Sound Fields Forever: Mapping sound fields via position-aware smartphones

Dr. Scott Hawley, Sebastian Alegre, Brynn Yonker

Department of Chemistry & Physics

Belmont University

143rd AES Convention, October 21 2017

Overview

- **Motivation**: Provide visualization of sound fields for education, live sound reinforcement, musical & architectural acoustics.
- **Goal:** Low-cost, accessible automated data acquisition & visualization

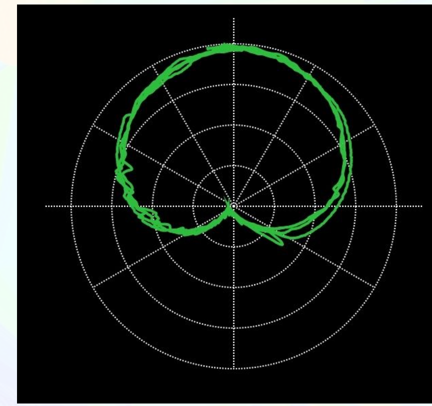
- This new system provides a visual representation of the acoustical properties of an environment (i.e. a room). Our Android app combines position information with sound intensity data in multiple frequency bands obtained from a comoving external microphone plugged into the phone's analog audio jack, and filtered digitally. These data are sent wirelessly in real time to a visualization server running in a web browser.

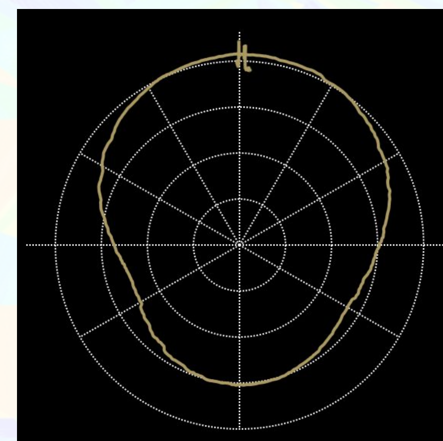
Previous Work: Polar Pattern Plotter

Download on the App Store

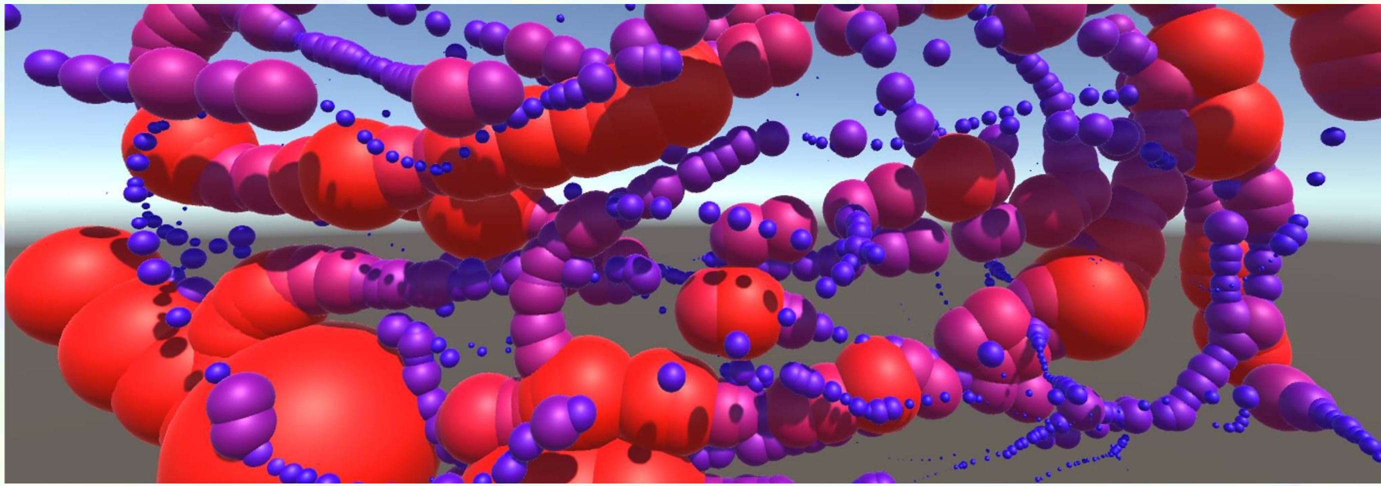
https://github.com/drscotthawley/PolarPatternPlotter

- **“Visualizing Sound Directivity via Smartphone Sensors,”** Scott H. Hawley, Robert E. McClain Jr. *The Physics Teacher*, December 2017. https://arxiv.org/abs/1702.06072
- Free iOS App for measuring mic & speaker directivity.
- Wanted to go 3D!





