Sound Processing Techniques in Multi-Source Environment

Project Overview

Human/Machine interaction has become more ubiquitous to daily life. People are good at focusing on a specific sound in a noisy environment, however, most robots can only react to one sound at a time. This project aims to improve sound localization and separation methods for robotics application, allowing robots to better react to simultaneous sound sources.

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2017-18 Senior Capstone Project

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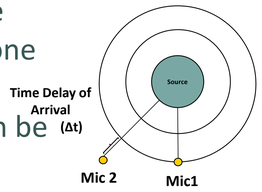
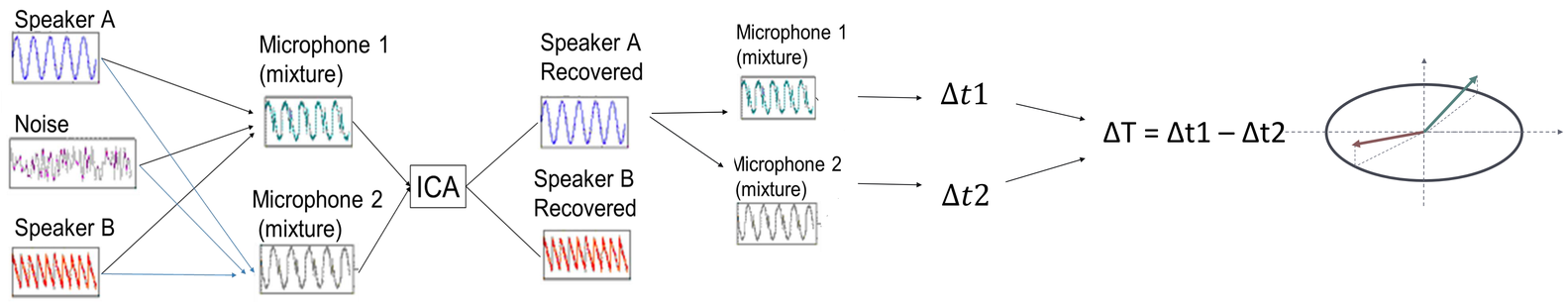
Separation Methodology: Independent Component Analysis(ICA)

Independent Component Analysis can be used to extract individual sound components in several mixtures of those signals and noise.

Localization Methodology: Time Delay of Arrival (TDOA)

Since the speed of sound is constant in air, the wave front of a sound arrives at one microphone earlier than the other. With a fixed distance between microphone pairs, the time delay can be used to calculated the angle between the microphone and the source.





Multiple sound sources received at the microphones

Source Separation using ICA

Extracted source signal cross correlated back with the microphone signal to get two time delay values

Time-delay between captured microphone signal to extracted source signal is calculated to localize sound sources

Planar Angle and Elevation of sound source

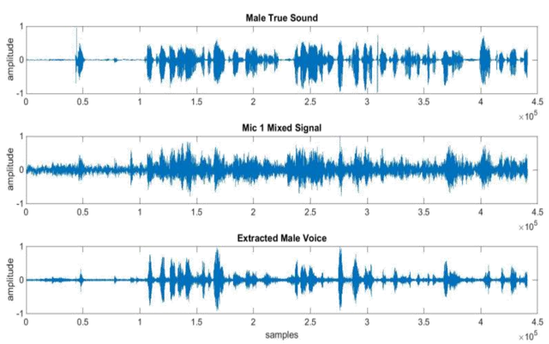
Process Flowchart

Sound Sources → Sensors → Audio Interface → **DSP** Digital Signal Processing → Results

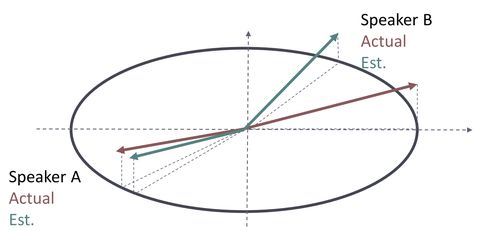
Experimental Setup

Source Separation Result

The graph on the right shows the waveform of the actual and extracted signal. The extracted male signal resembles the form of the true sound after the ICA algorithm.



Localization Result



Extracted Signal	Planar Angle			Vertical Angle		
	Actual	Est.	Error	Actual	Est.	Error
Speaker A	225	230	-5	95	92	3
Speaker B	0	56	-56	110	99	11

When testing with only one source, the accuracy is within +/- 6 degree, which validate our TDOA method for calculating incidence angle.
The result for multi-source localization is still unstable, depending on the quality of the ICA extracted result.

Conclusion

Experimenting with real signals show promising results in the ICA and single-source localization algorithm: the speaker of the extracted signal can be subjectively identified, and the localization error is +/- 6 degree. However the multi-source localization result is unstable, since its accuracy depends highly on the quality of the ICA output. Experiments show that the localization result is more accurate for higher frequency components, for example, the method can locate female's voice better than male's.

Future Works

- Refine multi-source localization results
- ML Classifier implementation
- Real-time implementation

References

- Bolbrock, Derderian, Gibbons, Maragos. SLIMA: Source Localization and Isolation with a Microphone Array. IEEE, 2007
- Valin,, Michaud, Rouat & Nakadai, Lkuno. Robust Recognition of Simultaneous Speech By a Mobile Robot.IEEE, 2016