

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

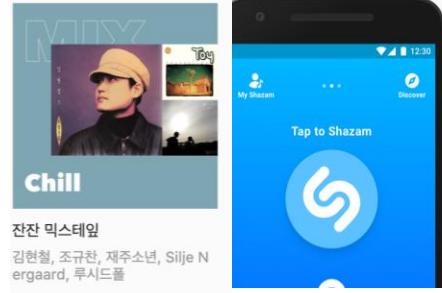
- Music is the most widely enjoyed cultural content
- We are engaged in music as listeners, performers, or creators.



Music at KAIST

# 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

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



Steinway Model D (1884)

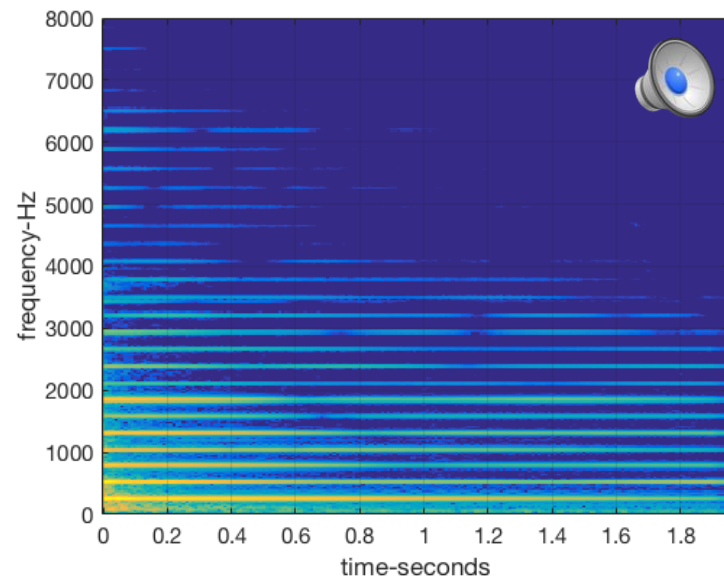
# Piano

- Characteristics

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

- Influence on music

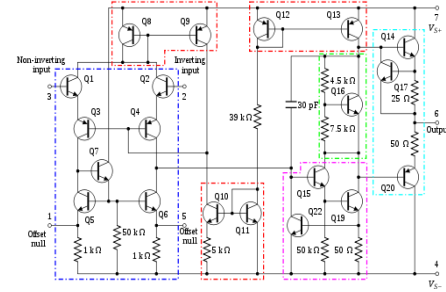
- Composers: Beethoven, Chopin, Schumann, Liszt
- Advance of tonal harmony: vertical relation of notes
- More musical expressions: dynamics, tempo, note duration
- Chopin's music on his own piano: <https://www.youtube.com/watch?v=cUgxELRgPLk>



Spectrogram of a piano tone (C4 note)

# 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





# Theremin

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



Theremin (Léon Theremin, 1928)

# Theremin

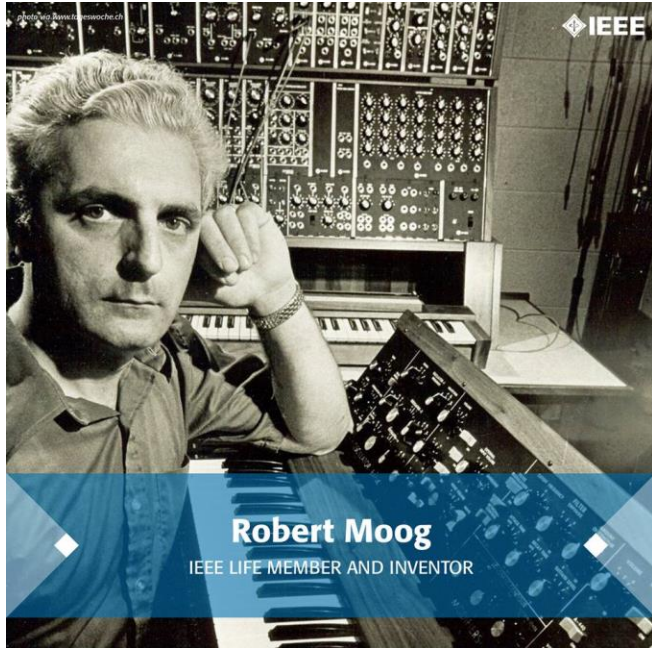


Theremin (Clara Rockmore)

