Senior Design Proposal

This document describes the contents of the project proposal that each team should submit. There is no required length for this document; it needs to be long enough to contain the required information.

The PowerPoint presentation that will also be part of the proposal should follow the same outline.

1 Introduction

Small Unmanned Aerial Vehicles (UAV) are becoming increasingly present on the modern battlefield. This growth in drone usage has become especially apparent in the war in Ukraine. The sophistication of these drones varies from coordinated swarms with integrated sensors and communication systems to hobby drones, explosives, and duct tape. Drones can be used for a multitude of purposes, from surveillance to explosive elimination. In the case of the latter, a three second warning could be the difference between the life and death of a soldier.

2 Problem Description

There is no current method for our armed forces to detect incoming drones. Special Operations Command has tasked us with creating a wearable device that could alert a soldier to the presence of an incoming UAV.

A detection device would have to be quick, reliable, and unobtrusive. Just like the detection of conventional ordnance, every millisecond counts. The sooner the user can receive the alert, the more time he or she has to react. False positives from the device would slow down operations and wear down the user’s trust in the readings, while false negatives could result in injury or death of the user. The device should not interfere with the intended force’s range of motion or add significant payload to their already significant fighting loads.

3 Proposed Solution

Our solution will integrate RF sensing and audio-based detection to quantify a likelihood of attack, and employ electro-stim as a method of notifying the operator of an incoming attack. The device will use an antenna mounted to the operator’s helmet to detect RF waves within the range of the most common drone operation frequencies. Omnidirectional microphones will detect the distinct sound of spinning quadcopter blades. This data will be dynamically processed and analyzed to output a “Threat Level” from 1 to 10. A threat level lower than 5 will induce no stimulus. A threat level between 5 and 10 will administer a proportional electronic stimulation to the back of the neck. The stimulation will be generally mild, meant to simulate the feeling of the hair on the back of your neck sticking up. This feeling will naturally encourage awareness and response to danger. Applying a stimulus in this way will prevent wasted time from needing to check a smartwatch screen or obstructing valuable screen space on the operator's Android Team Awareness Kit (ATAK) with a pop-up alert.

4 Demonstrated Features

This section should provide a detailed list of the features that you expect to demonstrate in May. Note that these features should demonstrate that you have solved the original problem. Should include at least the top 5 features you will be demonstrating.

- Directional RF Detection of Drones
    - Demonstration of RF sensors by detecting an emitter in the 900MHz and/or 2.4GHz bands. Emitter acts in place of a drone as we cannot use them on campus / indoors.
- Directional Audio-Based Frequency Analysis-based Detection of Drones
    - Demonstration of audio analysis program for positive (drone detected) and negative (no drone detected) results. Demonstration of directional and or distance-based detection and results.
- RF Signal processing
    - Demonstration of a computation and control system based on the strength and presence of audio and RF signals.
    - This system involves possible interrupts being called and handled as well as computing an estimated distance of the drone based on available signal metrics, such as RSSI.
    - This computation involves our system's ability to handle several different operations at the same time, as well as an ability to continuously process incoming data.
- Weighted algorithm output indicating the likelihood of an incoming drone
    - Demonstration of a weighing computed from the sound and RF signal presence and strength. This weighted "output" will serve as our triggering mechanism for whether or not the sensory stimulus is activated, and what level of activation is required.
- Analog sensory stimulus to provide instantaneous warning of incoming drones to operators
    - Demonstration of a functional TENS unit (or team-designed unit) in relation to the weighted output

5 Available Technologies

- Directional microphones
    - High Quality long distance directional microphones are quite expensive, however we can buy cheap ($6) microphone sound sensors to build a proof of concept and upgrade them (perhaps by stripping down a slightly

more expensive, but still affordable microphone like this) as necessary if we find that audio frequency analysis constitutes a viable solution to the problem of drone detection.

- RF sensors
    - Expensive and will likely use the largest portion of our budget if we end up having to buy one or two of them, however we may also consider buying a cheap ($16) radio receiver and implement an external antenna and filter specialized for our application. We may also purchase some cheap ($10) WiFi adapters as many commercially available drones operate via a Wifi connection and could likely be detected based on said WiFi signal.
- TENS unit
    - Affordable, but we can probably do the research into the technology and build our own instead of having to cannibalize one of these. If we take the DIY route we'll have to be careful with the way we deliver and step up the voltage the unit delivers. One of the members of our team owns a TENS unit at home, so he'll do some experiments with it over winter break.
- Microprocessor for signal processing
    - We have tons of choices, all of which are fairly affordable. If a Raspberry Pi zero has enough processing power, we can get one for $15. If we need more power, a Raspberry Pi 4 is $35. We may also look into using the ESP32 since we are familiar with it from working with it all semester, and there is the possibility of mounting it on a board, which would make our product a bit smaller and more compact. It should be said that we are using one of these boards for proof of concept. If this solution was ever used by special forces, the sensor array would likely be hooked into a computer that special operatives carry on their chests, and this computer would perform the signal processing.

1.

6 Engineering Content

We will have to design a board compatible with the RF components: antennas, RF module, processor, voltage regulator, microphone attachment, etc. Once the board is designed and manufactured, our focus shifts to the system, which will likely involve interrupts or RTOS in order to handle our multiple sensors and processing. Communication with the sensors will likely be done through I2C. We will need to write drivers to make the RaspberryPi compatible with the RF module, as well as compute a frequency and power analysis of the incoming audio signal. We must also design our system to produce an analog output using the TENS unit based on the real-time processing of our sensor data.

Once parts are chosen and ordered, there will be significant time in testing and ensuring they work individually with expected results, and then putting them together into a system. We will have to program each component to be compatible with our board and spend much of our time on writing the algorithms and code to process the inputs from our sensors to the board. We will then ensure that the weighted output system is working and implement it into our algorithm. From there most of the effort will go into testing the systems as built on various inputs and adjusting the code as necessary. This testing portion of the process has a high potential to lead to additional iterations and new parts as seen fit. We need to ensure the efficacy and reliability of the entire system, and also work towards minimizing false positives on potential incoming drones. We will prioritize a conservative system so as to not miss a detection, but the process of paring down false positive results will be a continuous one. We anticipate much of our time will be spent improving the system's RF and audio processing.

7 Conclusions

Our design could save lives and reshape an ever-evolving battlefield. Using RF and audio sensor data, data analysis, and electronic stimulus, we can create the US Armed Forces first ever small drone detection device. We already know from our sponsors that the project is in high demand. All that is left is to get to work.