Analyzing (Recorded) Musical Performance

Johanna Devaney
Assistant Professor of Music Theory and Cognition
School of Music
The Ohio State University

Introduction

Why study musical performance?

- **Performances convey musicians' interpretations**
- **Performances are what listeners actually hear**
- **It can help us gain insight into**
  - how an individual's performance practice evolves as they gain more experience
  - how performance practices evolve over time
- **Observing how performance practices relate to musical materials can help us develop models of "expressive" performance**

Introduction

Why study musical performance?

- **Empirical measurement of these expressive aspects of musical performances complements qualitative analyses of performance relating to**
  - intentions of the performers
  - subjective impressions of the listener
- **Some larger scale questions that may be asked**
  - “what constitutes a great performance?”
  - “what is unique about a particular performer’s style and how did this style develop over the course of their career?”

Introduction

What do I mean by studying performance?

- **Using (live) recorded performances**
- **Measuring performance parameters**
  - timing
  - dynamics
  - tuning
  - timbre
- **Assessing relationship between performance of various parameters and musical materials**

Introduction

Challenges of studying musical performances

- **Accurately extracting performance parameters**
- **Modeling performance parameters in a perceptually meaningful way**
- **Understanding the context of the performance**
  - the physical nature of the instrument
  - workings of the particular musical style
  - culture of the particular performance tradition
  - intentions of the performer

Introduction

“Quantitative” versus “Qualitative”

“When a quantitative test gives a certain outcome, and subsequent discussion then interprets that result and places it in the context of other work, it is fairly clear (if one accepts the premises of the method) where the reporting of results stops and the interpretation starts This is much less clearly the case with a qualitative method [...]. This objection partly reflects the fact that the interpretative assumptions of most quantitative methods have simply become so deeply embedded as to be invisible, but it remains the case that qualitative methods have yet to attain the systematic and explicit character of empiricism in the eyes of many." Clarke (2004, p. 92)

Introduction
Motivations and challenges.
1

A brief history
Quantitative and qualitative approaches to performance analysis.
2

My quantitative research
Studies of intonation in the singing voice.
3

Bridging the Quantitative and Qualitative
Ways in which these approaches can and do inform each other.
4

Conclusions
Summary and future directions.
5

Quantitative Performance Analysis

A brief history

Pioneers
Binet and Courtier
Sears
Miller

Quantitative Performance Analysis

A brief history

Pioneers
Binet and Courtier
Sears
Miller

1895–1930

1920–40s

1960s

1980s and 90s

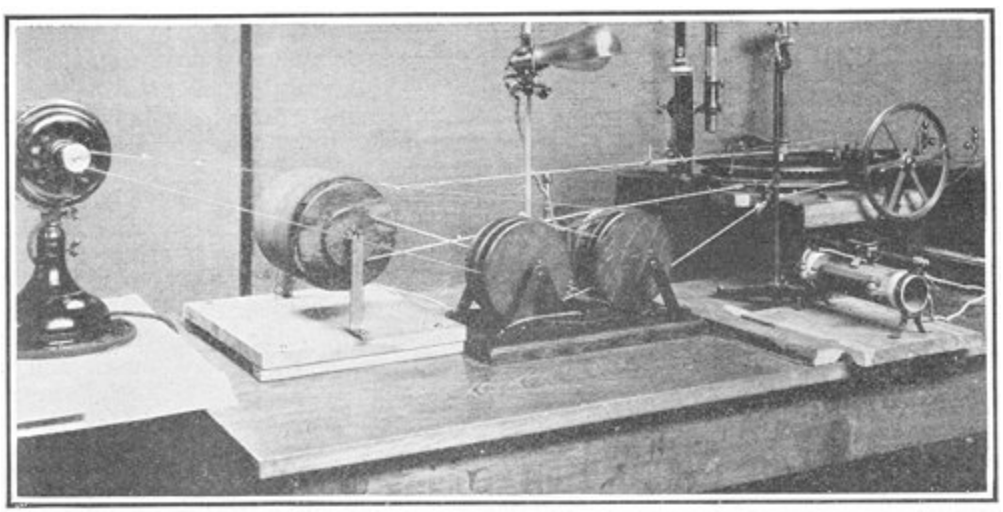
1990s and 2000s

Psychologists at University of Iowa
Seashore and colleagues

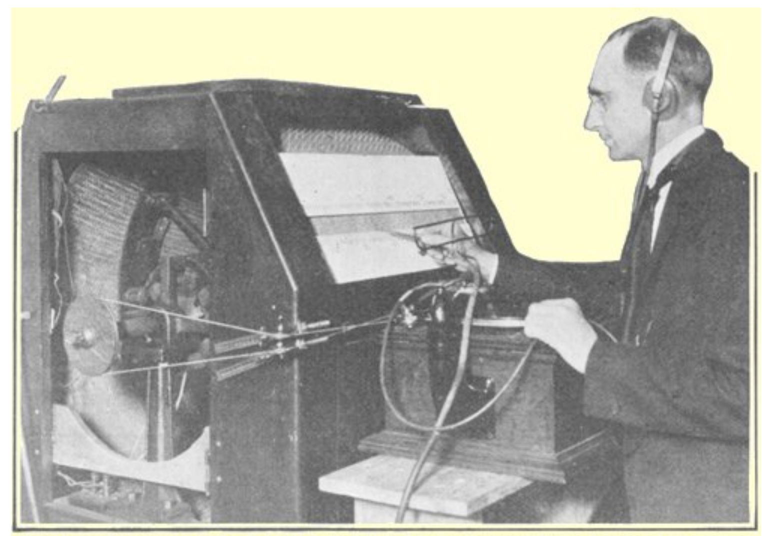
Quantitative Performance Analysis

University of Iowa

- **Carl Seashore (1938) and colleagues 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



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



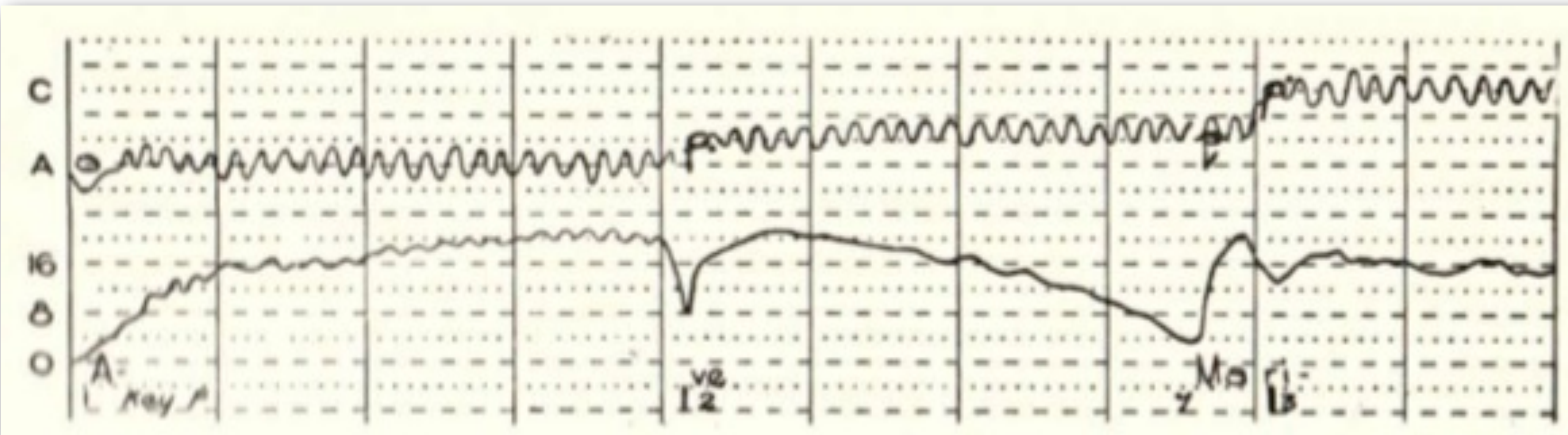
The tonoscope for analyzing the pitch of the tones on a disk phonograph record

Cary (1922)

Quantitative Performance Analysis

University of Iowa

Performance scores



Seashore (1936)