<https://www.youtube.com/watch?v=pSzTPGINa5U>

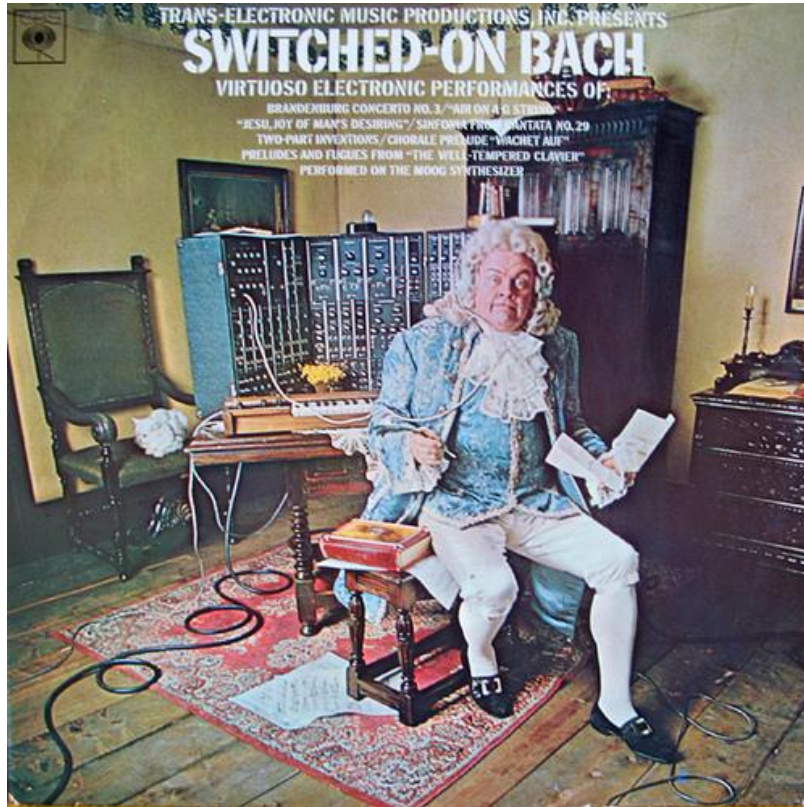
# Moog Synthesizer

- Subtractive synthesis



MiniMoog (1970)

# Moog Synthesizer



"Switched-On-Bach" by Wendy Carlos (1968)

# Electrical Guitar / Distortion Effects



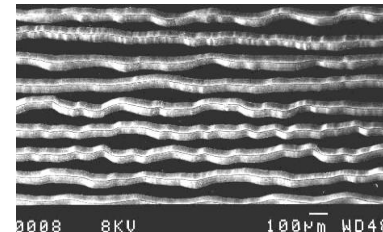
<https://www.youtube.com/watch?v=qFfnIYbFEiE>

# 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



## The Original Disc-Talking Machine.

A FEW POINTS ABOUT THE

## BERLINER GRAM-O-PHONE

Without doubt the best amusement producer and entertainer on earth. Its simplicity is such that a four-year-old child can operate it perfectly. It is substantial and solid. There are few parts to it and these few seldom, if ever, require any attention.

It is low priced—Fifteen Dollars (including a Record)—and we guarantee it to reproduce songs, choruses, bands, etc., etc., with more clearness and accuracy than any hundred dollar machine on the market.

Our records are indestructible, and will stand any amount of rough handling without danger of injuring them; they are so compact that fifty-two Gram-o-phone Records occupy less space than eight wax cylinder records.

Our records are the only ones on which you can get the GENUINE Sousa's Band production. All others claiming to have Sousa's Band records are FAKES, pure and simple, and Sousa will substantiate this statement.

Each record is signed by the maker, and the signature is reproduced in facsimile on every copy.

