The Flying Mustangs

CPE 350 - Project Charter

Machine Learning Hybrid UAS Systems

Mitchell Myjak

Zeph Nord

Trevor Gesell

Boris Tam

Executive Summary

The end goal of this project is to develop an embedded computing system capable of implementing machine learning algorithms for Prognostics and Health Management (PHM), of electric motors or internal combustion engines.

Step one will be understanding the key instrumentation available and required for an electric motor and small internal combustion engine.

Step two will be developing a lightweight data acquisition system for collecting information both on the ground and in-flight.

Step three will be collection of nominal and failure case datasets, along with cleaning up the collected data to prepare the training model.

Step four will be implementing the prognostics and health management algorithm using the training dataset.

Step five will be demonstrating the real-time anomaly detection of the system. Comparing the results of the system in real-time operation to the test data will give an evaluation of the accuracy of the implementation.

Customer Development

Clients/Customers:

The customer of the project is Empirical Systems Aerospace, Inc. (ESAero). The company was formed in 2003 and serves the engineering industry with its work on concept development, aircraft modifications, military and commercial conceptual air vehicle design, sub-scale technology demonstrators, hybrid propulsion system research and development, and niche engineering support. Currently, the company has about 30 employees and is headquartered by the Oceano County Airport. ES Aero will use the project to better develop their fault detecting algorithms. Currently, their algorithm does not involve machine learning, requiring hard coding to detect the faults. With the use of machine learning, the detection of faults will be more abundant and more accurate. For instance, just a single fault detection requires extensive testing and analysis of the results for each sensor. With the use of machine learning, this process can be automated which will lead to a significant decrease in the time in requires to implement a fault detection system. All deliverables from the project will be given to ES Aero at the end of the winter quarter.

Stakeholders:

The only stakeholders of the project are ES Aero. At the time it is not possible to know how they plan on using the device in their projects with other companies. In other words, the other stakeholders of the project either do not exist or they are not known at the moment. Due to this, the progress of this project will only need to be reported to Dr. Seng and ES Aero. In the future, it is possible others will be interested in the success of this project.

Framed Insights and Opportunities:

This embedded system will be used as part of the hybrid-electric and all-electric rotorcraft analysis and tool development project for a client of ES Aero's, NASA Ames. This project is phase I of NASA's SBIR program, which entails the opportunity to establish technical and commercial merit and feasibility of a proposed project. Phase I should provide a solid basis for continued development. NASA SBIR Phase I contracts last up to six months, and have a maximum budget of $125,000. The goal for this contract would be to qualify for phase II and follow on efforts. Phase II is focused on the development, demonstration, and delivery of the innovation. NASA eventually wants to commercialize innovative technologies that were a result of the Phase I and Phase II of the SBIR program.

Project Goals and Objectives:

Goals: Use a self-developed lightweight data acquisition system for data collection and utilize this data to train the machine learning algorithm to increase accuracy of anomaly detection in the unmanned aircraft system.

Objectives:

- Identify the sensors available and required to monitor the UAS system in both case of an electric motor and a hybrid electric motor and internal combustion engine.
- Develop a lightweight data acquisition system to collect sensor data for both training and real-time flight monitoring.
- Implement Keras on the Jetson TX1 to train the neural network with training datasets
- Compare the real-time operation of the system to expected models extracted from the training to verify accuracy of the algorithm.

Project Outcomes and Deliverables:

The project results will consist of a PHM system that can both detect and diagnose issues regarding electric and gas motors through a trained machine learning algorithm. The machine learning algorithm will be constructed using Keras, which uses a deep neural network. The product ES Aero will be left with will be a full system including a Jetson TX1, a sensor suite to monitor the health of the motor or engine, and some type of analog to digital converter or microcontroller that can handle the conversion from analog output from the sensors to digital input to the Jetson for data acquisition. This system will be versatile and will be able to handle the prognostics and health management of larger VTOL UAVs, for example.

Duration:

We will meet the objectives by the end of 20 weeks. By the end of that period of time, we will have a finished functional product that will be presentable to the customer. It will meet the customer's requirements and expectations.