Quantitative Performance Analysis

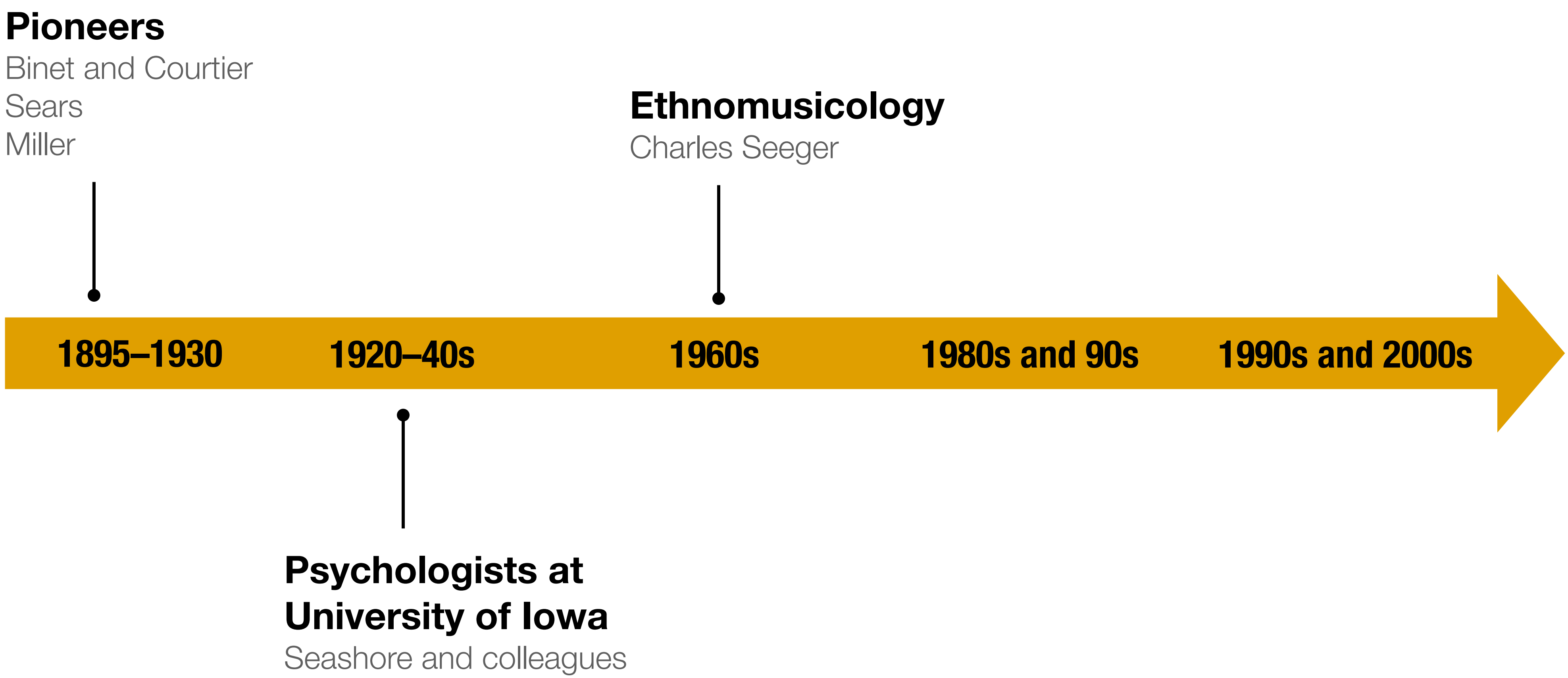
University of Iowa

Expressive Performance

"The artistic expression of feeling in music consists in aesthetic deviation from the regular - from pure tone, true pitch, even dynamics, metronomic time, rigid rhythms, etc." (Seashore 1938, p.9)

Quantitative Performance Analysis

A brief history

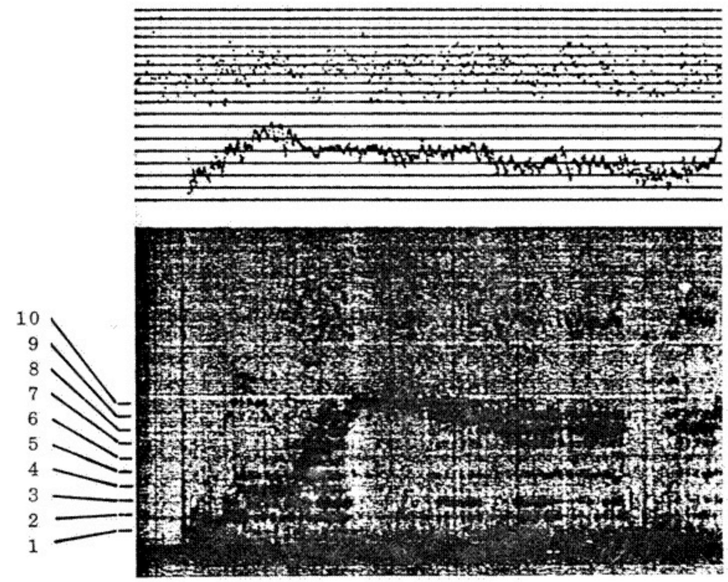


Quantitative Performance Analysis

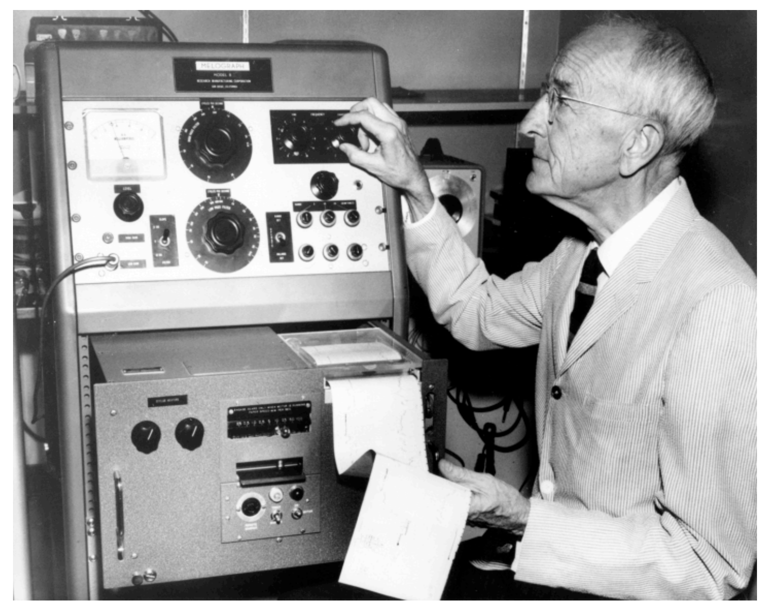
Seeger Melograph

- **Three versions (A,B,C)**
- **Measured pitch, loudness, and timbre (frequency spectrum)**

"Experience with these machines has shown that tape recordings preserve some sounds that the ear does not perceive and other sounds that, although they are perceived, do not enter into the listener's awareness. The graphs and data that come out of the new electronic analyses tend to expand the experience of the scholar; the analysis becomes a teaching device. In the process, ethnomusicologists will have acquired a kind of hearing that is different from that of the nontrained student, who experiences music solely through the naked ear." (Wachsmann 1969, p.175)



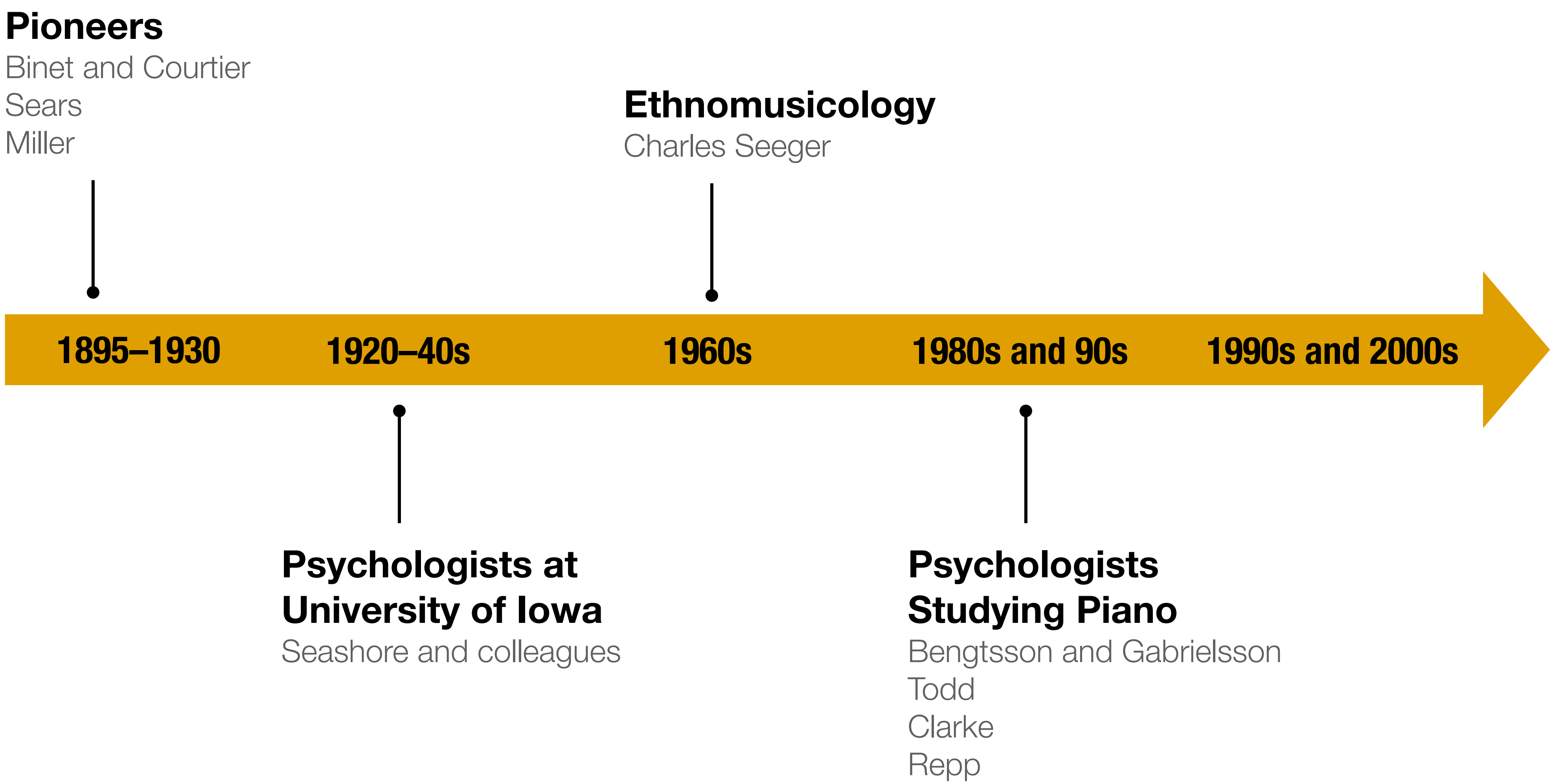
Walcott (1974)



UCLA Ethnomusicology Archive

Quantitative Performance Analysis

A brief history



Quantitative Performance Analysis

Popularity of the piano

- Large amount of solo repertoire
- Instrument's percussive nature
- Feasibility of using specially equipped pianos (e.g., MIDI)
  - cannot study existing recordings
  - new recordings are typically done in a lab environment

Bosendorfer SE piano at BRAMS, Montreal

Quantitative Performance Analysis

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1960s

Ethnomusicology
Charles Seeger

1980s and 90s

Psychologists Studying Piano
Gabrielsson
Todd
Clarke
Repp

1990s and 2000s

Intonation
Fyk
Prame
Vurma

Quantitative Performance Analysis

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Intonation
Fyk
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Vurma

Computational Models
Friberg
Mazola
Widmer

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Ways in which these approaches can and do inform each other.