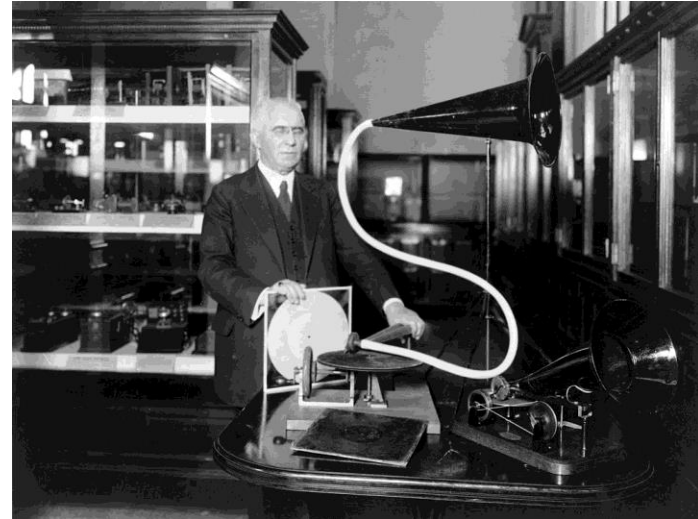
The Gram-o-phones and Records are made in Montreal; the factory is at 367-371 Aqueeduct Street—It is GUARANTEED for three years.

For Mr. E. BERLINER was awarded a medal by the City of Philadelphia for the invention of the GRAM-O-PHONE. Like most valuable inventions, the Gram-o-phone has imitators—machines using the methods of the inventor—put on the market under a name to deceive an unsuspecting public; ask the name of the inventor of the "fake" machine—it has none—The Berliner Gram-o-phone was invented by the undersigned—all flat record talking machines other than the Gram-o-phone are fakes, pure and simple.

EMANUEL BLOUT,  
Gen. Manager for Canada.

E. BERLINER,  
2316 St. Catherine Street, MONTREAL, CAN.  
Telephone Up 2418.

Beware of Trashy Imitations.



# 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



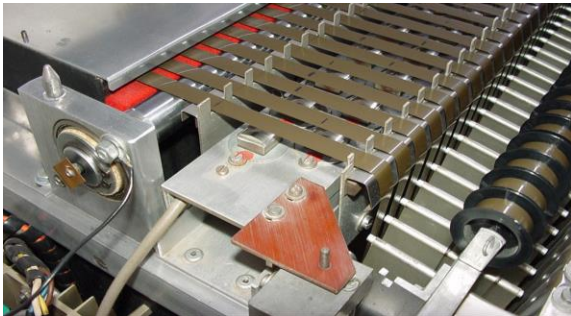
<https://www.youtube.com/watch?v=c4ea0sBrw6M>



