TITLE OF RESEARCH WORK:

Distributed Sensor Signal Acquisition, Analysis, and Representation for Environmental Surveillance

Research Description:

Environmental Surveillance can be widely defined as the monitoring of the environment behavior. Monitoring means the long-term repeated measurement of selected properties or characteristics of the environment and of the activities believed to be responsible for changes in the environment. These properties, in the form of observables, are acquired using sensors. Also, sensors dictate the type of surveillance, whether it is remote or in-situ.

We are addressing the in-situ Environmental Surveillance, i.e. the sensors are placed on the target environment in direct contact with the medium. Instead of following the Wireless Sensors Network (WSN) trend, where sensor nodes are conceived as small and low cost devices (thus, limiting processing capabilities); we propose a new smart sensor cumulus, comprised of numerous basic sensors like acoustic, temperature, humidity, barometric pressure, and high performance processing devices like Field Programmable Gate Arrays (FPGAs), Digital Signal Processors (DSPs), among others.

The proposed sensor will benefit from the increased processing power allowing more complex signal processing operations in-situ, such as acoustic beamforming, time-frequency signal analysis, time-series analysis, wavelets, data fusion, increased signal resolution, etc. Also, some grade of intelligence (Automation) can be added in order to transmit events information (change detection) instead of raw data packets. As a starter, we are focusing in the detection between human-made sounds and the natural acoustic environment of the site.

The research encompasses the design and test of a prototype using Commercial-off-the-shelf (COTS) components. The Jobos Bay NERRS Staff will be collaborating with the WALSAIP project and granted permission to use the reserve facility as testing scenario.

WALSAIP GROUP ASSOCIATION:
Automated Information Processing Group

THESIS TITLE:
Distributed Sensor Signal Acquisition, Analysis, and Representation for Environmental Surveillance

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RESEARCH PROJECT OUTCOMES:

Publications:

N/A

AIP LAB
AUTOMATED INFORMATION PROCESSING LABORATORY

NATIONAL SCIENCE FOUNDATION

ICIS
Institute for Computing and Informatics Studies

WALSAIP

Tools and Applications:

Acoustical Sensor Array: A linear array of microphones used for beamforming. We are evaluating the type and number of microphones/complexity of the system. Also, the mechanical characteristics of the array structure, for an efficient placement of the microphones. Audio-Technica ATR35s microphones are being used for initial testing.

Data Acquisition System: we are modifying a USB data acquisition system (Data Translation DT9816) with specs matched to the processing boards used in the prototype stand alone implementation. The sampling rate for acoustical signal will be 48,000 Hz with a resolution of 16 Bits.

