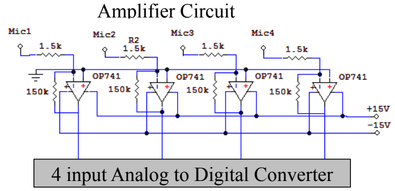
Sound Positioning System

Summary

We wanted to create something practical and interesting, using those two criteria we decided upon this project, locating objects in space using sound. Previous groups have worked on similar projects, but we were able to design a system which can give accurate and consistent results with a great degree of precision.

We constructed a circuit with 4 microphones as inputs. By connecting them to 4 op amps we are able to amplify the signals and pass them through a 4 input ADC, which we can now work with using Labview and Matlab. By using a series of equations that can compute relative delay between the microphones we were able to detect the exact position of the origin of the sound with great results.

Amplifier Circuit



Algorithm

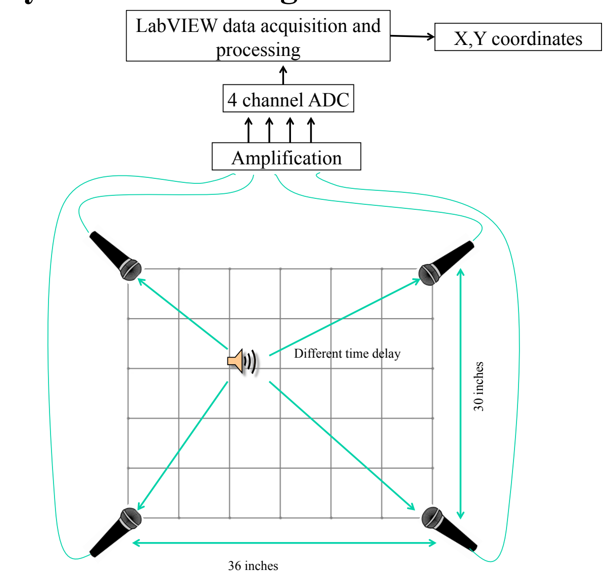
Method I: Direct Equation Solving

We measured the time delay of received sound among four microphones. Based on $\Delta d = v*\Delta t$, we know the relative distance difference from one point to four corners. For each spot on the plane, the three differences form a unique vector, we could get the coordinate of our sound source by directly solving the equations.

Method II: Match Filter

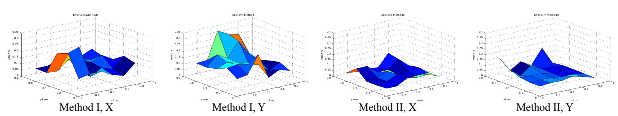
When a sound source is located at one spot on x-y plane, the generated time delays among microphones is unique. Therefore, we divide the board to 1cm*1cm grid and generate matrices contain standard delays. By comparing the measured delay with those matrices we choose the coordinate with the least error.

System Block Diagram



Testing Results:

At every 6 inches on the plane, we generate a sound pulse and record the system returned coordinates. At each spot, we did 6 trails and calculated the root-mean-square error. Below are the error map for both algorithm:



For our error plot corresponding to method I, we can clearly see that around the edges, we can see spikes in errors. While using method II, we get flatter error maps, meaning there are less deviations from the delay matrix.

Conclusion

From Method I, the average RMS error for all the testing points is 0.11m and 0.13m, x y respectively. Given our pre-fixed map resolution is 0.01m, the error is ten times of your resolution.

From Method II, the average RMS error for all the testing points is 0.04m and 0.04m, x y respectively. Less than 5 times of pre-fixed map resolution.

Compare two method, we conclude that Match Filter method returns us much better result. In theory, the compare algorithm suppress the error caused by hardware and eliminate the complex equation solving. The accurate results satisfy our needs for further system implements.

Future Works

Our system can be applied to a number of applications, all of which can give great results with only a few modifications. By using extra microphones we could easily add a 3rd dimension to the equation and be able to detect objects in a 3d space.

Anyone remember Billie Jean's music video by Michael Jackson, the sidewalk that lit up would be a very simple application to do even with our current setup.

One last possible application could be lighting in a house. By setting up microphones inside the house we could detect which rooms are in use and have the lights in that room turn on and off as people came and went.

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