Digital audio and computer music

COS 116, Spring 2012

Guest lecture: Rebecca Fiebrink

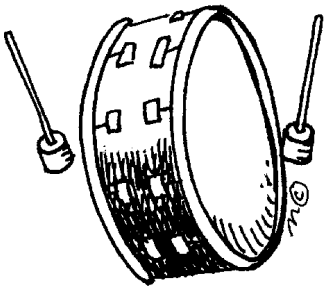
Overview

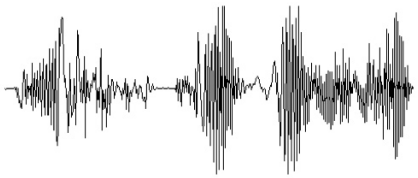
1. Physics & perception of sound & music
2. Representations of music
3. Analyzing music with computers
4. Creating music with computers

1. Sound and music

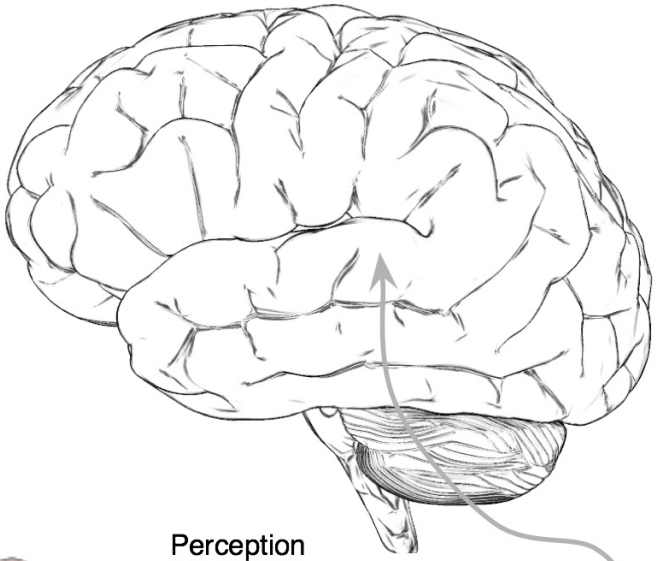
Discussion Time

What is sound?



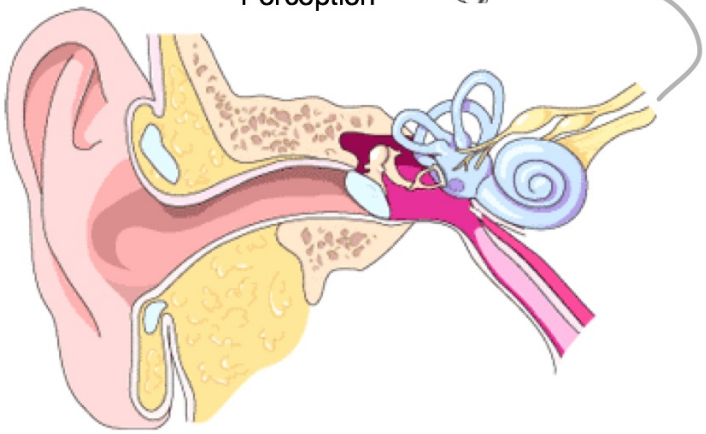


Sound



Perception

"Pressure wave"



