Fundamental Frequency Estimation in Music Tutorial

Part 3: Applications

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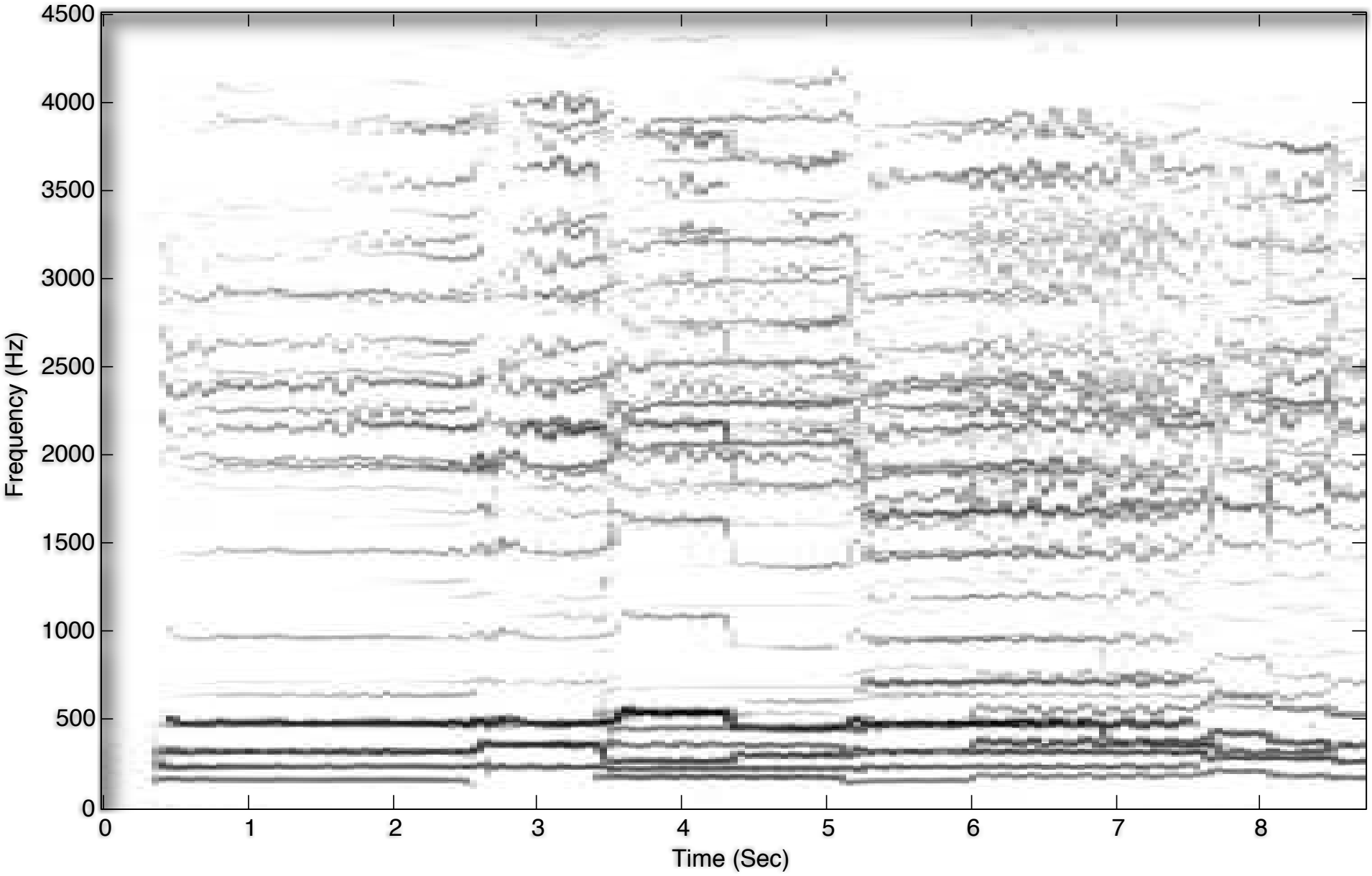
4500
4000
3500
3000
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Frequency (Hz)
