Music Source Separation

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목차

01

목표 및 필요성

Goals

1

효율적인 모델

••••

Colab 환경에서
작동하는 모델

2

양질의 stem 분리

••••

Loss, SDR
→ high quality

3

Stem to Midi

••••

mp3/wav 파일에서
mid 파일로 변경

Necessity

Stem to Midi

악기 별 음원에서
멜로디 추출

Auto-composing

멜로디, sound
design 자동화

Source Separation

음원 파일
→ 악기 별 구분

Melody vs Inst

멜로디와 Stem의
관계

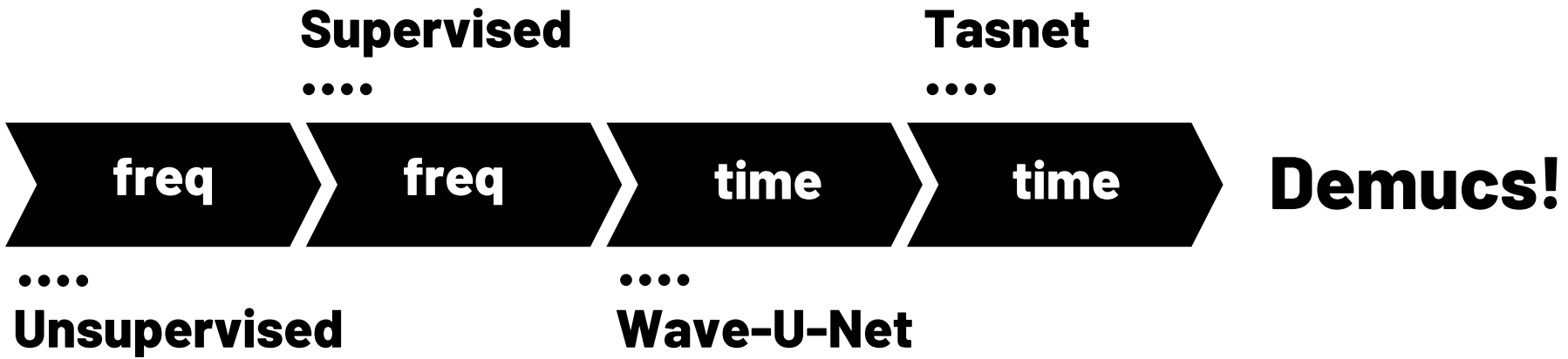
02

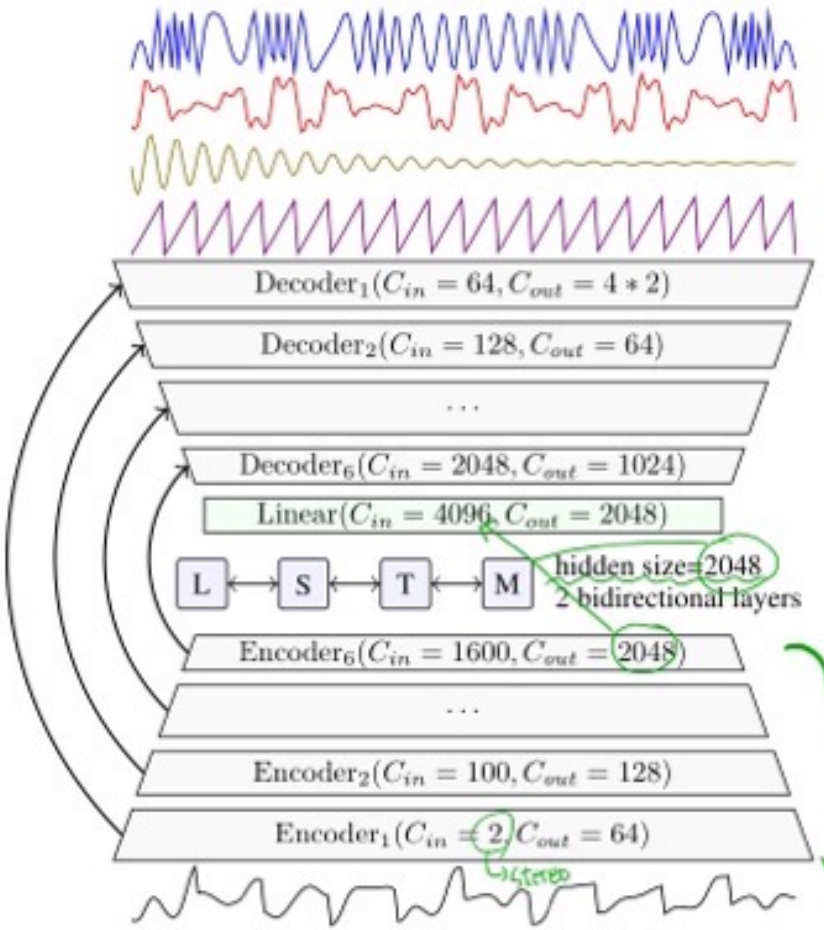
이론 및 개요

Demucs (Facebook AI Research. 2019)

