ACOUSTIC SOURCE DETECTION, CHARACTERIZATION, AND LOCALIZATION FROM DIFFRACTING MICROPHONE ARRAY

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The diffracting microphone array and node processor of a networked acoustic source localization system shall be demonstrated. The node processor is capable of detecting, classifying, and estimating a bearing on the top two signals above the noise in an acoustic environment utilizing less than a dozen microphone elements on a diffracting array.

INTRODUCTION

The ability to detect, characterize and localize acoustic sources is discussed and demonstrated. Motivation for this is for the detection and surveillance of dynamic sound-emitting sources. Significant research and implementation of this ability has occurred in the fields of radar and sonar, but airborne acoustics presents its own specific sets of problems such as limited propagation distance, limited array size, etc. A working system could provide situational awareness for mission-critical personnel, and therefore the arrays shown here are inspired by man-wearable application.

The sub-system demonstrated here, called a node processor, is part of a larger networked system that can track the acoustic sources. The node processor consists of a diffracting microphone array, mic power supply with shaping and anti-aliasing filters, data acquisition system and embedded computer. Diffracting arrays have been a subject of research, again inspired by the man-wearable platform. This research has proven that diffracting arrays are more sensitive than their free-field counterparts, since the diffracting body enhances the magnitude and phase differences seen by the mic array.

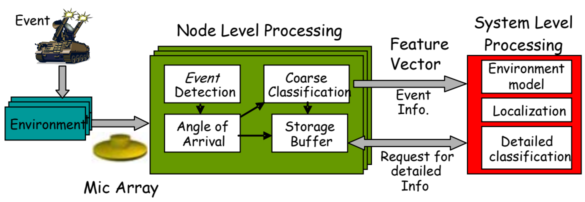

Figure 1: Networked acoustic array and tracking system.

1 SYSTEM DESCRIPTION

The full system is comprised of a number of diffracting arrays (“the sensor”) each coupled to an associated node processor, and a fusion center, as seen in Figure 1. The fusion center performs most of the calculations to distil time domain acoustic data to a “feature vector”, which contains estimates of the bearing and characteristics of the sound sources, along with the node ID, Location (GPS), Orientation (Compass), Detection time (Clock). Current characteristics are whether the event is tonal, impulsive, or broadband, and the 1/3rd octave levels.

1.1 Diffracting Array

The employment of diffracting arrays was originally motivated by the use of the human head as a sensor mount. Subsequently, diffracting arrays have been shown to be superior to free-field arrays.

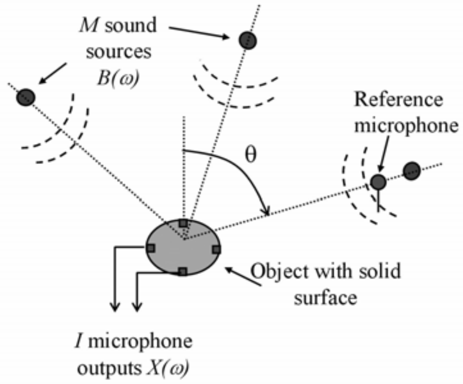

Figure 2. Acoustic Diffracting Array (ADA) consists of microphones distributed around a diffracting object.

1.1.1 Cylindrical and Spherical Arrays

Analytically-derived sensor platforms include cylindrical and spherical arrays leveraging mathematical models which predict empirical performance.

1.1.2 Headset and Helmet-Halo Arrays

Man-wearable platforms are more complex geometrically, and therefore more difficult to model. An experimental based technique to capture the diffraction effects has been implemented.

1.2 Node Processing

The node processor runs a detector at all times. Upon detection of signal above the noise, a two- and three-dimensional characterization is calculated. The subsequent bearing estimation (localization) may be assisted by characterization properties.

1.2.1 Detection

Detection of an event occurs when the instantaneous 1/3 octave band levels are greater than the running average levels.

1.2.2 Course Characterization

Characterization is used by the fusion center for correlating reports from numerous nodes for the purpose of triangulation. Impulsive events are found by taking a single microphone signal and dividing that signal by the median of the median value of the signal: $imp(\mathbf{x}) = \frac{|\mathbf{x}|}{median(|\mathbf{x}|)}$. In the frequency domain, tones will appear much the same way as impulses will in the time domain: $ton(\mathbf{X}) = \frac{|\mathbf{X}|}{median(|\mathbf{X}|)}$.

