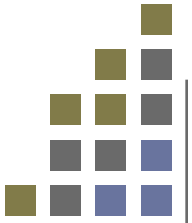

Bachelor Thesis
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Image Theory applied to Virtual Microphones

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Overview

- Introduction
- Problem definition & Methodology
- Theoretical Background
- MATLab Implementation
- Conclusions
- Future Work

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Introduction

- Sound behaviour
  - ✓ Ideal wave propagation
  - ✓ Enclosure spaces
- Building materials

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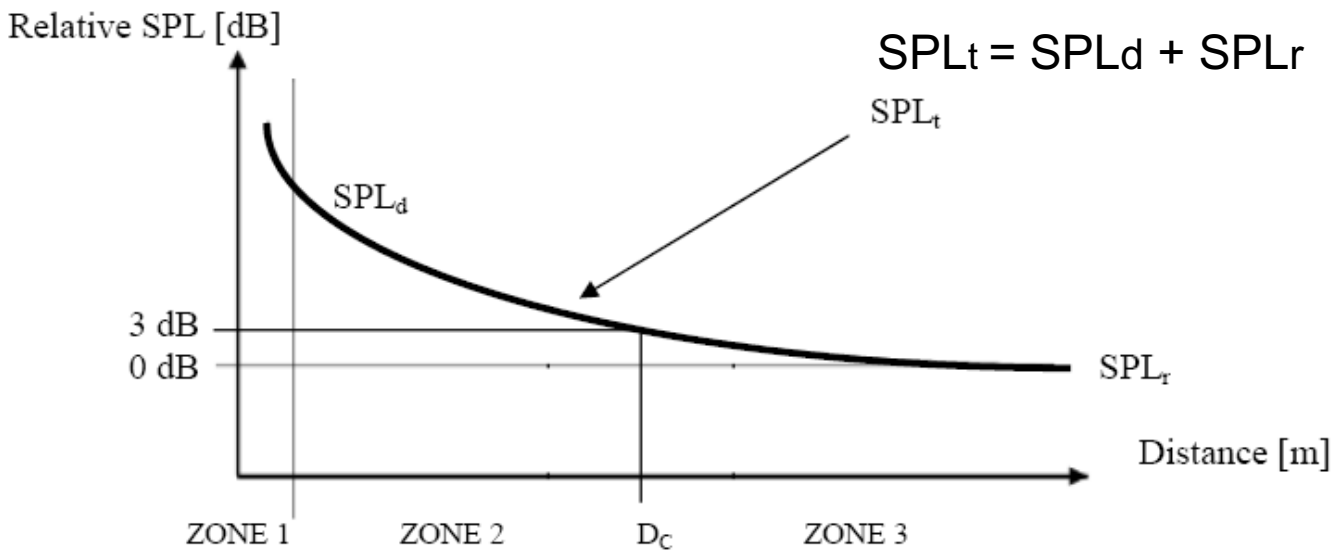
Sound Behaviour



ZONE 1. Loudspeaker close field. Particles chaotically distributed.
ZONE 2. Direct sound field. Spherical divergence.
Dc. Critical distance. SPLd = SPLr
ZONE 3. Reverberant field. SPLt due to reflections on the walls.

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Building Materials

Floor Materials	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
concrete or tile	0.01	0.01	0.15	0.02	0.02	0.02
parquet on concrete	0.04	0.04	0.07	0.06	0.06	0.07
carpet on concrete	0.02	0.06	0.14	0.37	0.60	0.65
carpet on foam	0.08	0.24	0.57	0.69	0.71	0.73

- Frequency range analysis.
- Direct relationship with reverberation time, RT60.
- Sound study based on either Sabine or Eyring equations:

$$T_{Sabine} = \frac{0.16 \cdot V}{A_t} \rightarrow \alpha < 0.2 \qquad T_{Eyring} = \frac{0.16 \cdot V}{(-S \cdot \ln(1-\overline{\alpha}))} \rightarrow \alpha > 0.2$$

α Sound absorption coefficient

$\overline{\alpha}$ Room's average sound absorption coefficient

At Equivalent absorption area measured in m2.

V and S are room volume and surface respectively.

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Problem Definition

Goal: Sound modeling of a room by studying the sound paths in an enclosure space.