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1
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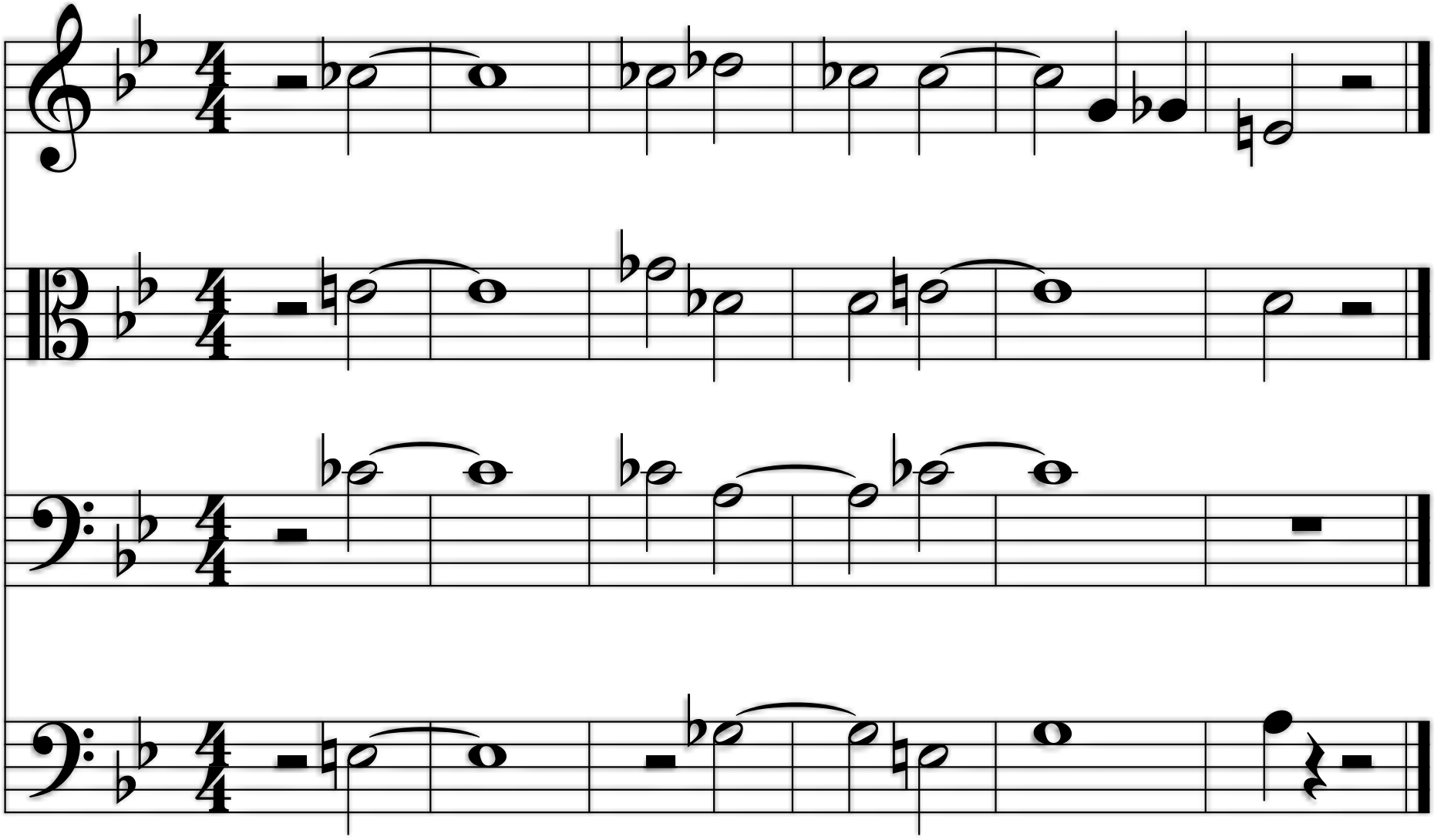
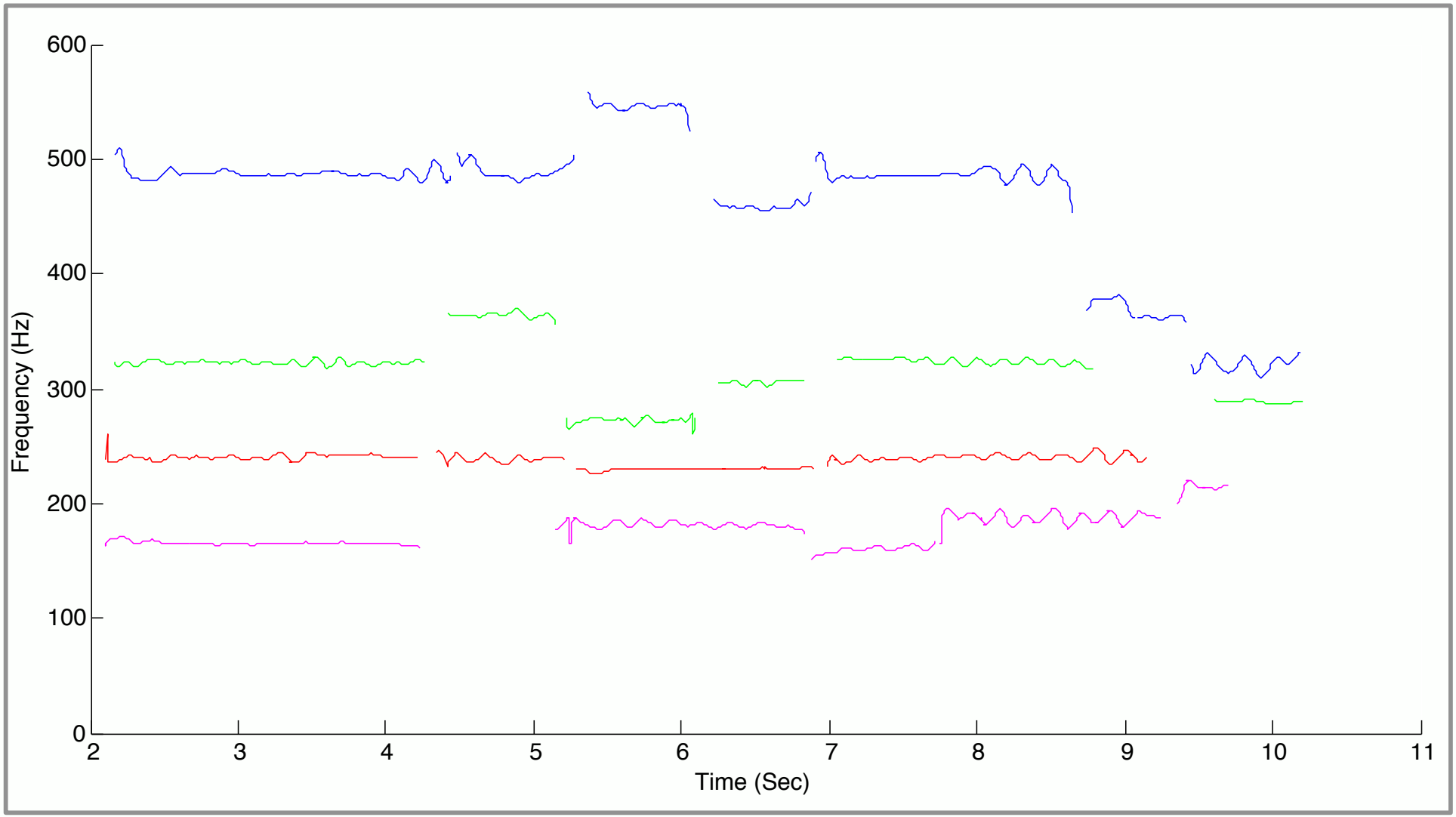
Time (Sec)

