Lecture

Music Processing

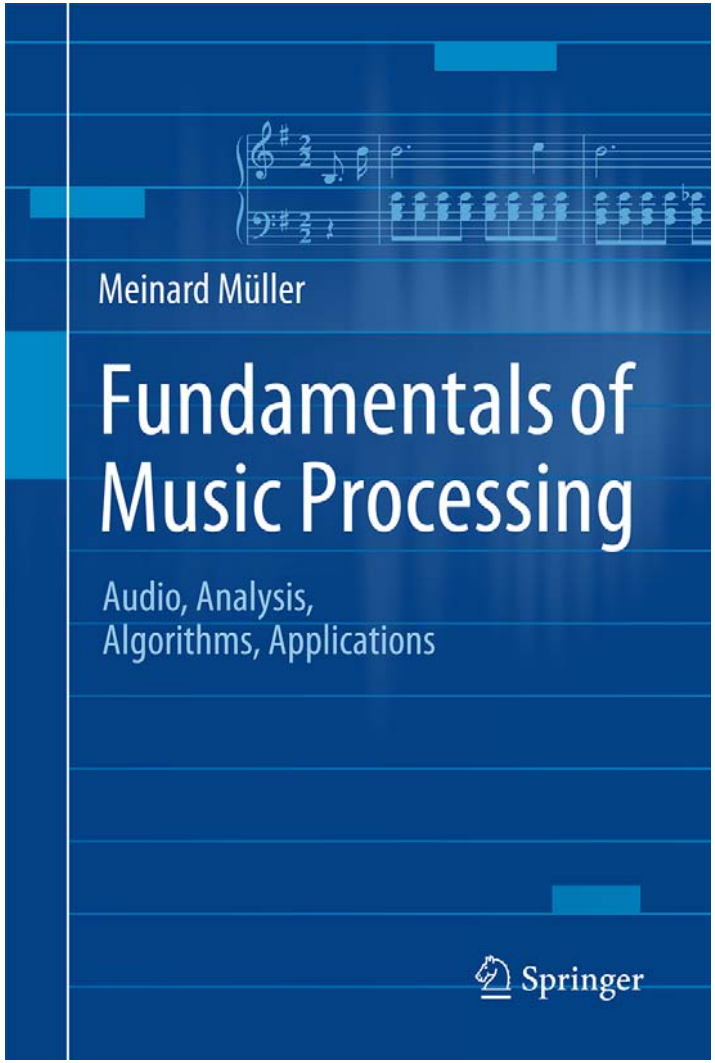
Audio Decomposition

Meinard Müller
International Audio Laboratories Erlangen
meinard.mueller@audiolabs-erlangen.de

FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG

Fraunhofer
IIS

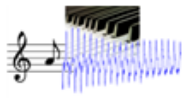
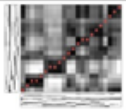
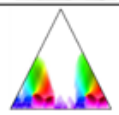
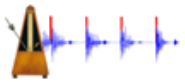
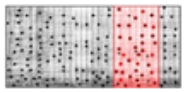
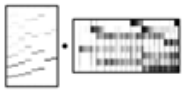
Book: Fundamentals of Music Processing



Meinard Müller
Fundamentals of Music Processing
Audio, Analysis, Algorithms, Applications
483 p., 249 illus., hardcover
ISBN: 978-3-319-21944-8
Springer, 2015

Accompanying website:
www.music-processing.de

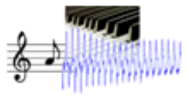
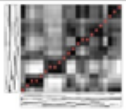
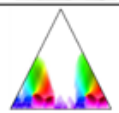
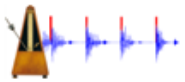
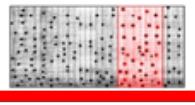
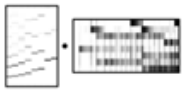
Book: Fundamentals of Music Processing

Chapter		Music Processing Scenario
1		Music Represenations
2		Fourier Analysis of Signals
3		Music Synchronization
4		Music Structure Analysis
5		Chord Recognition
6		Tempo and Beat Tracking
7		Content-Based Audio Retrieval
8		Musically Informed Audio Decomposition

Meinard Müller
Fundamentals of Music Processing
Audio, Analysis, Algorithms, Applications
483 p., 249 illus., hardcover
ISBN: 978-3-319-21944-8
Springer, 2015

Accompanying website:
www.music-processing.de

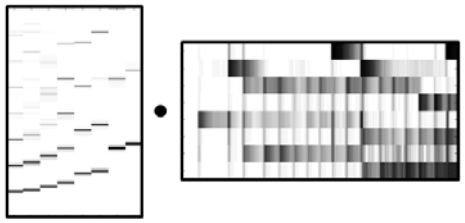
Book: Fundamentals of Music Processing

Chapter		Music Processing Scenario
1		Music Represenations
2		Fourier Analysis of Signals
3		Music Synchronization
4		Music Structure Analysis
5		Chord Recognition
6		Tempo and Beat Tracking
7		Content-Based Audio Retrieval
8		Musically Informed Audio Decomposition

Meinard Müller
Fundamentals of Music Processing
Audio, Analysis, Algorithms, Applications
483 p., 249 illus., hardcover
ISBN: 978-3-319-21944-8
Springer, 2015

Accompanying website:
www.music-processing.de

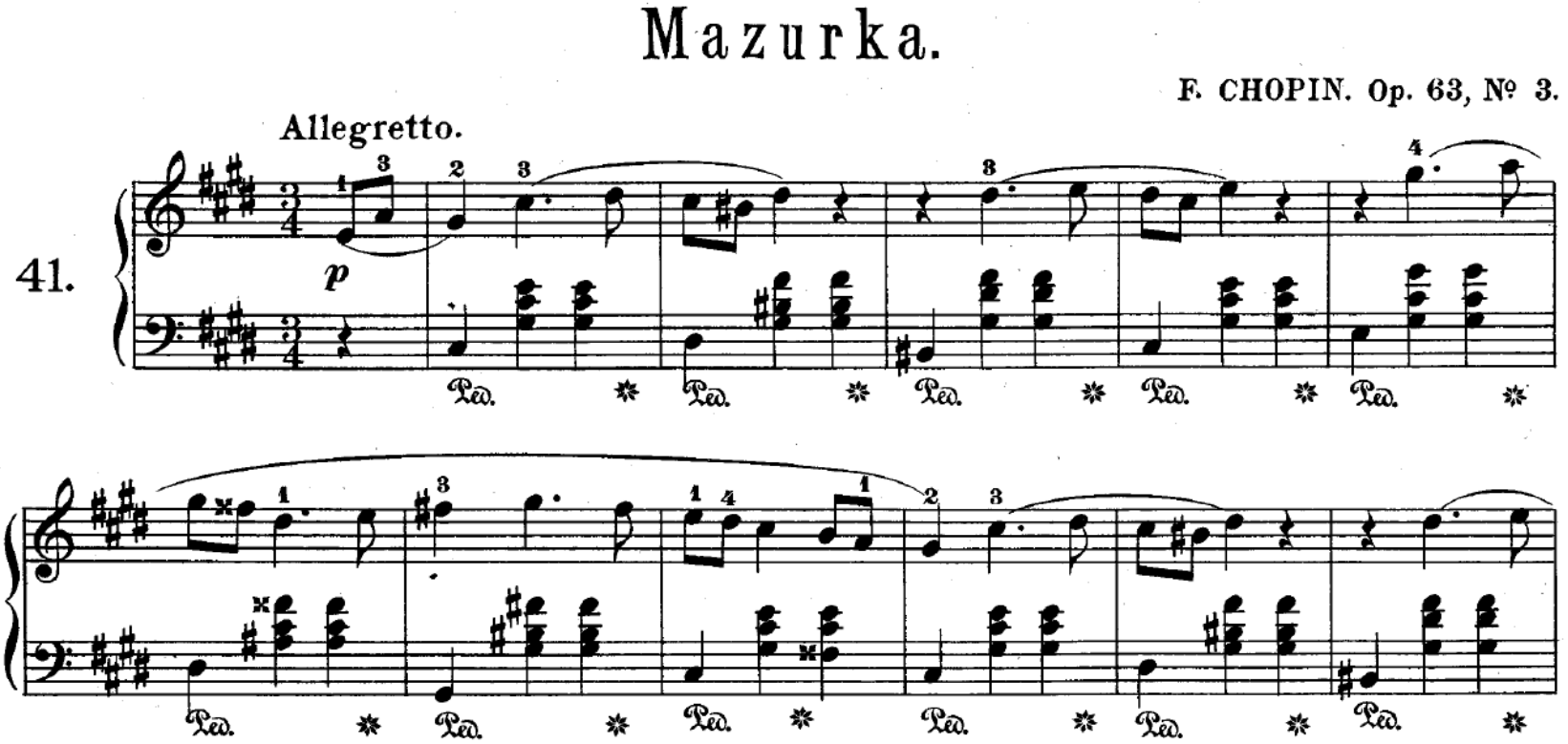
Chapter 8: Audio Decomposition



In the final Chapter 8 on audio decomposition, we present a challenging research direction that is closely related to source separation. Within this wide research area, we consider three subproblems: harmonic–percussive separation, main melody extraction, and score-informed audio decomposition. Within these scenarios, we discuss a number of key techniques including instantaneous frequency estimation, fundamental frequency (F0) estimation, spectrogram inversion, and nonnegative matrix factorization (NMF). Furthermore, we encounter a number of acoustic and musical properties of audio recordings that have been introduced and discussed in previous chapters, which rounds off the book.

Why is Music Processing Challenging?

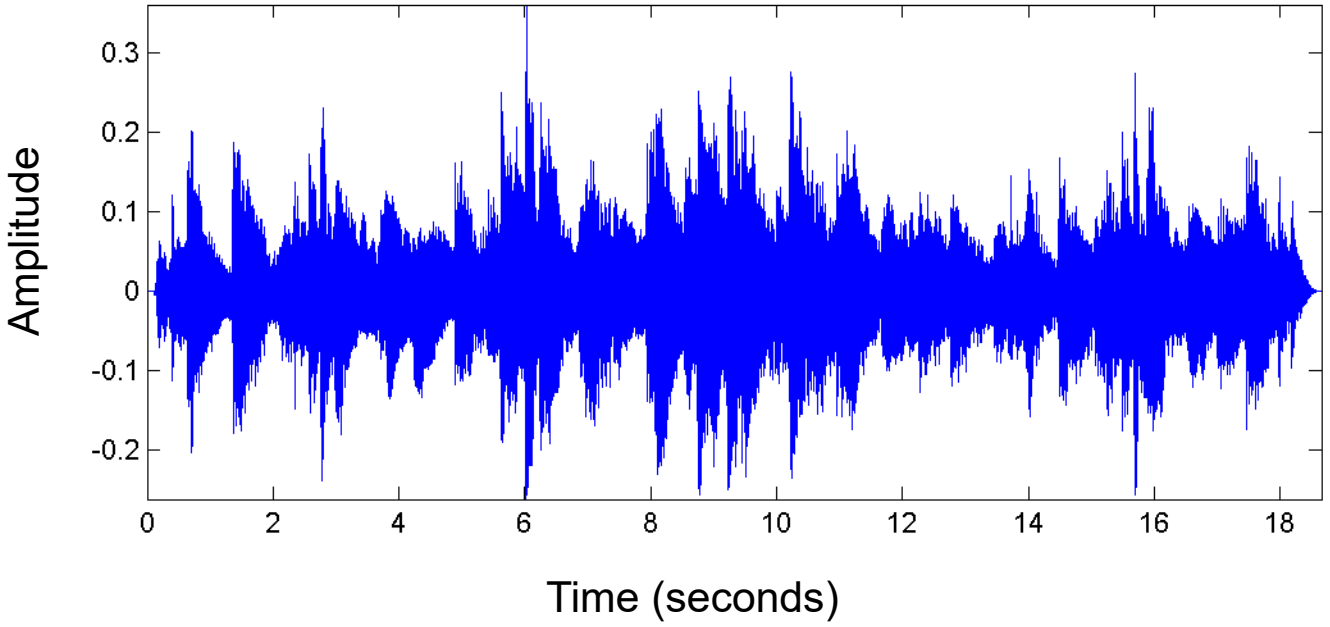
Example: Chopin, Mazurka Op. 63 No. 3



Why is Music Processing Challenging?

