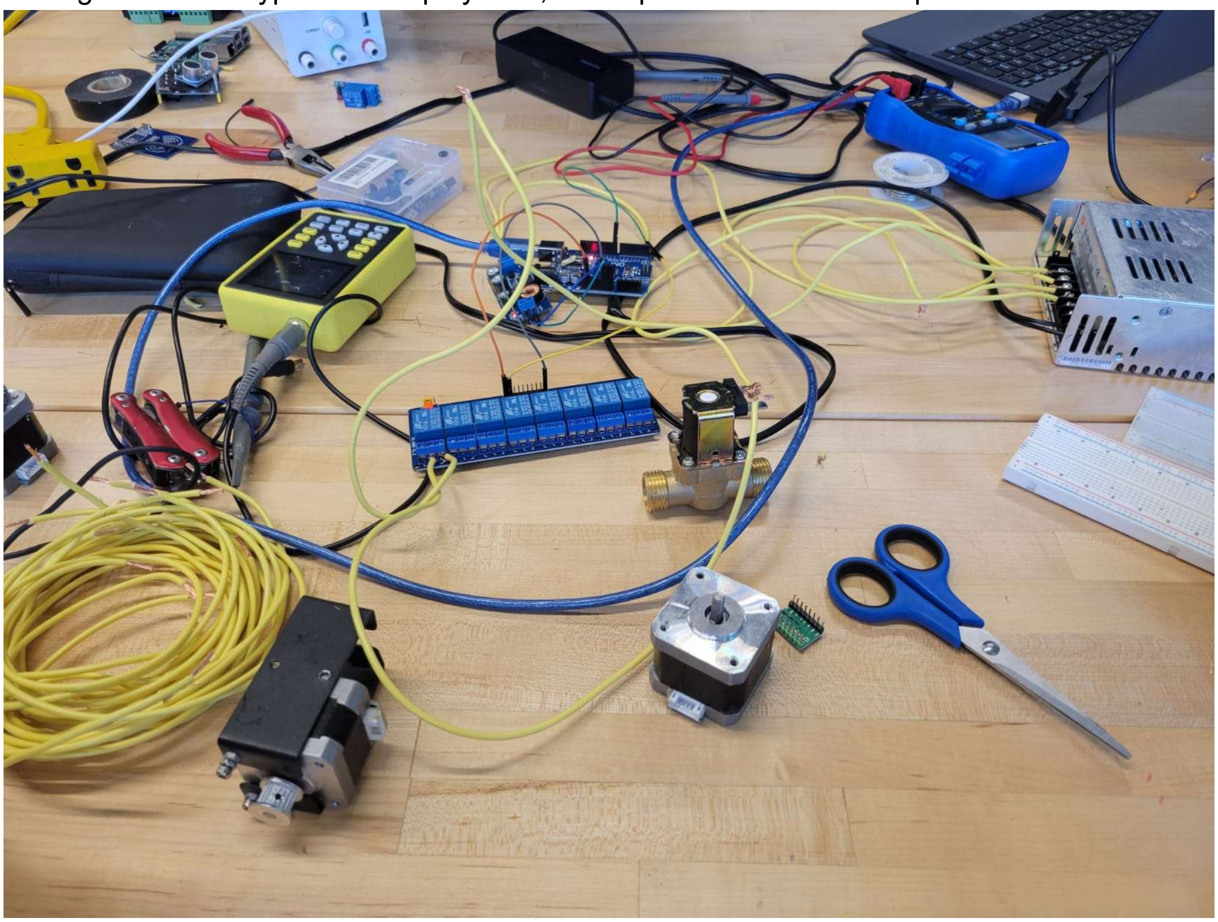
While it did not clearly demonstrate the loading process, we were still able to visualize how it would work because of how the steel beams were represented on the left. The boards will be stacked in the pile on the left and rise to the same level as the rollers, where a sensor will activate the mechanism that pushes the boards along the rollers to the collection area. The water jets will be placed around the roller area. It was a simple prototype that helped the team to understand our design concept and the separate components synchronously. We were then able to use this model to base our other prototyping ideas, and realized what the most critical components were.

