OPEnS Pyranometer: IoT Solar Radiation Sensor
Progress Report

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Abstract

Over the course of the fall term, we as a team have done substantial research into pyranometers and the various parts that they consist of. We have explored several different technologies and have come up with the most optimal implementations for the wireless, open-source pyranometer we plan to implement. We have kept in mind various criterion throughout the term and have gotten to the point were we are now ready to begin building and implementing a couple different pyranometer designs.

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1   Goals

The goal of the Pyranosaurs team is to make an IoT solar radiation sensor that is open-source, low-cost, accurate, and easy to assemble. Open-source pyranometers exist, but they are poorly documented and not wireless. To keep the pyranometer low-cost, the parts used will inexpensive or 3D printed. To make the pyranometer open-source, the CAD designs and code will be freely available online to give users the ability to construct the pyranometer anywhere with access to a Maker Space. Instructions to build, operate, and deploy the pyranometer will be thorough and easy to follow to make the pyranometer as user friendly as possible. As the pyranometer project progresses, it will continually be tested against commercial-grade sensors to verify accuracy. Due to the pyranometer project being sponsored by the OPEnS lab, it must successfully integrate into the LOOM IoT system and follow the same protocols as the other OPEnS lab projects. As with other OPEnS projects, the pyranometer will be wireless. To do this, the pyranometer will transmit data via LoRa radio to a data hub that will use a PushingBox API upload the data to Google sheet using a PushingBox API that translates the data into HTTPS.

2   Current State

Currently, we have a physical design finished for the thermopile and photo diode pyranometers. We are waiting for several parts to arrive so that we may implement the photo diode pyranometer. The thermopile pyranometer design consists of mostly 3D printed parts, so are ready to begin creating CAD designs for the thermopile pyranometer. We have tests written and designed to begin verifying and calibrating the thermopile, so we can begin performing those tests any time. Each team member has done thorough research on pyranometers in general and on their respective pyranometer parts (as seen in our tech reviews), so we are about ready to start buildign and implementing designs.

3   Problems and Solutions

Our first and biggest problem is waiting for parts to arrive. We ordered parts for a photo diode-based pyranometer a few weeks ago, but they have yet to arrive. We will being checking with our client and talk about expediting the shipping process, or see if something went wrong with the parts order. A second problem we are having is getting the thermopile to work with the multiplexer/Feather M0 combination. We will be working with the OPEnS staff and see what we are missing with the sensor integration and look into updating the LOOM documentation on how to integrate I2C sensors into LOOM.

4   Interesting Code

The below code segment is the setup function for the Adafruit TMP007, better known as the thermopile. The thermopile is registered under I2C address 0x41, which the multiplexer uses to interact with the thermopile. The delay value is the interval at which the thermopile takes readings, this value is adjusted per the thickness of the black body object being measured.

```
bool setup_tmp007()
{
    //Setup Here
    Serial.print("SETTING UP THERMOPILE\n");
        bool is_setup;
        state_tmp007.inst_tmp007 = Adafruit_TMP007(0x41);
        if(state_tmp007.inst_tmp007.begin()){
                is_setup = true;
                config_tmp007.delay = 4000;
                LOOM_DEBUG_Println("Initialized tmp007");
        }
        else{
                is_setup = false;
                LOOM_DEBUG_Println("Failed to initialize tmp007");
```

```
        }

    Serial.print("FINISHED SETTING UP THERMOPILE\n");
    return is_setup;
}
```
Listing 1: TMP007 Setup

Listing 2 shows the thermopile taking measurements. The thermopile reports the local temperature of an object (the black body), the temperature of the thermopile die, and the voltage generated by the thermopile. After this function is called by the multiplexer, the data is packed into an OSC bundle and either written to an SD card or transmitted over a wireless protocol (Wifi or LoRa).

```
void measure_tmp007()
{
  Serial.print("MEASURING\n");
        state_tmp007.volt = state_tmp007.inst_tmp007.readRawVoltage();
        state_tmp007.obj_temp = state_tmp007.inst_tmp007.readObjTempC();
        state_tmp007.die_temp = state_tmp007.inst_tmp007.readDieTempC();

  #if LOOM_DEBUG == 1
    Serial.print(F("[ ")); Serial.print(millis()); Serial.print(F(" ms ] "));
    Serial.print(F("Volts: ")); Serial.print(state_tmp007.volt); Serial.print(F("   "));
    Serial.print(F("Die Temp: ")); Serial.print(state_tmp007.die_temp); Serial.print(F("
"));
    Serial.print(F("Object Temp: ")); Serial.print(state_tmp007.obj_temp); Serial.print(F("
"));
  #endif

  Serial.print("DELAYING\n");
  delay(config_tmp007.delay);
}
```
Listing 2: TMP007 Setup

5   Week by Week Summary

5.1   Week 1

Week 1 was about becoming familiar with senior capstone and knowing what to expect throughout the year. At this point no one knew what project they would be working on.

