Automated Building Energy Efficiency Analysis

Executive Summary

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The objective of our project is to deliver a sensor package capable of autonomously performing tasks that would normally be performed during an energy audit. This sensor package must remain within the specifications of a selected unmanned aerial vehicle (UAV) in regards to weight and size. Performing an energy audit of a building can require a team of several people and can take a several hours to perform. By creating a UAV with autonomous energy auditing capabilities, both man-hours and money can be reduced and those resources reallocated elsewhere.

The UAV must integrate all of the various sensors, hardware, and software languages in order to be capable of conducting an energy assessment of a commercial building envelope, including fenestration, rooftop material, insulation, etc., and determining the operational baseline of the building (i.e. temperature, humidity, CO2, lighting level, occupancy, etc.)

The team has developed a few solutions to meet a number of the requirements so far. We decided to use the UAV hexacopter platform because it met all of the needs that we thought we would have going forward and was the best choice after a rating matrix analysis. Selecting this platform allowed us to focus more of our time and energy on selecting sensors and developing the sensor package, which was our main objective.

The following boards are important for the integration of the various sensors into one working package. Arduino was selected as the main sensor platform for the project due to its simple programming environment, cost, and compatibility with a variety of sensors. The Grove Shield which connects to the Arduino was selected because it allows for easy plug and play capability for many of the sensors that are needed to perform the autonomous energy audit. A Raspberry Pi was also selected due to its input capabilities and data storage ability.

The sensors that are compatible with the plug and play Grove Shield are the: temperature and humidity sensor, ambient light sensor, and the occupancy sensor. The temperature and humidity sensor will take readings as the UAV travels throughout the room. The number of readings taken will depend on both the data storage capabilities and the response time of the sensor. Relative humidity sensor readings can begin to drift off from the true value with time. To prevent interpreting inaccurate readings as the true value we plan to introduce a redundant temperature and humidity sensor. The two values obtained will be compared to one another making sure they are within a certain tolerance of one another. If one sensor begins to drift then we will quickly become aware of this and will be able to recalibrate it. The ambient light sensor detects the light intensity of a room through the use of a photoresistor. In order to determine if a building is occupied a passive infrared motion detector will be used when the UAV is in a stationary position.

Two of the other sensors that are not Grove Shield compatible are the carbon dioxide sensor and the light reflectivity sensor. The carbon dioxide sensor selected still functions in the Arduino environment and must either use a special sensor jack or be soldered onto the Arduino board. The decision was made to keep this sensor within the Arduino environment when possible to
keep the sensor integration simpler. The light reflectivity sensor will be used to determine the reflectance of the roofing material. The plan is to place the light reflectivity sensor inside one of the landing gears of the hexacopter. By placing the sensor inside the team believes that the sensor will be: protected, shielded from undesired light, and in very close proximity to the roof.

The thermal camera selected is a small form FLIR Tau 2. This camera will give us the capabilities we need to analyze fenestration, infiltration, and insulation issues. This model thermal camera is also small and lightweight, both requirements are highly desired given our UAV. Pictures will be taken of the building envelope while flying around the exterior and interior then stored on an SD card connected to the Raspberry Pi. These images will be analyzed for issues using a program we created in MATLAB. This program compares adjacent pixels for significant temperature differences and flags these anomalies. MATLAB was selected as the programming environment for analyzing the images because it has a built in imaging toolbox while also the most familiar programming language for the majority of the team.

The power for all of the sensor and UAV components will be provided by a LiPo battery. Voltages will need to be regulated and wiring done properly to ensure that the hardware does not burn out due to an oversupply of power. The battery should have sufficient energy storage capabilities to be able to allow the UAV to sustain a flight of a desired length while remaining lightweight.

The team members consist of four senior mechanical engineering students, and two AggiE Challenge students (electrical and computer engineering). Each student has their own experiences, interests, and areas of expertise that are brought to the table. Areas of the project are broken down and each team member is assigned a lead role on certain tasks. Everyone is responsible for their main area and has the support of one another in decision making and problem solving.

A majority of the design decisions have been made and hardware purchased. Next semester the building and integrating of all of the components will begin. Software design, implementing, and testing will be an ongoing and iterative process. Optimizing other design parameters of the hexacopter, once built, will also be ongoing.

The long term goal of the project is for the continued growth and development of this technology. Autonomous navigation will hopefully be added to the capabilities of the UAV in the future and will aid in making the energy auditing process truly independent of human input. The technology will likely get cheaper, smaller, and more efficient leading to the creation of a fleet of energy auditing UAVs. A greater number of vehicles will be able to perform a greater number of energy audits which will increase energy efficiency and reduce costs.