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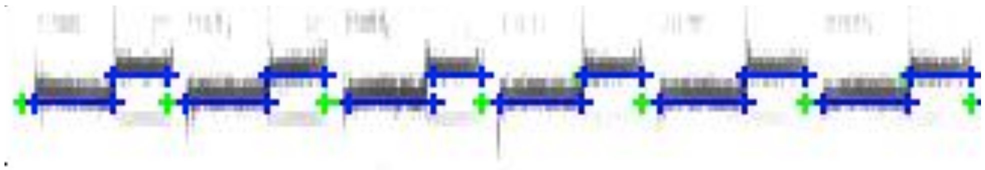
Extracting Performance Data

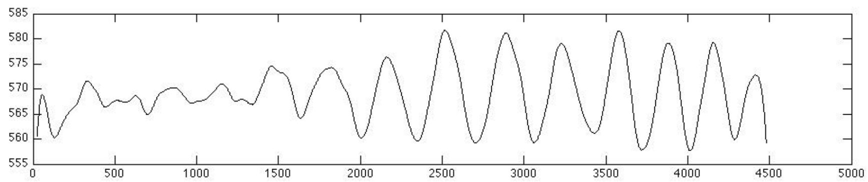
Experiments with Singers

Comparing Performances

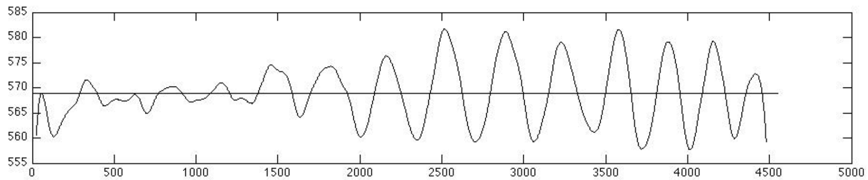
Identify Note Onsets and Offsets



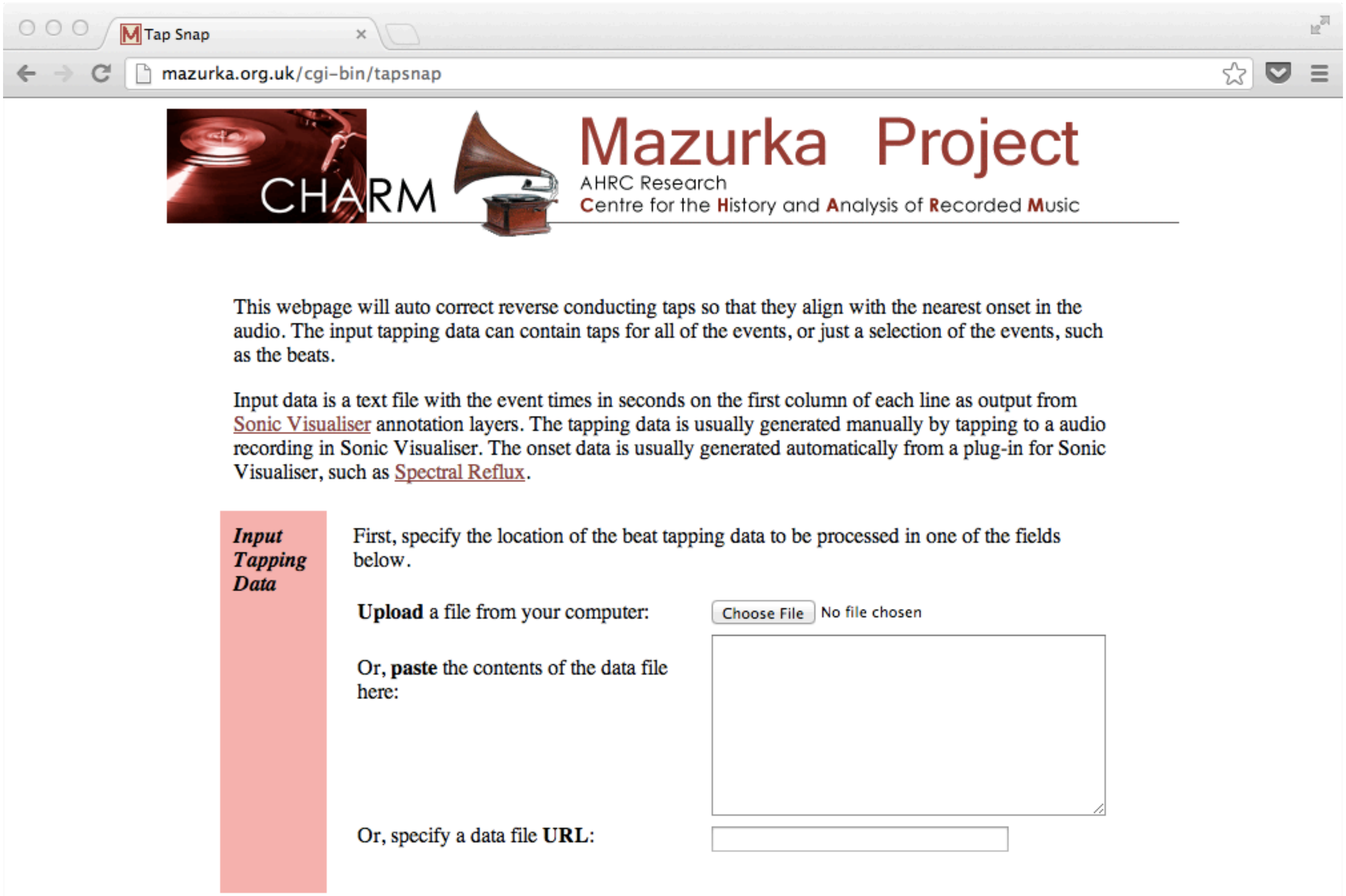
Fundamental Frequency (F_0) Estimation



Perceived Pitch

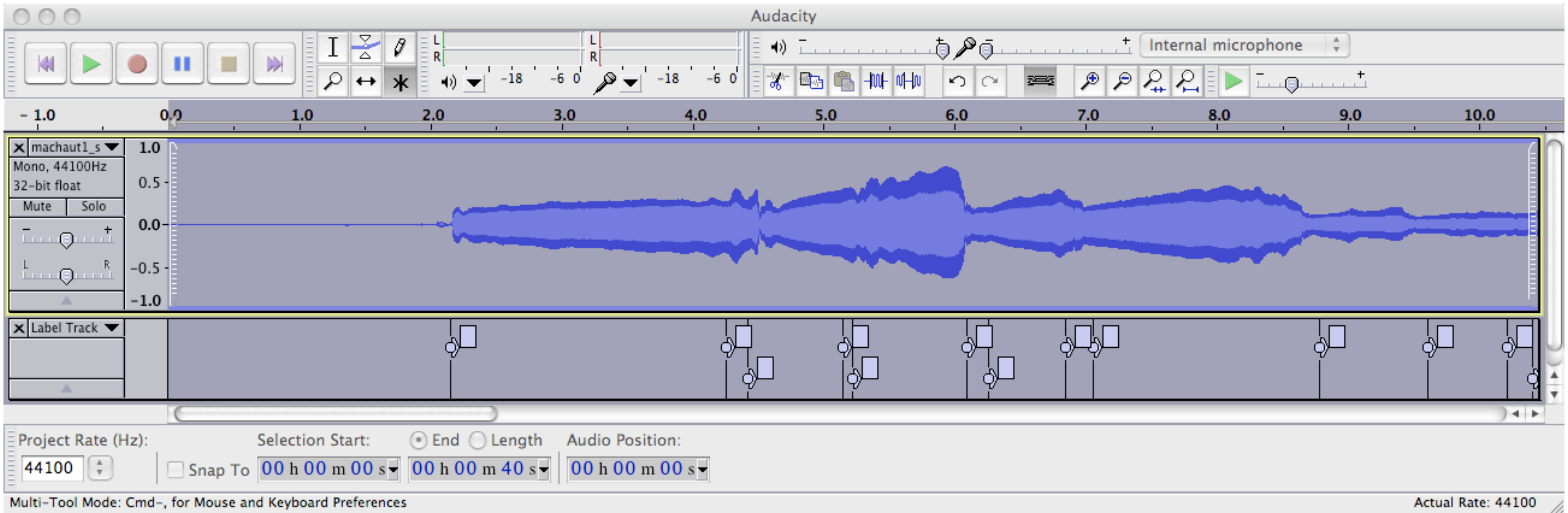


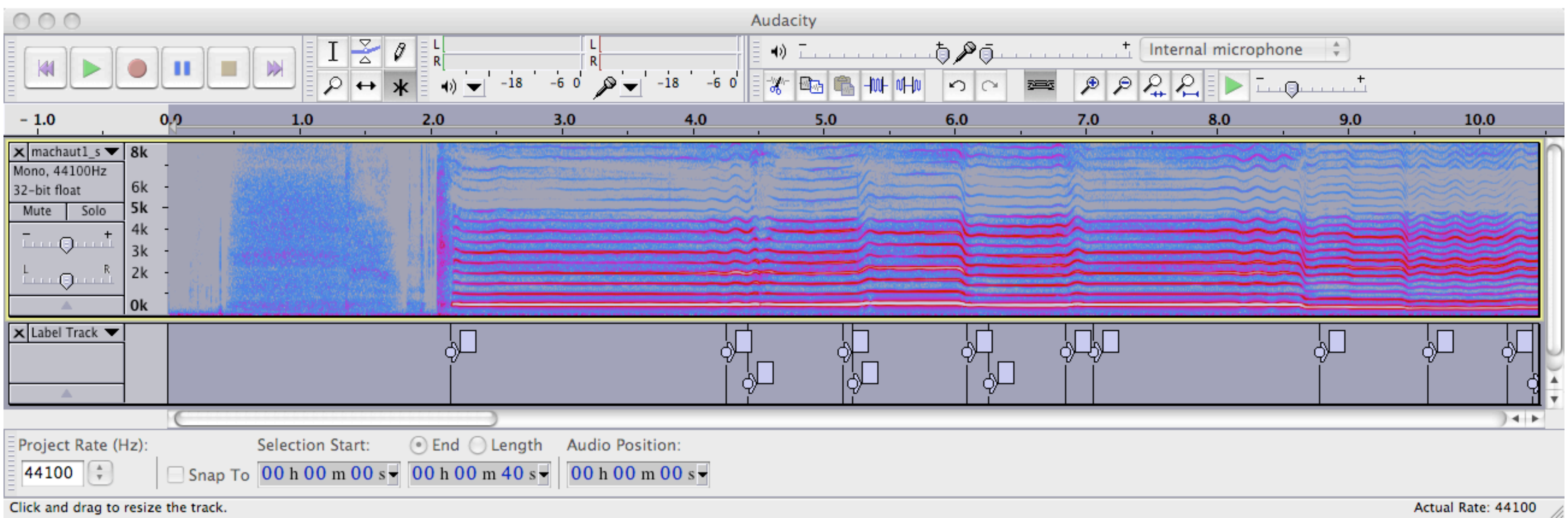
Manual Annotation by Tapping



Manual Annotation with Software

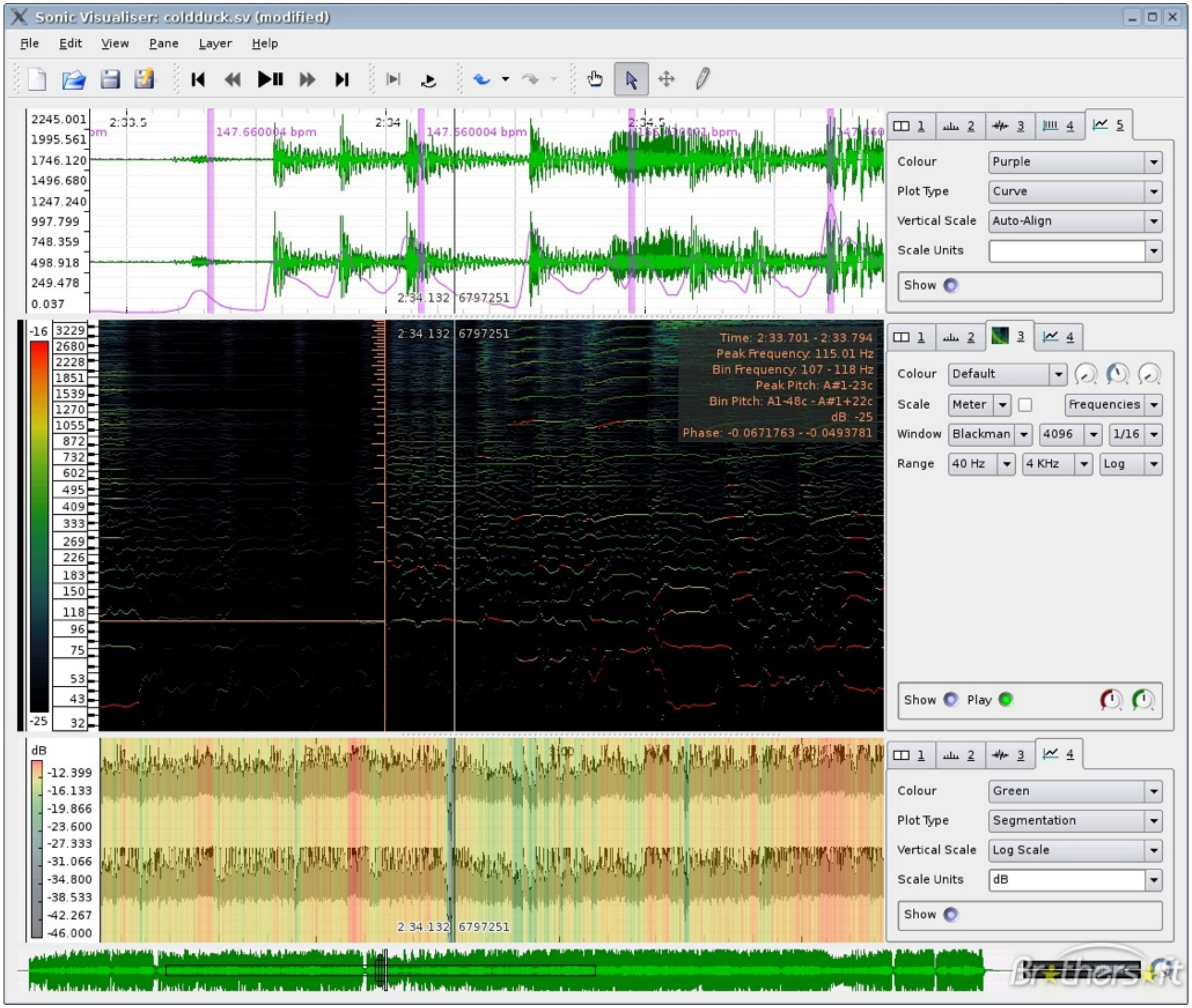
Audacity





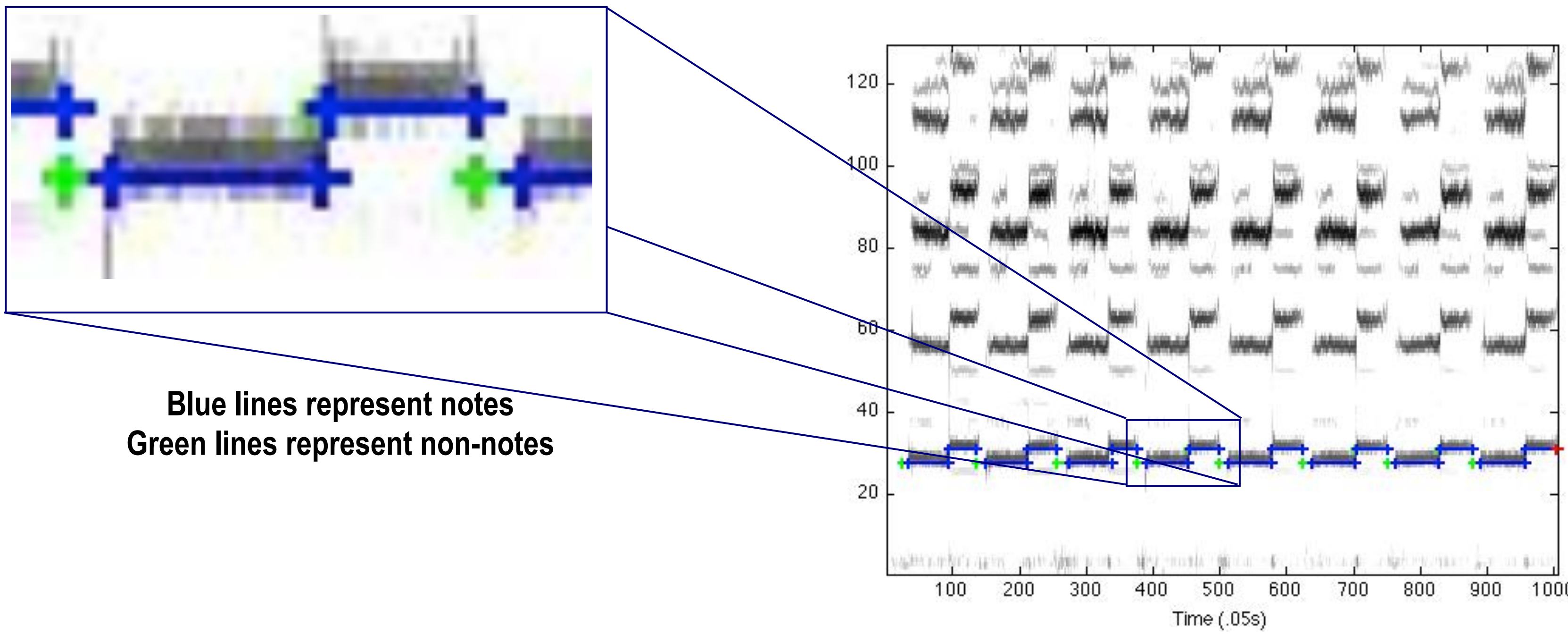
Audio Onset Detection

Sonic Visualiser



