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Analysis, Parametric Synthesis, and Control of Hand Clapping Sounds

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Introduction

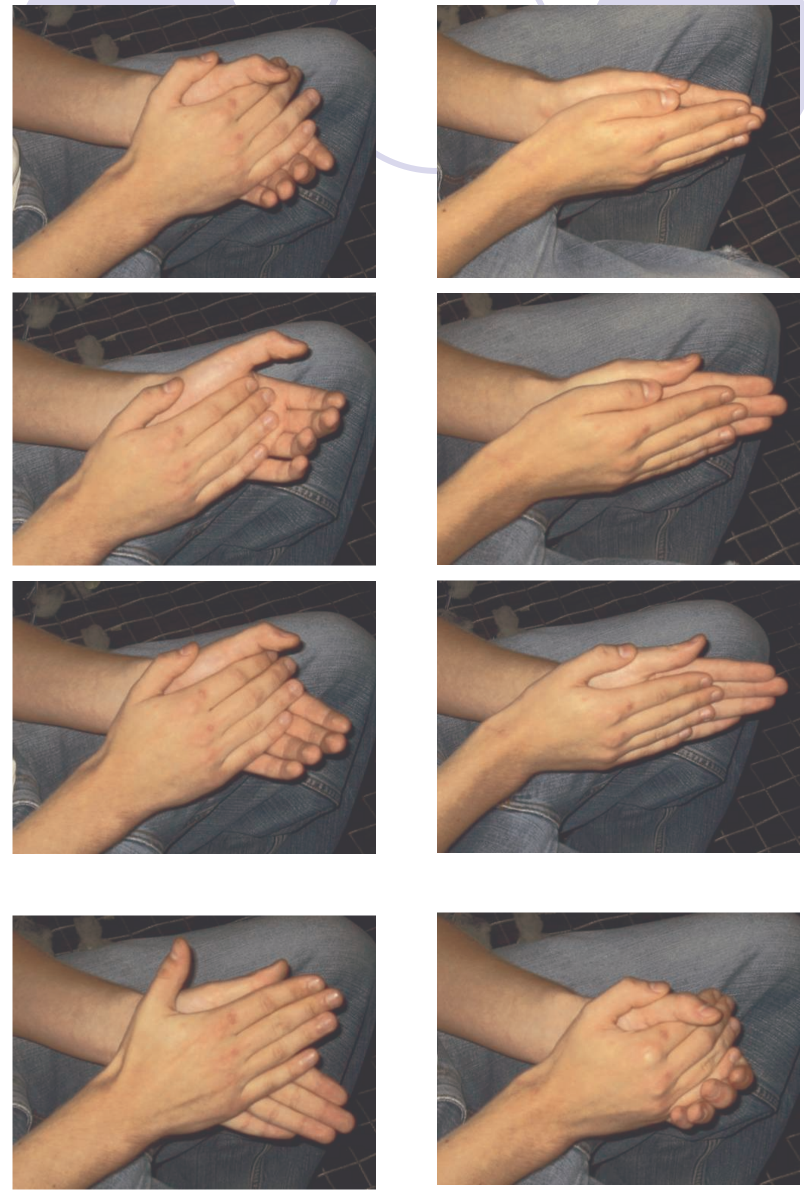
- Hand clapping is very popular audible activity in many cultures but there have not been many studies about it.
- Physically-based synthesis and control model for hand clapping would have many uses:
  - Virtual reality and computer games
  - Prettifying live recordings
  - General MIDI
  - Easily expanded to other similar sounds

Contents

- Synthesis model for the sound of hand clap
  - Measurements
  - Analysis of test data
  - The synthesis model
- Control models
  - One clapper
  - Synchronized audience based on coupled oscillators