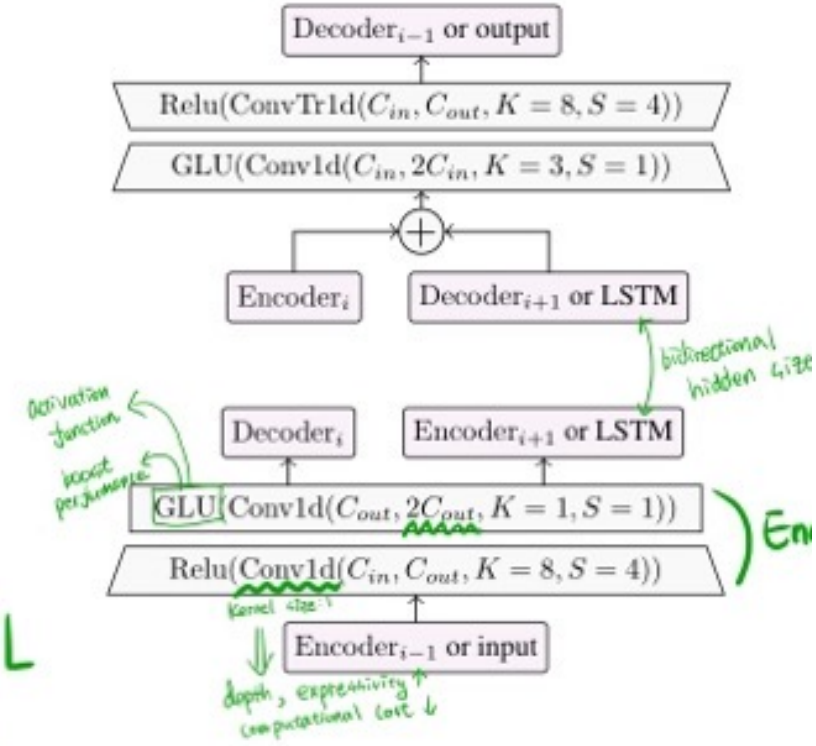
- **Time domain**에서 동작
- **U-Net** 구조
- 기존 모델보다 우수한 동작

Time domain


Supervised
Tasnet
freq
freq
time
time
Demucs!
Unsupervised
Wave-U-Net



(a) Demucs architecture with the mixture waveform as



(b) Detailed view of the layers Decoder_i on the top a
Encoder_i on the bottom. Arrows represent connecti
to other parts of the model. For convolutions, $C_i n$ (r

Dataset & Epoch

MusDB

- 44.1kHz sampled / Stereo / 150 곡
- Drums, Bass, Others, vocals
- Train set : 84곡 Valid set : 16곡 Test set : 50곡

360 epoch

SDR

Reusing the notations from Vincent et al. [2006], let us take a source $j \in 1, 2, 3, 4$ and introduce P_{s_j} (resp P_{s}) the orthogonal projection on s_j (resp on $\mathrm{Span}(s_1, \ldots, s_4)$). We then take with $\hat{s}_j$ the estimate of source s_j

$$s_{\mathrm{target}} := P_{s_j}(\hat{s}_j) \qquad e_{\mathrm{interf}} := P_{\mathrm{s}}(\hat{s}_j) - P_{s_j}(\hat{s}_j) \qquad e_{\mathrm{artif}} := \hat{s}_j - P_{\mathrm{s}}(\hat{s}_j)$$

We can now define various signal to noise ratio, expressed in decibels (dB): the source to distortion ratio

$$\mathrm{SDR} := 10 \log_{10} \frac{\|s_{\mathrm{target}}\|^2}{\|e_{\mathrm{interf}} + e_{\mathrm{artif}}\|^2},$$

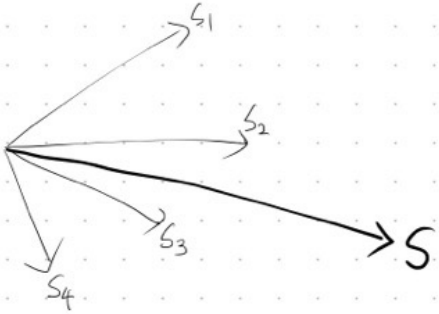
the source to interference ratio

$$\mathrm{SIR} := 10 \log_{10} \frac{\|s_{\mathrm{target}}\|^2}{\|e_{\mathrm{interf}}\|^2}$$

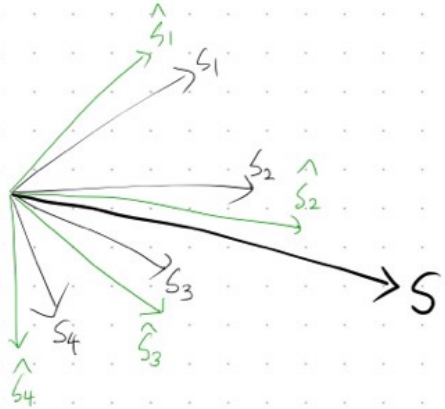
and the sources to artifacts ratio

$$\mathrm{SAR} := 10 \log_{10} \frac{\|s_{\mathrm{target}} + e_{\mathrm{interf}}\|^2}{\|e_{\mathrm{artif}}\|^2}.$$