Example: Chopin, Mazurka Op. 63 No. 3

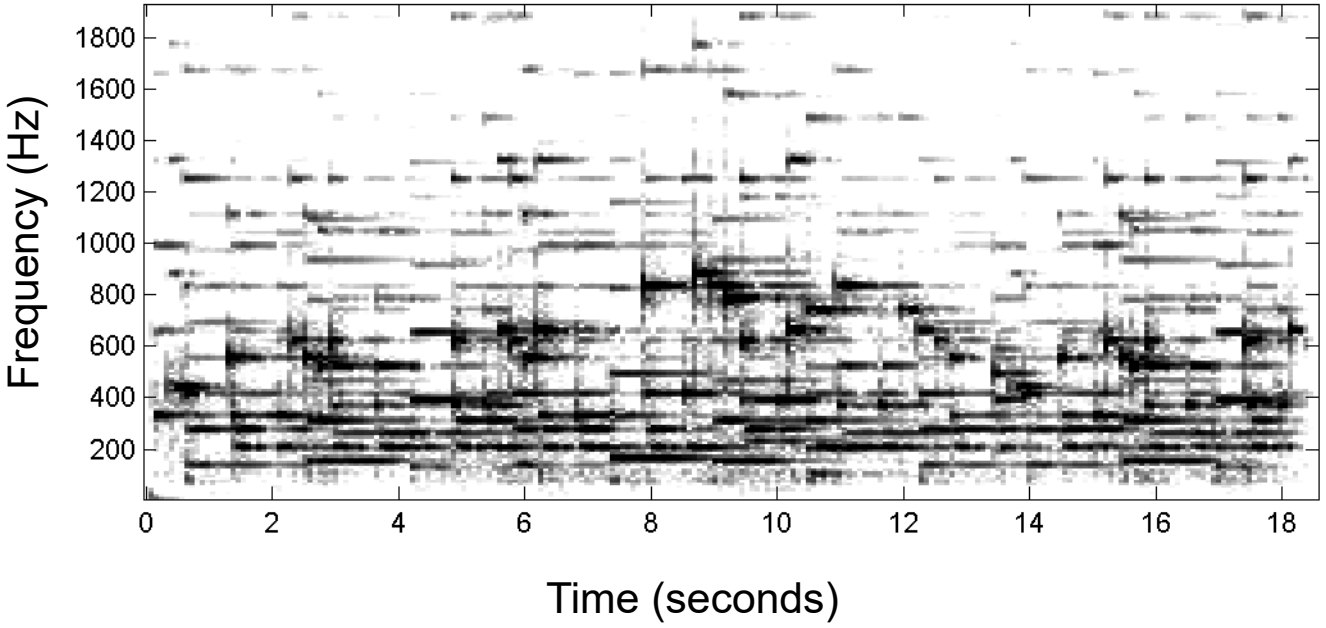
- Waveform



Why is Music Processing Challenging?

Example: Chopin, Mazurka Op. 63 No. 3

- Waveform / Spectrogram



Why is Music Processing Challenging?

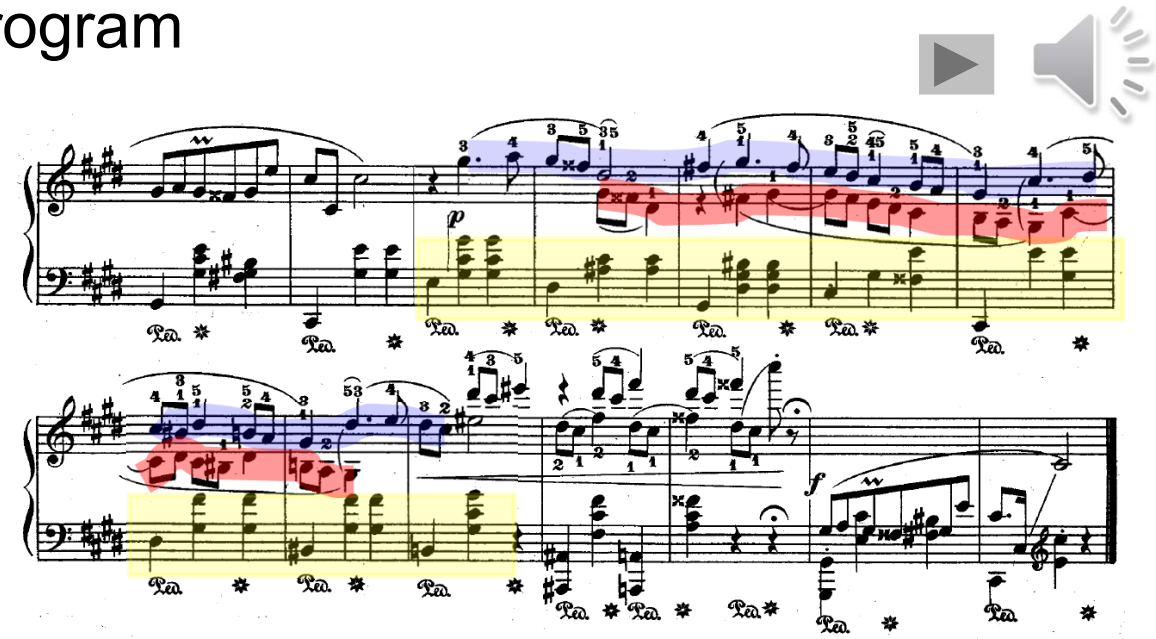
Example: Chopin, Mazurka Op. 63 No. 3

- Waveform / Spectrogram
- Performance
  - Tempo
  - Dynamics
  - Note deviations
  - Sustain pedal

Why is Music Processing Challenging?

Example: Chopin, Mazurka Op. 63 No. 3

- Waveform / Spectrogram
- Performance
  - Tempo
  - Dynamics
  - Note deviations
  - Sustain pedal
- Polyphony



Main Melody

Additional melody line

Accompaniment

Source Separation

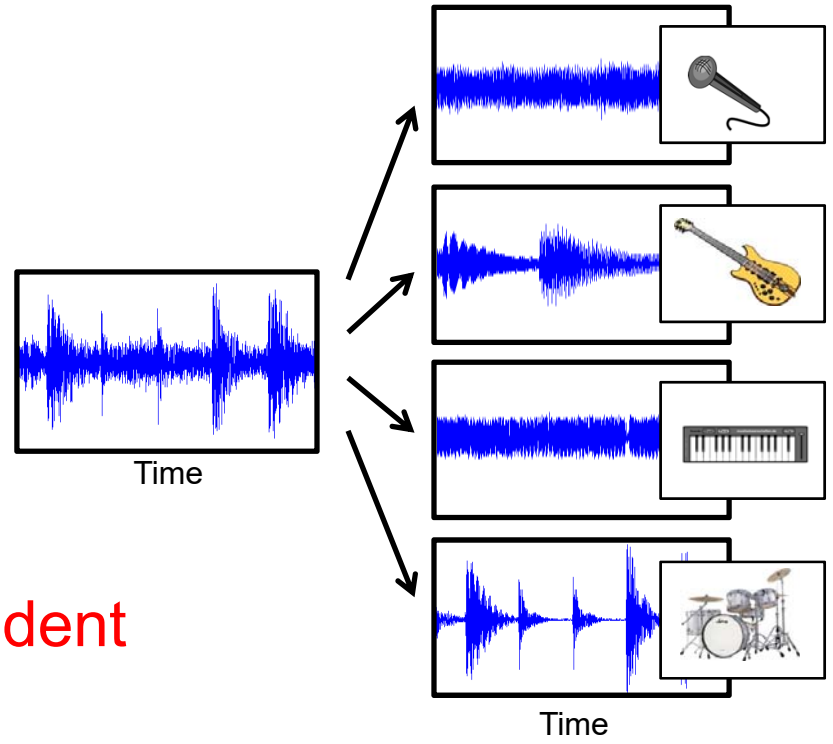
- Decomposition of audio stream into different sound sources
- Central task in digital signal processing
- “Cocktail party effect”

Source Separation

- Decomposition of audio stream into different sound sources
- Central task in digital signal processing
- “Cocktail party effect”
- Several input signals
- Sources are assumed to be statistically independent

Source Separation (Music)

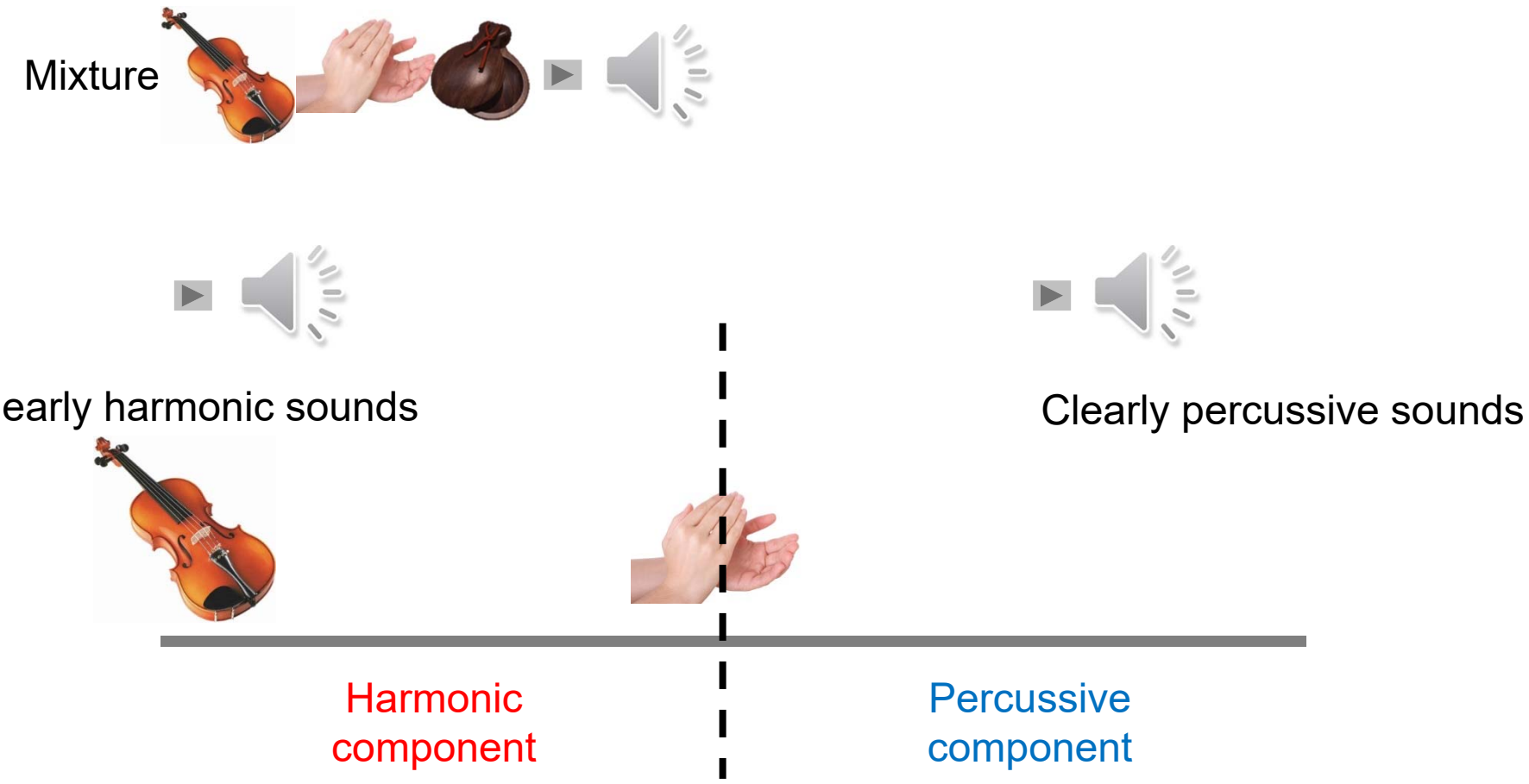
- Main melody, accompaniment, drum track
- Instrumental voices
- Individual note events
- Only mono or stereo
- Sources are often highly dependent



