CTP431: Fundamentals of Computer Music

Course Introduction

Juhan Nam

Who We Are

- Instructor: Juhan Nam
  - Professor, Graduate School of Culture Technology (GSCT)
    - Affiliated Professor, Kim Jaechul Graduate School of Artificial Intelligence
    - Affiliated Professor, Graduate School of Metaverse
  - Music and Audio Computing Lab: https://mac.kaist.ac.kr/

- TAs
  - Haheong Bang, PhD Student, GSCT
  - Hoyeol Sohn, MS Student, GSCT

Outlines

- A brief history of music technology
- Course introduction

Music and Human

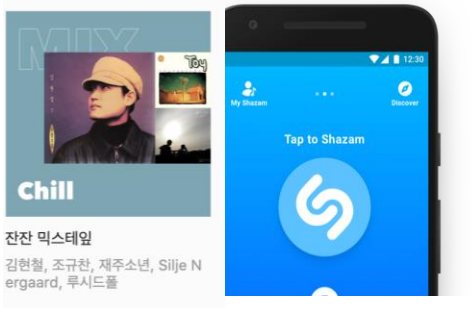
- Music is the most widely enjoyed cultural content
- We are engaged in music as listeners, performers, or creators.

Music at KAIST

Source: http://times.kaist.ac.kr/news/articleView.html?idxno=3835, http://times.kaist.ac.kr/news/articleView.html?idxno=3185

Technology is essential in the musical activities

- Music listening
  - Media format: fidelity, compactness, accessibility
  - Spatial audio: immersiveness
  - Music search and recommendation
- Music performance
  - Amp, mixer, audio effects: dynamics and tone controls
  - Instrument: timbre and expressiveness
  - Electronic sheet music, auto accompaniment
- Music composition/production
  - Arrange multiple sound/MIDI tracks (DAW)
  - Virtual instrument, sound design, and programming
  - Samples, loops, and AI generation



History of Music Technology

- Mechanical
- Electric/Electro-Mechanical
- Digital
- AI

History of Music Technology: Mechanical

- Sound as “physical vibration”
  - Crafting wood and processing metal
  - New acoustic musical instruments

Stradivarius Violin

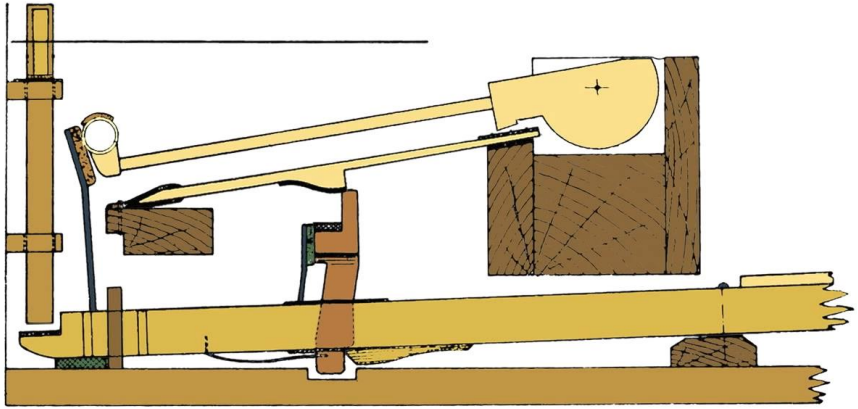
Saxophone

Pikasso 42-string guitar

Piano

- Invented by Bartolomeo Cristofori (1720s)
  - Control the sound volume of each note: fortepiano (or pianoforte, pf)
  - “Escapement” of the hammer action

Cristofori’s FortePiano (1722)



The Piano Action

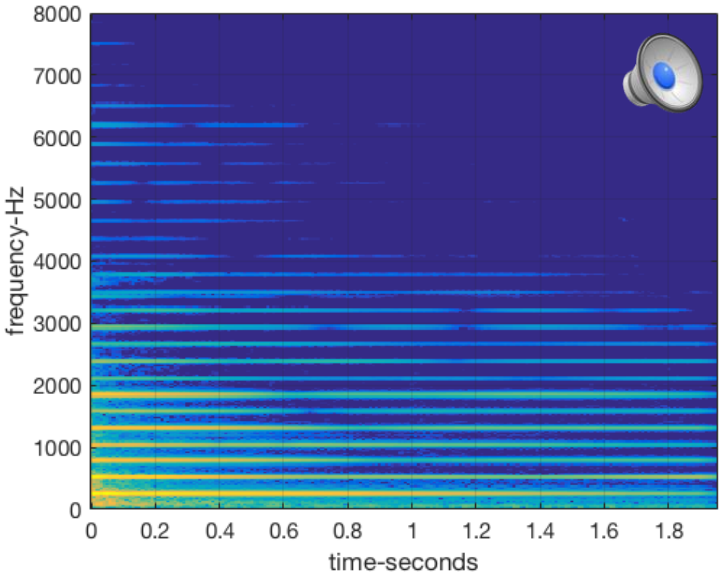
Piano

- Renovated with better crafting of materials and design
  - Action, strings, Iron frame, and soundboards

Steinway Model D (1884)

Piano

- Characteristics
  - Rich harmonics
  - Sustained tone with the pedal
  - Wide dynamic range
  - Wide pitch range with polyphony

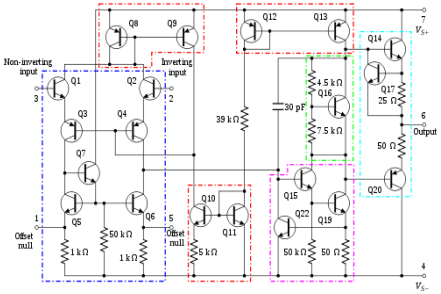


Spectrogram of a piano tone (C4 note)

