Visualizing Expressive Performance in Tempo-Loudness Space

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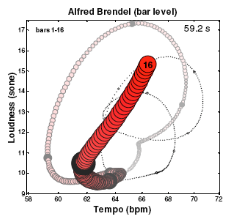

Presented by Eric Cheng
2.22.06
ISE 599

Background Information - Werner Goebl

- Postdoctoral Fellow at McGill University
  - Sequence Production Lab
  - Working under Caroline Palmer
- Undergraduate training in musicology and psychology
- Research interests:
  - Expressive piano performance
  - Artificial intelligence methods of visualization
  - Machine learning of music
  - Timing and Coordination in Music Performance
- Unable to locate information on Langner

Sources: • http://www.mcgill.ca/spl/members/
• http://www.ofai.at/~werner.goebl/

Outline

- Introduction
- Method
- Case Study I: Chopin’s E-Major Etude
- Case Study II: Schubert’s G-Flat Major Impromptu
- Conclusions
- Discussion

Introduction

- Performance research often focuses on piano performance, because:
  - Relatively few expressive parameters involved
  - Parameters are relatively easy to measure
- Majority of research has focused on a single expressive parameter in isolation.
  - In most cases, focus is on expressive timing

Introduction

- However…
  - In everyday experience, we never listen to a single performance parameter in isolation
  - Musical experience results from an integrated perception of all performance parameters
  - Performance parameters influence and depend on each other in intricate ways

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Introduction

- Therefore…
  - We need novel research techniques to analyze performances in a more holistic way
  - This paper presents such an integrated analysis technique.
  - Look at tempo and loudness
  - Analysis technique is tested on performances of musical excerpts by Chopin and Schubert.

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Method

- Basic Steps:
  1. Data Acquisition
  2. Data Reduction/Smoothing
  3. 2-D display

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1. Data Acquisition: Timing Data

- Timing Data from Two sources:
  1. MIDI recordings
  2. Audio recordings
- MIDI:
  - Onsets clearly defined
  - Precision of computer-monitored pianos not much higher than obtaining data from audio recordings

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1. Data Acquisition: Timing Data

- MIDI Method:
  - Performed onsets matched to score
  - Tempo changes measured at various *track levels*, or resolutions
  - Track levels usually faster than the beat indicated in the time signature
  - Track level determines the scale at which we examine tempo changes

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1. Data Acquisition: Timing Data

- Audio Recordings Method:
  - Used interactive beat detection software
  - Software finds onsets of as many notes as possible and proposes potential beat track
  - Track times can be saved to disk
  - Typical error of +/- 20 msec

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1. Data Acquisition: Loudness Data

- Loudness Data Two sources:
  - WAV recording of MIDI file
  - Audio file in WAV format
- Converted WAV files into loudness envelopes in sones (loudness sensation):
  - Method:
    1. Audio file converted to frequency domain
    2. Bundled into critical-bands according to Bark scale
    3. Sones computed after determining spectral and temporal masking effects

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1. Data Acquisition: Loudness Data

- Why use sones?
  - Sound intensity in dB is not the same as loudness.
  - Our perception of loudness depends also on frequency and temporal content of the signal
    - Spectral and Temporal Masking
  - Sones are unit of loudness referenced to a 1 kHz tone

Source: http://hyperphysics.phy-astr.gsu.edu/hbase/sound/phon.html

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1. Data Acquisition: Loudness Data

- What are critical bands? Barks?
  - Cochlea (inner ear) can be modeled as consisting of a series of highly overlapping bandpass filters
  - Each filter is tuned to a different "critical band," or region of the frequency domain

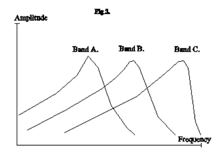

Image Source: http://www.music.gla.ac.uk/~george/audio/psy/psy.html

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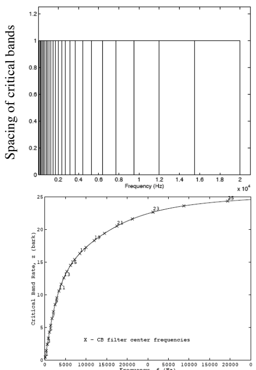
1. Data Acquisition: Loudness Data



- The critical bands are not evenly spaced across the spectrum (see top left)
  - We have better spectral resolution in the lower frequencies
  - The Bark scale is a scaling of frequency axis so filters are uniformly spread across spectrum (see bottom left)
  - Therefore 1 Bark corresponds to one filter

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Method

- Basic Steps:
  1. Data Acquisition
  2. Data Reduction/Smoothing ←
  3. 2-D display

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2. Data Reduction

- All data smoothed using overlapping Gaussian windows
- Window size equal to 2 standard deviations
- Window size determines scale of analysis:
  – Smaller window size -> local phenomena
  – Larger window size -> global phenomena
- Point y(t) determined by eq. (1) where x(t) is unsmoothed data

$$y(t) = \frac{\sum_{i=-k}^{k} x(t+iF)\cdot e^{-\frac{(iF)^2}{2\sigma^2}}}{\sum_{i=-k}^{k} e^{-\frac{(iF)^2}{2\sigma^2}}} \quad (1)$$

