Title

Self-Calibrating Distributed Acoustic Sensor Array: Localization of Bio-acoustic Sources (SYS 3)

Authors
Lewis Girod
Martin Lukac
Andreas Mantik
et al.

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Self-Calibrating Distributed Acoustic Sensor Array: Localization of Bio-Acoustic Sources

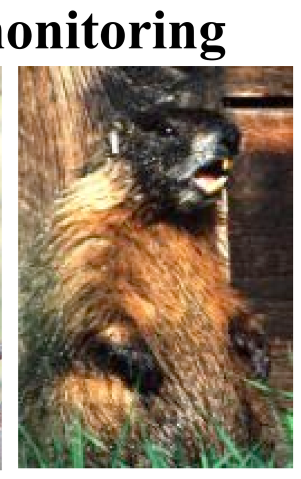
Lewis Girod, Martin Lukac, Andreas Mantik, Vlad Trifa, Travis Collier, Deborah Estrin
CENS Systems Lab – http://research.cens.ucla.edu

Introduction: Self-configuring platform for collaborative acoustic monitoring

Passive Acoustic Monitoring Applications

- **Detect, classify, and localize targets using sound**
- **Minimize disturbance to targets and environment**
- **Suitable for animal behavior monitoring**

Vocal social animals:
Woodpeckers
Marmots
Wolves
and many more

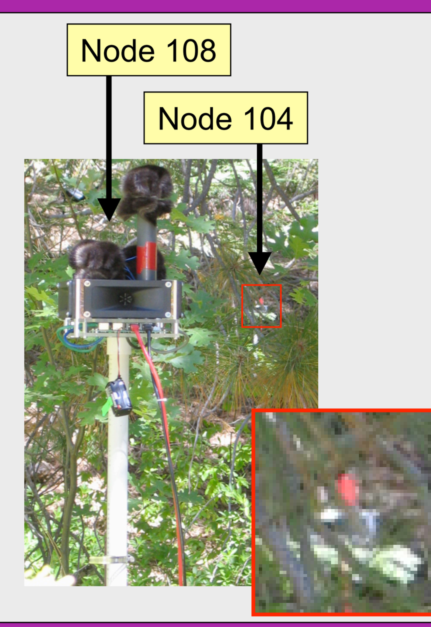




System architecture

- **Network of acoustic arrays distributed in field**
  - Four microphones in a tetrahedral array
  - PXA255 platform, 2.6 Linux kernel
  - VXPocket 440 PCMCIA 4-channel 48kHz sound card
  - Arrays are wirelessly connected via 802.11
- **Acoustic monitoring through collaborative processing**
  - Animal vocalization is detected by nearby acoustic arrays
  - All nodes are triggered to record data
  - Sound is classified and DOA is estimated from phase comparison
  - Animal location is estimated through collaboration of multiple arrays

Problem Description: Challenges in collaborative acoustic monitoring

- **Self-calibration and self-localization are required**
  - Each node's location is needed for target localization
  - Difficult to obtain manually, especially in dense-foliage
  - Localization info must be maintained when bumped or moved
  - Requires precise time synchronization
- **High data rates are required**
  - 4 channels of 48kHz 16 bit data
  - Very low power systems such as motes are not suitable
  - Transmitting/collecting all data is not feasible



- **Must be truly "field-deployable"**
  - Small size and physically robust to transport
  - Highly weather-resistant
  - Simple to setup and low maintenance
- **Flexibility is critical**
  - Algorithms, especially detection, must be tunable in the field
  - Precise deployment geometry cannot be determined in advance
  - Conditions such as network connectivity, environmental noise, and target signal probability will change over time