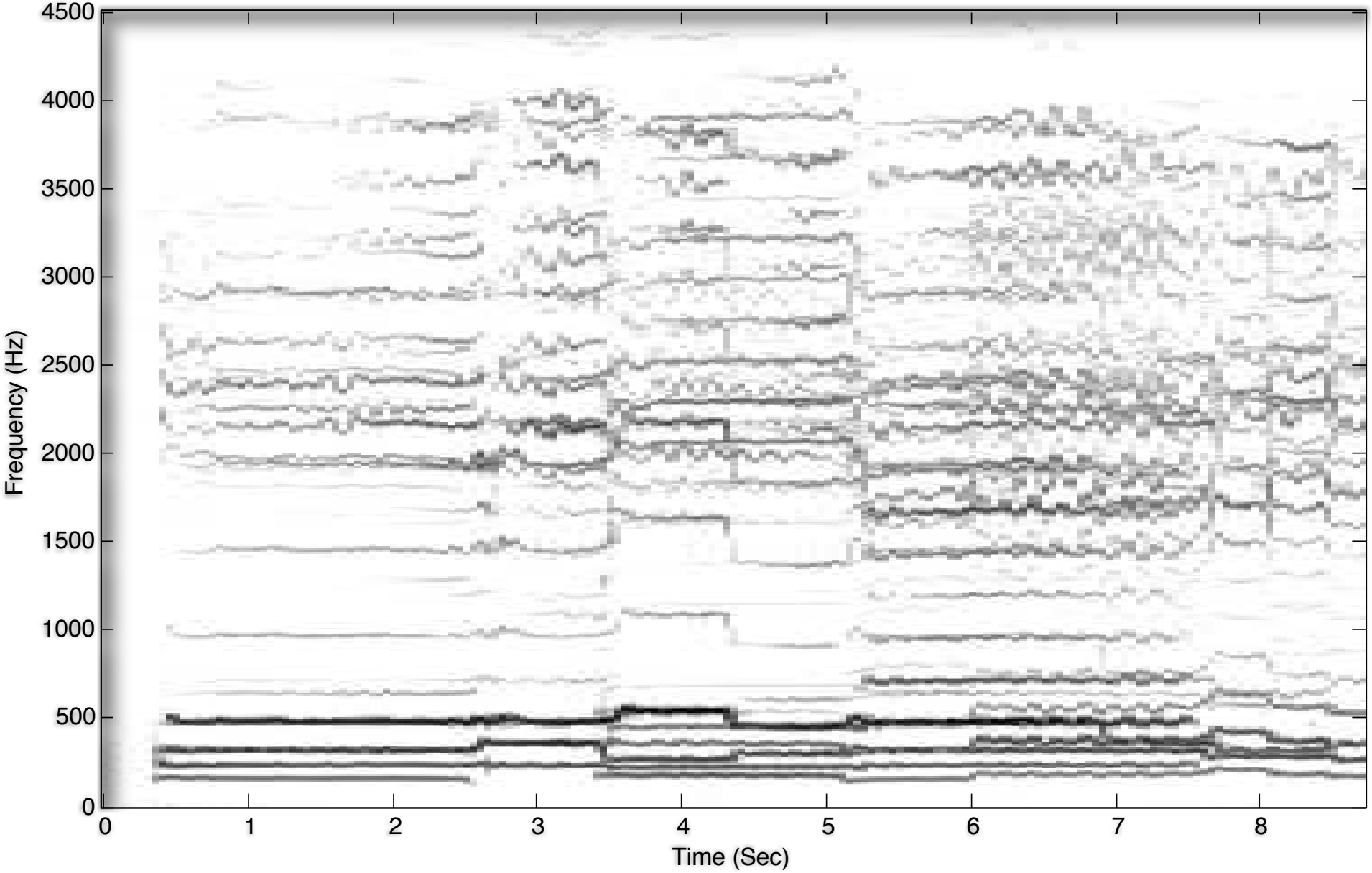
Music Transcription



F_0 Trajectories



Source Separation



Transcription

Automatic Music Transcription

- **Automatic music transcription aims to mimic musicians' ability to transcribe audio into a notated score**
- **multiple f_0 detection is only one subtask of automatic music transcription**
  - Other tasks include (Benetos et al. 2013):
    - note onset/offset detection
    - extraction of rhythmic information and time quantization
    - loudness estimation and quantization
    - instrument recognition

Transcription

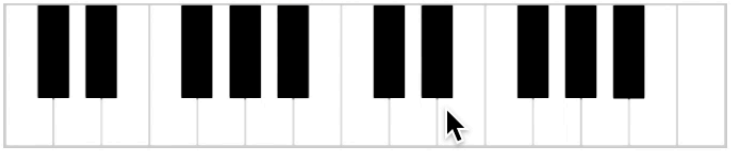
Searching Musical Data

