Project Deliverable G:
Prototype II and Customer Feedback

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1.0 Introduction

This document describes the current development of the JAMZ drone's climate sensor prototype as well as the plan for testing the prototype. This document supports the following objectives:

- Identify existing project information and research
- List the recommended testing requirements and objectives
- Recommend and describe the testing strategies to be used
- Incorporation of feedback from previous prototypes
- Prototype development and analysis
- Identify the required resources and estimates of the prototype testing efforts
- Analyze customer feedback and comments on the prototype

2.0 Prototype Testing Plan

Table 1. Prototype testing plan and objectives for the first climate sensor prototype.

Test ID	Test Objective (Why)	Description of Prototype used and of Basic Test Method (What)	Description of Results to be Recorded and how these results will be used (How)	Estimated Test duration and planned start date (When)
1	**Blink Test**	● Analytical	● See if COM5 links properly to the computer for both the Uno board (test board) and the nano board	Time: 2min When: 2021-03-11
2	**Closed box test**	● Experimental	● See how the temperature and humidity values vary under ambient conditions (small fluctuations)	Time: 10 min When: 2021-03-12
3	**Hair-dryer test**	● Experimental	● See how the	Time: 15min

			temperature and humidity values fluctuate from the heat of the hair-dryer	When: 2021-03-12
4	**Coffee test**	● Experimental & Analytical	● Compare the module's data from an external thermometers data, and then get customer feedback on the product.	Time: 30min When: 2021-03-12
5	**Multiplexer code test**	● Analytical	● Check if the Arduino can receive data from sensor 1 and switch to receiving data from sensor 2	Time: 2min When: 2021-03-13
6	**Relay speed test**	● Analytical	● Check the time required for each data reading (1 temperature and 1 humidity value)	Time: 10min When: 2021-03-12

3.0 Feedback from Prototype I

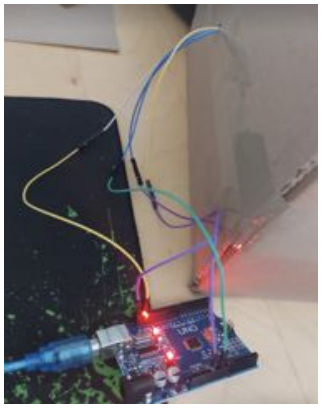
During the second client meeting, prototype one was presented to the client, JAMZ, to receive feedback, areas of improvement and things that were done well so far in the project. In order to receive the output from more than one sensor to the arduino, a multiplexer was included in the design which although the client said would work, they also said was not strictly needed as the Arduino Nano (the chosen board) could also be used as a multiplexer. The client also recommended that the USB opening on the housing for the Arduino Nano be closed to prevent moisture or dust from getting inside the Arduino housing.

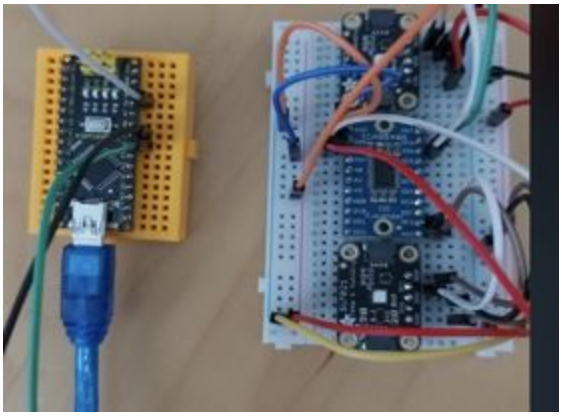
As the physical parts used to assemble the prototype had not been received before the second client meeting, the presentation to the client could not include a test of the physical sensor. Instead, Prototype I consisted of an exploded view of a CAD drawing as well as the code that would be used to run the Arduino. It showed the full details of the project which was received positively by the client. After meeting with the team, it was decided to keep the multiplexer in the design and close the USB port on the Arduino housing. After receiving the physical components, Prototype II was assembled and the testing of the sensors for output functionality could proceed.

In addition to specific feedback, the client also gave the general feedback to all teams to incorporate waterproofing to systems that will be attached external to the drone. Waterproofing will not impact this design as the sensors and Arduino in the climate sensor module as discussed will be placed on the inside of the drone housing and fastened. This will limit any external impact the module might face and/or contact with a liquid.

4.0 Prototype II

Prototype II consists of the major components such as the arduino nano, two Si7021 temperature and humidity sensors, as well as the multiplexer. These components make up the most critical subsystem: the temperature and humidity sensor. The subsystem's main objective is to monitor the package's climate and relay consistent data continuously (per second). This will ultimately help determine the good standing of the buyer's package. The figures below show how the prototype is wired, by attaching the Arduino to the two Adafruit Si7021 sensors.





