
Lost Voices of Hagia Sophia Recording and Production in Live Virtual Acoustics

Elliot K. Canfield-Dafilou (kermit@ccrma.stanford.edu)



Room Acoustics



- Rooms have their own characteristic sound
 - The size, materials, geometry, etc. all affect how a room sounds
 - The nature of this reverberation influences music performance
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Acoustics and Music Performance

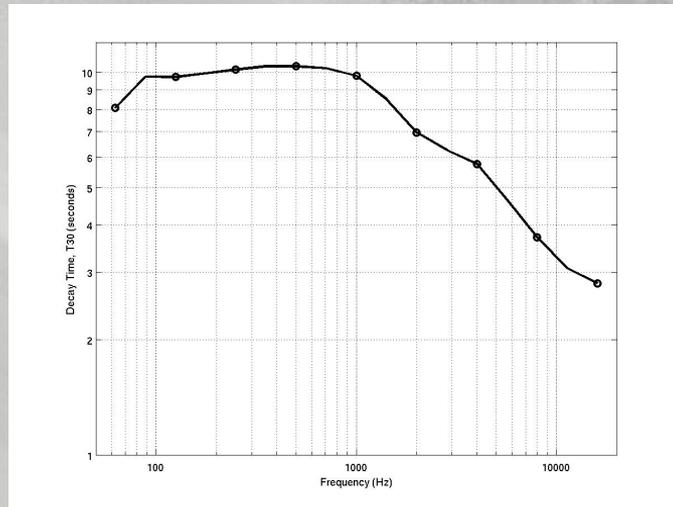
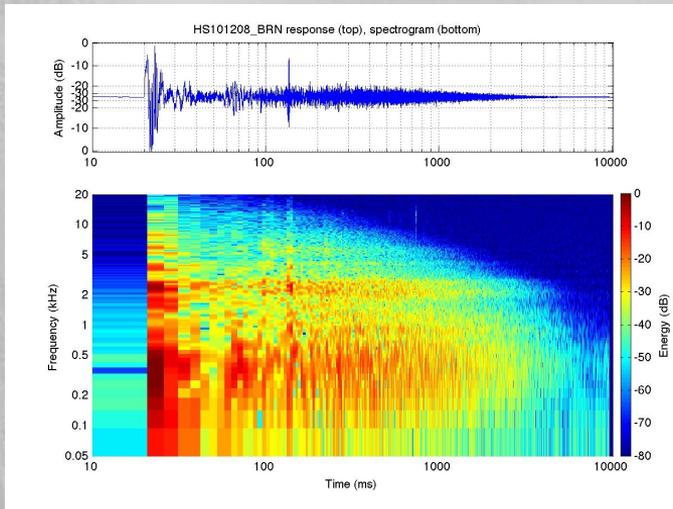


- Performers interact with the reverberation of a space like an instrument
 - Sometimes music written for a particular space is tied to the acoustics of that space
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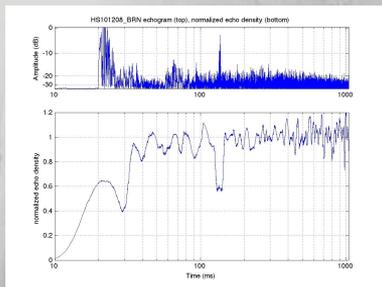
Hagia Sophia Acoustics, Spectral Features