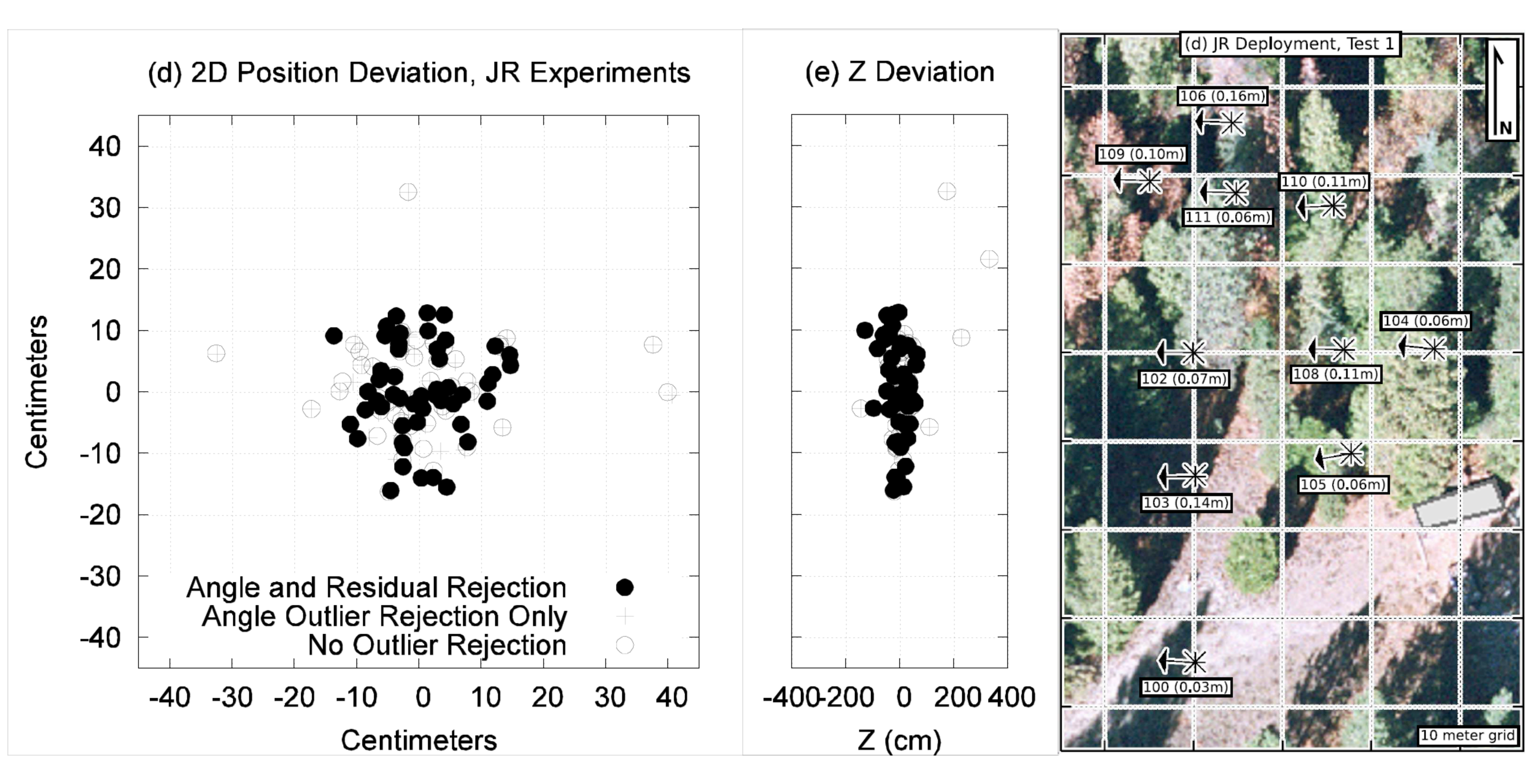
System Design: Acoustic ENSBox: a portable acoustic monitoring node

Staged signal processing model

- Detection of possible events (low false rejection rate)
- Signal alignment, correlation based between nodes
- Time-of-flight localization estimate using alignment lags
- Single node DOA (search space limited by TOF estimate)
- Precise localization from combining DOAs across nodes
- Signal Enhancement / Beamforming
- Classification and data association

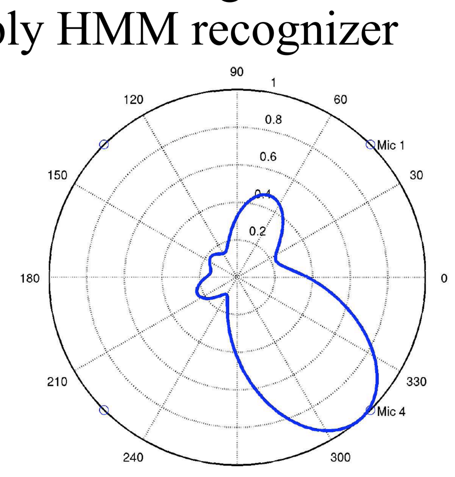
Self-Localization

- Based on time of flight (TOF) of acoustic signals
- Deviation from ground-truth results from experiment at the James Reserve in the San Jacinto mountains of California

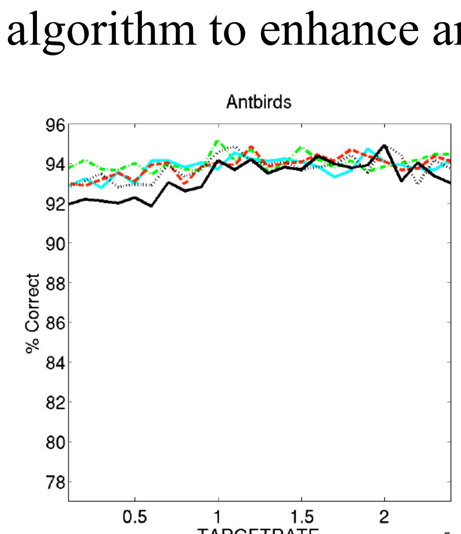


Signal Enhancement & Classification

Applied AML bearing estimation algorithm to enhance antbird calls and apply HMM recognizer



AML Bearing Estimator



Antbird Species Recognition, for varying HMM parameters

Software System

- **Buffered Continuous Sampling Interface**
  - Allows online detection and post-facto processing
  - Abstracts away non-deterministic system delays, such as network latency
- **Multihop Time Conversion**
  - Nodes have independent clocks and maintain time conversion parameters
  - Service provides pair wise time base conversion and global event time service
- **Collaborative Network Primitives**
  - Flood service with hop-by-hop time conversion
  - Reliable state dissemination mechanism with publish-subscribe interface
- **Location and Orientation Self-Calibration**
  - 3D location and orientation of sensor array

DOA based target localization

- Combined DOA from a wild marmot alarm call at the Rocky Mountain Biology Laboratory in Colorado