Sensor Network Laboratory
Mapleseed Project

Mapleseed Flyer, Micro-Airplane Sensor Carriers, and Drone-Based Optical Microscope

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DOCUMENT OUTLINE

1: INTRODUCTION

Since its inception in the Winter of 2014, a team of undergraduate and graduate students at the University of Michigan has been developing a new method of studying the atmosphere. The Mapleseed approach uses wireless sensor nodes in the shape of maple seeds and is designed to complement traditional methods such as remote sensing and radiosondes. The benefit of the Mapleseed approach is its ability to gather time-synchronous measurements with high temporal and spatial resolution while covering a vast cross-section of the atmosphere.

This report starts off with going into the history of the Mapleseed Project from its early days to the present and describes the project's mission statement, the system requirements and motivation behind the effort. It then proceeds to describe the future directions of the team including the new microdrone technologies being explored in addition to the Mapleseed Flyers. As these additional projects are still in early, exploratory stages of development, they do not have specific motivations and system requirements as is outlined for the Mapleseed Flyers.

From then on, the report is sectioned into four main parts describing work done by subteams. The first details the work of the Mapleseed Flyer team, which works on the writing and preliminary testing of code operating the flyer PCB. The second subteam explores the design of Micro-Airplane Sensor Carriers as an active flyer system and data collection platform compared to Mapleseed Flyer's passive flyer system. The third subteam analyzes collected particles from a drone-carried microscope using image recognition machine learning software. Finally, the 3D PCB subteam conducts early investigation into creating cheap 3D-printed PCBs to be used in Mapleseed Flyers.

The detailed report, compiled by the contributions of the subteam leaders and their team members, provides valuable information on this semester's accomplishments, incomplete work, and future plans for onboarding members. The report is submitted in partial satisfaction of the Fall 2021 evaluation criteria defined by Professor Xiaogan Liang.

2: MOTIVATION AND SYSTEM REQUIREMENTS

2.1: Beginning

As long as man has strived to conquer the elements, he has attempted to imitate nature. Bird wings inspired airplanes' and the geckos' ability to blend into their environment lead to the development of military camouflage. The idea of creating a synthetic maple seed-like device first arose in the minds of researchers including Dr. Dean Aslam, a professor of Electrical and Computer Engineering at Michigan State University. In his 2014 paper titled *"Passive Maple-Seed Robotic Fliers for Education, Research and Entrepreneurship"*, Professor Aslam described a vision of microfabricated, maple seed inspired robotic fliers for different purposes such as education, research, and even defense applications.

However, Dean Aslam was not alone at seeing the utility of the maple seed. Lockheed Martin was busy developing their active mapleseed for surveillance purposes and the Australian Samara research team was researching Flex PCB maple seeds for monitoring wildfires. After getting in contact with climate change and cloud and precipitation expert Dr. Derek Posselt (now a research scientist at NASA-JPL), atmospheric chemist Dr. Allison Steiner and Nano-Fabrication Professor Dr. Jay Guo, all University of Michigan researchers, the three formulated the idea to use maple seed-inspired sensors for atmospheric research.

Samara seeds, another name for maple seeds, evolved over time in such a way that their aerodynamic qualities carry them far from their parent tree. The seeds are able to flow with the wind for great distances and the more turbulent the wind the further they can fly. This contributes to the evolutionary success of the Maple tree. The seeds' ability to trail the wind also makes them ideal in-situ sensors for atmospheric sensing applications. Although the team has begun researching flyer mechanisms not based on maple seeds, the name for the team still remains.

Current methods to collect atmospheric measurements - temperature, humidity, pressure and wind vectors - rely either on tools that give broad scale measurements such as RADAR and LIDAR or single-point measurements such as weather balloons, stations and radiosondes. Retrofitted with sensors and wireless capabilities, synthetic maple seeds released in the dozens would be able to send back data on an unprecedented temporal and spatial resolution while covering a vast cross-section of the atmosphere. Turbulence, wind patterns and atmospheric composition would finally be able to be studied on the local scale.

In 2013, Professors Aslam, Steiner, Guo and Posselt applied for funding to kickstart a project to develop such a device, and Derek Posselt successfully received seed funding from the newly formed Multidisciplinary Design Program at the University of Michigan. The project would be housed in Dr. Posselt's home department, Climate and Space, and students would be recruited through the Multidisciplinary Design program. While developing the novel instrument, students would earn academic credit and receive an interdisciplinary experience that would jumpstart their professional careers.

2.2: Mission Formulation

To narrow down the scope of the project and make it easier for the team to develop an initial prototype, the Planetary Boundary Layer (PBL) was chosen as the primary layer of the atmosphere of interest. The PBL is the lowest part of the atmosphere and most accessible for study. Furthermore, the PBL is directly influenced by contact with the planetary surface and is of great interest to scientists.

Derek Posselt, who set the direction of the project back in 2014 as the Primary Investigator, described the decision in the following way:

"I and other atmospheric scientists are primarily interested in understanding the composition of the Planetary Boundary Layer in terms of temperature, humidity, pressure and wind speed. The PBL was chosen as the focus of research because it is the layer of the atmosphere influenced directly by the Earth. This includes the ground topography and composition that influences the atmosphere as well as pollution, vegetation and water vapor that is exchanged between the ground and the air. Another reason the PBL was chosen is because it is a relatively peaceful layer that is easier to develop a device for than say tornados and hurricanes which occur in the troposphere (the layer above the PBL).