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



Fairlight CMI

Featured on 'This Week'  
ABC-TV Australia  
1980

# 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

**ROLAND  
TR-808**

**\*FAMOUS BEATS\***

**BY RETROSOUND**

# Virtual Instruments

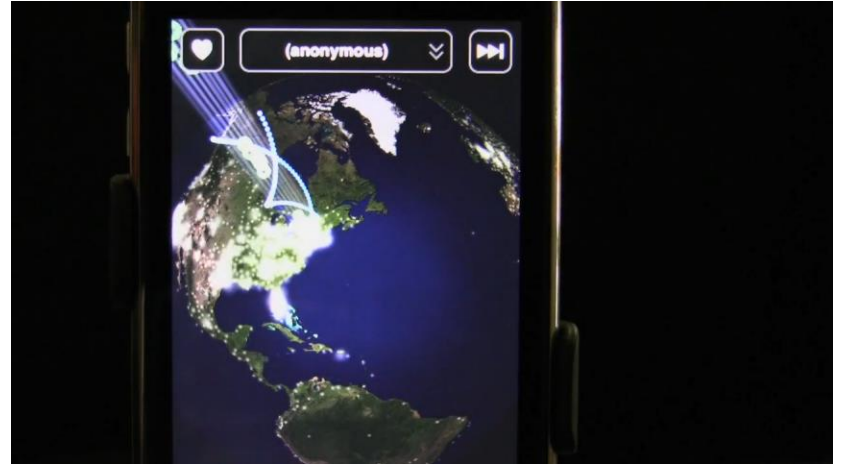
- DAW Plug-ins



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

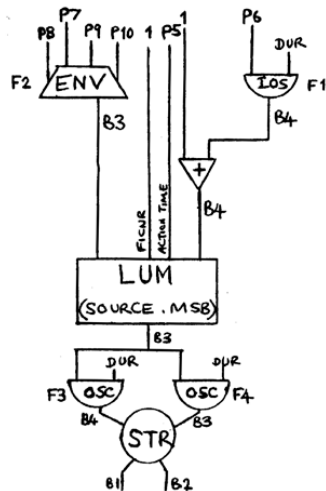


Ableton Live + Launchpad (Sae Byul Park)

# Music-N

- Composition as programming

```
PAC 1; PS1 1; PS2 1; IILN 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;
```



Max V. Mathews

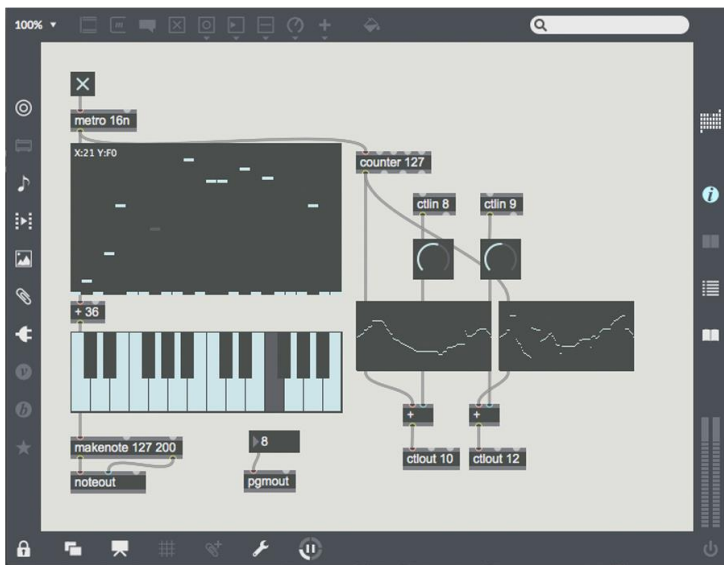
## Daisy Bell

by Harry Dacre

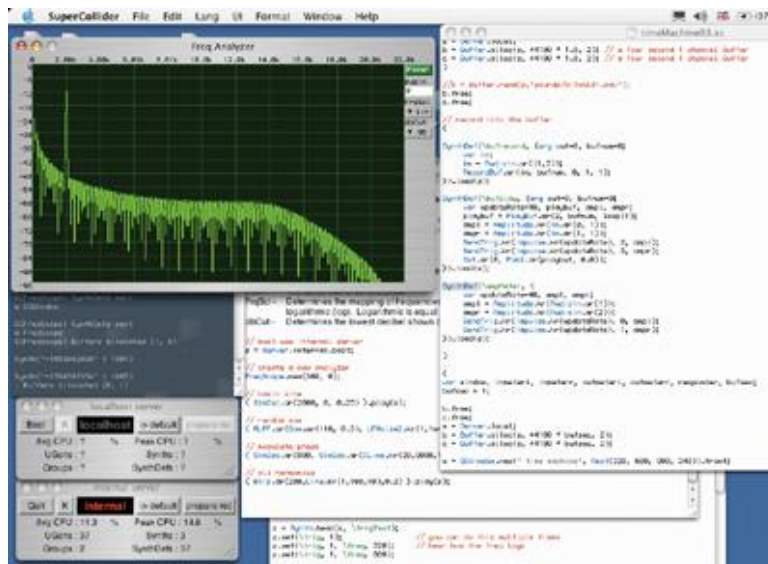
1892.

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

# Audio Programming Languages



MAX



SuperCollider

"On-the-fly Counterpoint"

Ge Wang and Perry Cook

Proof of Concept Video for NIME 2004

Excerpts from:

Listening in the Sound Kitchen 2003

2003.11.14

Princeton, NJ, U.S.A.

