# An Overview of Empirical Performance Analysis

Johanna Devaney, Schulich School of Music, McGill University.

Workshop on Expressive Performance

*May 12, 2009*

McGill

Schulich School of Music
École de musique Schulich

CIRMMT Centre for Interdisciplinary Research in Music Media and Technology

DDMAL DISTRIBUTED DIGITAL MUSIC ARCHIVES & LIBRARIES LAB

# Performance & Music Psychology

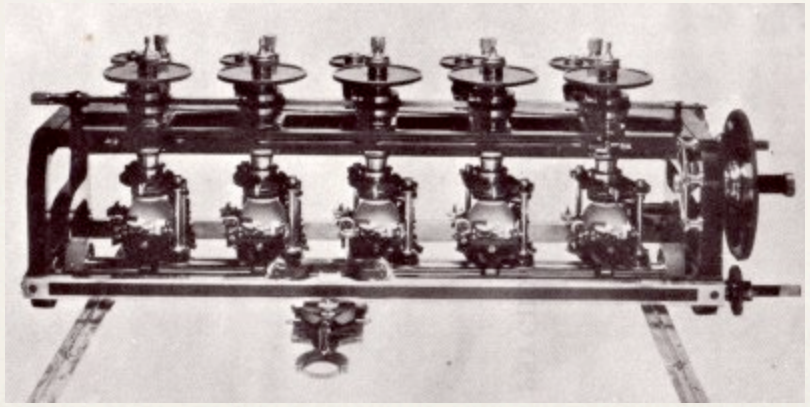
## Performance Models

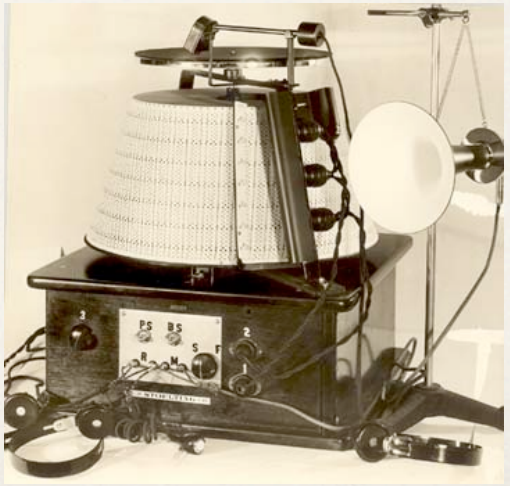
## Studying Intonation Practices

# Performance & Music Psychology

# Performance & Music Psychology

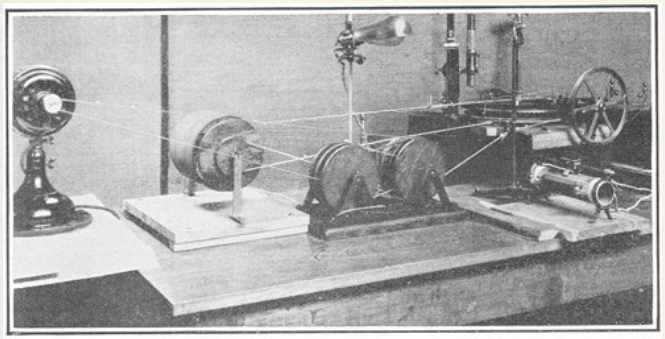
- Carl Seashore (1938) studied timing, dynamics, intonation, and vibrato in pianists, violinists, and singers
  - Equipment: piano rolls, films of the movement of hammers during performance, phono-photographic apparatus



