Prototype II and Customer Feedback

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1. <u>Introduction:</u>

After developing a rough model of the overall design in the first prototype, it's now important to ensure that the subsystems of the design actually work. Therefore, targeting the most important subsystem of the design is crucial as the whole design is dependent on it functioning correctly. If it doesn't function properly, it's important to figure out why and what the next steps are. Additionally, it's still important to get feedback on your ideas as you progress through the project to ensure that you're still on the right track to satisfying the customer's needs for the project.

2. <u>Client Meeting Feedback and Implementation:</u>

In the second client meeting, we presented our initial prototype to the client. The client appeared to be satisfied with what we had come up with so far, and they didn't see any areas that needed major improvement or altering. This feedback was very useful to us as it shows that we are on the right track with our design so far.

During the meeting, we also asked the client some questions of our own to further our understanding of the problem. We were informed that the silos are approximately 20 m away from the nearest connection to the HMI system, but simply running a cable that distance like what we're intending to do should work just fine. We were also told that other sensors in the brewery usually provide some sort of visual notice when levels of their measurements exceed/fall below the intended value. This would include the display changing colours or a warning message popping up on the screen. Some sensors also set off an audible alarm, but these are usually reserved for significant issues. This information is useful to us as we now have a clearer understanding of what type of alerts need to be issued. Similarly, a different group with a similar design to us was told that the client would prefer to have the dust concentrations displayed on the screen at all times, which also verified our plan to do that.

3. <u>Prototype II Test Plan:</u>

Our next prototype will be of the most important part of the design, that being the dust sensor and its ability to detect dust. Obviously, this is important as we need to know if our sensor can detect dust before we move forwards with the project. If the sensor doesn't work, there's still enough time to modify our design and use a different sensor that we identified earlier. To do this, we will perform a small-scale representation of malt being unloaded into a silo. This will likely be our most expensive prototype, but also our most important as the functionality of the dust sensor is critical to the functionality of our device.

Required materials:

-PM2.5 laser dust sensor

-Arduino UNO

-Arduino jumper cables

-USB A/B cable

-Laptop with Arduino IDE installed

-Grain malt

-Plastic funnel

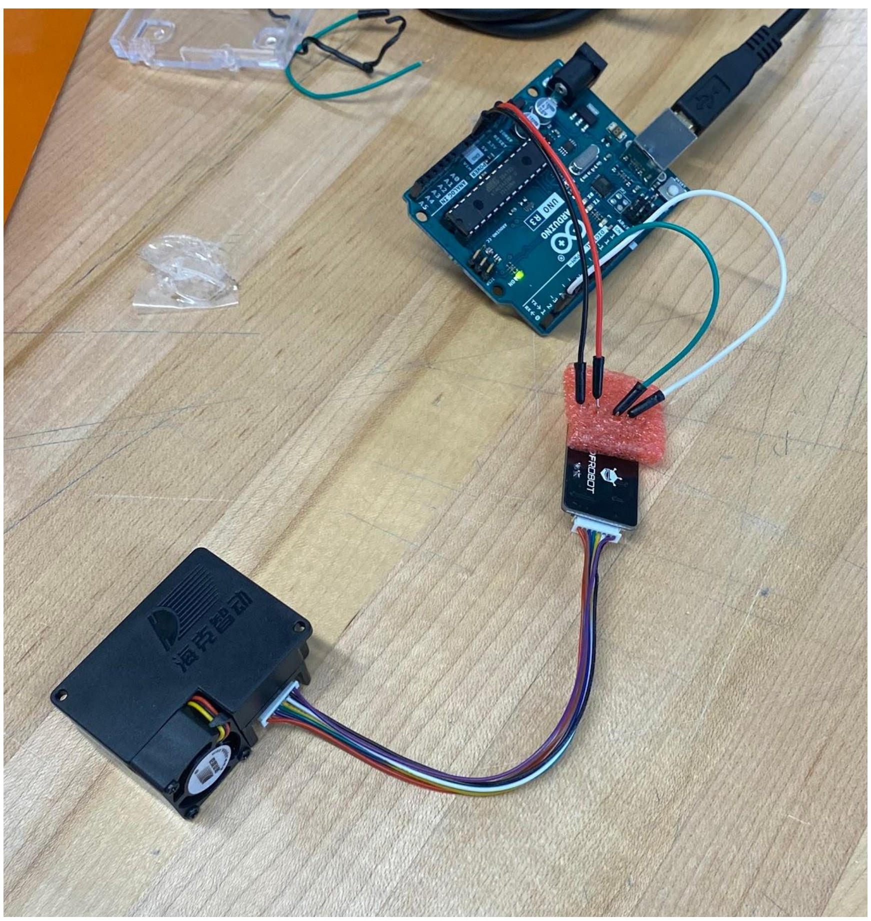
-Garbage bag

The prototype will consist of the PM2.5 sensor connected to the Arduino which will be connected to a laptop running the default sample code that's listed on the site the sensor was purchased on. The sensor will then be placed inside the garbage bag which will be held open. The funnel will then be held over the bag and the malt will be poured into the funnel in order to have a constant flow of malt. The malt rubbing up against the funnel and falling through the air should cause an increase in dust concentrations, allowing us to have plenty of available dust for the sensor to measure.

