A Modular Computational Acoustic Model of Ancient Chavín de Huántar, Perú

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Outline

1. Computational acoustic modeling for archaeology

2. Chavín de Huántar context

3. Model architecture, design process

4. Implementation w/alternate data forms
   (estimated vs measured filter data)

5. Application to Laberintos Gallery west wing

6. Future development goals

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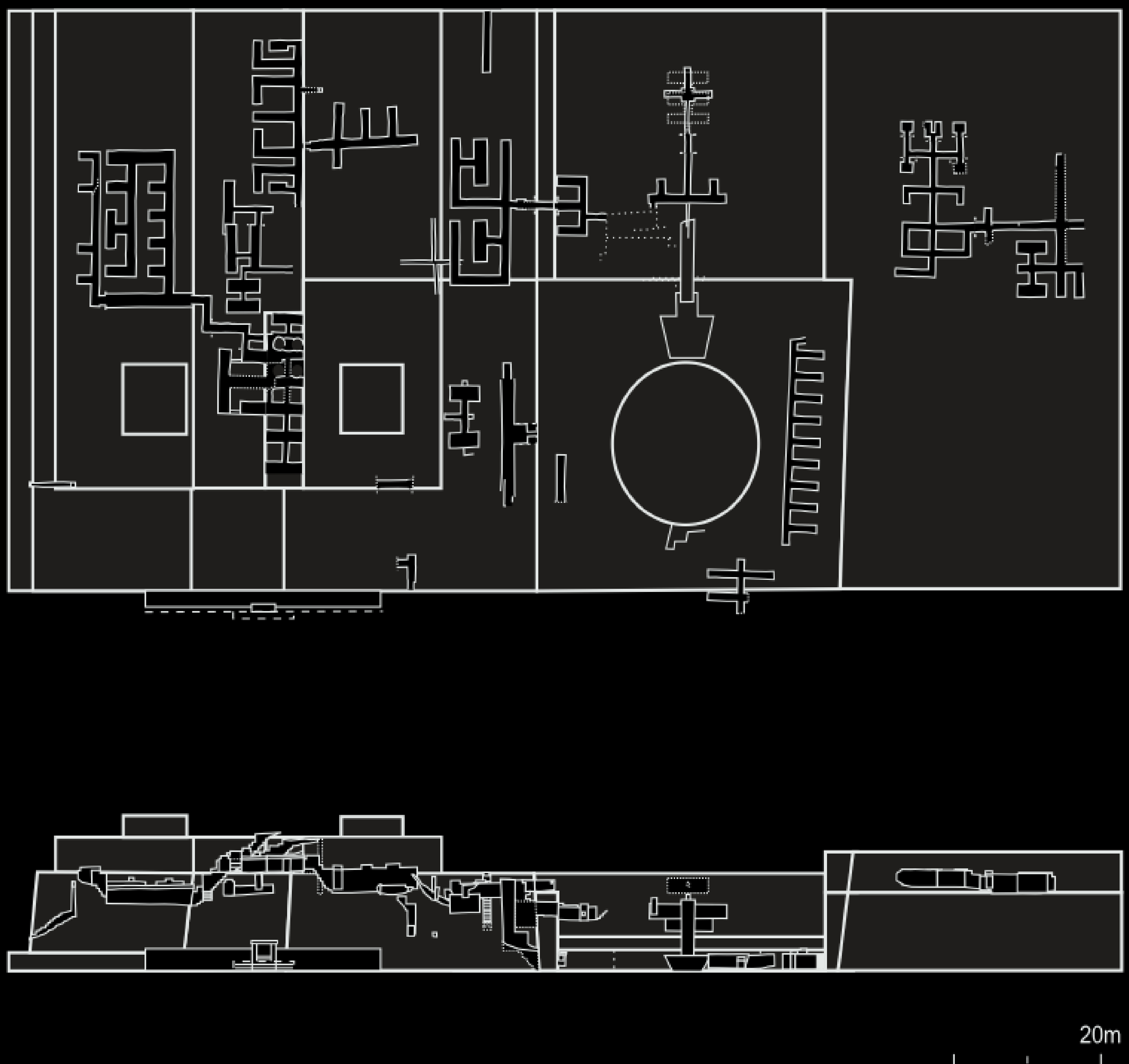
1. Computational Models in Archaeoacoustics