- Influence on music
  - Composers: Beethoven, Chopin, Schumann, Liszt
  - Advance of tonal harmony: vertical relation of notes
  - More musical expressions: dynamics, tempo, note duration
  - Chopin’s music on his own piano: https://www.youtube.com/watch?v=cUgxELRgPLk

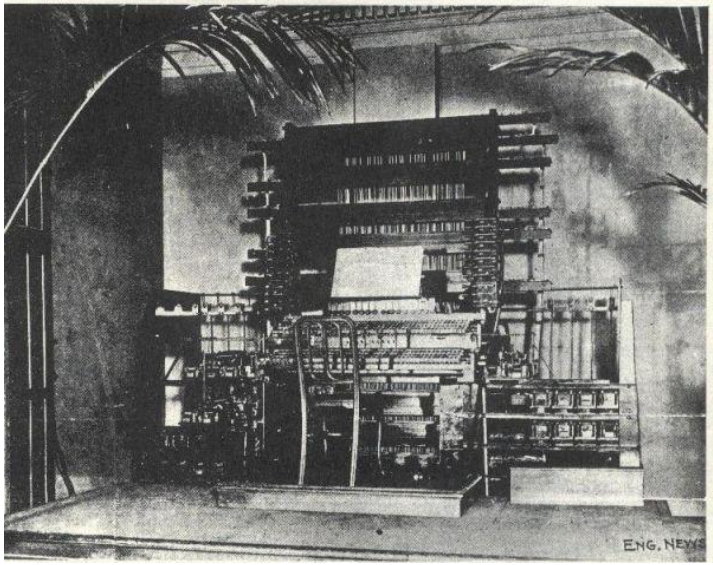
History of Music Technology: Electric/Electro-Mechanical

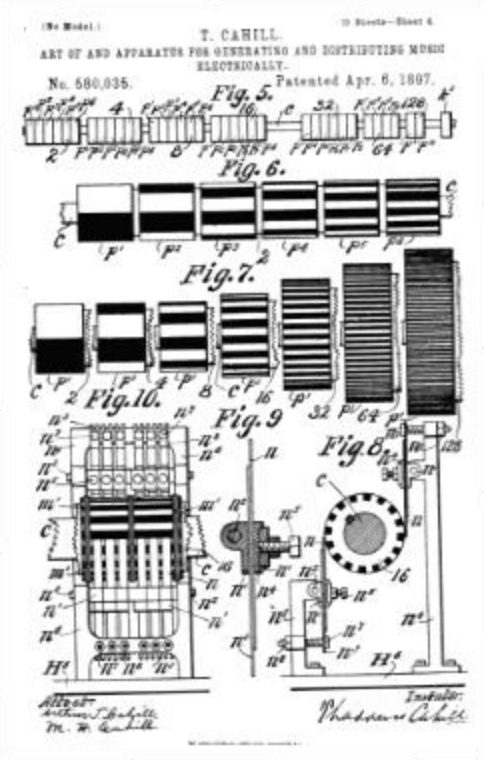
- Sound as “electrical signals”
  - Transducers: microphone and speakers
  - Amplifier and effects: loudness and timbre control
  - New musical instruments: electric guitars, synthesizers
  - Recorder/Player: paradigm shift in music creation and distribution



Telharmonium

- Additive synthesizer using electro-magnetic “tone wheels” (Cahill, 1897)
- Transmitted through telephone lines





Theremin

- A sinusoidal tone generator
  - Two antennas are remotely controlled to adjust pitch and volume

Theremin (Léon Theremin, 1928)

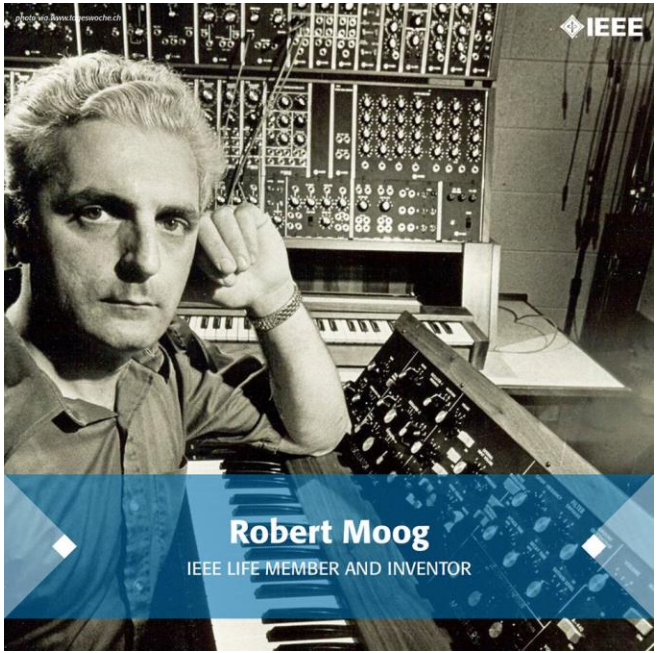
Theremin

Theremin (Clara Rockmore)