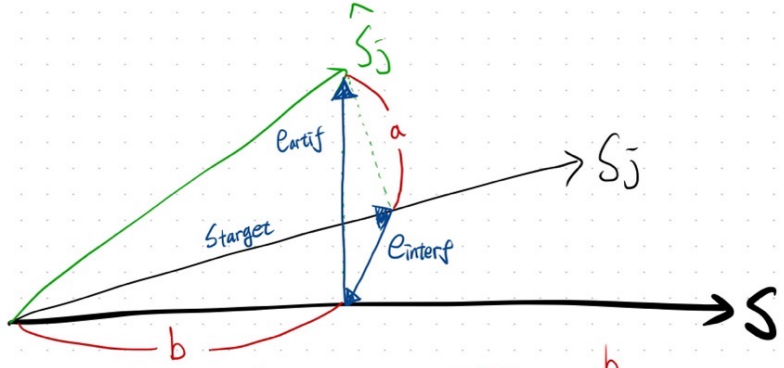
SDR



ideal



— : estimation



$$SDR : \frac{s_{target}}{a} \qquad SAR : \frac{b}{e_{artif}}$$

$$SIR : \frac{s_{target}}{e_{interf}}$$

```
[ ]  !pip install demucs
```

```
[ ]  # Please BE VERY CAREFUL, this will link your entire drive.
     # So don't edit code, except the one that says 'Customize the following options',
     # or you might mess up your files.
     # IF YOU DO NO WANT TO LINK DRIVE, please see below for an alternative!
     from google.colab import drive
     drive.mount('/content/drive')
```

wav source file: https://www.ee.columbia.edu/~dpwe/sounds/music/

```
[ ]  # Customize the following options!
     model = "mdx_extra"
     extensions = ["mp3", "wav", "ogg", "flac"]  # we will look for all those file types.
     two_stems = None   # only separate one stems from the rest, for instance
     # two_stems = "vocals"

     # Options for the output audio.
     mp3 = True
     mp3_rate = 320
     float32 = False  # output as float 32 wavs, unsused if 'mp3' is True.
     int24 = False    # output as int24 wavs, unused if 'mp3' is True.
     # You cannot set both `float32 = True` and `int24 = True` !!

     in_path = '/content/drive/MyDrive/demucs/'
     out_path = '/content/drive/MyDrive/demucs_separated/'
```

Useful functions, don't forget to execute

코드 표시

```
[ ]  # This can be quite slow, in particular the loading, and saving from GDrive. Please be patient!
     # This is from google drive! Also, this will separate all the files inside the MyDrive/demucs folder,
     # so when you are happy with the results, remove the songs from there.
     separate()
```

madmom (S Böck. 2016)

- 객체 지향 programming
- Machine Learning 기반
- 의존성이 낮다

https://www.ofoct.com/audio-converter/convert-wav-or-mp3-ogg-aac-wma-to-midi.html

Run Terminal Help graduation_projects

Release Notes: 1.74.2 | audio_comparison.ipynb | madmom_main.ipynb

Audio_to_midi > madmom_main.ipynb > Wav file analysis > D = np.abs(librosa.stft(y, n_fft=2048, hop_length=512))

Code + Markdown | Run All | Clear Outputs of All Cells | Restart | Variables | Outline ...

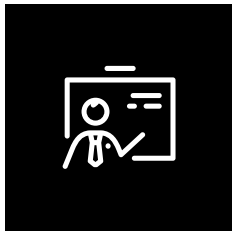
```
proc = RNNPianoNoteProcessor()
abs_path = 'C:/Users/Admin/graduation_projects/Audio_to_midi/'
act = proc(abs_path+'wav/vocals.wav')

print("(frame #, piano keys) = (%d, %d)" %act.shape)
print(act)
```

```
proc = NoteOnsetPeakPickingProcessor(fps=100, pitch_offset=21)
act = RNNPianoNoteProcessor()(abs_path+'wav/vocals.wav')
print(proc(act).shape)
print(proc(act))
```

```
proc = CNNPianoNoteProcessor()
adsr = ADSRNoteTrackingProcessor(onset_threshold=0.55, pitch_offset=21)

# long runtime: 2m 20s
act = proc(abs_path+'wav/vocals.wav')

# midi matrix
MIDI_notes = adsr(act)

print(MIDI_notes)

# Requirements for midi file
#   1. midiutil library
#   2. track # : 1
#   3. beginning time(sec) : 0
#   4. volume : 100
```

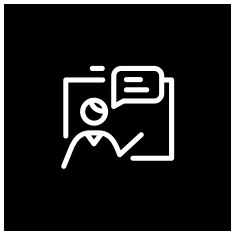
onset_threshold : float, optional
Require notes to have an onset activation greater or equal this threshold.

