Robotic Sensing: Adaptive Robotic Control for Improved Acoustic Source Localization in 2D

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Abstract

In this project we expand our previous work entitled "Design of a Robotic Platform and Algorithms for Adaptive Control of Sensing Parameters". We have shown that the performance of our algorithm for acoustic source location in 2D can be improved by adaptively controlling the microphone array geometry. To this end, we built a robotic microphone array with capability of autonomous control of array geometry constrained to movement in 1D. In this project we increase the degrees of freedom of our robotic platform and design a new controlling algorithm in order to improve even further the performance. In particular, our robots move in 2D and the pair of microphones can also rotate independently of the robot orientation. A heuristic approach for the control of robot locations is presented and validated with real experiments. Labview and Matlab are used for the implementation of the system.

Overview

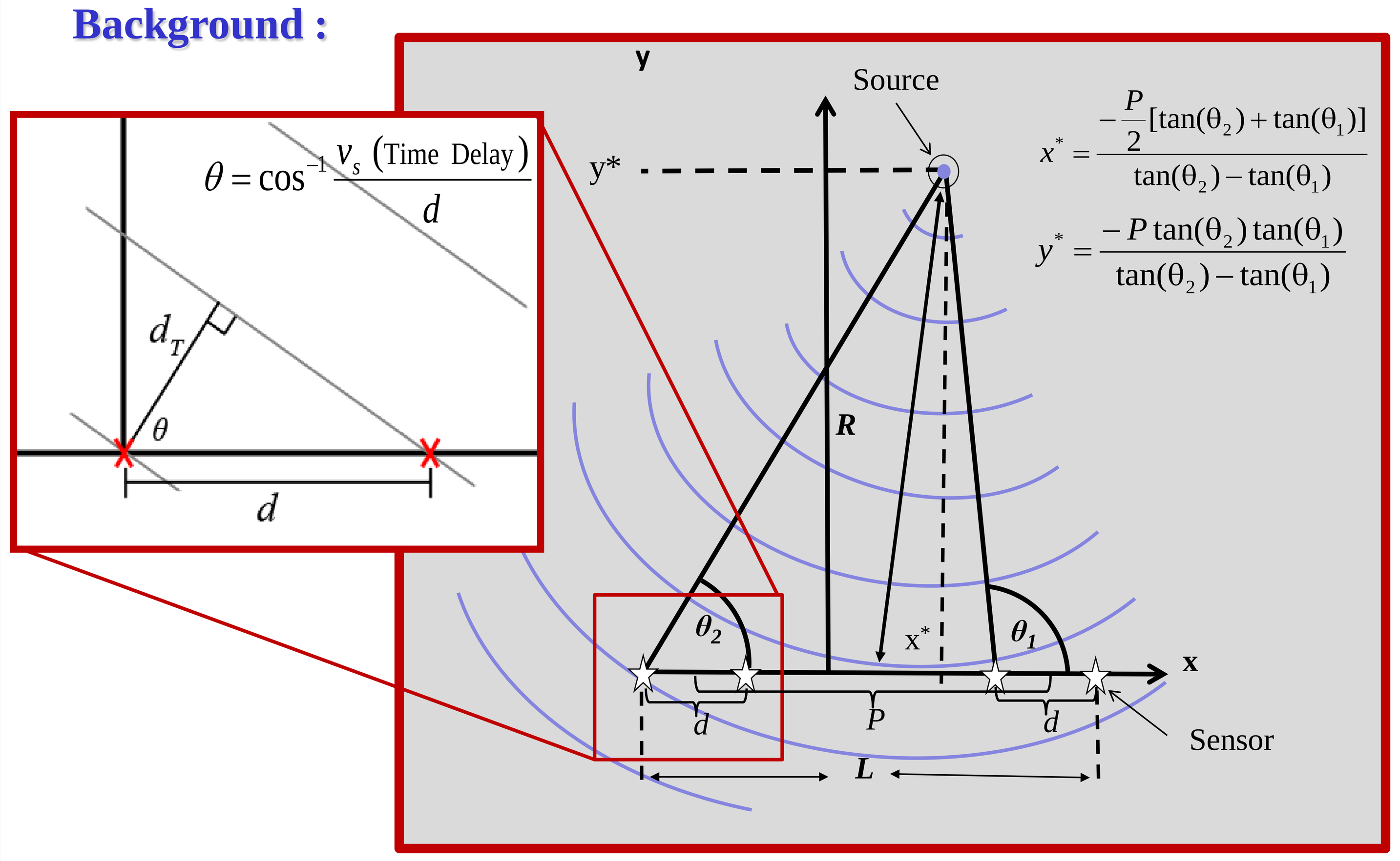
Goal:

