Impulse noise localization from an Unmanned Arial Vehicle

Hans-Elias de Bree, Jelmer Wind
Microflown Technologies

Abstract

The unmanned aerial vehicle (UAV) plays an increasingly important role in defense and security applications. This article considers the prospect of combining acoustic vector sensors (AVS's) with the conventional cameras to determine the moment and the direction of sounds that are reason for alarm, such as explosions and gunshots.

Acoustic vector sensors (AVS's) combine a microphone with three, perpendicularly placed, acoustic particle velocity sensors. Since the three particle velocity components are proportional to the three components of the source direction, the source direction can be determined with little or no processing in the entire frequency range of the sensor (10Hz-20kHz).

This article explores the opportunities and challenges of sound source localization using acoustic vector sensors which are mounted to a UAV. The required signal processing is considered and experimental research is presented.

1. Introduction

An Unmanned Aerial Vehicle UAV) is defined as a reusable, remotely controlled aircraft capable of controlled, sustained, level flight and powered by propulsion systems. This article focuses on fixed-wing miniature UAV's, which have a wingspan of around 1.5m. An example is the EMT Aladin, which is used by the German armed forces.

The narrow viewing angle of UAV cameras is very well adapted to observe a single object, but the UAV cannot respond to threats outside of the camera's view. Hence, an acoustic system is a great asset, making it able to respond to explosions and weapon sounds from any angle as well as avoiding other aircraft.

An acoustic system on a UAV also has the potential to perform much better than an acoustic system on the ground, because the sound does not have to travel around as many obstacles such as trees or even mountains and the signals do not suffer from ground damping [1]. The other advantage is that the range of sources on the ground can be directly deduced from the direction of arrival of the sound wave. However, it is a challenge to achieve this quality in practice because of propeller noise and airframe scattering(see section 3).

This article is built up as follows. Section 2 outlines the previous research on acoustic source localization from aerial platforms, with an emphasis on the difference between acoustic vector sensors and conventional microphones. Section 3 explains the experimental research and signal processing. Conclusions are drawn in section 4.

2. AVS's compared to pressure arrays

Traditionally, the direction of sound sources is determined using an array of spaced microphones. The size of the array determines the frequencies for which direction can be determined. The lowest frequency is determined by the array size, which is limited by the size of the vehicle. By rule of thumb, a 4 microphone UAV-based system can determine direction in about an octave, somewhere in the 10^2-10^3Hz range, depending on the sensor spacing.

Since acoustic vector sensors directly measure the source direction in the form of the acoustic particle velocity vector, the source direction can be obtained in a much wider frequency range (10Hz-20kHz).

3. Experimental study

This section considers the experiments which have been performed. The accuracy is considered and the propeller removal software is explained. Experimental results of a flight test are presented to show the promise of UAV-based source localization.

The accuracy of source localization is deteriorated somewhat by reflections from the UAV. To minimize this effect, the sensor is placed ahead of the nose of the aircraft (see figure 1). The error has been studied for a grid of azimuth and elevation angles and an example is given in figure 3.

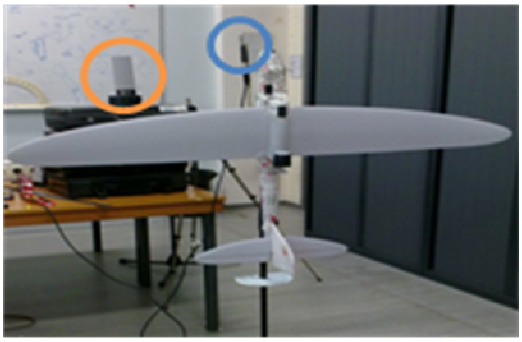

Figure 1. *Experimental setup. Orange: loudspeaker, blue: Acoustic Vector Sensor*

The propeller sound of the UAV used in the experiments is significantly louder than that of military UAV's and it is usually dominant over the other sound sources. However, the propeller sound can be removed by first estimating the blade passing frequency and then applying a comb filter to remove the propeller ground tone and its higher harmonics. With this processing in place, the results are comparable to the results with the engine turned off (see figure 2).

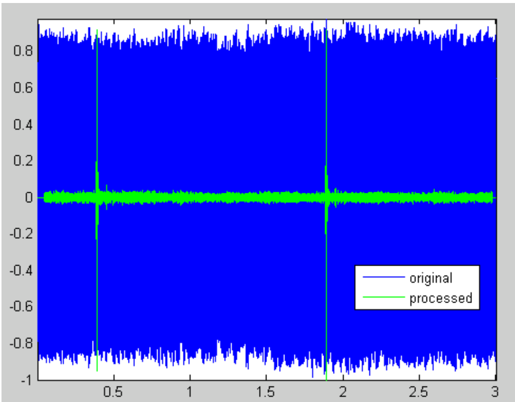

Figure 2. Effect of the propeller removal filter.

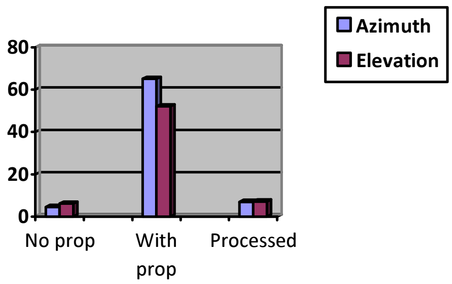

Figure 3. Experimental results of the accuracy of acoustic source localization.

A flight test is performed to demonstrate the developed capabilities (see figure 4). The measurement data is recorded on a flash drive and it is post-processed. To simulate gun shots, two 0.5m wooden planks are clapped together, yielding a sharp impulsive noise.

Figure 4. *Flight test. UAV flies over a person clapping.*

The time-frequency plot of the measurement data is depicted in figure 5. It can be seen that, while flying, the engine is turned on around second 291 and turned off around second 294. Since propeller removal is not used here, the propeller overshadows the measurement data. When the engine is turned off, the claps dominate the measurement data, showing that the used wind cap is sufficient for this UAV.

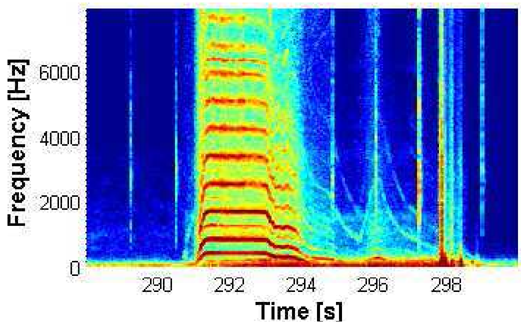

Figure 5. *Time-frequency plot of the UAV*

4. Conclusions

Given the research presented in this article, it can be concluded that the source direction can be identified in the frequency range of 10Hz-10kHz in flying conditions. This makes acoustic vector sensors (AVS) a very promising sensor for Unmanned Arial Vehicles (UAV's).

Acknowledgements

Swathi Krishna of Delft University of Technology vastly improved the propeller removal algorithm and performed the acoustic testing presented in figure 3. Her contributions are gratefully acknowledged.

Bibliography

[1] D.N. Robertson and Tien Pham. *Acoustic Sensing from small-size UAV's.* In the proceedings of SPIE Vol. 6562 656208-1 (2007).