Midi vs Audio



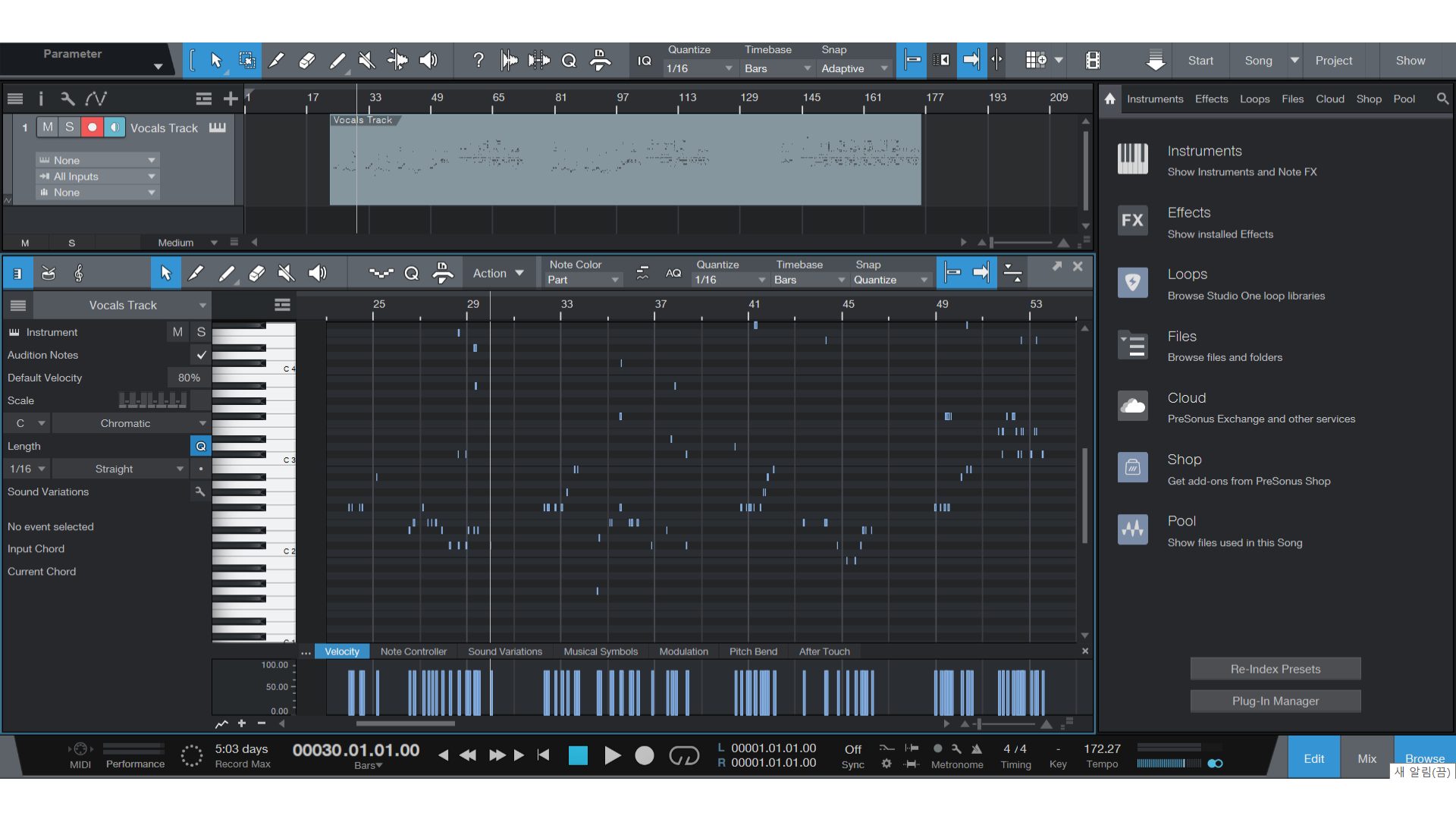
Midi

Piano roll (keys)에 따라
위치만 표현



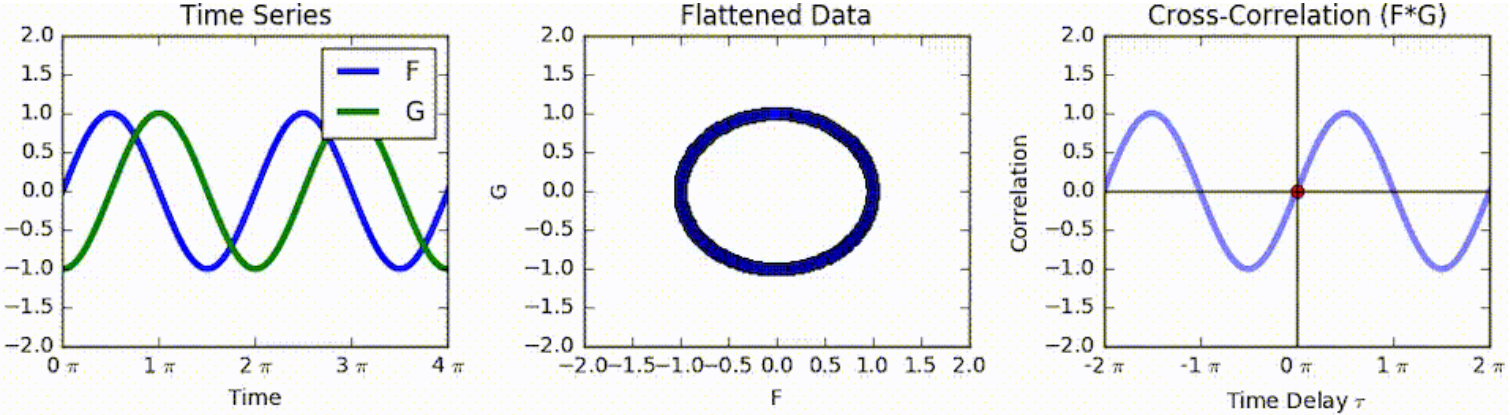
Audio

실제로 들을 수 있는 파일


Parameter
Quantize
1/16
Timebase
Bars
Snap
Adaptive
Start
Song
Project
Show
Vocals Track
Instruments
Effects
Loops
Files
Cloud
Shop
Pool
Instruments
Show Instruments and Note FX
Effects
Show installed Effects
Loops
Browse Studio One loop libraries
Files
Browse files and folders
Cloud
PreSonus Exchange and other services
Shop
Get add-ons from PreSonus Shop
Pool
Show files used in this Song
Action
Note Color
Part
Quantize
1/16
Timebase
Bars
Snap
Quantize
Vocals Track
Instrument
Audition Notes
Default Velocity
80%
Scale
C
Chromatic
Length
1/16
Straight
Sound Variations
No event selected
Input Chord
Current Chord
Velocity
Note Controller
Sound Variations
Musical Symbols
Modulation
Pitch Bend
After Touch
Re-Index Presets
Plug-In Manager
MIDI
Performance
5:03 days
Record Max
00030.01.01.00
Bars
L 00001.01.01.00
R 00001.01.01.00
Off
Sync
Metronome
4 / 4
Timing
Key
172.27
Tempo
Edit
Mix
Browse


Parameter
Instruments
1 - Presence
Grand Piano
None
Auto: Off
Artist Instruments
Brass
Guitar
Keyboards
Organ
Percussion
Piano
Strings
Vox
Winds
Grand Piano
LFO 1
Rate
LFO 2
Rate
Filter
Soft
Drive
Vel
Punch
Key
Cutoff
Res
Amp Env
A
D
S
R
Global
Volume
Velocity
Poly