# Web Audio

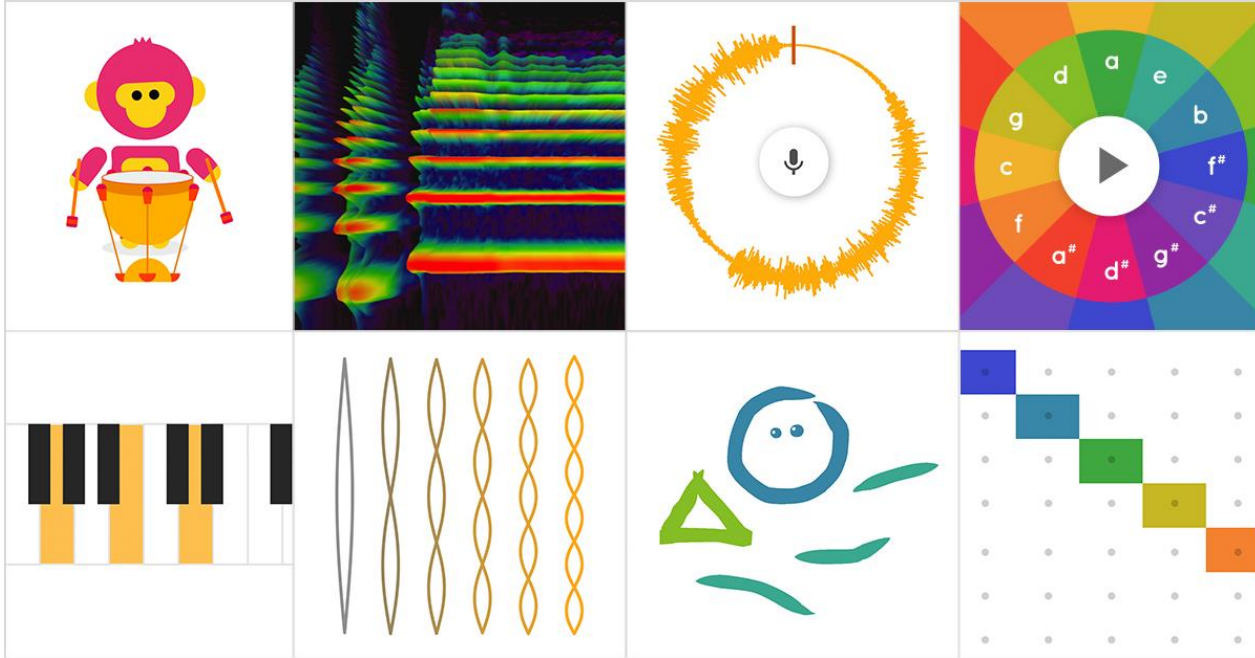


Google Search

I'm Feeling Lucky

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

# Web Audio

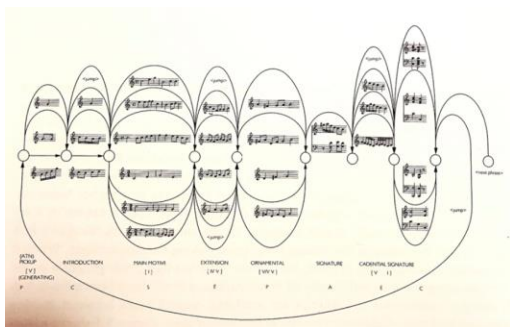


Chrome Music Lab

<https://musiclab.chromeexperiments.com/Experiments>

# History of Music Technology: AI

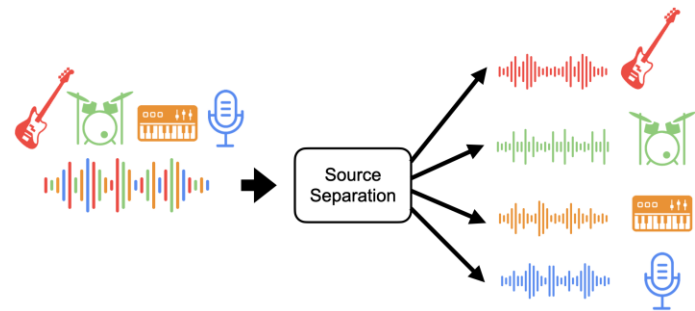
- Music content is created by a generative model
  - Symbolic music generation
  - Audio-level music generation
- Neural audio processing
  - Neural sound synthesis and audio effects
  - Music source separation