Previous Work: HTC Vive



- Strapped microphone to hand controller of HTC Vive VR system
- Wrote Unity app, which left “spheres” behind as you “paint” the air. Spheres’ color & size depicted sound intensity
- Excellent spatial / freq accuracy, *but not portable, not suitable for large spaces*
- *Was purely broadband, no frequency information*

Tango

- The app is based on a sensor technology called Project Tango (intended for Augmented Reality applications), which enables certain Android devices to perceive their position in three-dimensional space *without any additional hardware* (unlike, e.g. HTC Vive). At development time, there was only one Tango-enabled device on the consumer market: the Lenovo Phab 2 Pro (shown).
- Recently, Asus has released a Tango device as well.

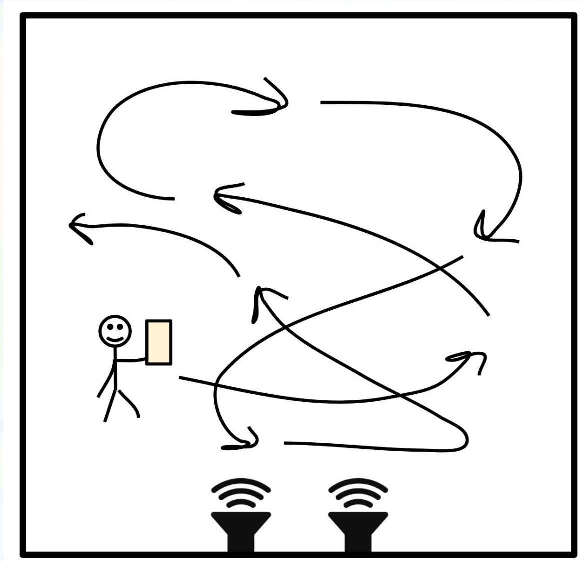
System Design

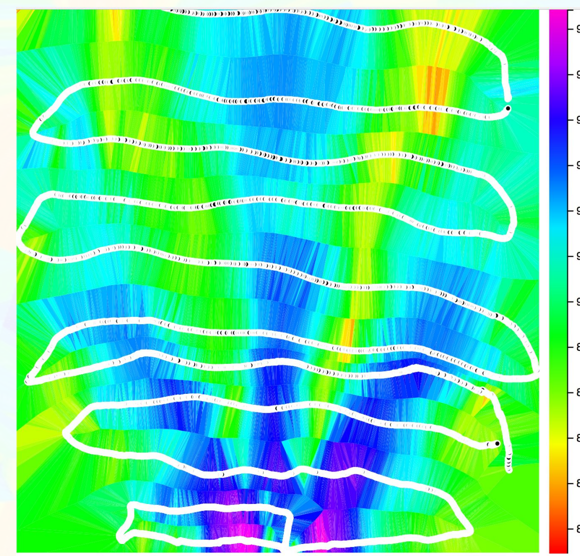
- The **mobile app** is written in Java for Android and consists of a component which manages all of the Tango positioning and motion tracking systems, an audio recorder used to calculate sound pressure levels (SPL), and a WebSocket client to pass the collected data to the *visualization server*. The device is calibrated to give accurate SPL readings with a precision of ±2 dB.

- The **visualization server** is written in JavaScript using D3.js. The datastream that comes in from the application is graphed in a Voronoi diagram, which is a partitioning of a plane into regions based on the closest distance to the data locations. Also does contour plots, spatial smoothing.

Measurement Method

- Walk with the device around the room while data is recorded. The visualization server is updated as new data are acquired
- The viz server can look in different frequency bands, and can smooth out location-error “noise” in the image





