

The Hand Clap as an Impulse Source for Measuring Room Acoustics

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Why?

The Upshot

Claps are easy to produce.

Reliable acoustic measurements from claps allows amateurs to diagnose acoustic problems quickly and easily.

Background

Room acoustics

There are three qualities which determine a room's sound.

1. Space
2. Warmth
3. Clarity

Background

Room acoustics

There are three qualities which determine a room's sound.

1. Space - Reverberation time
2. Warmth - Frequency response
3. Clarity - Frequency decay

Background

Impulse response

Definition: how a room reacts to a short, loud sound.

Ideal impulse response

1. Very short
2. Covers a wide frequency range
3. Consistent

Background

Good impulse sources

1. Balloon pops
2. Starter pistol shots
3. Firecrackers, etc.

Motivation

An amateur acoustician's ideal workflow

1. Clap a few times in a room.
2. Have a program quickly respond with analysis.
3. Diagnose and improve room based on analysis.

Motivation

An amateur acoustician's current workflow

1. Hire a professional acoustician.

Hand Claps

What's in a clap?

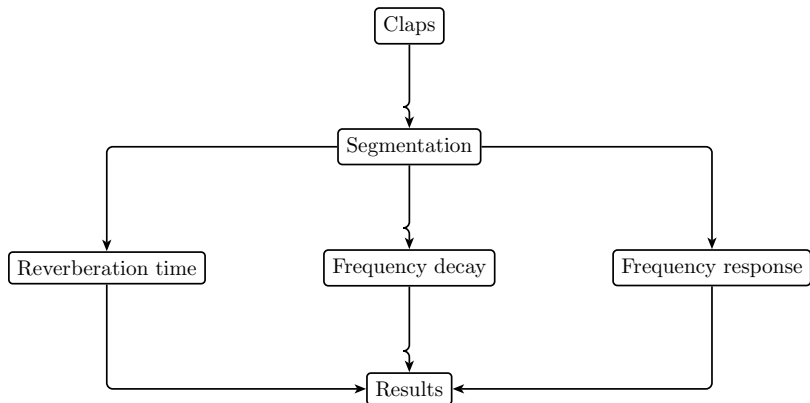
Advantages:

1. Easily produced

Disadvantages:

1. Low energy
2. Long duration
3. Inconsistent
4. Mediocre frequency coverage

Approach



Setup

Recording

Clap from the stage, record from the center with a Zoom H4N recorder.

Datasets

1. Pick-Staiger Concert Hall (Northwestern Univ.): 19 claps.
2. Lutkin Concert Hall (Northwestern Univ.): 12 claps.
3. Makeshift home recording studio: 6 claps.

Ground truth

A professional acoustic survey performed by Northwestern on Pick-Staiger Concert Hall.

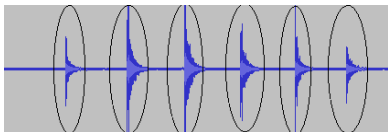
Segment claps

Thresholding

Input: a series of claps.

1. Clap onset: power is ten times the background level.
2. Clap end: power returns to twice the background level.

Output: individual claps.



Reverberation time

Definition

RT_{60} : time required for a sound level to decay by 60 dB.

Problem: 60 dB above background level = jet engine – a dial tone.

Solution: Extrapolate the rest via a line-fitting approximation.

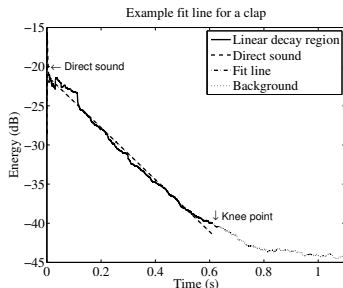
Reverberation time

Problems with claps

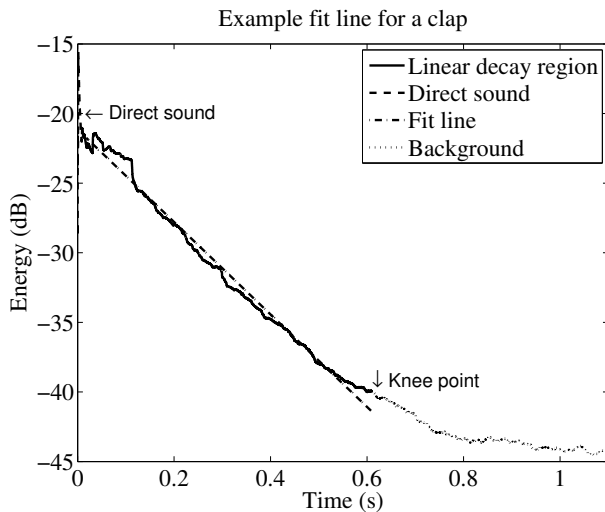
Low energy: end of clap (the "knee" point) is difficult to find.

