Distributed Sensor Signal Acquisition, Analysis, and Representation for Environmental Surveillance Monitoring Applications (ESM)

By: Yuji Yunes, MS Student

Advisor: Prof. Domingo Rodriguez

Automated Information Processing Laboratory (AIP) University of Puerto Rico, Mayagüez Campus (UPRM) March 14, 2007



Problem Formulation

- There is a need to explore new and efficient ways for the monitoring and surveillance of the environment.
- Two types of monitoring: Remote vs. In-situ
 - In-situ Monitoring: physical contact between sensor and phenomenon (e.g. Microphones, Thermometers, Wireless Sensor Networks WSN, etc)
- Can acoustic signals (sound) be used for ESM applications?
 - Sound is an excellent carrier of information
 - Omnidirectional propagation
 - Light absence immunity
 - Low cost hardware
 - May exploit new tech standards such as High Definition (HD) Audio



Proposed Solution: Acoustical Map (A-Map)

How we extract information relevant to an user? Use an A-Map

Acoustical Map (A-Map) Foundations

Acoustical Beamforming

A computational signal processing tool utilized to estimate important acoustic parameters such as Direction of Arrival (DoA) from a number of sources using a microphone array

Developing algorithm: DFT-Beamforming

Cyclic Short-Time Fourier Transform CSTFT (a TF Tool)

A Time-Frequency technique used to analyze how the frequency content of a signal changes over time.

Given a signal $x[n] \in l^2(Z_N)$ And a window $v[n] \in l^2(Z_N)$ The CSTFT is computed as: $S_{x,v}[m,k] = \sum_{n=0}^{N-1} x[n] \cdot v[\langle m-n \rangle_N] W_N^{kn}$ $x_m[n] = x[n] \cdot v[\langle m-n \rangle_N]$ $S_{x,v}[m,k] = DFT\{x_m[n]\} = X_m[k]$

 $k,n,\in Z_N$; $W_N^{kn} = e^{-j\frac{2\pi kn}{N}}$

Sensor Fusion

Signal processing technique for combining data from different types of sensors (e.g. temperature, humidity, solar radiation) with acoustic signal data in order to reduce measurements errors and to help improve detection and estimation operations.



Acoustical Map (A-Map) Depiction

- An A-Map result produces imaging representation of detected acoustic sources (e.g. coqui and/or bufo lemur frogs, native birds, human-made sounds, etc) for time-frequency analysis as well as a map of their estimated location in an environmental observatory.
- The A-Map tool is being designed to interact with the WALSAIP Visual Terrain Explorer Application.



 Inside each blue-box, a master sensor node (MSN), may exist a configuration of DSP's and/or FPGA's, with an embedded computer to deal with the processing tasks.

ALSAIP

A-Map Tools and Development Environment

- MATLAB is being used for development and testing of the algorithms.
- A MATLAB-based A-Map is currently under development.
- TI 6713 (floating point) DSPs with Code Composer Studio IDE.
- Xilinx Virtex 4 and Virtex II-Pro FPGAs with ISE and System Generator v8.1.
- Crossbows mica2, mica2dot, and micaZ motes (WSN).
- Tmote Invent and Sky motes (WSN).
- Gumstix Embedded PCs.
- Elite PMI8M w/Pentium M 1.6G Embedded PC.
- Data Translation DT-9816 Data acquisition boards.

