Robot Sound Source Localization Using a Host Computer

Daniel C. Simon, Brian P. DeJong (Advisor)
Central Michigan University, simon2dc@cmich.edu, b.dejong@cmich.edu

***Abstract* – As a result of the increase in robots needing to interact with their environment, this student project builds upon an idea for a sound source localizing robot. The modification from the original idea mainly deals with shortening the time a robot takes to locate a sound source. This involved adding three omnidirectional microphones to amplifiers directly on top of the robot, and shortening the window of time for sound collection and processing. The building of this robot consisted of some mechanical design, mechanical and electrical part fabrication and programming. The robot is completed and is capable of locating the loudest sound in an area with relative visual accuracy.**

Index Terms – Far Field Assumption, mobile robot, sound location

INTRODUCTION

Robots are increasingly capable of being aware of their surroundings. One of the major senses they truly lack is hearing. While robots today can listen to a sound, record it, and even recognize it, they cannot tell where it comes from. If the robots of the future are supposed to interact with their surroundings they will need to depend more than just on sight and touch.

This student project involves taking a basic robot design from Northwestern University and altering it to locate sound sources in almost real time. The robot consists of three arms, each with an omnidirectional microphone, attached to an acrylic plate positioned on the top of a PC/104 computer stack. On the same plate as the arms there are two servo motors connected via custom designed, acrylic holsters. The robot is designed to locate a sound source by analyzing the time delay between microphones. A user will initiate the process on a host computer, which will interact with the robot. The sounds are gathered by the robot in a very small window of time, as a sinusoidal wave, and run through an amplifier connected to the breakout board of the robot. These waves are then sent to a host computer running mathematical software. The waves are compared using cross correlation. The host computer then runs a mathematical algorithm to triangulate the sound source. This data is then sent back to the robot, which uses motor control circuits to position a servomotor configuration to point in the specified direction.

The design of this robot uses the assumption that the loudest sound in the area is the only sound that the robot is interested in. It is also assumed that the directional vectors pointing from the microphones to the sound of interest are parallel to each other; this is known as the Far Field Assumption.

An in depth description of the mechanical, electrical, and software components of the robot are detailed in the following sections.

MECHANICAL DESIGN DESCRIPTION

While this robot is not necessarily an improvement from the original design from Northwestern University, it is focusing on a different possible use while using slightly different hardware and software. The following is a detailed explanation of the mechanical aspects of the robot.

The omnidirectional microphones, their amplifiers and the servo motor control circuits needed a place to be mounted on the robot; preferably on a surface that would not be affected too much from the CPU heat being released below. As a result, two acrylic plates were fabricated and made to fit on top of the existing supports of the PC/104 stack. The microphones are on the top most plate, the amplifiers and motor control circuits on the one below it.

In addition to the microphones, on top of this plate there rests two servomotors. These motors needed to be held down to the plate, and to each other. An acrylic holster was designed to connect directly to the acrylic plate mentioned earlier. The holster was first cut using a bandsaw and then more accurate cuts were made with a mill. Holes were drilled and tapped so that screws could connect the holster to the plate. Another acrylic holster was designed to connect the remaining motor to the attached motor in a way that the motor movements are in a perpendicular plane to that of the first motor. This holster was also first cut with a bandsaw, milled, drilled and tapped. With this design, the two motors working in tandem can only cover the whole hemisphere above the robot, being limited because of the turning capabilities of the motors.

FIGURE 1
MILLING OF SERVOMOTOR HOLSTER

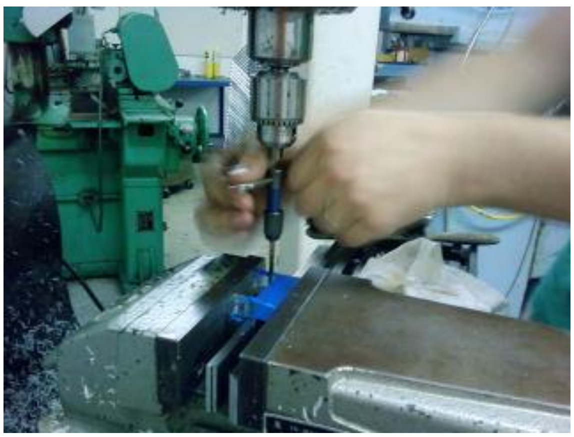

FIGURE 2
TAPPING SERVOMOTOR HOLSTER

For an observer to more easily understand the direction the robot was pointing towards, a compact flashlight was mounted on the servomotor configuration. This flashlight was placed in an acrylic clamp designed to be attached to the topmost servo motor. This clamp was cut using a bandsaw, drilled and tapped.