4.1 Prototype Simple Analysis

Based off of the client meets and the feedback received, an improved prototype two was developed . The following changes/improvements to the prototype include:

- During the second client meet, the client said that the Arduino Nano casing did not need to have a USB port opening as it was in the original design. The design has since been changed so the case does not have the USB port opening. This change will provide more protection for the Arduino by preventing moisture and dust from accumulating inside the case.

- Also during the client meet for prototype one, we were told that technically we did not need to use a multiplexer since the arduino nano could act as one. After taking this into consideration we decided to keep the multiplexer as we had already developed a code for it to average the two temperature values each of our sensors give and give a true or false statement. Although the client said it technically was not necessary to have a multiplexer it was still not wrong to include it in prototype two.

- It was also brought to our attention that the client wanted to have the minimum amount of wiring included in our designs. This is to make the system more organized and simple in case something needs to be fixed etc. When developing the sensor system with the arduino nano, we took that feedback into consideration by only putting wires that are critical to make our system run.

- Another piece of criteria the client asked us to meet was to make data as accurate as possible, and also take the average of the two sensors and base it off of a range of temperatures to print a true or false statement for the operator to see if everything is okay about the food. This is something we have been able to achieve by purchasing one of the most accurate sensors on the market available to us and also through our multiplexer and code.

Overall, prototype two has been improved significantly from taking the feedback on prototype one into consideration in order to generate a product more in line with the client needs.

4.2 Prototype Stopping Criteria

Prototyping in theory should never stop. A product is never flawless. However, due to time constraints, prototyping must be stopped a day before the deliverable is due to allow for time to analyse prototype test data and understand the customer feedback to prepare changes for the next prototype.

4.3 Prototype Test

The most critical subsystem for the success of the climate sensor module is the temperature and humidity sensor. To test this system we analysed the data of the sensor under three different scenarios:

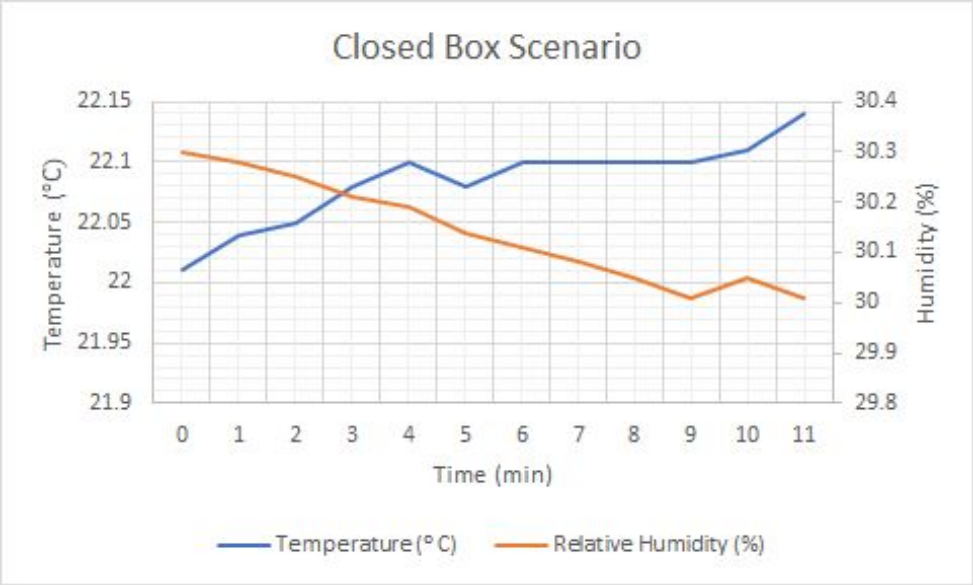
1. Placing the sensor in a closed box.
2. Placing the sensor in an open box with a hair dryer directed at it.
3. Placing the sensor inside a closed box with a cup of hot coffee.

The data gathered by the sensor was analysed to determine the accuracy and speed of the temperature and humidity readings. Moreover, the third scenario was also used to collect customer feedback. One parent of the team member was asked to rate the proportionality of the decrease in temperature of the coffee measured by the external thermometer and decrease in temperature measured by the sensor. As well as rate the proportionality of the decrease in temperature of the box measured by the external thermometer and the sensor. The rate is based on a scale of 0-5, 0 being no relation, while 5 is directly proportional.