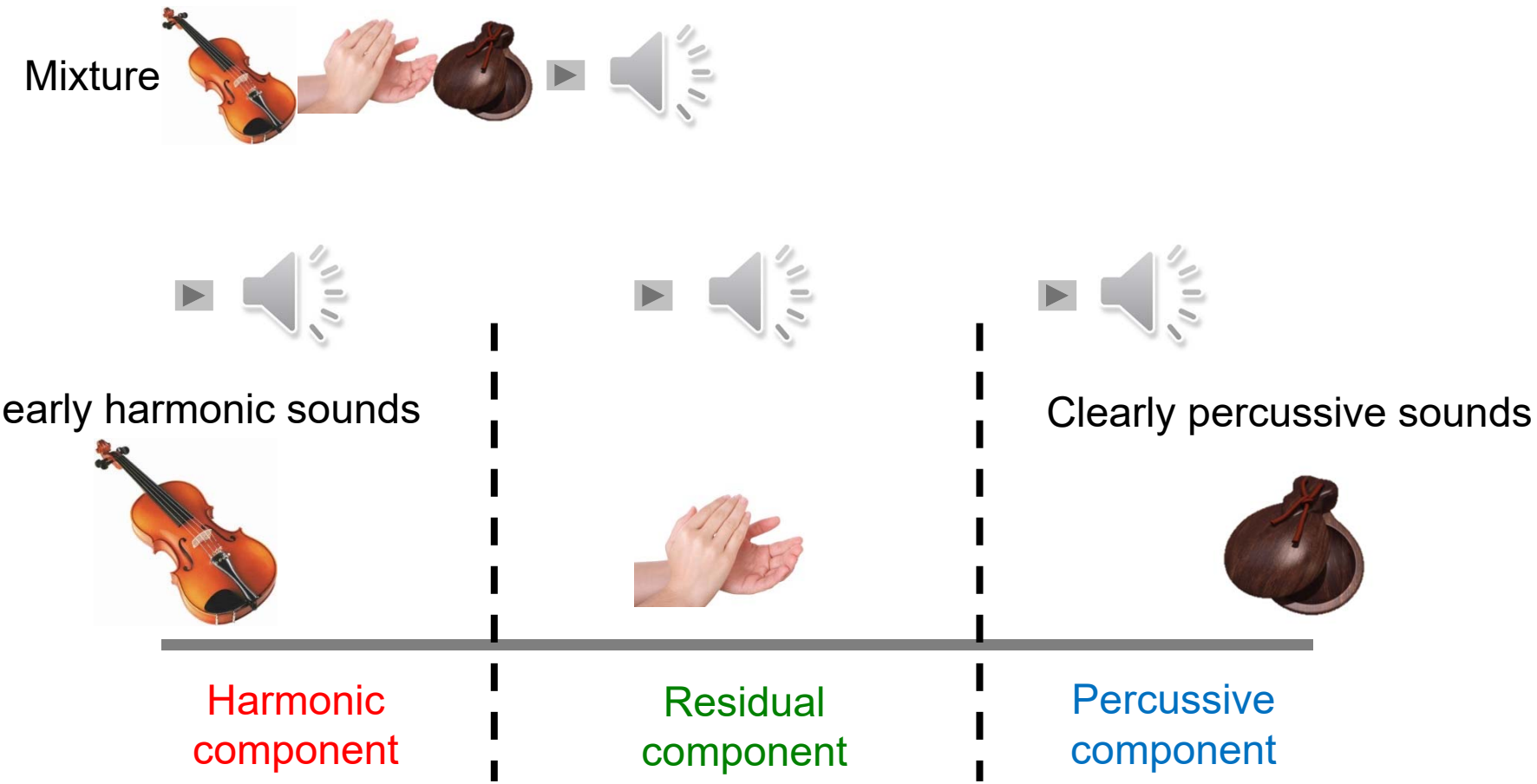
Harmonic-Percussive Decomposition

Mixture 

Harmonic-Percussive Decomposition

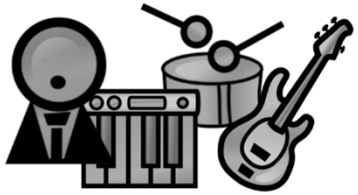


Harmonic-Percussive Decomposition



Harmonic-Percussive Decomposition

Mixture:



- Clearly harmonic sounds of singing voice and accompaniment

- Noise-like sounds
- Vibrato/glissando sounds

- Drum hits
- Fricatives & plosives in singing voice

Harmonic component

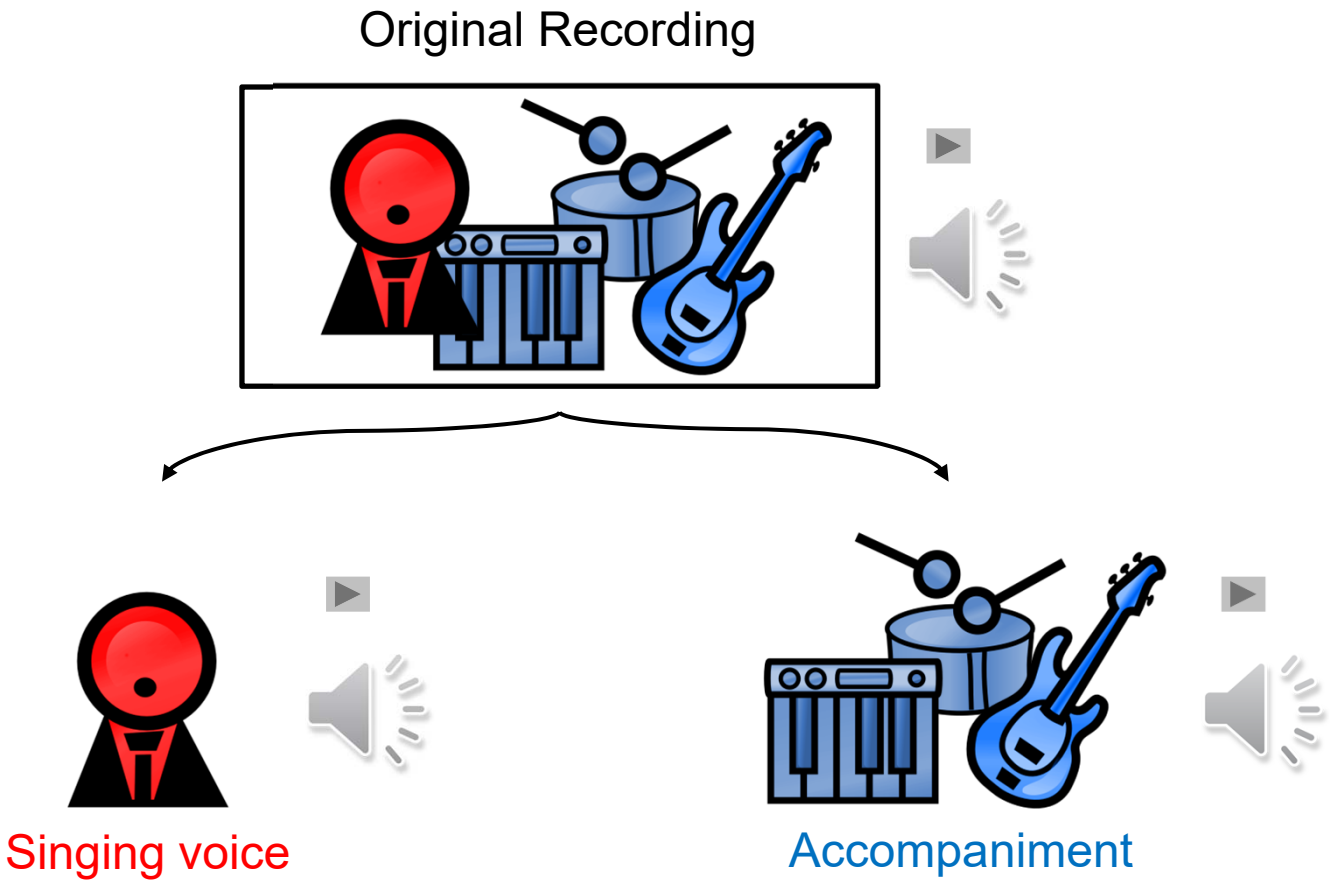
Residual component

Percussive component

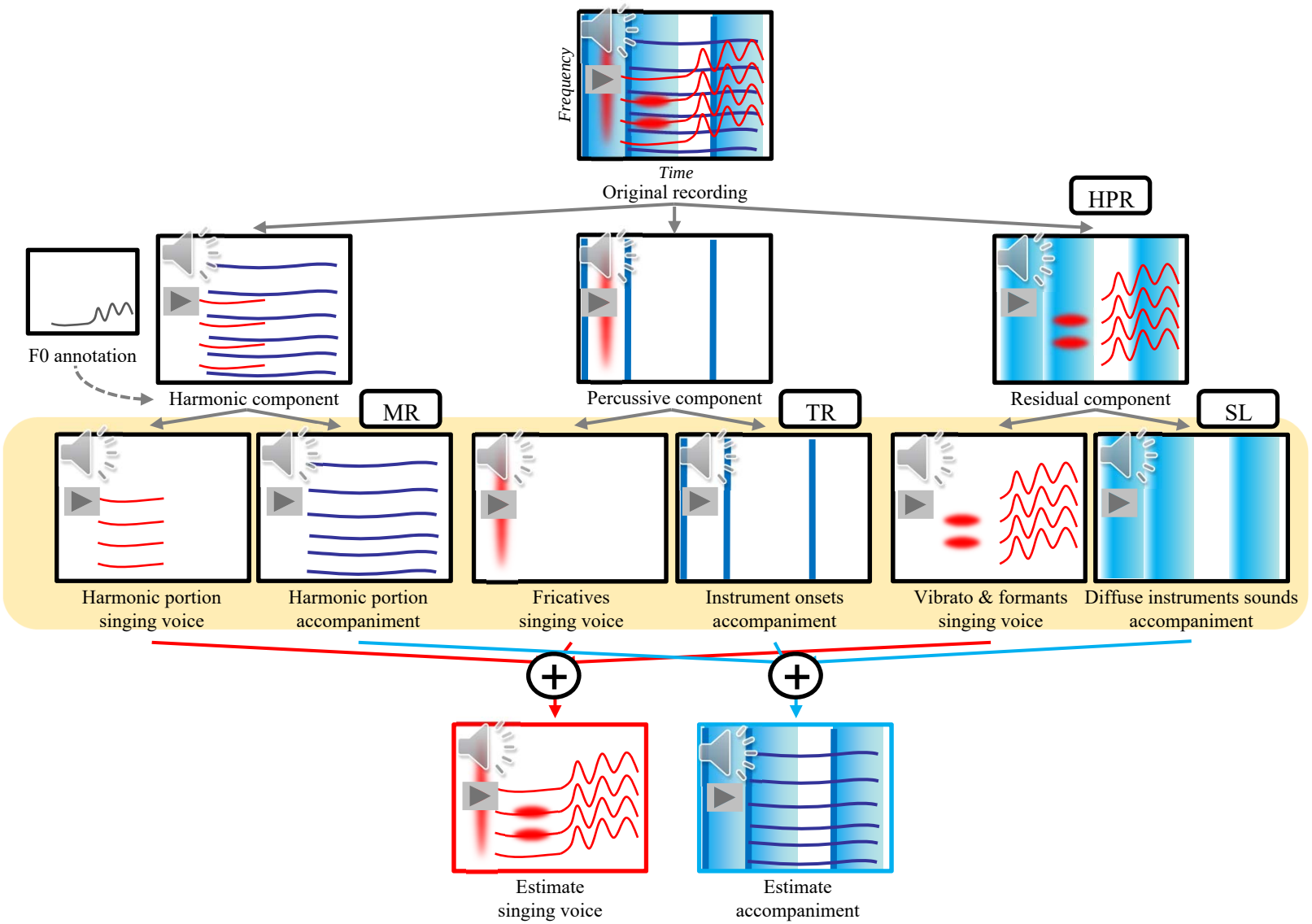
Literature: [Driedger/Müller/Disch, ISMIR 2014]

