

A STUDY OF INTONATION TENDENCIES OF SOLO VERSUS ENSEMBLE SINGING

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Introduction

Prior Work on Solo Intonation

Automatically Extracting Intonation Data

Empirical Evaluation of Solo and Ensemble Singing

Comparison of Intonation in Solo
and Ensemble Singing

Conclusions and Future Work

Introduction

- This talk focuses on my work on intonation in trained singers in the Western tradition
- Summarises earlier work on solo intonation
- Discusses the result of more recent experiments on ensemble singing
- interaction between melodic and vertical intonation tendencies
- 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)

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Prior Work on Intonation

- Schoen (1922) studied accompanied professional singers
 - sharper than equal temperament
 - ascending intervals were larger than descending intervals
- Prame (1997) studied accompanied professional singers
 - deviated substantially, though not consistently, from equal temperament
- Jers and Terström (2005) studied a 16-voice ensemble
 - showed greater amount of intonation dispersion at the faster tempo
 - ascending intervals were larger than descending intervals

Prior Work on Intonation

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

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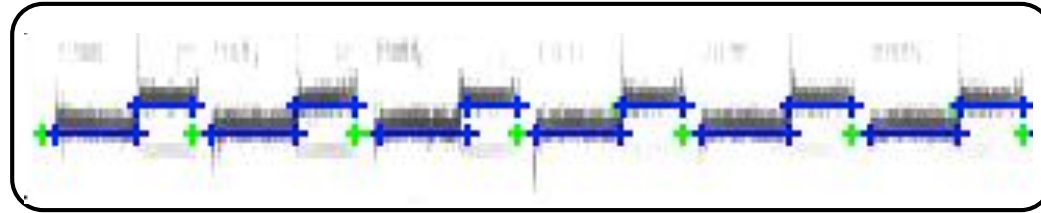
Empirical Evaluation of Solo and Ensemble Singing