https://www.youtube.com/watch?v=pSzTPGlNa5U

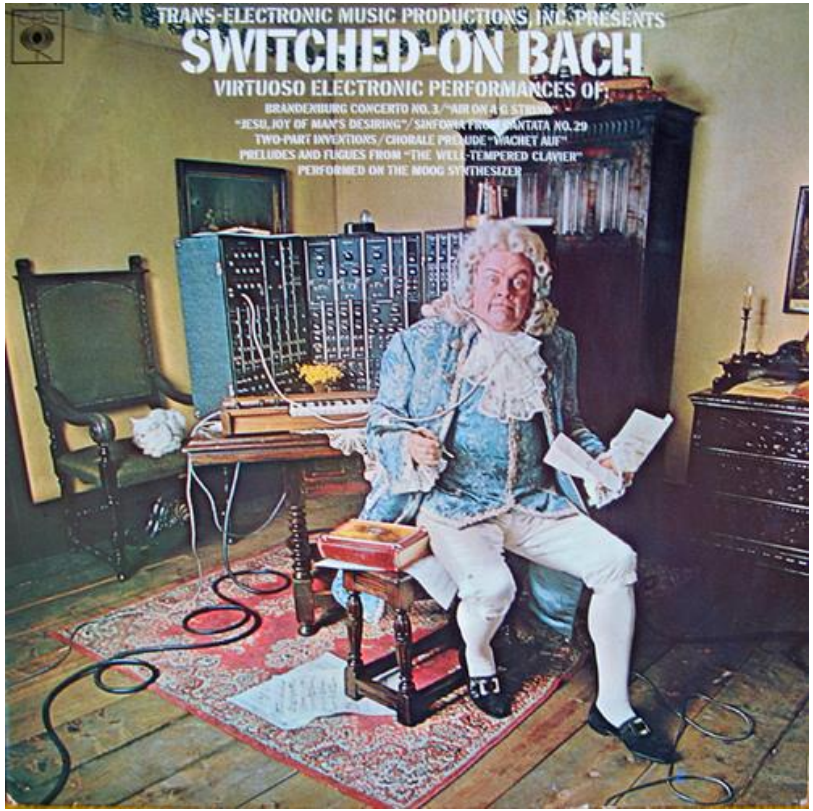
Moog Synthesizer

- Subtractive synthesis



MiniMoog (1970)

Moog Synthesizer



“Switched-On-Bach” by Wendy Carlos (1968)

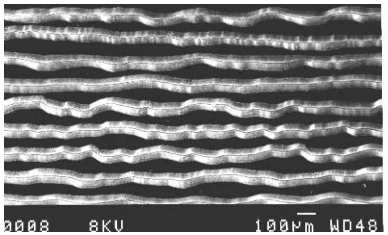
Electrical Guitar / Distortion Effects

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

Sound Recording

- Phonograph: Thomas Edison (1877)
  - Can record and playback
  - Used for recording voices and music (stenography, education, memo, etc.)

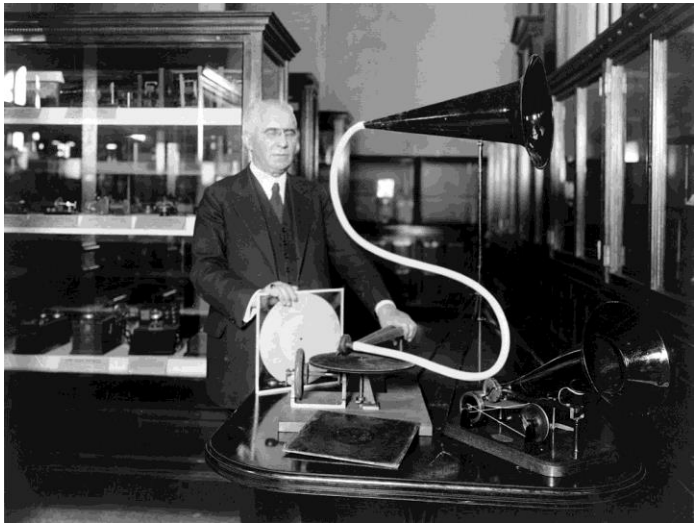
Edison cylinder



Grooves in Edison cylinder

Sound Recording

- Gramophone: Emile Berliner (1887)
  - Can playback only: cheaper to manufacture than cylinder
  - Focused on music recording (carried artist names on the disk)
  - Commercially succeeded and becomes the standard



Magnetic Tape Recording

- High fidelity
  - Nearly flat over audible frequency range
- Malleable
  - Record audio can be edited
- Multi-track recording
  - Record and playback simultaneously
  - Layer by layer recording

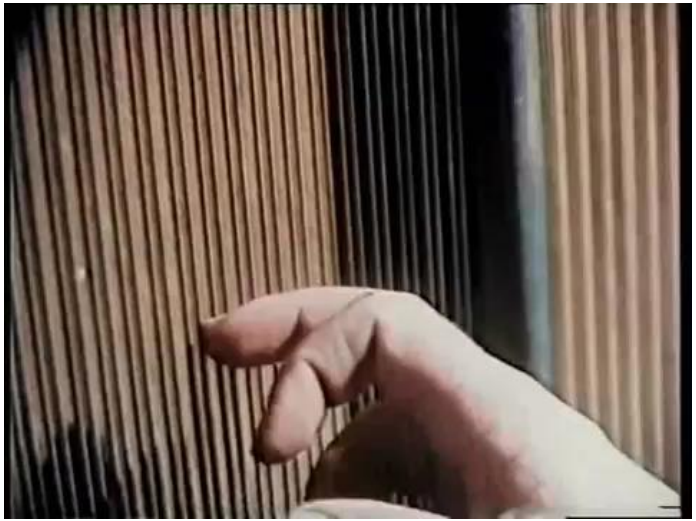
Magnetic Tape Recording

- Les Paul's Innovation
  - Overdubbing: ensemble/doubling effects https://www.youtube.com/watch?v=pHgAALr8LUo
  - Tape delay: delay effect https://www.youtube.com/watch?v=y3Whi-g-0A0

