Acoustic Beamforming with a MEMS Microphone Array

4th Year Project Final Report

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I. INTRODUCTION

1. OVERVIEW AND BACKGROUND

A method that utilizes principles of depth, perception, triangulation and wave transmission is referred to beamforming. Beamforming is used to analyze a signal and determine the direction of transmission. The overview of the project is an analog sound signal is transmitted from any direction, then is received by an array of microphones and is then processed and analyzed digitally. The microphones used in the project are the Microelectromechanical Systems (MEMS) microphones. The signals are received by the microphones and using the Matlab software, the direction of arrival (DOA) of the sound signal to determined. The direction of arrival of the sound signal is the end goal of the project. The following report include the steps taken to achieve this, the theory and techniques used, the different methods that were considered and used to achieve the project goal and a discussion. The report will then conclude by summarizing the project and the future work that will be done with the project.

Beamforming

Beamforming refers to the technique that aims at improving captured sound quality by exploiting the diversity in the received signals of the microphone array [1]. The following technology can also be used in an active state, this is seen in sonar and radar applications. Beamforming limits the phase and amplitude at each array element to influence the direction of signal transmission. Beamforming can also track moving object by collecting the sound that the moving object creates. With the understanding of how waves act and are analyzed and the understanding the techniques of beamforming, the filtered sound is can be analyzed further to obtain a direction of where it was transmitted from.

Sensor Array

A sensor array is used to find the most efficient method for signal optimization and sound localization. The larger the effective distance of the sensor array yields a greater accuracy in signal processing during the analyzing phase. The distance between the sensors and the number of sensors used can be altered to find the most efficient configuration for the project. The distance between the sensors can be configured by changing the spacing between the MEMS microphones in the array. The following method is more effective and a more practical approach to achieving the goal of the project. With the sensor array completed and utilizing the beamforming technique, the array of microphones captures a signal from multiple MEMS microphones and is processed in Matlab.

Matlab Software

Matlab is a powerful high-performance software that focuses on matrix and array mathematics. The software aids in the processing, analyzing and plotting of the captured sound signals. The use of the Matlab libraries allows for minimization of unnecessary sound and obtaining a source location.

Direction of Arrival

The direction of arrival focuses on when and how the analog sound signal arrives at each microphone in the array. Each signal arrives at a different phase and at a different time to the microphones in the array, depending on the position of the microphones in the array and the direction of where the sound signal was transmitted from. The sound localization principles stem from the direction of arrival of the sound signal to the sensor array.

2. MOTIVATIONS AND SIGNIFICANCE

The objective of the project is to investigate and examine beamforming methods using a STM32F401 Nucleo microcontroller and X-Nucleo-CCA02M1 microphone expansion board, four microelectromechanical systems (MEMS) microphones, Matlab software and audacity software. Sound localization is a very valuable tool that can be used when other observation methods have failed or have demonstrated to be less effective. Using the principles and techniques mentioned, the use of sound localization methods is vast. The applications that may benefit from the use of this technology are military, biomedical and acoustic. For example, a military application would be detecting, and the direction of a sniper shot. This technology will help determine the direction of arrival of the sniper bullet resulting in a reduction of casualties and injuries on the battlefield.

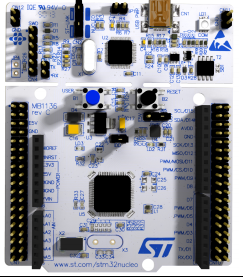
3. OBJECTIVES AND SPECIFICATIONS

The objective of the project was to determine a direction of arrival of an analog sound signal with the use of a microcontroller and 4 MEMS microphones. The project compared simulated results that were created in Matlab to the ones generated from a built physical system in the lab. Next, the system was to be built in a way to be portable in order to use this technology in a variety of circumstances and different environments.

There are two main physical components that were used in the build of the project. A STM32F401 Nucleo microcontroller and four microelectromechanical systems (MEMS) microphones.

STM32F401 Nucleo microcontroller

The micro-controller used in the project is the STM32F401 Nucleo micro-controller. The nucleo microcontroller can be seen in figure 1 below. On board was attached was the X-Nucleo CCA02M1 microphone expansion board. The expansion board can be seen in the figure 2 below. The expansion board contains four on board microphones and has the option for additional microphones to be added. The jumper setting on the micro-controller board allows for external microphones to be added. Due to the formation and how close the built-in microphones are to one another; the jumper setting was turned on and the external microphones were used. The micro-controller is then connected to a computer through a USB, and then Matlab software is then used to analyze the signals created. The CCA02M1 microphone expansion board connected to the STM32F401 Nucleo micro-controller can be seen in figure 3 below.



*Figure 1: STM32F401 Nucleo micro-controller [2] Figure 2*: X-Nucleo CCA02M1 microphone expansion board [3]

*Figure 3*: CCA02M1 microphone expansion on-board the *STM32F401 Nucleo micro-controller* [4]

MicroElectroMechanical Systems (MEMS) Microphones

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