For example, something that scientists have not been able to model well is the function of temperature and wind called the turbulence flux. RADAR is able to give measurements of wind patterns on a large scale and there are methods to measure temperature of large areas of the atmosphere. However, there has never been a way to map local temperature to local wind turbulence. Doing so would yield interesting results that would increase our understanding of the PBL."

2.3: System Motivation

To summarize the reasons for wanting to develop a new instrument to study the Planetary Boundary Layer, the motivation can be defined by the following points:

1. Local dynamics of the Planetary Boundary Layer (0.5-3 km above surface) are poorly understood
2. Understanding the PBL will lead to more accurate predictions of weather and other local atmospheric events
3. Existing measurement tools (RADAR/LiDAR, Probes) only provide large scale coarse measurements
4. In-situ measurements are required to capture local (1-10 m resolution) complex phenomena

2.4: Mission Statement

Based on the motivating scientific factors and the promise that maple seeds presented with their unique aerodynamic qualities the following mission statement was agreed upon:

"To develop a passive in-situ sensor platform inspired by the natural aerodynamic performance of maple seeds for detailed testing of Earth's atmosphere."

2.5: System Requirements

Based on the mission statement, key system requirements were defined:

Project Goal	Engineering Requirement
Measures Air Pressure	±1 hPa .01 hPa 10 Hz
Measures Relative Humidity	± 5% RH .05 % RH 10 Hz
Measures Air Temperature	±1 °C 0.1 °C 10 Hz
Measures Drift Velocity	1 m/s resolution 10 Hz
Measures Location	±1-2 m
Minimizes Terminal Velocity	2-5 m/s
Minimizes Data Loss in Required Range	≤ 50% data loss ≥ 7.5km range
Operates in High Winds	≤ 10 m/s
Maximizes Operational Life	≥15 min

2.6: Project Direction

Due to meeting restrictions during the COVID-19 pandemic, some essential parts of work throughout the semester was undertaken remotely which limited the extent of flyer testing and tasks the team was able to undertake.

Our primary objective this semester was to code for the PCB and establish and test range of GPS sensor's real-time wireless communication, as the manufacturing of the PCB and the physical Mapleseed Flyer had been completed in previous semesters.

Side objectives included exploring novel technologies to address shortcomings observed in current Mapleseed Flyers through subteams.

3: Mapleseed Flyer

3.1: Introduction

This semester, the team focused on the addition of a particulate matter (PM) sensor to the Mapleseed flyer. Building upon previous semesters' work on the Mapleseed flyer software, the team completed the necessary work for using the PM sensor with the wireless communications system. The use of the PM sensor required the team to seek alternative communication protocols for connecting the GPS sensor. Other work included attempts to increase wireless communication range.

3.2: Semester Accomplishments

3.2.1 - Particulate Matter Sensor

This semester, the Mapleseed team completed work on the addition of a particulate matter sensor using a pair of Texas Instruments CC1310 Launchpad boards. Accomplishing this required significant changes to the existing codebase for the boards that was previously developed for the GPS sensor. Since the Launchpad boards have only one UART interface, the existing GPS code was unable to be preserved with the addition of the PM sensor, since the PM sensor only supports UART communication. The GPS sensor and Launchpad boards both support I2C and SPI communication, so these protocols were explored further to allow the GPS and PM sensors to coexist on the board, as discussed in Section 3.2.2.

Due to complications with UART communication between the PM sensor and CC1310 Launchpad, an Arduino Nano was used as an intermediary to read binary data from the PM sensor, parse it into a comma-separated list of values, and then relay the processed data to the Launchpad. Using this the team was able to obtain particulate matter concentration values for 1.0-, 2.5-, and 10-micron particles with both standardized values and those under the present atmospheric conditions. The data is validated on the Arduino using a checksum before being sent to the Launchpad board to ensure the sensor data is valid.

3.2.2 - Alternative Communication Protocols for GPS Sensor

After the addition of the PM sensor described in Section 3.2.1, the UART interface previously used by the GPS was no longer available. For the GPS and PM sensors to coexist, the team turned to the use of alternative communication protocols supported by both the GPS and the CC1310 Launchpad, namely I2C and SPI. Progress this semester was largely centered around understanding these communication protocols and constructing basic implementations using these methods.

3.2.3 - Increasing Wireless Communication Range

Work continued on increasing the wireless communication range between the pair of CC1310 Launchpad boards. The team focused on using software changes with the existing hardware to attempt to increase the range, including modulating the radio frequency and increasing the power available to the radio communication unit. While these changes were anticipated to increase the range, informal testing did not yield results that outperformed the previous semester's field test range of 120 m. It is suspected that range increases will require hardware changes in order to achieve the near-term target range of 1 km and the future targeted range of 8.5 km.

3.3 Future Plans

3.3.1 - Alternative Communication Protocols for GPS Sensor

Building on the work described in section 3.2.2, the team plans to integrate the GPS sensor with the PM sensor on the CC1310 board using either I2C or SPI. This is a necessary task for a complete sensor platform.

This integration work will likely incur some additional complexity due to nature of the sensors – the GPS and PM sensors operate at different measurement rates, so ensuring that data from both can be communicated wirelessly in tandem will require additional work in packaging and transmitted data between the two CC1310 boards.