5.2   Week 2

Week 2 was similar to week 1, but at this point each student was trying to figure out which projects they would be interested in.

5.3   Week 3

In week 3 we learned we would be working with Chet on building a wireless, open-source pyranometer. Each team member drafted a problem statement which were later combined into a single problem statement. We made contact with our client and set up a time to meet and discuss the project.

5.4 Week 4

We first met our client during week 4 and we were able to discuss the project and work out different goals to strive for each term. Fall term was to be a time to develop three pyranometer prototypes; winter term is to involve testing the prototypes and seeing which implementations are best; and during spring we are to synthesize the three prototypes into a single pyranometer. We were introduced to Chad Higgins and set up a time to meet with him the following week. Finally, we finished our problem statement and submitted it.

5.5 Week 5

During week 5 we created a rough draft of our requirements document, ordered parts for two of our pyranometer prototypes, and met with Chad Higgins. During our meeting with Chad, we modified our time-line slightly and pushed back the due date for our three prototypes to halfway through winter term. Chad pointed out some potential difficulties we may encounter when implementing our different designs. We as a team came up with 3 parts for each team member to focus on for our tech reviews and for the rest of the year. Each team member was to become an expert on their assigned parts.

5.6 Week 6

During week 6 we submitted our requirements document to our client and he gave us some helpful feedback. As a team, we say down and wrote a document that outline the expectations we have of each other and as a team. We began writing our respective tech review documents and each began researching pyranometers, thermopiles, and photodiodes heavily. We began workign with a lux sensor and were able to program a Feather M0 to get record readings from the lux sensor to an SD card. The lux method is to be one of our pyranometer designs, so this week we essentially finished the hardware portion of the lux-pyranometer design.

5.7 Week 7

Our thermopile arrived week 7 and we were able to solder pins to it and wire it to a Feather M0. We were able to get readings from the thermopile via the serial monitor in the Arduino IDE. We reached to Chad Higgins to setup a meeting with him about how to verify the accuracy of the thermopile and how to translate the thermopile data to W/m^2. We each finished our tech reviews this week.

5.8 Week 8

During week 8 we met with Chad Higgins and discussed the thermopile and photo diode methods in detail. We went over how they work, how to verify them, and how to create useful data from them. From the information gained in the meeting, we were able to refine our thermopile-based pyranometer design and create tests that verify the thermopile and photo diode methods. We began trying to integrate the thermopile sensor into LOOM, but were unsuccessful.

5.9 Week 9

Week 9 was a short week due to Thanksgiving break. We began work on our design document, which entailed each of us discussing how are going to implement the technologies and parts discussed in our tech reviews.

5.10 Week 10

During week 10 we finalized and submitted our design document. We revised our requirements document using the revision recommendations made by our client. We created our fall term progress report (both the video and written portion) and submitted our design document, requirements document, progress report, and problem statement to our client for verification.

6 Retrospective

Task	Positives	Deltas	Actions
Problem Statement	Completed	None	None
Requirements	On second draft	Continue to revise	Change based on further comments from Chet
Design Document	On first draft	Continue to revise	Make changes based on client feedback
Feather M0	Works with Adalogger and sensors; able to write sensor data to an SD car.	Be able to get readings from multiple sensors, be powered wirelessly, and transmit data over LoRa.	Connect feather to a multiplexer (Adafruit TCA9548A) and configure it to control multiple chips; wire a lithium-ion battery pack to the feather.
Lux sensor	Able to sense and put data on an SD card; integrated into LOOM.	Verify accuracy of reported data.	Do some test?
Thermopile	Able to Sense and output data to serial monitor	Needs to be integrated into LOOM and work with a multiplexer	Work with OPEnS lab staff on how to finish integrating the thermopile into LOOM.
Photodiode	We understand how the photodiode method works.	Need the parts to arrive; need to construct a photodiode based pyranometer.	Talk with our client and see about expediting the shipping process for hte photodiode parts.
LOOM	We understand the purpose and function of LOOM; we understand how new sensors can be integrated into LOOM.	Configure the thermopile to correctly integrate with the multiplexer.	Work with OPEnS staff to understand how the multiplexer communicates with attached chips.