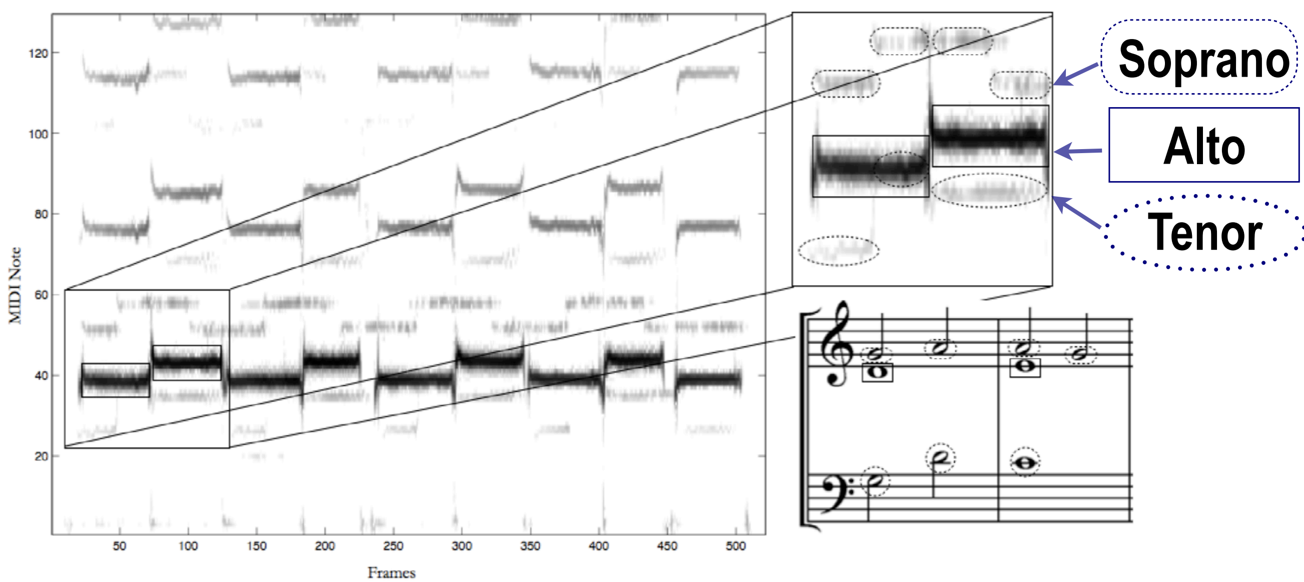
Identifying Note Onsets and Offsets

Using MIDI-audio alignment



F_0 Estimation

For monophonic or quasi-monophonic recordings

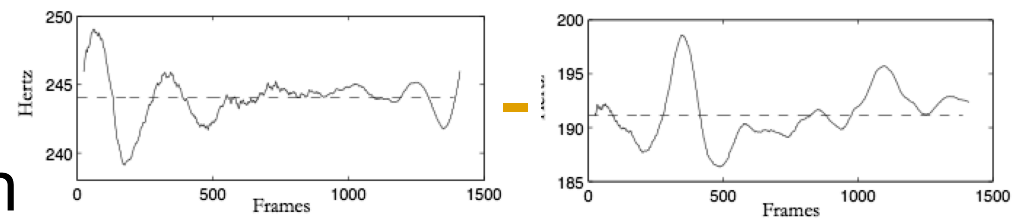


Perceived Pitch

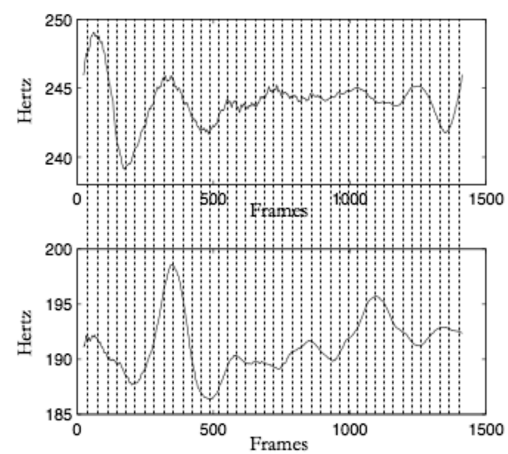
Perceived Pitch and Interval Size Calculation

- Perceived pitch was calculated by taking a weighted mean based on the fundamental frequencies' rate of change, with higher weightings for frames that had a smaller rate of change (Gockel et al. 2001)

- Horizontal interval size was calculated as the difference between two perceived pitch calculations



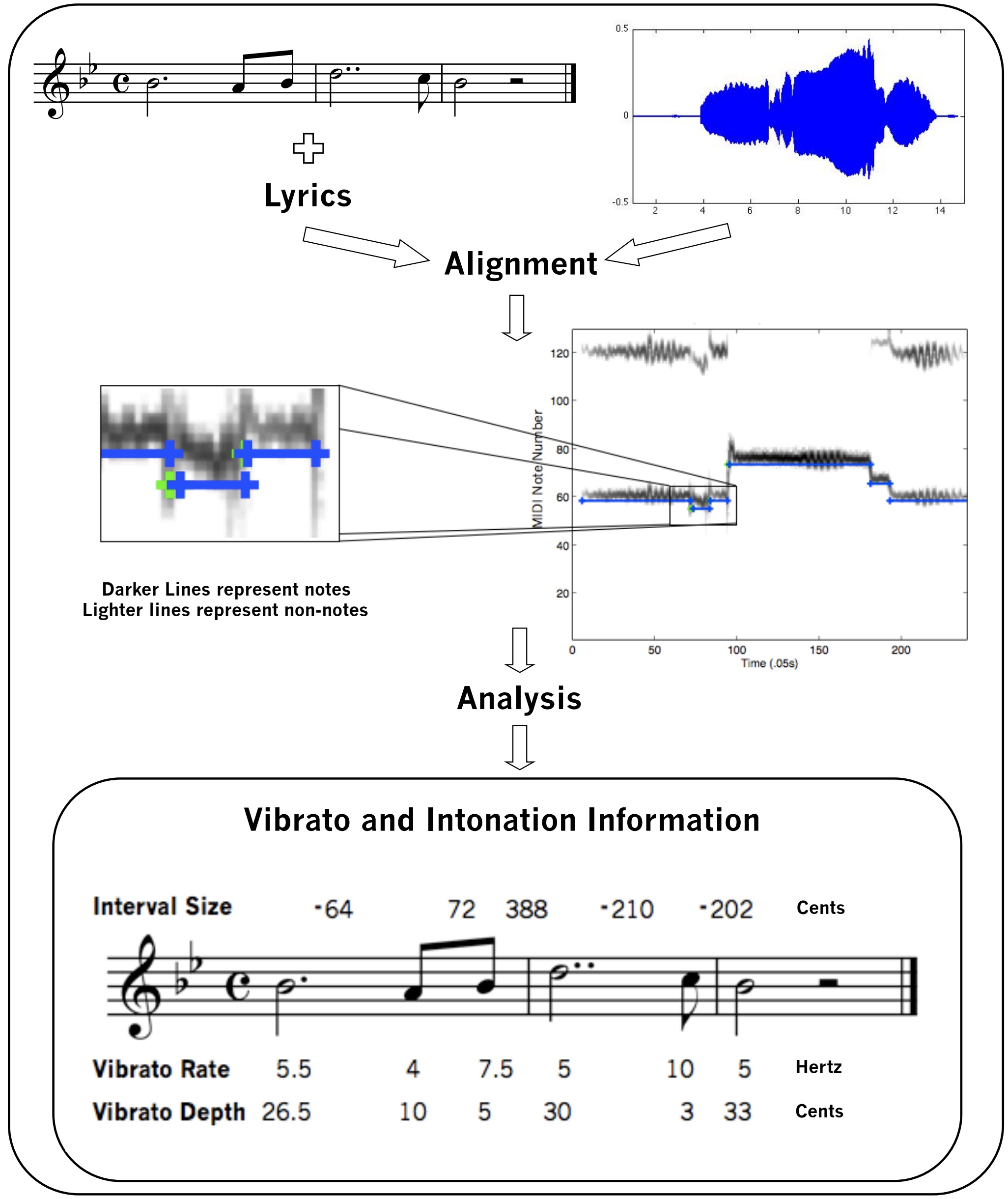
- Vertical interval size was calculated by taking the mean across the difference in F_0 estimates for each frame



AMPACT

Automatic Music Performance and Comparison Toolkit

www.ampact.org



My quantitative research

Studies of intonation in the singing voice.

3

Extracting Performance Data

Experiments with Singers

Comparing Performances

Experiments with Performers

Overview

- Intonation in trained singers in the Western tradition
- Solo and small ensemble (2-4 voices)
- Various aspect of the work was done in collaboration with Dan Ellis (Columbia), Jason Hockman (McGill), Ichiro Fujinaga (McGill), Michael Mandel (Ohio State), Peter Schubert (McGill), and Jon Wild (McGill)

Experiments with Performers

Why study the singing voice?