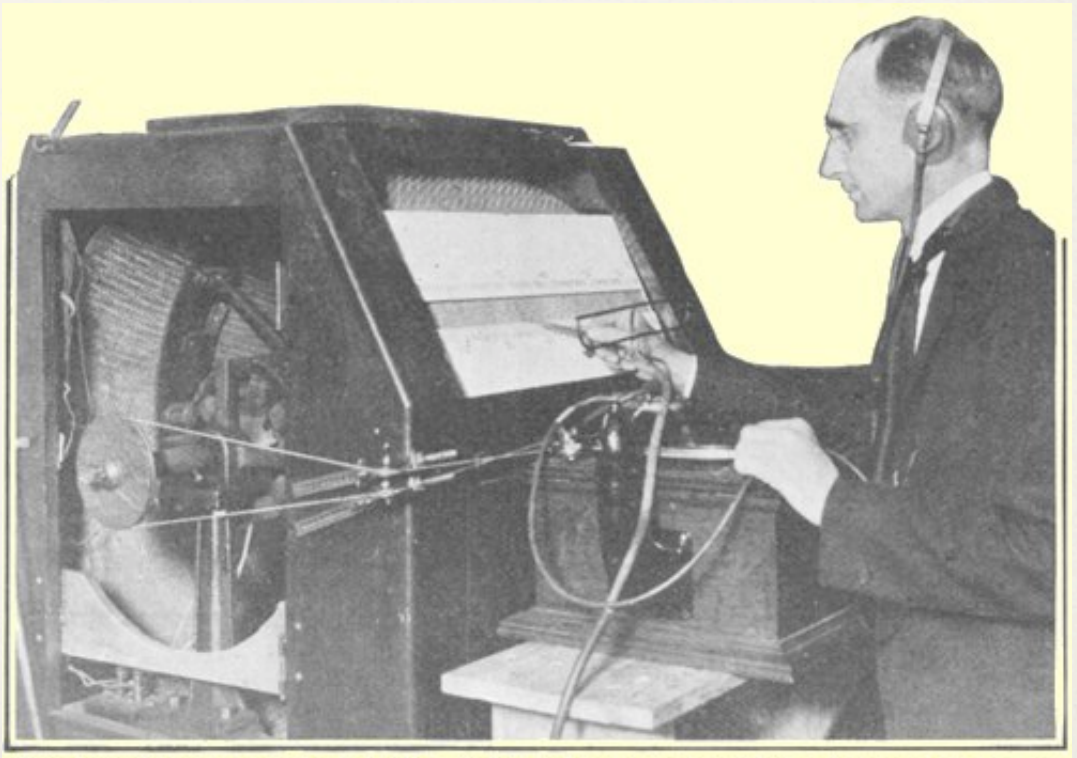


# Performance & Music Psychology

- Interest in empirical performance analysis diminished between the Second World War and 1980's, in part due to its labouriousness



Wave recorder for use with disk phonograph; the lever, acting like a pantograph, traces the waves on a revolving smoked drum



The tonoscope for analyzing the pitch of the tones on a disk phonograph record

# Performance & Music Psychology

- The resurgence in interest in the late 1970s/early 1980s coincided with
  - a movement by musicologists away from equating scores with music
  - an increased interest by cognitive psychologists in music
- Ingemar Bengtsson and Alf Gabrielsson (1980) undertook a number of systematic experiments on musical rhythm in performance
- Neil Todd (1985) studied both rubato and dynamics in piano performance, and developed a model to account for the relationship to structure

# Piano Performance Studies

- Bruno Repp also examined timing in piano performance and found that
  - the degree of ritardando in the performances could be consistently related to the hierarchical levels of the phrase, and observed that the higher the structural level the more pronounced the ritardandi were (1992)
  - re-created versions of piano performances based on the average of the timing variations were pleasing to listeners in perceptual experiments (1997)

# Repp Musical Examples

## Chopin's Etude in E major

Example One

# Repp Musical Examples

## Chopin's Etude in E major

Example One

Example Two

# Repp Musical Examples

## Chopin's Etude in E major

Example One

Example Two

Example Three

Audio files available at: http://www.haskins.yale.edu/misc/REPP/AP.html

# Popularity of the Piano

- Factors
  - the large amount of solo repertoire
  - the instrument's percussive nature
  - the ease with which one can acquire accurate, minimally intrusive performance measurements from a pianist via MIDI technology
  - the feasibility of using specially equipped pianos to measure performance data more precisely than with MIDI

# Popularity of the Piano

- Some issues with MIDI-based studies
  - require a MIDI-rigged piano
  - typically done in a lab environment
  - precision is limited for other instruments (when possible)

- The ability to automatically analyze recordings would greatly increase the amount of data available for empirical performance analysis

# Performance Models

# KTH's rule-based approach

- KTH "analysis-by-synthesis" approach (Friberg et al. 2006)
  - researchers developed rules and professional musicians evaluated them
  - based on speech synthesis approach
  - implemented in *Director Musices* (Sundberg et al. 2003)