- **Full transcription would allow for audio files to be indexed and searched in a manner similar to musical scores**
- **e.g., an audio version of PeachNote's N-Gram viewer (Viro 2011), which allows users to search for melodies or chords in a number of music libraries**
  - including Petrucci (which has over nearly 450,000 musical scores
  - compare this to Spotify's ~30 million audio tracks

Music Ngram Viewer

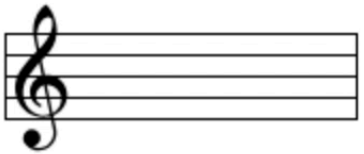
Tweet

Please enter a melody or a sequence of chords (advanced use)



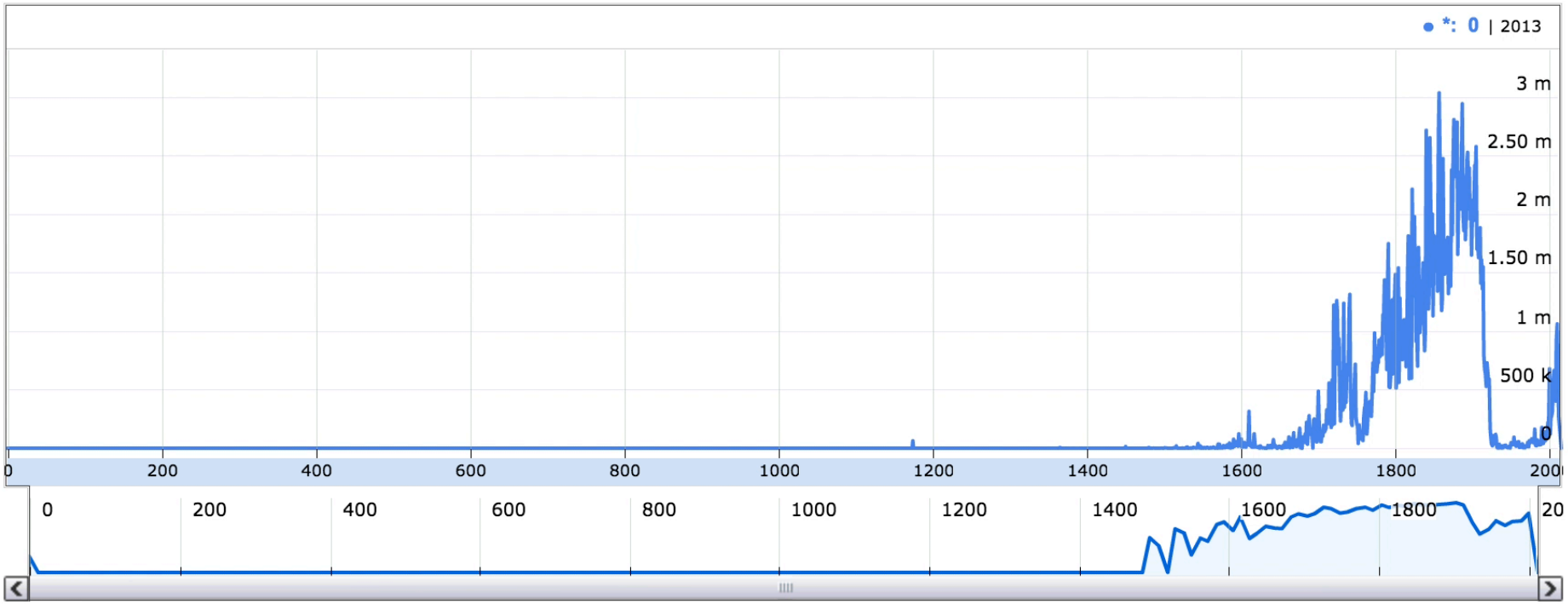
melody Search

Petrucci Music Library Smoothing: 0 Normalized



Keyboard shortcuts

Showing the number of notes indexed for each year.