David cope's EMI (1980s)



OpenAI Jukebox (2019)



Music Source Separation

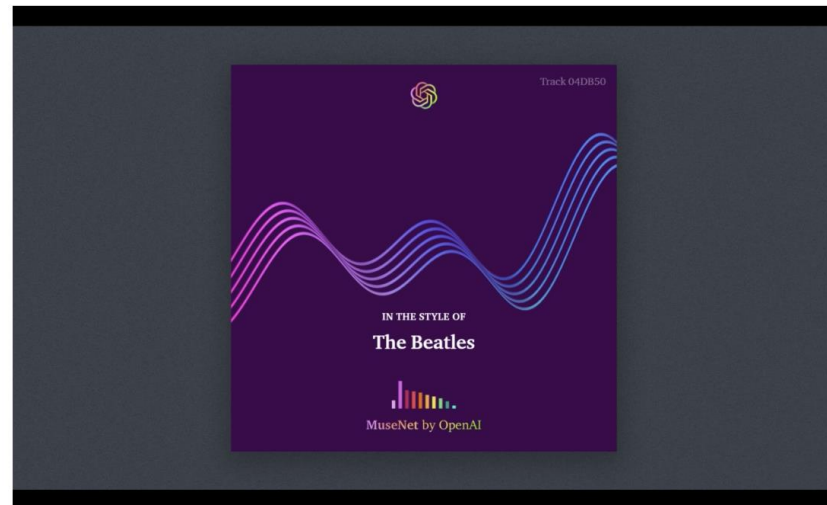
# Symbolic Music Generation

## 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.



The screenshot shows the MuseNet web interface. On the left is a dark sidebar with a list of styles: CHOPIN, MOZART, RACHMANINOFF, LADY GAGA, COUNTRY, DISNEY, JAZZ, BACH, BEETHOVEN, JOURNEY, THE BEATLES, VIDEO GAMES, BROADWAY, FRANK SINATRA, BLUEGRASS, and TCHAIKOVSKY. The main panel has a light gray background. At the top, 'STYLE' is set to 'CHOPIN'. Below that, 'INTRO' is set to 'BEETHOVEN'S FÜR ELISE'. The 'INSTRUMENTS' section shows 'PIANO' selected, with other options being STRINGS, WINDS, DRUMS, HARP, GUITAR, and BASS. A 'NUMBER OF TOKENS' slider is set to 225. Below the settings is a 'HIDE ADVANCED SETTINGS' link. The main display area shows a piano roll visualization with blue horizontal bars on a black background, with a white vertical line indicating the current playback position. At the bottom, there are controls: a play button with 'STOP PLAYBACK' text, a 'DOWNLOAD' button with a dropdown arrow, a 'TWEET' button with a Twitter icon, and a 'RESET' button with a circular arrow icon.