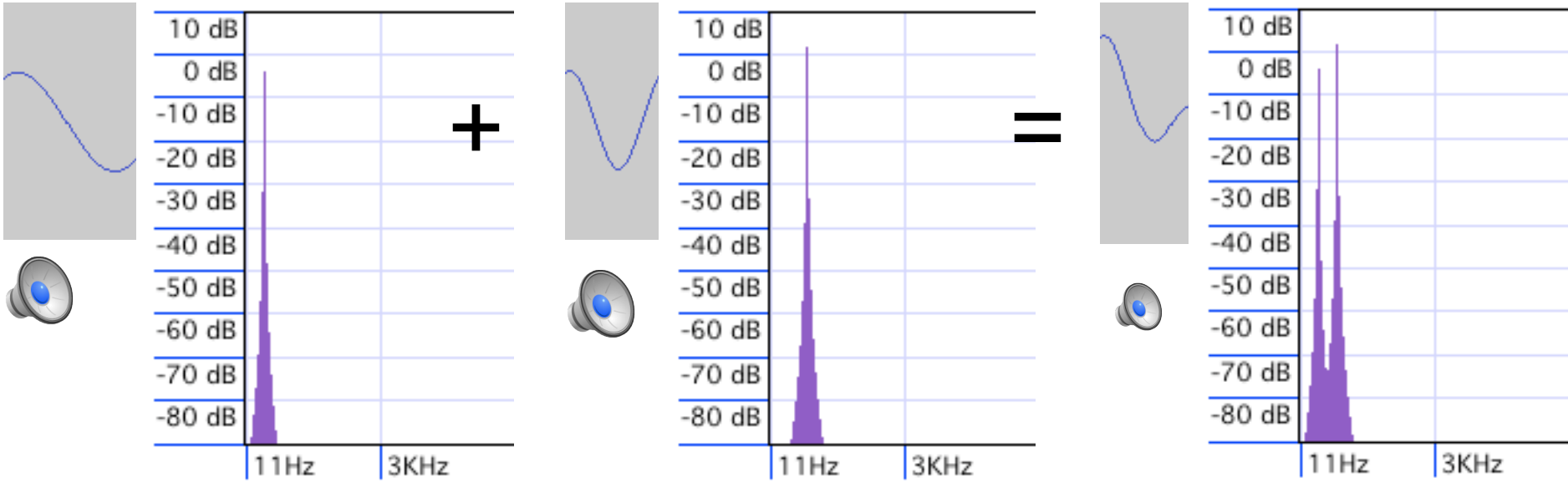
What do we hear?

http://www.youtube.com/watch?v=EvxS_bJ0yOU
http://www.youtube.com/watch?v=wY1EMwDeaBw
http://www.youtube.com/watch?v=nIt9QF_5C_w

- Pitch
- Loudness
- Timbre
- Location
- Meter, rhythm, harmony, melody, structure
- etc...

Psychoacoustics

- Psychoacoustics: relationships between **physical phenomenon** and our **perception**
- Frequency: pitch (20-20,000Hz)
- Amplitude: loudness
- Timbre: Identities and strengths of frequencies present



Discussion Time

What is music?

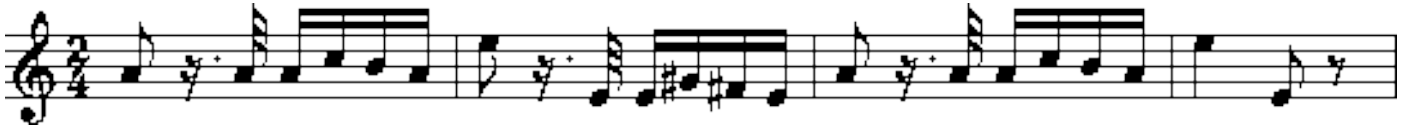
"Organized sound"

- Psychoacoustics play an important role
- Also dependence upon history, culture, experience
- Engages listeners' psychological mechanisms for expectation/reward

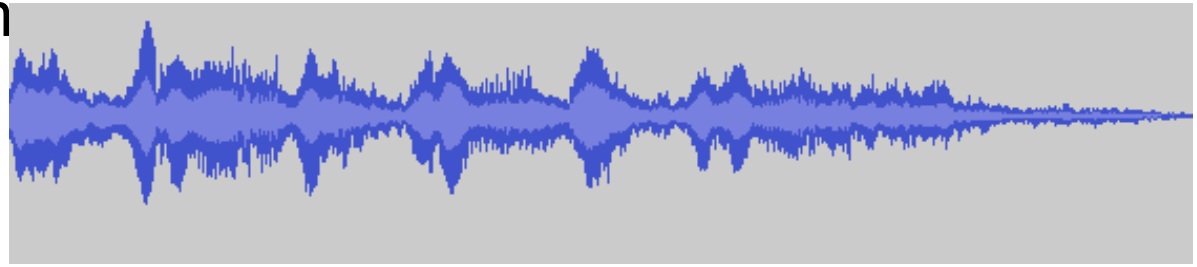
2. Representations of sound and music

How do you represent music?