Demo: https://www.audiolabs-erlangen.de/resources/2014-ISMIR-ExtHPSep/

Singing Voice Extraction

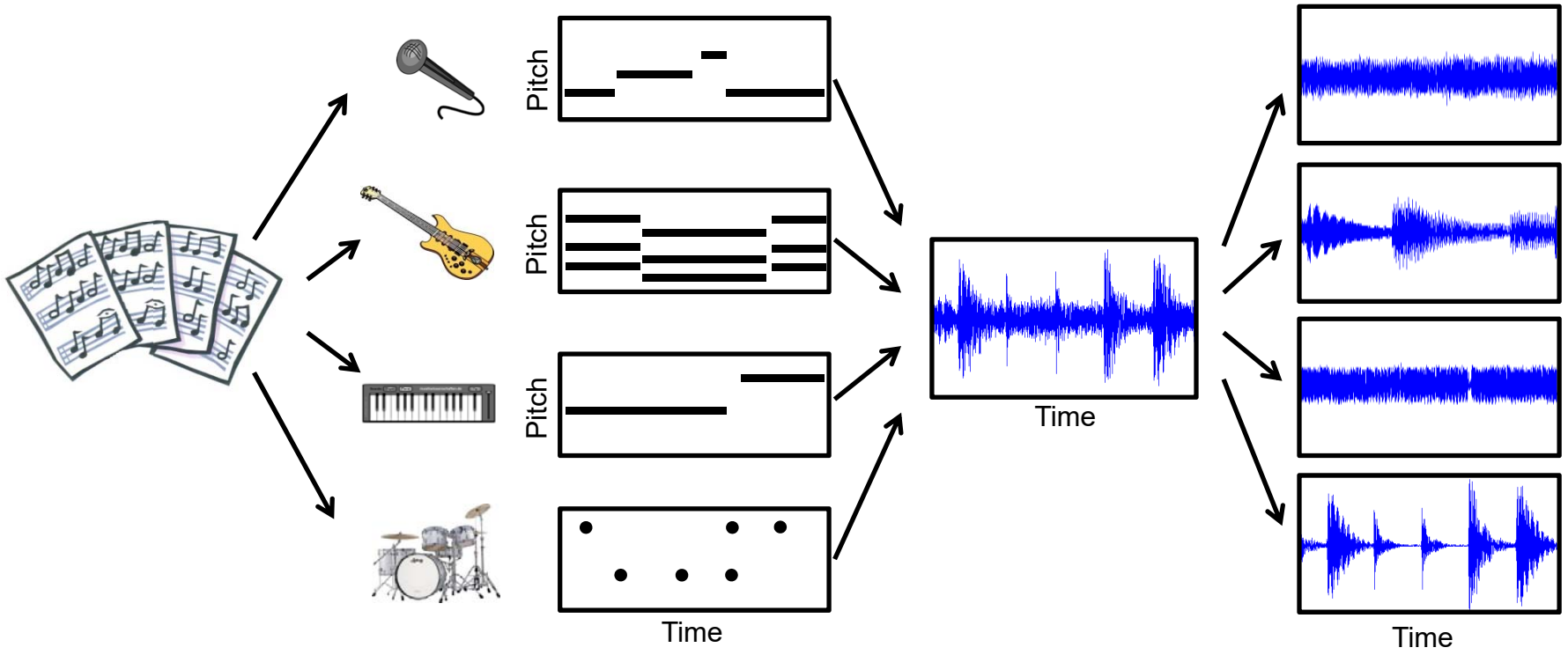


Singing Voice Extraction



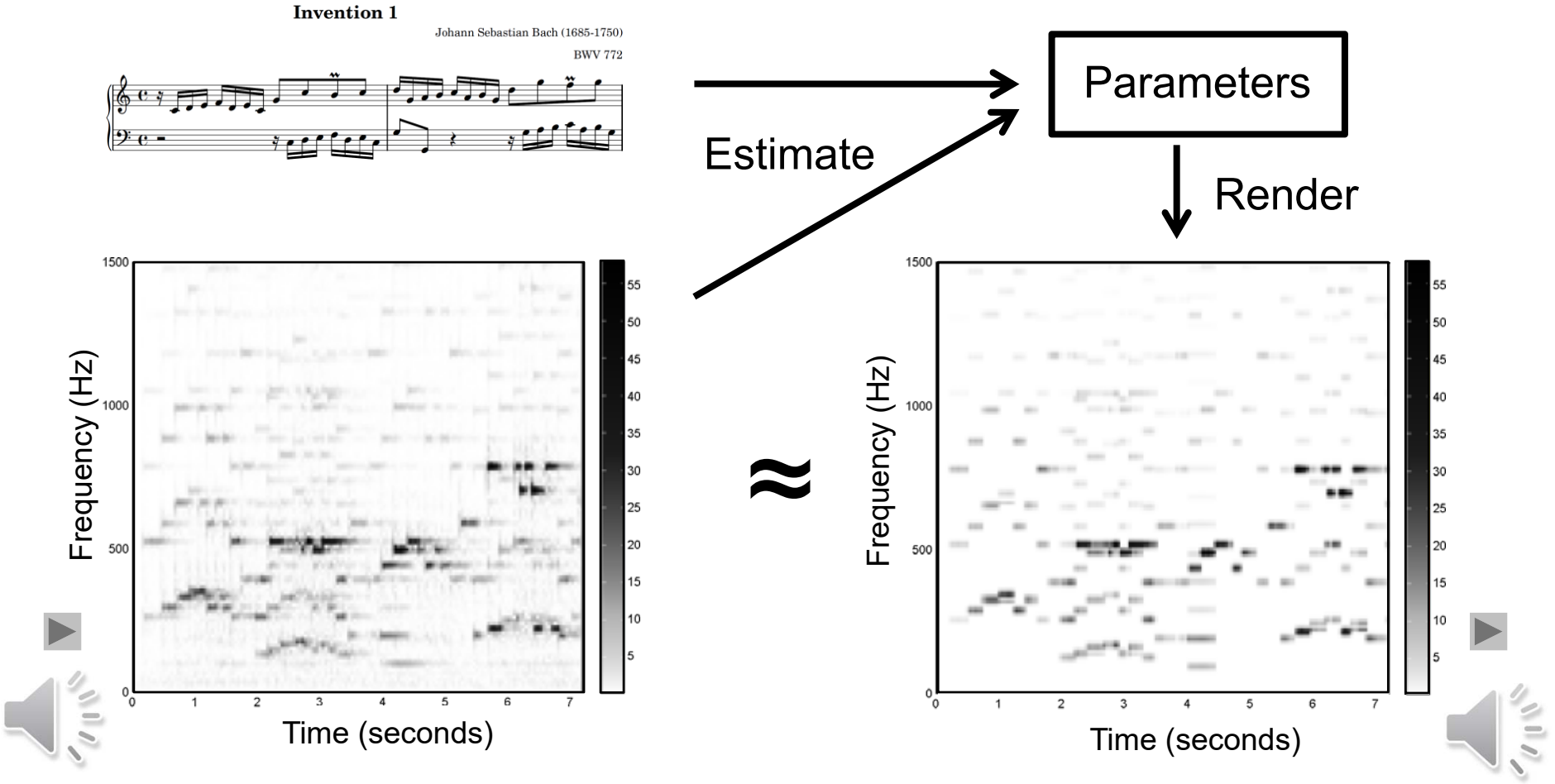
Score-Informed Source Separation

Exploit musical score to support separation process

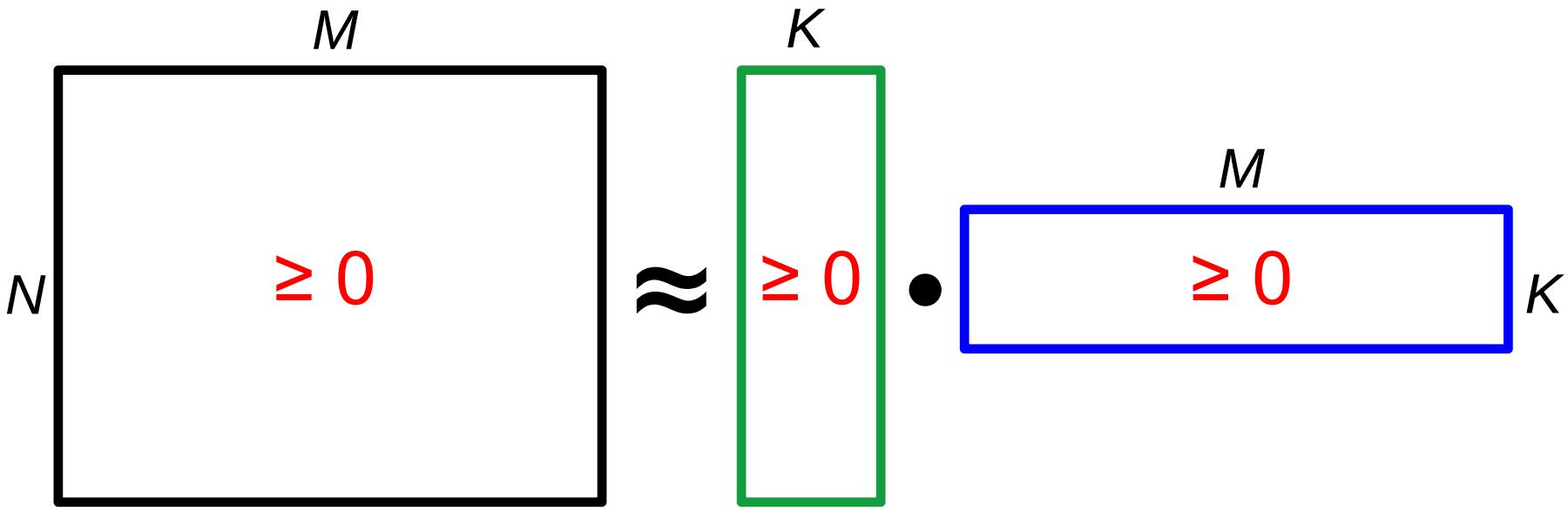


Parametric Model Approach

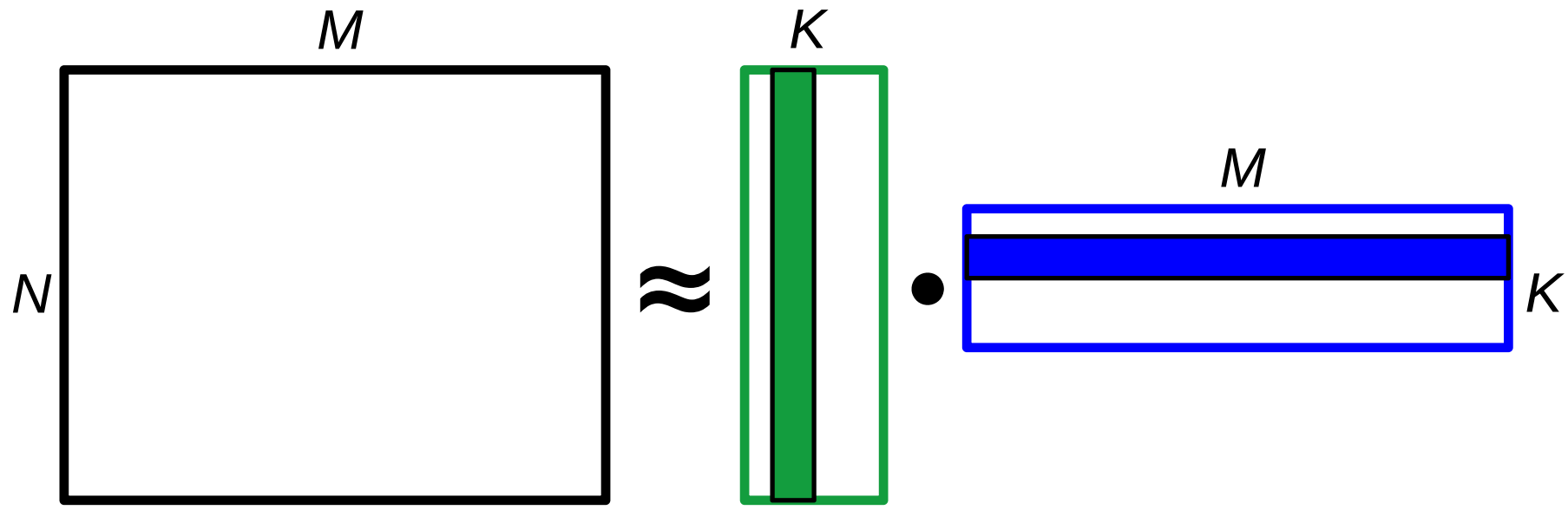
Rebuild spectrogram information



NMF (Nonnegative Matrix Factorization)



NMF (Nonnegative Matrix Factorization)

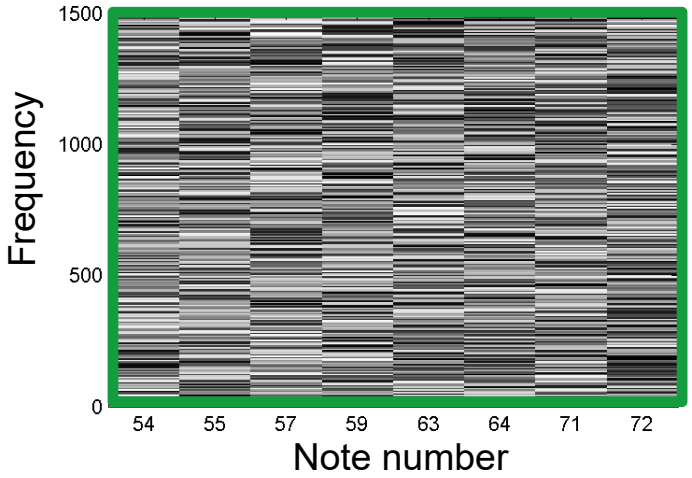


Templates: Pitch + Timbre — "How does it sound"