# Todd's model

- Structure-level model of expressive timing and dynamics (1989)
  - relates performance analysis to theoretical framework to assess musical context (Lerdahl and Jackendoff 1983)
  - the relationship between timing and dynamics are a little simplistic ("the faster, the louder")
- Hierarchical grouping controls the instantaneous tempo
  - increased dynamics and tempo at the middle of phrases
  - reduced dynamics/slowing down at points of stability, such as phrase boundaries
  - modeled at each level of the piece's hierarchy

# Widmer's model

- Uses large amounts of empirical data extracted from a performance to train a machine learning model to predict local, note-level expressive deviations and higher-level phrasing pattern (2002, 2004)
  - applies inductive machine learning and data mining techniques
- Note-level Model - how the performer will play a particular note in terms of timing, dynamics, and articulation
- Multi-level Model - the role of tempo, dynamics, and articulation in shaping abstract structures, such as motifs, groups, and phrases
- Two models can be combined, the note-level model compensates for the "residuals" from the multi-level model

# Study of Intonation Practices

# INTONATION IN SOLO VOCAL PERFORMANCE

Original

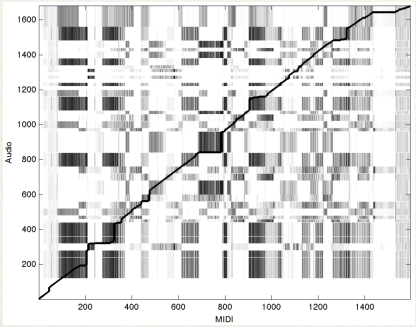
# INTONATION IN SOLO VOCAL PERFORMANCE

Original

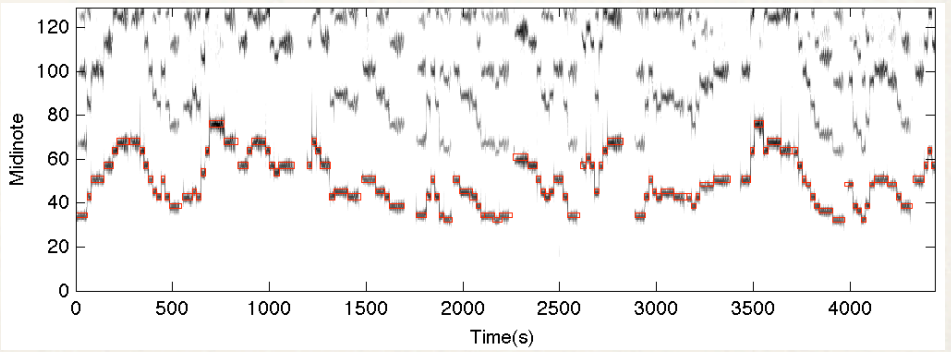
Quantized

# Onset and Offset Estimation

- Existing beat tracking generally perform poorly for non-percussive instruments
- Note onsets and offsets are determined by first aligning a MIDI version of the score to the audio using Dynamic Time Warping