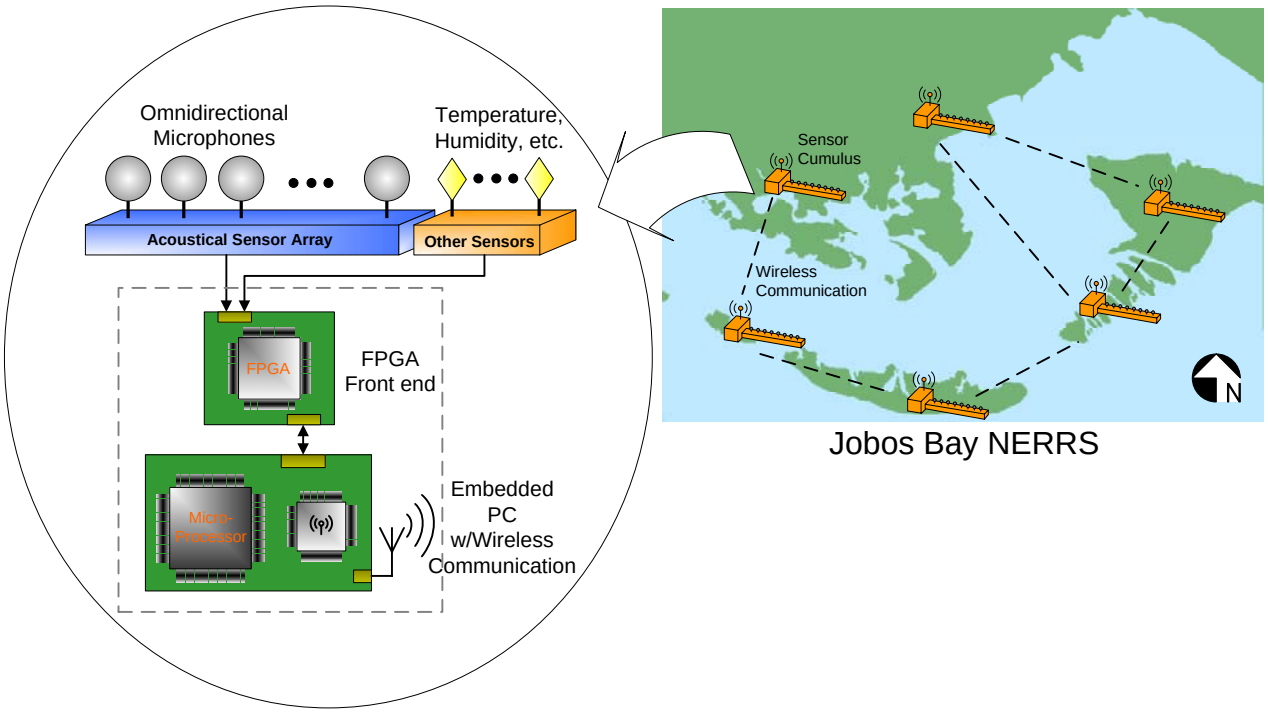
Processing Boards: Currently we are exploiting the Signal Processing capabilities of the Digilent XUP-Virtex II Pro development board and the Xilinx Virtex 4 SX evaluation platform. For this end, we are using the following software: MATLAB 7.2 w/Simulink, Xilinx System Generator v8.1, Xilinx Platform Studio 8.1i, Xilinx ISE 8.1 and ModelSim XE 6.0d. Depending on the preliminary results it may be necessary to incorporate a Texas Instrument DSP TMS320C6713 for more arithmetic precision in the signal processing operations, since the fixed point representation of the FPGAs may not be sufficient for some algorithms.

Currently we are evaluating the acquisition of a Single Board Computer (SBC), the Thunderbird Mini-ITX starter kit from Lippert; since the decreasing cost of these SBCs and performance increment can make them potential competitors to DSPs and FPGAs based solutions; also to decrease the time-to-market of the prototype.

RELATION OF RESEARCH WORK TO WALSAIP PROJECT:

The WALSAIP project is developing a new conceptual framework for the automated processing of information arriving from physical sensors in a generalized wide-area, large-scale distributed network infrastructure; focusing on water-related ecological and environmental applications. Also the WALSAIP project envisions the acquisition of data via remote (Satellite, SAR…) and in-situ sensing (WSN). My research is setting the basis for the in-situ sensing, incorporating sensors tailored to meet Jobos Bay NERRS scientist specific needs.

IMAGE REPRESENTATIVE OF RESEARCH WORK:



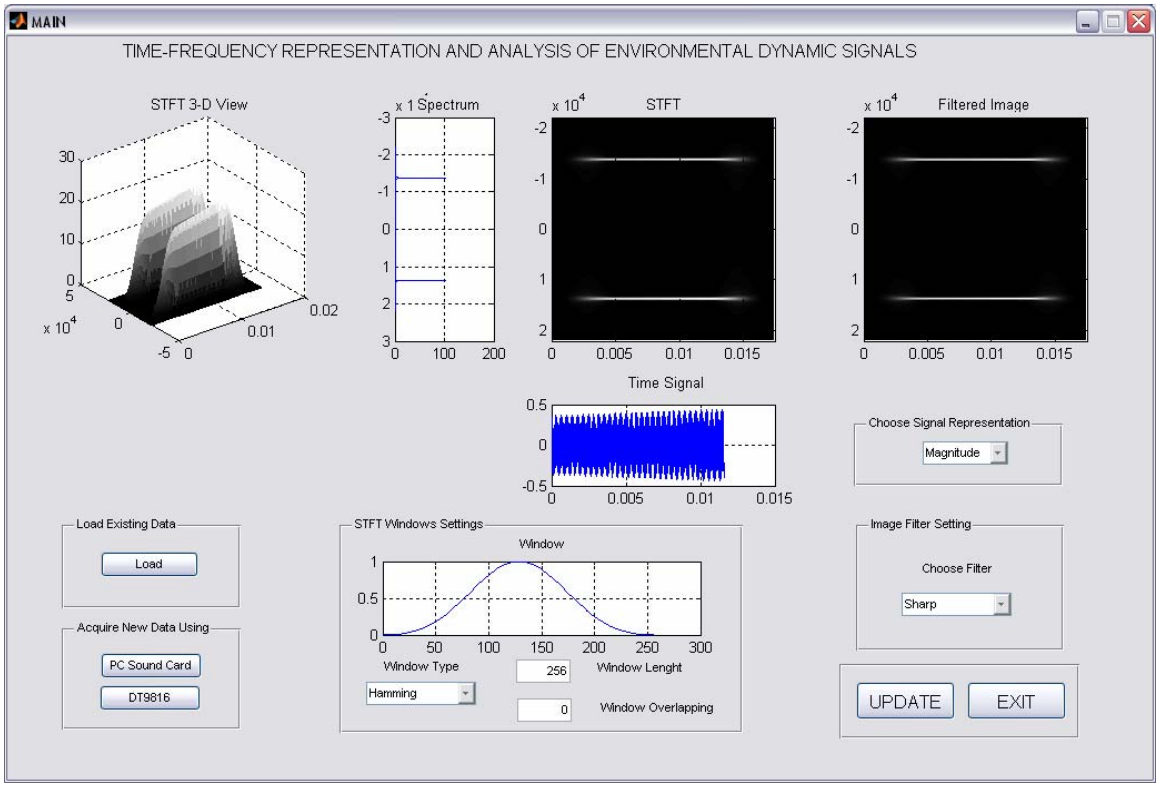
The Smart Sensor Cumulus most important features are graphically illustrated above:

- Basic sensors such as temperature, humidity, barometric pressure, solar radiation, among others.
- An acoustical sensor array, for beamforming purposes and the recording of acoustic signal with increased SNR.
- An FPGA which serves as a front end and to perform some signal processing operations in real-time.
- An Embedded PC with wireless communication capability to perform in-situ processing of the signals in order to transmit information instead of raw data.

RESEARCH DEMONSTRATION:

The "Time-Frequency representation and analysis of environmental dynamic signals" is a MATLAB-based tool developed in conjunction with partner student Ivan Rivera. The purpose of the tool is to facilitate Time-Frequency analysis of ASCII-type data and to compare the results with hardware implementation of the Short-Time Fourier Transform (STFT).

The tool performs the STFT of the input signal and, basic 2-D filtering operations (derivative with respect to x, y and x-y; sobel; sharp; etc.). The user can modify important parameters to compute the STFT such as the window type, length and overlapping. Also the user can select between magnitude or phase representation for the signal. Below is presented a screen-shot of the tool interface. Currently I am working in the tool trying to enhance the computational performance and incorporating other signal analysis tools. A more refined version will be available at the end of the semester, with the associated user's guide. Also a rough version of the Smart Sensor Cumulus is targeted to be available at the end of the semester.



The signal analyzed in the screen-shot is the famous "mosquito ringtone". Although not clearly seen, the ringtone operates in a high-frequency of approximately 14,000 Hz, making it difficult to adults to hear.