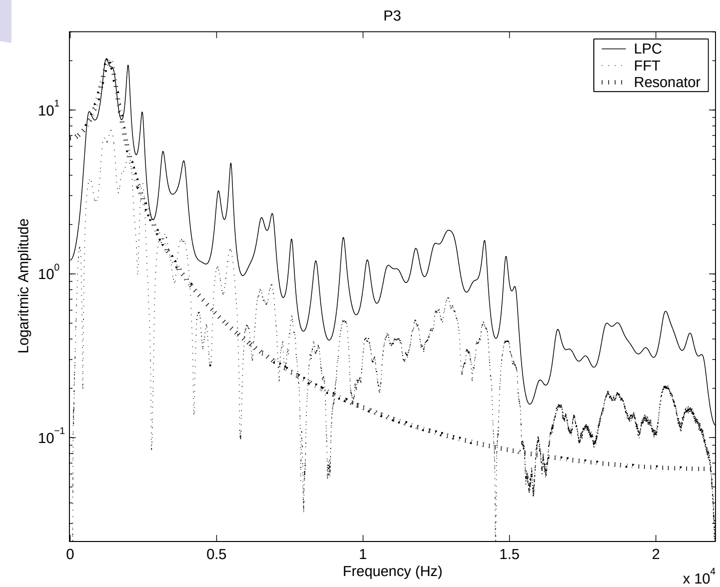
Measurements

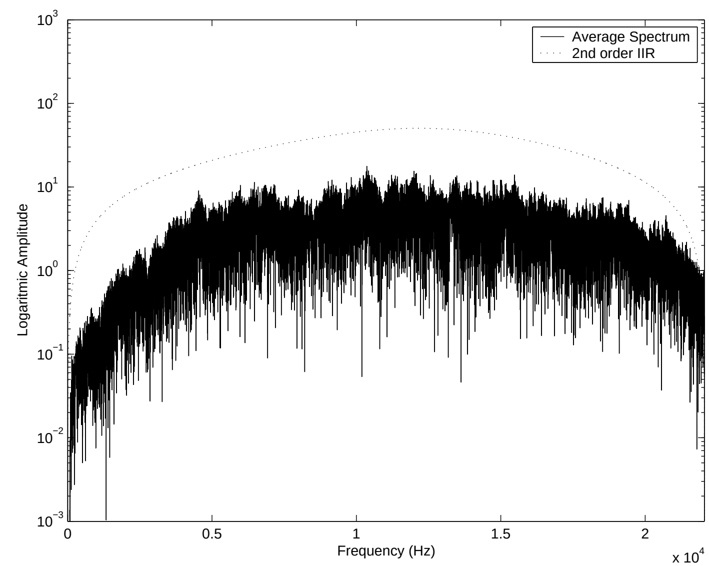
- In anechoic chamber
- 3 subjects, 8 clapping modes, 5 test claps for each mode
- Also sequences for bored, natural, and enthusiastic clapping



Analysis of Test Data

- The strongest resonance peaks were extracted using linear prediction
- Peaks were inverse filtered and resulting signals were used to derive a band-pass filter
- Also time domain analysis (attack and decay time)





Simplified Resynthesis

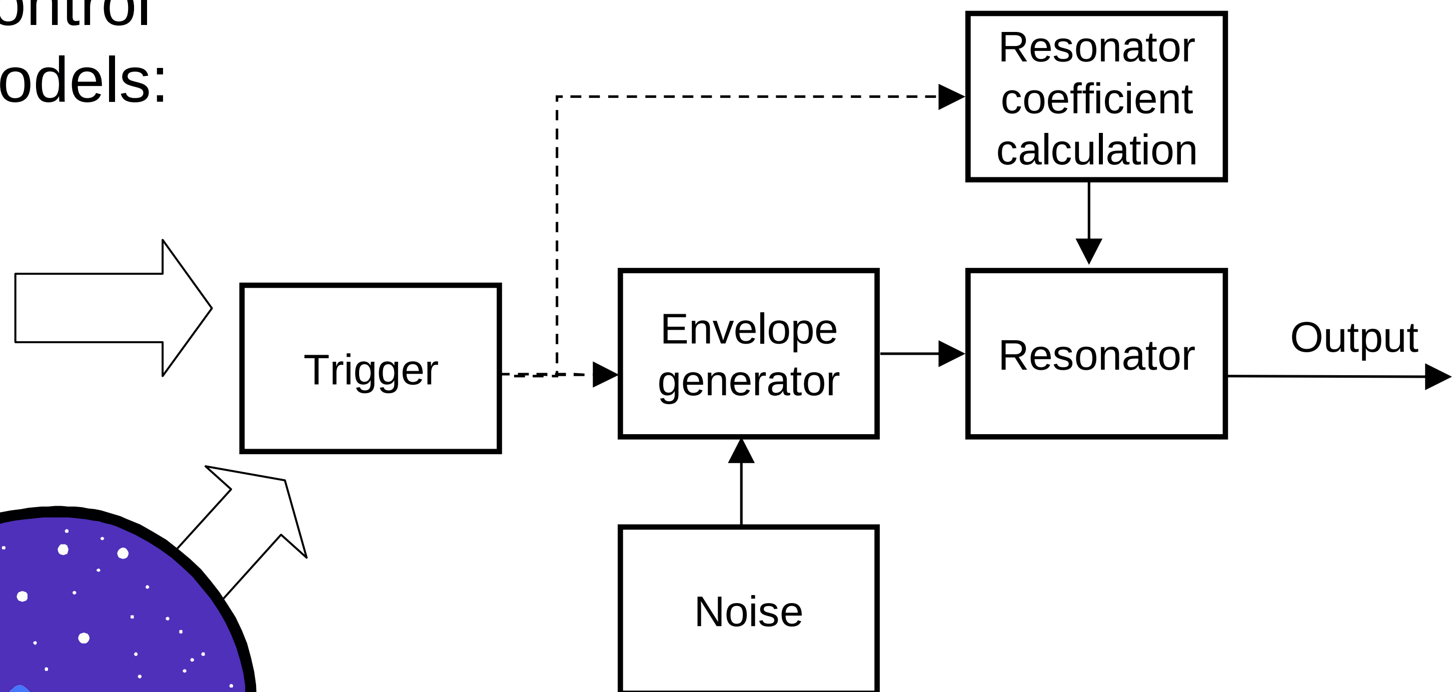
- Based on two-pole resonator filter:

  $$y(n) = A_0 x(n) + 2R\cos(\theta) y(n-1) + R^2 y(n-2)$$

  where A_0 is the gain that makes the magnitude response unity at resonant frequency, θ is the pole angle, and R is the pole radius
- Coefficients are defined from the center frequency and bandwidth
- The resonator is excited with short exponentially rising band-pass filtered noise pulses
- Implemented in Pd

Block Diagram of Synthesis Model

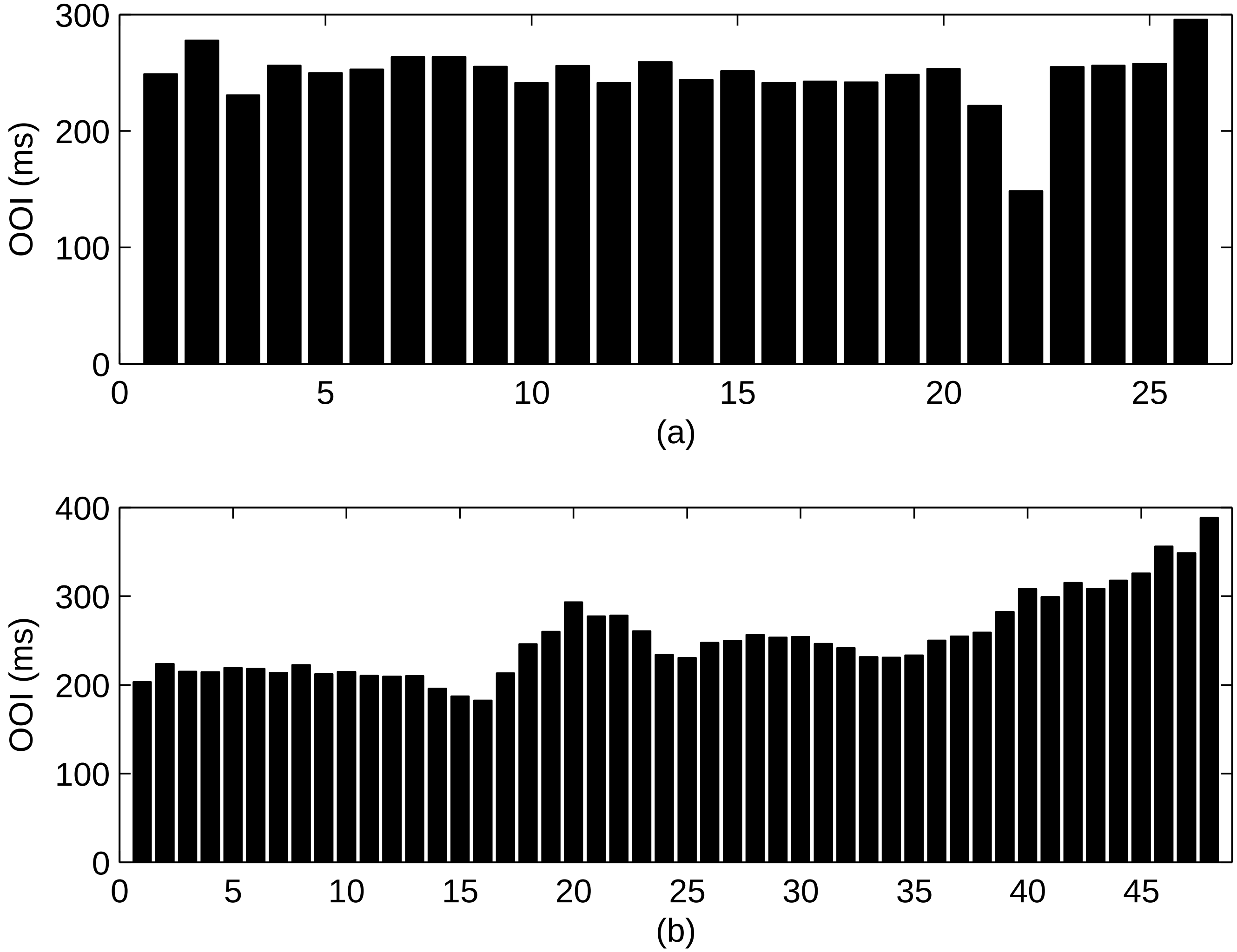
Control Models:



