Speech Intelligibility Enhancement using Microphone Array via Intra-Vehicular Beamforming

Senior Project Proposal Presentation

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Agenda

- Problem Background
- Project Objectives
- ✤ Beamforming
- System Description
- Efforts and Preliminary Results



Problem Background

According to the National Safety Council, there are approximately

1.6 million

crashes **each year** due to distracted driving involving mobile phones ^[1].



Figure 1 - Man talking on phone while driving



Problem Background





Figure 2 - Difficult to understand speech

Project Objectives

To reduce the risk of hands-on mobile phones usage in cars

- Increase speech intelligibility for far-end user
 - Uniform Linear Array (ULA) of microphones
 - Beamforming
 - Principle to Interference Signal Ratio



Array of Microphones and Signal Processing



Figure 3 - Easier to understand speech



Beamforming

- Beamforming or spatial filtering is a signal processing technique used in sensor arrays for directional signal transmission or reception.
- Delay-and-Sum Beamforming
 - Straightforward structure (see next few slides)
 - Simple implementation with less computation
- Minimum Variance Distortionless Response (MVDR) Beamforming
 - Adaptive approach for optimization
 - Heavy computation for implementation



Delay and Sum Beamforming



 $y[n] = \frac{1}{N} \sum_{k=0}^{N-1} x_k[n]$

Figure 4 - Delay and Sum Beamforming at 0° explained ^[5]



Delay and Sum Beamforming



 $y[n] = \frac{1}{N} \sum_{k=0}^{N-1} x_k[n]$

Figure 5 - Delay and Sum Beamforming at 45° explained ^[5]



Delay and Sum Beamforming



Figure 6 - Delay and Sum Beamforming with delays^[5]



System Block Diagram



Figure 7 - System block diagram



System Description

N-Element Microphone Array ULA of microphones will output signal via XLR.

Filters

A-Weighting Filters implemented in MATLAB/Simulink are designed to focus on the prominent frequencies of human speech (~500Hz to ~4kHz).

Delay

Delays will work as a part of the "Delay" and Sum beamforming algorithm

User input

The end user will be able to switch beam patterns to control where the beam is steered and who in the vehicle can be heard.

Audio Interface

The Focusrite Scarlett 18i20 will send digitized audio data from the microphones to the computer via USB.

Audio System Toolbox

The audio system toolbox in Simulink will be used to communicate with the audio interface and get stream data into Simulink.



Requirements

Functional

- □ The system is tested and demonstrated in intravehicular or similar environment.
- □ The system includes a ULA microphone array.
- □ Each microphone is routed to a system (such as MATLAB) for data acquisition.
- □ Beamforming is implemented in real-time.

Non-Functional

- □ The system will increase the intelligibility of near-end speech sent to the far-end user.
- □ The system requires little user manipulation or calibration.
- □ The system can be integrated within a vehicle.



Parts List

Quantity	Description	Price	Ext. Price
1	XLR Patch Cables	\$31.75	\$31.75
3	Behringer UltraVoice XM1800S Microphones	\$39.99	\$119.97
5	Pro Black Adjustable Dual Plastic 2pcs Drum Microphone Clip	\$7.44	\$37.20
1	Scarlett 18i20	\$499.99	\$499.99



Engineering Efforts

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Figure 8 - Engineering efforts timeline



First Test Setup





Figure 10 - First test setup picture

Linear Translation Test

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B



Figure 11 - Linear translation diagram





Figure 12 - Theoretical 1kHz beamforming results

Experimental Results





Figure 13 - Experimental 1kHz beamforming results

Experimental Results





Figure 14 - Normalized array power from 1 kHz beamforming results

Spectral Sweep Test

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B



Figure 15 - Spectral sweep diagram





Issues

- Used laptop speaker
- Walked and held laptop for linear translation test
- Environmental interference



Suggestion Add Microphones

- 7 Microphones
- 0.2 Meters
- -20 dB

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Figure 16 - The advantage of increased microphones



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Figure 16 - The advantage of increased microphones

References

[1] "Texting and Driving Accident Statistics - Distracted Driving." *Edgarsnyder.com*. Accessed October 5, 2017. Available: <u>https://www.edgarsnyder.com/car-accident/cause-of-accident/cell-phone/cell-phone-statistics.html</u>

[2] "Phased Array System Toolbox - mvdrweights." (R2017b). *MathWorks.com*. Accessed July 14, 2017. Available: <u>https://www.mathworks.com/help/phased/ref/mvdrweights.html</u>

[3] "(Ultra) Cheap Microphone Array." *Maxime Ayotte*. Accessed November 28, 2017. Available: http://maximeayotte.wixsite.com/mypage/single-post/2015/06/25/Ultra-Cheap-microphone-array

[4] "Microphone Array Beamforming." *InvenSense*. Accessed November 28, 2017. Available: <u>https://www.invensense.com/wp-content/uploads/2015/02/Microphone-Array-Beamforming.pdf</u>

[5] "Delay Sum Beamforming." *The Lab Book Pages*. Accessed November 28, 2017. Available: <u>http://www.labbookpages.co.uk/audio/beamforming/delaySum.html</u>



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Appendix



Second Test Setup





Matlab GUI for Beamforming



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A-weighting (blue), B (yellow), C (red), and D-weighting (blk)

BRADLEY University A-Weighting graph from https://en.wikipedia.org/wiki/A-weighting

Parts List With URLs

Quantity	Description	Price	Ext. Price
1	XLR Patch Cables https://www.amazon.com/Pack-Female-Microphone-Extension- Cable/dp/B01M0JQX2E/ref=sr_1_3?ie=UTF8&qid=1510258105&sr=8- 3&keywords=3ft+xlr+pack&dpID=61YjshJDuwL&preST=_SY300_QL70_&dpSrc=srch	\$31.75	\$31.75
3	Behringer UltraVoice XM1800S Microphones https://www.amazon.com/Behringer-XM1800S-BEHRINGER- ULTRAVOICE/dp/B000NJ2TIE/ref=sr_1_4?ie=UTF8&qid=1510257881&sr=8- 4&keywords=behringer+dynamic+microphone	\$39.99	\$119.97
5	Pro Black Adjustable Dual Plastic 2pcs Drum Microphone Clip https://www.amazon.com/Professional-Adjustable-Plastic-Microphone- Karaoke/dp/B06ZZCMJ26/ref=sr_1_87?s=musical-instruments&ie=UTF8&qid=1510262769&sr=1- 87&keywords=mic+clamp	\$7.44	\$37.20
1	Scarlett 18i20 http://www.musiciansfriend.com/pro-audio/focusrite-scarlett-18i20-2nd-gen-usb-audio- interface/j3522200000000?cntry=us&source=3WWRWXGP&gclid=EAIaIQobChMliu7F8a291wIV0LjA Ch36FQCZEAQYASABEgI3D_BwE&kwid=productads-adid^221957295827-device^c- plaid^323968843383-sku^J3522200000000@ADL4MF-adType^PLA	\$499.99	\$499.99



Fractional Delay

Fs = 44.1 kHz

f = 1 kHZ

Sampled sinc pulse





Helpful Scales

Minimum Sample Delay at 44.1 kHz is 22.676 us

Time delay from a source 1 m away where microphones are 0.2 m apart is 57.737 us

The speed of sound is approximately 343 m/s

Wavelength of a 1 kHz signal is 0.343 m