To ensure that the team is meeting its objectives on time, we will break down our big goal of making a sensor suite that tracks an electric UAV motor into weekly milestones, after having a better understanding of the entire project. We will set milestones such as making a list of parts, planning out how they will be connected to one another, connecting the parts, configuring the hardware, and programming the hardware.

Project Development

Customer Requirements:

- Develop an embedded computing system capable of performing prognostic and health management of electric motors and internal combustion engines.
- Develop a lightweight data acquisition system for collecting information on the ground and in-flight.
- Demonstrate real-time anomaly detection.
- Present a finished product by the end of winter quarter.
- Create a testbench to develop the machine learning algorithm.
- Understand the concepts of machine learning and be able to implement it into a device.

- Report weekly to ES Aero to update the company on the progress of the project and inform them of any equipment that is needed.

Prototypes:

The first prototype will identify that there is an issue with the health of an electric motor. This prototype will be improved so that the exact issue will be diagnosed, such as a temperature spike. The next prototype, which will be developed in the winter quarter, will identify an issue with the health of a gas motor. A final product would ideally be able to provide PHM for both a gas motor and an electric motor simultaneously. The first prototype will be for an electric motor due to the relative ease with which issues can be identified, like current spikes, while gas motors may have issues that are more difficult to diagnose.

Team Development

Team Mission and Team Objectives:

Team Mission: To develop and create a well designed, lightweight, and reliable PHM system through hard work, teamwork, and exceptional communication both within the team and with ES Aero.

Team objectives: Fully understand how artificial neural networks work, and how to build one using Keras. Weigh the pros and cons and choose the optimal peripherals for this project using sound reasoning and extensive research. Enhance the understanding of embedded systems and communication protocols such as SPI and I2C. Execute the team mission as well as possible to provide the best product for the client.

Team Membership and Roles:

Zeph Nord: Project Manager

- Ensures that goals are met by the end of the capstone by monitoring and tracking the progress of the milestones and tasks
- Maintain the timelines and shift responsibilities if tasks fall behind in part of the team
- Communicate with the customer and schedule weekly meetings to ensure the team is on track

Mitchell Myjak: Procurement and Financial Officer

- Purchase and keep track of borrowed and purchased parts for the project
- Ensure that necessary parts are purchased
- Monitor the team's finances and request more funds from customer when necessary

a. System Architect - Mitchell Myjak

b. Hardware Architect - Trevor Gesell

c. Software Architect - Boris Tam

d. Hardware Designer - Trevor Gesell

e. Software Designer - Zeph Nord

f. System Interface - Boris Tam

g. Development Tools Specialist - Zeph Nord

h. Product Verification - Mitchell Myjak

i. Product Reliability and Serviceability - Mitchell Myjak

Planning Information:

The current design phase entails choosing the best sensors for the sensor suite. The platform with which the analog outputs of the sensors are converted to digital inputs to the Jetson is still being decided. A labjack will work incredibly well in the testing and training phase due to its many analog inputs and 16-18 bit resolution. However, the labjack is different than the majority of ADCs found on microcontrollers, as it uses Sigma delta modulation as its method of encoding analog signals into digital signals. This method provides a more precise resolution than the alternative, SAR, which generally has a 12 bit resolution, but at a much slower sampling rate. The sampling rate for a labjack U6 is 50 ksps, while the sampling rate for an ADC which uses SAR can be as high as 1 Msps, or around 300 ksps, on average.

Another aspect of the current design phase is determining how to introduce distinct faults into the motor for training purposes. There would ideally be a way to automate this process so that the deep neural net can be trained for hours at a time, or perhaps overnight, depending on the amount of data it will need to properly determine the weights between nodes for a reliable fault detection system.

The last design issue has a low priority since it will not need to be addressed until the implementation phase. That is the battery setup for the Jetson and the motor. It will need to be determined whether the Jetson should be powered by a 3S or a 4S battery and whether the battery will power both the motor(s) and the Jetson, or if the Jetson will have its own independent power source.