Prototype I and Customer Feedback

Ben Sedgwick
Cameron Carter
Hung Hoang
Jason Liu
Jean-Claude Khacho

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1. Introduction:

In the prototyping stage, the first prototype is used for getting an overall understanding of the validity of your idea. It should be fairly simple, but also provide enough information that it's worth doing in the first place. It's also important to be in communication with the user(s) in order for you to communicate your ideas to them and for them to give feedback on the ideas based on their experience/needs. This communication is important as it ensures that you don't stray too far from the user(s) needs, as a lack of communication can cause you to lose sight of the problem and head off in the wrong direction.

2. Client Meeting Feedback and Implementation:

The most important feedback gained during the second client meeting was the nature of the connection to the HMI system. Previously, we weren't too sure about how the connection would work, and we just assumed that a USB connection would work, but in the meeting, we were told that a simple 4-20 mA connection would suffice. We incorporated this into our design by still having a USB cable plugged directly into the Arduino, but now there's a USB to I2C adapter that will transfer the 4-20 mA current. We elected for a connection via an adaptor instead of a direct connection as the required components to connect the I2C cable were far more expensive than the adapter, and both options served the exact same functionality, so we went with the cheaper option. We were also told that the HMI system the brewery uses is the Botec F1 system which is useful to us as we can now do research as to how to integrate our device into that specific system.

Additionally, we were told that the device had to be food safe when exposed to the conditions inside the silo, which includes an inflow of malt of 600 kg per minute. We will take this into account by ensuring that we test for durability during our various prototypes. We will have to ensure that nothing detaches from the device, as even a tiny chip breaking off can pose a serious health risk to consumers.

3. Prototype I Test Plan:

For our first prototype, we wanted to get a better visual understanding of how our components will fit together and interact with each other. In order to accomplish this, we decided to create a scaled model of our design to visualize our device and foresee any potential issues that may arise that we weren't able to observe in the initial 2D drawings.

Required materials:

-Cardboard

-Tape

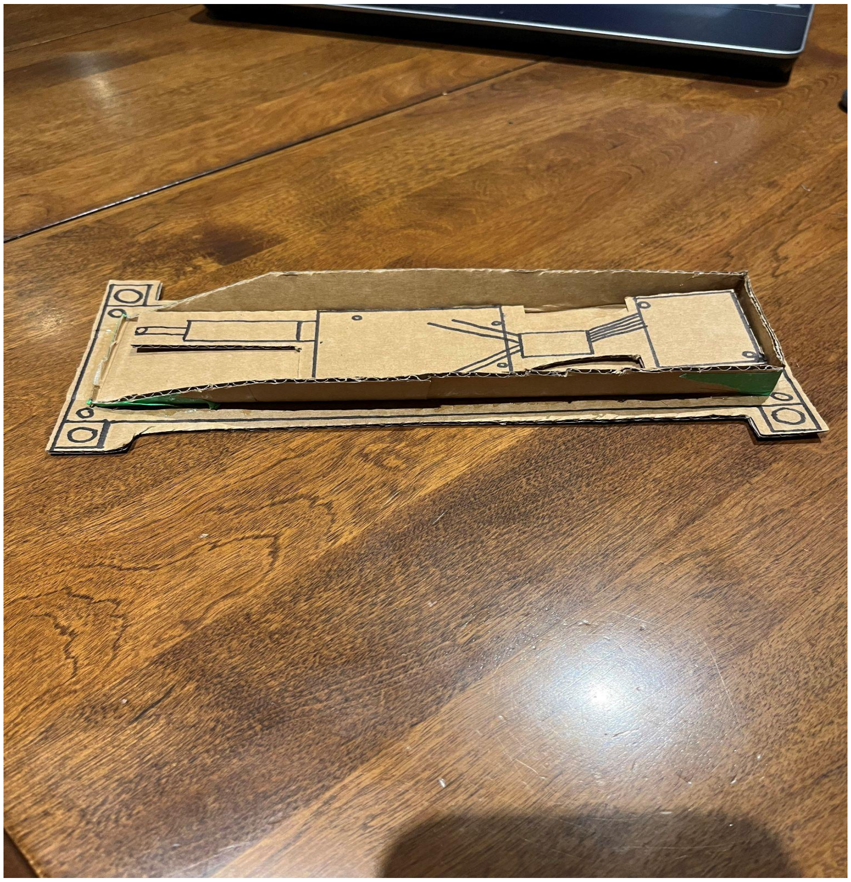
-Glue

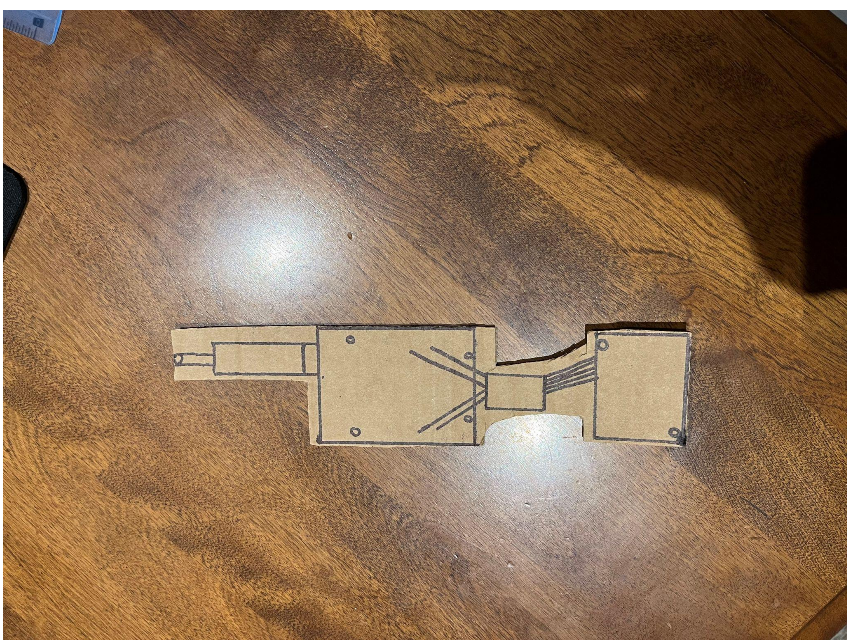
The prototype will consist of just cardboard and tape and will be made in the shape of the device as seen in our detailed design. The housing is made to scale, although only the interior wall of the housing is elevated in 3D. This is because it's quite difficult to increase the thickness of the cardboard and we're mostly interested in the layout of the interior components, so because increasing the thickness won't really help us with the goal of the prototype, we decided that it isn't worth the effort to go through it. For a similar reason, the interior components will consist of 2D pieces of cardboard placed on the bottom of the housing as it's difficult to manipulate the cardboard into very small 3D components without the tape distorting the shape of the components.

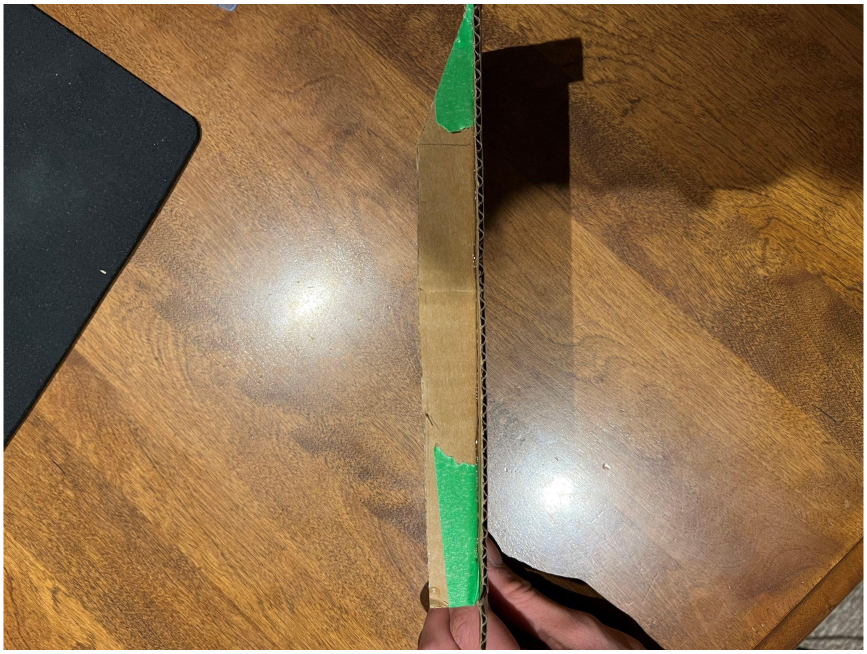
The testing part of this prototype will consist of simply looking over the prototype to see if there are any obvious potential issues or room for improvement. In order to do this, we will compare the prototype with our detailed design and our general understanding of the device. We will note all identified areas where we can improve our design based on the prototype. The test will be concluded once every part of the prototype has been analyzed with the detailed design.

The prototype will be constructed and analyzed on Sunday as initially, we wanted to go with a more in-depth prototype, but due to the bill of materials not being approved until last week, it wasn't possible for all required components to arrive in time so we had to switch to a more basic, general prototype.