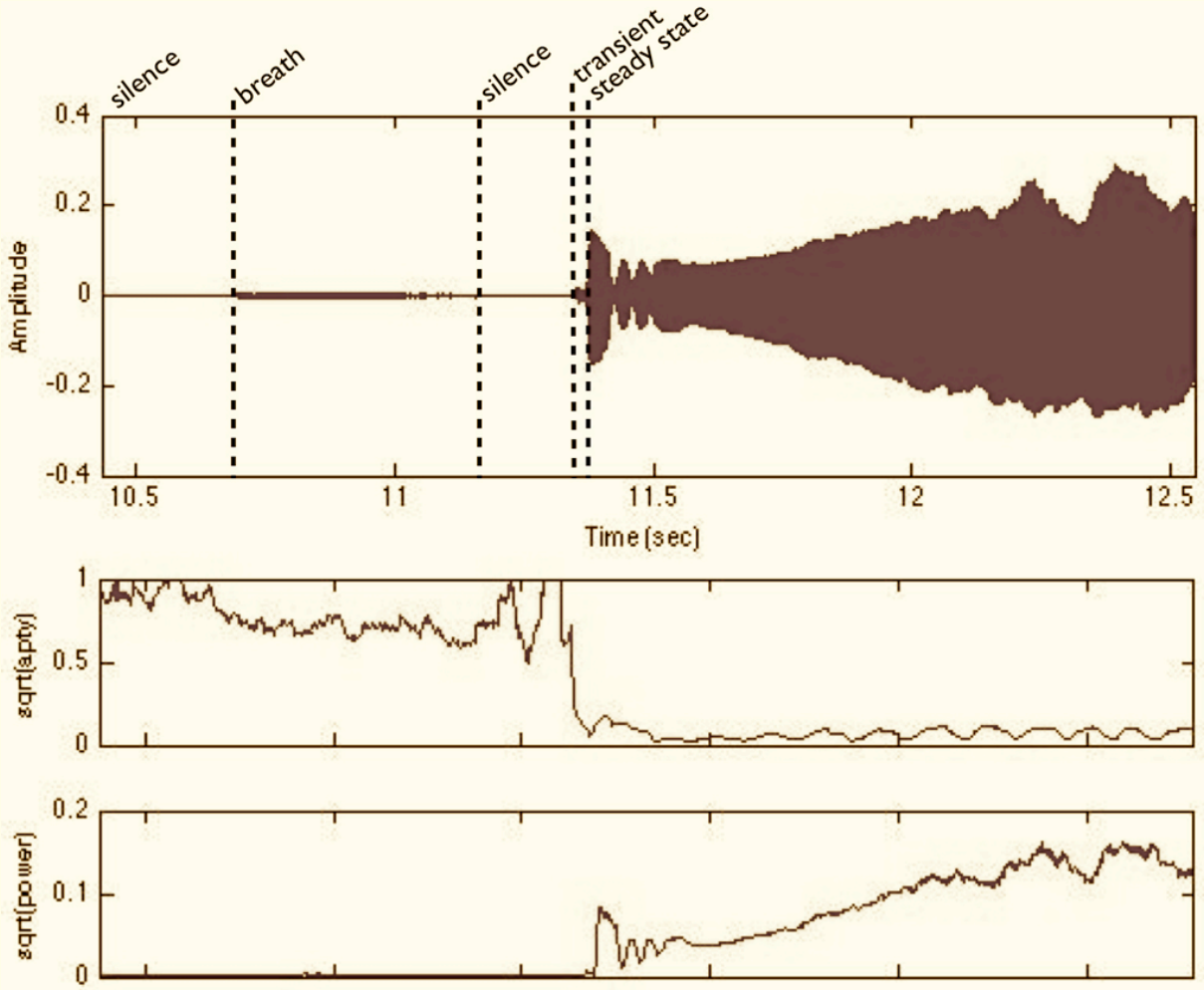



Similarity matrix with the DTW path indicated in black

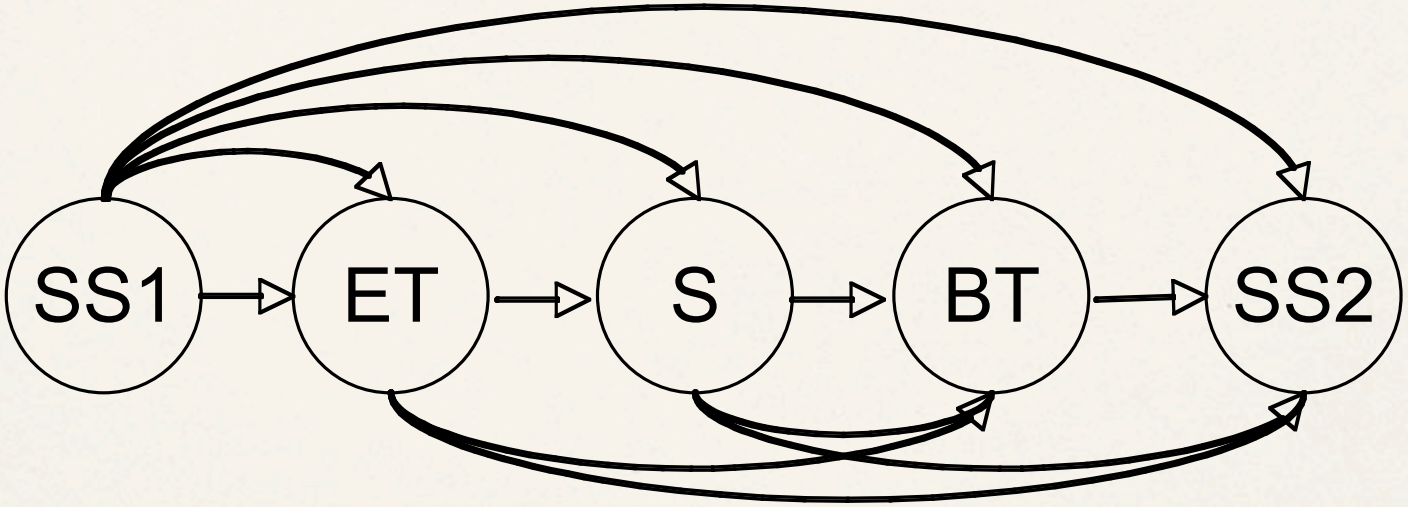



Note onsets and offset predicted by Dynamic Time Warping

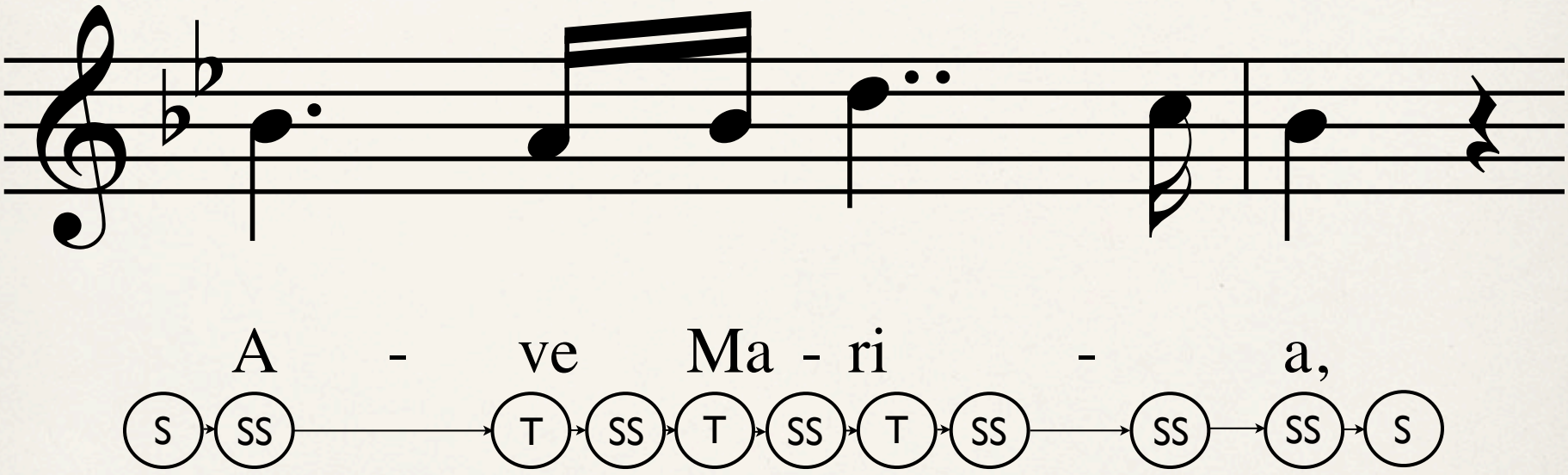
# Acoustical Features of Singing

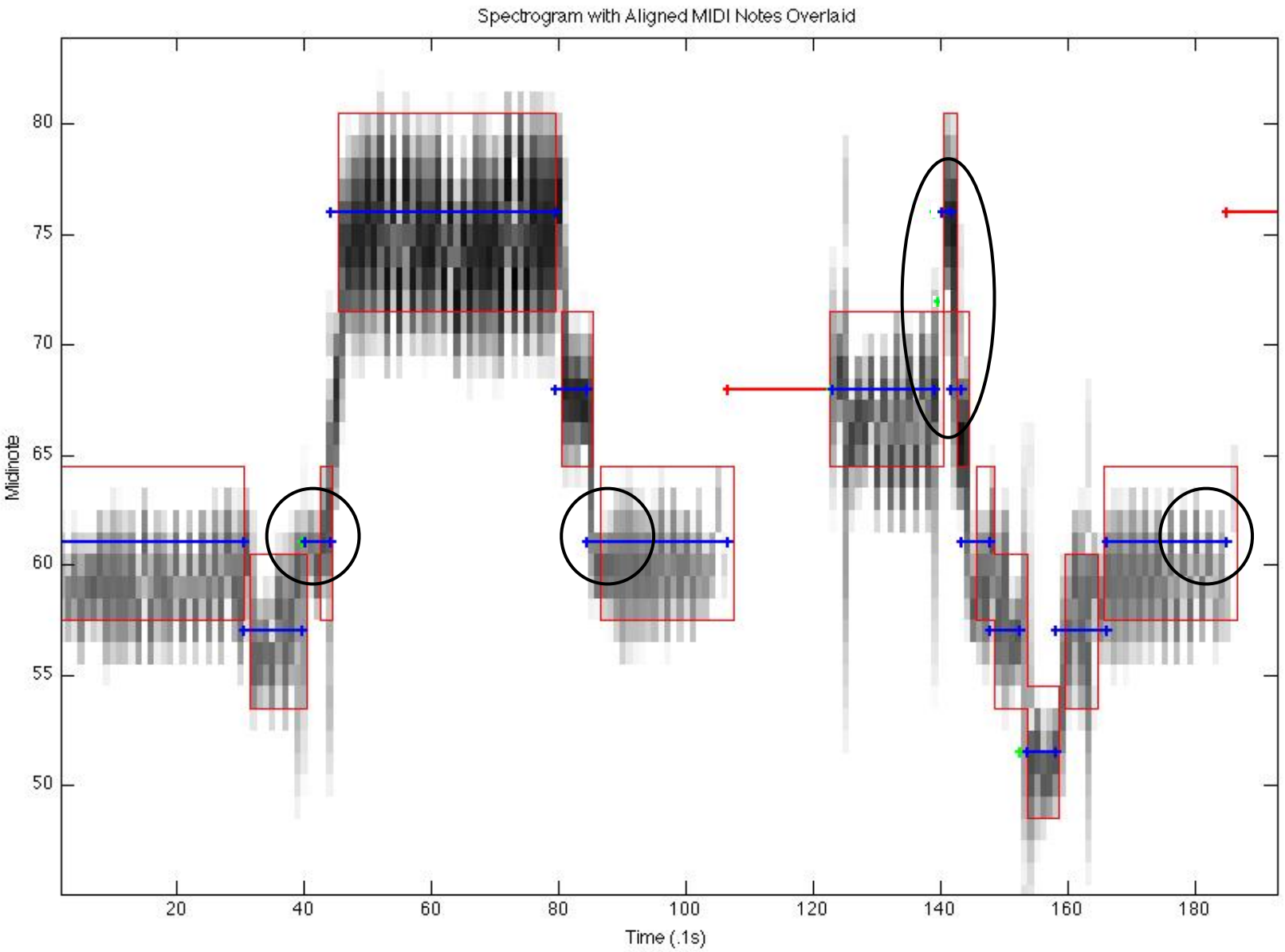


# State Space Diagram



# Modified State Space Diagram



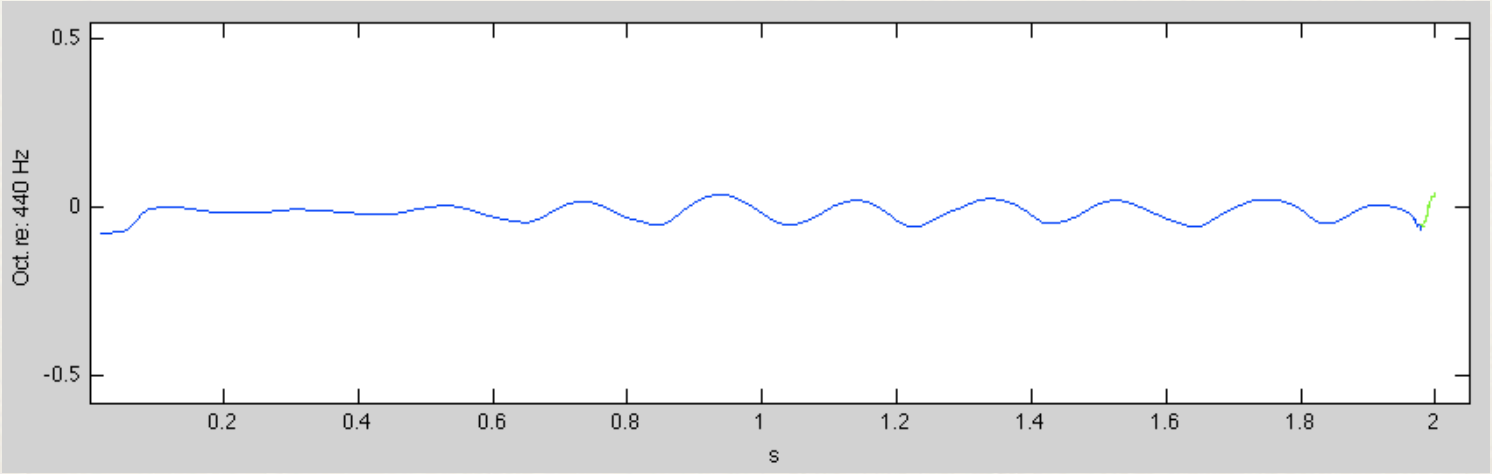

Spectrogram with Aligned MIDI Notes Overlaid
Midinote
80
75
70
65
60
55
50
20
40
60
80
100
120
140
160
180
Time (.1s)

# Results

- Mean error for note onsets and offsets
  - Dynamic Time Warping: 52 ms
  - General state space mean error: 48 ms
  - Modified state space mean error: 28 ms
- The HMM provided similar accuracy against the ground truth for the transient and steady state onsets and offsets
- Inclusion of breath didn't improve the results for the transients and steady state onset and offset estimation