Control Model for One Clapper

- Onset-to-Onset Interval (OOI) varies roughly between 240 ms for enthusiastic and 400 ms for bored clapping
- Also some characteristics that are typical for humans when clapping:
  - Variation of OOI is larger at the start of a sequence
  - Clapping rate is some times faster and sometimes slower
  - Especially at the end of a clapping sequence the tempo is usually slowing down

Two examples of recorded clapping sequences



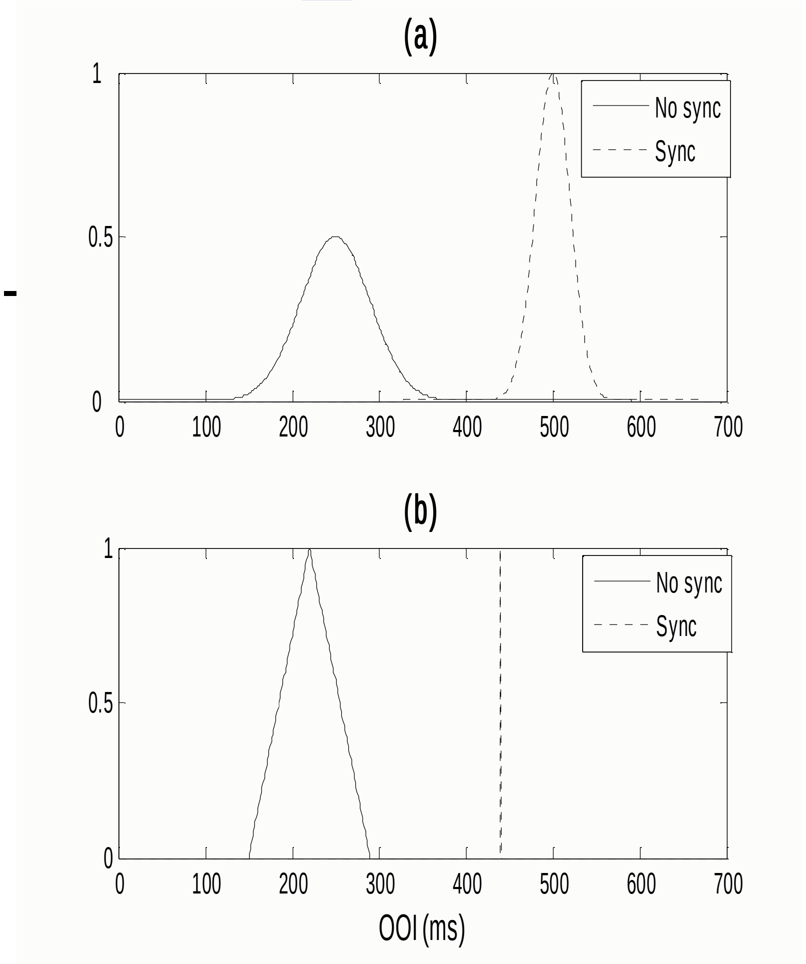
Several Clappers (Synchronization)

- Also reverb is needed
- Only mathematical models for synchronization but never tested in practice
- Most popular is the Kuramoto model of coupled nonlinear oscillators (Kuramoto, 1987)
- The synchronization is explained by the doubling of clapping period (Néda et al., 2000)
  - Fast clapping -> wide distribution of clapping rate
  - Slow clapping -> reduced dispersion allows synchronization

Simulation

Clapping rate of an oscillator is controlled by following rules:

- If trailing behind the lead oscillator ->speed up
- If ahead of the lead oscillator -> slow down
- If switched to non-synchronized mode -> slow down until natural rate is achieved
- Else just keep on clapping



Comments and Future Work

- Synthesis:
  - More test data to get more reliable results
  - Echoes are very important
  - Computationally very light model
- Control:
  - Model for one clapper quite useless
  - It would be interesting to investigate the synchronization process more carefully (multi-channel measurements)

The End

- Demos
- Questions