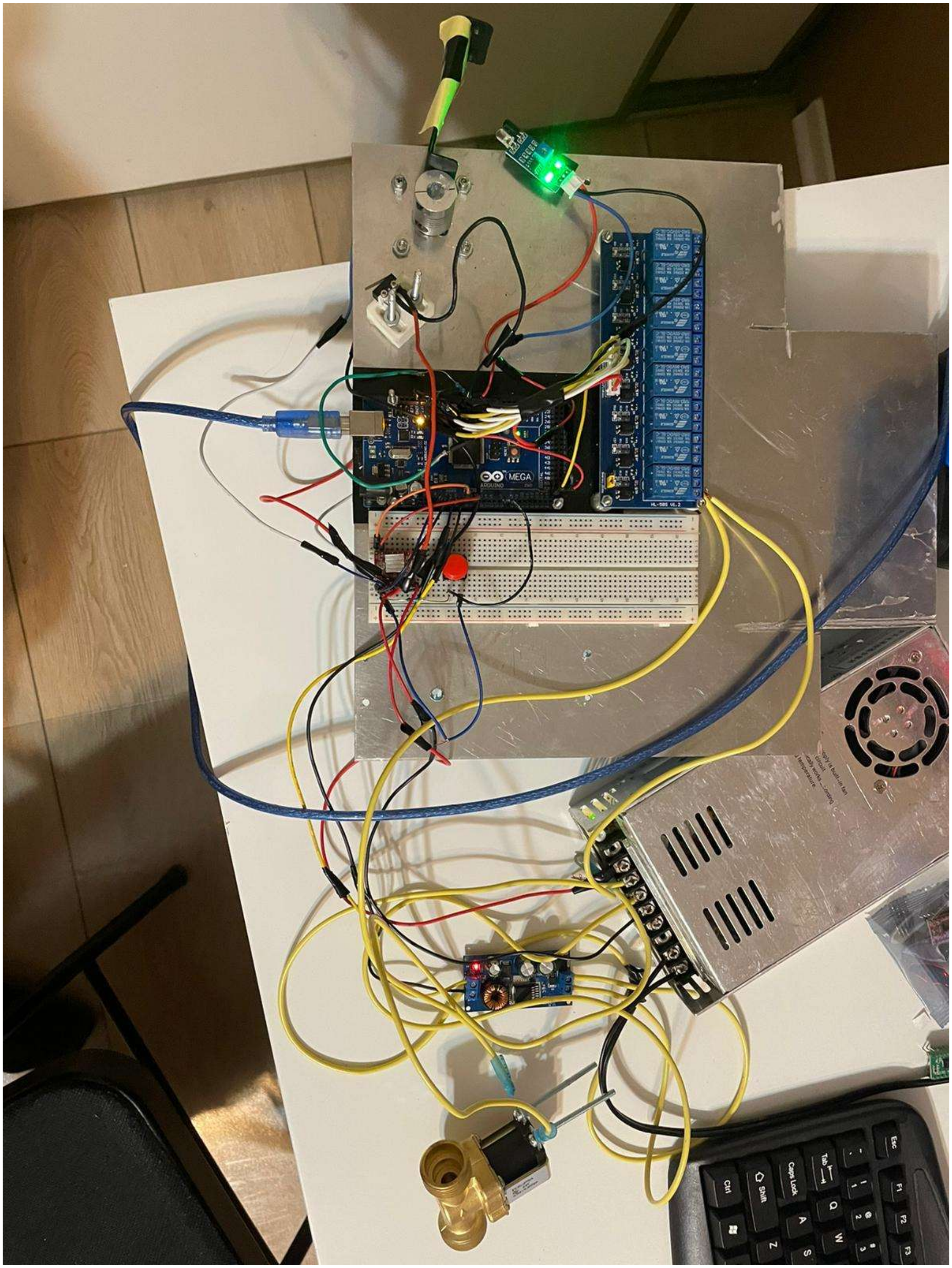
Our second prototype represented one of the key aspects behind our design concept; automation. We greatly value this design criteria, and implement it using sensors to activate the running mechanisms and solenoid valves to control the water flow into the device. These critical components inspired us to prototype the circuitry behind it all, and we aimed to reduce the risks that come with coding the Arduino Uno and creating circuits. (Note throughout the report the arduino is referred to as both an Arduino mega and an Arduino UNO. The concept uses an Arduino UNO as it is cheaper. The prototype uses an arduino mega as it is what we already had available. Except for when we were working in the makerspace we borrowed an arduino uno. After which it got switched back to a mega.) The following paragraphs describe some of the specific results that were derived from our second prototype.

The prototype represents the loading/unloading mechanism electronics and the solenoid valve control. The platforms for the boards are lifted up and down by a lead screw in the concept; however in the prototype a motor with an arm represents this motion simply by turning back and forth. The motor turns counter clockwise first which represents the platform going down and hits the homing sensor (Limit switch). Afterwards it goes clockwise until the infrared sensor detects the arm which represents the platforms moving upwards until the first boards are detected. In the final concept the board would also be moved horizontally before reaching the jets. Afterwards the solenoid valve would allow water into the pressure pump and the pump would be turned on by the same set of relays which will open the solenoid valve. Not all of this could be done within the budget however the prototype also includes a solenoid valve which opens after the motor reaches the infrared sensor.