Les Paul

Music Concrete

- Composition by tape editing
  - Cut, splice, reverse
  - Speed up/down

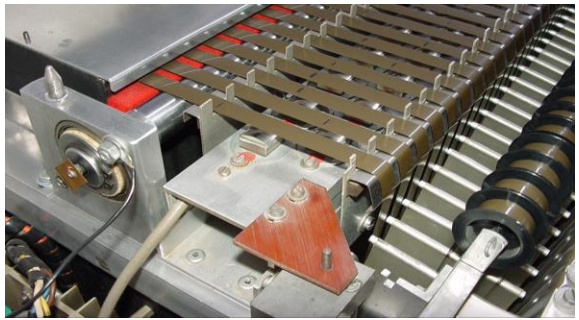


https://www.youtube.com/watch?v=c4ea0sBrw6M

Pierre Schaeffer -- Études de bruits (1948)

Mellotron

- Sampling-based analog sound keyboard using magnetic tapes (1960s)



History of Music Technology: Digital

- Sound as “discrete numbers”
  - A/D, D/A converters
  - Digital signal processing
  - Virtual analog: synthesizer, digital audio effects
  - Sample-based Instruments
  - Digital audio workstation (DAW): music recording, editing and production

Fairlight CMI

- The first digital sampling-based synthesiser

Yamaha DX7

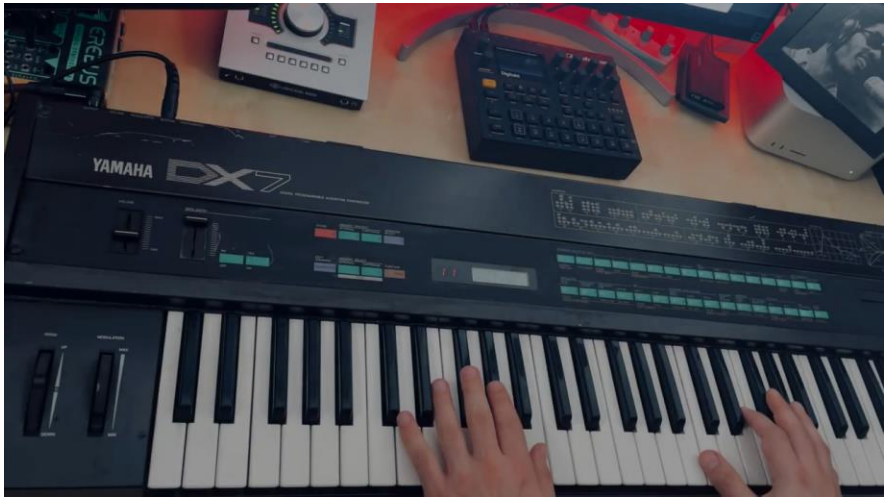
- FM synthesis

Yamaha DX7 (1983)

Yamaha DX7

- DX7 sounds in famous songs

https://www.youtube.com/watch?v=BCwn26FePAo



https://www.youtube.com/watch?v=rE5DFsxKx9c

Sampler and Drum Machine

AKAI MPC

Roland TR-808

Sampler and Drum Machine

Roland TR-808

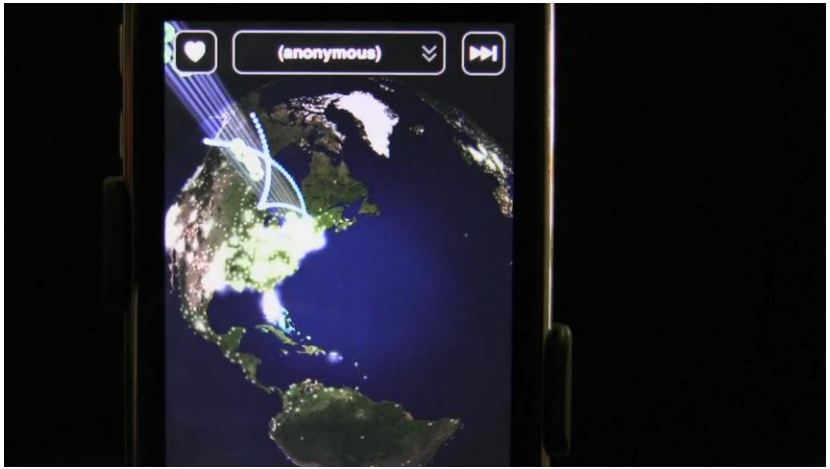
Virtual Instruments

- DAW Plug-ins

Synthogy Ivory II Piano (2011) : 77GB+, Steinway D Grand

Smule Ocarina

- Social music play on mobile phones



Smule Ocarina (2008)

Launchpad

- Sample-base audio-visual live music play

Ableton Live + Launchpad (Sae Byul Park)