3.3.2 - Increasing Wireless Communication Range

As mentioned in section 3.2.3, it is expected that reaching the short-term and long-term target wireless communication ranges will require hardware changes. Next semester, the team will investigate what such changes could be made that would achieve the desired range without requiring prohibitive changes to the existing codebase and prototype. One example of such a hardware change is the addition of an antenna. The team will attempt to optimize the software and hardware settings in order to maximize the communication range while staying within the necessary power, space, and cost constraints.

3.4 Conclusion

The Fall 2021 semester saw a significant shift in operations for the Mapleseed flyer team. Previously completely remote, the team was able to meet in-person, which helped increase collaboration and morale. The team was able to successfully add a particulate matter sensor to the board, accomplishing the primary objective for this semester. The addition of the PM sensor marks significant step in fulfilling the goal of the Mapleseed flyer to deliver real-time atmospheric data using a freefalling device. The team is moving towards a functional codebase that integrates multiple sensors and can be used on a small PCB board and mounted on the Mapleseed flyer.

4: Micro-Airplane Sensor Carriers

4.1: Introduction

This semester, the micro-airplane team have accomplished serval keystones. The mechanical team finalized the design of the micro-airplane and conduct a flight test with the existing design. The electrical team has begun the development of flight simulator software. One test flight was able to be performed.

The micro-airplane is a small-scale remote-controlled airplane with collapsible wings to facilitate tight storage. This would allow many airplanes to be dropped out of one aerial vehicle allowing for many airplanes to coast around an area for some time. With onboard sensors, high quality atmospheric data can be collected for a longer time than with a passive device.

4.2: Semester Accomplishments

4.2.1 – Folding Mechanism Redesign

The wings of the micro-airplane need to be able to fold in to allow for compact storage of the airplane. In the previous semester a very robust design was created shown below in figure 4.1. Although this design worked well, it was not very lightweight and did not integrate with the fuselage of the aircraft very well. The new design, shown below in figure 4.2, is an improvement on the design. This improved design is much lighter and allows room for the electronics of the aircraft. This design used a 3D printed shell with carbon rods to function as the rotating points of the wings. Elastic bands pull the wings into the extended position and the geometry of the shell keeps the wings extended.

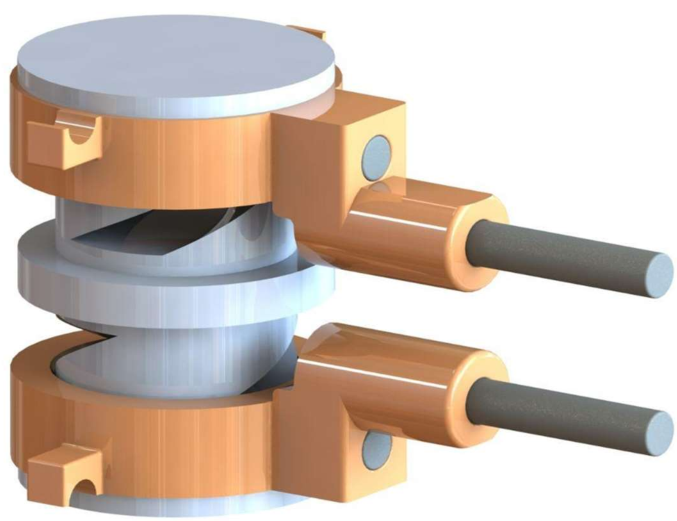


Figure 4.1. Previous Folding Mechanism Design

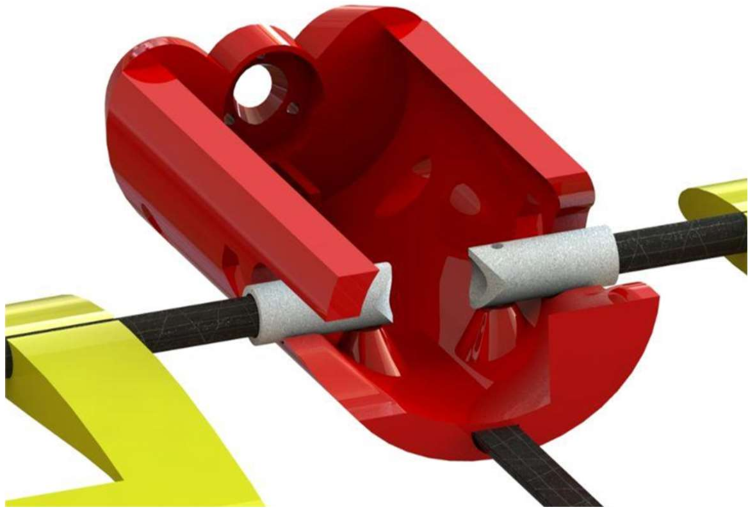


Figure 4.2. Improved Folding Mechanism Design

The new design was prototyped and tested to verify the design. Successful tests provided confidence in the design.

4.2.2 – Prototype Assembly and Modifications

Once the final design was developed, a prototype was made of the entire plane. A 3D rendering of the CAD for the micro-airplane is shown below in figure 4.3.