response spectrogram

T30

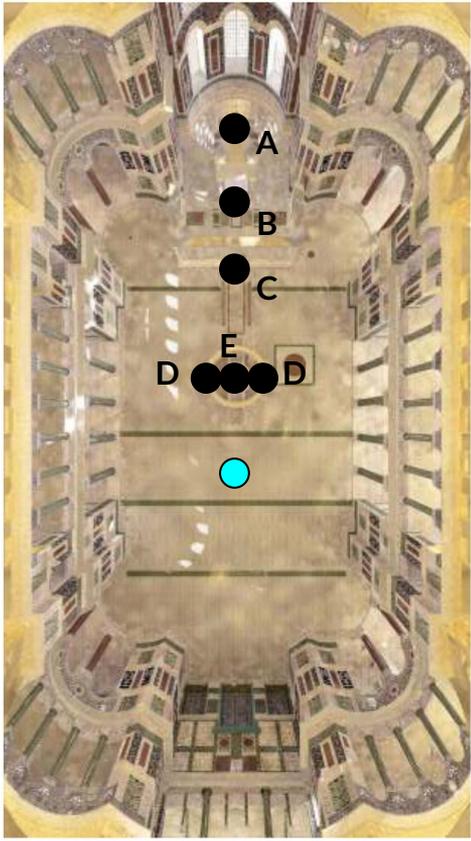


perceived echo density



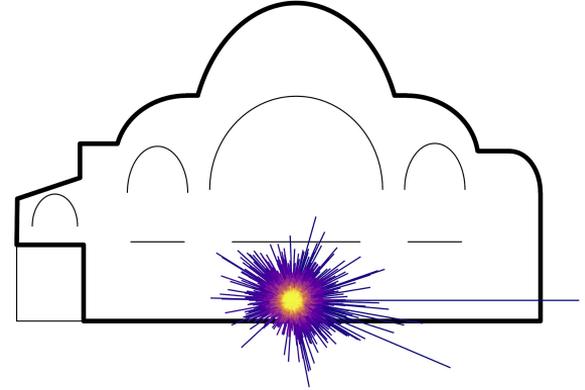
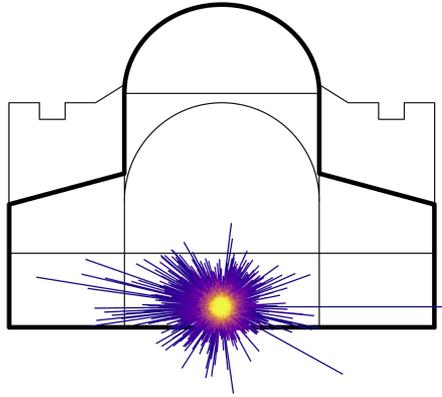
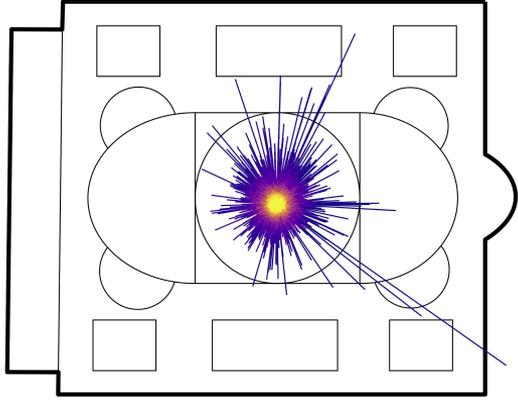
- Exceedingly long, bright reverberation (large volume, marble, tessera)
- Reflections greatly influenced by the domes and colonnades

Hagia Sophia IR Measurement/Processing



- Measurements from several locations in HS using coresound tetramic
- Sine sweep measurements are converted to IRs
- IR tails are processed to remove noise floor
- Dry microphone signals are submixed and used to drive convolution reverb for each speaker
- **For recording:** all speakers use statistically similar IRs
- **For production:** spatial IRs are used, both to place singers in different spots of HS and to provide 3d spatial cues

Hagia Sophia Acoustics, Spatial Features



- Statistically independent, directional impulse responses were synthesized for the 5.1.4 immersive mix
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Typical (Classical) Recording Process

1. Choose a room with favorable acoustics
 2. Place musicians and microphones in the room and record
 - Room mics form the baseline sound and are supplemented with spot microphones
 3. Edit/Mix
 - Room sound and spatial position is already primarily set from decisions made earlier in the recording process
 4. Post production
 - May add tasteful supplemental reverberation
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Virtual Acoustics Recording Process