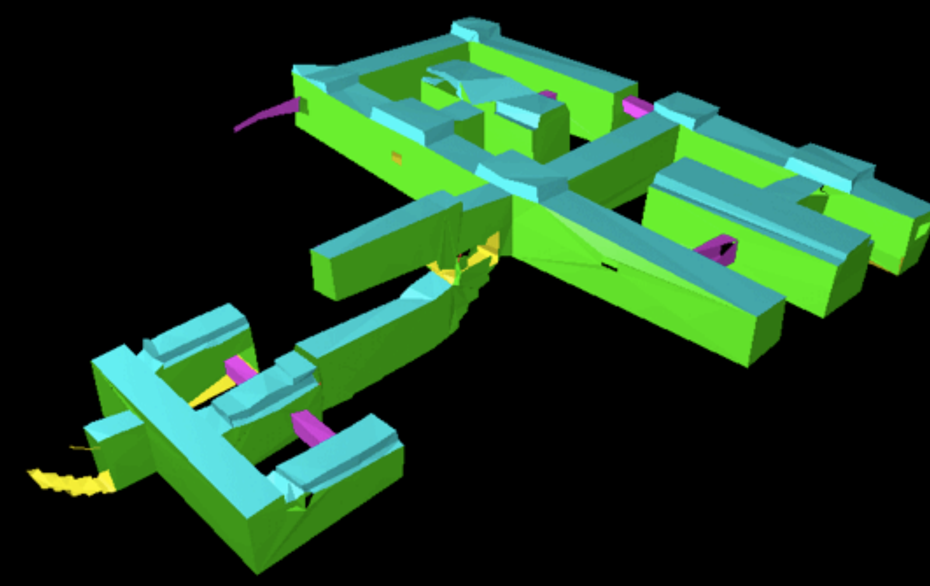
- document and preserve ephemeral artifact
- virtual reconstruction of acoustics of damaged, destroyed, or hypothetical site structures & materials
- tools for archaeological hypothesis testing, (auralizations, sound transmission maps)
- tools for psychoacoustic experimentation (perceptual effects of sound source and environment dynamics)

2. Chavín Context

- 3,000 years old; ~3,150 meters high Andes
- Formative Period site of emerging social hierarchy
- massive ceremonial "center" complex
- record suggests sensory interest/focus