Music-N

- Composition as programming

```
PAC 1; PS1 1; PS2 1; IIN 300; CHA 2;

SAM 25000; com Sampling Rate;

INS 0 1;

IOS P6 DUR B4 F1; com Glissando;
ENV P7 F2 B3 ATDK(P8,P9,P10,W8,W9);
AD2 1  B4 B4; com IOS output + 1;
LUM B3 B4 B3 1 P5; com Sound Input;

OSC B3 DUR B4 F3; com Ch 1 proportion;
OSC B3 DUR B3 F4; com Ch 2 proportion;

STR B4 B3 B1; com Stereo Output;

END;

GEN 0 9 1 512 0,1 1,512; com Gliss ↑;
GEN 0 9 2 512 0,1 1,128 1,256, 0,384;
GEN 0 1 3 512 0,1 1,256 0,512;
GEN 0 1 4 512 1,1 0,256 1,512;

FIC 0 1 SOURCE.MSB; NTA 1; LON 128*32;
com Source File - 1 Buffer, length 4K;

NOT 1 1 4 2.51 1 1.5 .2 1.8; com Play;

FIN;
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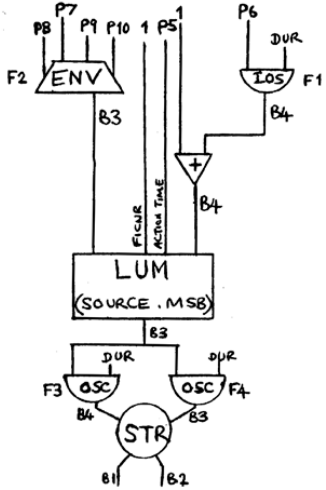
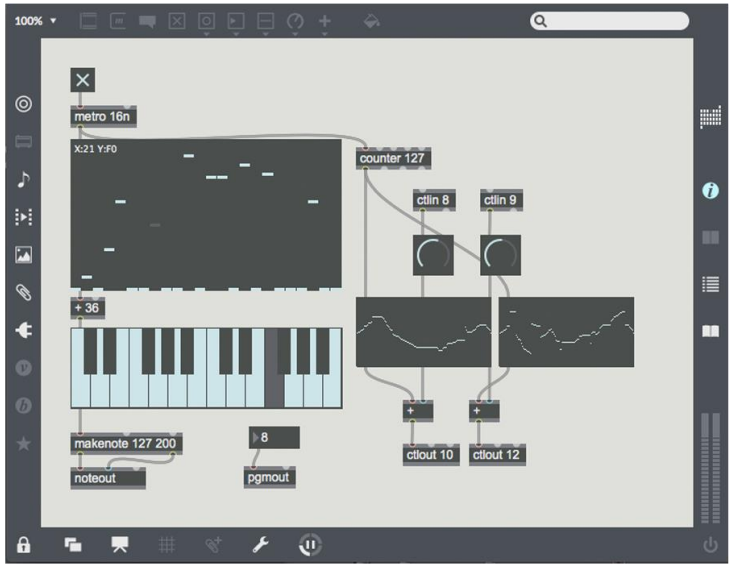


Max V. Mathews

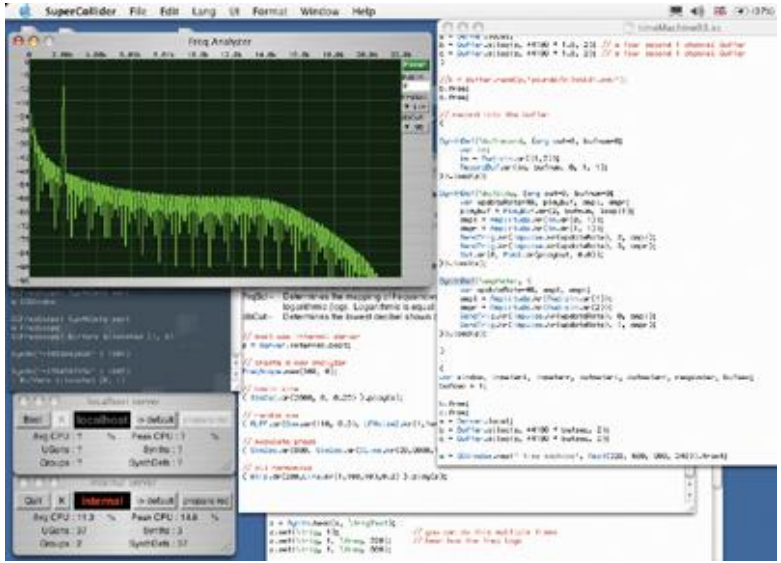
Music-N

"Daisy Bell”, programmed by John Kelly and Carol Lockbaum and the accompaniment was programmed by Max Mathews.

Audio Programming Languages



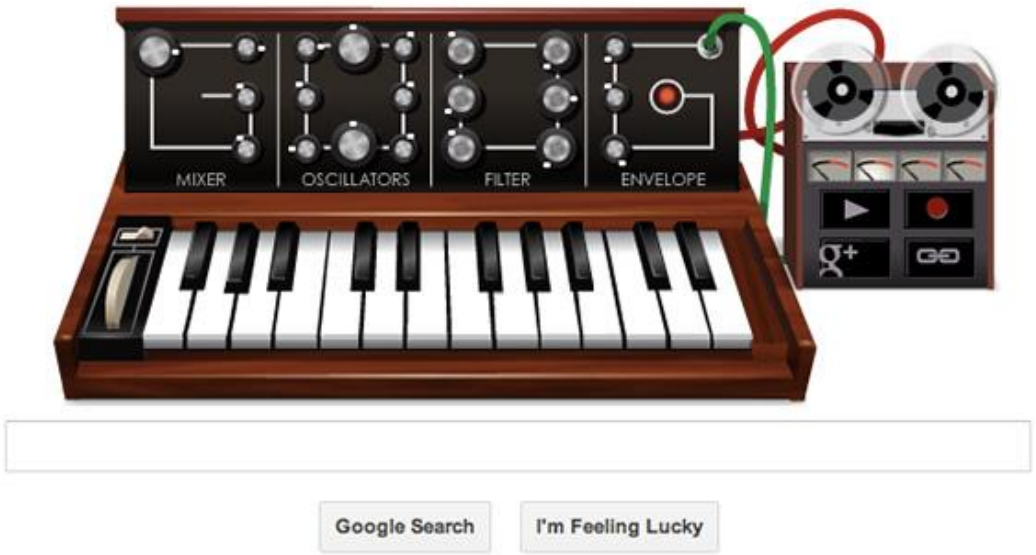
MAX



SuperCollider

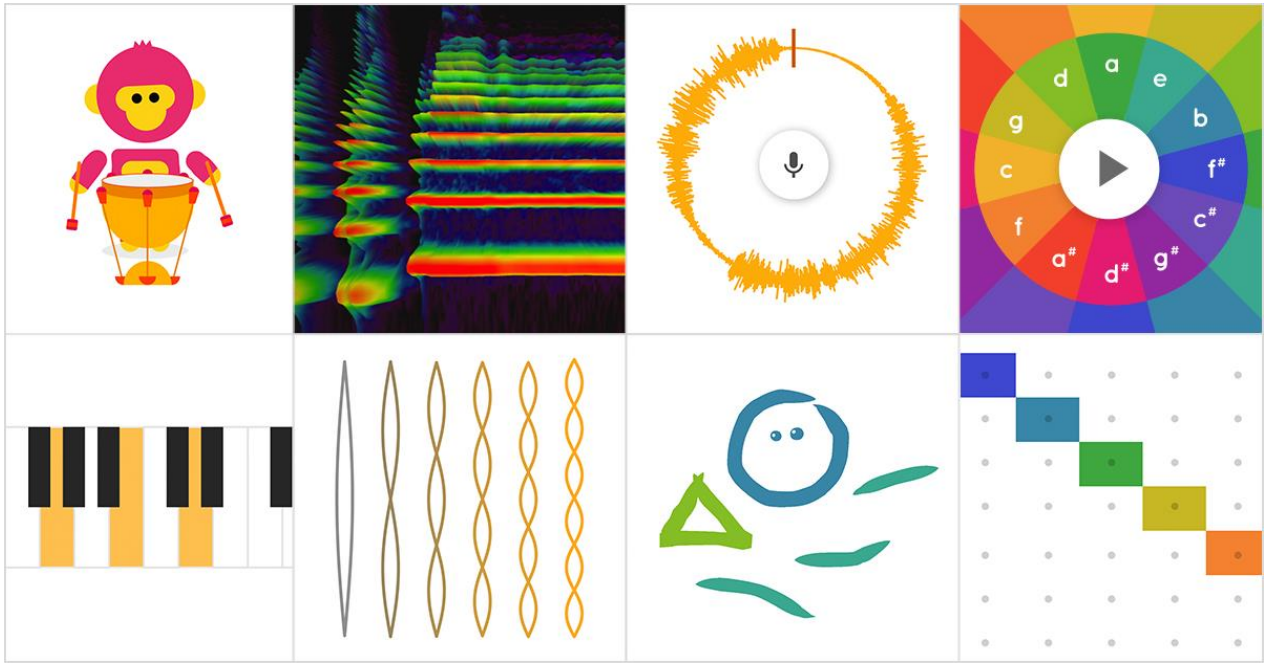
Live Coding: Chuck

Web Audio



http://www.google.com/doodles/robert-moogs-78th-birthday

Web Audio

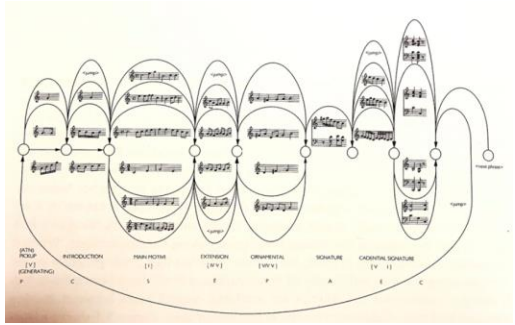


Chrome Music Lab