Statements:

1. Equipment requirements: omnidirectional transducers.
2. Room dimensions and properties:
   - Parallel, flat and rigid walls.
   - Uniform absorption in each surface.
   - No windows, doors, furniture or audience inside.
   - Static loudspeakers and microphones.
   - Room volume between 10 m^3 and 5000 m^3

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Theoretical Background

- Ray-based geometric sound methods
  - Ray Tracing Technique
  - Image Theory Method
- Impulse response observation

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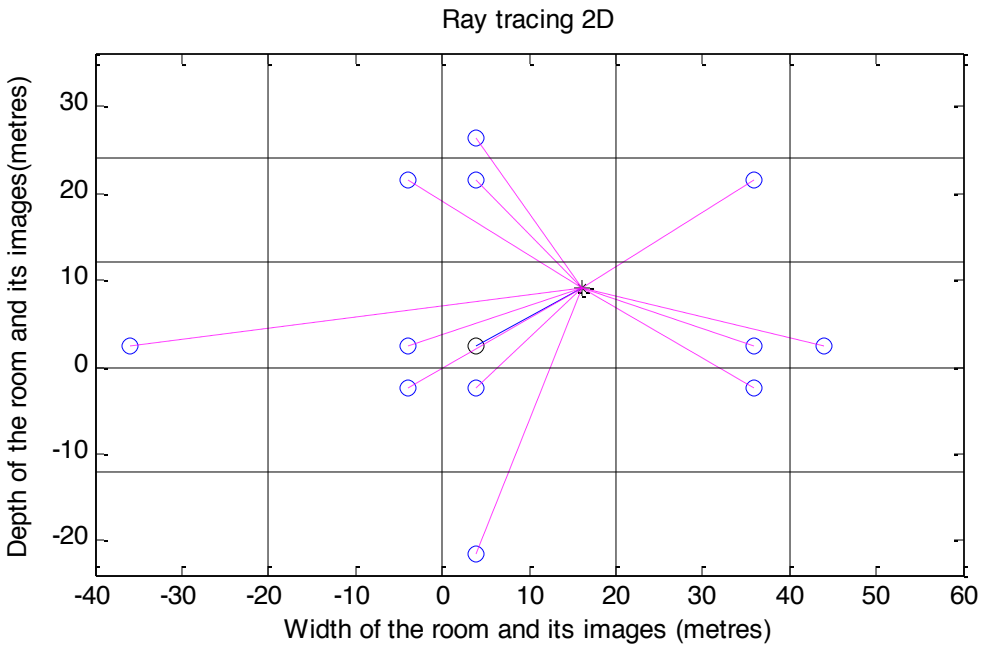
Ray Tracing



- Ray paths observation by listing each wall impacts.
- Only specular reflections considered according to Snell's Law.

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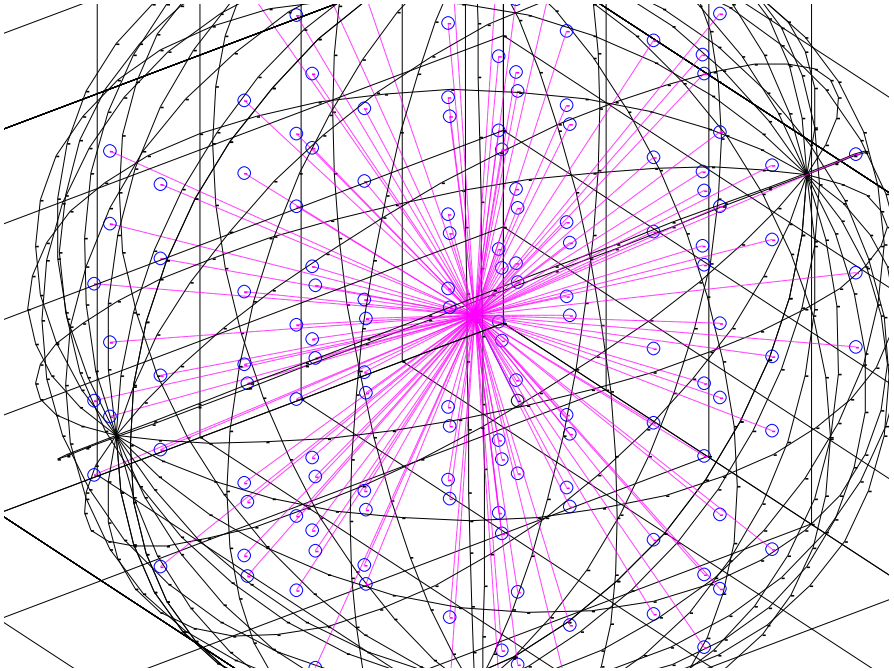
Image Theory