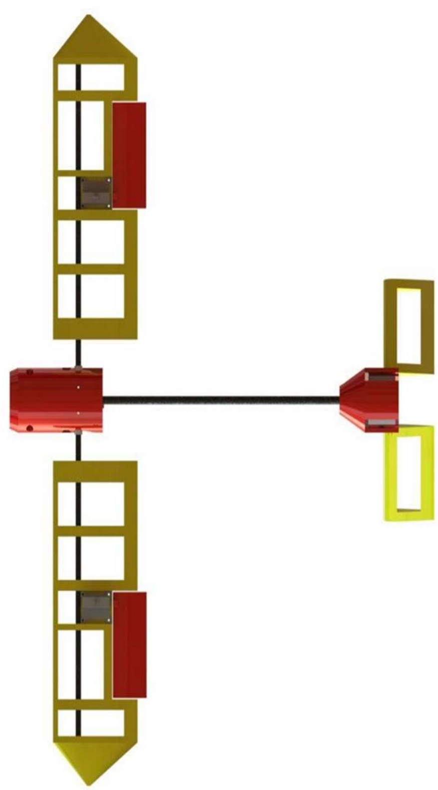


Figure 4.3. Bottom-up rendering of the micro-airplane final design

This design includes several unique features. As previously discussed, the design has collapsible wings for improved storage capability. The structure of the airplane is carbon fiber rods for durability and light weighting. For more light weighting, the wings are a 3D printed structure that has a thin film wrapped over it for a lighter design than printing the entire structure. There are 4 control surfaces, two on the front wings and two in the rear, controlled by four servos. All the electronics are stored in the body and the battery is stored just behind the body. The prototype was made and is shown in figure 4.4 below.

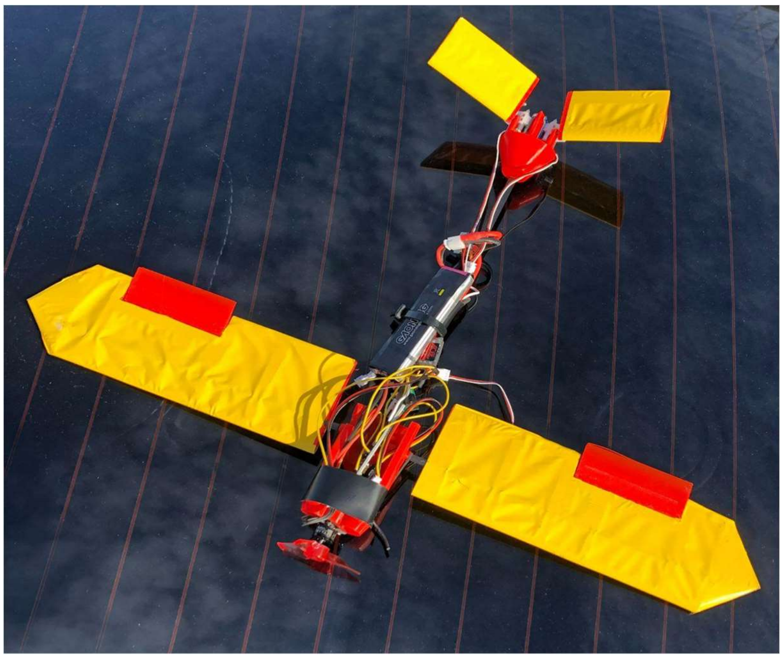


Figure 4.4. Fully assembled prototype

Once the first prototype was created, it became apparent the connection with the rear wings to the rear servo was not working. A quick resign to change the servo position slightly and the wing hook position was done, and a new prototype worked well.

4.2.3 – Finalizing Mechanical Design

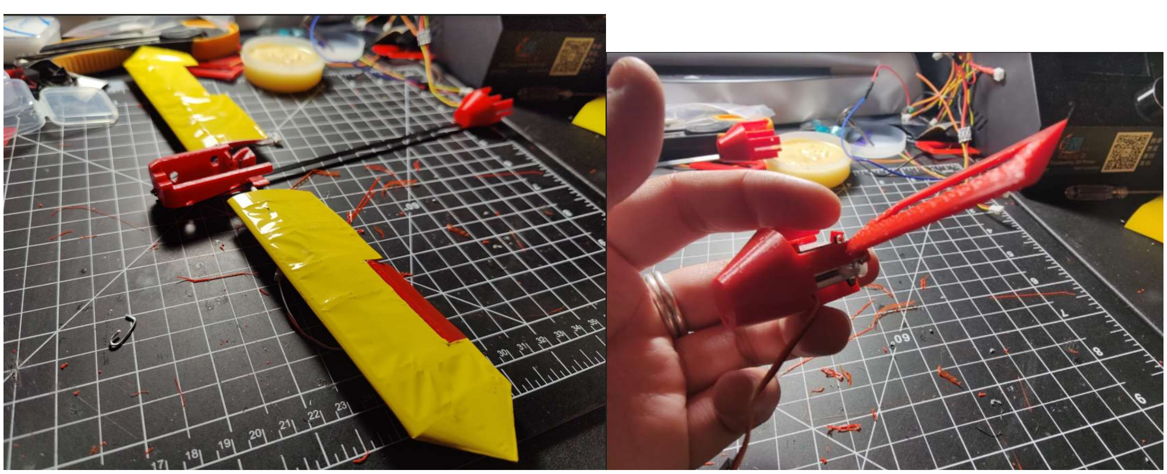


Figure 4.5. Fully assembled prototype (2)

Based on the designed from previous semester, the mechanical team integrated the folding wing design into the base of the micro airplane. The overall weight of the airplane is around 60gm, while the size is about 25-cm by 30-cm. The battery contributes to more than half of the weight. Wings are covered with a heat-adhesive material to create a smooth aerodynamic surface, while the structure is entirely 3D-printed to limit the weight. There are in total of four control surfaces: two ailerons and two ruddervators. Each of them is controlled by a micro linear motor and have deflection of about 30 degrees each side.