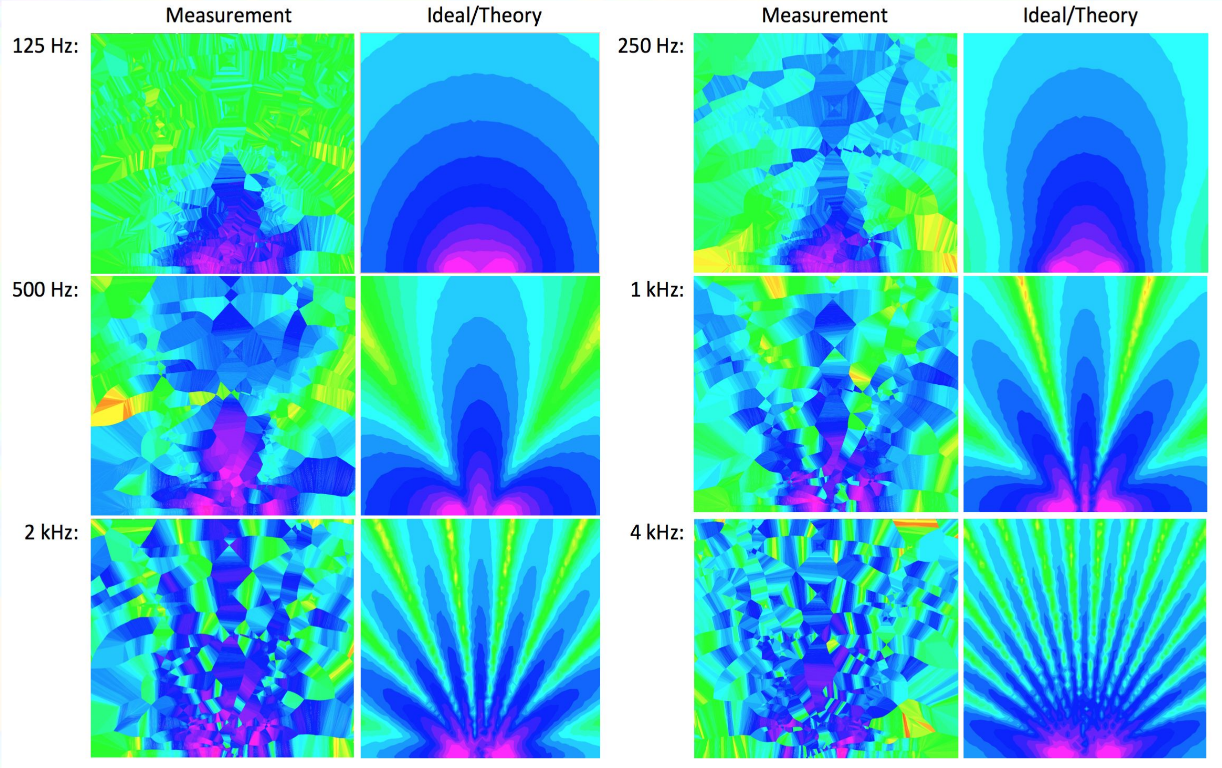
(Many audio engineers want us to reverse the colormap. Ok..)

Challenges

- The Lenovo Phab 2 Pro smartphone presents a few problems...
  - Built-in mic applies automatic gain reduction which cannot be bypassed.
  - With external mic, audio chip clips at ~99dB SPL
  - Tango hardware deactivates within 3 inches from a wall. This limits accuracy in small spaces, but not a significant limitation for large venues.
  - There is some location drift: occasionally the system briefly reports an incorrect position.

Results: Two-Speaker Interference

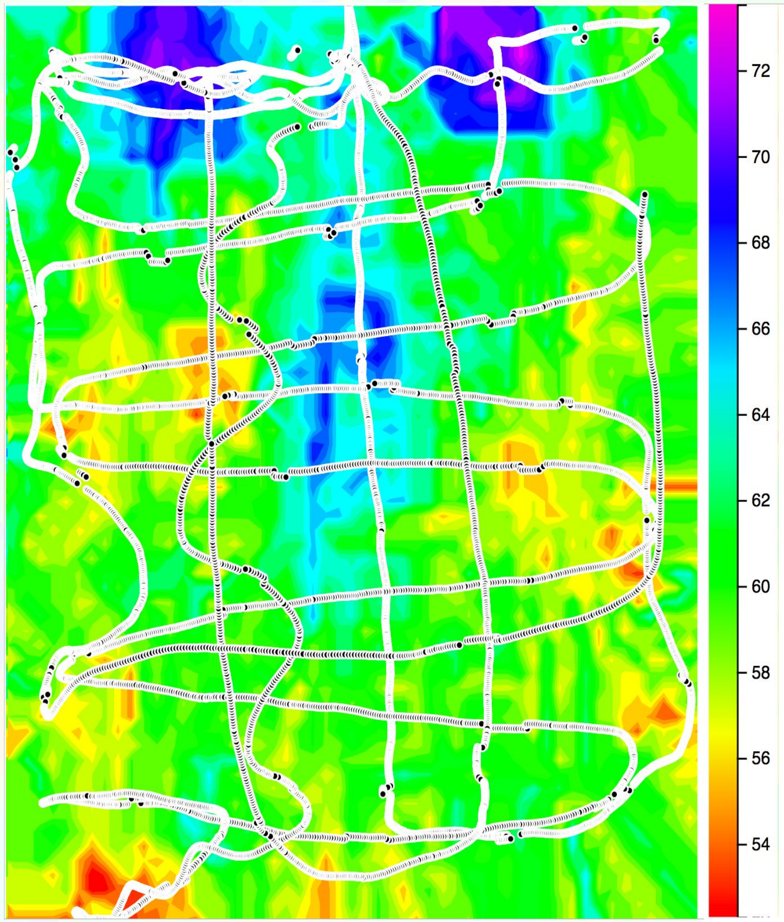
- Sound intensity map for two-speaker interference, in various octave bands. Colors are in analogy to light energy
- Two loudspeakers placed 2 ft. apart in an anechoic room, and played a multiple frequencies simultaneously
- Although some positional drift is evident, we see the expected angular dependencies.