- In its most basic form singing is innate and universal
    - Training and enculturation refine specific practices of singing
- The voice is one of the most expressive instruments
- Singing research is complementary to speech research

Prior Findings on Vocal Intonation

- **Schoen (1922) – accompanied solo singers**
  - less sharp when descending than when ascending
- **Prame (1997) – accompanied solo singers**
  - intonation deviated substantially, but not consistently, from equal temperament
- **Jers and Terström (2005) – 16-voice ensemble**
  - showed greater amount of intonation dispersion at the faster tempo ascending intervals were larger than descending intervals

Prior Findings on Vocal Intonation

- **Vurma and Ross (2006) – solo singers**
  - ascending/descending semitones smaller than EQT
  - ascending/descending tritones and fifths larger than than EQT
- **Howard (2007a, 2007b) – a cappella quartets**
  - used non-equal temperament with a tendency toward, though not full compliance with, Just Intonation
- **Vurma (2010) – 2-part singing against a synthesized lower voice**
  - found that singers' intonation did not change significantly when the synthesized voice was detuned

Recording Set-Up

- **Rooms**
  - Critical Listening Lab in CIRMMT
  - St Mathias Church, Westmount

- **Microphones**
  - Solo singers and the whole ensembles were recorded with a pair of cardioid microphone
  - Each ensemble singer was miked with a cardioid headband mic

- **Recording Equipment**
  - Lab: Mac Pro
  - Church: portable 16-track recorder

Solo Singing

Overview

- **Schubert's "Ave Maria"**
  - 3x a cappella & 3x accompanied
- **12 solo singers**
  - 6 non-professional singers: undergraduate vocal majors
  - 6 professional singers: possess at least one graduate-level degree in voice performance
- **Melodic semitones and whole tones analyzed**

Devaney, Mandel, Ellis and Fujinaga (2011)
Devaney, Wild, and Fujinaga (2011)

Solo Singing

Significant trends

- **TUNING SYSTEMS**
  - No strict adherence, on average smaller than equal temperament (more so for semitones than whole tones)
- **DIRECTION**:
  - Ascending semitones were 7–8 cents larger on average than descending semitones
- **EFFECT OF TRAINING**
  - Pros more consistent with one another
  - Pros semitones were 6 cents larger on average
  - Non-pros tended to compress leading tones
  - Non-pros’ accompanied semitones were 3 cents larger than a cappella semitones

Three-Part Singing

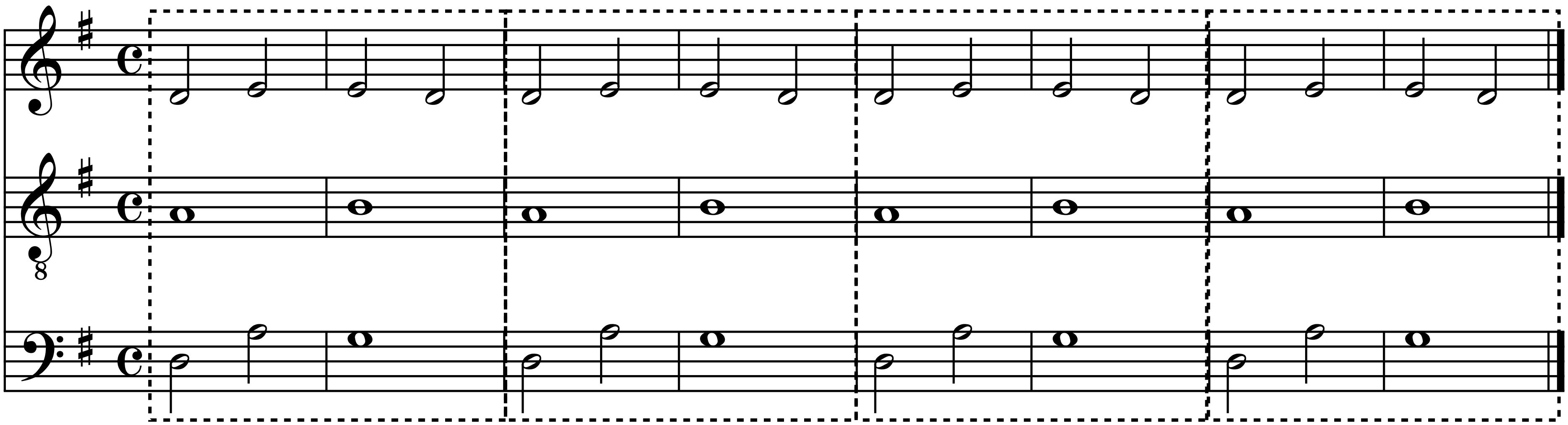
Overview

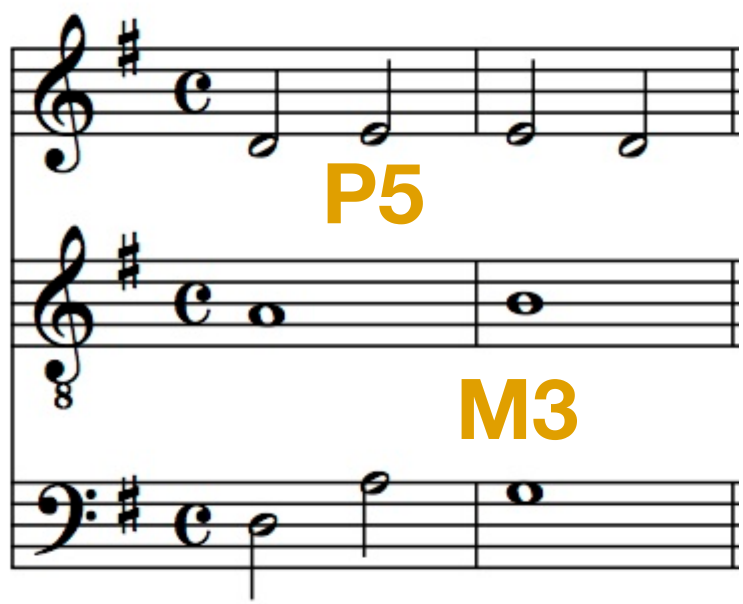
- **Chord progression by Giambattista Benedetti**
- **4 ensembles**
  - Ensemble 1 (lab): semi-professional alto, tenor, and bass singers who performed without a conductor - *pilot*
  - Ensemble 2 (lab): professional alto, tenor, and bass singers who performed with a conductor
  - Ensemble 3 (church): professional soprano, alto, and tenor singers who performed with a conductor
  - Ensemble 4 (church) professional alto, tenor, and bass singers who performed with a conductor
- **Melodic whole tones in regards to vertical M3 and P5 contexts**

Devaney, Mandel, and Fujinaga (2012)

Three-Part Singing

Exercises

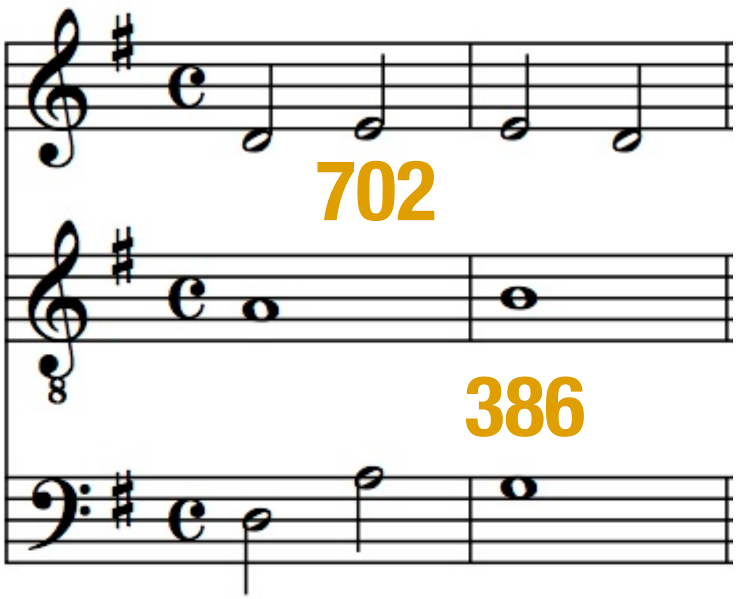




Three-Part Singing

Significant trends

- **TUNING SYSTEMS:** No strict adherence, generally closer to equal temperament
- **DIRECTION:** not significant
- **VERTICAL INTERVAL CONTEXT:** melodic whole tones sung over a P5 were 15 cents larger on average than those sung over a M3