Mono
Glide
Glide
Env 2
Sample Start Mod
Pitch Fine Tune
Sample shift
Transpose
MOD/FX
PRESENCE XT
Grand Piano
Program: Grand Piano
Voices 0 64 3.69 MB
FX A
FX B
Mod A
Mod B
Modulation
Chorus
Flanger
Phaser
Mono
Delay
Speed
Width
FB
Sync
Depth
Delay
Off
Reverb
Low
High
1/4
FB
Mix
Reverb
Pre
Damp
Size
Low
High
Mix
C 1
C 2
C 3
C 4
C 5
2 Bend 2
Bend
Mod
Vocals Track
Instrument
Audition Notes
Default Velocity
80%
Scale
C
Chromatic
Length
1/16
Straight
Sound Variations
No event selected
Input Chord
Current Chord
Song
Project
Show
Loops
Files
Cloud
Shop
Pool
Vendor
Type
Presence
Edit
Mix
Browse
MIDI
Performance
5:03 days
Record Max
00030.01.01.00
Bars
L 00001.01.01.00
R 00001.01.01.00
Off
Sync
Metronome
4 / 4
Timing
Key
172.27
Tempo

Cross correlation



$$(f \star g)(\tau) \triangleq \int_{-\infty}^{\infty} \overline{f(t)} g(t+\tau)\, dt$$

which is equivalent to

$$(f \star g)(\tau) \triangleq \int_{-\infty}^{\infty} \overline{f(t-\tau)} g(t)\, dt$$

audio_comparison.m

```
[x,fs]=audioread("vocal_test.wav");
[y,fs]=audioread("vocal_07.wav");
lx = length(x);
ly = length(y);
samples = 1:min(lx,ly);

 subplot(3,1,1), plot (x(samples));
 subplot(3,1,2), plot (y(samples));
 [C1, lag1] = xcorr(x(samples),y(samples));
  subplot(3,1,3), plot(lag1/fs,C1);
  ylabel("Amplitude"); grid on
   title("Cross-correlation ")
```