Run your own experiment! Raw data is available for download here.

Feedback

Transcription

Similarity

- **Score-based similarity approaches are largely focused on Western music**
- **Audio-based methods have traditionally been based on timbral features rather than melody and harmony**
- **Audio-based data would allow for a wider range of musical languages to be modeled**

Source Separation

Interactive Music Systems

- **Improved score-following**
  - Single-instrument score-following is largely a solved problem which has produced usable products (e.g., Music Plus One and Metronaut by Antescofo)
  - Robust multiple f0 estimation could improve single-instrument following in multiple-instrument audio and multi-instrument following

Metronaut by Antescofo

Transcription

Musicology

- **Transcription facilitates the analysis of un-notated music**
  - Particularly music outside of the Western art music tradition
- **Long history of musicological score-based corpus studies that goes back to 1960s**
  - Current work is typically done in Humdrum or music21
  - Translating audio into score notation would allow musicologists to use existing tools for analysis

Introduction 1
Overview

Transcription-Related 2
Music Search, Music Similarity, Interactive Music Systems, Musicology

Performance-Related 3
Note-level Descriptors, Music Generation, Style Transfer

Source Separation-Related 4
Melody Estimation, Music Retrieval, Music Production

Conclusions 5
Summary

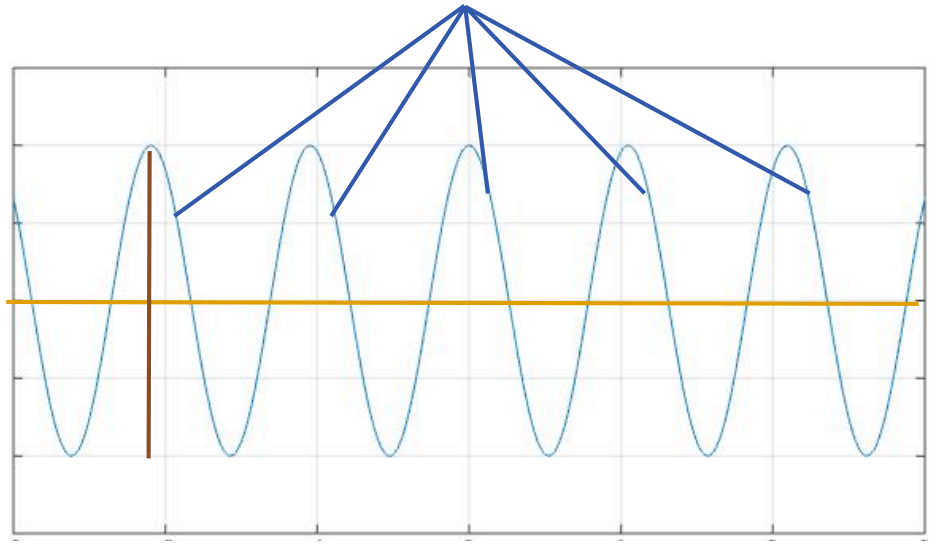
Performance

Note-level descriptors

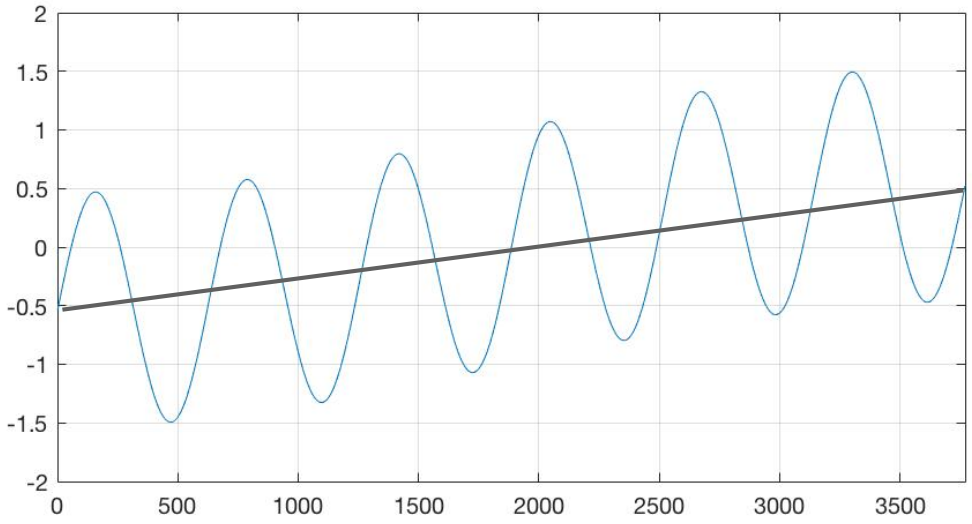
Perceived pitch

Vibrato Depth

Vibrato Rate



Slope



Performance

Note-level descriptors

- **Perceived Pitch**
  - Based on psychophysical testing
  - Simple mean, e.g., arithmetic or geometric (Shonle and Horan 1980)
  - Weighted mean, e.g., based on f_0 rate of change (Gockel et al. 2001)