Finding the "knee":

1. Too early: linear fit doesn't use enough data.
2. Too late: linear fit is too shallow.
3. Getting it just right:
 - 3.1 Try all possible knee points after the first 100 ms, and minimize error of the resultant fit line.



Reverberation time



Reverberation time

Results

Highly encouraging. For Pick-Staiger Concert Hall:

1. Mean: 1.74 seconds.
2. Standard deviation: .07 seconds.

Ground truth comparison

Overall reverberation results unavailable, but close to middle band frequency results from the acoustic survey.

Frequency decay

Definition

RT_{60} of a particular frequency.

Process:

1. Split recording up into frequencies using a spectrogram method.
2. Pass each signal to our RT_{60} method.

Frequency decay

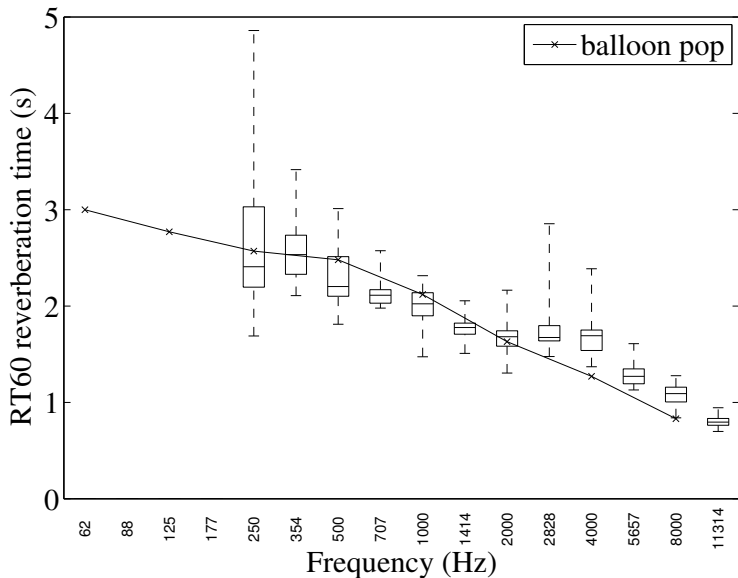
Problems with claps

Lacks low frequency information.

Balloons also lack low frequencies, but claps provide about an octave less than balloons do.

