2019 IEEE SIGNAL PROCESSING CUP ON SEARCH AND RESCUE WITH DRONE-EMBEDDED SOUND SOURCE LOCALISATION: UAV ROTOR NOISE RECORDINGS REPORT

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ABSTRACT

As part of the bonus task for the 2019 IEEE Signal Processing Cup on Search and Rescue with Drone-Embedded Sound Source Localisation, this report details the provided audio recordings of the rotor noise of an unmanned aerial vehicle (UAV). The recordings come from an 8-channel microphone array mounted parallel to the UAV rotor plane and recorded with consideration towards background noise in an outdoor park located in an urban area.

***Index Terms*—** Microphone array, unmanned aerial vehicle, rotor noise

1. INTRODUCTION

Unmanned aerial vehicles (UAVs) have recently gained massive popularity for a wide range of applications. Among these, search and rescue has quickly found strong footing particularly in remote environments where human or transport accessibility and navigation becomes a challenge. There has been several reports of successful rescue missions where victims were found stranded in unknown territory that are prospected to be difficult to reach by conventional means [1, 2, 3], utilising various sensing technologies such as high-resolution cameras or thermal imaging etc.

There are many viable techniques that can provide useful information to aid search and rescue. Apart from those mentioned prior, audio signals are also one that should not be overlooked. It is common to encounter scenarios where the environment renders visual information as unusable (i.e. night, fog, dense forests etc.). However, this would not affect the projection of sound. Therefore under such conditions, audio signals could be of utmost importance in helping with localising people in an emergency and is the central theme of the 2019 IEEE Signal Processing Cup (SPCup2019).

However, audio recording using UAVs have shown to be challenging due to the high noise levels radiated from the UAV rotors. This significantly affects the quality of the audio signals to aid with any application. The noise from a UAV, received by the microphones, consists of a multitude of tones and broadband noise from a combination of the propeller, motor and structural vibration of the UAV chassis, and wind noise induced by the rotating blades. Coupling with the fact that multiple rotors operate simultaneously results in a complex nature of the UAV noise formation. Therefore, as part of gaining further insight towards UAV rotor noise, this report describes the details of the drone recordings provided for the SPCup2019 that would eventually be made freely available online for research and education purposes.

The rest of the paper is organised as follows. A description of the UAV and microphones used is given in Section 2, followed by details of the recording setting and UAV operating conditions in Section 3. Details corresponding to the UAV audio dataset is given in Section 4. The paper is concluded with some remarks in Section 5.

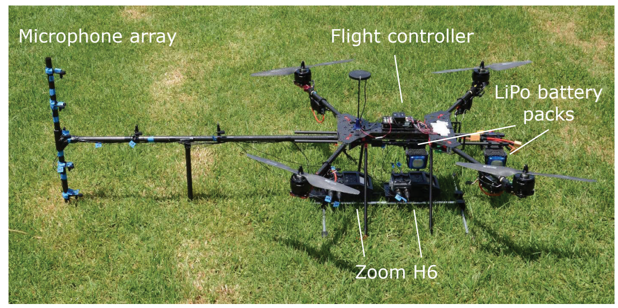


Fig. 1: Audio recording UAV overview.

2. UAV SYSTEM SPECIFICATION

2.1. UAV description

Fig. 1 shows an overview of the UAV system used in this study. The UAV is a custom build developed by Dotterel Technologies. The structure/chassis of the UAV is based off a Skylark M4-680 frame with several custom modifications made. These are outlined as follows:

- The microphone array frame is constructed from two carbon fibre tubes and a 3D printed bracket.
- The mountings for the two Zoom H6 audio recorders and the microphone array are 3D printed parts.
- Several mountings and miscellaneous parts are 3D printed to aid with stiffening the frame/chassis. This would help with shifting the vibration response of the UAV structure to a higher frequency region, thereby aiding with audio recording and subsequent noise reduction via hardware alterations.
- The utilised motor mounts are from Tarot instead of the stock Skylark mounts to again improve frame stiffness.

The Zoom H6 audio recorders and LiPo battery packs were carefully positioned so that the centre of gravity was in the centre of the UAV, which improve the UAV's stability. Details of the UAV system hardware specifications are shown in Table. 1.

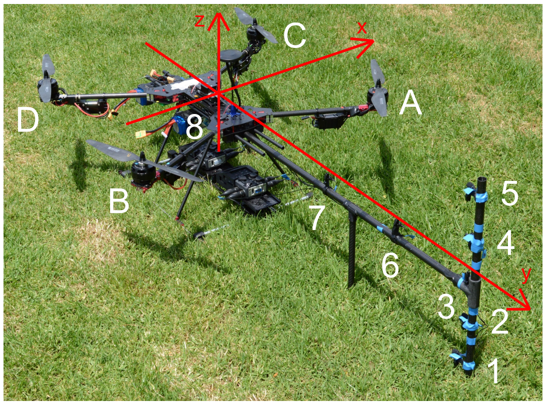


Fig. 2: Microphone array and rotor overview.

Table 1: UAV system hardware specifications.