4.2.4 – Flight Testing

Once the prototype was fully assembled, a test of the servos and wings was done. These worked well but the rear wing connection could be improved upon because it is not very robust.

With the electronics all working well it was time for a flight test. The testing conditions were very poor as the wind was blowing harshly. Launching was done simply by throwing by hand as the propellor was spinning at full speed as shown in figure 4.6 below. The test was not successful. The airplane pitched up briefly but almost immediately spiraled out of control and crashed into the ground. The airplane was damaged and it is apparent that further testing in the future with better weather was needed. A recording of the flight test shows the airplane has the ability to fly. The team will investigate the dynamics of the airplane and make necessary modification to the design. Different methods of launching the airplane could be explored as well.

Figure 4.6. Method of launching the prototype during flight tests

4.2.5 – Flight Guidance and Simulator Software

Eventually, it is desirable for the micro-airplane to be autonomously controlled instead of controlled by a ground pilot. This would allow for multiple planes to roam in an area at once without supervision. Although currently the plane is controlled by a person, a MATLAB program is being developed to help create a controller that will allow for the plane to fly itself.

Additionally, a simulator is essential in order to test the dynamics and flight control algorithm without using a physical airplane. The electrical team is developing a simulator on MATLAB for the micro-airplane. The simulator uses a simplified model of the aerodynamics of the airplane using the geometric constants of the airplane in order to predict pitch angle, altitude, and position and their corresponding velocities. The model determines lift and drag coefficients by interpolating for a given angle of attack based on the airfoil profile data. The current iteration of the simulator visualizes the trajectory of the airplane with individual points plotted on a graph over time.

4.3: Future Plans

4.3.1 – Further Testing

Only one flight test was completed this semester. Further flight tests need to be completed on days when the weather is more forgiving. This would make it clearer if major design changes are needed. Another possible test that could be performed is to attach some sort of line to the front of the airplane and then hold it outside of a vehicle moving at different speeds. This would allow for studying the performance of the wings and control surfaces. If the aircraft keeps pitching down at speeds higher than it is expected to achieve then there a design changes that need to be made. Also, the control surfaces can be studied to see if they properly control the airplane.

4.3.2 – Tail Modification

During the fabricating process, the team discovered the tail design in combination with the linear motor makes movement difficult due to the low voltage of the system. The team will further investigate possible solution to the problem.

4.3.3 – Rear Wing Redesign

The rear wing connection to the servo is currently not very robust. A redesign of the connecting points between the two is needed to allow for better control of the rear control surfaces. Additionally, further light weighting of the design could be done. If further testing shows that the control of the rear wings is insufficient, more design will be needed.

4.3.4 – Flight Software and Simulator Development

The next stage of onboard software is to achieve autonomous flight with attitude control and waypoint tracking. On a long term, it is optimal to have communication capability with ground station using direct 2.4G wireless connection or Bluetooth.

On the current state, the flight simulator is still under development. The electrical team will need assist in create a better dynamic model of the airplane, and add control surface simulation. In the future, more features will be added such as 3D visualization, user defined environment, etc.

4.4: Conclusion

This semester great progress was made in bringing the design into reality with a prototype. Some minor changes made after the prototype was made allowed the functioning prototype to be tested. This test flight was not successful likely in part due to the unforgiving weather conditions. Further testing will be needed to determine if there needs to be a change in the current design.

Progress on the flight simulator is promising for starting to develop autonomous control of the airplane. In the future this could be used to collect high quality atmospheric data.

5: Drone-Based Optical Microscope

5.1: Introduction

The goal of the team is to capture the particle sample in the air and recognize the type in real time with a drone-carried microscope system. In the semester of Winter 2021, the team focused on designing a system that could recognize the type of particle within a small amount of the particle.

5.2: Semester Accomplishments

5.2.1 - Particle Collector Model and Simulation

The goal for the particle collector model and simulation subteam is to round up previous experiments data and perform analysis on selecting the best model.

The results for best performance model - Model 2.3 airfoil is shown below. It shows that the capture rate is much better in a higher wind speed. However, to have better collection rate, the particle concentration in the air should be high. This might not be ideal in the real world so we are enforcing more on the classification on small amount of particles side.