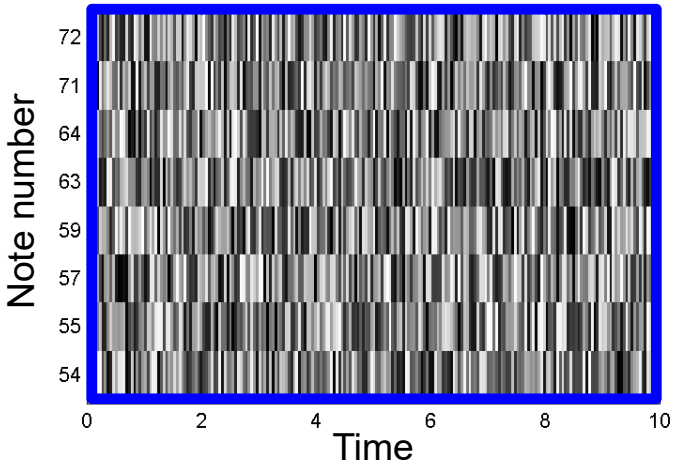
Activations: Onset time + Duration — "When does it sound"

NMF-Decomposition

Initialized template



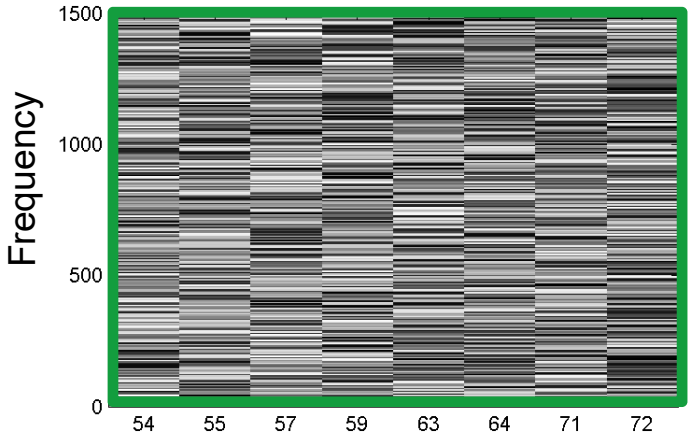
Initialized activations



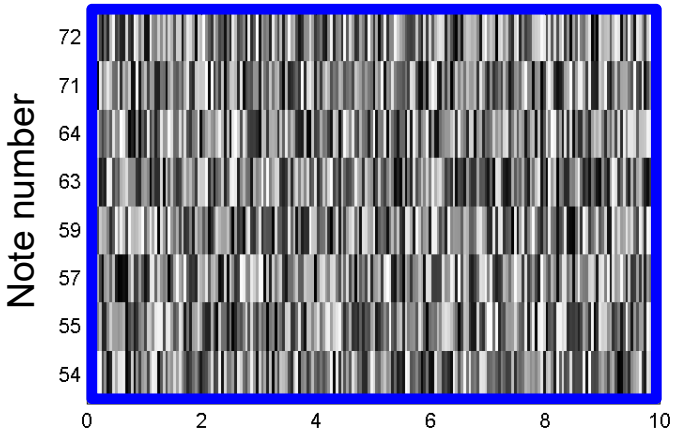
Random initialization

NMF-Decomposition

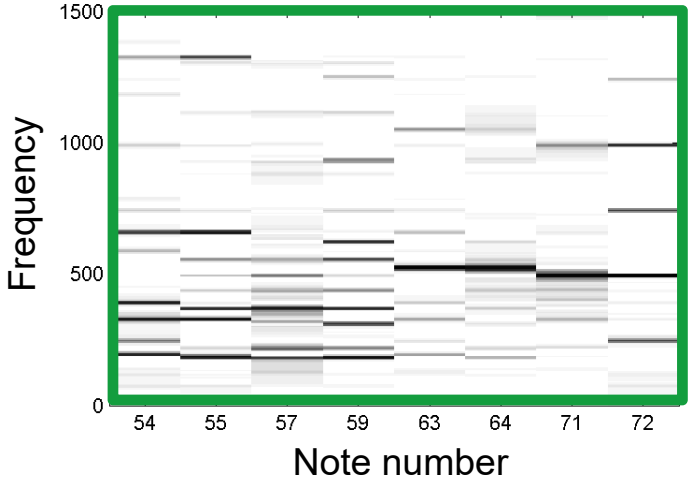
Initialized template



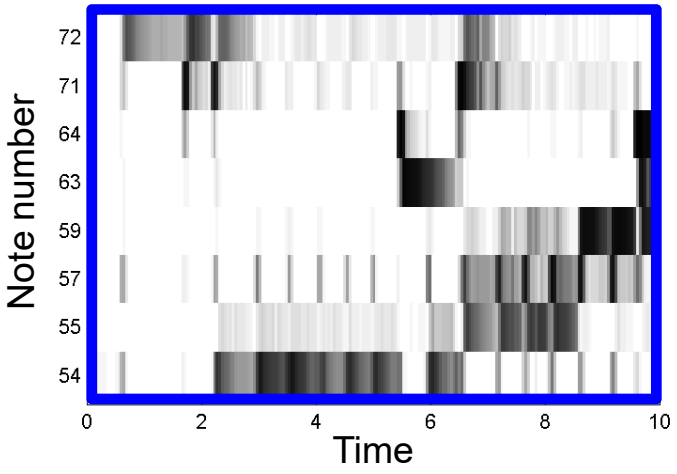
Initialized activations



Learnt templates



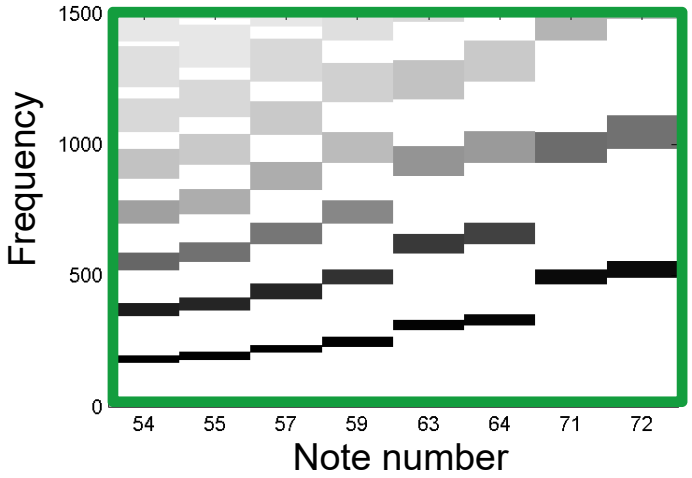
Learnt activations



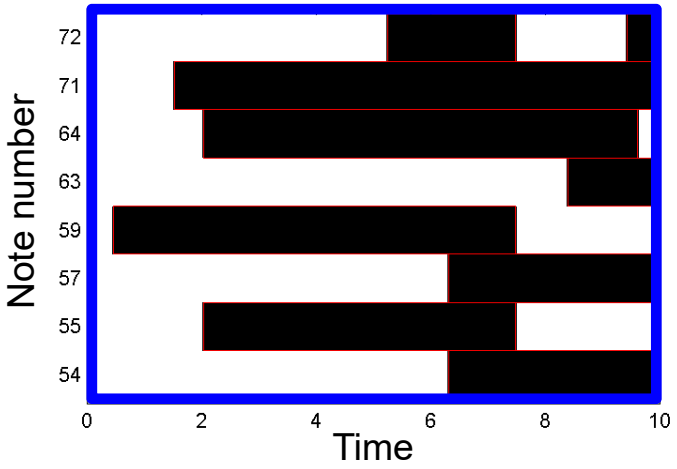
Random initialization → No semantic meaning