We learned the inputs of the Arduino and the relay board need pulldown resistors to work. When testing the end-stop, occasionally, the motor would stop and switch direction before hitting the end-stop, or it would behave as though it had hit it multiple times. This was not expected behavior. This indicated that digital pin 5 was being registered as high. The void loop functions also took a long time to repeat and acted as if they had an unexpected delay of approximately 5 seconds +/- 1 second. The delay in code was only a fraction of a second, and there was nothing overly computationally taxing which would cause it to run slow. When moving a hand over the circuit, particularly the wires for the switch, the unexpected behavior increased, and when moving away, it went away. This indicated that the issue was caused by a floating input. “By not being connected to a source, Vcc, or GND, the I/O pin is susceptible to electrical noise that makes the I/O randomly fluctuate between low and high. Such sources include thermal noise and electromagnetic interference (EMI) since the leads of the chip act like tiny antennas when they are floating.” (Parks, 2014). Connecting it to the ground with a high resistance resistor worked because it forced the input low when the switch was open; however, the resistance was high enough such that when the switch was closed, it did not cause excessive power loss, voltage drop, and or heat output. After fixing the end-stop and wiring the IR sensor, it had the same issues.

The button and the inputs of the relay board also suffered from floating inputs, so all inputs got pulled down. Another result was that the infrared sensors, advertised to have an adjustable range of 2-30 cm, only worked with their potentiometer in a single position with a fixed range of about 1.5 inches. We learned the importance of using crimp connectors, JST connectors, electrical tape, and screws as opposed to loose parts and wires which were just twisted together. All components are mounted to an aluminum plate with secure wire connections. Previously wires kept coming disconnected, making it very difficult to test the prototype and keep it working. In the final concept, it would be a good idea to use soldering and connectors. Finally, we learned that the buck converter we purchased to convert 24v from our power supply to a lower voltage for the Arduino needs to be adjusted as advertised and is insufficient for powering the Arduino and its peripherals. It was supposed to be flexible from 3.3 - 12v and instead outputs 5V exactly. The Arduino runs on 5V; however, when connecting 5V to the Vin, it goes through a voltage regulator, which causes a voltage drop. It requires at least 7v to run correctly and can regulate up to 20v. The USB power input bypasses the voltage regulator as it is assumed to be 5V exactly, so when connecting the USB cable, the Arduino functions correctly. The IR sensor cannot work properly with the USB cable unplugged, and neither are the relays. The stepper motors driver is okay because it can use 5v or 3.3v logic levels. An alternative solution is to connect the positive of the buck converter to 5V as opposed to VIN, which would bypass the voltage regulator but leave the Arduino more susceptible to damage as it also bypasses the poly fuse, which provides overcurrent protection.




MEGA

4. Second Prototype Test Plan

Test ID	Test Objective (Why)	Prototype Used & Basic Test Method (What)	Expected Results and How They will be Used (How)	Test Duration & Start Date (When)
3	Create a medium fidelity pressure jet system to see how water pressure is distributed among the jets, depending on the number of jets.	This will be a focused and physical prototype to see the distribution of water pressure between the jets. With a constant water pressure and source, we will visually inspect how the water pressure is affected with the number of jets added, to determine the best cleaning system for our design.	It's difficult to know what to expect before we run the test, however in a perfect world, the water pressure would stay relatively high (high enough to clean algae off boards) no matter how many jets are added. While we can test and expect the pressure to drop, the results will be used to reduce risk and uncertainty surrounding the cleaning process.	We will have one week to prototype, from November 7th to November 13th. The duration of the test should take around 2 hours and we can meet November 9th.
4	Calculate the percentage of	We will create an analytical prototype that focuses on	Our results will come in a percentage, and we	The test itself is timeless as it is

	board cleaned, to ensure we meet and can prove the class's design requirements.	the cleaning ability of our device. We will use factors such as the number of jets, the placement of the jets around the board, the water pressure and the cling factor of the algae on the board to calculate how much algae will be cleaned from the board.	expect them to be between 90% and 100%. This is within the tenth percentile of cleanliness and can prove to the client that our system is effective. We will use these results and show them to the client on Design Day.	simply calculations, though we will take the time to do this on November 12th.

5. Conclusion

In conclusion, when creating our prototypes - the low fidelity model made of cardboard as well as the medium fidelity circuit - the group was able to gather in depth insight on the project. The cardboard machine allowed the group to be able to visualize the product in a much clearer manner, and be able to execute any appropriate changes. It also helped us to confirm the critical components of the design concept that we used in our second prototype and will continue to use for the next prototyping stage. The machine circuit allowed the group to test the circuits that are used for the sensors, stepper motors, and solenoid valve; this is necessary because the product is very dependent on automation. Both the cardboard and circuit proptypes were successful and demonstrated to the group what needs to be developed, and how we can implement them in our design. Additionally, we have identified that circuits, water jets and the pressure jet system are the critical components of the prototype.

Bibliography:

1. Parks, M. (2014, October 28). *Bench talk*. Don't Leave Your Pins Floating | Bench Talk. Retrieved November 6, 2022, from https://www.mouser.com/blog/dont-leave-your-pins-floating