Musical Interfaces
(Past to Present)

Guest Lecture for ECE 590.21
10/10/2018

David J. Zielinski
Kenneth D. Stewart
Learning Objectives

● Instructor Backgrounds
● How does sound work? Audio/Music Terminology
● Drums: Past to Present
● Theremin (Gestural Interface)
● Turntables
● Drum Machines
● Case Studies
  ○ Virtual Vibrphone
  ○ SoundSpace / SoundSense
  ○ Kinect Sound Environment
  ○ A Historically Informed Guitar & Circuit
● Modular Synths
● Ableton Live
● Musical Interface Design Questions
David J. Zielinski (Virtual Reality)

- Undergrad (2002) in Computer Science from UIUC
- Masters (2004) in Computer Science from UIUC
  Studied with William (Bill) Sherman (now Indiana University)

2004-2018  R&D Engineer, Duke University
            DiVE Virtual Reality Lab.
            http://virtualreality.duke.edu/

2018-present  Smith Media Labs Technology Specialist
              Duke University
              Art, Art History, and Visual Studies

Website: http://people.duke.edu/~djzielin/
David J. Zielinski (Music/Audio)

- **Traditional Instruments**
  - Piano
  - Guitar, Bass
  - Drums, Marimba

- **Recording**
  - 4 track cassette tape
  - Digital (computer): Cakewalk/Sonar, Protools, Ardour

- **Electro-Acoustic and Beyond**
  - Classes at the Experimental Music Studio (UIUC)
  - Masters degree focused on VR musical instruments (more on that later)
  - Currently working on low latency processing of drum sounds
Kenneth D. Stewart (Music/Audio)

- Traditional Instruments
  - Composition (Acoustic/Jazz/Electronic)
  - Cello (Classical, Experimental, Alt-cello)
  - Guitar, Ukes
- Recording
  - 4 track, microcassettes, radio, SDR,
  - Digital (computer): Logic, Max8, Ableton
- Electro-Acoustic and Beyond
  - RA/TA in the REMLabs (Rice University)
  - Researching Artist in the Slippage Lab (Duke)
  - Currently working on using loopers and audio delays with traditional American string styles/genres
How does sound work?

“Sound is a vibration that typically propagates as an audible wave of pressure, through a transmission medium such as a gas, liquid or solid.”

https://en.wikipedia.org/wiki/Sound
How does Listening Work?

Source: Hairs in Cochlea
Listener: Electrical Signals
Auditory Cortex
How do speakers work?

Source

Speaker Cone
Pushes Out
(via magnets)

Listener

Speaker Cone
Retracted in
(via magnets)
Frequency (Pitch)
Frequency (Pitch)
Other Animal’s Frequency Range
Amplitude (Loudness)

The amplitude of a wave is related to the energy which it transports.
Timbre (Quality)

- Tuning fork: Simple harmonic oscillation
- Flute: Additional harmonics
- Voice: Variable harmonics
- Violin: Complex harmonics

Additional harmonics/overtones.
How do we represent sound on computers?

We sample the waveform at specific time intervals and record the amplitude.

Things to be aware of:

**Sample rate**: how often the computer measures the amplitude (often 44.1kHz or 44100 times per second).

**Bit depth**: how many bits of resolution per sample. For files, 16-bit is common. Inside audio engines, 32-bit floating point (-1 to 1), is common.
4 types of “non-digital” instruments

Hornbostel–Sachs Classification System (1914)
https://en.wikipedia.org/wiki/Hornbostel%E2%80%93Sachs

<table>
<thead>
<tr>
<th>Name</th>
<th>What Vibrates?</th>
<th>Example</th>
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<tbody>
<tr>
<td>Idiophones</td>
<td>object itself</td>
<td>bells</td>
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<td>Aerophones</td>
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<td>guitar</td>
</tr>
<tr>
<td>Memranophone</td>
<td>membrane</td>
<td>drum</td>
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The Pipe Organ
Drums

1. User strikes the drum head with an object (stick or hands)

2. We hear a sound.

Or more formally we are seeing:
Drums

Design goals of a “traditional” drum:
● Convert users biomechanical actions into sound
● Generate sound
  ○ Larger volume / amplitude
  ○ Extension of sound in time (the sound rings for a while) - Resonance
  ○ Stability of tuning (tension on head)
Simmons Electronic Drums (SDS-V: 1981)

Early electronic drums design issues:

- Lacked sensitivity to strength of hit *
- Lacked sensitivity to location of hit *
- Lack of visual feedback (no motion in drum heads / cymbals).
- Fatigue / joint issues from hitting hard (unmoving) pads.
- Crosstalk / False Triggering

* The constraint of lack of sensitivity to hit location/strength, makes the resulting audio output have more consistency. Could this be useful for certain styles?
Modern (commercial) electronic drums:

Traditional drumset interface but with control over the sound output:

Allows:
- Play at low volumes (don’t disturb neighbors)
- Direct output for shows (no microphones needed).
- Play different sounds.

