Title
Sensor Arrays for Acoustic Monitoring of Bird Behavior, Diversity

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The natural environment is often a cacophony of noise – Current acoustic observations rely on directional microphones to minimize noise, but are clumsy and require actively locating and pointing at a single source

Problem Description: Observing Bird Behavior in the Environment

Introduction: Embedded Sensors for Population Biology and Ecology

The Promise of Sensor Networks

“Increasingly, a spatially extended network of multivariable intelligent sensor arrays are seen as revolutionary tools for studying the environment. The temporally and spatially dense monitoring afforded by this technology portends a major paradigm shift in environmental science and engineering. Realizing this vision will require new cyber-infrastructure capabilities, methodologies, middleware, deployed infrastructure and a community of multidisciplinary scientists and engineers equipped to pose newly-enabled scientific questions.”

- 2003 NSF workshop (www.LTERNET.edu/sensor_report)

Goals

- Birds as a first application
  - Well studied
  - Important for biodiversity
- Automated acoustic observation
  - Identify species and/or individual
  - Localize (determine the point in space a sound is coming from)
  - Correlate with abiotic observations
  - Observe social interactions among individuals
- Develop and test newly enabled hypotheses

System Design: Acoustic Monitoring Sensor Arrays

Field Locations

- UC Hasting Reserve
  - Definitive studies of highly social Acorn Woodpeckers were conducted here
  - All individuals known and banded
  - Several neighboring groups allows for inter-group behavior studies
- UC James Reserve
  - Already highly instrumented, including several large CENS deployments, weather monitoring, and existing Acorn Woodpecker monitoring
  - Full time staff is extremely knowledgeable and involved with sensor array technology
- Montes Azules Biosphere Reserve, Chiapas, Mexico
  - Neo-tropical rainforest with a large diversity of species

Introduction: Observing Bird Behavior in the Environment

Problem Description: Observing Bird Behavior in the Environment

Filtering, Identification, and Localization

- The natural environment is often a cacophony of noise
  - Current acoustic observations rely on directional microphones to minimize noise, but are clumsy and require actively locating and pointing at a single source
- Rare but important events are often missed
- Birds are often hidden from view, and hard to observe in many environments

Observing Social Interactions

- The social context of vocal behavior requires tracking the location and calls of multiple birds simultaneously
- Calls and songs are typically classified only as territorial or mating, but many species exhibit a variety of vocal behaviors beyond this that are not well understood

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System Design: Acoustic Monitoring Sensor Arrays

Develop the ability to:

- Filter out noise
  - Characterize the acoustic background
  - Use information from identification and classification to focus on sounds of potential interest
- Identify
  - Identify species of antbirds and wrens at field stations in Chiapas
  - Identify individual acorn woodpeckers at the UC Hastings Reserve and James Reserve
- Correlate the presence of species/individuals with temporal abiotic information
- Localize
  - Use beamforming techniques to determine the point in space a sound is coming from

Technologies

- Hidden Markov Models for Identification
  - Successful in identifying individual Acorn Woodpeckers
- Localization and Beamforming
  - Direction of Arrival (DOA) localization using narrow band sources has been successful
  - 4 microphone sensor nodes capable of determining DOA have been developed by CENS [picture to right]

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