• Design a system capable of acquiring measurements to estimate the acoustic source position in real time and adaptively move the microphone pairs in 2-D to improve localization resolution.

Approach:

• Dataflow programming techniques were used to implement signal processing architectures. A heuristic algorithm was used to control movement based on our experimental observations.

Background :



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

Robotic Platform

Motivation

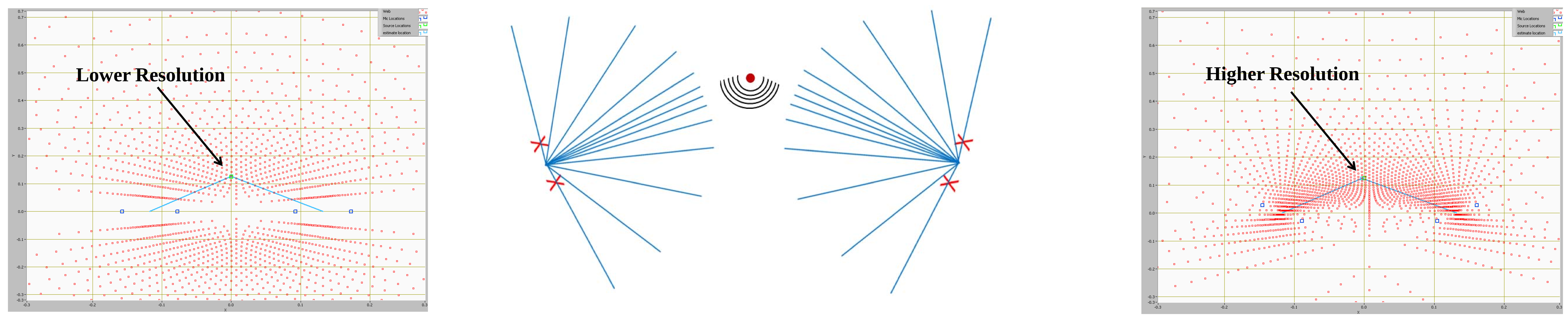
It can be shown that given a particular array geometry and sampling frequency, there are a finite number of possible locations which can be estimated using two pairs of microphones. This set of possible points is not uniformly distributed, as is shown in Figure 2. Further the **resolution** (defined as the number of points around the actual source location) depends on the orientation of the microphone pairs. In this work, we intend mount the microphone pairs on a robot and adaptively move them such that they have a good resolution around the source.

• Mounting the microphone array on robots allows us to change the physical parameters of the system in real time.

• Altering the distance between microphone pairs affects the spatial distribution of the possible estimation points.

• Shifting the array brings the source in-line with the array center.

• These movements increase the resolution near the source and improve the estimation.



Linear Array Configuration

Figure 2

Rotated Array Configuration

Real Time Architecture and Controller Algorithm

Adaptive Control Algorithm for Robot movement

A simulation based heuristic algorithm is used to determine potential resolution improvement of moving the robots in each of the system's four degrees of freedom. For each degree of freedom a number of simulations are performed to model a variety of different robotic movements. The robotic movements which produced a significant simulated resolution improvement are then used as the commands for the next movement. This process is performed until the microphones have been moved to a configuration which best optimizes localization resolution, given the physical constraints of movement. A threshold is defined to characterize the optimal resolution.