4.4 Prototype II Test Results

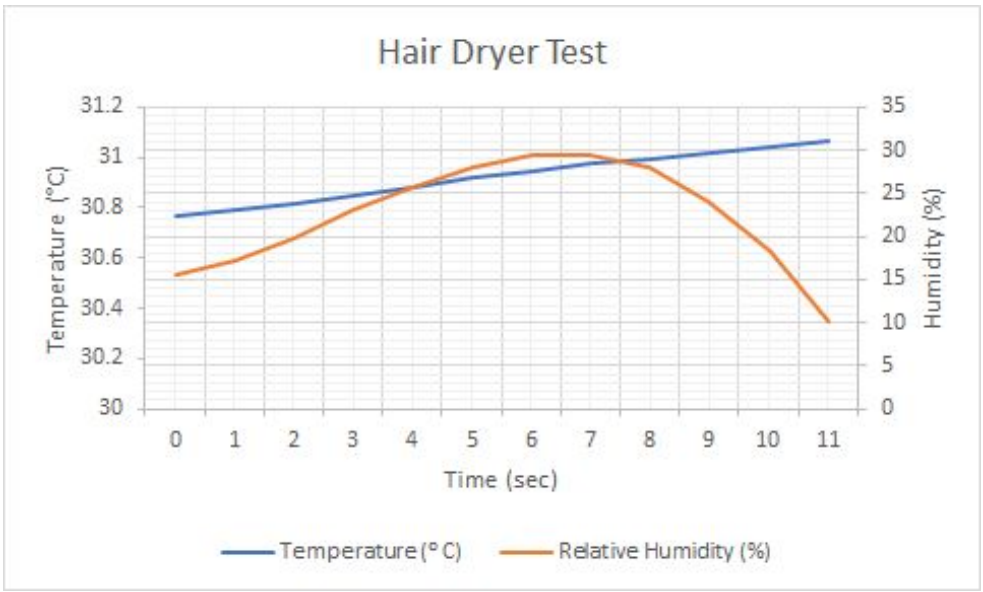
4.4.1 First Scenario - Closed Box

First, the Si7021 sensor was placed inside a closed cardboard box to measure the ambient temperature inside for 11 minutes. Overall, the temperature and humidity data was consistent over the measured time interval.



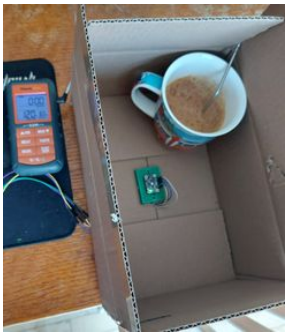
4.4.2 Second Scenario - Hair Dryer

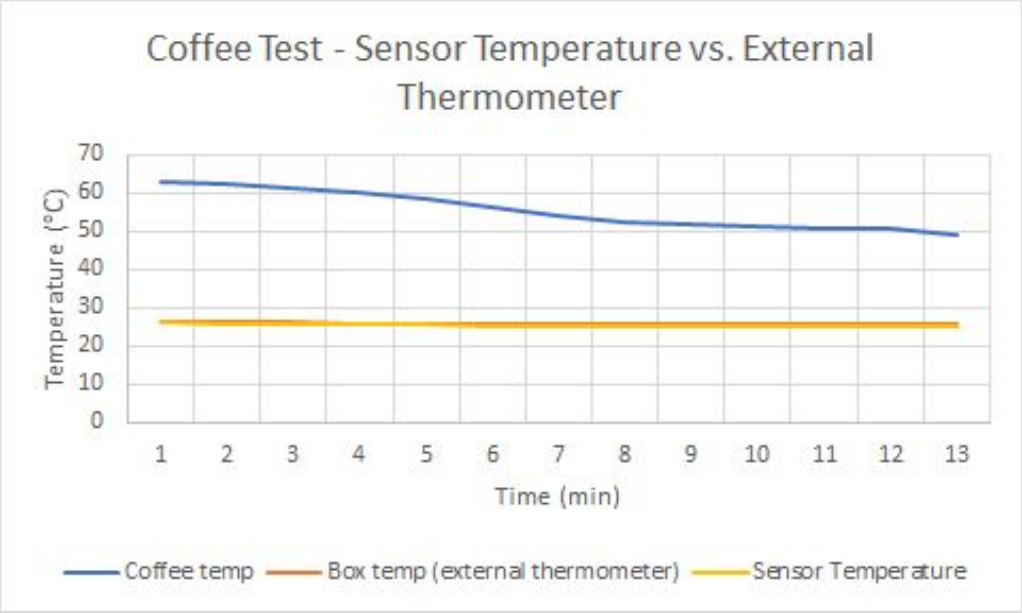
Second, the Si7021 sensor was placed inside an open cardboard box and heated with a hair dryer to measure the inside of the box during a temperature increase. The measured temperature increased and the measured humidity decreased over the measured time interval of 11 sec, which is consistent with the expected results.