NMF-Decomposition

Initialized template



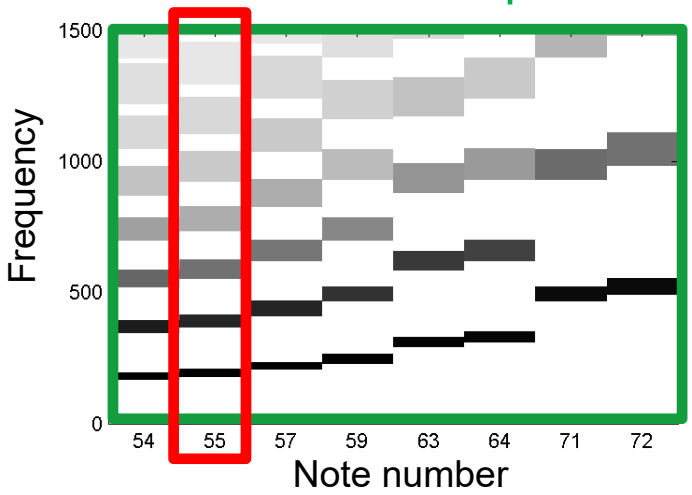
Initialized activations



Constrained initialization

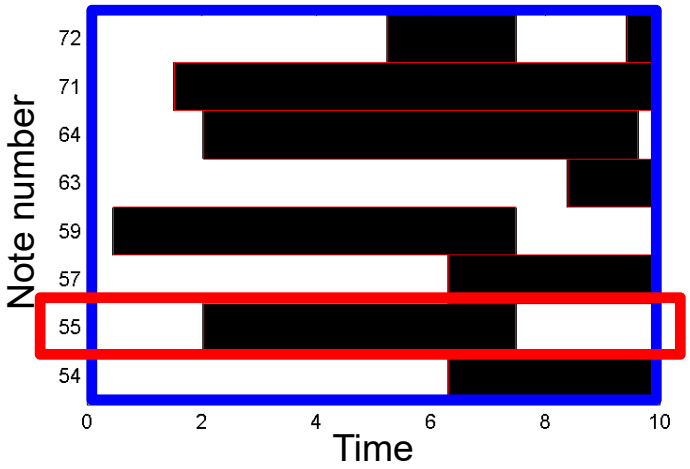
NMF-Decomposition

Initialized template



Template constraint for p=55

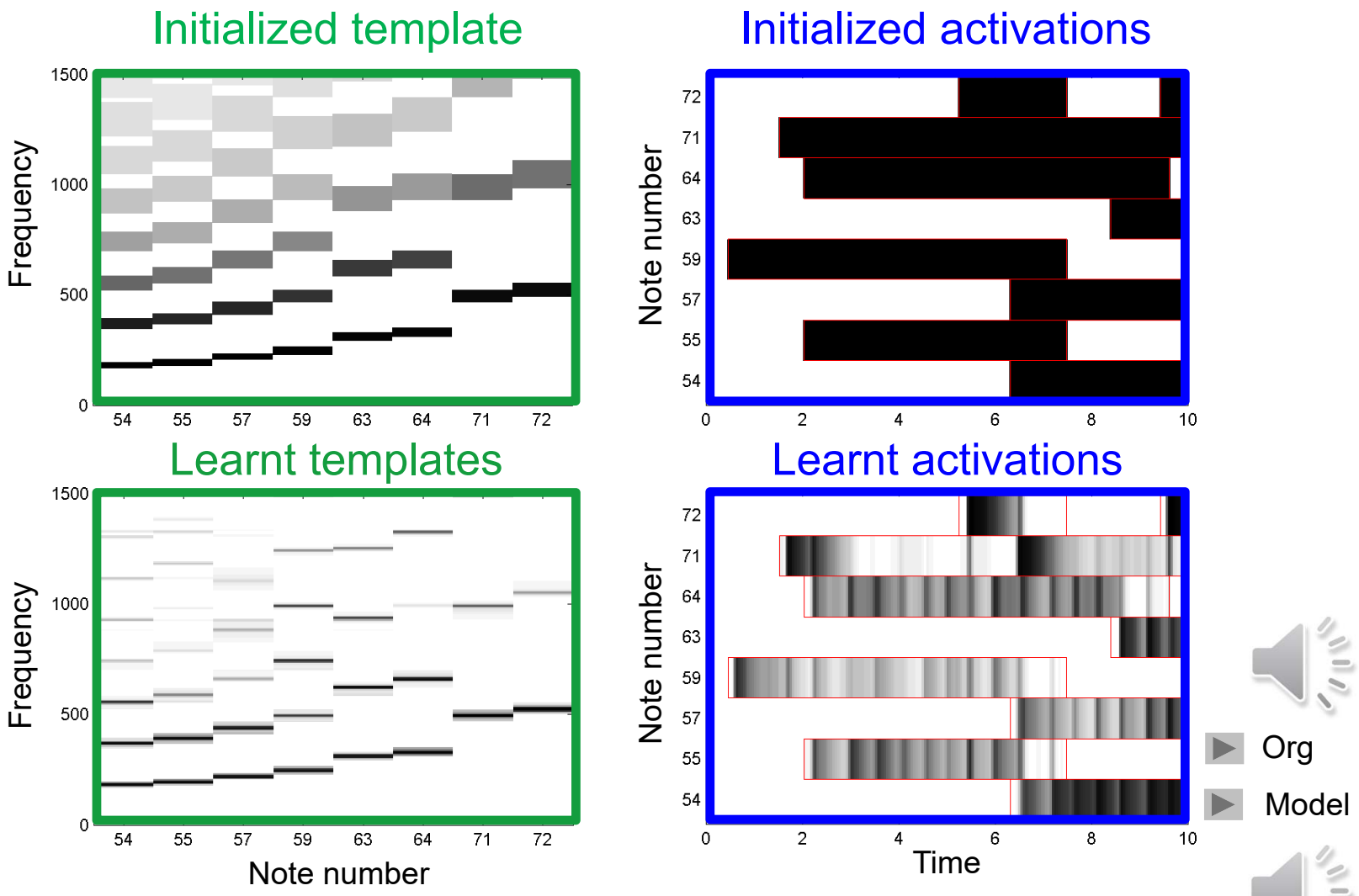
Initialized activations



Activation constraints for p=55

Constrained initialization

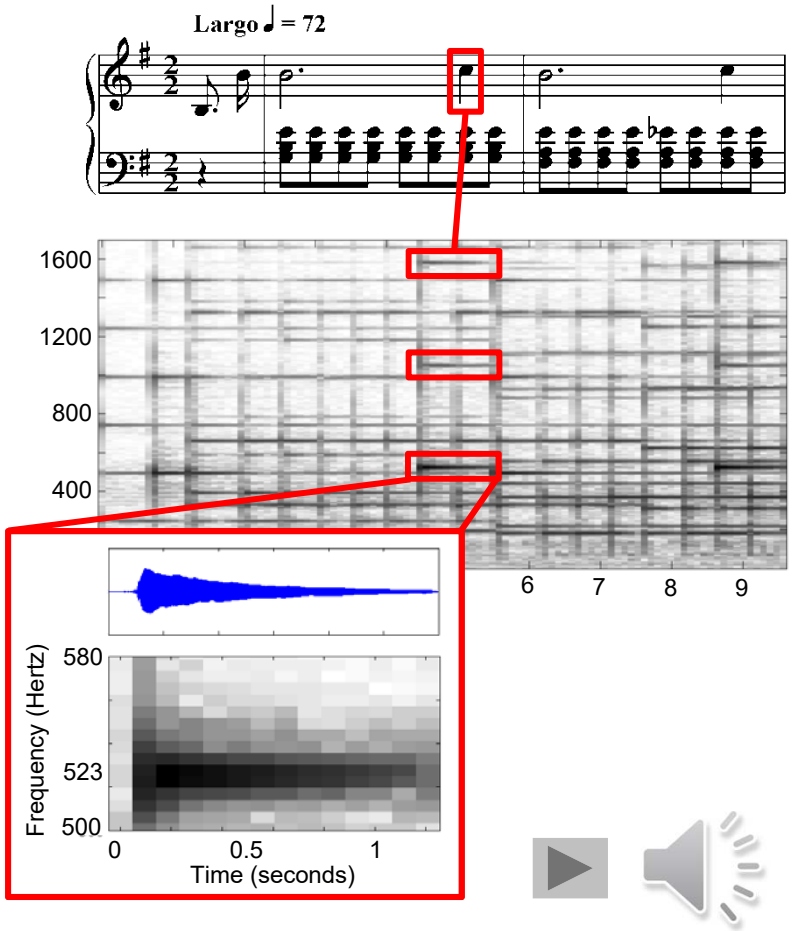
NMF-Decomposition

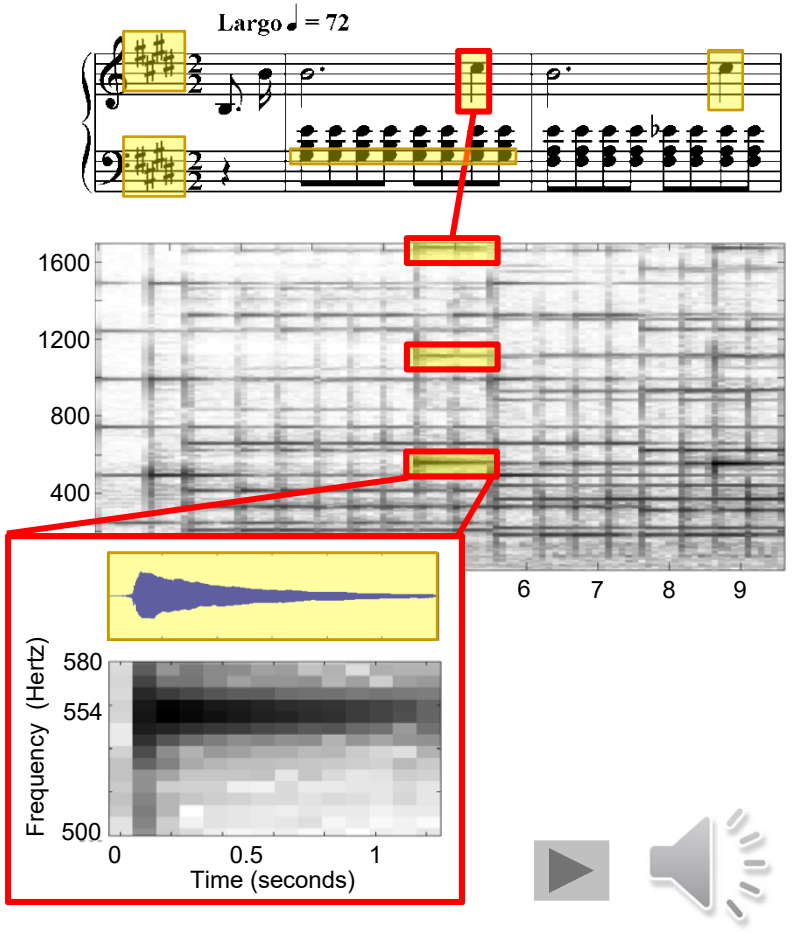


Constrained initialization → NMF as refinement

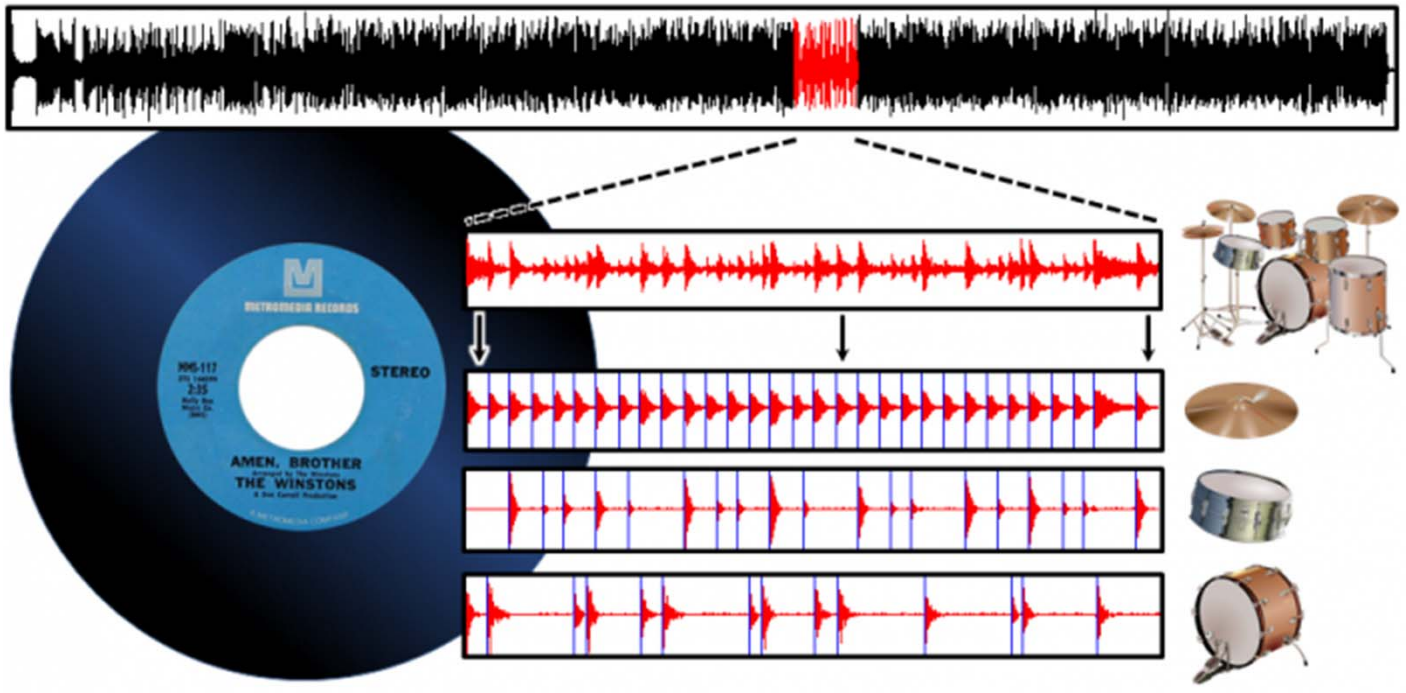
Score-Informed Audio Decomposition

Application: Audio editing





Informed Drum-Sound Decomposition

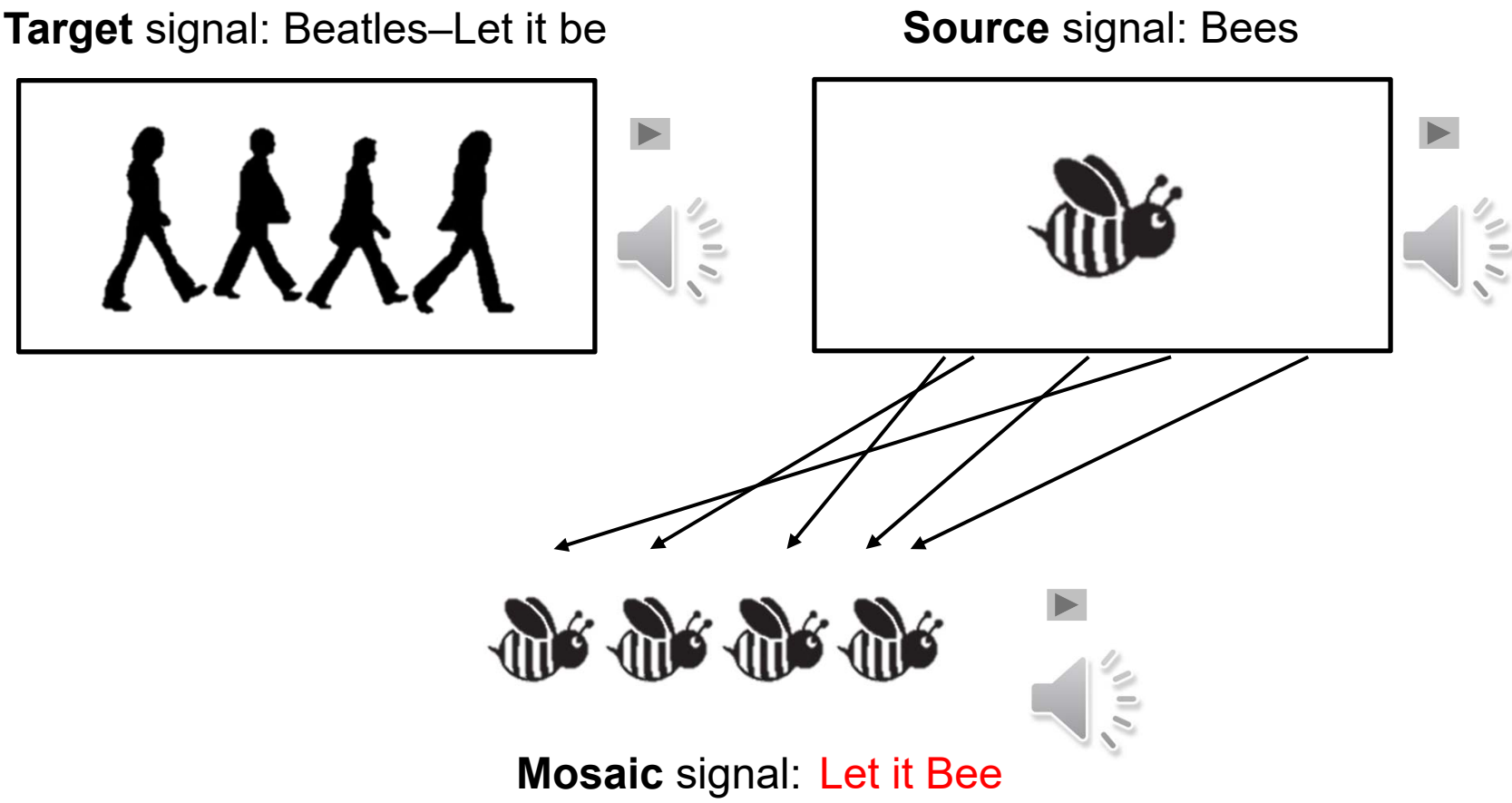


Remix:

Literature: [Dittmar/Müller, IEEE/ACM-TASLP 2016]

Demo: https://www.audiolabs-erlangen.de/resources/MIR/2016-IEEE-TASLP-DrumSeparation

Audio Mosaicing

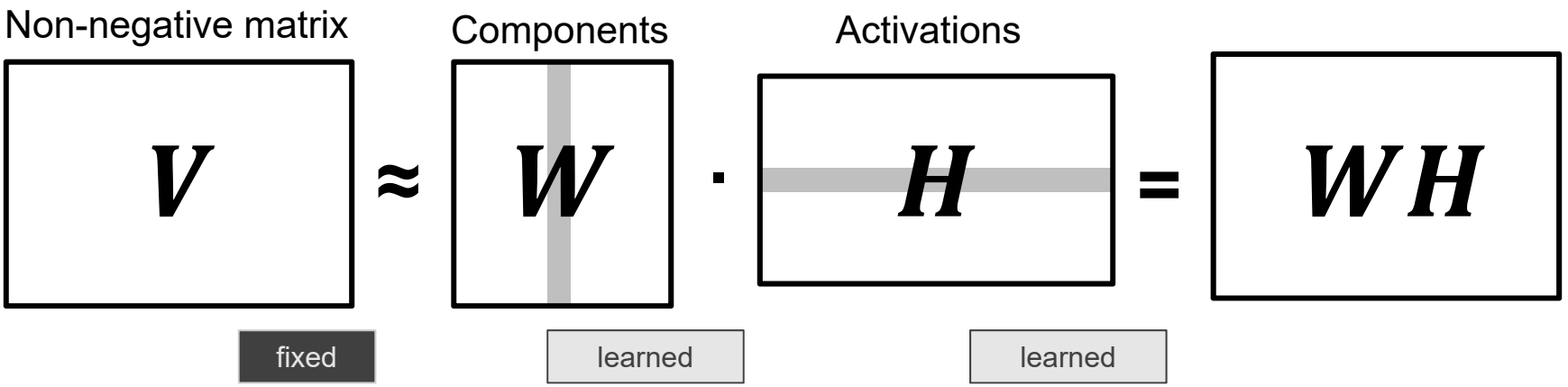


Literature: [Driedger/Müller, ISMIR 2015]

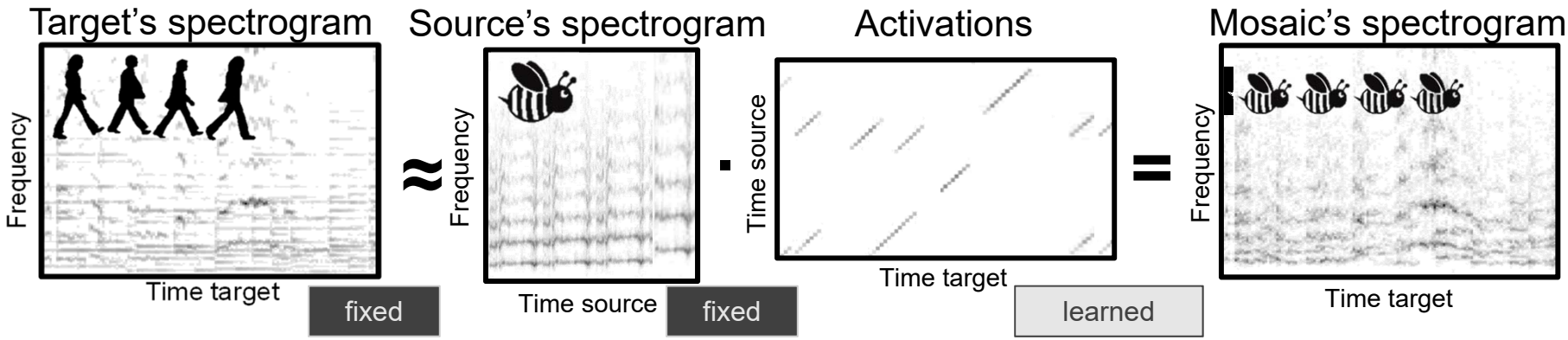
Demo: https://www.audiolabs-erlangen.de/resources/MIR/2015-ISMIR-LetItBee

NMF-Inspired Audio Mosaicing

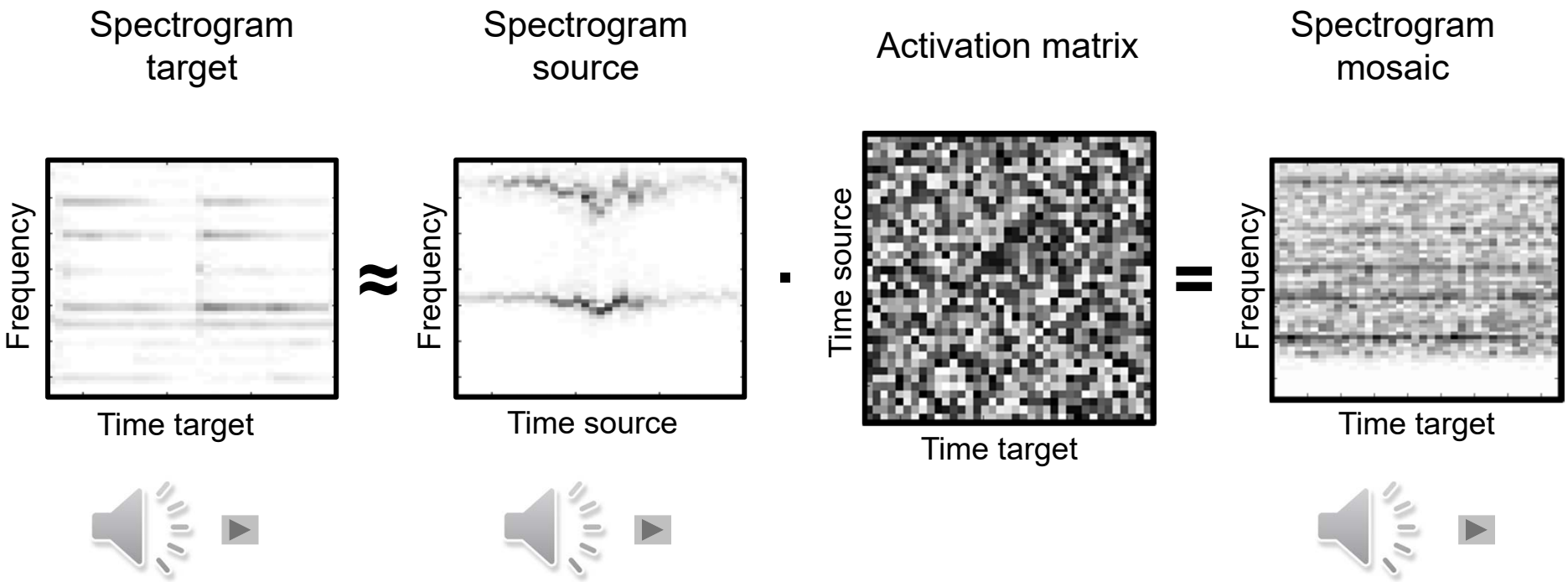
Non-negative matrix factorization (NMF)