The four degrees of freedom which the algorithm seeks to optimize are the:

- Distance between the robots
- Orientation of the robots with respect to the source
- Movement in the horizontal axis with respect to the source (shifting movement)
- Movement in the vertical axis with respect to the source (approaching/retreating movement)

The adaptive algorithm also utilizes the robots' rotational capability to point each of the microphone pairs to best face the source, further improving estimation

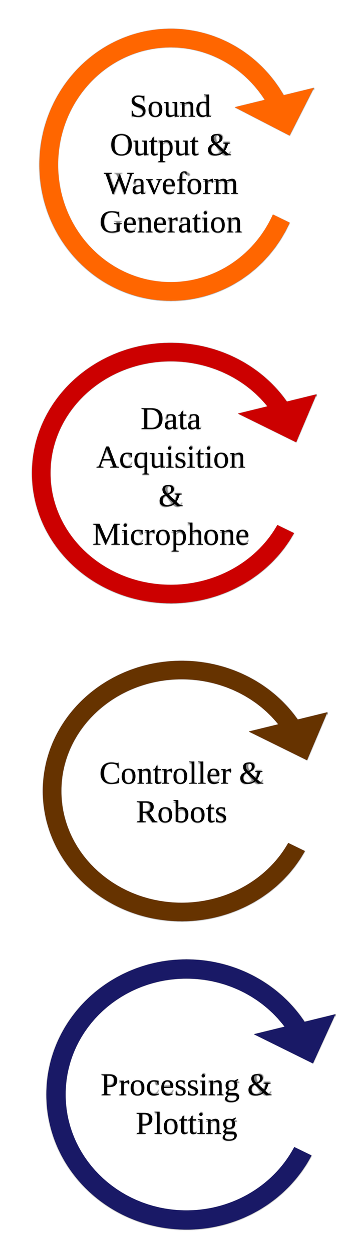


Figure 3

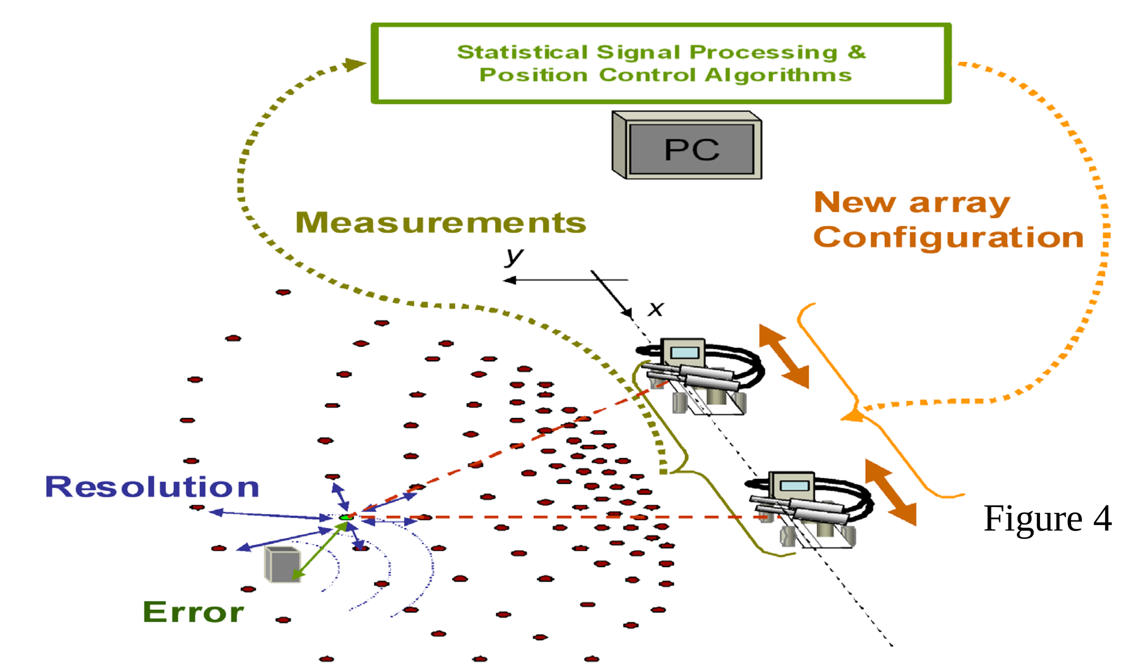


Figure 4

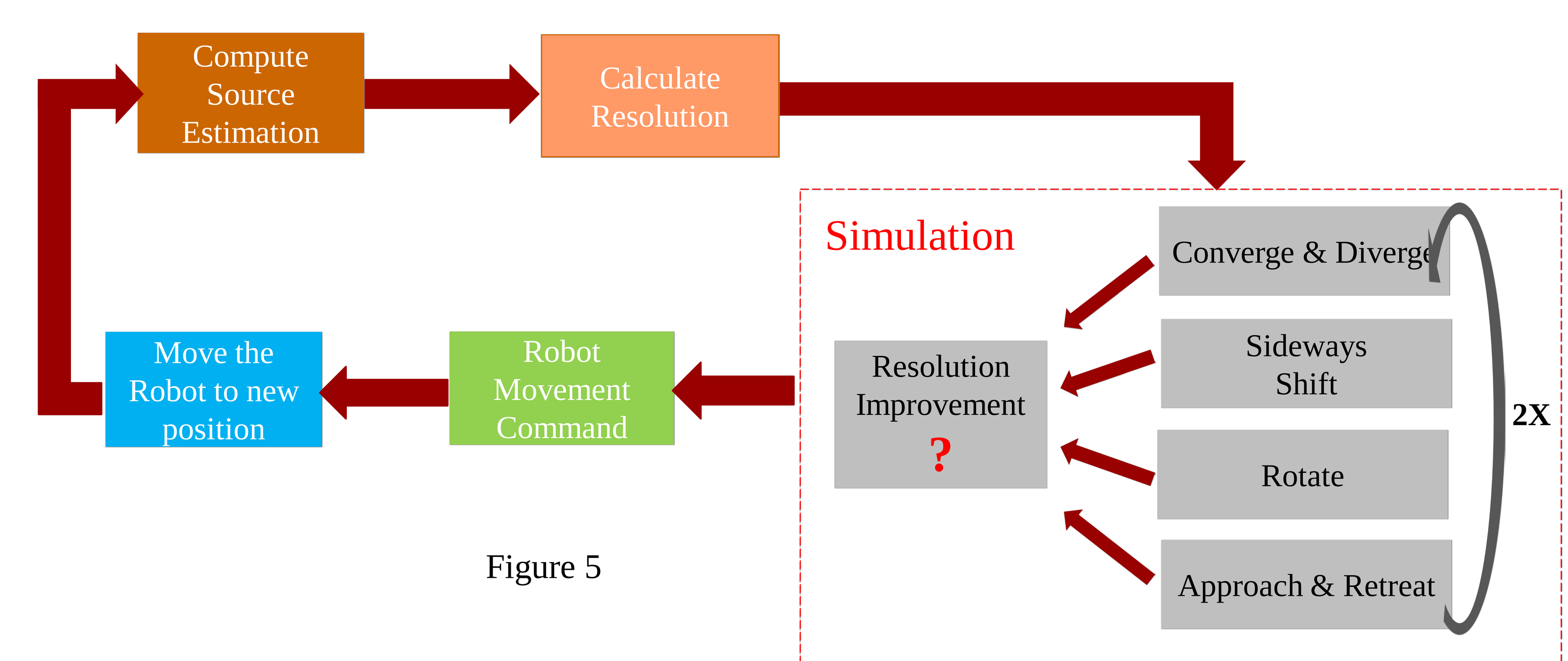


Figure 5

References

• Joshua York, "Acoustic Source Location Using Cross-correlation Algorithms", Fall 2008, http://ese.wustl.edu/~nehorai/josh/students.cec.wustl.edu/_jly1/

• Chase LaFont, "Robotic Microphone Sensing: Design of A Robotic Platform and Algorithms for Adaptive Control of Sensing Parameters", Fall 2009