4.4.3 Third Scenario - Coffee Test

In the third scenario, the Si7021 sensor was placed inside a cardboard box with a cup of coffee and an external thermometer in the box, as well as a thermometer in the coffee, in order to measure the difference between the sensor temperature and the temperature measured with an external thermometer.





5.0 Customer Feedback

The collected data was shown to team member's parents to get input on if the data we received from our tests is accurate enough for the client's uses. They were asked to rate what they saw on a scale of 0-5; 0 being the no relation between the two sets of data while 5 being a directly proportional relationship between the data sets. A summary of this feedback is shown in the table below.

Table 2. Summary of customer feedback on the prototype testing data.

Team Member's Parent	**Feedback on the Sensor's Accuracy**	**Feedback on the proportionality of the Coffee Temperature with Sensor Data**
Evan's Parents	4 - "The **lines** of the graph showing the external sensor and the other sensor seem to be almost **identical**"	4 - "You can clearly see that there is a **decrease** in temperature in the box **as well as decrease** in temperature from the coffee"
Supathira's Parents	4 - "The values the sensor and the anode **output** are very **similar**. As seen in the graph their **line of best fit overlap**. This indicates that the sensor's **data** is **reliable**."	3 - "The **proportionality** is **visible** though it may **not** be a **1:1 ratio** between the coffee's temperature and sensor's temperature."
Benjamin's Parents	5-"The lines of the graph of the anode and sensor's data **overlap** for most of the part. The two sensors probably output slightly different values due to the **difference in placement** of the sensor."	2-"The **difference** is slightly **noticeable** in the line of the sensor but it is not similar to the **decrease experienced by the anode**."
Gabriel's Parents	5 - "The sensor data looks **identical** to the actual temperature"	5 - "The box looks like it **kept the temperature** of the coffee hot"
Alison's Parents	5 - "Based on the graph, the lines indicating the sensor and external thermometer temperatures are **indistinguishable** so it is **reliable and precise**"	3 - "Based on your graph, the **decrease in temperature is noticeable** when **comparing the two sensors**"

6.0 Analysis of Feedback

Based on the customer's feedback and the analysis of the prototype test results, several areas in need of improvement were identified for the development of prototype three.

The analysis of the closed box test results show that the sensor is recording consistent climate values over time. Moreover the standard room temperature is 20-22°C, this value corresponds to the average temperature measured by the sensor. Therefore, this prototyping test ensures that the sensor is able to read correct values of data that relate to room temperature.

The analysis of the hair dryer test shows that the sensor has the ability to measure differentiable changes in temperature. When the hair dryer was turned on, the sensor temperature increased, while the sensor humidity decreased, as expected. This prototyping test shows that the sensor is able to calculate differentiable changes in temperature which it might experience when in contact with foods with high temperatures inside the drone. The sensor being able to detect these temperature changes is an indication of a critical subsystem functioning.

The analysis of the coffee test is an accuracy check of the sensor with an external monitoring source. When comparing the sensor values and the external thermometer values, the values when graphed were almost indistinguishable. This overlapping of values between the two sensors indicates that the sensor is accurately representing the temperature of the box. Although the similarity of the two data sets is evident, from customer feedback and graphical representation it can be seen that it is not identical. A common feedback received is that the temperature readings of the coffee and box were very different and that it could be helpful for the readings to resemble that of the food in the box as well. To achieve this, the placement of the sensor should be further tested in prototype III in such a way that it gives an accurate reading of the package upon the customer's receipt.

Finally, when considering the safety of the system, putting the sensor near the package could be a cause for concern. Recalling prototype I, the enclosing case for the whole system will ensure the safety of the sensor, arduino nano, etc. This case design will then allow for the system to be placed near the package ensuring an accurate measurement of the package's climate without compromising the safety of the parts or the safety of the customer.

From the analysis of the prototype test data as well as the feedback received on the prototype, the concepts analysed will be changed in order to better meet the needs of the client and their customers.

7.0 Conclusions and Recommendations for Future Work

In this deliverable, the current state of development for the second prototype was discussed. By developing a test plan for the prototype and considering future customer feedback, a better understanding of how to further improve the prototype can be achieved. Future work will consist of development of a third prototype with the data gathered from the prototype test plan and the analysis of customer feedback.