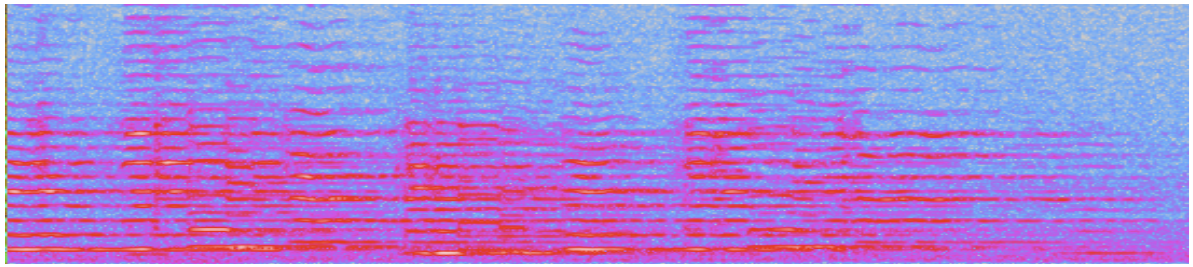
- Score:



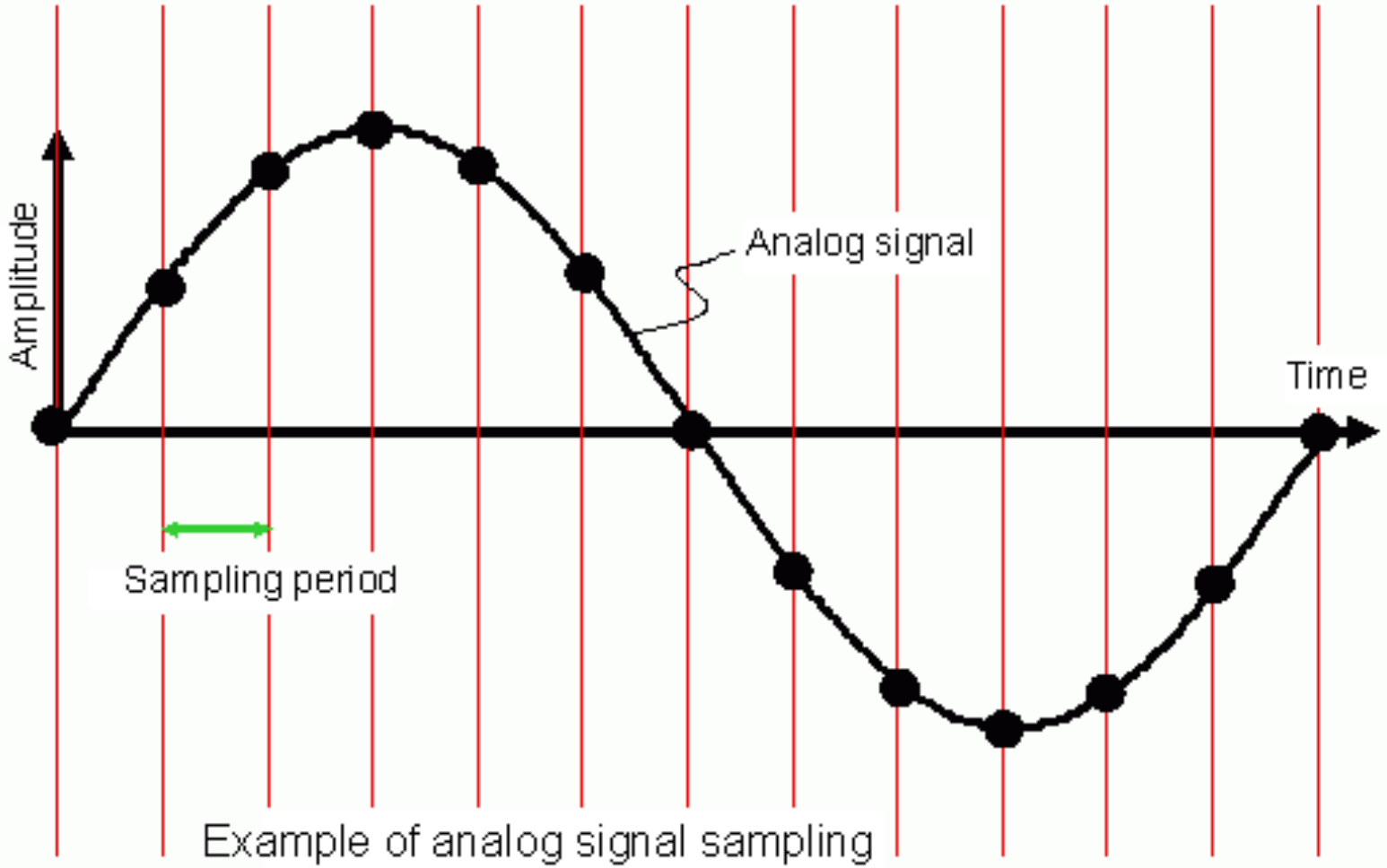
- Digital waveform



- Spectrogram



Digital representation of music



Example of analog signal sampling

Compression

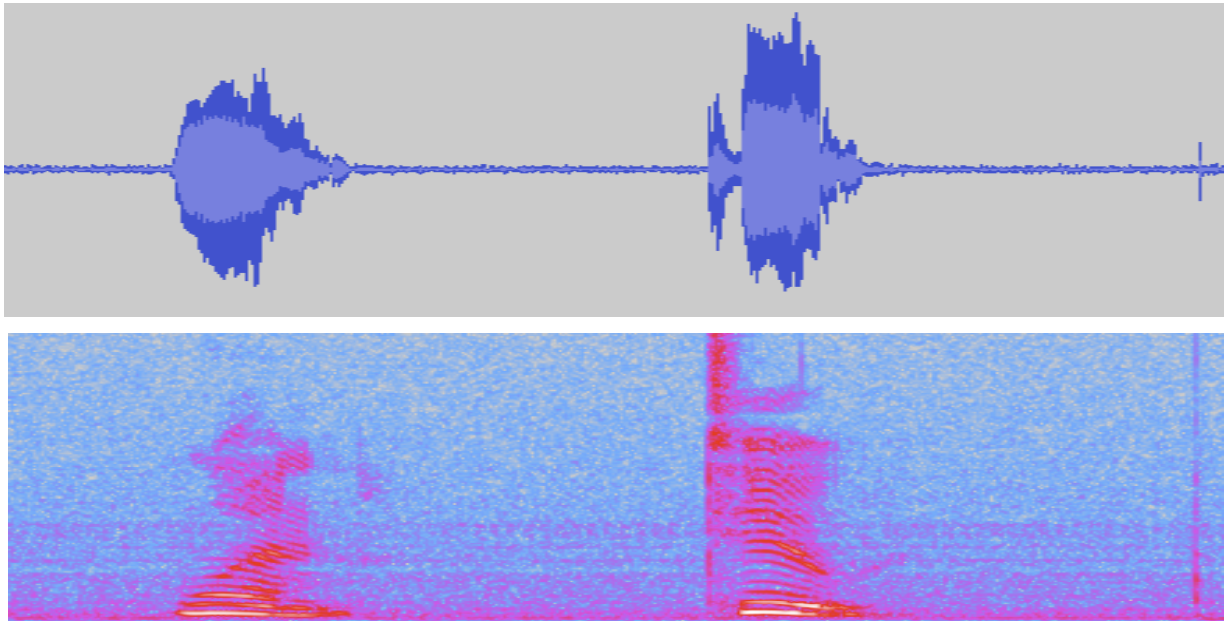
- A “better” representation with fewer bits
- Why? Security, transmission, storage
- How?
  - Psychoacoustic principles
    - MP3: Masking
  - Physical principles of sound production (uses models of sound source)

Choosing a representation

- Representations make compromises
- Standard representations are somewhat arbitrary
- Appropriate choice is task-dependent