1.2.3 Localization

If X is the vector of sound pressures measured by I microphones at frequency ω and B is a vector of sound pressures arriving from M directions at frequency ω then X and B are related by an $I \times M$ matrix of transfer functions G which describe the way sound diffracts around the object to the microphones. Where $g_{im}(\omega)$ is the transfer function between the sound arriving from direction m and the i^{th} microphone. These equations are related as follows: $X = [x_1(\omega) \ \cdots \ x_I(\omega)]^T$, $B = [b_1(\omega) \ \cdots \ b_M(\omega)]^T$, $X = GB$, $G = \begin{bmatrix} g_{1,1}(\omega) & \cdots & g_{1,M}(\omega) \\ \vdots & \ddots & \vdots \\ g_{I,1}(\omega) & \cdots & g_{I,M}(\omega) \end{bmatrix}$. Currently, this matrix was measured experimentally in an anechoic chamber and used to find an optimal set of localization filters G^p (pseudo inverse of G) for sources located on the azimuth plane: $B \approx G^p X = \left([G^H G + \alpha * norm(G) I]^{-1} G^H\right) X$ where 'H' denotes the Hermitian or conjugate transpose, α is the conditioning factor, *norm* is the matrix norm (2) and I is the identity matrix.

When a node processor is used within the larger global localization system, each node shall be outfitted for six-degree of freedom position tracking. For outdoor applications, this implies a GPS sensor integrated with compass and inclination sensors.

1.3 Fusion Center

The Fusion center is a Bayesian belief network that performs the following functions in order:

1. Detection Association: Associates detections from two different nodes into a single Observation
2. Observation fusion: Combines multiple Observations to estimate location and time of Event
3. Event to Object association: Determines whether an Event came from a known Object and if not creates new Object
4. Track motion of Objects

2 RESULTS

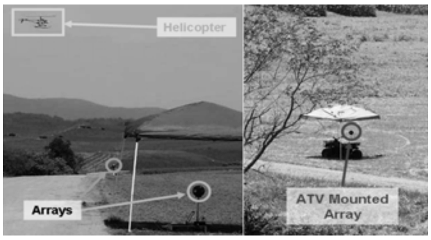

Figure 3. Experimental Setup to Track helicopter.

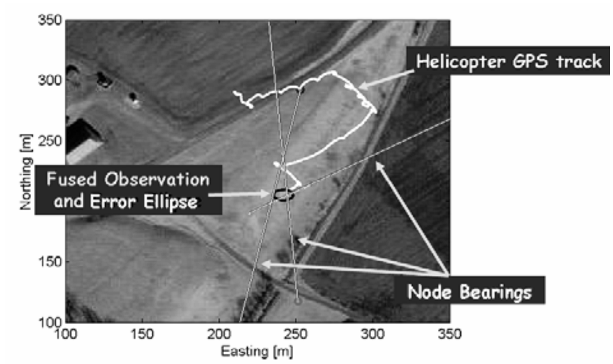

Figure 4. Experimental Results of helicopter track.

3 CONCLUSIONS

A networked system of node processors with acoustic diffracting arrays has been shown to effectively track a noise source in real-time.

4 DEMO DESCRIPTION

A single-node diffracting microphone array will demonstrate node processing with graphic visual display of localization bearing and textual visual display of feature vector. The single node sensor will track the top two signals within a noisy environment.

SELECTED REFERENCES

[1] Johnson, M., Carneal, J., Mennitt, D., and Gillett, P., "Noise Source Tracking Using Multiple Diffracting Arrays," Sixth International Symposium on Active Noise and Vibration Control, Adelaide Australia, 18-20 September 2006.

[1] Johnson, M., Carneal, J. and Gillett, P., "Comparison of a Diffracting and Non-Diffracting Cylindrical Microphone Array," *ICSV13, Thirteenth International Congress on Sound and Vibration*, Vienna, Austria, July 2-6, 2006.