https://musiclab.chromeexperiments.com/Experiments

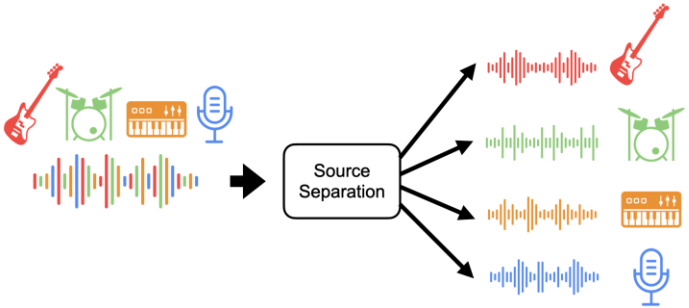
History of Music Technology: AI

- Music content is created by a generative model
  - Symbolic music generation
  - Audio-level music generation
- Neural audio processing
  - Neural sound synthesis and audio effects
  - Music source separation



David cope's EMI (1980s)

OpenAI Jukebox (2019)



Music Source Separation

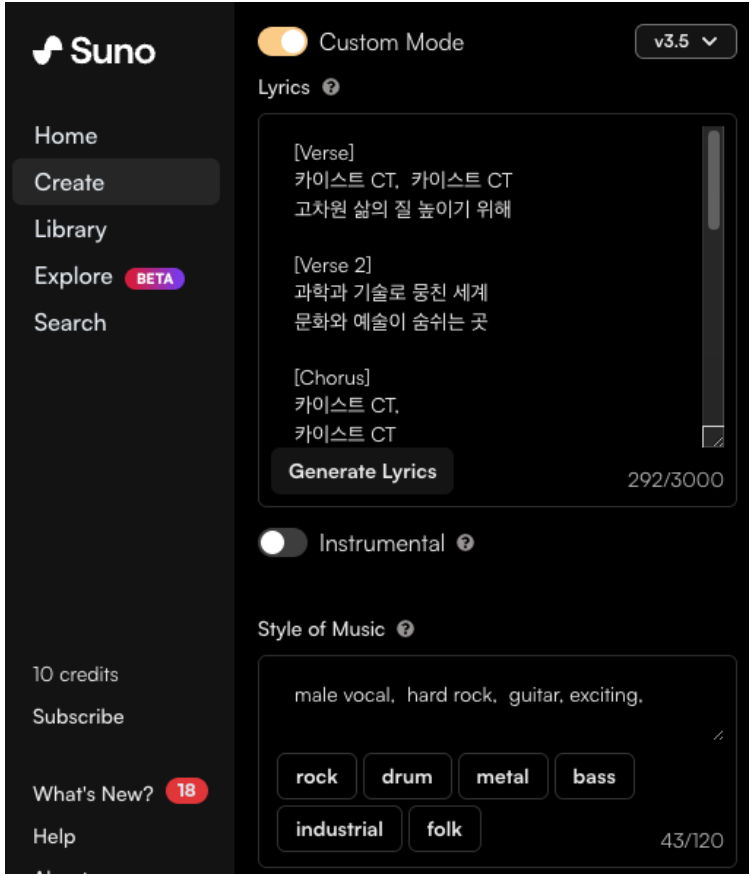
Symbolic Music Generation

MuseNet

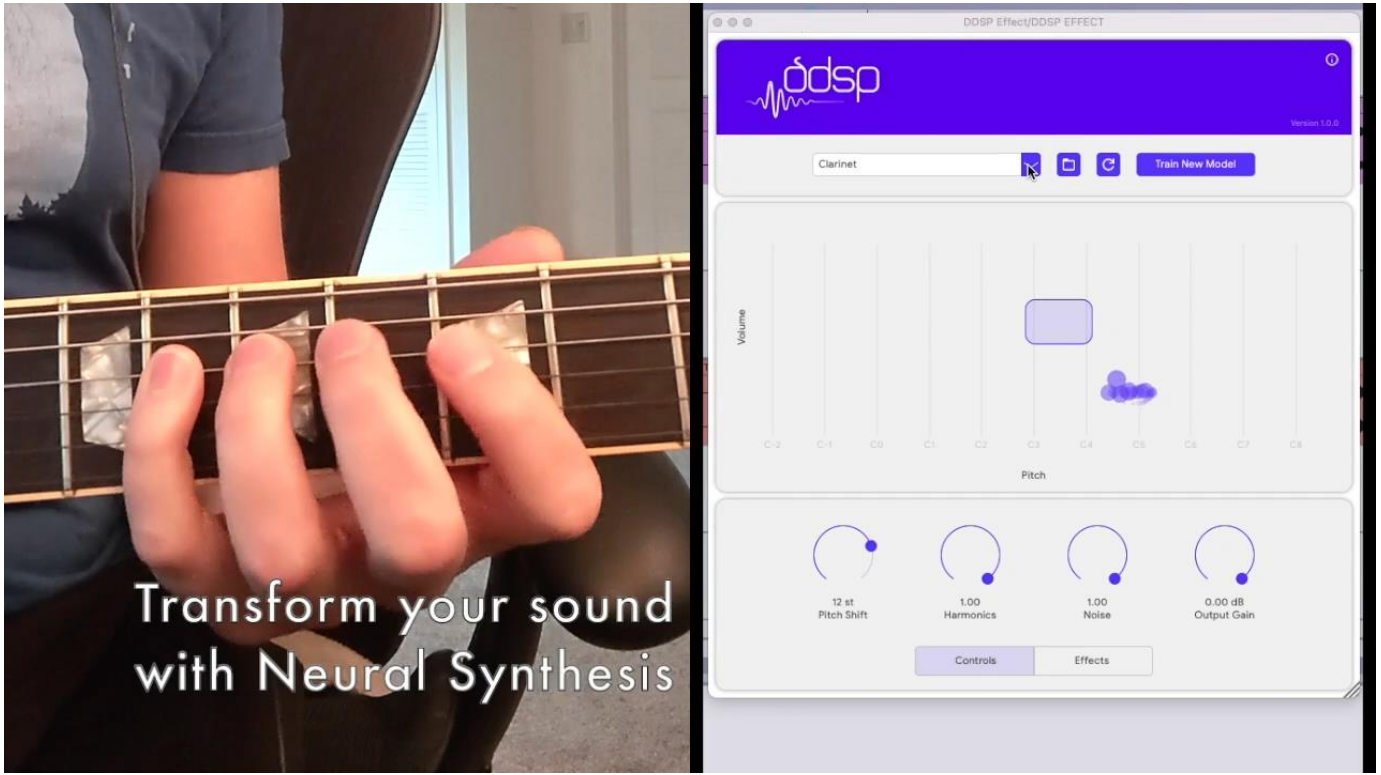
We've created MuseNet, a deep neural network that can generate 4-minute musical compositions with 10 different instruments, and can combine styles from country to Mozart to the Beatles.

MuseNet played an experimental concert on April 25th, 2019, livestreamed on OpenAI's Twitch channel, in which no human (including us) had heard the pieces before.

Audio-Level Music Generation



Tone Transfer - DDSP

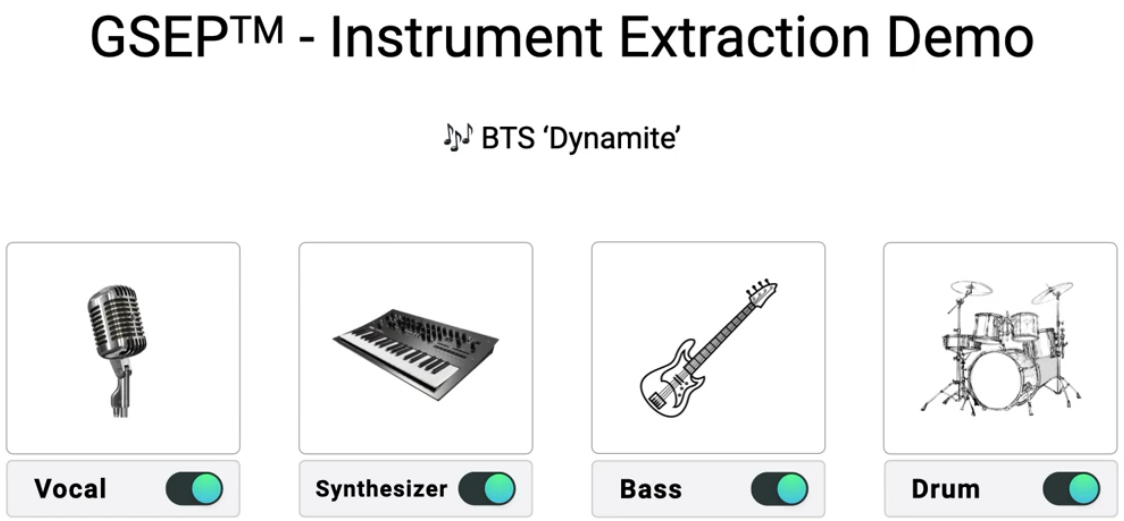


https://magenta.tensorflow.org/ddsp-vst

AI Cover Song

https://www.youtube.com/watch?v=ge0Lw5I1Tw8

Music Source Separation



https://www.youtube.com/watch?v=66SaSVa9R7g

Characteristics of Recent Music Technology

- Interactive
- Audio-visual
- Flexible (programmable)
- Social
- Easy and accessible
