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Communication vs. Performance in Source Localization

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Introduction: Wireless Communication Costs and Acoustic Source Localization

Acoustic Source Localization

- **Source localization**

  Acoustic source localization is the process by which the location of an acoustic source is estimated. Locating a bird using microphones listening for a bird call is an example of an application for source localization.

- **Methods of source localization**

  There are many different methods for source localization. Some examples of these methods are *Beamforming*, MUSIC, AML, and ESPRIT. Most methods require full transmission of the received waveform to a fusion center. Many methods have very good performance in open fields where there is no reverberation.

Cost of Wireless Communication

- **Energy can be a scarce resource**

  In many applications of sensor networks, access to a power line can be difficult. This is especially true when sensors are deployed in remote areas for a long duration. Thus energy is often a valuable resource and there are efforts to reduce energy usage in many ways including reducing *communication costs*.

- **Considerable energy is used in wireless communication**

  In a sensor network, energy can be consumed in different components and processes. Sensing, processing and communication are three main areas where energy is expended. In situations where sensors have to wirelessly transmit complete waveforms to a fusion center, a considerable amount of energy is consumed through wireless communication.

Problem Description: Localizing with Less Communication

Compromising Performance, Reducing Cost

Often there are efforts to push the system to optimize one characteristic. For example, there are usually efforts to optimize performance assuming one has the capability of communicating a large number of bits. In practical situations where there exist distributed arrays of wireless nodes each with a microphone, one can not afford to assume infinite energy resources. Localization methods mentioned in introduction all require transmission of the complete received waveform to the fusion center and thus they all assume abundance of energy for communication or existence of a wired infrastructure. It is reasonable to consider a case where instead of aiming for optimum performance with high energy costs, we focus on the study of a compromise between performance and the number of bits communicated. One can then choose a suitable point to operate according to the specific conditions for an application.

Proposed Solution: A Simple Tradeoff Study between Communication and Performance

One-bit Communication

A simple scheme is simulated where each sensor is capable of sensing received power levels and is restricted to transmitting one bit only. Figure 1 shows an example of this setup. The source is assumed to be in the near field. The circles show the range within which a source was sensed. A sensor sends a 1 if its received power level is above a certain threshold -and thus inside a disk with radius R- and a 0 if the power level is below that threshold. In this case we require the acoustic source to send a signal with constant power and that sensors be able to accurately detect the threshold. These are not realistic assumptions in a real environment but are necessary for our simplified analysis.

For this setup, performance was examined in two different ways. First, the source location was estimated to be the center of the region where all the disks overlapped. Performance was shown as the mean squared error of this estimate as shown in Figure 6. In another instance, we looked at uncertainty in the estimate by looking at the area of the overlap region. This is demonstrated in Figure 3.

Two-bit Communication

In the second case, the same scheme was used with each sensor sending two bits rather than one bit. Therefore, rather than having one circle to show a threshold in power, each sensor has three different levels to detect. Figure 2 demonstrates this setup. Since in some cases where the overlap area is not convex, the center of mass can fall outside of the overlap area, we only consider the area of the overlap region. All of the simulations were done assuming 5 sensors. In a run of 50 cycles, the area of the overlap region was found to be smaller for the two-bit case by a factor of 4.5.

Narrowband Beamforming with Less Samples

Communication can also be reduced by reducing the number of samples used for localization. Narrowband Beamforming is a simple way to find the angle of arrival of an acoustic signal. Here we simulated an array of 5 microphones that perform this Beamforming. A graph of the absolute error in degrees versus number of samples used for Beamforming is shown in Figure 5. SNR is assumed to be -5 dB. Error is reduced and the estimate converged to a close estimate after about 10 to 15 samples.
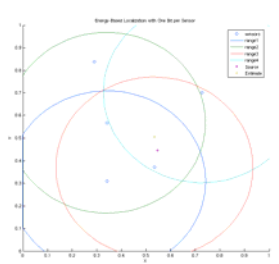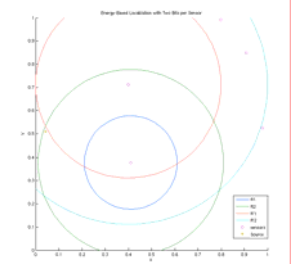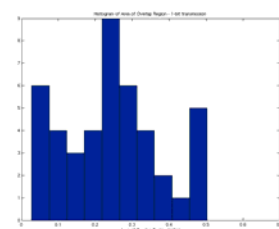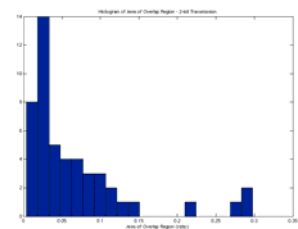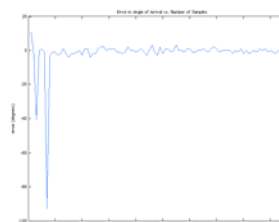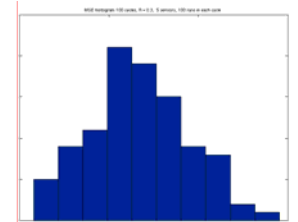

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6