# LET THE MUSIC FIND YOU

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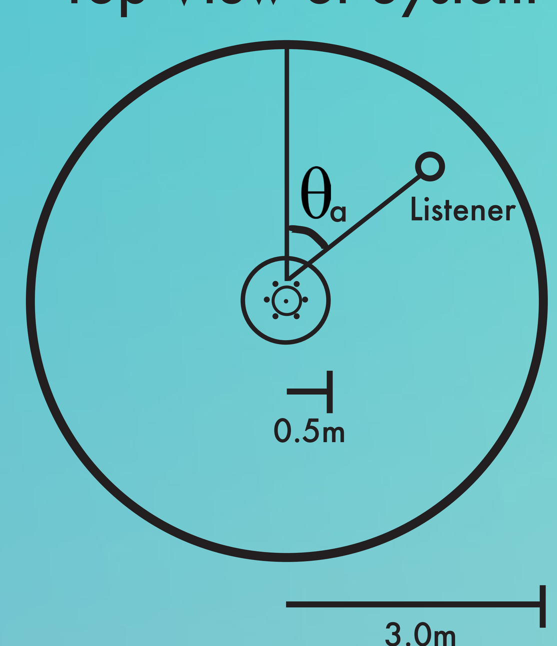
LOCATE

## OVERVIEW

- Outdoors, there are no walls to evenly distribute music playing from a loudspeaker, significantly reducing the tonal quality.
- The sound quality outdoors can potentially be enhanced if the position of the listener relative to the speaker is known.
- We implemented a position estimator to estimate the listener's location, using an array of six microphones to measure sounds made by the listener.
- The time-delays between sound arriving at different microphone pairs serve as the basis for our estimator.
- SPECS: Estimator should work for distances of 0.5m - 3m, with an area accuracy of $1 m^2$.
- SPECS: Priority given to azimuth angle estimate, +/- $6.5^0$ accuracy.

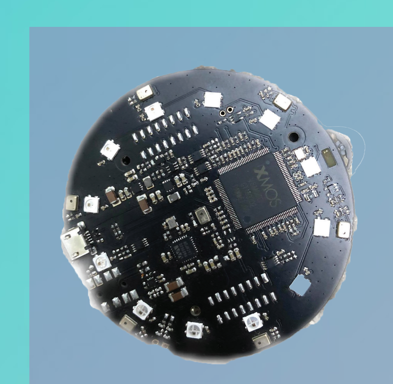
Top View of System




## APPLICATIONS

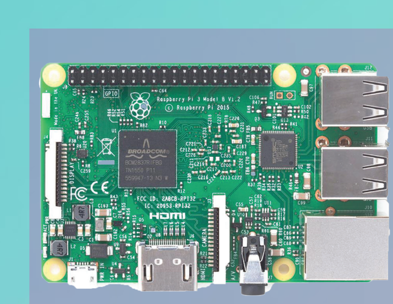
The microphone array lies flat inside the SONOS One speaker, and is used for voice command features. Our position estimator can be incorporated into the SONOS One without hardware changes.

## HARDWARE



### SEEED RESPEAKER MIC ARRAY

6 microphones measure sounds made by the listeners with a sampling rate of 32 kHz. Diameter of 65 mm.