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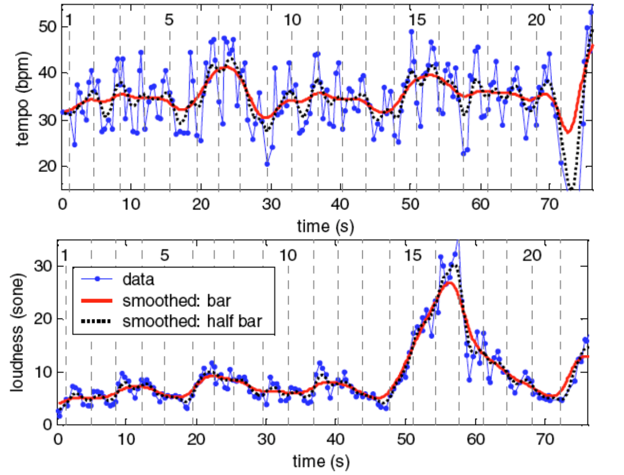

Method

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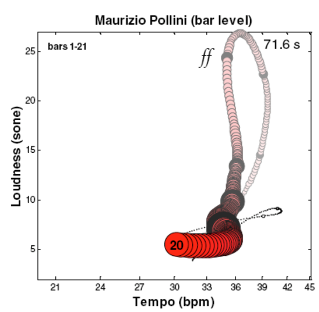
3. 2-D Display

- Smoothed data displayed in 2-D tempo-loudness space
- X-axis = tempo (bpm)
- Y-axis = loudness (sones)
- Trajectory of red dot fades and decreases in size over time
- Third dimension: time
- Current dot displays higher level information such as bar number



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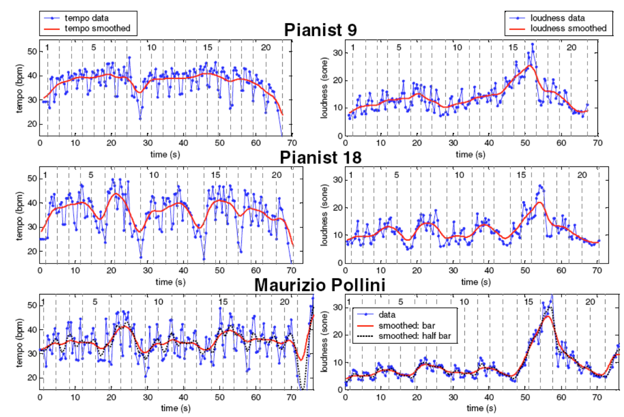
Chopin Etude in E-Major

- Analyzed first 21 bars
- 2 recordings from Bösendorfer SE290 computer-controlled grand piano
- 1 recording by Maurio Pollini (1985)
- Track level set to 16th note

Chopin Etude in E-Major

Chopin Etude Data



Chopin Etude in E-Major

- Observations:

1. Expressive trajectory tended towards lower left at phrase boundaries in measures 6, 9, and 14
   - Corresponds to a slowing down and decrescendo towards ends of phrases
   - Pianist 9 is the exception to this, ignoring phrase boundaries at bars 6 and 14

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Chopin Etude in E-Major

2. Phrase beginnings start with increase in tempo followed by increase in loudness
3. Tendency towards a counterclockwise movement to the trajectories
4. Pollini slows down less at end of excerpt because he planned to play the whole Etude
5. Shape of trajectory is dependent on window size
6. Dynamic peak in measure 17 does not coincide with marking in score - occurs later

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Schubert G-Flat Major Impromptu

- Analyzed first 16 bars
- Compared Todd's "faster-louder, slower-softer" model to performance by Alfred Brendl
- Used "hybrid" performance based on Todd's model from previous study by Windsor and Clarke (1997)

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Schubert G-Flat Major Impromptu

- Observations:
  1. Hybrid performance shows diagonal trajectories as expected from “louder-faster, slower-softer”
  2. Not a perfect diagonal because different parameters used for timing and intensity. Also, nonlinear relationship between tempo and sones
  3. Analysis clearly shows differences in phrasing

Conclusions

- Display method elucidates the interaction between tempo and loudness
- Useful for scientific research as well as musicians and audiences
- Serves as a visual link between performance research and performance practice

Conclusions

- Some observations from the model:
  - Pianists tended to approach climax of a phrase by increasing tempo first and loudness slightly later
  - Pianists tended to create counterclockwise expressive trajectories
  - Pianists tended to increase loudness at tempo maxima, decrease tempo at loudness maxima

Conclusions

- Smoothing allows for choice of resolution
- Could have perceptual basis: perceived tempo is more stable than tempo resulting from onsets measured
- There are side effects of smoothing: can miss important developments

Discussion

- Further Research:
  - Reverse the process:
    - Use 2-D space as an interactive control of music performance
  - Real-time implementations
  - Use different parameters
  - Modify the animation display to include other performance information