Performance

Note-level descriptors

- **Vibrato**
  - Fitting a sinusoid to a normalized version of the f_0 trace (Panteli et al. 2017)
  - Applying an FFT, the position of second peak is the vibrato rate and its value is the depth (Devaney 2015)

Performance

Note-level descriptors

- **Slope (and Curvature)**
  - Fitting a polynomial to f_0 trace (Panteli et al. 2017)
  - Decomposing f_0 trace with the DCT (Devaney et al. 2011)

Performance

Manual and Score-Informed Approaches

- **Much of the work on note-level performance analysis has either been done**
  - Manually using tools like Sonic Visualiser or TONY
  - With score-informed approaches
    - Turkish makam (Şentürk et al. 2014)
    - Jazz solos (Abeßer et al. 2017)
    - Classical string performances (Li et al. 2017)
    - Classical vocal performances (Devaney and Mandel 2017)

Performance

Contours

- **In the absence of full transcriptions, contours can been used for musicological corpus studies**
- **The same techniques used for note-level descriptors can be applied to contours**
- **Shown to be useful for characterizing singing style (Panteli et al. 2017)**

Performance

Music Generation

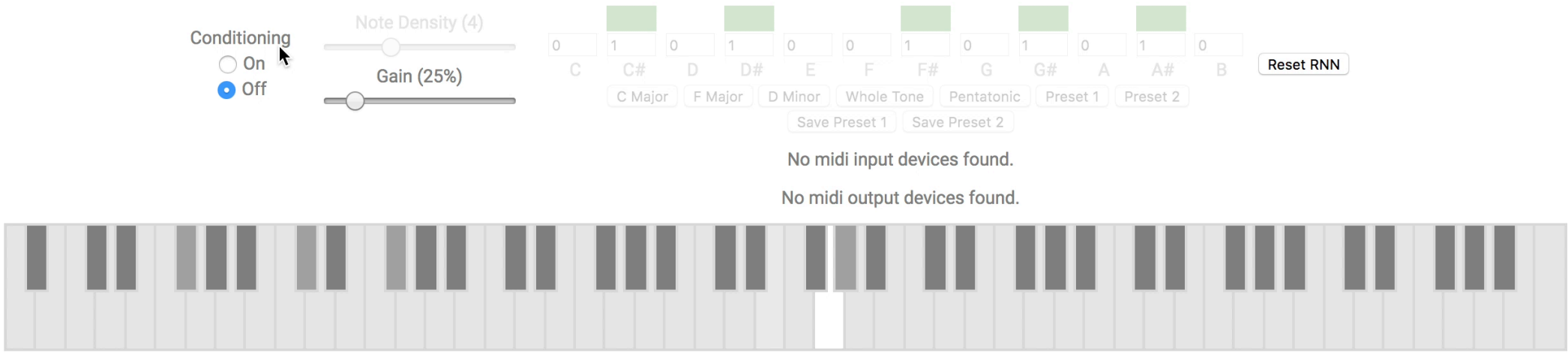
- **Automatic music generation greatly benefits from automatic transcription, but the task also requires performance data in order to produce human-sounding performances**
- **E.g., an audio trained version of Magenta's Performance RNN, which uses MIDI recordings from the Yamaha ePiano Competition**

Quantized

Human performance

Audio examples from magenta.tensorflow.org

Performance RNN



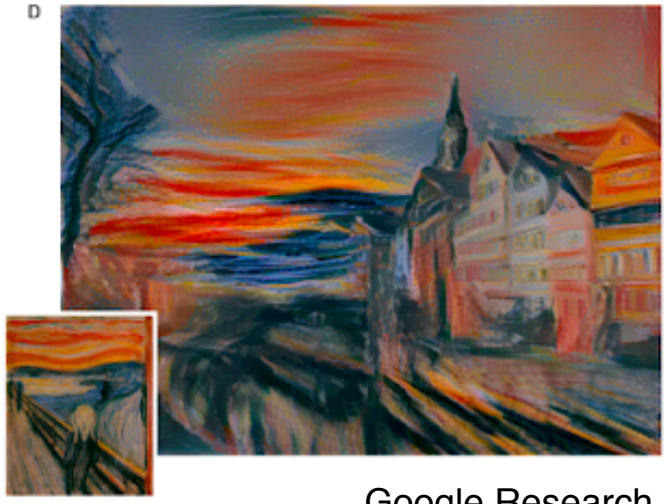
magenta

[Performance RNN](#) was trained in TensorFlow on MIDI from piano performances. It was then ported to run in the browser using only Javascript in the [TensorFlow.js](#) environment. Piano samples are from [Salamander Grand Piano](#).

