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Title
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Center for Embedded Networked Sensing

VoxNet - an end-to-end system to support on-line, real-time bioacoustics research

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Introduction: Processing challenges in bioacoustics research

Studying acoustic communication

- **Dynamics of acoustic communication**
  Bioacoustics research field has interest in understanding behavior of animals/birds through vocalizations; e.g. ***marmots***, ***antbirds*** and ***wolves***
- **Three important challenges**
  Census, ***classification*** and ***localization*** are three important aspects of studying animal or bird behavior from vocalizations
- **Data processing**
  Typically these observations are made manually or using suitably configured ***automated event detectors*** which pick out events of interest for further processing

Data gathering/processing approaches

- **Data gathering**
  - Scientists would traditionally use ***manual observation*** or an ***array of wired microphones*** to record acoustic data over area of interest
  - Also , Acoustic ENSBox network (IPSN 2007) allows wireless, time synced data gathering, OR ***on-line automated event detection***
- **Data processing**
  - Wide variety of standalone/integrated tools – no one specific approach
  - Matlab, Labview, Audacity, Sox, Baudline, Raven, Ishmael, RTS/SIGNAL

Problem: Using a purely off-line or on-line approach can be problematic

Off-line processing

•Scientist cannot interact with data processing/gathering in the field

•Potentially can miss useful interactions based on feedback of system (i.e. take a photo based on localization results)

•Current off-line processing tools vary in generality and complexity

•Using more powerful recording tools creates very large datasets – for instance, 8 hours continuous recording @ 48KHz = 10GB/Node (typically 8 Acoustic ENSBoxes/deployment)

On-line processing

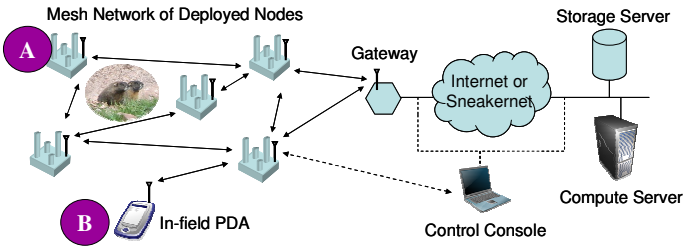
•Potentially huge data sets can be reduced as data is recorded to make processing more manageable, using on-line event detectors

•However, reducing data set may reduce its usability – badly configured detectors may yield bad results (missed detections for example, which is problematic for census)

•The data lost may have been useful for another purpose, for example to identify other animals/birds present in recordings

VoxNet: A system to support bioacoustics research both on-line and off-line

Overview of proposed architecture



Hardware for distributed acoustic sensing

- **Existing Acoustic ENSBox**
  - 2x400 MHz PXA processors, 64 MB RAM, 16GB CF
  - 802.11 wireless, 4 x 48KHz audio chans
  - 20.8 x 14.4 x 9.2 cm, 2.3 kg, 7.5W consumption
  - Supports time sync, self-localization
- **Proposal for new h/w platform (VoxBox)**
  - 1x600 MHz PXA processor, 128 MB RAM, 16GB CF
  - 10x increase in energy efficiency, 20x comms. Range
  - 19 x 14.5 x 5.4 cm, 0.75 kg, 0.75 W consumption

A

Queries as Applications

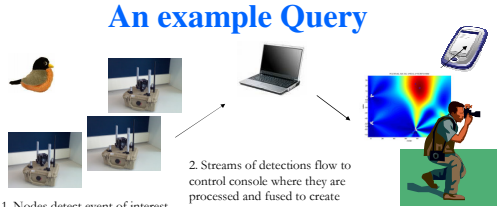
• Nodes have a set of 'core' functionality – self-localization, time sync, routing, archiving

• Actual 'applications' are queries, which are programmed using Wavescript (MIT)

• Wavescript takes macro-programming approach, abstracting out networking issues for the programmer

•Queries can be run over offline data also

An example Query

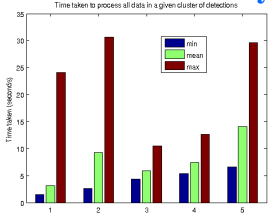


1. Nodes detect event of interest, send audio data back to sink over wireless channel

2. Streams of detections flow to control console where they are processed and fused to create streams of position estimate maps

3. Scientist reads position estimate from map displayed on PDA to direct observation in-field

End to end latency



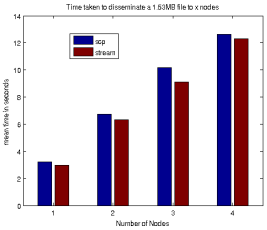
The time taken to process a cluster of detections corresponding to a single vocalization. Graph was re-created off-line from data log using a different clustering algorithm than used in the field (experimentation from RMBL, CO).

Dynamic reconfigurability

• Queries can be dynamically replaced during system run-time, to allow most flexibility

• Queries are compiled at the Control console, and disseminated over reliable publish/subscribe streams to all nodes simultaneously

•Performance is comparable to manually copying binary files to each node in turn



Mean time taken to transfer a 1.5MB file to a certain number of nodes over one hop. A bar is the mean of 5 tries.

B

Visualization of data

• Using PDA in-field, scientist can 'subscribe' to streams which run in the network (node, sink, network), and visualize the data that is coming from them (see example Query above)

• Visualizers can be dynamically plugged into data streams – for example, a time domain visualizer for audio data, or a polar plot visualiser for DoAs