1 Problem Formulation

There is a need to explore new and efficient ways for the monitoring and surveillance of the environment. Remote Monitoring and Surveillance (not-physical contact between sensor and phenomenon e.g. Satellite, Aircraft, Space Craft). In-situ Monitoring and Surveillance (physical contact between sensor and phenomenon e.g. Microphones, thermometers, barometers, WSN).

Sound is an excellent carrier of information, nevertheless in the “computing world” the information extraction of acoustics signals is not that straightforward.

Can acoustic signals be used for Environmental Surveillance and Monitoring (ESM) applications? We think yes! The “how” and “why” questions are detailed next.

2 Proposed Solution

Why use acoustic signals for ESM applications?
- Sound is an excellent carrier of information
- Low cost hardware
- Omni-directional propagation
- Exploit new technology (HD audio)
- Challenging and interesting problem

How we extract information relevant to an user?
Using Signal Processing and Mathematical techniques such as:
- Time-Frequency representation
- Acoustical Beamforming
- Sensor Fusion
- Time series analysis

3 Theoretical Framework

Time-Frequency representation: The Cyclic Short Time Fourier Transform
Given a signal \( x[n] \in l^{2}(\mathbb{Z}) \) and a window function \( \psi[n] \in l^{2}(\mathbb{Z}) \)

The Cyclic Short-Time Fourier Transform (CSTFT) is computed as follows:

\[
S_{\psi}(m,k) = \sum_{n=-\infty}^{\infty} x[n] \psi[n-m] e^{-j2\pi mk/n}
\]

Where \( W_{n,m}^{k} = e^{-j2\pi mk/n} \)

If we let \( x_{\psi}[n] = \psi[n] e^{-j2\pi mn/n} \), then we could write

\[
S_{\psi}(m,k) = \sum_{n=-\infty}^{\infty} x_{\psi}[n] W_{n,m}^{k}
\]

which can be seen as

\[
S_{\psi}(m,k) = \text{DFT} \{ x_{\psi}[n] \} = X_{m,k}
\]

Pictorial representation of the CSTFT
Given the signal \( x[n] \) and \( n \in \mathbb{Z} \)

The family of signals \( x_{\psi}[n] \) which are obtained from the product of the moving window function and the signal of interest are depicted below along with their corresponding CSTFT:

\[
\text{CSTFT} = \text{DFT} \{ x_{\psi}[n] \} = X_{m,k}
\]

Acoustical Beamforming:
It is a Signal Processing technique which basically allows the localization of acoustic sources based upon the time delay of signals at a microphone array with known characteristics.

Sensor Fusion:
By fusing data from different type of sensors (e.g. temperature, humidity, barometric pressure, solar radiation) with the acoustical signals, measurements errors are reduced, thus the system performance to detect changes increases. For example, it is common that male coqui frogs call during the night and after rainfall, so events like a coqui calling at noon, at low humidity and high temperature should be rare!

4 Implementation Effort

5 Conclusions and Future Work

Preliminary results show the potential use of the CSTFT for detection of male coqui frogs calling. Analysis for other animals (we’re also interested in birds) is mandatory!

The MATLAB-based GUI developed for computing the CSTFT have proved to be a useful tool for testing different configuration settings such as acoustic signal length, analysis window type, length, and overlapping. A stand-alone hardware implementation is being developed at the time targeting both, FPGA’s and DSP’s.

Beamforming and sensor fusion stages will dictate overall system feasibility, as a tool for detecting significant changes in the environment.

6 References


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