03

코드 실행 결과

Source Separation

Original

Runtime : 8m 30s ~ 9m (in Google Colab pro env)

vocal

bass

drum

other

Source Separation

Architecture	Wav?	Extra?	Test SDR in dB				
			All	Drums	Bass	Other	Vocals
IRM oracle	✗	N/A	8.22	8.45	7.12	7.85	9.43
Wave-U-Net	✓	✗	3.23	4.22	3.21	2.25	3.25
Open-Unmix	✗	✗	5.33	5.73	5.23	4.02	6.32
Meta-Tasnet	✓	✗	5.52	5.91	5.58	4.19	6.40
Conv-Tasnet†	✓	✗	5.73 ±.10	6.02 ±.08	6.20 ±.15	4.27 ±.03	6.43 ±.16
DPRNN	✓	✗	5.82	6.15	5.88	4.32	6.92
D3Net	✗	✗	6.01	**7.01**	5.25	**4.53**	**7.24**
Demucs†	✓	✗	6.28 ±.03	6.86 ±.05	**7.01** ±.19	4.42 ±.06	6.84 ±.10
Spleeter	✗	∼ 25k*	5.91	6.71	5.51	4.55	6.86
TasNet	✓	∼ 2.5k	6.01	7.01	5.25	4.53	7.24
MMDenseLSTM	✗	804	6.04	6.81	5.40	4.80	7.16
Conv-Tasnet††	✓	150	6.32 ±.04	7.11 ±.13	7.00 ±.05	4.44±.03	6.74 ±.06
D3Net	✗	1.5k	6.68	7.36	6.20	**5.37**	**7.80**
Demucs†	✓	150	**6.79** ±.02	**7.58** ±.02	**7.60** ±.13	4.69 ±.04	7.29 ±.06

*: each track is only 30 seconds, †: from current work, ††: trained without pitch/tempo augmentation, as it deteriorates performance.

Audio to Midi


stem

Runtime : 4m ~ 4m 30s (in GTX 1060)