Comparison of Intonation in Solo and Ensemble Singing

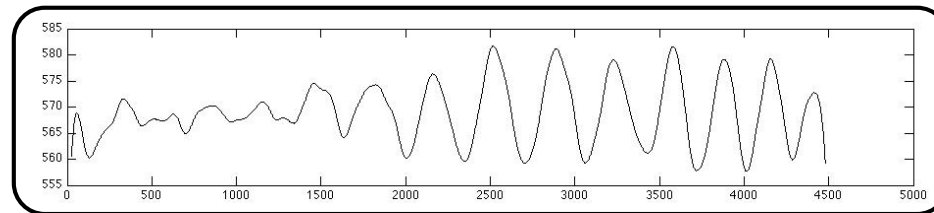
Conclusions and Future Work

Extracting Performance Data

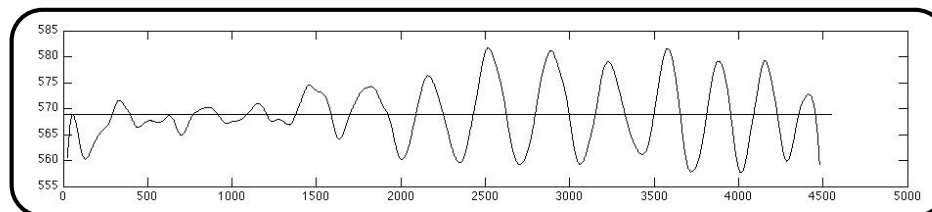
Identify Note Onsets and Offsets



Fundamental Frequency (Fo) Estimation



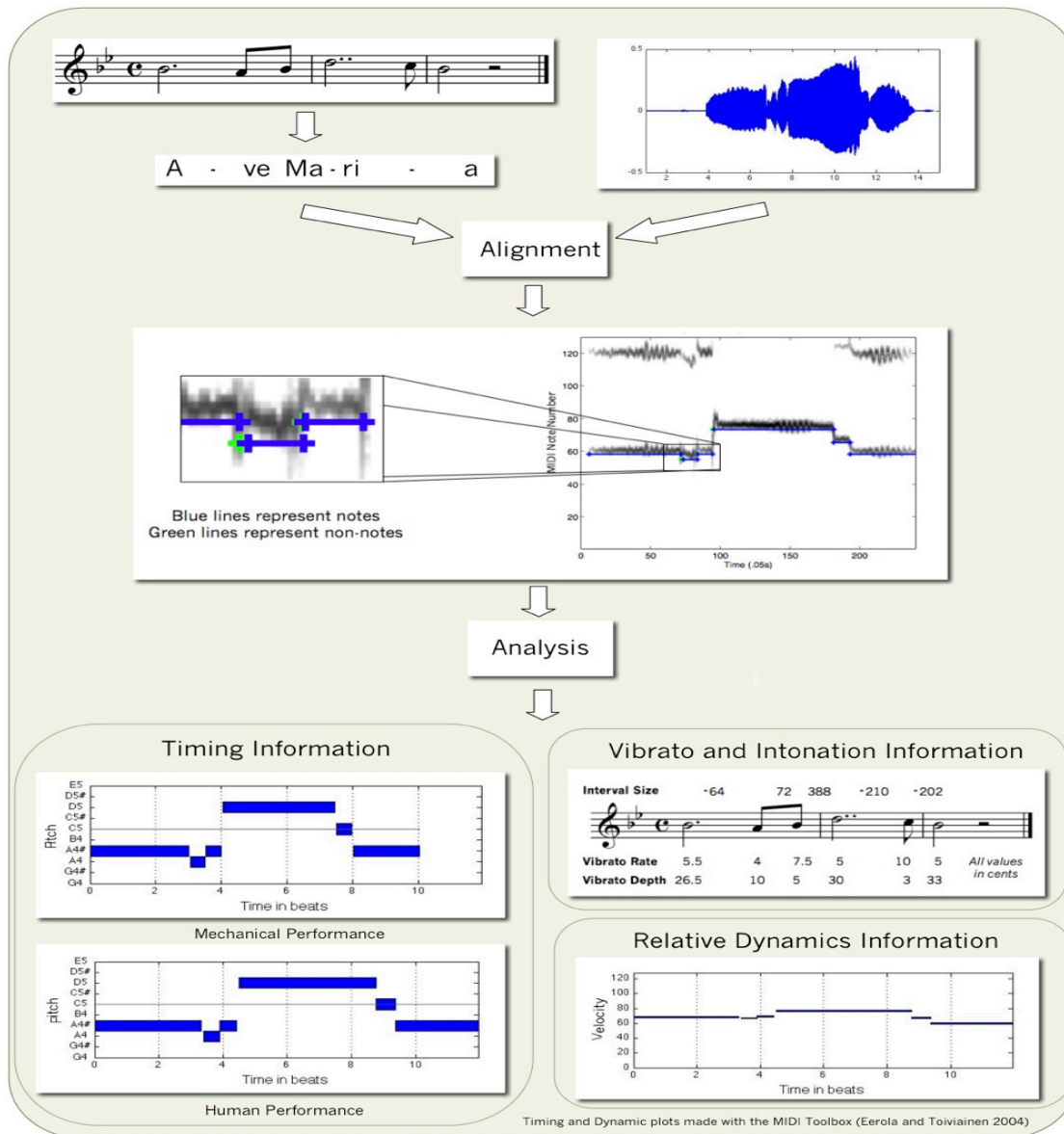
Perceived Pitch



Older Approaches

- Annotation of note onsets and offsets done manually
- Manual pitch extraction
 - phono-photographic apparatus
 - computer-generated spectrographic representations of the audio
- Automatic fundamental frequency estimation
 - electroglottograph
 - PRAAT (Boersma 2001)
 - YIN (de Cheveigné and Kawahara 2002)

Automatic Music Performance Analysis and Comparison Toolkit (ampact.org)



MIDI-audio alignment
(Devaney, Mandel and Ellis 2009)

F₀ estimation
(de Cheveigné and Kawahara 2002)

Perceived pitch estimation
(Gockel et al. 2001)

Loudness estimation
(Glasberg and Moore 2002)

Devaney, Mandel, and Fujinaga (2012)

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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 subjects
 - 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 analysed

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 ones
- EFFECT OF TRAINING
 - Pro singers were more consistent with one another in their intonation than non-professionals
 - Pro singers' semitones were 6 cents larger on average than non-pro singers' semitones
 - Non-pro singers tended to compress leading tones, pro singers did not
 - **Non-pro singers' accompanied semitones were 3 cents larger than *a cappella* ones**