ELECTRICAL DESIGN DESCRIPTION

As previously stated, this robot is not necessarily an improvement on a previous design, as much as an alteration of its use. As such, the main body of the robot, the PC/104 stack, was ordered, not designed. However, the breakout board was not included with the PC/104 stack. This had to be constructed specifically for this type of robot. The design for the breakout board was the same used by Northwestern University. Some individual parts for the breakout board had to be tested or altered. Then all the parts were soldered on, the chips placed in their sockets, and the breakout board as a whole was tested.

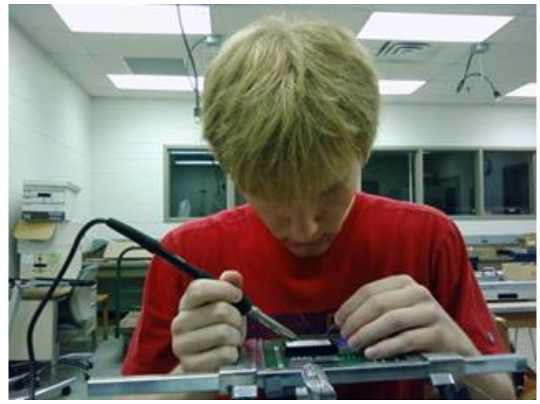

FIGURE 3
SOLDERING THE BREAKOUT BOARD

Each of the omnidirectional microphones needed an amplifier to connect to before interfacing with the breakout board. These amplifiers were first built and tested on a breadboard. All three were then designed to fit onto a small electronics board and mounted on the acrylic sheet directly above the robot CPU.

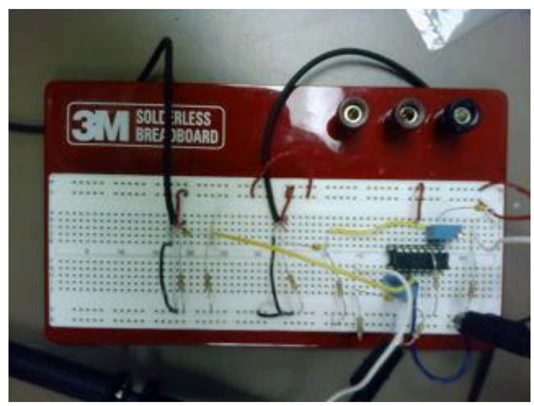

FIGURE 4
TWO AMPLIFIERS BEING TESTED ON BREADBOARD

To direct the servomotors the robot uses two control circuits. These circuits were designed from the manufacturer recommended design; they were built and tested on breadboards similar to the amplifiers. Once completed they were designed to fit onto a small electronics board and mounted next to the amplifier circuit, located on the acrylic sheet directly above the robot CPU.

In addition, a simple battery pack powers the flashlight.

PROGRAMMING

The programming required is handled through MATLAB xPC Simulink software. Using this software allows the foregoing of directly writing code for the robot. All that is necessary is writing the mathematical algorithm to triangulate sound sources, and building a basic program layout using the Simulink software.

The mathematical algorithm used is based on the Far Field Assumption. This assumption makes all vectors parallel that are coming from a single distant origin to two relatively close points in space. To make this assumption more accurate, the distance to the source must be much larger than the distance between the microphones [1].