  - created some confusion with the onset and offset of breath and silence states

# Signal Processing

- Once the onsets and offsets have been determined, fundamental frequency estimation can be done
- The perceived pitch over the duration of the steady state portion of the note was calculated as the geometric mean



# Future Work

- Expand to polyphonic music
- Analyse the collected data
  - Short-term goal is to find if any generalities exist
  - Longer-term goal is to develop a theory of how vocal intonation practices relate to musical context

# Conclusions

- There is a long and rich history of work on empirical evaluation of performance
- Early work was completely manual
- We still do not have the appropriate tools for automatically extracting performance data but we are moving in that direction
- The more data we can extract, the more accurate models we can build

# References


Bengtsson, I., and A. Gabrielsson. 1980. Methods for analyzing performance of Musical rhythm. *Scandinavian Journal of Psychology.* 21: 257-68.

Friberg, A., and R. Bresin, and J. Sundberg. 2006. Overview of the KTH rule system for musical performance. *Advances in Cognitive Psychology*. 2(2–3): 145–6.

Lerdahl and Jackendoff. 1983. *A Generative Theory of Tonal Music*. Cambridge, Mass.: MIT Press.

Repp, B. H. 1992. Diversity and commonality in music performance: an analysis of timing microstructure in Schumann's 'Träumerei'. *Journal of the Acoustical Society of America.* 92: 2546–68.

Repp, B. H. 1997. The aesthetic quality of a quantitatively average music performance: two preliminary experiments. *Music Perception*. 14: 419–44.

Todd, N. 1985. A model of expressive timing in tonal music. *Music Perception*. 3: 33–58.

Todd, N. 1989. The dynamics of dynamics: A model of musical expression. J*ournal of the Acoustical Society of America*. 91(6): 3540–50.

Seashore, C. E. 1938. *Psychology of Music.* New York: Dover Publications.

Sundberg, J., Friberg, A., & Bresin, R. 2003. Attempts to reproduce a pianist's expressive timing with Director Musices performance rules. *Journal of New Music Research*. 32: 317–325.

Todd, N.P.M. (1992). The dynamics of dynamics: A model of musical expression. *Journal of the Acoustical Society of America*. 91: 3540–50.

Widmer, G. (2002). Machine discoveries: A few simple, robust local expression principles. *Journal of New Music Research*. 31: 37–50.

Widmer, G. & W. Goebl. (2004). Computational models of expressive performance: The state of the art. *Journal of New Music Research.* 33: 203-16.

Widmer, G., & Tobudic, A. (2003). Playing Mozart by analogy: Learning multi-level timing and dynamics strategies. *Journal of New Music Research*. 32: 259–68.