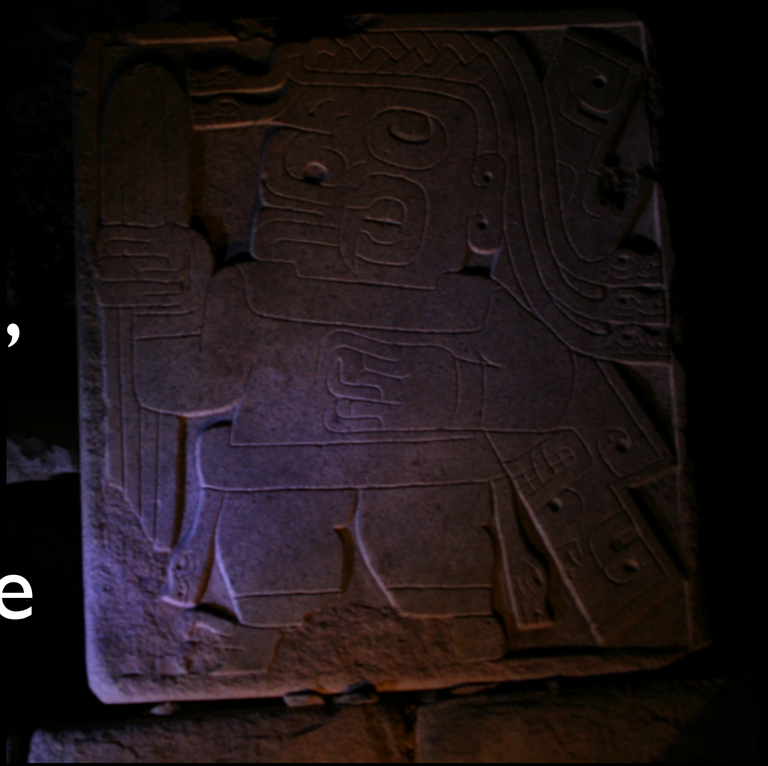
2. Chavín Context





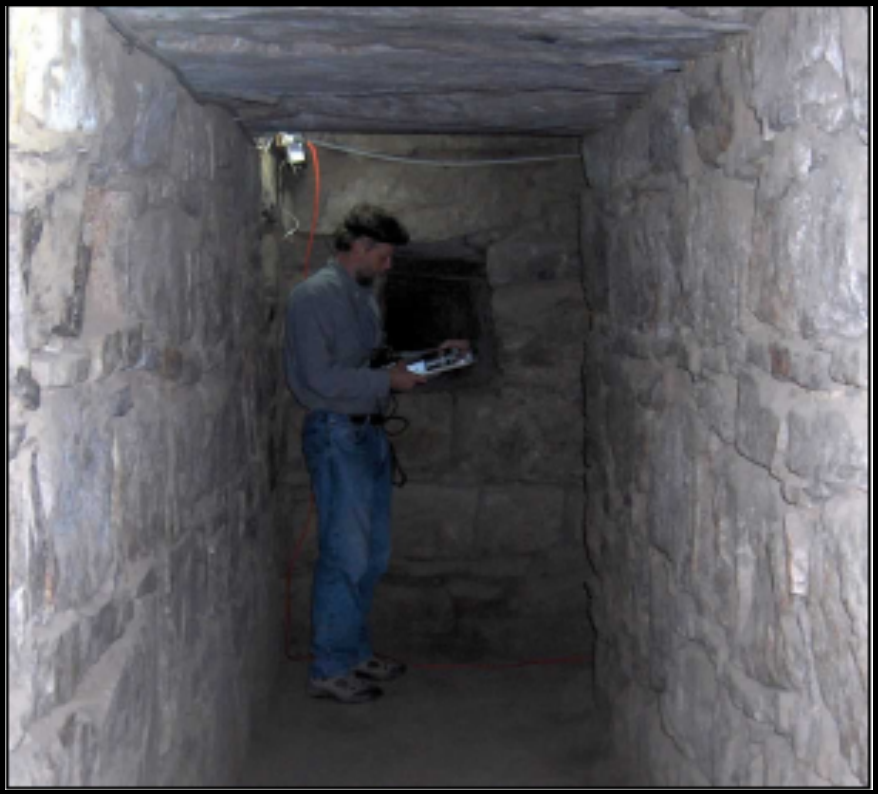
2. Chavín Context
sensory culture

- psychoactive plant substances, tools, depictions
- maze-like interior architecture
- light/shadow manipulation
- marine shell trumpets "pututus"



- observed and measured "sound effects"

2. Chavín Context



2. Chavín Context
acoustics

- Lumbreras, Gonzáles and Lietaer (1976)
  "network of resonance rooms
  connected by sound transmission tubes"
- Abel et. al. CCRMA research (2008, 2009)
  characterization: short RT; rapidly dense echos;
  unlike natural world; highly coupled spaces
- ancient, intact & enclosed, can still be measured!
- observed & measured modal resonance

2. Chavín Context
model requirements

- translate across the site
  (structural specificity, physical breadth)
- capture large-scale physical dynamics
- approximate perceptually-relevant local features
- minimal data collection
- modest computing power (real-time)

3. Model

- 1:1 translation of gallery architectural forms and topology to model modules and network
- 2 module types: digital waveguides (WGDs) and reverberant scattering junctions (RJNs)
- distributed system to lumped element model

3. Model Architecture

- WGD models 1-D traveling wave propagation (bi-directional delay; spatial samples = distance)
- like typical scattering junction, RJN models impedance changes
- unlike typical scattering junction, RJN filters have spatial, reverberant character
- RJN receives 1/2 energy from each WGD

3. Model Architecture

- filters model source directivity, materials absorption, propagation loss
- RJN reflection filters incorporate time delay and reverberant characteristics
- WGDs are pure delays w/filter for attenuation
- all modules have short RT, assume well-mixed state
- signal exits at module boundaries, returns via network
- energy scaled by distance & cross-sectional area changes