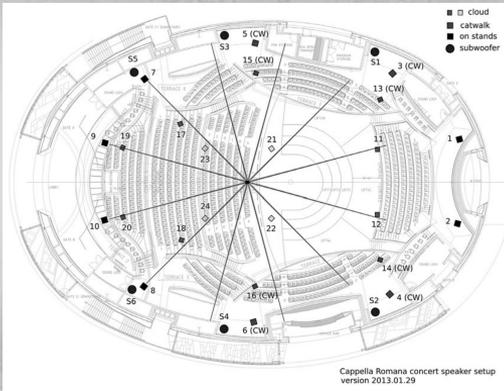
1. Choose a neutral room with low amount of reverberation
 2. Place musicians and microphones in the room
 - Close mics drive live auralization system & capture “dry” individuals
 - Room microphones capture better sound than close mics, but the mix is not primarily derived from the room mics
 3. Record, using speakers to provide baseline auralization
 4. Editing can be performed using “dry” tracks
 5. Mixing, spatialization, and final auralization
 - Room mics and close mics are combined affording more control to spatialize the musicians
 - Acoustics are added to the relatively dry tracks
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Virtual Acoustics: Live Performance vs. Recording



Live performance:

- Performers and audience need to hear the musicians in the virtual acoustics
- Only close microphones are used, so as to mitigate feedback
- Speakers in concert hall provide directional/spatialized auralization

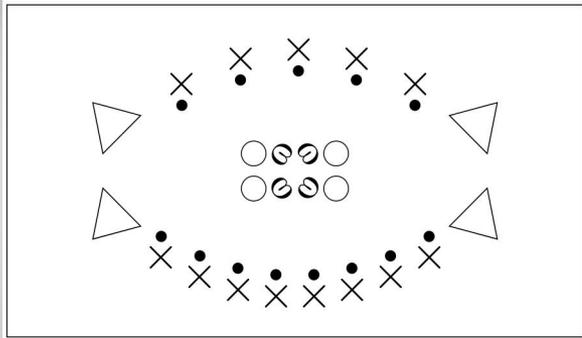


Virtual Acoustics: Recording Requirements

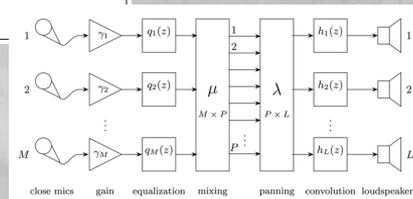
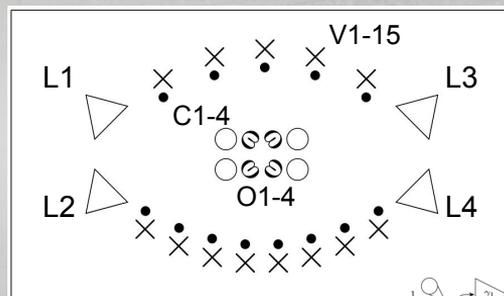


Recording:

- (Classical) musicians loath headphones...
- ... but we need live virtual acoustics for the musicians to interact with the HS acoustics
- Auralization system is used at a low level, with speakers and mics placed to minimize reverberation in room microphones