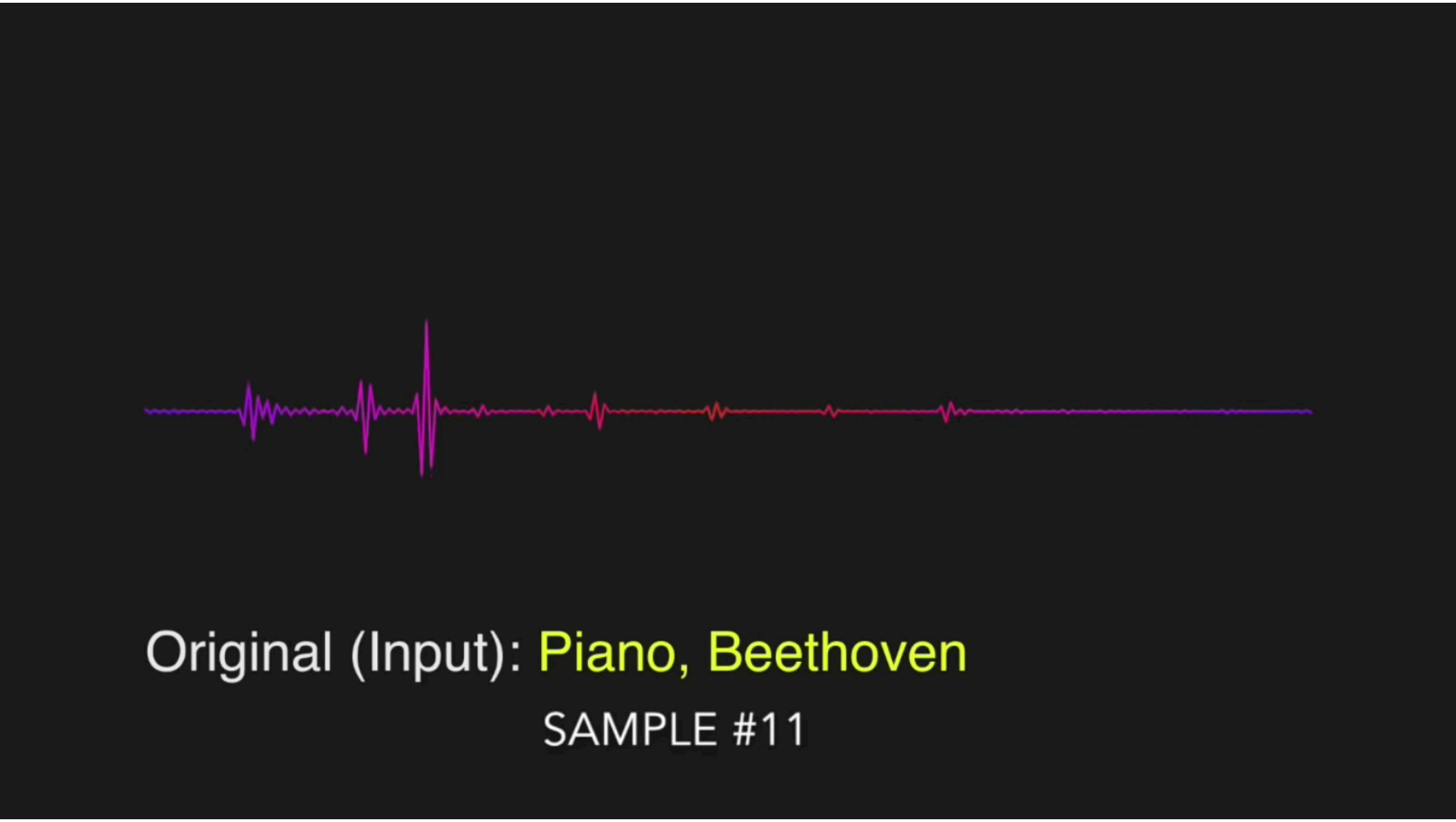
magenta.tensorflow.org

Performance

Style Transfer



Google Research



Facebook Artificial Intelligence Research

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Source Separation

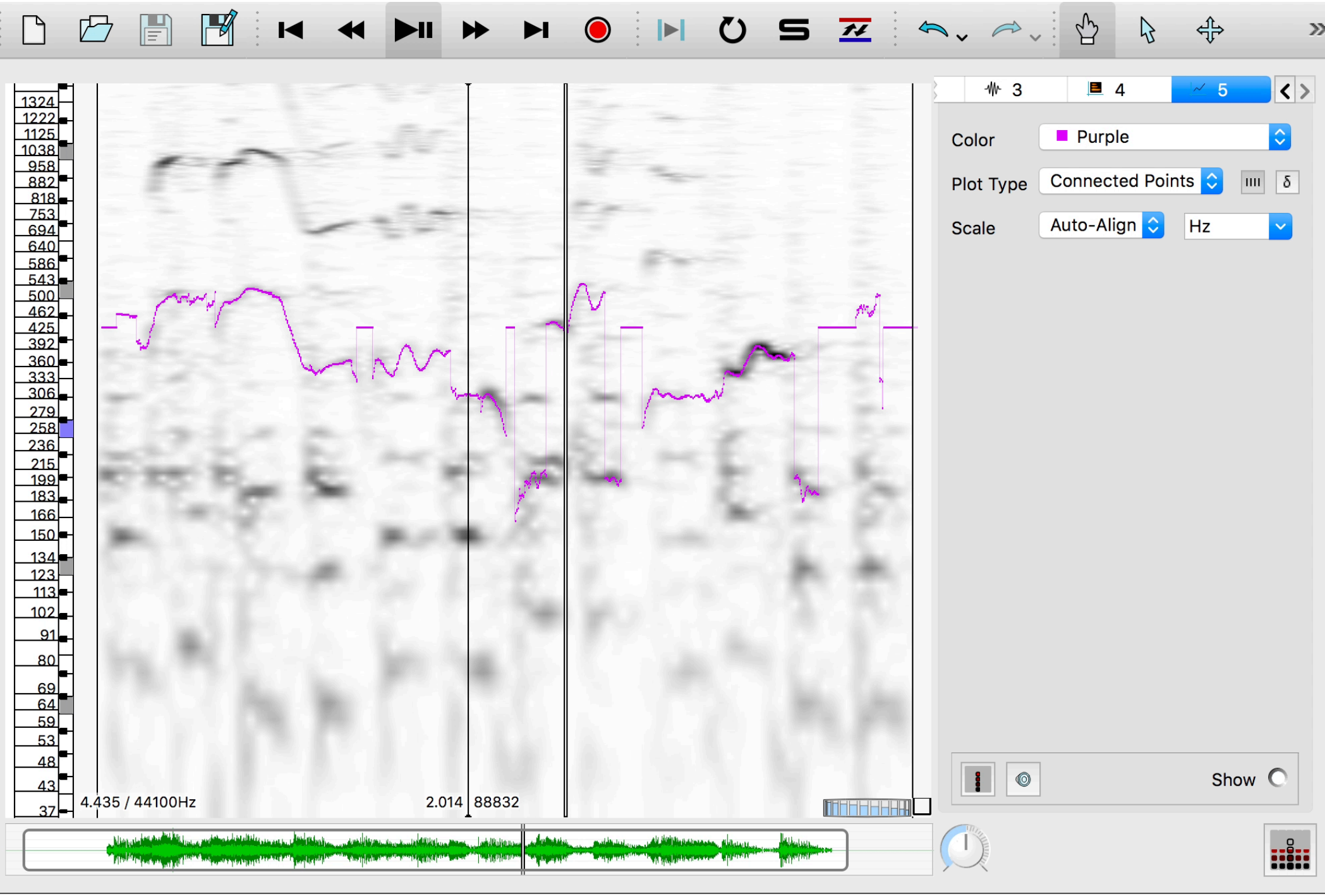
Overview

- **The practical relationship between multiple f_0 estimation and source separation is not entirely clear**
  - Multiple f_0 estimation could inform source separation
  - Source separation could inform multiple f_0 estimation
  - Joint estimation
- **Much work remains to be done in this area and currently many of the solutions are score-informed**

Source Separation

Melody Extraction

- **Melody extraction algorithms estimate f_0 for the dominant melodic line in a polyphonic musical recording**
- **Active area of research in MIR (Salamon et al. 2014)**
- **Related to bass and other single-line transcription tasks**



Melodia VAMP Plugin

Source Separation

Music Retrieval

- **Ability to extract the melody facilitates a number of retrieval tasks**
  - Query by humming - where the user sings or hums a melody and the system finds matching examples of recorded audio
  - Query by example - where the user provides an audio recording with a melody to be matched the system finds matching examples of recorded audio
    - A specific case of query-by-example is cover song identification
      - Particularly when the melody is preserved in the cover but other musical aspects are varied

Source Separation

Music Retrieval

- **Extraction of individual musical lines (melody or otherwise) can facilitate classification tasks**
  - Performer classification - *as with the work discussed earlier using contours for characterizing singing*
  - Genre classification - *certain performance styles are characteristic of different genre styles*
    - as is the balance between the vocals and instruments
    - this can provide valuable data in addition to analyses of the full audio signal

Source Separation

Music Production

- **Full separation of the music sources in a signal can facilitate a number of music production tasks**
  - Generating new mixes - *where the relative levels of the sources in a pre-mixed audio source can be adjusted*
  - De-soloing - *where the lead melodic line can be removed*
    - Useful for
      - resetting the lead melodic line against other musical material
      - karaoke applications using only the accompaniment

Source Separation

Music Production

- **Multiple f_0 detection is also useful for guiding audio processing algorithms**
  - e.g., retuning vocals

Melodyne

Autotone

Images from soundonsound.com

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Conclusions

Summary

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- **Source Separation-Related**
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Thank you!

Questions?

References

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