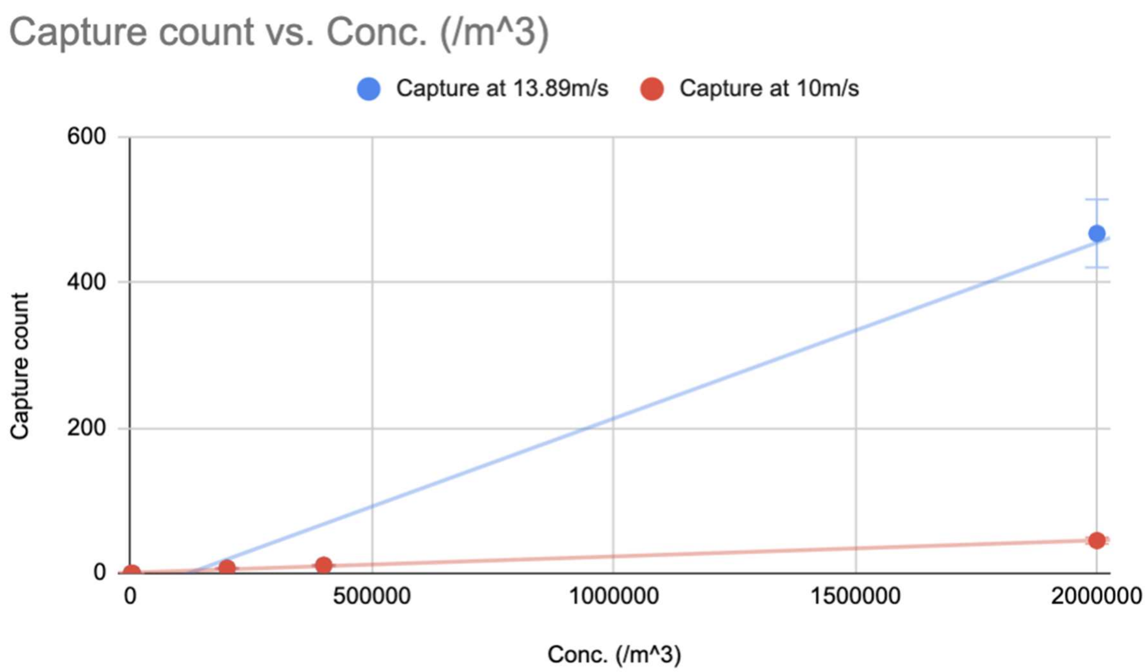


Figure 5.1. Capture count for Model 2.3 airfoil at Wind speed 13.89m/s (50km/hr) and 10m/s (36km/hr)

5.2.2 - Micro Particle Sensor

The goal for the Micro Particle Sensor subteam is to create a laser visualization component on the microscope system.
Previous design efforts of the micro particle sensor were unable to capture and visualize particles and then further classify them. The fundamental problem is previous setups were identified to be the following:

- Lack of laser focusing through a simple plastic spherical lens

- Lack of high quality CCD to allow for particle visualization

Thus, to make adjustments to the current setup, the functional requirements of the micro particle sensor are identified to be the following:

- The micro particle sensor setup must allow for visualization of particles around the size of 10^{-6} m.
- The micro particle sensor setup must have a mass of less than 300 g and able to be carried by the drone
- The micro particle sensor should allow for rapid adjustments to capture clear images of particles

Previous studies in particle visualization primarily utilizes around 500 nm lasers with the addition of Webcams / CCD and optical lens setup to visualize the particles. Such PIV imaging techniques are commonly used in medical imaging, aerodynamic flow analysis, and photoacoustic microscopes. Thus, we analyzed the possibilities of incorporating these techniques to micro particle visualization. The design selection process can be visualized in the following Pugh chart:

Criteria	**Weight**	**Plano Convex Lens**	**Rectangular Prism**	**Double Laser Setup**
Cost (higher for cheaper)	3	1	-1	0
Assembling Difficulty	2	0	1	0
Reliability	2	0	1	0
Particle Visualization	2	1	1	0
Mass	3	1	-1	0
Capturing Frequency	2	1	1	1
Total	N/A	**10**	**2**	**2**

Figure 5.2: *Pugh Chart Design Selection for Micro Particle Visualization*. A primary concern of the design was the cost of the design. Thus, although the rectangular prism allowed for the most precise, accurate, best visualization and highest reliability, it received a lower score. Thus, we chose the plano convex lens setup to be our final design for micro particle visualization.

We decided to have two slidable parallel plano convex lenses with the same focal length in front of the CCD to obtain an image of particles onto the CCD. The equation for the distance calculation is shown below,

$$\frac{1}{f} = (n_i - 1)[\frac{1}{R_1} - \frac{1}{R_2} + \frac{(n_i-1)d}{n_i R_1 R_2}]$$

where l_p is particle length, l_i is image length, f_{B1} and f_{B2} are the back focal lengths of the lens, R1 and R2 are the radii of curvature for the surfaces, and n_i represents the index of refraction of the lens. respectively. We are assuming particle size to be 10^{-6} and CCD image size to be 10^{-2}. The distance between the focal lengths would enable us to achieve slight adjustments in image quality and magnification ratio. The encasing for the lens would be 3D printed and allow for the lens to slide along a parallel slide. The particle collector would then be connected to an airflow conditioner, which would allow for more accurate particle sampling.

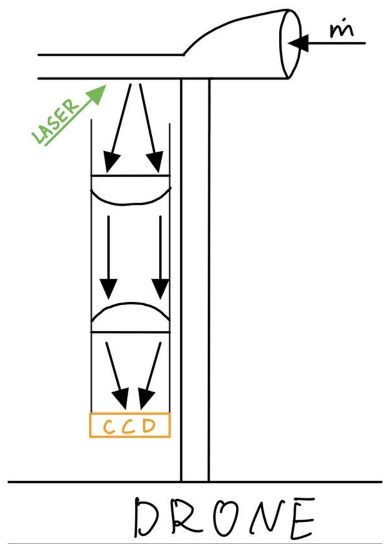


Figure 5.3: *Illustration of Plano Convex Lens setup for micro particle visualization*. Red lines represent the transfer of optical light. Black dots represent particles. Shaded red line represents the 550 nm laser.