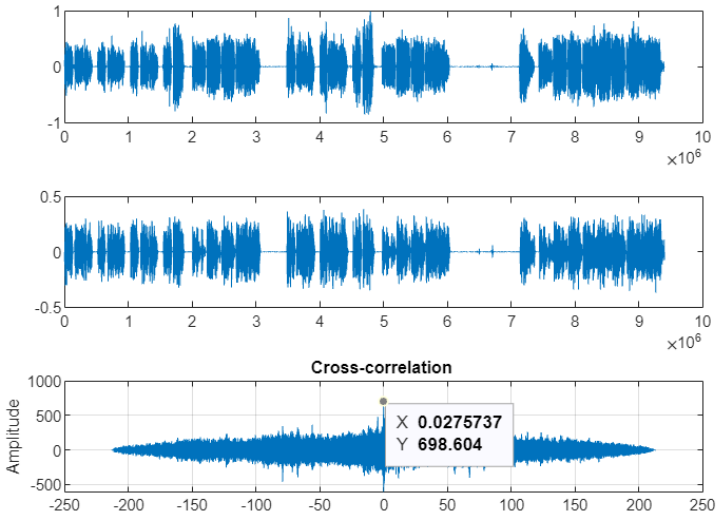




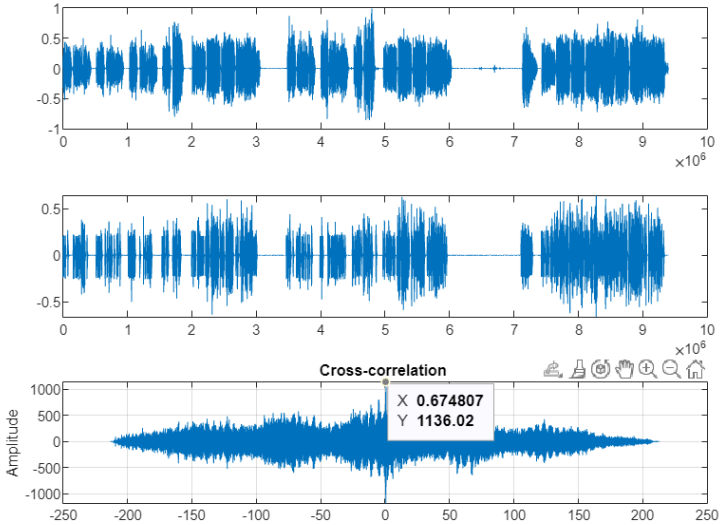


vocal test **0.55** **0.7** **0.9**

Cross Correlation

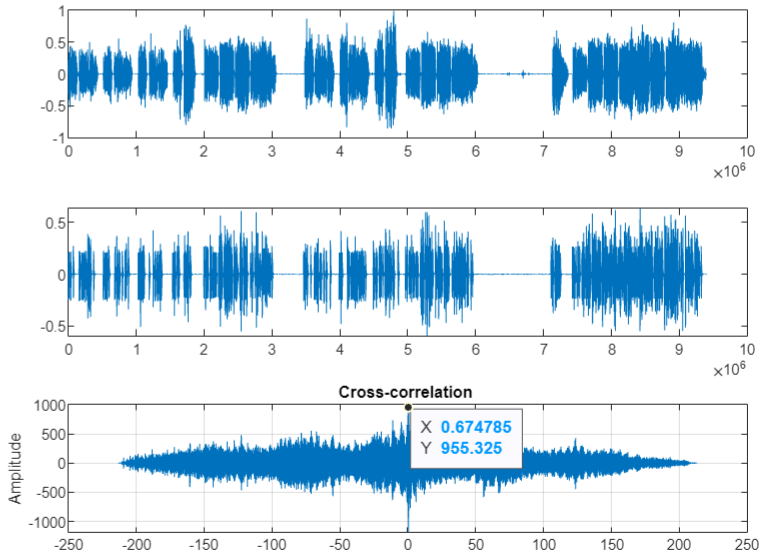


stem vs test

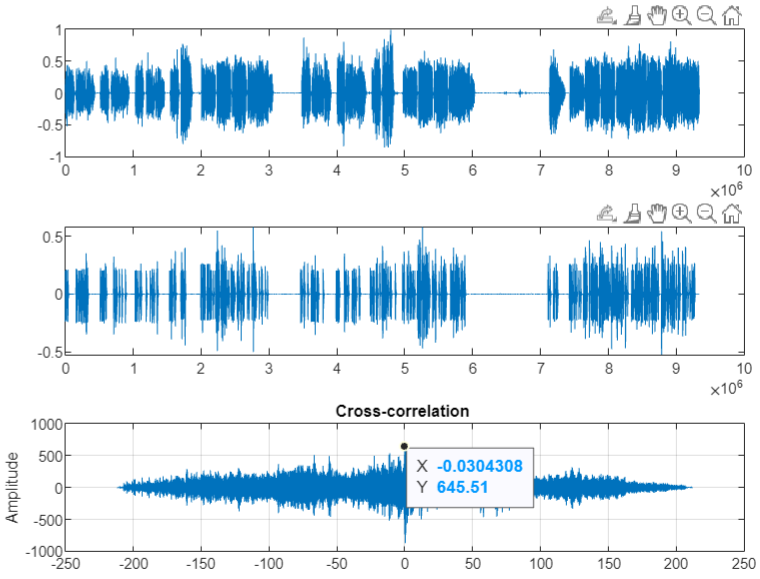


stem vs 0.55

Cross Correlation

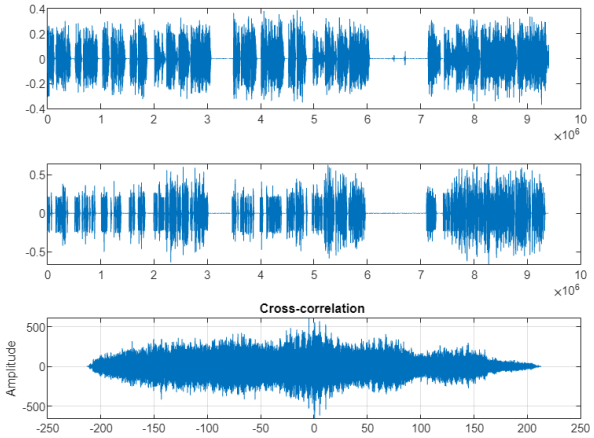


stem vs 0.7

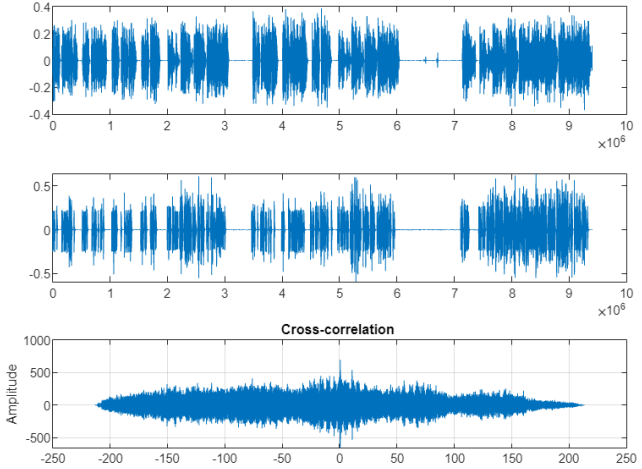


stem vs 0.9

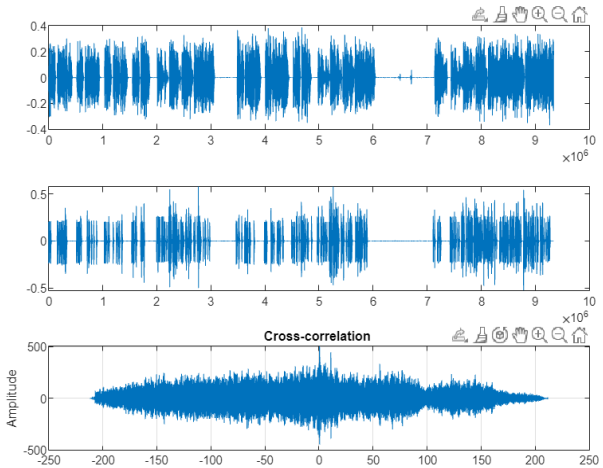
Cross Correlation



test vs 0.55



test vs 0.7



test vs 0.9

Cross Corr Table

vs stem	Test	0.55	0.7	0.9
Correlation max	698.60	1.1360e+03	955.32	672.08

```
>> audio_comparison
  698.6040

>> audio_comparison
   1.1360e+03

>> audio_comparison
  955.3251

>> audio_comparison
  672.0814
```

vs test	0.55	0.7	0.9
Correlation max	606.58	695.43	501.62

```
>> audio_comparison
  606.5845

>> audio_comparison
  695.4330

>> audio_comparison
  501.6190
```

