Robotic Microphone Sensing: Design of a Robotic Platform and Algorithms for Adaptive Control of Sensing Parameters

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Abstract

In our previous undergraduate research project on "Acoustic source location using cross-correlation algorithms" we found that the performance of the 2D position estimation algorithms using two pairs of microphones depends on array variables such as the distances between the individual and pairs of microphones, and also the sampling frequency. Therefore, we propose to build a robotic microphone array with autonomous control of the array geometry for improving the localization performance of a wideband acoustic source in 2D space at a constant sampling rate. In particular, we designed two mobile robotic-platforms carrying a pair of microphones each. Each platform is capable of real-time communication between the PC and the robot microcontroller independently. We designed a control algorithm for modifying adaptively each robot position along a single axis such that the resolution for estimating the source position is improved. We tested the performance of our system using numerical examples and real experiments.

Overview

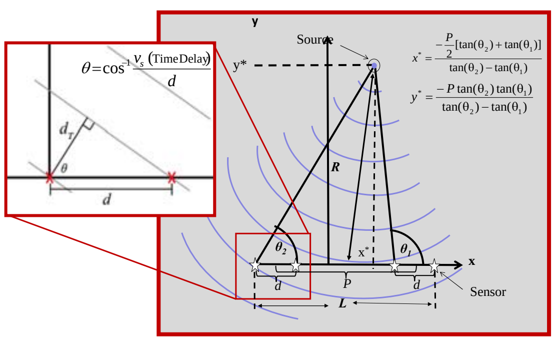
Goal:

Design and build a robotic platform equipped with a microphone array such that the array's geometry can be controlled autonomously. Furthermore, develop algorithms and strategies to control the microphone array in order to improve localization performance.

Approach:

- Modified the existing platform of LEGO® MINDSTORM® NXT robots and securely mounted the microphone array to the robotic platform.
- Observed the system's response to array variables and established algorithms to optimize resolution at the estimated source location.

Background :



Resolution:

The angle of estimation depends on the following equations

$$\hat{\theta} = \cos^{-1}\alpha\,\hat{n} \qquad \text{Where, } \alpha = \frac{v_s}{d f_s}$$

n bounded by the range, $-\left[\left(\frac{1}{\alpha}\right)\right] \le \hat{n} \le \left[\left(\frac{1}{\alpha}\right)\right]$

Variables

L is the length of the linear array

λ is the wavelength of the acoustic waveform

R is the radial distance from the source of the array

d if the distance between sensors pairs

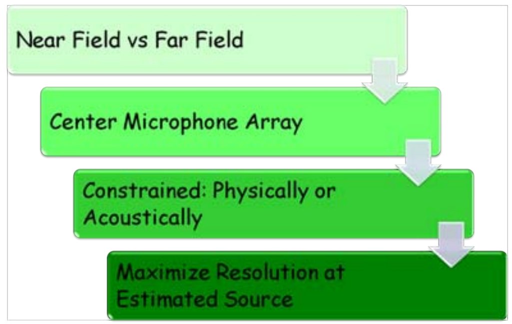
Controller Algorithms and Performance Analysis

Development and Optimization of Controller Algorithms

Important Input Variables:

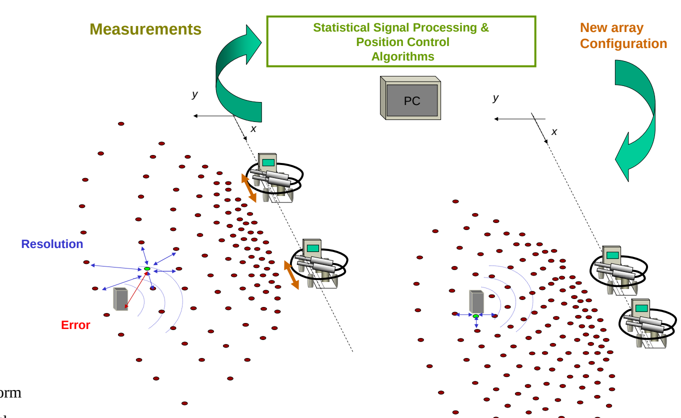
Previous Position	Critical Resolution
Estimated Source Position	Acoustic limitation Distance

Maximizing Resolution through algorithms:

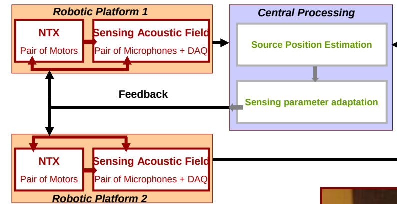


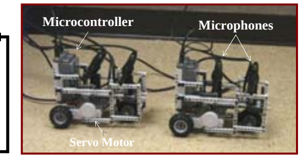
- Question 1 – Is the Microphone Array in near field or far field?
- Question 2 – Is the Microphone Array centered around the estimated source position?
- Question 3 – Are robots' movement constrained by physical or acoustic limitations?
- Question 4 – Is the current resolution better than the previous resolution at the estimated position?

Increasing the Resolution at the Estimated Source



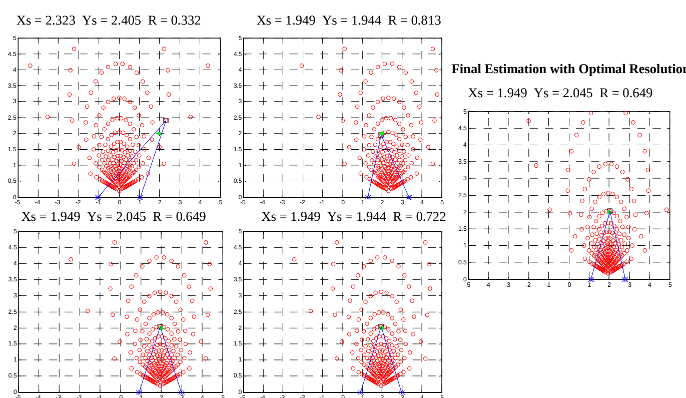
Experimental Setup





Along with designing a robotic microphone array, this research project developed an adaptive controller to maximize the resolution at an acoustic source position. Both of these aspects were then integrated with the Robotic Microphone Sensing: Data Processing Architectures for Real Time Acoustic Source Position Estimation research project. The experimental set up for collecting data is given in the pictures above.

Resolution Analysis



References

- Joshua York, "Acoustic Source Location Using Cross-correlation Algorithms", Fall 2008, http://ese.wustl.edu/~nehorai/josh/students.cec.wustl.edu/_jly1/
- Raphael Schwartz and Zachary Knudsen, et al., "Data Processing Architectures for Real-Time Acoustic Source Position Estimation ", Fall 2009