The test will be stopped when the dust concentrations accurately display on the screen (increase when malt is added, decrease when it isn't), or if they don't display, stop pouring the malt and check to ensure that everything's connected right. Resume the test after checking the connections and if it still doesn't work, stop the test and consider other reasons as to why it's not working, and consider switching to a different sensor.

The test will be performed on Thursday, as all required parts and components are scheduled to arrive by Wednesday. It may take a bit of time to assemble the prototype, as we have to familiarize ourselves with the components and how they fit together. However, this should only take an hour or two, so we should still be able to conduct the actual test on Thursday.

4. Results:



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PM1.0: 0  ug/m3
PM2.5: 0  ug/m3
PM1 0: 0  ug/m3
```

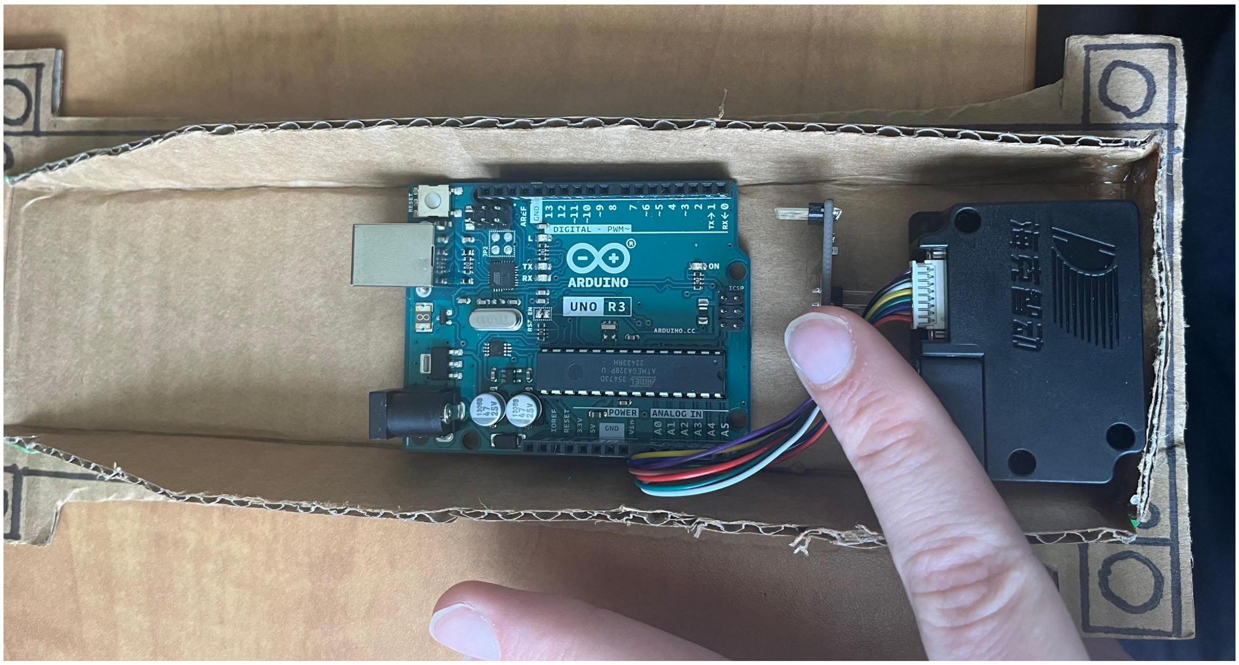
As soon as we began assembling the prototype, we noticed a significant issue, that being that we had ordered the wrong type of jumper cables for connecting the Arduino to the adapter. We needed M-F cables, but we ordered M-M cables instead. This was due to there being misleading/poor imagery on the product site of the adapter, as there appeared to be points to insert the wires into. In reality, there were prongs on the adapter where we were supposed to slide the wires over. Additionally, there was no mention on the site of the type of wire to use, so we simply made a poor assumption about it.

The result of this was that we had to manually hold the jumper wires up against the prongs on the adapter. This was problematic as the prongs are all very close together and touching the wrong wire to the wrong prong resulted in the device not functioning properly. Later. we placed a thin piece of styrofoam that came with a package on top of the prongs, then inserted the jumper wires into the styrofoam in an attempt to hold them in place. Unfortunately, this didn't really work either as the wires didn't want to stay in place. Additionally, the cable that connected the sensor to the adapter did not attach very well. If you bumped it at all after it was connected, one or both ends would fall off. This meant that we had to have another person hold that cable in place, in addition to the person holding the jumper wires.

On the product site, it stated that the device needed 30 seconds of stable connection to begin transmitting data. Unfortunately, we were not able to accomplish this with our methods of holding the wires in place. There were a couple of ways that we could verify that this was the case. First, there is a small fan inside of the sensor that helps to circulate the air that turns on when power is running to the sensor. A slight vibration in the sensor can be felt when this occurs. Unfortunately, the fan, and therefore the sensor, did not stay on for 30 seconds. Additionally, there are two lights on the adapter: a red one when power is flowing, and a green one when data is being transmitted. Both needed to be constantly on to verify that the device was working, but they also didn't stay on for more than 30 seconds.

After reconvening as a group, we believe that we have developed solutions for these issues. We have ordered the correct jumper wires. This will eliminate the need for us to manually hold the wires in place, and hopefully will allow for a stable connection. Additionally, we have also ordered some electrical tape. It will be used to hold the cable between the sensor and the adapter in place so that it doesn't become dislodged when bumped, also allowing for a more stable connection.