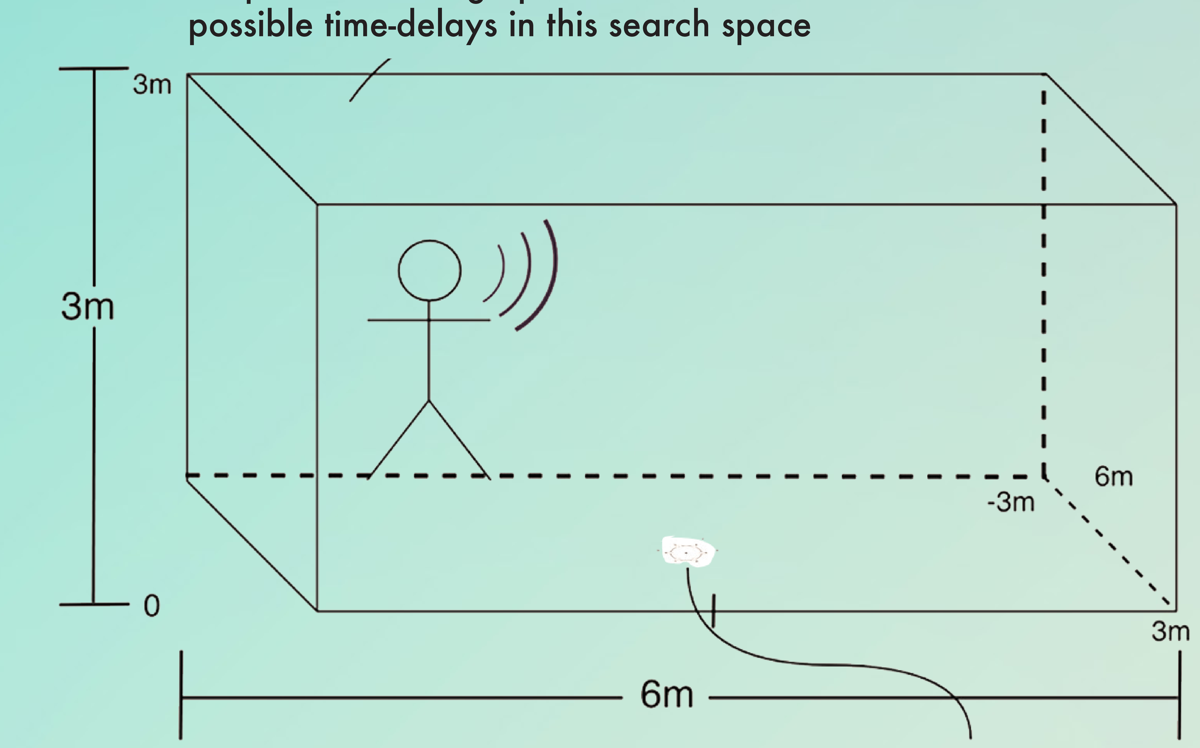


### RASPBERRY PI 3B

Interface between microphone array and computer, which runs our position estimation algorithm.

## POSITION ESTIMATOR

Estimate time-delays between sound arriving to different mic pairs, do phase-matching optimisaton over possible time-delays in this search space

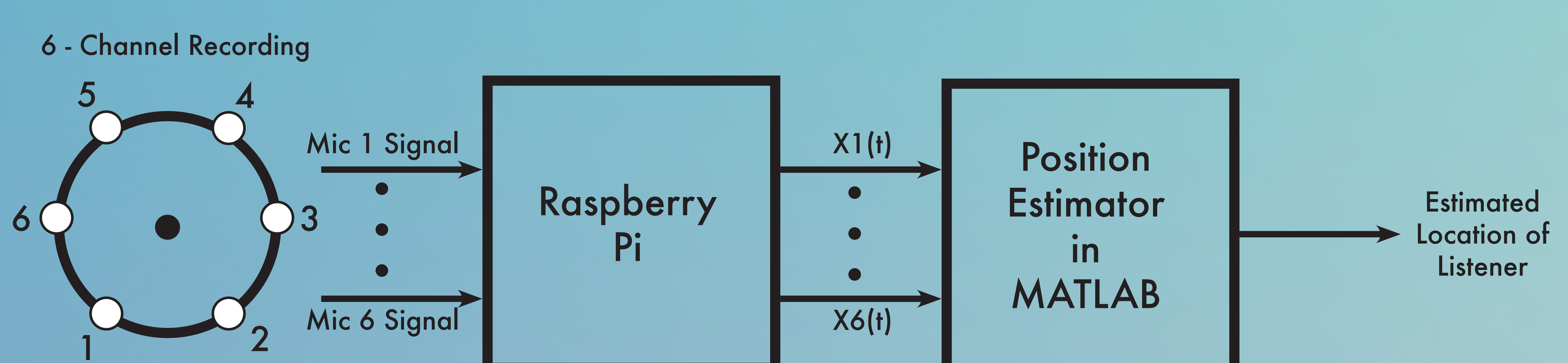



Center at (0,0,0)

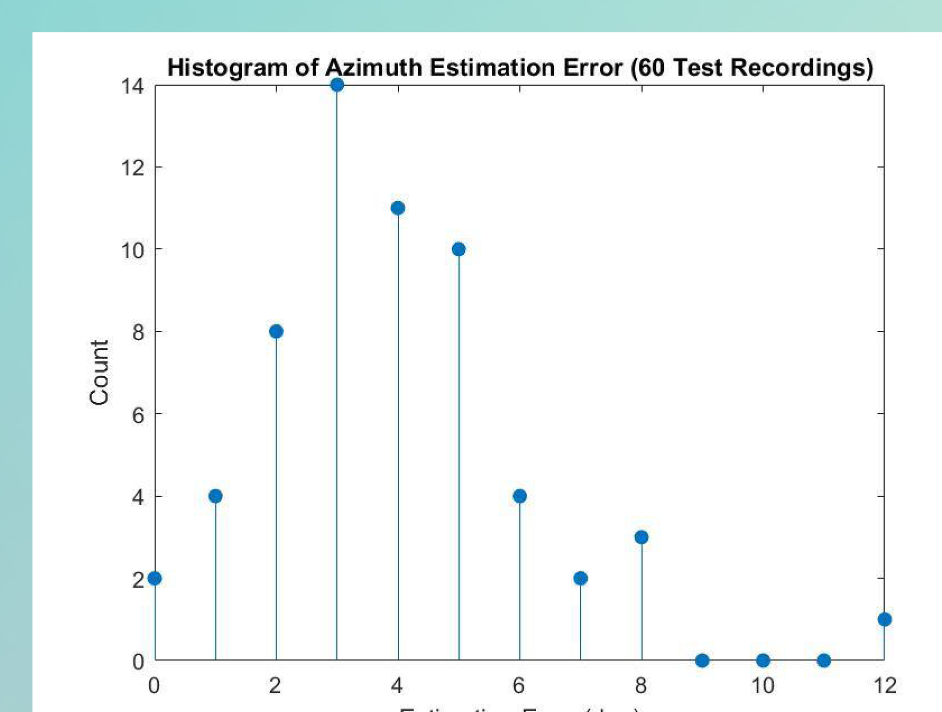
Search space:
$-3m \le x \le 3m$
$-3m \le y \le 3m$
$0m \le z \le 3m$