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: Exercise

Three-Part Singing: Exercise

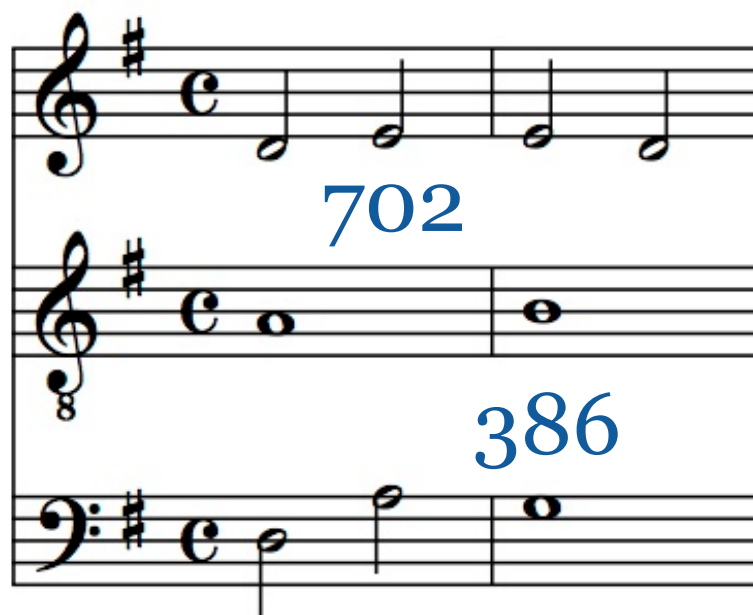
P5

M3



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

Devaney, Mandel, and Fujinaga (2012)

Exercises by Wild and Schubert



1 2 3 4 5 6

S

A

T

B



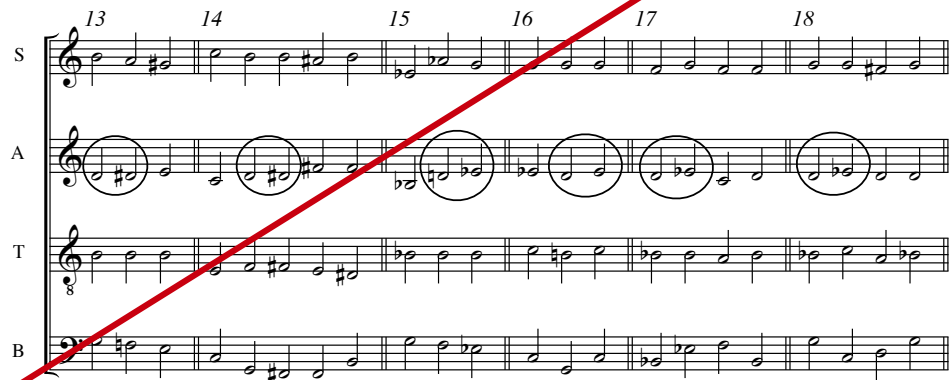
7 8 9 10 11 12

S

A

T

B



13 14 15 16 17 18

S

A

T

B



1 2 3 4 5 6

S

A

T

B



7 8 9 10 11 12

S

A

T

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13 14 15 16 17 18

S

A

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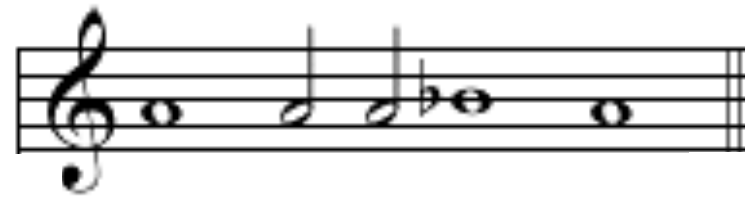
Praetorius - Es ist ein Ros' ent sprungen

The image displays a musical score for four voices (Soprano, Alto, Tenor, Bass) in a four-part setting of 'Es ist ein Ros' ent sprungen' by Michael Praetorius. The score is divided into three systems, each containing four staves. The first system is marked with a '7' above the Soprano staff, and the third system is marked with a '13' above the Soprano staff. Vertical intervals are highlighted with solid black boxes, and cadential contexts are indicated by dashed lines. The intervals are labeled as V (Dominant) and vi (Submediant) in the first system, and V (Dominant) and I (Tonic) in the second and third systems. The score is written in a key signature of one flat (B-flat) and a common time signature (C).

