Acoustic ENSBox: a Platform for Collaborative Acoustic Environmental Monitoring

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Introduction: Self-configuring platform for collaborative acoustic monitoring

Passive Acoustic Monitoring Applications

- Detect, classify, and localize targets using sound
- Free of interference to targets and environment
- Suitable for animal behavior monitoring

Wolf Howls

Woodpecker Knocks

System architecture

- **Network of acoustic arrays distributed in field**
  - Four microphones in a square array
  - Stargate, platform, 2.6 Linux kernel
  - VXPocket 440 PCMCIA 4-channel sound card
  - Arrays are wirelessly connected via 802.11
- **Acoustic monitoring through collaborative processing**
  - Animal vocalization is detected by nearby acoustic arrays
  - 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

Collaborative monitoring system

- **Staged signal processing model**
  - Early stages filter out periods where there are no events
  - Later stages detect, classify, and compute DOA
  - Collaborative phase: data association and localization
- **Precise synchronization between sampled channels**
  - Required for accurate direction of arrival (DOA)
  - Need to overcome limitations of VXP hardware

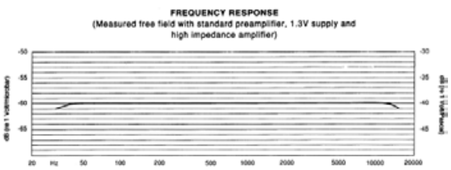
Self-calibration

- **3-D location and orientation of microphone arrays**
  - Required for 3-D target localization via bearing-crossing
  - Difficult to obtain and maintain manually in field
  - Can change if system is bumped or moved
- **Acoustic localization system**
  - Based on time of flight (TOF) of acoustic signals
  - Requires precise synchronization between nodes and from sample clock to node CPU clock

System Design: Acoustic ENSBox: a portable acoustic monitoring box

Prototype Platform design

- **Main Objectives**
  - Synchonized acoustic sampling
  - 12-24 Hour lifetime on batteries
  - Self-contained, water-resistant enclosure
- **Hardware Features**
  - Stargate CPU
  - 4 Channel VXP440 sampling card (16 bit/48K)
  - Internal LI+ battery pack
  - 802.11 card with external antenna
  - Audio mic preamps (TI OPA726) and speaker amplifier (COTS computer speaker)
  - RTI 1207A condenser mic capsule
- **Acoustic performance**
  - Speaker/Mic/Sampling system response
  - Preamp and microphone module are selected to have a very flat frequency response



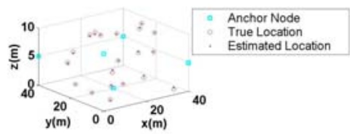
[1] L. Girod, J. Elson, A. Cerpa, T. Stathopoulos, N. Ramanathan, D. Estrin, "EmStar: a Software Environment for Developing and Deploying Wireless Sensor Networks", in Proceedings of USENIX 04.

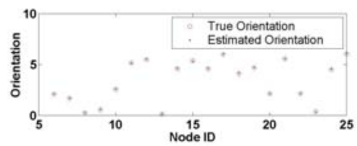
[2] Lewis Girod, Martin Lukac, Andrew Parker, Thanos Stathopoulos, Jeffrey Tseng, Hanbiao Wang, Deborah Estrin, Richard Guy, Eddie Kohler, "A Reliable Multicast Mechanism for Sensor Network Applications", *CENS Technical Report #48* , April 25, 2005 2005.

[3] Lewis Girod, Vladimir Bychkovskiy, Jeremy Elson, and Deborah Estrin, "Locating tiny sensors in time and space: A case study", *In Proceedings of the International Conference on Computer Design (ICCD 2002)*, Freiburg, Germany. September 16-18 2002. (Invited)

Preliminary Results

- **Acoustic Ranging Component**
  - In-lab tests with 4 nodes
  - In line of sight (LOS) conditions, achieves accuracy to a centimeter
  - Multipath and obstructions can introduce larger errors which can be persistent aspects of the environment [3].
  - Still room to optimize detection algs
- **Localization Component**
  - Simulation tests in MatLAB:





- **System Components**
  - EmStar environment [1].
  - Time synchonized sampling and sensor device infrastructure, supporting staged event driven processing [4].
  - Network support for collaboration via multi-hop wireless network [2]

[4] Hanbiao Wang, Lewis Girod, Nithya Ramanathan, Deborah Estrin and Kung Yao, "A Platform for Collaborate Acoustic Signal Processing" CENS Technical Report 00XX, November 28, 2004