Despite the lack of a stable connection, there were some positives that we learned from this prototype. The default code that came from the product site compiled and ran as intended, outputting dust concentrations once per second, although these values were all 0 due to the lack of a stable connection. Also, since we now physically had our components, we could place them inside prototype I to verify the fit, as seen below. We noticed that we were able to reduce the length of the device by placing the sensor on its side. This also simplified the connection as it was much easier to run the cable from the sensor to the adapter when it was on its side compared to when it was right side up. The length was also shortened by the observation of how flexible the USB cable was, as it could point directly 90° downwards almost immediately after the head. Because of this, we can shorten the overall length to 22 cm, which will allow us to print the casing in one piece in the 3D printers which have a maximum size of 22.3 cm. We were also able to observe how far the wires protruded from the Arduino, which was about 5 cm. This coincided with our initial design, so the height of the device can remain the same.



5. <u>Updated Materials:</u>

Current BOM, all objects

Item	Quantity	Cost/Unit	Total Cost	Justification
[PM2.5 Laser Sensor]	1	Subtotal: $46.90 USD ≈ $63.77 CAD + Taxes and Duties (website does not specify); Shipping:	$92.32 CAD ($28.55 of that is shipping)	Needed to sense dust

		$21.00 USD ≈ 28.55 CAD		
Arduino connector	1	Included w/ PM2.5	Included w/ PM2.5	Required to connect sensor to Arduino
Connector cable	1	Included w/ PM2.5	Included w/ PM2.5	Required to connect Arduino to HMI
Superglue	1	Already acquired	Already acquired (Would be about $3.72)	Needed to fasten adapter to side of housing
M2-0.4 x 6 mm screw (10 pack) https://www.amazon.ca/Prime-Line-9120609-Machine-Phillips-Stainless/dp/B07D5TLKHF	1	$3.99	$3.99	Needed to attach sensor to the side of housing
Arduino Uno Rev3	1	$48.16 CAD including everything (amazon)	$48.16 CAD	Uses our code to interpret data
Arduino jumper wire pack	1	$9.48	$9.48 CAD	Needed to connect the adapter to the Arduino
4.8 m USB-A/B cable	1	$8.11	$8.11 CAD	Arduino connected to HMI via USB-A/B cable
USB A-A adapter	1	$10.59	$10.59	For connecting USB cable to I2C adapter

USB-I2C Adapter	1	$14.99	$14.99	Connects USB A-B cable to I2C cable
2 m I2C cable	1	$6.95	$6.95	Connection to the HMI system
M3 x 10 mm screw (5 pack)	1	$5.29	$5.29	Needed to attach the Arduino to the side of the housing
Sensor housing material (Plastic/Resin)	1	Free in Makerspace	Free in Makerspace	Durable enough, light weight, easy to design with
3D printed sensor lid(Plastic/Resin)	1	Free in Makerspace	Free in Makerspace	To be attached on the main points in the housing
M5 x 10 mm screw (5 pack)	1	$5.29	$5.29	Needed to attach the lid to the housing
⅜ x 2” stainless steel bolt (5 pack)	1	$9.58	$9.58	Needed to connect the housing to the silo from the inside
⅜” nut	4	$0.24	$0.96	Needed to fasten the bolts in place from the outside
⅜” washer	4	$0.21	$0.84	Needed to fasten the bolts in place from the outside
2-row malt (1lb bag)	3	$1.99 x 3 + $14.41 Shipping	$20.38 CAD ($14.41 is shipping)	To simulate filling silos with malt for testing

16 oz ¾" opening funnel	1	$9.61 including everything	$9.61 CAD	Used for pouring the malt for test 1, the malt rubbing against it should increase dust levels for testing verification
Garbage bag	1	Already acquired	Already acquired (would be about $1.29)	Needed to contain the malt dust during prototype 1
Tape	1	Already acquired	Already acquired (would be about $1.72)	Used to hold the housing and lid together for prototype 2
Electrical Tape	1	$4.75	$4.75 CAD	Needed to hold loose-fitting electrical components together
Other Jumper Wires (Including M to F)	1	$9.99	$9.99 CAD	Needed to connect arduino to adapter
Duties	N/A	N/A	$28.08 CAD	Needed to pay for international shipping
Total			$275.61 ($71.04 of that is shipping and duties) Additionally, there is about $6.73 of material we already owned, not included in this total Note: may be slightly higher with additional shipping and taxes	

6. Prototype III Test Plan:

The third and final prototype will be a fully functional version of our design. It should be based on the detailed design, while also incorporating things that we've learned from previous prototypes. Although this prototype isn't supposed to be exactly like the version that we'd sell, it should fully satisfy the problem statement that was defined earlier in the design process. It's also important to test the functionality of the device fully assembled, as even though the subsystems have been tested individually, it's important to verify that they all work together as one when assembled.

Required materials:
-PM2.5 laser sensor
-Arduino connector
-Connector cable
-Superglue
-Electrical tape
-2x 2 mm screws (M2-0.4 x 6 mm)
-Arduino Uno Rev3
-Arduino wiring
-4.8 m USB-A/B cable
-4x ⅛" screws (M3-0.5 x 10 mm)
-3D printed sensor housing
-3D printed sensor lid
-4x 5 mm screws (M5 x 10 mm)
-4x ⅜" bolts (⅜" x 2")
-4x ⅜" nuts
-4x ⅜" washers
-Laptop with Ardino IDE installed
-Grain malt
-Plastic funnel
-Garbage bag

The prototype will consist of all the materials listed above assembled together as seen in the detailed design. Before this, however, all connection points (holes) will be 3D printed to scale, and then the bolts and screws will be inserted to ensure that they fit correctly. If they don't they will be redesigned and the process will be repealed. The same will be done with the housing and the lid, although they will be scaled down when printed in over to save time. After this, the full-scale housing and lid will be printed out, then the components will be screwed or glued into place. Then, the test from prototype II will be redone with the fully assembled device and revised code to ensure that everything is working as intended.

Similarly to prototype II, the test will be completed once we observe dust concentrations appearing on our screen in the indented manner. The difference will be that we will continue to pour the malt in after we verify the data appearing on the screen in order to ensure that the device will work for longer periods of time. The test will be concluded once all of the malt has been emptied into the bag and dust levels have stabilized. In the event that the dust data doesn't display correctly or any other error occurs, we will stop the test in order to try to get an understanding of what went wrong and how to fix it. Since time will be limited until the deadline, we will likely have to consider how to fix things with our current resources rather than ordering new material to solve the problem.

Due to a high course load for pretty much everyone in our group right now due to midterms and presentations, work won't be able to be started on the final prototype until later this week. Printing out the connection points and scaled-down housing will be the first things completed, which will likely be on Sunday or Monday. Once they have been printed and verified, the full-scaled housing will be printed, likely Tuesday. Because it's a very large job for the 3D printer, it will likely take all day to print, and therefore we will begin constructing the prototype on Wednesday. Depending on how long it takes to construct the prototype, the testing will occur on Wednesday or Thursday. After that, assuming everything goes to plan, we can work on fine-tuning it for the rest of the week until the prototype is due.

7. Conclusion:

In the client meeting, we were pleased to find out that we were on the right track with our prototype and were also able to receive information about other aspects that we needed guidance on. We developed a focused prototype of our dust detection mechanism which although it didn't work as intended, we were able to identify the issues as well as the positive takeaways before proceeding with the construction of the final prototype.

Wrike snapshot:
https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=r7Pit5rALx6YQr8bBvy2kwv5OeCE7Haf%7CIE2DSNZVHA2DELSTGIYA