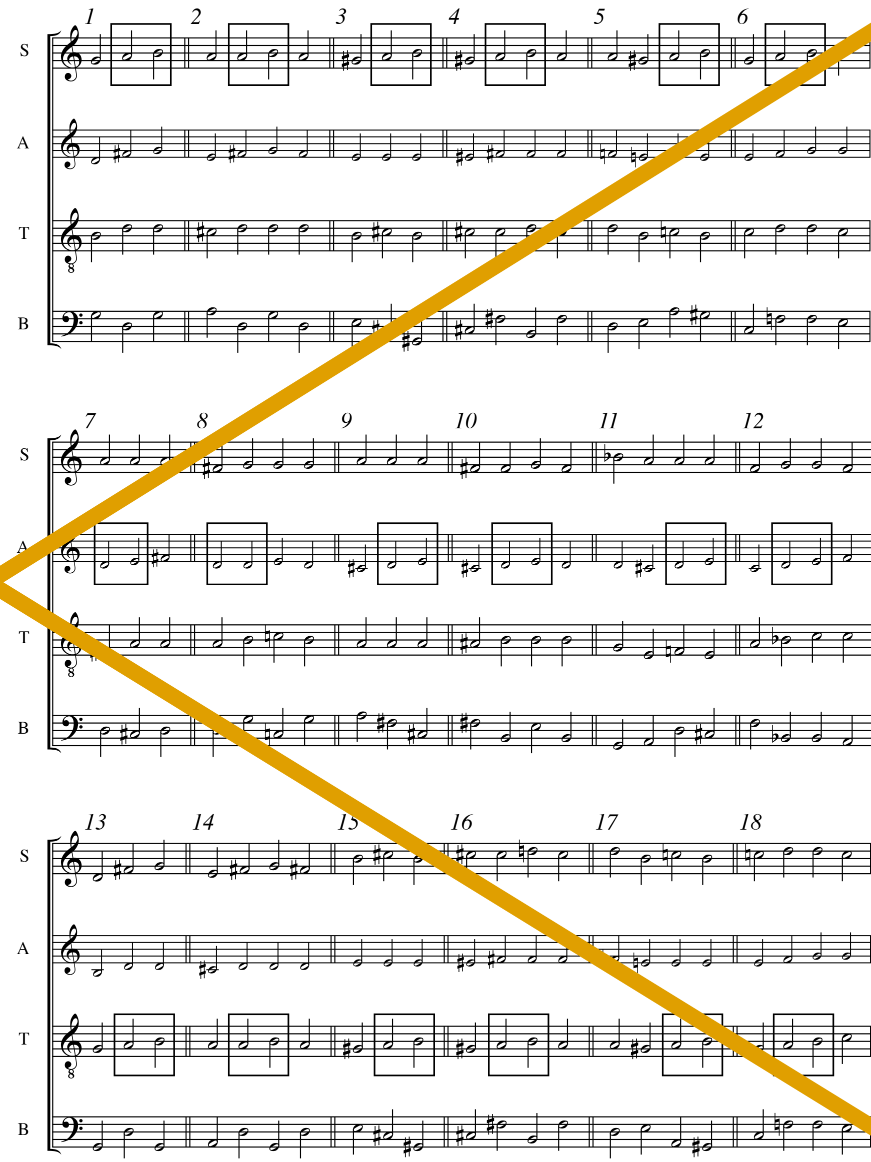
Four-Part Singing

Overview

- **Exercises composed by Jonathan Wild and Peter Schubert**
- **3 ensembles**
  - Ensemble 1 (lab): semi-professional SATB ensemble who performed without a conductor - *pilot*
  - Ensemble 2 (lab): professional SATB ensemble who performed with a conductor
  - Ensemble 3 (church): professional SATB ensemble who performed with a conductor
- **Melodic semitones and whole tones in regards to vertical contexts**

Four-Part Singing

Exercises by Wild and Schubert



Four-Part Singing

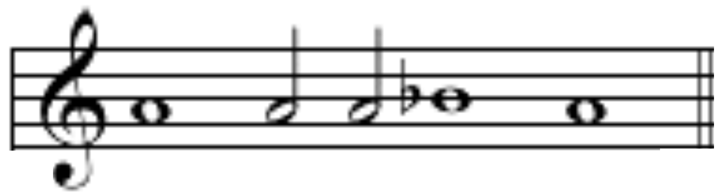
Praetorius - Es ist ein Ros' ent sprungen

vertical intervals in cadential contexts were significantly closer to Just Intonation than those in non-cadential contexts

Two-Part Singing

Overview

- **Semitone pattern sung a sung against a recorded version of the lower-line that was detuned in various ways at two pitch heights**



- **6 of 12 subjects *(analysis of remaining 6 subjects ongoing)***
  - 3 non-professional: amateur singers
  - 3 professionals: possess at least one graduate-level degree in voice performance
- **Melodic whole tones in regards to vertical m3, TT, P5, m6, and P8 contexts**

Two-Part Singing

Tuning systems

Just Intonation

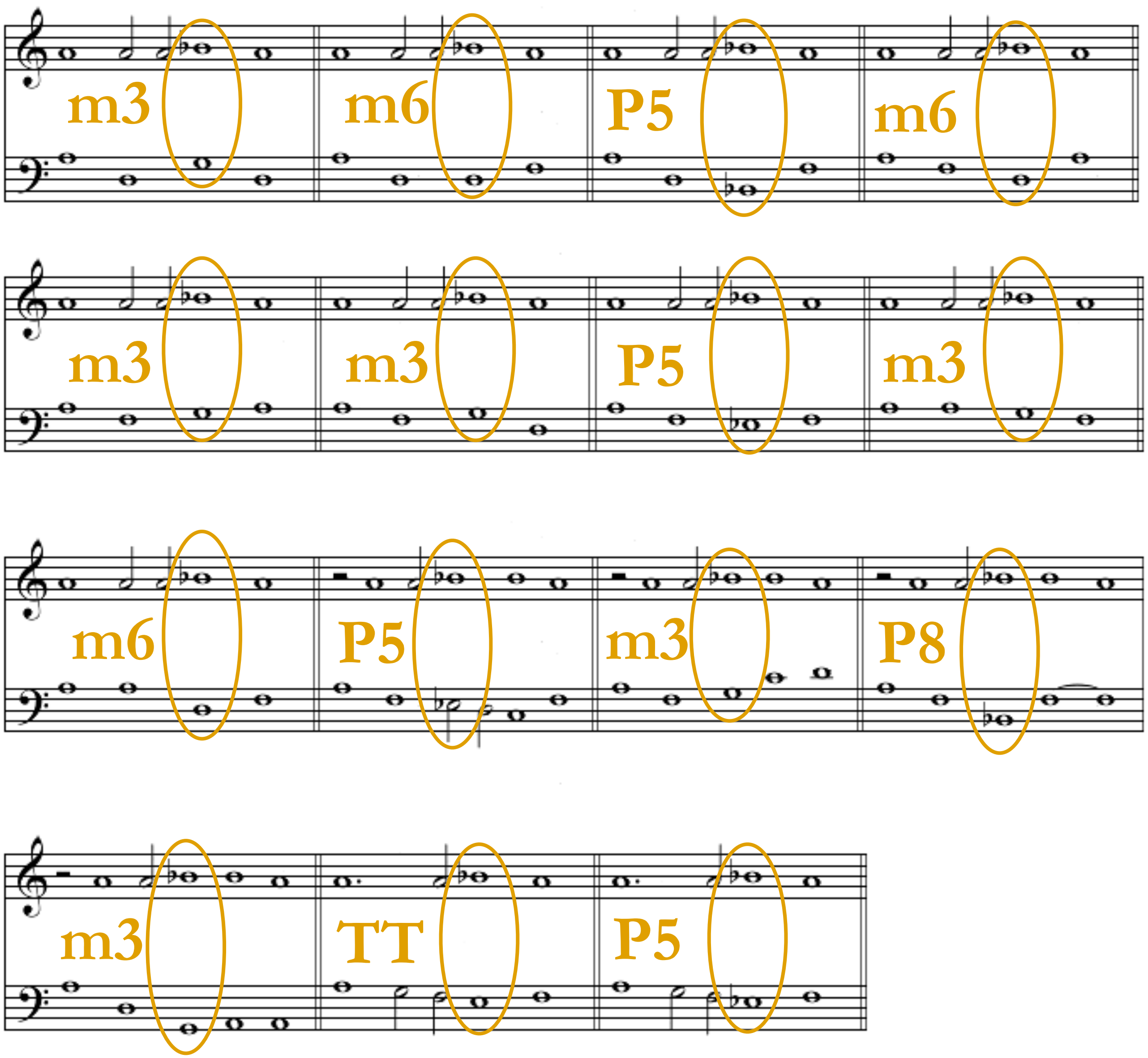
1	**D** -2	**G** -4	**D** -2		
2	**D** -2	**D** -2	**F** 14		
3	**D** -2	**Bb** 12	**F** 14		
4	**F** 14	**D** -2	**A** 0		
5	**F** 14	**G** 18	**A** 0		
6	**F** 14	**G** 18	**D** 20		
7	**F** -8	**Eb** -12	**F** -8		
8	**A** 0	**G** -4	**F** -8		
9	**A** 0	**D** -2	**F** -8		
10	**F** 14	**Eb** 10	**D** -2	**C** 16	**F** 14
11	**F** -8	**G** -4	**C** -6	**D** -2	
12	**F** -8	**Bb** -10	**F** -8		
13	**D** 20	**G** 18	**A** 22	**A** 22	
14	**G** -4	**F** -8	**E** 2	**F** -8	
15	**G** -4	**F** -8	**Eb** -12	**F** -8	

Modified Just Intonation

1	**D** -2	**G** 18	**D** 20		
2	**D** -2	**D** -25	**F** -8		
3	**D** -2	**Bb** -10	**F** -8		
4	**F** 14	**D** 20	**A** 22		
5	**F** -8	**G** -4	**A** -23		
6	**F** -8	**G** -27	**D** -25		
7	**F** 14	**Eb** 33	**F** 14		
8	**A** 0	**G** 18	**F** 37		
9	**A** 22	**D** 20	**F** 14		
10	**F** -8	**Eb** -12	**D** -2	**C** -6	**F** -8
11	**F** 14	**G** 18	**C** 16	**D** 20	
12	**F** 14	**Bb** 12	**F** 14		
13	**D**	**G** -27	**A** -23	**A** -23	
14	**G** 18	**F** 14	**E** 2	**F** 14	
15	**G** 18	**F** 14	**Eb** 10	**F** 14	

Two-Part Singing

Exercises



Two-Part Singing

Significant trends

- **TUNINGS SYSTEM:** No strict adherence, on average smaller than equal temperament
- **DIRECTION:** Ascending semitones were on average 21 cents larger on average than descending semitones
- **EFFECT OF TRAINING:** Non-pros' semitones were on average 17 cents on average smaller than pros' semitones
- **DETUNING:** not significant
- **VERTICAL INTERVAL CONTEXT:** Semitones sung a perfect octave above the lower voice were 7 cents larger on average than those sung above other intervals there were no significant differences for other intervals