The phase-matching optimization procedure is similar to doing a least-squares fit. To do the phase-matching optimization, we compute the Circular Integrated Cross Spectrum (CICS) of the sound received by the microphones.

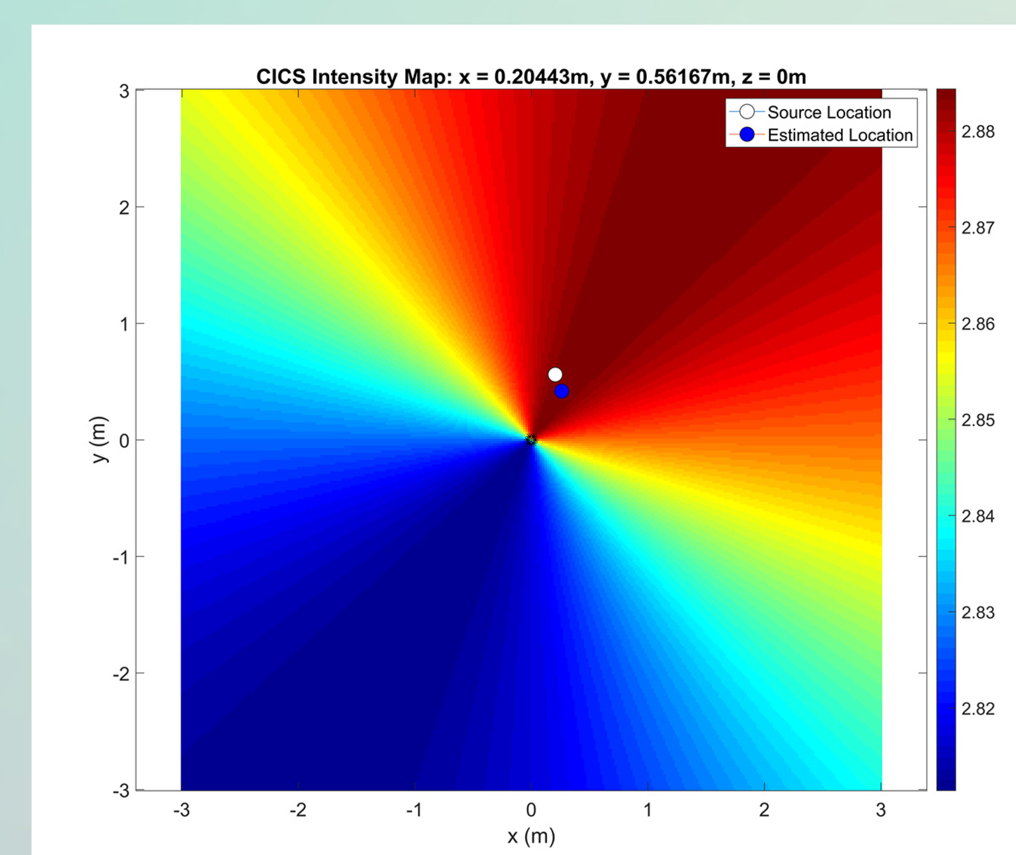
## FUNCTIONAL FLOW CHART




## RESULTS




- Our error in azimuth angle estimation was usually $2^0$-$5^0$.
- Largest error in estimation was $12^0$.




- The CICS intensity map was calculated for a real test recording.
- We chose to show results from a recording with 0 elevation relative to the array because the CICS intensity map is easier to visualize in 2D.
- The direction of the source is well-estimated, but the distance is not. This is what we expected, given the small size of our array.

SONOS

## ACKNOWLEDGEMENTS:

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