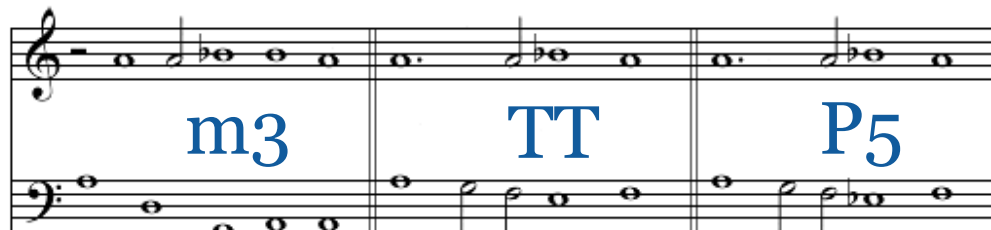
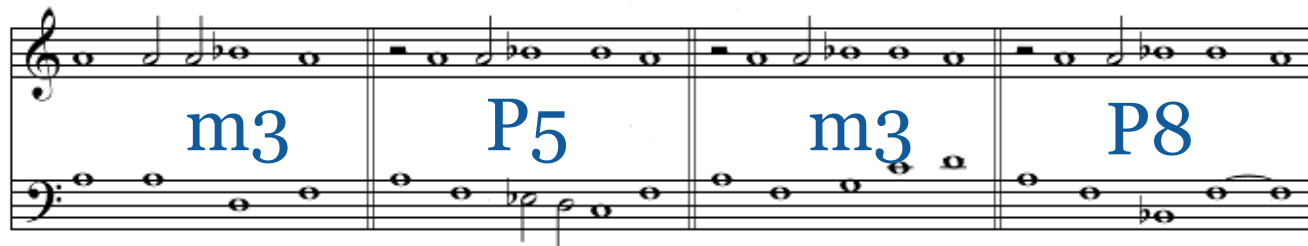
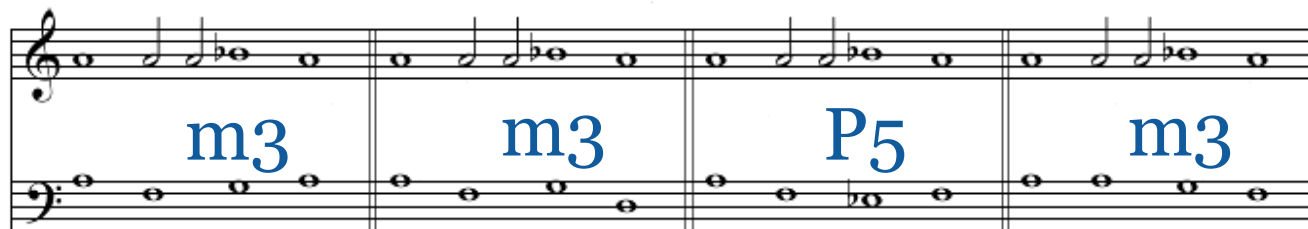
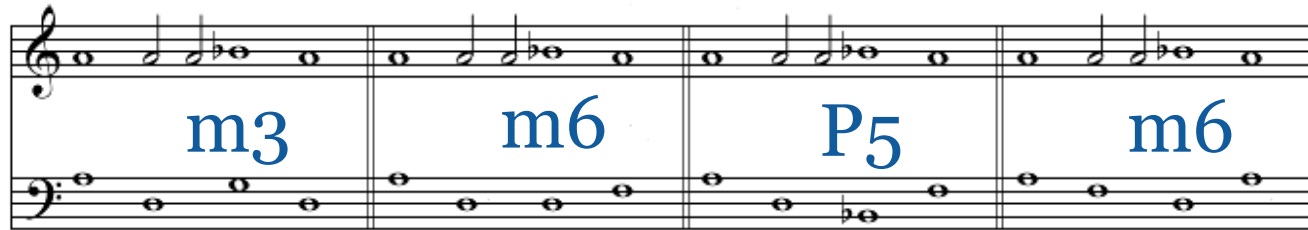
vertical intervals in
cadential contexts were
significantly closer to Just
Intonation than those in
non-cadential contexts

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 (*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: 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*

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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

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- The observed trends suggest that there *may be* an influence of vertical intervals on melodic intonation, but this is likely limited to those intervals with a greater coincidence of partials
- More experiment are needed
 - Longer exercises
 - More voices
 - Detailed instructions about tuning reference

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