- Intelligent
- Generative

Applications

- Popular music
- Media arts
- Games
- Product design (e.g. home appliances, electric cars)

Course Objective

- This course introduces theories and practices to **make music with computers**
- Topics includes:
  - Basic acoustics
  - DSP: Fourier transform, spectrum analysis, digital filters
  - Sound synthesis, digital audio effect
  - MIDI, sequencer, music inferences
  - Music AI models
- Students will also gain hands-on experience with programming and audio software

Schedules

- Week 1
  - Course introduction and history of music technology
  - Fundamentals of tone generation and perception
- Week 2
  - Digital audio
  - Fourier series and Spectrum analysis
  - *[HW1] Observing Sounds through the Lens of Fourier Analysis*
- Week 3
  - Sound synthesis
  - *[HW2] Making Simple Music from Zero Using Python*

Schedules

- Week 4
  - ISMIR conference break
- Week 5
  - Digital audio effects
  - *[HW3] Adding digital audio effect and mixing*
- Week 6
  - Chuseok break
- Week 7
  - MIDI, sequencer, and DAW

Schedules

- Week 8
  - Homework presentations
- Week 9
  - Real-time audio programming
  - *[HW4] Perform live music with multi-modal input*
- Week 10
  - Interactive music performance
- Week 11 /12