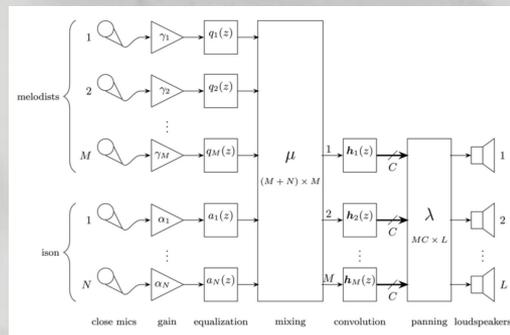
Lost Voices: Recording



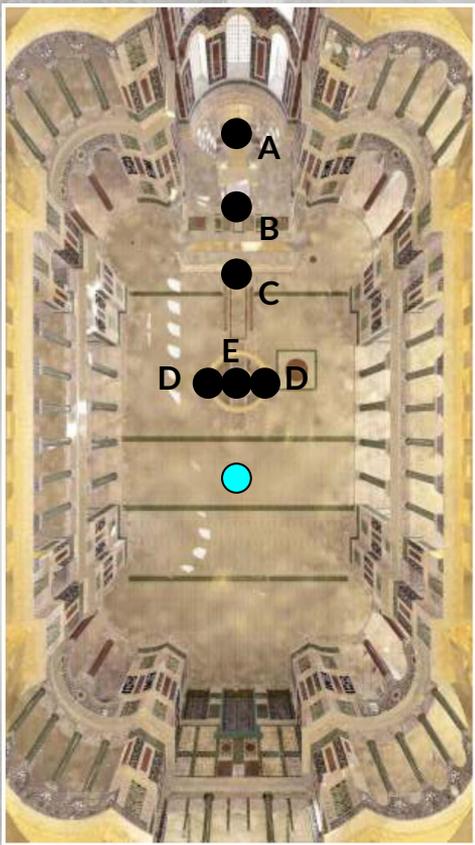
- Ions (drones) and melodists were spatially separated
- 3 live mixes: room auralization for performers, extra dry mix for producer, and balanced mix for recording engineer
- All auralization signals were similar to provide baseline reverberation
- Multiple stereo room mic pairs were used to provide options when mixing

Lost Voices: Editing and Mixing

- Dry takes were spliced together; easier than with reverb
- Panned close mics formed the baseline stereo field and were supplemented with a mix of room microphones
- This base “dry” spatial mix fed banks of spatial impulse responses



Lost Voices Surround Mixing and Mastering

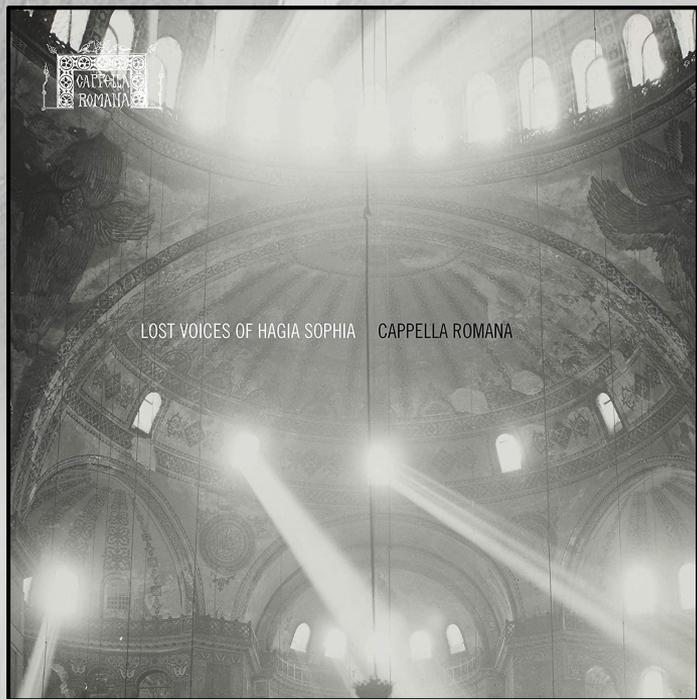


- *Lost Voices* presents the liturgy of a specific event (The Feast of the Exaltation of the Holy Cross)
 - Various deacons, priests, choir members, etc. were virtually placed in Hagia Sophia according to where they would have been positioned for each of the pieces by analyzing spatial impulse response measurements
 - The listener is given a privileged location
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Related work

- *Virtual Haydn* (historic keyboards and historic rooms)
 - Notre Dame reconstruction (studying the acoustics, modeling the cathedral throughout time, and [giving suggestions for] rebuilding the cathedral after the fire)
 - Other Archeo-acoustic studies (measuring/preserving acoustics of historically interesting/important spaces)
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Lost Voices of Hagia Sophia Listening Tour



Prokeimenon: (Gradual Ps. 98:9, 1-2), Barys Mode
Track 11, *Lost Voices of Hagia Sophia*, Cappella Romana

Listening guide:

- The vocalists use Hagia Sophia like an instrument
- Long reverberation time dictates tempo
- Ison (drones) tune higher partials to resonances in the reverberation
- Listen for the deacon and priest located closer to the apse than the main choir
- Reflections from the domes, colonnades, apse, etc. “move” sound around the listener*

We hope you enjoy listening!

* This is more prominent in the 5.1.4 version