5.3: Future Plans

5.3.1 Micro Particle Sensor

Additional literature reviews and research will be necessary to determine/refine the final design of our sensor. Then, we will determine materials to purchase and models to 3D-print, which allows us to test the sensor setup and refine the model based on physical experiments.

5.4: Conclusion

Overall, the team has made progress in collecting simulation data and designing new components. We hope to move forward with the micro particle sensor approach, while considering the possible obstacles with the pandemic situation.

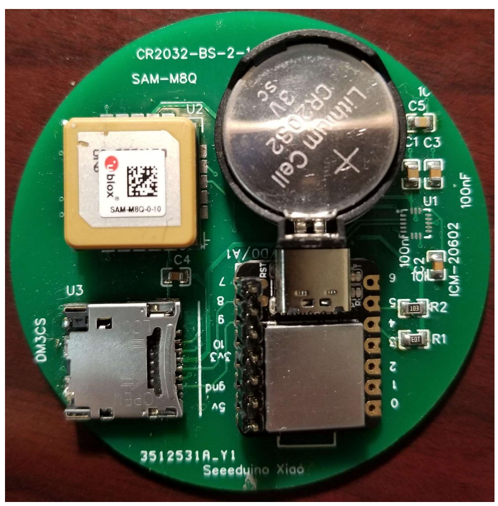
6: 3D-printed PCB

6.1: Introduction

To achieve a functional Mapleseed-flyer, a PCB is necessary to assist the data collection part of its functionality, which includes various sensors for GPS and motion, and supports wireless connection to the ground monitor. 3D-printing technology offers us a solution into both Mapleseed flyer and PCB manufacturing, with high precision, low weight, and automatic production, the overall design can serve various purposes in the air-monitoring applications and offer a replicable approach in drone-based Mapleseed-flyer scenarios.

6.2: Semester Accomplishments

In this semester, the recently produced PCB prototype is thus soldered and tested with its individual functionality, the two-layered prototype is circular-shaped with diameter of 5.9cm, a thorough PCB hardware characterization test was performed and assured the internal route conformed with the schematic. The soldered PCB, with various components and power units has reached a total weight of around 22g. The functionality test was then conducted, while we found a major deficiency causing the whole circuit unable to function properly. The power storage of the lithium battery, CR2032, is not capable of driving all the components, the microcontroller unit may take too much power, and the voltage level of the lithium battery has dropped to a dangerously low level after a short amount of time.



6.3. Future Plans

The future plan of this subteam is to remodify the PCB to a more reasonable product, including less features and possibly a stronger battery to address the unsustainable power problem. The rerouting of the power signal net will be the top priority of this project, a possible software-based test can be designed ahead of time as the microcontroller has been proved to work functionality if offered the right power voltage.

6.4. Conclusions

The semester has been a slow progress for this subteam as soldering takes sometimes unnecessarily long time for a beginner to perform, and a couple serious issues comes with testing the prototype PCB, but overall this is expected before the start of the semester. The viability of implementing a small PCB onto a tiny mapleseed-flyer is still a very difficult task with lots of technical challenges waiting to be overcome. The adjustment of the functionalities of the PCB may need to be discussed and reduced if necessary.