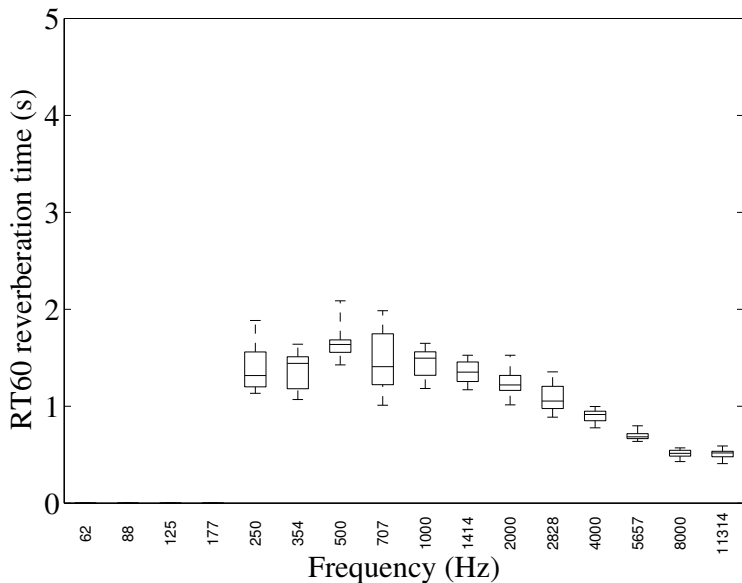
Frequency decay

Results: Pick-Staiger Concert Hall



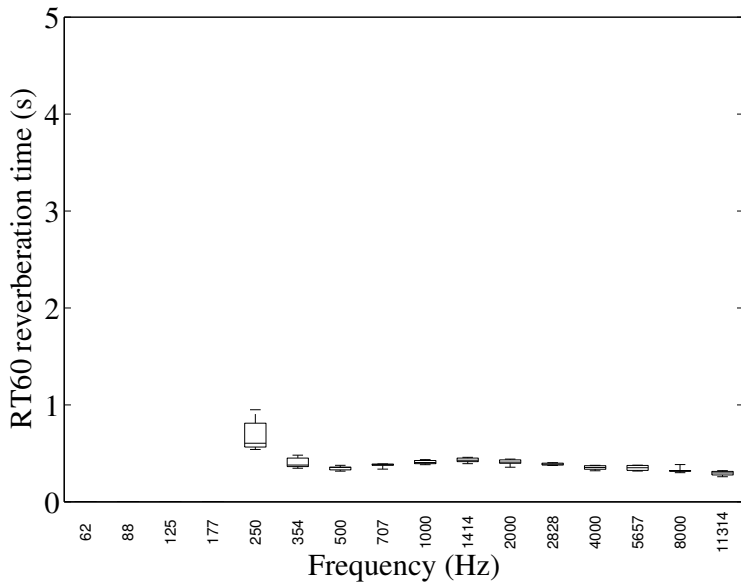
Frequency decay

Results: Lutkin Concert Hall



Frequency decay

Results: Makeshift home recording studio



Frequency response

Definition

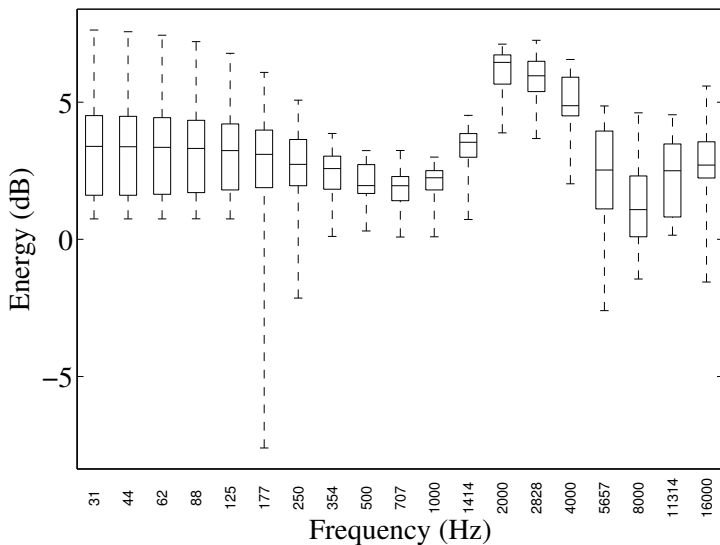
Ratio of reverberant and direct sound spectra.

Process:

1. Split signal up into frequency bins
2. Divide reverberant sound spectrum by direct sound spectrum.

Frequency response

Results: Frequency response for Pick-Staiger Concert Hall
Frequency responses



Clap consistency

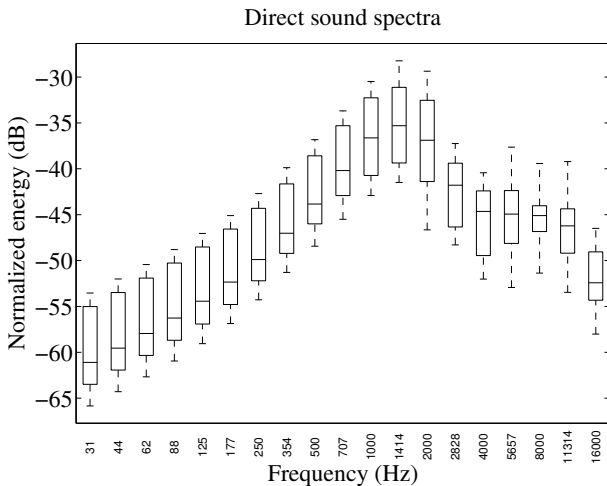
Not all claps are created equal?

Claps can vary in intensity and frequency spread.

We can account for this using the direct sound spectrum.

Clap consistency

Results: Direct sound clap spectra for Pick-Staiger concert Hall



Conclusions

Reverberation Time

Reliable.

Frequency Decay

Reliable for frequencies > 300 Hz.

Frequency Response

Reliable for middle frequencies (mid and treble response).

Application

iOS app: ClapIR

A mobile application that allows amateurs to obtain reliable acoustic measurements in any room.