  - Music AI: music understanding and generation

Schedules

- Week 13
  - Final project idea presentation
- Week 14
  - Invited talk
- Week 15
  - TBD
- Week 16
  - Final project presentations

Hand-on Experiences

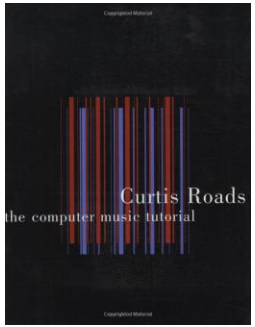
- Programming
  - Python on Jupyter notebook: offline low-level coding
  - Chuck: online (real-time) audio programing
- DAW software
  - Audacity: https://www.audacityteam.org/
  - Reaper: https://www.reaper.fm/

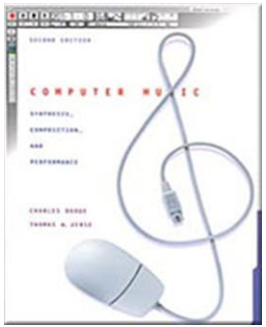
Pre-requisite

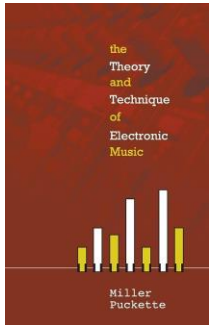
- Prior experience with programming languages: Python
- Engineering mathematics (공학수학): desired but not required
- Signals and systems: desired but not required

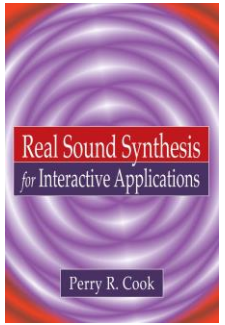
Reference Books

- **The Computer Music Tutorial (2nd edition), Curtis Roads**
- Computer Music: Synthesis, Composition, and Performance (2nd edition), Charles Dodge, Thomas A. Jerse
- The Theory and Technique of Electronic Music, Miller Puckette
  - http://msp.ucsd.edu/techniques.htm
- Real sound synthesis for interactive applications, Perry Cook









Grading

- Attendance: 5%
- Homework: 65%
  - HW1, HW2, HW3, HW4: 10%, 20%, 20%, 15%
- Final project: 30%

Course Website

- http://mac.kaist.ac.kr/~juhan/ctp431