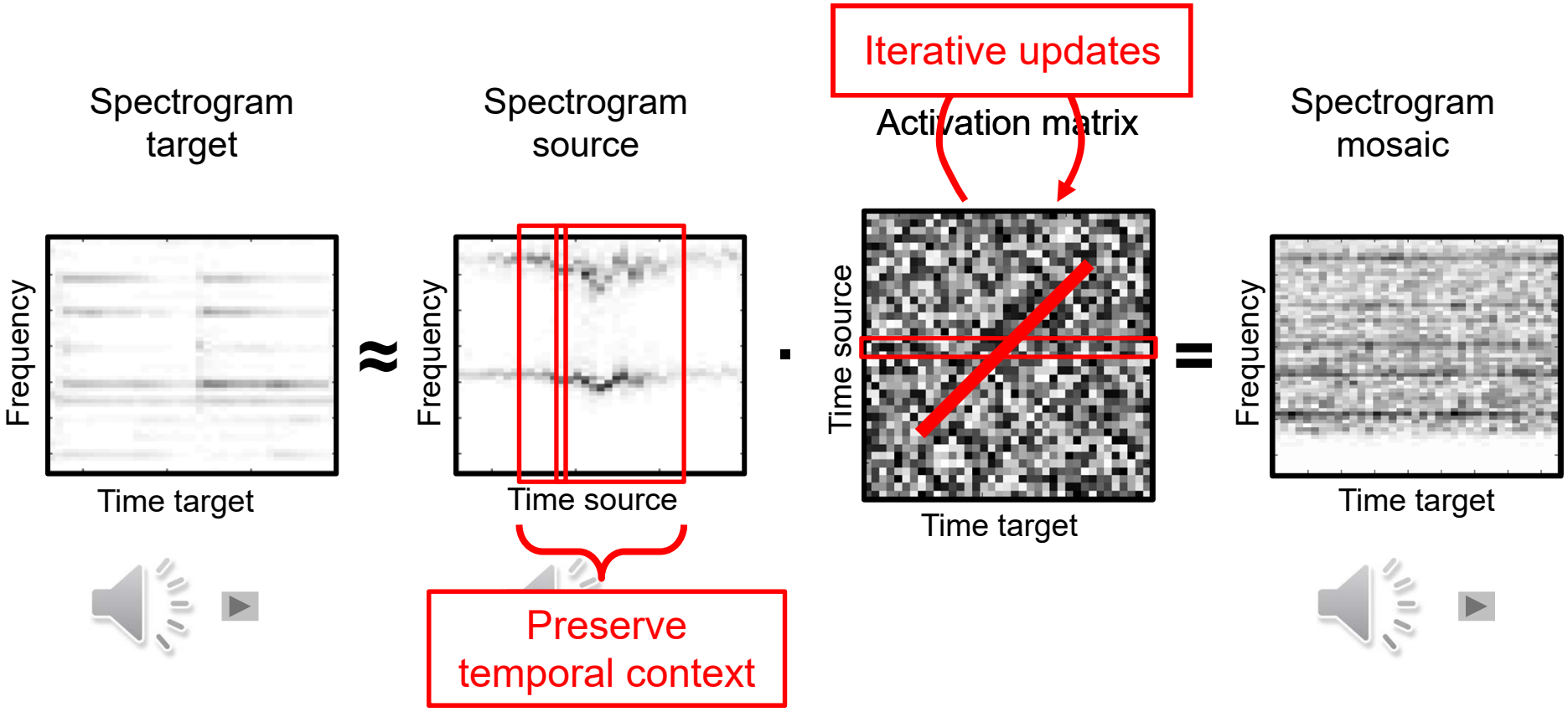
Proposed audio mosaicing approach



NMF-Inspired Audio Mosaicing

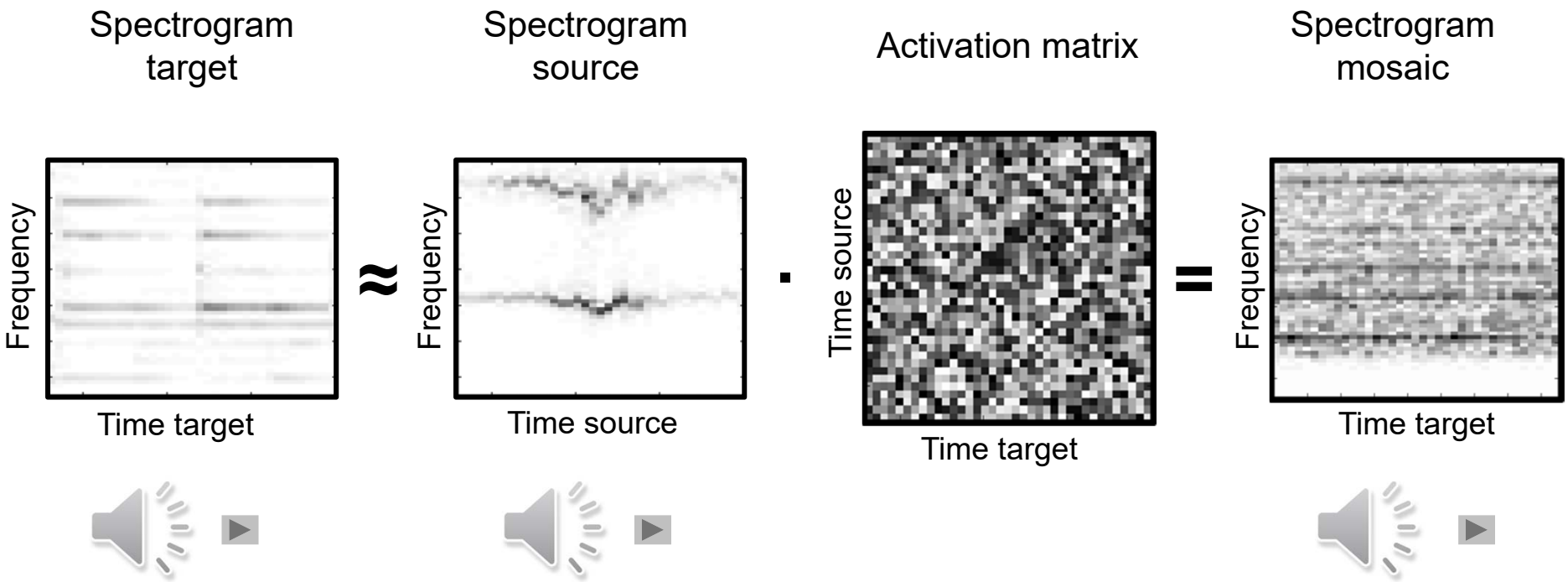


NMF-Inspired Audio Mosaicing

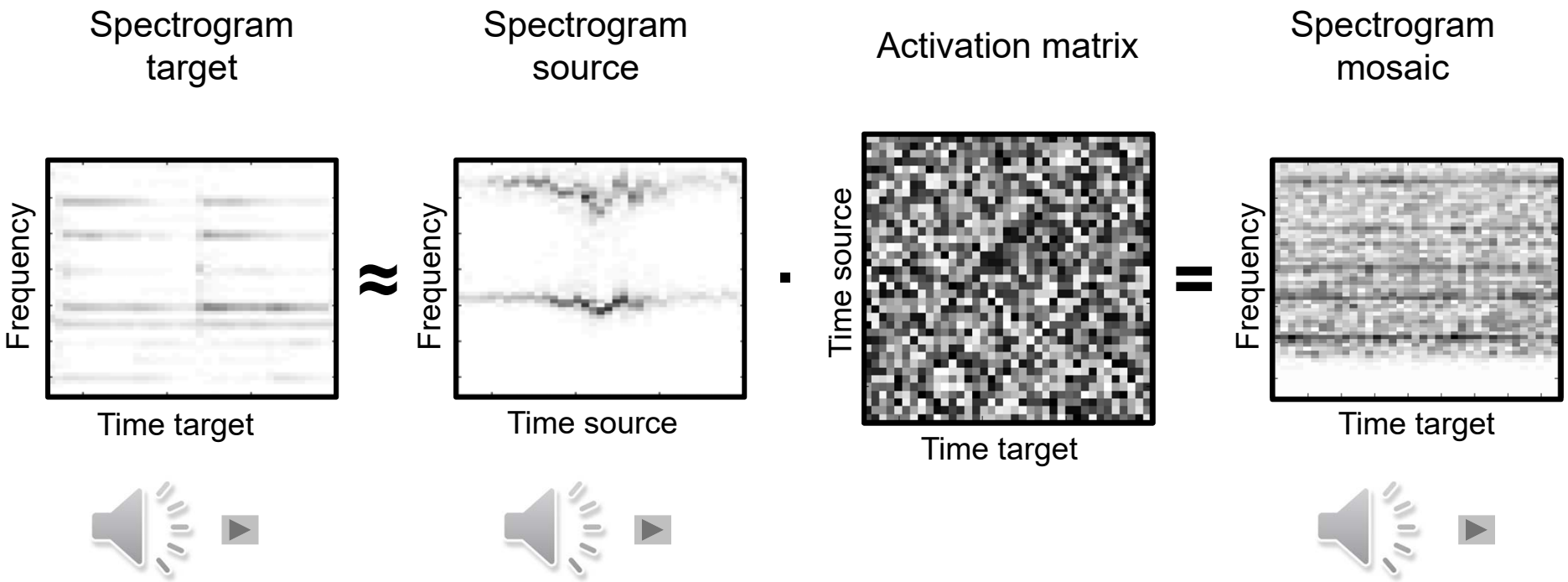


Core idea: support the development of sparse diagonal activation structures

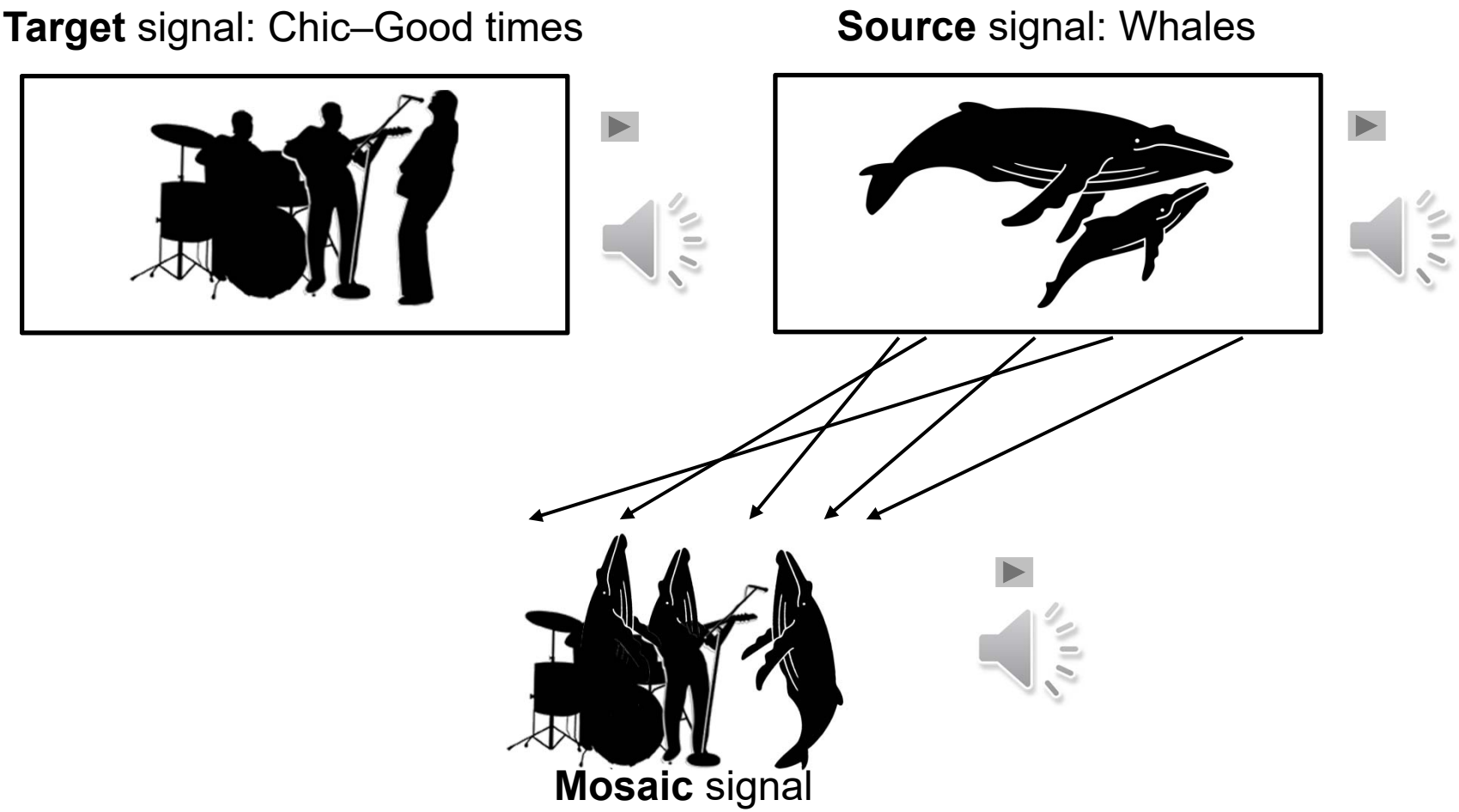
NMF-Inspired Audio Mosaicing



NMF-Inspired Audio Mosaicing



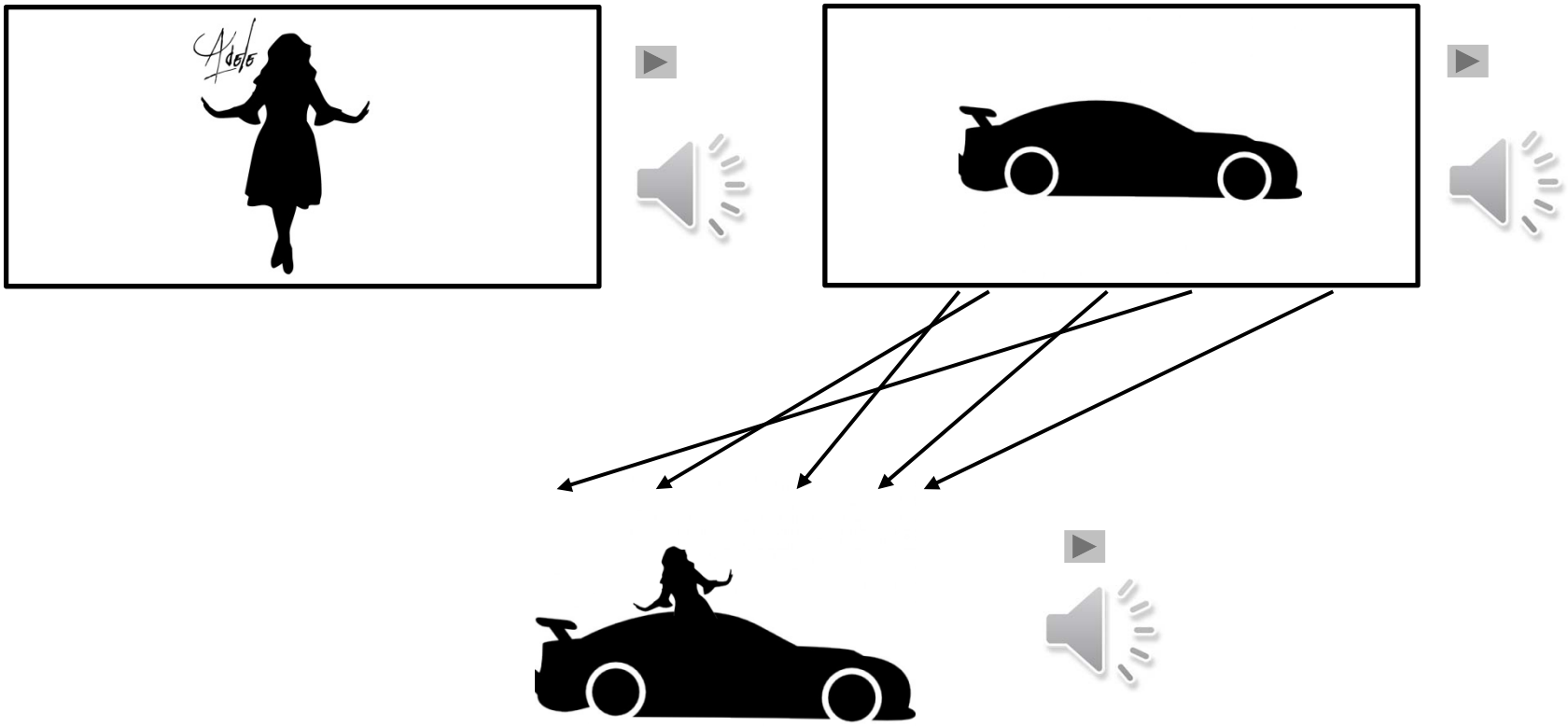
Audio Mosaicing



Audio Mosaicing

Target signal: Adele–Rolling in the Deep

Source signal: Race car



Mosaic signal

Links

- SiSEC: Signal Separation Evaluation Campaign
  https://www.sisec17.audiolabs-erlangen.de/
- MedleyDB: A Dataset of Multitrack Audio
  http://steinhardt.nyu.edu/marl/research/medleydb
- LibROSA (Python)
  https://librosa.github.io/librosa/