- The goal is to obtain the impulse response.
- Calculus of imaginary sources inside a given time.
- Sphere radius based on Statistic Theory: Reverberation time.



$$radius = c \cdot t$$

c, sound speed
t, RT60

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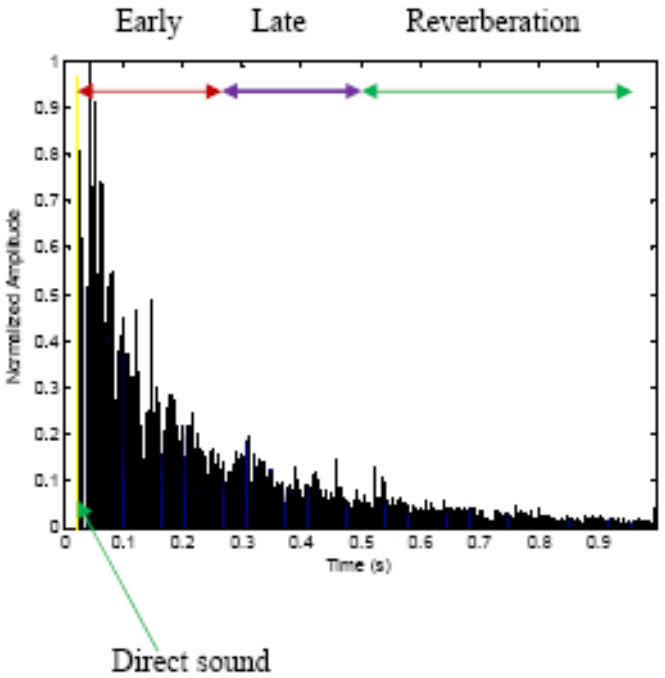
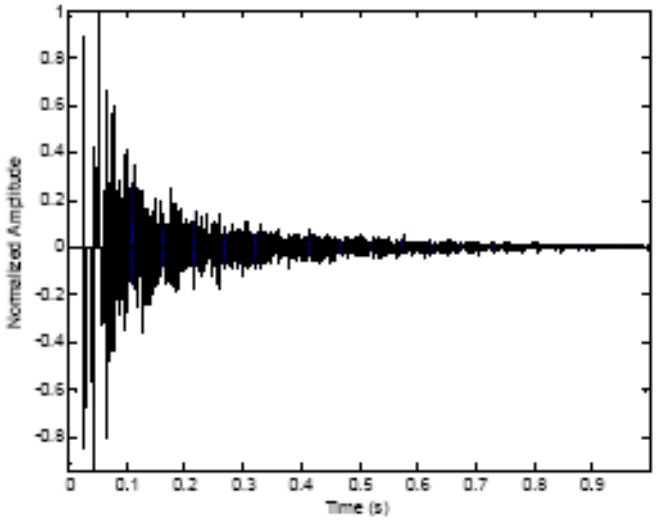
Impulse Response





Doak & Bolt representation

Symmetrical representation

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Research Methodology

- Ray Tracing 2D - 3D
- Image Theory 3D
- Multi Image Theory

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imgthry3d.m

[h, time, tr, f0] = imgthry3d (room, source, …
mic, absorption, fs, timec, plotIR, plotVS)

h: impulse response
time: time axis
tr: reverberation time
f0: frequency from which the impulse response is valid

timec: calculation time. If 0, reverberation time is used
plotIR: if 1, plots the impulse response
plotVS: if 1, plots the geometrical representation of the virtual sources

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multi_imgthry3d.m

[h, time, tr, f0] = multi_imgthry3d (room, sources,…
mics, absorption, fs, timec, plotIR, plotVS)

Uses imgthry3d to calculate the impulse response between several microphones and sources

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Conclusions

- Fairly accurate results obtained under the observation conditions.
- Most outstanding parameters:
  - Direct distance source - microphone.
  - Matching walls' absorption coefficients.
- Straightforward method valid for checking the sound behaviour in office environments.

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Future Work

- Geometry – absorption modifications in the model.
- Multiple image theory studied under an electroacoustic point of view, including the transducers close field observation.
- Application of diffuse reflections.
- Reverberation simulated by using recursive filters such as Schröder Diffusor.
- Non-static transducers performance.

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