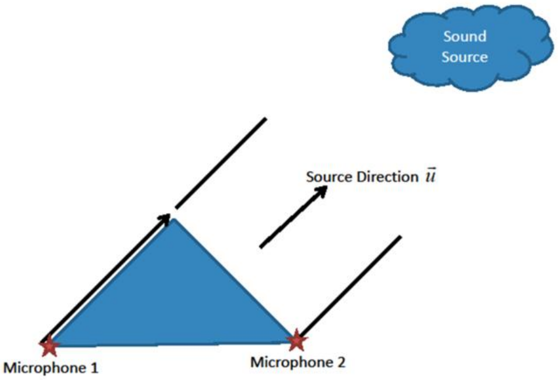

FIGURE 5
FAR FIELD ASSUMPTION DIAGRAM

The algorithm uses the known distance between the microphones in combination with the known speed of sound in air to calculate a sphere of possible locations for the sound to be at for each microphone. The location where these spheres meet is the location of the sound source.

Theoretically this algorithm would work for three dimensions; however it would require four microphones. As such, this robot only has three microphones, and can only search for sound sources in two dimensions.

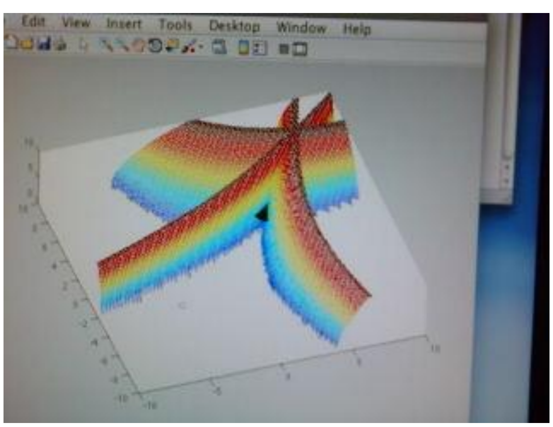

FIGURE 6
CONVERGING SPHERES OF POSSIBILITY IN MATLAB

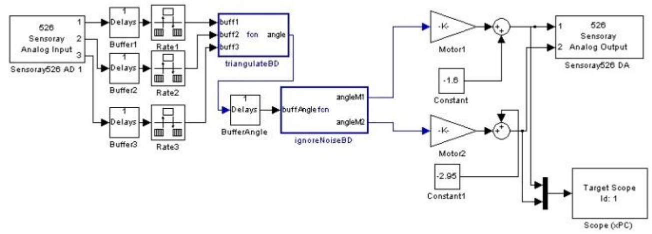

FIGURE 7
SIMULINK PROGRAM LAYOUT USED

CONCLUSION AND FUTURE WORK

The robot as described has been completed. The design seemed to meet the desired goal, with visual confirmation of it being capable of seeking out the loudest sound in its surrounding area. While the accuracy of the robot was not tested, visually it appeared to be more successful with objects the closer they were to being placed at 90° or 270° on the assigned coordinates of the horizontal plane for the robot.

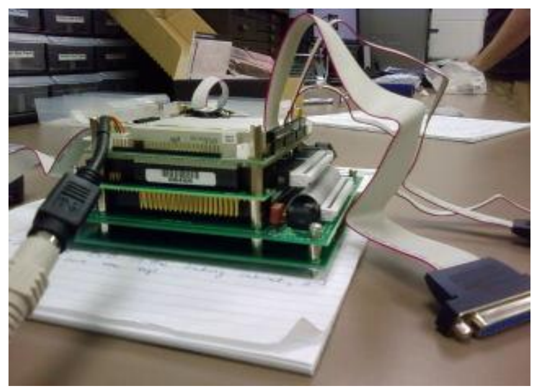

FIGURE 8
DISCONNECTED ROBOT WITHOUT ACRYLIC PLATES

At this point it is impossible to get specific data on the accuracy of the robot described in this paper, as the robot has been altered by another researcher for a different project. This new robot will eventually take a record of sounds to create a landscape of sound sources. This will allow the robot to locate more than just the loudest sound in a room, and will allow the robot to better sort out echoes.

ACKNOWLEDGMENT

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REFERENCES

[1] Valin, Jean-Marc, Francois Michaud, Jean Rouat, Dominic Letourneau. October 2003. "Robust Sound Source Localization Using a Microphone Array on a Mobile Robot." *Intelligent Robots and Systems*. Vol. 2, pp. 1228-1233.