4. Results:







From visually analyzing the prototype, it becomes apparent that the components laterally fit in the housing as intended. There is adequate space on both sides of all components which will allow for a good balance of easy assembly while minimizing excess space.

One potential issue could occur at the top of the sensor, where the USB cable exits the device. The hole is very close to the top wall of the housing. The issue is that it may be difficult to bend the USB cable through the hole when there is very low clearance between the hole and the lid due to the slanted part of the housing at the top (which is intended to reduce the impact of the malt falling on the sensor). We will wait until the USB cable arrives this week to determine how flexible it is, however, if it isn't flexible enough we can lengthen the housing or decrease the slant in order to accommodate it.

Another potential issue that can be seen from the prototype is the height of the casing. The Arduino and PM2.5 sensor should easily fit inside the housing, however, the wiring may be an issue. The jumper cables ordered to connect the sensor to the Arduino didn't have the length of the unbendable plastic portion at the ends of the cable, so extra vertical space was added in the detailed design to compensate for this. However, being allowed to actually see the size of the housing provided the realization that there might not be enough space for the jumper wires vertically depending on the length of the plastic portions. There is no way to definitely know if the wires will fit until they arrive this week. Once they arrive, we can place them inside the prototype to get a clear understanding as to if they'll fit or not. If they don't fit, we can easily raise the height of the housing to accommodate them.

In general, it was very useful to get an actual physical representation of how the components will fit together. A sketch on paper was useful for getting a basic understanding of how it will fit together, but an actual representative model makes it much easier to comprehend how the device will function.

5. Component Analysis and Error:

Our prototype consists entirely of cardboard and tape, which obviously aren't the strongest materials and definitely aren't representative of the material that the device will be made of. However, the cardboard can be manipulated into roughly the intended shape so it can be representative of the shape of the device. Because of this, even though the material is much different than the intended material, it can be a valuable insight into the actual shape and layout of our device.

In terms of assumptions, we are assuming that the cardboard is representative of the material of our actual components which isn't the case. The shape is very similar, but the weight and properties are far different so we cannot use this prototype to find out information other than the general shape and layout.

Additionally, we are assuming the interior components are 2D with the thickness of a piece of cardboard as it's difficult to manipulate small components into the required shape as stated earlier. We know the heights of all of the components from our previous research, so we know that they should fit inside the housing, but we cannot definitively verify this based off of the prototype.

In terms of error, the prototype isn't perfectly scaled. All measurements except for thickness are all very close to the intended value, but it's very hard to work with cardboard to get them to the exact proper measurements. This means that the components and housing may fit slightly differently than what's shown in the prototype, but they should be very close.

Also, it's possible that the listed sizes of components online aren't the actual sizes. We have no way of knowing which components have incorrectly listed sizes or how incorrect the sizes are. Because of this, it's quite possible that some of the components may not fit together exactly as how they're shown in the prototype.

6. Updated Materials:

Current BOM (items highlighted in green have already been ordered):

Item	Quantity	Cost/Unit	Total Cost	Justification
PM2.5 Laser	1	Subtotal:	$92.32 CAD +	Needed to

Sensor		$46.90 USD ≈ $63.77 CAD + Taxes and Duties (website does not specify); Shipping: $21.00 USD ≈ 28.55 CAD	Taxes and Duties ($28.55 of that is shipping)	sense dust
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)	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 2, 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 2
Tape	1	Already acquired	Already acquired (would be about $1.72)	Used to tape the cardboard together and hold the housing and lid together for prototypes 1 and 3
Cardboard box	1	Already acquired	Already acquired (would be about $1.55)	Used to make the scaled model for prototype 1
Total			$246.53 ($42.96 of that is shipping) 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	

7. **Prototype II Test Plan:**

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 out 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 as soon as all required parts arrive and are assembled. If all the listed shipping dates are correct, everything should arrive by the end of next week. However, assembling the components may take some time as there are many components to put together and they all have to be assembled perfectly in order for the prototype to function as intended. Because of this, it's likely that the test will be performed on either Friday or Saturday of next week.

8. <u>Conclusion:</u>

By having a meeting with the clients, we were able to get feedback on our initial idea and incorporate that feedback to improve our design. We designed a basic but insightful prototype that allowed us to verify the performance of our initial idea while noticing areas for improvement before moving on to a more in-depth prototype.

Wrike snapshot:
https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=DQs4swszydqMc1If2MECYJc4854pxaoM%7CIE2DSNZVHA2DELSTGIYA