Acoustic Source Localization Using the Acoustic ENSBox

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ABSTRACT

Field biologists use animal sounds to discover the presence of individuals and to study their behavior. The recent development of new deployable acoustic sensor platforms presents opportunities to develop automated tools for bio-acoustic field research. In this work, we demonstrate a real-time wireless sensor system that implements an AML-based source localization algorithm. We will demonstrate a system that is easy to set up and that can localize a whistle in the demonstration area in real time. This demonstration will use the techniques we described in our corresponding paper [1].

Categories and Subject Descriptors

C.3 [**Special-purpose and application-based systems**]: Signal processing systems

General Terms

Algorithms, Experimentation, Measurement

Keywords

Bioacoustics, distributed signal processing, acoustic source localization, wireless sensor networks, AML

1. MOTIVATION

Field biologists use the vocalizations of animals to identify individuals, census species and to study the dynamics of acoustic communication [3, 7]. However, even experienced field biologists have difficulty accurately identifying and locating species acoustically, and most researchers are unable to identify more than a few distinctive individuals. Some acoustic phenomena such as alarm calling (where individuals produce specific vocalizations in response to predators [2]) are relatively rare, and are thus difficult to study, while others, such as duetting (where two individuals interdigitate their vocalizations [6]) are extremely difficult to properly describe. Thus, field research of natural populations will benefit from the use of embedded sensor arrays that are constantly alert, and that are able to detect acoustic events, localize the sound's source, and identify the individual or species producing the sound.

In this demo, we show how our system can collaboratively localize a source at a particular frequency in real time. In the deployment described in [1] we used this system to localize marmot calls. For the purposes of the demo, we have instead tuned the system to listen for a particular whistle which we can generate indoors during the demo. The system will then use the techniques we describe to localize the source.

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2. OVERVIEW OF APPROACH

Distributed source localization is a broad and active research area, and a diverse set of solutions have been proposed. Our approach has focused primarily on "cross-beam localization", in which DOA estimates assessed at a distributed set of locations are combined to estimate the most likely location of the source. Our implementation employs a distributed set of small "sub-arrays", each capable of independently detecting the target signal and producing a DOA bearing estimate. The crossing of these bearing estimates are then combined to produce an estimate of the most likely source location.

In the next sections, we give a brief overview of this implementation, and highlight some key features of the platform.

2.1 DOA-based localization using sub-arrays

Fig. 1 shows a high level diagram of a DOA-based localization system. To apply this method, we deploy a collection of sub-arrays surrounding a target of interest. The sub-arrays are typically deployed over a wide area relative to the size of each sub-array. In this paper, we use the Acoustic ENSBox platform [5] shown in Fig. 2 and described in more detail in Section 2.2. Each node in the system hosts a 17 cm tetrahedral microphone sub-array, rotated to form an 12 cm square when viewed from above. In outdoor settings, these sub-arrays are typically deployed at least 10–20 m apart. Given the constraints of an indoor demo context, the laydown will be substantially more compressed during the demo.

After we set up the nodes and turn them on, the sub-arrays will automatically self-calibrate to determine the relative positions and orientations of the sub-arrays in the system. Next, software on the nodes will begin implementing the detection and localization algorithms.

The detection software on each node performs a streaming analysis of the acoustic data in real time, identifying likely animal call events. Whenever any individual node's call detector is triggered, a radio message is sent to trigger all the nodes in the system to start recording that event and queue it for further processing. This approach enables optimization of the detection threshold such that only the nearest node to a source need to be triggered.

Once identified, segments of audio containing calls are an-

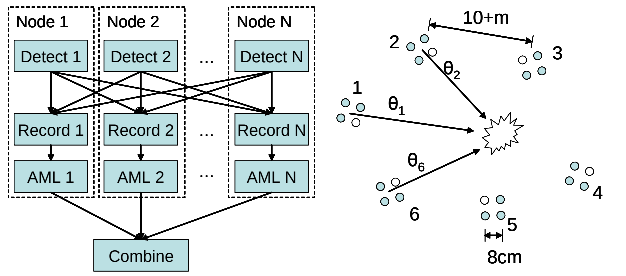

Figure 1: Block diagram of a DOA-based localization system.

alyzed using an Approximate-Maximum-Likelihood (AML) algorithm [4]. This algorithm uses the relative phases of signals recorded at the microphones in a given sub-array to determine a likelihood metric describing the likely bearing to the source. These metrics are then collected centrally, placed on a map according to the location and orientation of each sub-array, and combined into a 2-D pseudo-likelihood map of the source location. This map is formed by projecting each likelihood metric outwards from each node to form the pseudo-likelihood of a source at every point in the 2D space. Figure 3 shows an example of this approach for a localization experiment of a marmot acoustic source in an open meadow field in Colorado.

2.2 The Demo

The demo includes 8 Acoustic ENSBox [5] nodes, each an independent wireless processor hosting a sub-array. The ENSBox was specifically designed to support this type of application with low deployment overhead. In particular, the ENSBox supports automated self-configuration through the existing acoustic sensor interface that can compute relative array positions to within 10 cm, and estimate array orientation to within 1.5 degrees [5].

The software written for the demo will show how the ENSBox provides a powerful application development platform. The software will detect the target whistle, determine DOA to the source from multiple points, and forward that information to a central point, where the data will be fused into a location estimate and displayed for the user to see.

Figure 2: The Acoustic ENSBox Platform.

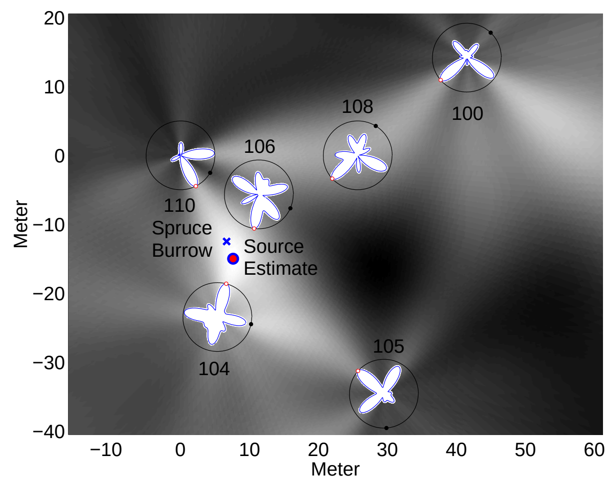

Figure 3: A pseudo-likelihood map generated based on the log-likelihood of all nodes, taken from the compact deployment. Main lobes are denoted by small dark gray circle on the log-likelihood ring. Black dots points to the array zero degrees.

During the demo, we will be happy to show details of the implementation to interested visitors.

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