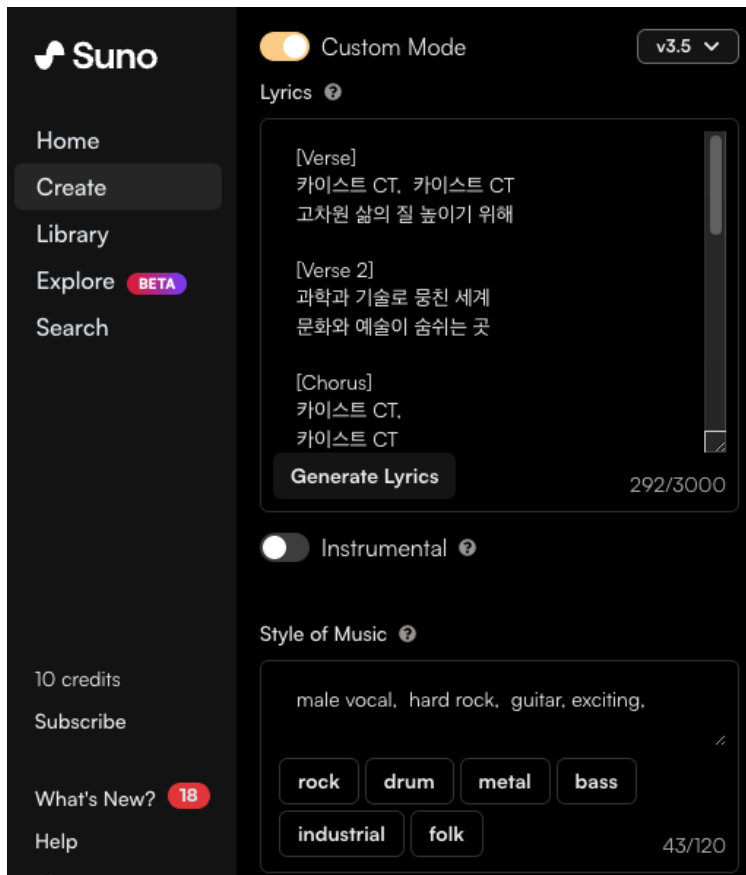


The screenshot shows a track cover for a piece generated by MuseNet. The cover has a dark purple background. At the top right, it says 'Track 04DB50'. In the center, there are several wavy, glowing lines in shades of purple and blue. Below the waves, the text reads 'IN THE STYLE OF The Beatles'. At the bottom, there is a small bar chart with colored bars and the text 'MuseNet by OpenAI'. The OpenAI logo is visible at the top center of the cover.

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



The screenshot shows the Suno AI music generation interface. At the top left is the Suno logo. Below it is a navigation menu with options: Home, Create, Library, Explore (marked BETA), and Search. On the right side of the interface, there are controls for 'Custom Mode' (a toggle switch), a version dropdown set to 'v3.5', and a 'Lyrics' section with a question mark icon. The lyrics section contains three verses: [Verse], [Verse 2], and [Chorus], each with Korean text. Below the lyrics is a 'Generate Lyrics' button and a character count '292/3000'. Further down, there is an 'Instrumental' toggle switch and a 'Style of Music' section with a question mark icon. The style section contains the text 'male vocal, hard rock, guitar, exciting.' and several genre buttons: 'rock', 'drum', 'metal', 'bass', 'industrial', and 'folk'. At the bottom right of the style section is a character count '43/120'. On the left side of the interface, there are additional options: '10 credits', 'Subscribe', 'What's New?' (with a red badge '18'), and 'Help'.

Suno

Custom Mode v3.5

Lyrics ?

[Verse]  
카이스트 CT, 카이스트 CT  
고차원 삶의 질 높이기 위해

[Verse 2]  
과학과 기술로 뭉친 세계  
문화와 예술이 숨쉬는 곳

[Chorus]  
카이스트 CT,  
카이스트 CT

Generate Lyrics 292/3000

Instrumental ?

Style of Music ?

male vocal, hard rock, guitar, exciting.

rock drum metal bass

industrial folk 43/120

10 credits

Subscribe

What's New? 18

Help



The image shows a generated music card for Suno AI. At the top is a square album art image featuring a vibrant, abstract collage of geometric shapes in various colors (red, orange, yellow, blue, purple, black, white). Below the album art is the title 'KAIST CT' in a bold, white, sans-serif font. Underneath the title is the genre description 'male vocal, hard rock, guitar...' in a smaller, white, sans-serif font. Below the genre description are two verses of lyrics, each preceded by a bracketed label: [Verse] and [Verse 2]. The lyrics are in Korean. At the bottom right of the card is the Suno logo, consisting of a stylized white 'S' followed by the word 'Suno' in a white, sans-serif font.