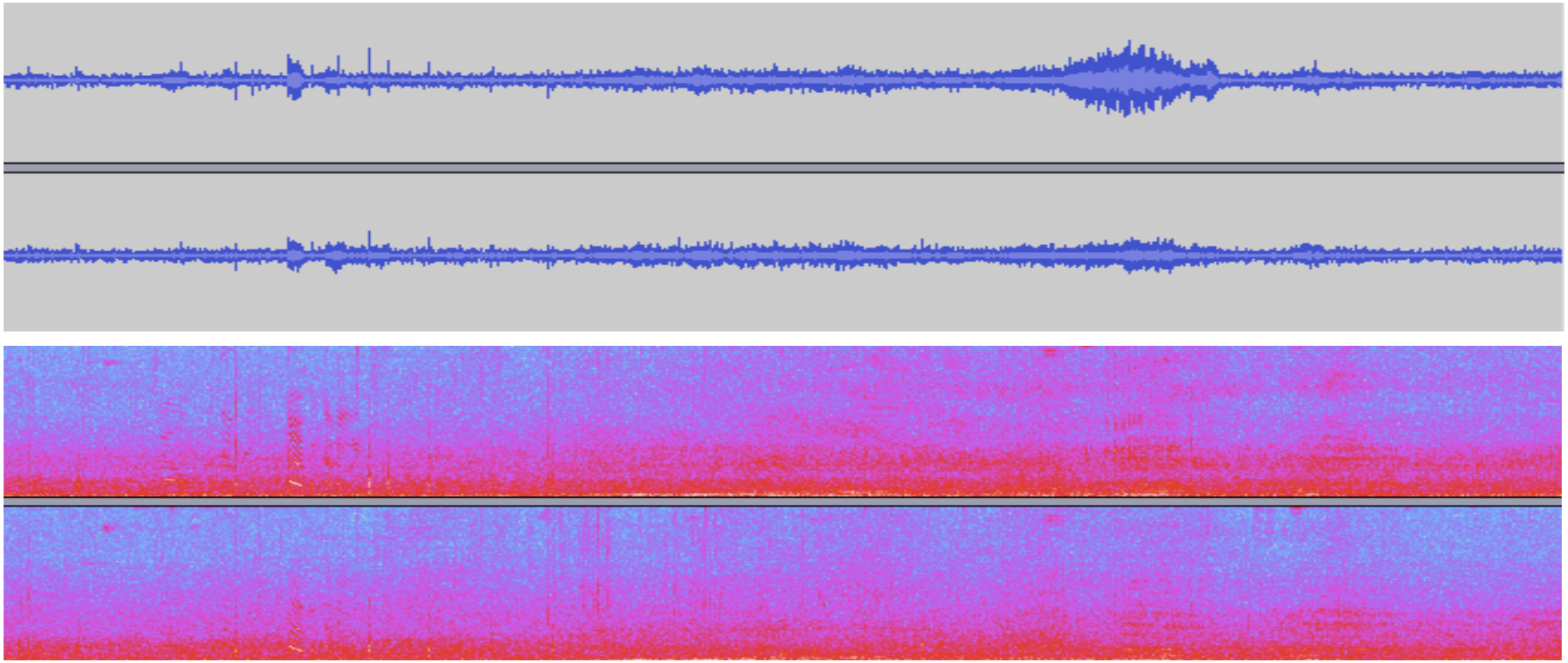
3. Using technology to analyze sound and music

Analyzing speech



- Real-life apps:
  - Customer service phone routing
  - Voice recognition software

