# Unmanned Aerial Vehicle Detection via Acoustic Feature Extraction

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## Purpose

The inexpensive unmanned aerial vehicle (UAV), or drone, hinders perimeter security. In order to develop a solution, how can one detect a nearby drone via sound?

## Process

• The popular “Phantom 3 Pro” drone was measured in various configurations with a GRAS microphone sensitive to 100 kHz. The resulting data was analyzed using MATLAB.

• A Python-based application to display a real-time spectrogram waterfall and analysis of the audio signal was created to more easily observe the drone’s acoustic characteristics.

• The blade passing frequency, or the number of times a single propeller blade passes a point in one second, was measured at a steady 177 Hz with a laser-based photogate.

The Phantom 3 Pro quadcopter manufactured by DJI.

*How to Detect a Phantom 3 UAV*

### Data Collection

Sound pressure level is logged 100,000 times per second.

### Fourier Transform

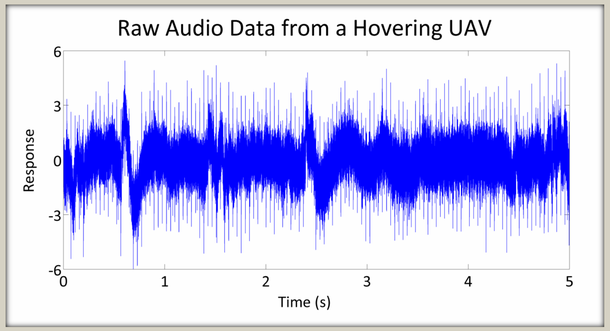
A Fast Fourier Transform (FFT) is used to translate the data into the frequency domain.

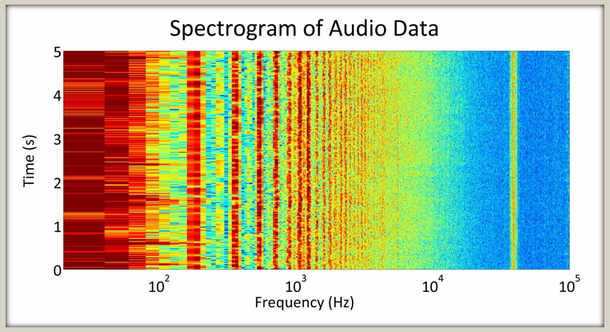
### Window

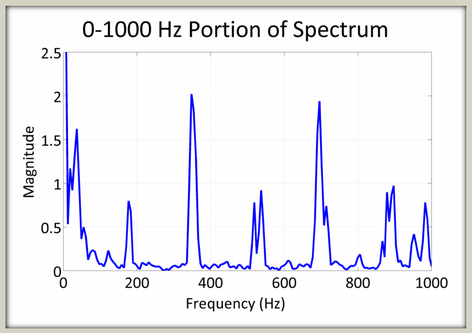
The 0-1000 Hz band is kept for further analysis while the 40 kHz signal from the ultrasonic rangefinder is measured.

### Autocorrelation

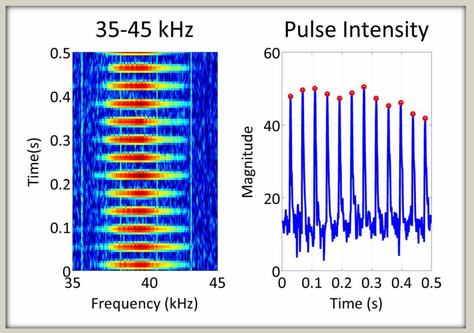
Cross-correlating the 0-1000 Hz band with itself gives a measure of the blade passing frequency.



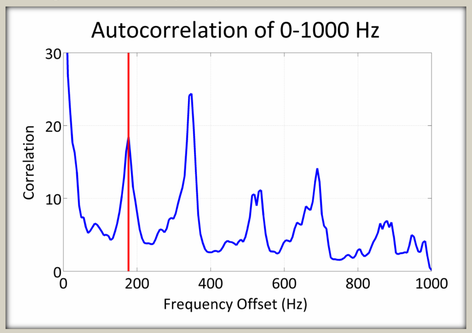



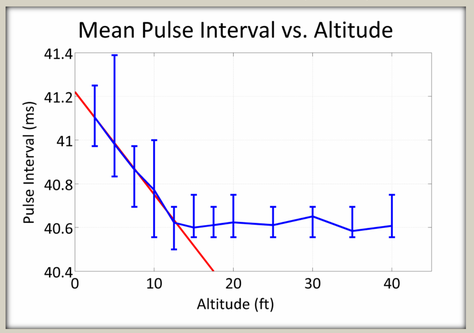

The audio frequency spectrum from 0 to 1000 Hz contains the basic blade passing frequency and its harmonics. The fundamental is nearly 177 Hz, which is twice the 88.4 Hz average rotational frequency of the UAV’s motors.




The audio frequency spectrum from 35 to 45 kHz contains the pulsed signal emitted by the Phantom 3’s ultrasonic altitude rangefinder. The intensity of the pulses relative to the noise floor is a useful metric of UAV proximity.




The 0 to 1000 Hz spectrum correlates strongly with itself at the harmonic interval (here, 177 Hz). The location of this peak determines current blade passing frequency, while its height relative to the noise floor determines UAV proximity.




The ultrasonic rangefinder’s pulses are emitted at a rate directly proportional to its altitude. Thus, measurement of the pulse interval gives an indirect measurement of altitude for heights below 10 feet.

## Results

Detectable acoustic features of the Phantom 3 are a sequence of 177 Hz harmonics and a pulsed 40 kHz signal. The former determines blade frequency, the latter, altitude, and both indicate proximity when measured relative to the noise floor. These signals can be extracted from raw audio with a Fourier transform and autocorrelation, as shown in the flowchart to the left. Evidence suggests detection and analysis with the techniques presented here is feasible to at least 100 feet.

## Further Research

• The basic blade passing frequency detected here should increase with any load the drone carries.

• Information about the drone’s lateral speed may be encoded in the audio via slightly split blade harmonics.

• The ultrasonic signal’s altitude characteristics may not be constant across models or even devices.

• Other UAV models ought to be characterized in a similar way.

• Other detection schemes, such as radar, RF detection, and video, remain to be pursued.

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