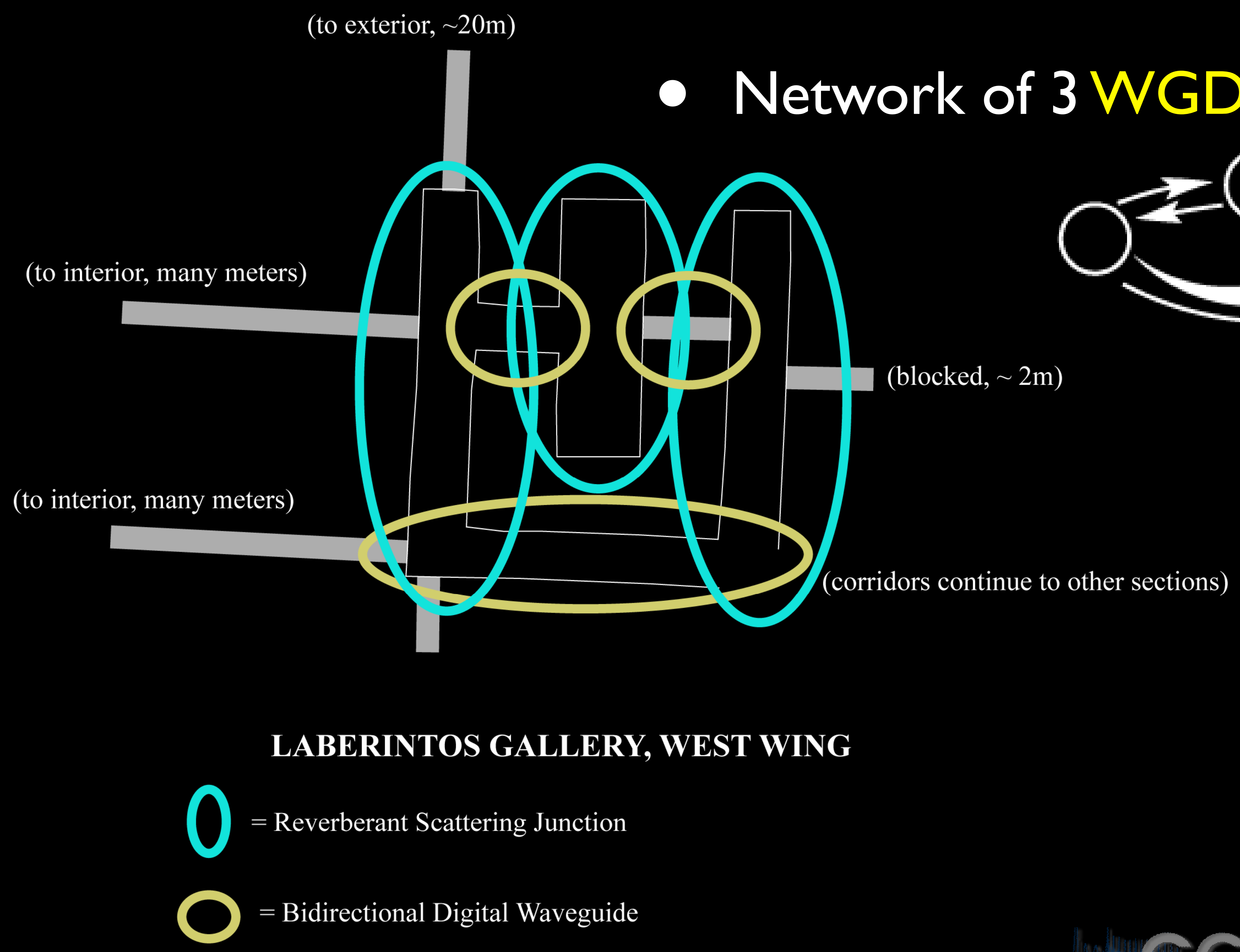
4. Implementation

design process

- parse architectural topology, assign WGDs & RJNs
- map WGD and RJN to network diagram
- specify input point(s) to inject sound source(s)
- specify output point(s) for listener perspectives
- incorporate measured and materials data