Auditory Scene Analysis

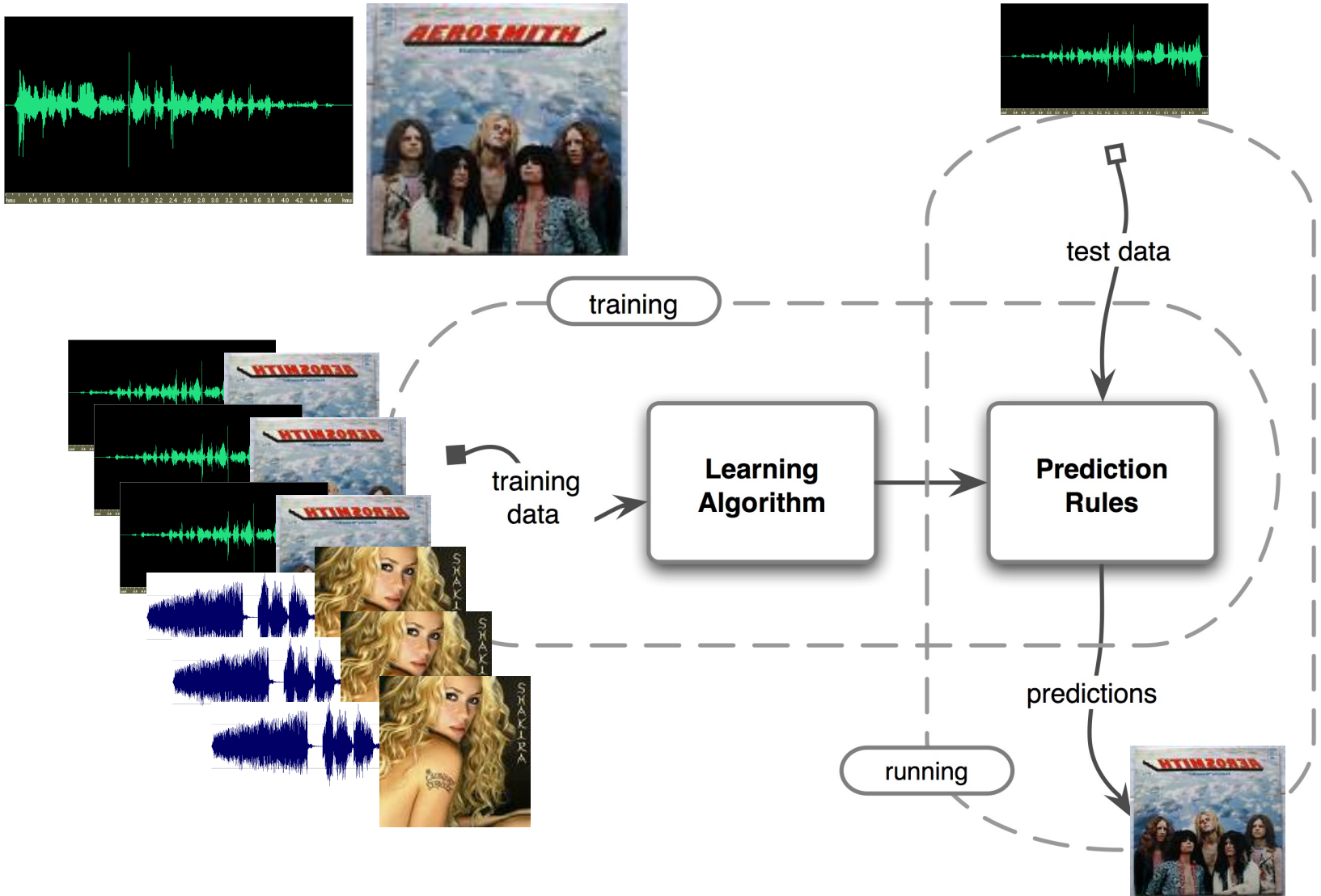


- Applications: Archival and retrieval, forensics, AI

Music information retrieval

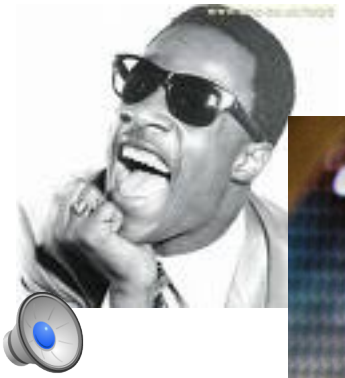
- Analyzing musical data
- Query, recommend, visualize, transcribe, detect plagiarism, follow along score
- Sites/apps you can try
  - midomi
  - Themefinder.com
  - Pandora.com (includes “human-powered” algorithms)
  - Shazaam