Microphone	Røde Lavalier Lapel Omnidirectional×8
Audio recorder + preamp	Zoom H6×2
Propeller	T-Motor P15x5
Motor	T-Motor U7-V2.0 KV490
Electronic Speed Controller (ESC)	T-Motor Flame 80A
Flight controller	Pixhawk 2 Cube
Chassis	Skylark M4-680 + custom parts (see Section 2.1)

2.2. Microphone array description

Fig. 2 shows an overview of the microphone array of the UAV system. The microphones were connected to the microphone array frame using 3D printed parts as well as their standard clips. Table 2 shows the relative positions of the microphones, with the microphone number corresponding to that outlined in Fig. 2. The horizontal distance has its origin with respect to the position of microphone 8, where it is located at the centre of the UAV chassis. The vertical distance was measured with respect to the plane of the UAV propellers. The coordinate system is detailed in Fig. 2.

3. UAV RECORDING SETTING

3.1. UAV flight location

The UAV recording took place on 13th December 2018 between 9am-12pm at Dove Myer Robinson Park in Parnell, Auckland, New Zealand (-36.8493,174.7865). Fig. 3 shows a map of the location used for the UAV recordings. It is a moderate size reserve park located in an urban area. Testing was performed on a calm day with a wind speed of $\sim$ 5 km/h. While minor instances of traffic noise were to be expected, along with low levels of ambient noise, these noises are in general very difficult to avoid completely, in particular, ambient noise which is present in any outdoor environment. Regardless, the rotor noise recordings were carried out with considerations of these factors.

3.2. UAV operating condition

Rotor noise recordings were made with 1, 2 and 3 propellers, which were stacked on top of each other to create blade numbers of 2, 4 and 6. To account for variations in tests, approximately one minute long tests were performed. Each propeller combination was tested three times in a random order (i.e. Tests 1-3 tested 1-3 blades, then tests 4-6 retested 1-3 blades in a different order etc.). Details of these test configurations are outlined in Table 3. Each microphone was calibrated using a class 1 acoustic calibrator which output a 94 dB(Z) 1kHz tone.

The altitude during UAV flight was maintained at $\sim$ 2.5 m above the ground via the flight controller. The only control input from human piloting was to account and correct the small amounts of drift, in order to allow the UAV to remain reasonably stationary throughout testing.

Table 2: Microphone and rotor positions. Refer to Fig. 2 for reference origin.

Microphone	x (mm)	y (mm)	z (mm)
1	1020	0	-290
2	1030	0	-180
3	1040	0	-50
4	1030	0	20
5	1020	0	140
6	800	0	-50
7	550	0	-50
8	0	0	-50
Rotor	**x (mm)**	**y (mm)**	**z (mm)**
A	293	367.5	0
B	-293	-367.5	0
C	293	367.5	0
D	-293	-367.5	0

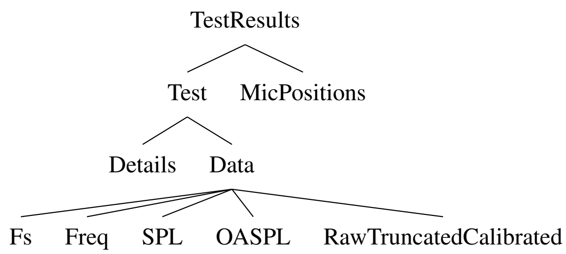
Fig. 3: UAV flight location.

Table 3: UAV recording condition, outlined by the data TestResults.Test (see Section 4.1).

Test no.	Propeller(s)
1	1
2	2
3	3
4	2
5	3
6	1
7	1
8	2
9	3

4. DATASET

4.1. Dataset structure



This section briefly explains the data structure of the submitted recordings dataset. The dataset contains the calibrated UAV rotor noise recordings along with some background information of the recordings itself.

All data is packaged in a MATLAB MAT-file, which contains the data structure *TestResults*, where the recordings can be found in *TestResults.Test* along with the coordinates of the microphone positions (described in Table 2) which are stored separately in *TestResults.MicPositions*. Within the *TestResults.Test* layer, testing conditions such as propeller number and test order are outlined in *TestResults.Test.Details*, alongside with the actual test data of each test. *TestResults.Test(test number).Data* is the main layer of the data structure. Here, the calibrated audio data, along with the sampling frequency (Fs), overall spectrum (Freq), sound pressure level (SPL) spectrum in dB(Z) and overall SPL (OASPL) in dB(Z) can be found. The audio recordings were truncated accordingly to ensure only audio of the UAV under hover is present (i.e. audio segments corresponding to take off and landing were removed).

5. CONCLUSION

A set of UAV rotor noise recordings has been provided as part of a bonus task for the 2019 SPCup. The dataset provides sets of approximately one-minute recordings over a microphone array of 8 channels, with calibration. Background information such as microphone positions, SPL etc. are also provided.

6. ACKNOWLEDGEMENT

We would like to give our thanks to Dotterel Technologies, who allowed us to use their UAV system and to submit the recordings collected to the 2019 SPCup, and Ryan McKay (University of Auckland) for his assistance in collecting and preparing the recordings.

7. REFERENCES

[1] S. McCarthy, "Chinese police use drone to rescue man lost in XinJiang desert," *South China Morning Post*, Oct. 2018.

[2] A. Lusher, "Teenage rape victim found by police drone with thermal imaging camera," *The Independent*, Oct. 2018.

[3] M. Ablon, "Crews: Both climbers from looking glass rock rescued, one taken to hospital after nearly 150-foot fall," *FOX Carolina*, Feb. 2019.