But...
- Still sitting down?
- No big visual feedback (lights?)
- Bulky (need a van to transport)
- Doesn’t cover all percussion techniques (e.g. bowing cymbal, placing different objects on heads).
Going Further?

Their setup was actually developed with help from:

http://www.tangibleinteraction.com/

Check out there website - they have alot of interactive projects!

Dave Notes: Can be tricky to switch between drum sticks, and turning knobs… opportunity for innovation?

https://www.youtube.com/watch?v=y0d4KSnaez4
Goto Time: 3:45
**Theremin (1928)**

- Right hand controls pitch.
- Left hand controls volume.
- User doesn’t “touch” the instrument
  - Gestural interface
  - Lacks constraints and haptics of conventional instrument.
  - Difficult to play “traditional” music.

Clara Rockmore - first theremin virtuoso
[https://youtu.be/pSzTPGIa5U](https://youtu.be/pSzTPGIa5U)

New sounds for early sci-fi movies
[https://youtu.be/pSzTPGIa5U](https://youtu.be/pSzTPGIa5U)
Turntable History

Phonograph (1878) - Thomas Edison

Gramophone (1887) - Emile Berliner
Turntablism

DJ Kool Herc (1972)

Developed “break-beat” technique
- 2 copies of the same record
- one record played while other record rewound to beginning of section
- Allowed extension of one section of the song indefinitely.

Grand Wizzard Theodore (1977)
https://www.youtube.com/watch?v=qBS26-qMwyQ

Invented “Scratching”
Goto time 1:00
Turntables / Turntablism

- Change pitch/speed of playback
- Move to different points in time of recording
- Generate new sounds (scratching)

Modern setups eliminate the vinyl records, but still replicate the historical interface. Opportunity for innovation?
Drum Machines

- User selects times where drum hit should play
- Can play endlessly (doesn’t get tired)
- Consistent performance
- Can tweak knobs and patterns while playing
- Often just a grid. Opportunity for innovation?

https://www.youtube.com/watch?v=KC7UaUD5rEA

Time

At end of loop, jumps back to beginning

- Vibraphone - supported alternative keyboard layouts (microtonality)
- Drum Machine - ‘jumping’ visual feedback
- Theremin - distance from pole and height off ground as parameters. Added “lightning” visual effect.
- DJ Setup - visualization of audio output.

Problems
- Difficult to play (The 2004 tracking system had lots of errors + distortion)
- Hitting vibraphone keys was tricky (nothing to stop you going right through)
- Interesting for Performer: But how could an audience enjoy a VR performance? Remains an open issue!

https://www.youtube.com/watch?v=2vdmNWUDZY8
Case Studies: SoundSpace / SoundSense (2004-present)

Cameras mounted in ceiling.
Generate music based on motion.
Different grid cells are different “instruments”.

Good:
- Supports multiple participants.
- Blurring between performer and audience.
- No gear to put on (unencumbered).
- Fun!

Bad:
- Latency
- With multiple participants, not always clear what sound you are contributing.
- Can be tiring (could be a good thing?)

https://www.youtube.com/watch?v=9M4qz5ipUz0
Infrared (IR) cameras built into the controller Generate music based on motion.

Good:
- Musically expressive.
- No gear to put on (unencumbered).
- Fun!

Bad:
- Latency
- Lack of sample variety
- With multiple participants, not always clear what sound you are contributing.
- Requires tedious libraries/updates
- Camera requires dim/careful lighting (many current ‘VR’ trackers are based on IR - subject to issues with stage lighting and sunlight!)

https://www.youtube.com/watch?v=7uPmN-U2E0Y
Case Studies: Kinect Sound Environment (2013-present)

Parameters for sound generation:
- Relative angle of the hands to one another to pass over a threshold specified in degrees
- Absolute position of each hand in the X axis taken when the angle-threshold is passed
- Relative distance of the hands to pass under a threshold to trigger 'hand closeness'
- Relative distance of each hand to the neck to specify whether a hand is close to the body
- Average absolute position of both hands relative to the camera's 'absolute zero' in the Y-axis
- Average absolute position of the head, neck and torso in the Z axis
Finding Ibrida: A Historically Informed Guitar & Circuit
Modular Synth  (Moog + Buchla: 1963)

- Performer has many knobs
- Performer can repatch signal path between different signal processor
- New Sounds
- Can be hard for audience to understand what is happening

https://www.youtube.com/watch?v=Jr_jVge1OH4
Ableton Live (with hardware controller)


Controller adds tangible interface (performer not just using laptop).

Due to popularity of Ableton Live, could design a different (perhaps more visible to audience) hardware interface. Opportunity for innovation?

https://www.youtube.com/watch?v=A5xXYaSECvI
Some design goal questions to think about...

Is it interesting for the performer to operate the interface?

Is it interesting for the audience to watch the performer operate the interface?

Can the audience participate in the operation of the interface?

Is there a coupling between the operation of the interface with the production of the sound? Or does device just send a “Note On” message to a sound generator.

Does an interface need constant (human) input to continue generating sound?

Room for performers to discover new ways of using the device?

Room for performers to fail? Excitement that things may not work out?

Technical Limitations: high latency, infrared light requirements?