Summary of Results

Solo vs. ensemble singing

- A general trend of ascending intervals being larger than descending intervals was found in both solo and ensemble singing
  - Also observed by Schoen (solo) and Jers and Ternstrom (ensemble)
- Results are variable for influence of specific vertical intervals on melodic intonation
- 3-part experiment – melodic intervals sung over a P5 versus M3 showed a significant difference
- 2-part experiment – melodic intervals only showed a significant difference when sung over a P8
- Detuning of accompaniment did not influence melodic intonation in the short exercises studied

Summary of Results

Comparison to earlier work

- **Schoen (1922)**
  - sharper than equal temperament ✗
  - less sharp when descending than when ascending ✓
- **Howard**
  - tendency towards Just Intonation ✗ ✓
- **Vurma and Ross (2006)**
  - ascending/descending semitones smaller than EQT ✓
- **Vurma (2010)**
  - singers' intonation did not change significantly when the synthesized voice was detuned ✓
- **Devaney, Mandel, and Fujinaga (2011)**
  - ascending semitones larger on average ✓
  - non-pros' semitones smaller on average ✓

My quantitative research

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Comparing Performances

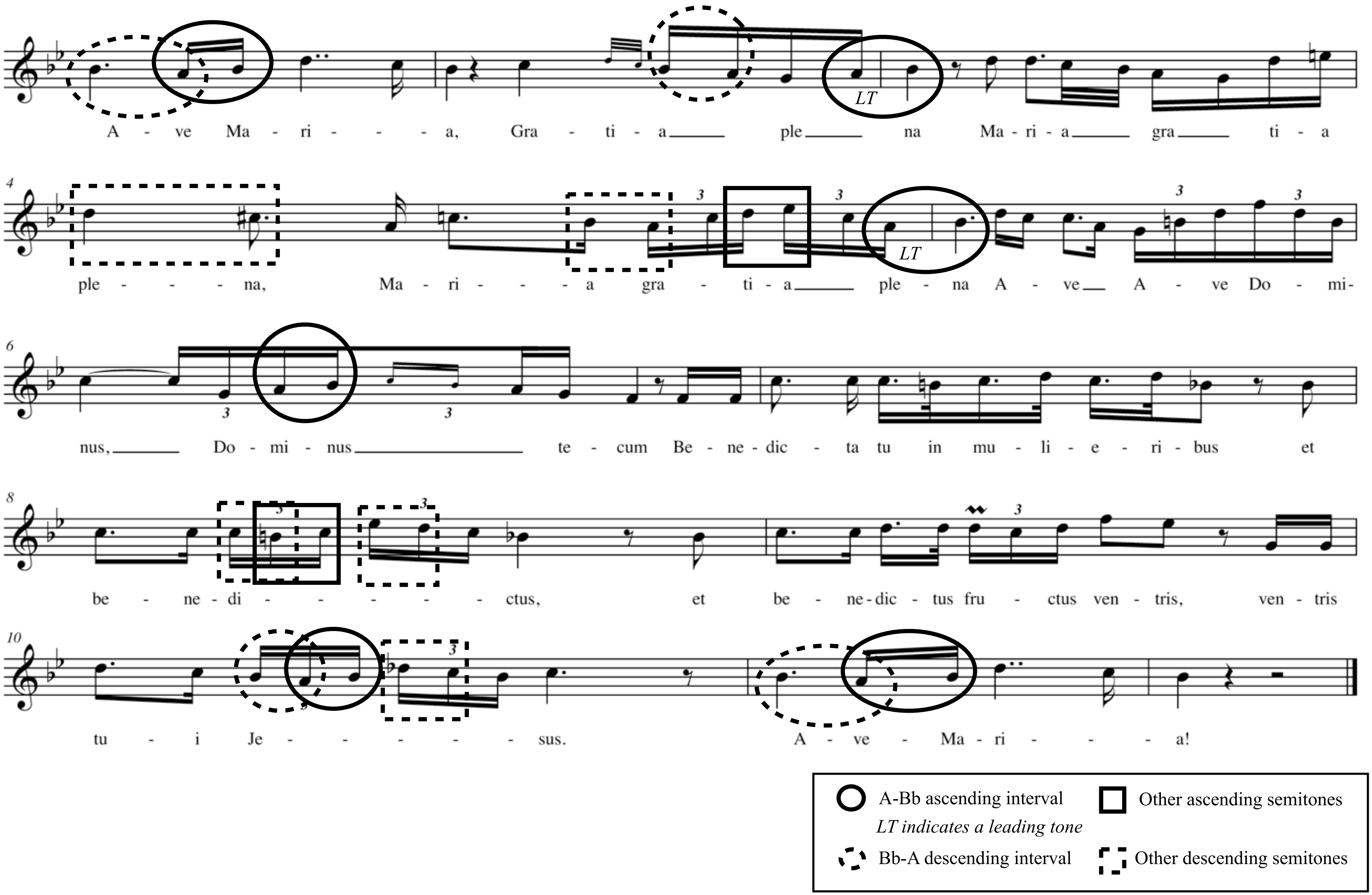
Comparing Performances

Determining which notes to analyze

- **Comparisons both within and across pieces require an assessment of which aspects of different pieces are similar in some dimension**
    - melody
    - rhythm
    - harmony
    - structural importance

Manual Approach

Semitones in Schubert's Ave Maria



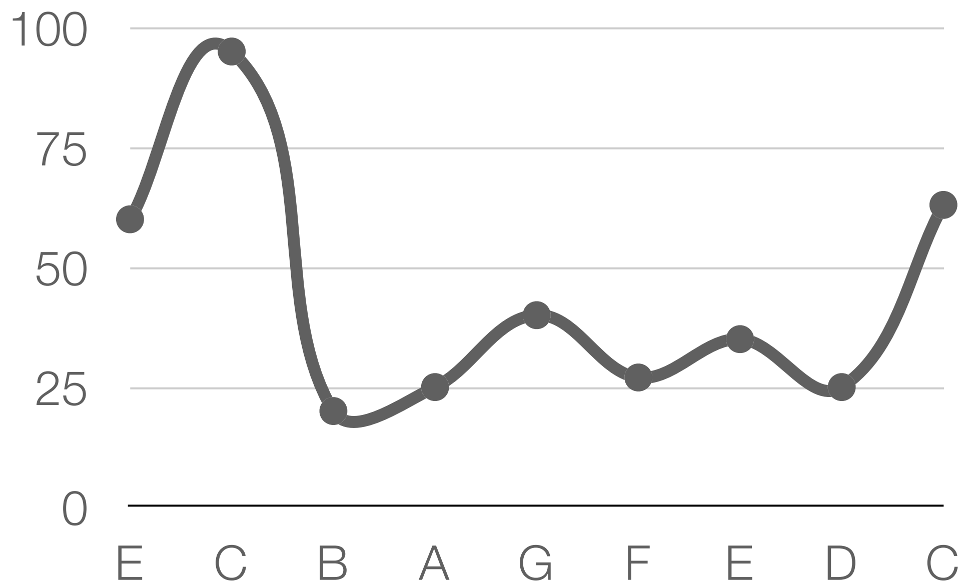
Computational Approach

Representing Symbolic Music

- **Need a symbolic representation that**
  - provides an estimate of which notes are structurally significant
  - works for a range of musical textures
  - captures temporal relationships
  - facilitates the analysis of multiple levels of musical structure

Computational Approach

What might such a representation look like?

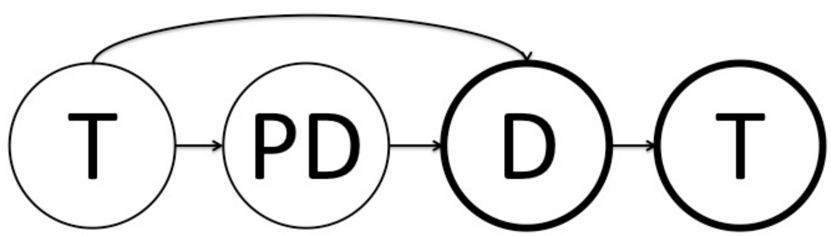


Computational Approach

Developing a “language model” for music

Functional harmonic analysis may be flawed but it can be useful

A model of phrase-level function and its relationship to roman numeral labels can be used as a “language model”



Bridging Quantitative and Qualitative

Analyzing Performance Data

- **Variability in production**
  - Perceptual limens
  - Limitations of instrument
  - Internal versus external consistency
  - Performer intention
    - focus on particular parameters
    - “loose” versus “tight”

Bridging Quantitative and Qualitative

Contextualizing performances

- **Social aspects of performance**
  - inter-performer interaction
    - verbalizable assessments versus what is observable in performance parameters
  - interaction between performer and audience (real or imagined)
    - stated intentions versus measured variations across performances of the same piece

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Summary

Where we have been

Future Work

Where we are (or at least I am) going

Acknowledgements

- School of Music and College of Arts and Sciences (OSU)
- Center for New Music and Audio Technologies (CNMAT)
- Distributed Digital Music Archives and Libraries (DDMAL)
- Centre for Research in Music Media and Technology (CIRMMT)
- Fonds de recherche sur la société et la culture (FQRSC)
- Social Sciences and Humanities Research Council of Canada (SSHRC)
- Advancing Interdisciplinary Research in Singing (AIRS)

Thank you!

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