5. Application: Laberintos wing

- Network of 3 WGDs, 3 RJNs



5. Application

measurements

5. Application

measurements

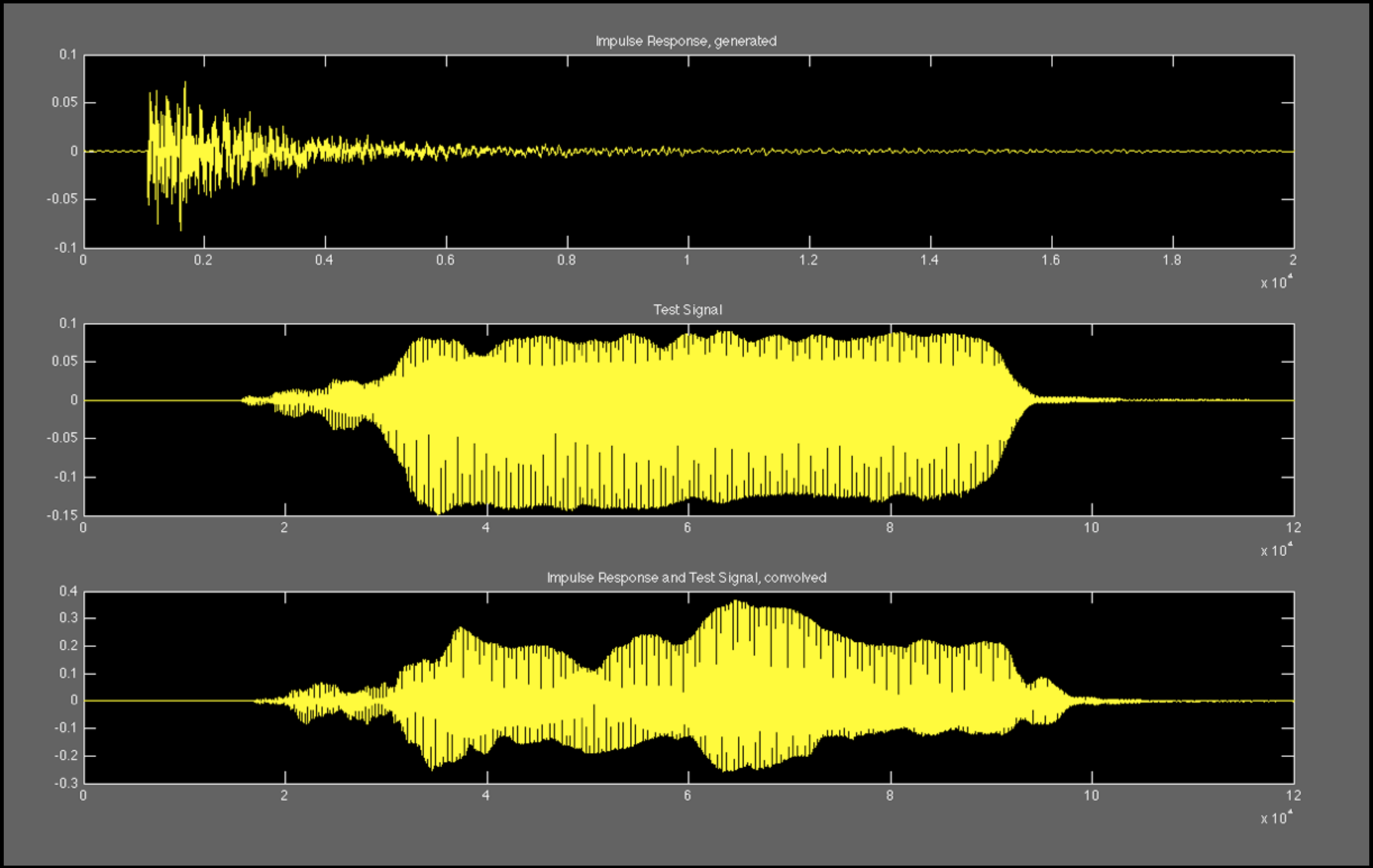
5. Application

measurements

5. Application

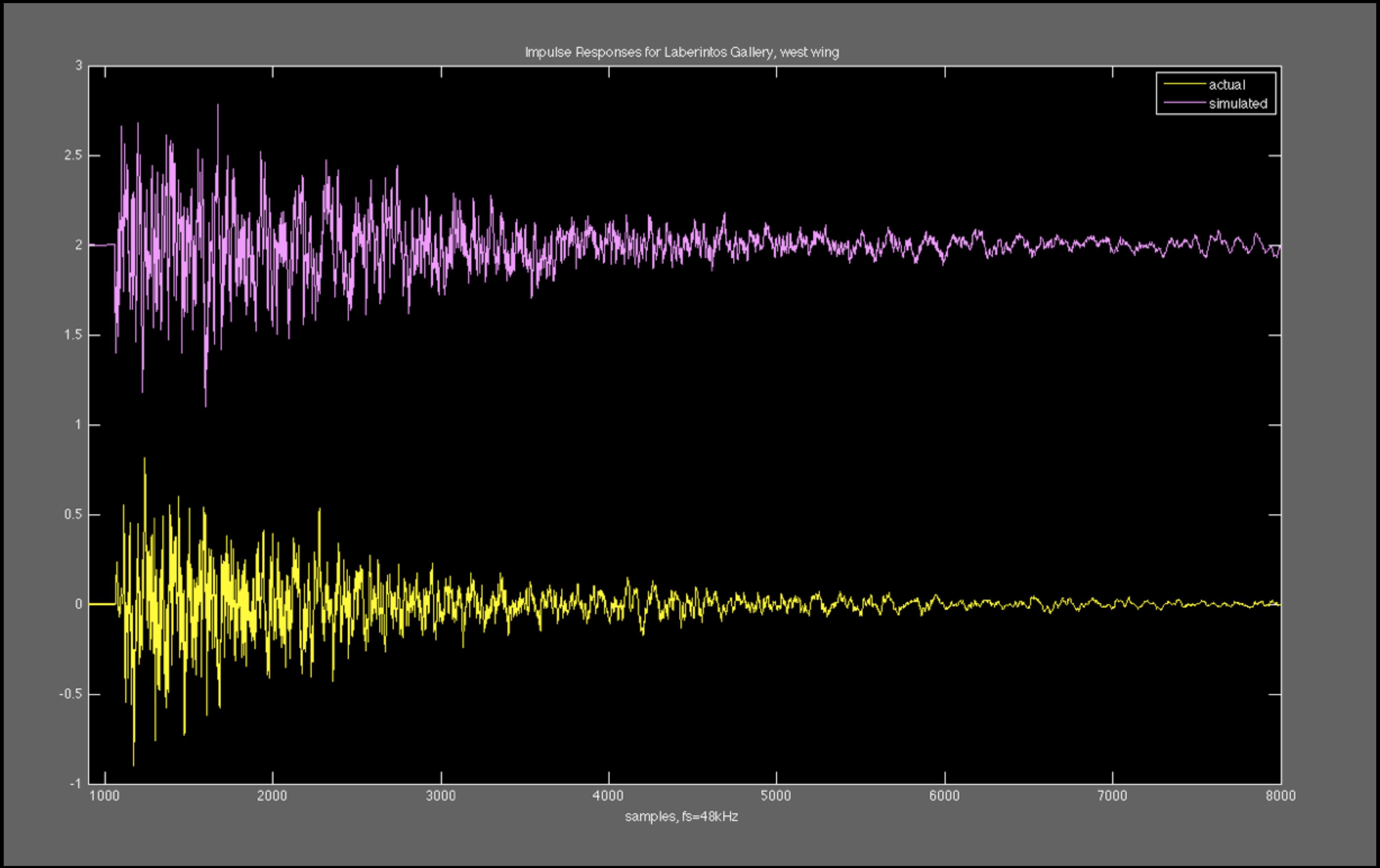
measurements

5. Application: Laberintos wing



- modeled IR, source signal, auralization

5. Application: Laberintos wing



- IR modeled, IR measured

6. Future Development

- real-time implementation
- improved filters driven by materials data
- scaling to capture ceiling height variations
- HRTF filters for binaural implementation
- psychoacoustic evaluation

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https://ccrma.stanford.edu/groups/chavin