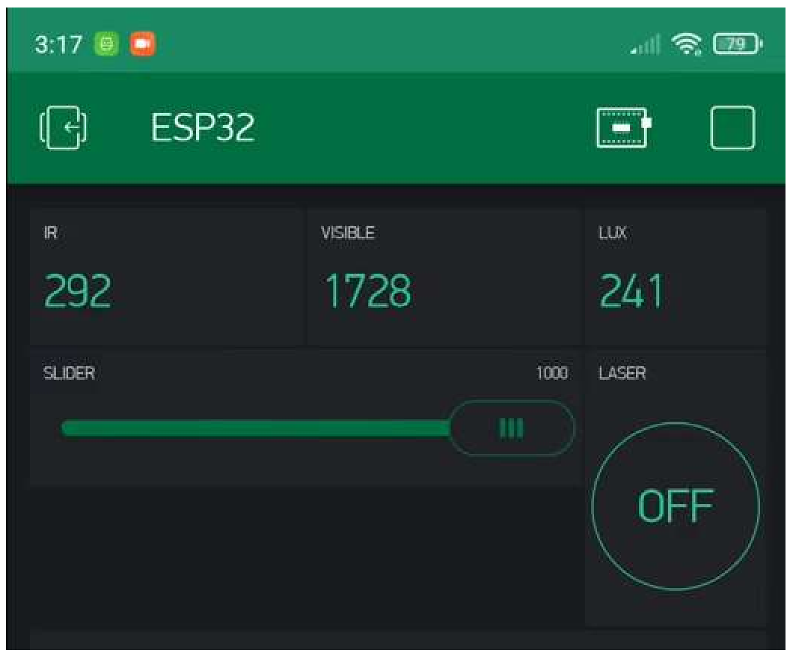
7: MCU Sensor Visualization app

7.1: Introduction

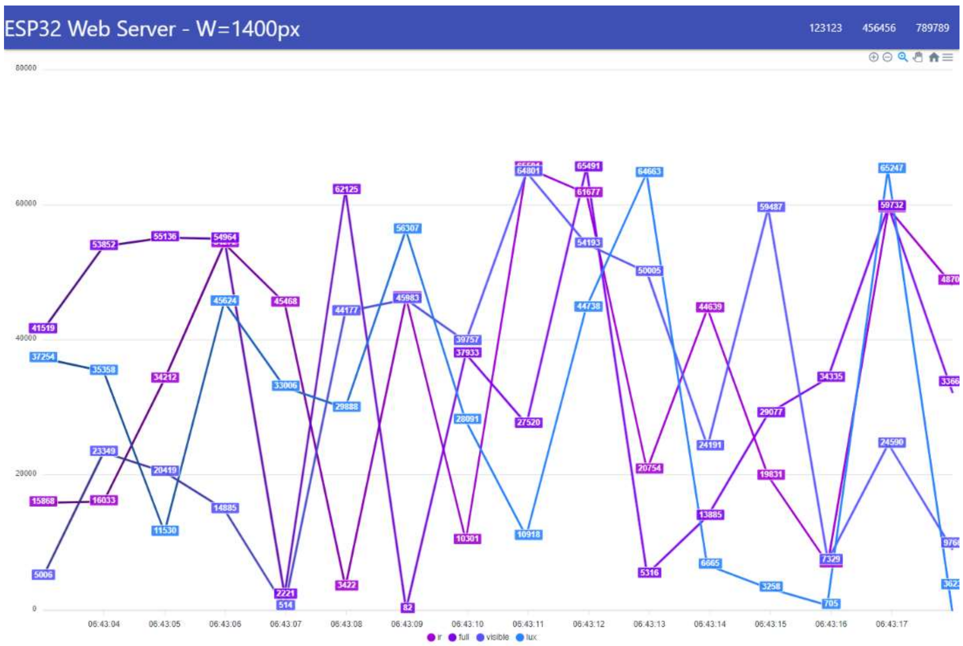
The sub-project was started this Winter 2021 semester aiming to create an accessible and convenient visualization tool for MCU sensors. Our team is trying to build a cross platform (universal) approach to visualize data passed from MCU sensors.

7.2: Semester Accomplishments

Data can be accessed from the MCU sensors through serial output, the most primitive approach of data visualization and analysis. However, it has poor availability because it requires a USB cable connecting to a running PC.



Switching to Blynk mobile application, it is more flexible and available since our team could control the MCU remotely through Wi-Fi. It also has decent aesthetic elements such as buttons, text labels, and graphs. However, it has limited functionality on its free tier (free use copy) because of its commercial product nature.



Through Full-stack Web application, there are much more flexible and available because our team is building this web application from scratch, which means that we have full control over its visual appearance and functionality. It is completely open-source, which means that our team does not have to use pre-built functionalities and will never be charged. It is also self-developed and self-maintained, which means that our team can add more features along our development at minimal cost.

7.3 Future Plans

The plan is to both aesthetically and functionally polish the web application and add more controls for the MCU though the web interface.

7.4 Conclusion

Our team is trying and building various visualization approaches to facilitate the productivity of the sensor development.

8: Machine Learning and Particle Classification

8.1: Introduction

The Machine Learning subteam's goal is to achieve real-time image recognition of particles collected by the optical microscope on a fast drone. To achieve this, the team first developed models for image recognition and trained the model based on images taken at the lab, which are clear and more useful for the initial stage of our development.

8.2.1: Data Prepossessing

The current dataset includes three particles: pebble, salt, and sand. The team extracts each frame from videos taken in the lab to form the dataset, augments the dataset by applying random transformations such as random flipping and random crop, resizes and normalizes the images.

Figure 8.1 Visualization of the raw dataset extracted from microscopic videos (pebble: 0, salt: 1, sand: 2)

8.2.2: Training Process

This semester, the team adopted a relatively simple model. The team trained a simple CNN model with two convolutional layers, one pooling layer and two fully connected layers to output the classification result. Professor Liang also helped us with another version of the Xception Network, which achieved over 60% accuracy.

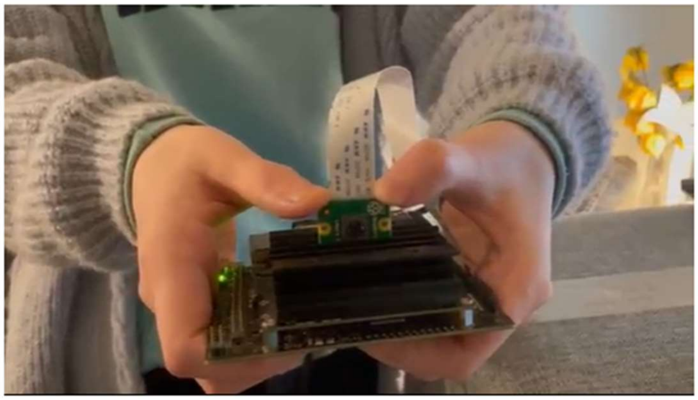


Figure 8.2 Raspberry Pi camera mounted on NVIDIA Jetson Nano board

8.3 Future Plans & Conclusion

The final goal of this project is to design a system mounted on drones performing real-time particle classification. Therefore, the team will work on two objectives in parallel. Firstly, the team will improve the accuracy and the efficiency of the model. The current model is a relatively simple one. In the future, we are looking into utilizing transfer learning and fine-tuning pre-trained models. We are also considering conducting research on models that have better performance on recognizing small particles in images. Moreover, although we spent most of the time training the model this semester, we will continue our mini-projects with various AI platforms in the future. In particular, we will utilize the NVIDIA Jetson Nano GPU Board to achieve real-time classification tasks.