KAIST CT

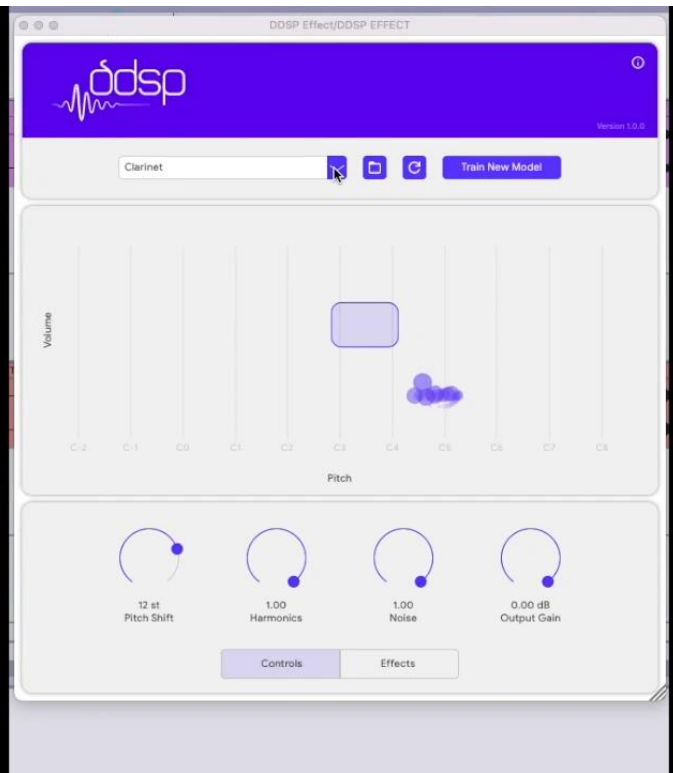
male vocal, hard rock, guitar...

[Verse]  
카이스트 CT, 카이스트 CT  
고차원 삶의 질 높이기 위해

[Verse 2]  
과학과 기술로 뭉친 세계  
문화와 예술이 숨쉬는 곳

Suno

# Tone Transfer - DDSP



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

# AI Cover Song



<https://www.youtube.com/watch?v=ge0Lw511Tw8>

# Music Source Separation

## GSEP™ - Instrument Extraction Demo

🎵 BTS 'Dynamite'



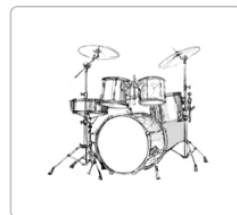
Vocal



Synthesizer



Bass



Drum



**GAUDIO**

<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

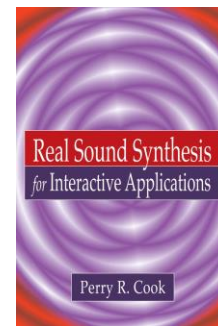
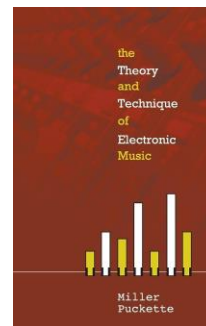
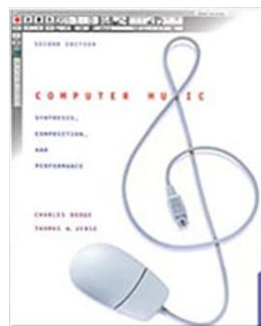
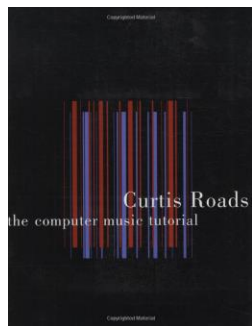
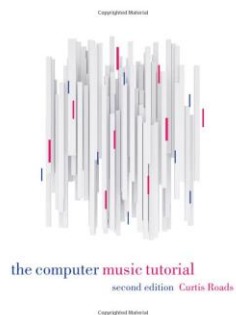
- Programming
  - Python on Jupyter notebook: offline low-level coding
  - Chuck: online (real-time) audio programming
- DAW software
  - Audacity: <https://www.audacityteam.org/>
  - Reaper: <https://www.reaper.fm/>

# 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 (2<sup>nd</sup> edition), Curtis Roads**
- Computer Music: Synthesis, Composition, and Performance (2<sup>nd</sup> 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>