Conclusions

1

효율적인 모델

- Runtime이 각각 8~8.5m / 4~4.5m
- Demucs : 150MB / madmom : 90MB
- 객체 지향적 → 사용하기 쉬움

Conclusions

2

양질의 stem 분리

- SDR 값이 대체적으로 높다
- 다양한 file format (wav)

Conclusions

3

Stem to Midi

- Original stem과 가장 근접한 것 → 0.55
- Test와 가장 근접한 것 → 0.7
- 0.55 ~ 0.7 사이 값이 적정

References

Demucs

- https://github.com/facebookresearch/demucs
- Music Source Separation in the Waveform Domain (2019)

Madmom

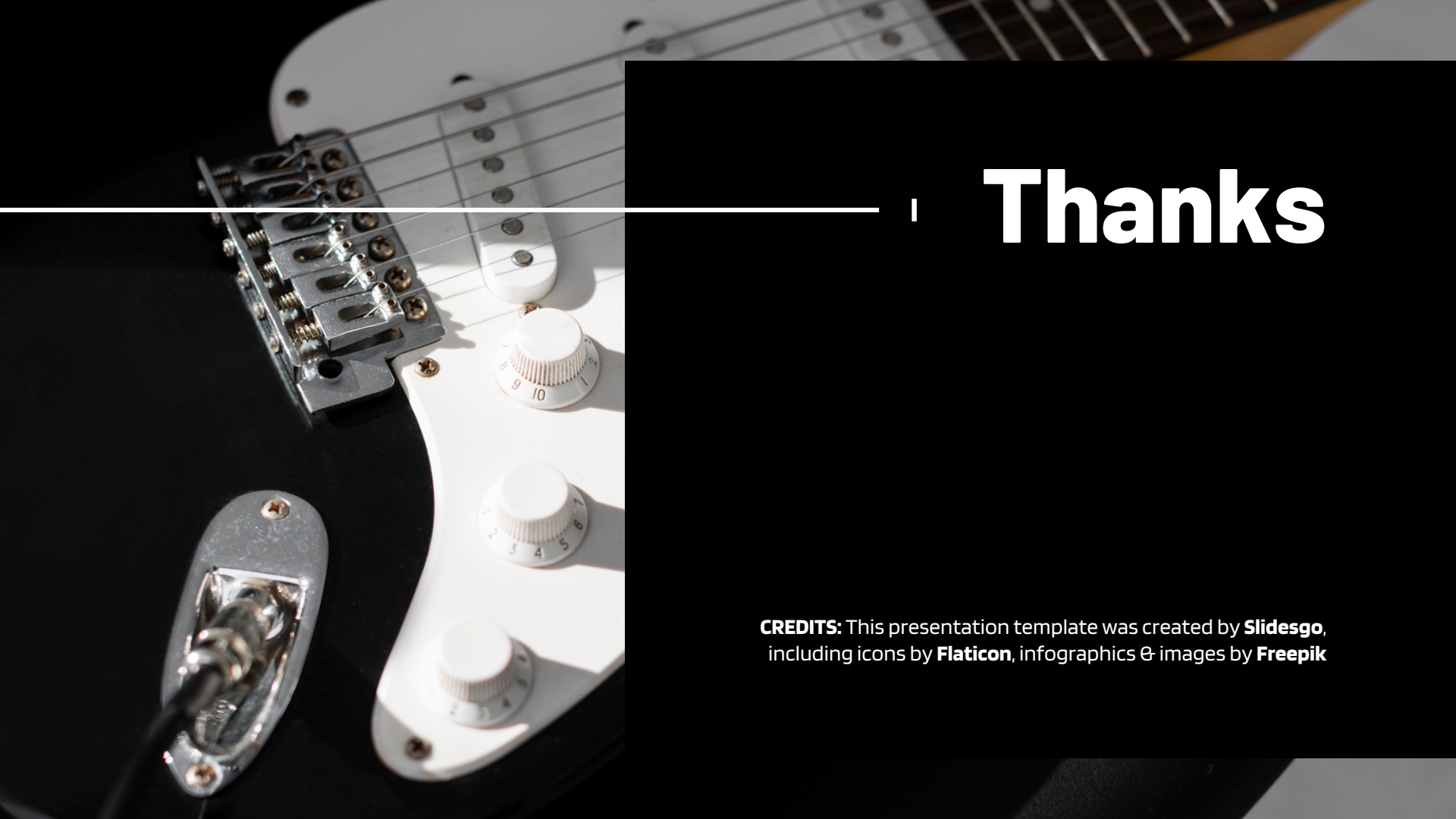
- https://github.com/CPJKU/madmom
- madmom: A New Python Audio and Music Signal Processing Library (2016)
- https://madmom.readthedocs.io/en/latest/index.html

SDR

- Performance Measurement in Blind Audio Source Separation (2006)

Correlation

- https://en.wikipedia.org/wiki/Cross-correlation



Thanks