Purple/Blue=Loud, Green/Red=Quiet

Results: Columbia Studio A

- 2D contour plot of sound intensity level in Columbia Studio A, with *pink noise* played from a PA at the top of the figure.



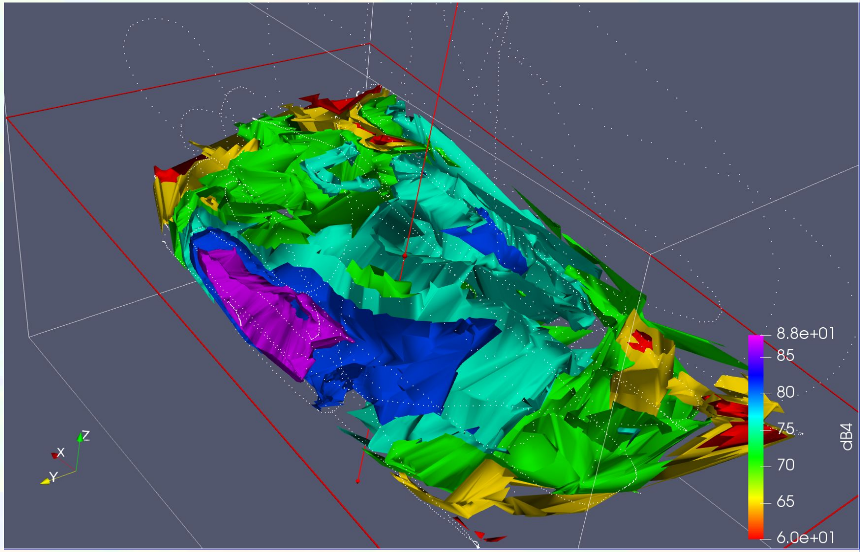
Purple=Loud

Red=Quiet

Feature request: Yes, we will allow you to reverse the colormap

Results: Loudspeaker (Near Field)

- Set of 3D isosurfaces for sound in front of Mackie HR824mk2 playing 1kHz tone, plotted using ParaView.
- Here the 3D surfaces are sliced horizontally to reveal structure.
- Variability & lack of symmetry may be due to drift errors from Tango system.



- Plan to re-measure using upgraded HTC Vive / Unity app for better location accuracy

Future Work

- **More testing:** Compare to HTC-Vive-based measurements
- **More mapping:**
  - More venues: churches, studios
  - Room modes in small rooms
- **More education laboratory demos:**
  - Could "slice through" 3D dataset to demonstrate, e.g. inverse square law
- **More mathematical analysis:**
  - Add Spherical harmonic decomposition
  - Add smoothing method based on radial basis functions
- **More devices:** Port to ARCore (Android), ARKit (Apple)

Conclusion

- Location-aware smartphones provide a viable method for mapping acoustical environments
- Our method is appropriate for steady-state sound fields
- Some drift occurs resulting in location errors, which we currently solve by multiple passes through a region and smoothing the data
- We hope to get out into Nashville soon to demonstrate the utility of this tool!
- As more devices are manufactured with Tango technology, we hope the audio will become more robust
- *ASIDE: People remark that the (vector) graphics look like art! Might start printing posters!*