Machine learning for analysis



4. Using technology to create music and sound

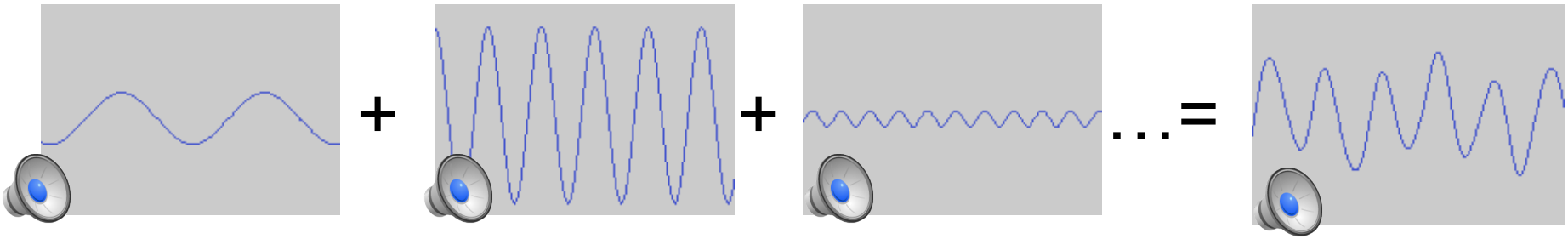
Creating music: Synthesis



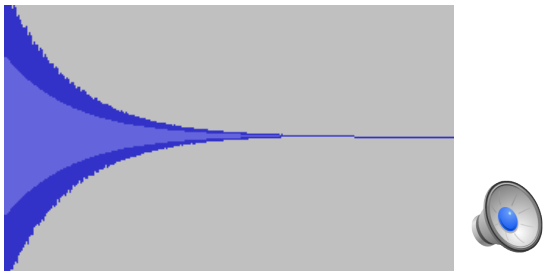
Four approaches to synthesis

1. Additive synthesis

1. Figure out proportions of various frequencies
2. Synthesize waves and superimpose them



3. Modify amplitude using an “envelope”:



2. FM Synthesis

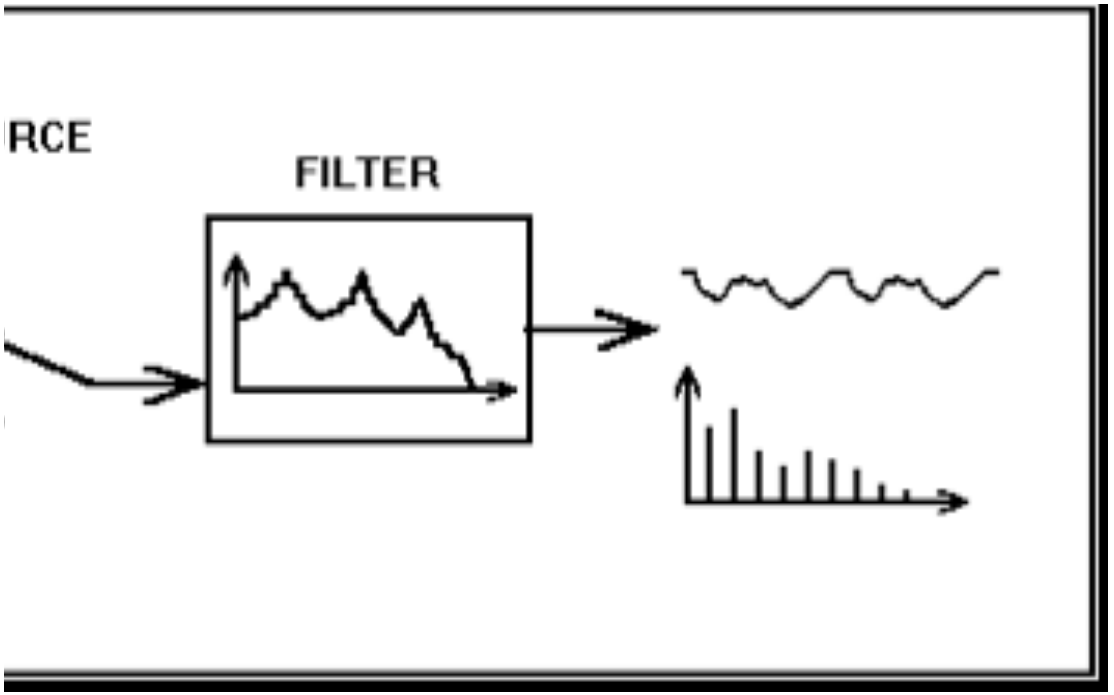
Modulate the frequency of one sine oscillator using the output of another oscillator

3. Physical Models

1. Start with knowledge of physical systems
2. Simulate oscillation (Recall Lecture 4)

4. Cross-synthesis

- Choose filter for speech (vowel)
- Choose source to be another sound



How can computers be used in making music?

- Synthesizing new sounds
- Processing and transforming sound
  - Demo: T-Pain
- Accompanying human performers
  - Demo: Raphael
- Composing new music
  - Demo: Copin
- As **new musical instruments**
- *And many other ways, too…*

Computer as Instrument

- Demo: SMELT keyboard, motion
- Video: Clix
- Demo: Wekinator
- Video: CMMV, Blinky
- Demo: Live coding

Questions: How can we….

- develop new ways to synthesize sound?
- give a user control over synthesis parameters?
- make machines interactive in a musical way?
- augment human capabilities?
- design new instruments that are easy to play? allow expert musicality?
- create music that is emotionally and aesthetically compelling?

Final remarks

- Distinctions in this presentation are superficial
  - Analysis, representation, and creation interact
  - Technology draws on and contributes to our understanding of the physics and psychophysics of sound
- Computer music is interdisciplinary
  - HCI, AI, programming languages, algorithms, systems building
  - Also psychology, music theory, acoustics, signal processing, engineering, physics, performance practice, library science, applied math & statistics, …
- **Technology is constantly complicating and changing the landscape of our musical experiences as creators, participants, listeners, and consumers.**

http://soundlab.cs.princeton.edu/