Characterizing the Acoustic Signature of a Quadrotor in Hovering Flight

Jacob Harrison (Faculty Advisor: Dr. Artur Wolek)
Mechanical Engineering and Engineering Science, UNC Charlotte

ARSL Autonomous Robots and Systems Laboratory

UNC CHARLOTTE

Presented at the 2021 UNC Charlotte Undergraduate Research Conference (URC)

Introduction

- Methods to detect and localize quadrotors are important for counter-drone security to protect from drones that malfunction or have malicious intent.
- Existing detection approaches based on machine vision or radar are ineffective for small, mostly plastic, drones that fly in low-visibility conditions.
- However, acoustic techniques that exploit noise generated by a quadrotor's motors, propeller blades, and airframe vibration are a promising alternative.

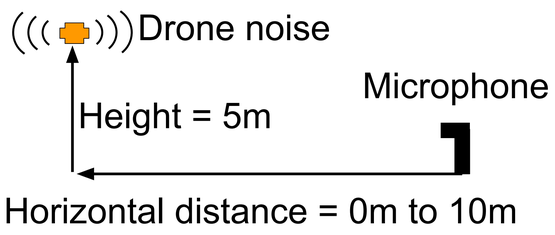
Objectives

- To measure the steady hovering noise of a small quadrotor in an outdoor environment and differentiate it from ambient noise in audio recordings at different relative ranges.

The custom-built quadrotor used in the experiment utilizes four Cobra CM-4008 motors with 11" two-bladed propellers.

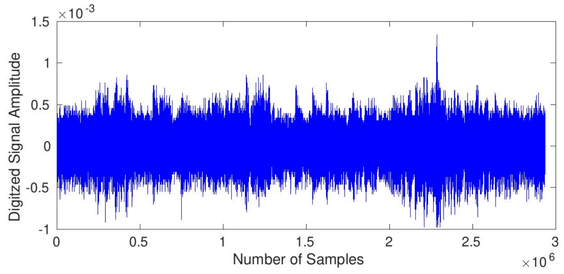
Methods and Data Collected

- A flight test was conducted in a gravel lot beside the UNC Charlotte football practice field with a quadrotor in a fixed hovering position at 5m altitude.
- One-minute length audio recordings were collected from zero to ten meters in one meter intervals by moving a laptop and tripod with a mounted Dayton Audio UMM-6 microphone (frequency response 20 kHz).



Experimental setup: A quadrotor hovered at 5m altitude while audio recording were obtained at various horizontal distances.

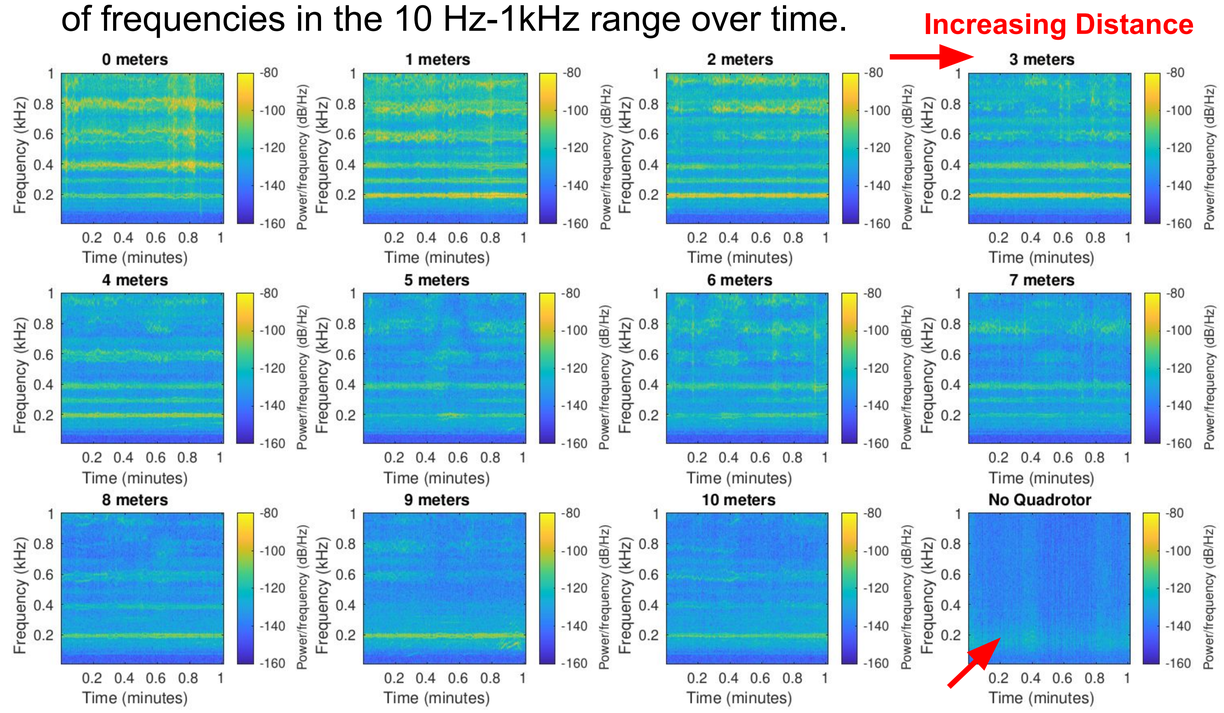
- Onboard telemetry recorded drone states, including altitude, position, and motor RPM.
- A control data set (with no quadrotor) and a ground level data set were also recorded.



Example audio recording (48,000 samp./sec)

Results

- Spectrograms were generated to visually represent the energy content of frequencies in the 10 Hz-1kHz range over time.



Spectrograms of quadrotor in hovering flight from 0m to 10m

Ambient Noise Case

Discussion

- Higher sound intensity in audio recordings with the quadrotor operating is evident and decreasing with horizontal distance.
- The spectrogram displays a pattern of high energy frequency bands corresponding to the motor RPM, blade frequency, and their harmonics.

Conclusion

- Sound was recorded from a hovering quadrotor at horizontal distances from 0-10m and compared to ambient noise recordings, showing higher energy that decreased with range in several distinct frequency bands.
- Ongoing work aims to develop an algorithm that detects quadrotor presence and estimates range by processing acoustic data in real-time.

Acknowledgements: We thank Kalan (Gunner) Petrea for developing the quadrotor platforms and his assistance in conducting outdoor data collection experiments.