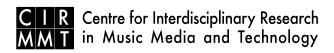
## **Empirical evaluation of intonation** practices in singers and their relationship to musical context

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Social Sciences and Humanities Research Council of Canada

Conseil de recherches en sciences humaines du Canada







Extraction of intonation data from recordings



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Preliminary results from experiments on solo singers and vocal ensembles



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Open questions

- The question of which tuning system is used by singers has been debated since the Renaissance
  - Empirical evaluations have shown that singers do not sing in any fixed tuning system (Howard 2007a, 2007b; Prame 1997)
- In order to make generalizations about what singers are doing requires the examination of a large number of performances
- This talk presents some work I have undertaken with Ichiro Fujinaga (McGill University), Dan Ellis (Columbia University), and Michael Mandel (University of Montreal)

### **Extraction of Intonation Data**

- Labeling of note onsets and offsets in the recording
  - Onset detection techniques work for instruments with percussive onsets, e.g., piano, but generally perform poorly for non-percussive instruments (MIREX Audio Onset Detection, 2007)
  - MIDI/Audio alignment is another option for onset and offset detection
    - This research uses a hybrid dynamic time warping(DTW)/hidden Markov model(HMM) alignment algorithm optimized for the singing voice (Devaney, Mandel, & Ellis 2009)

### **Extraction of Intonation Data**

- Fundamental frequency (F0) estimation for each frame of audio
  - F0 estimation for monophonic signals is a solved problem
  - This research uses the YIN algorithm (de Cheveigné & Kawahara 2002)
- Perceived pitch over the duration of each note
  - Calculated as the geometric mean of the frame-wise F0 estimates (Brown and Vaughn 1996)
- Evolution of F0 over the duration of the note
  - Slope (1st Discrete Cosine Transform Coefficient) whether the singers are gliding up or down into the next note

## Preliminary Results - Solo Singers

- Subjects
  - Six undergraduate sopranos from McGill University
  - Six Montreal-based professional singers (ongoing)
- Task
  - 3 performances of Schubert's 'Ave Maria' a cappella and 3 with recorded accompaniment
- Analysis of singer's self-consistency and intra-singer consistency under various conditions
  - A-Bb a cappella and accompanied
  - Bb-A a cappella and accompanied
  - other semitones ascending a cappella and accompanied
  - other semitone descending a cappella and accompanied



## Preliminary Results - Solo Singers

- Fundamental frequency analysis
  - Weak effects for singer identity and accompaniment
  - No effects were found leading tone function or intervallic direction
- Slope
  - Weak effects for direction, accompaniment, and singer identity
- Overall
  - No observable effects for leading tone function
  - General tendency for small semitones

## Preliminary Results - Vocal Ensembles

- Subjects
  - Professional SATB ensemble (four singers)
- Task
  - Perform a cappella four exercises
    - Exercises were designed to explore
      - potential points of opposition between beat-free tuning of vertical sonorities and melodic intonation tendencies
      - pitch drift

## Preliminary Results - Vocal Ensembles



- Horizontal and vertical intervals tended to be smaller than Equal Temperament and (in some cases) Just-Intonation
  - Amount of variation was singer dependent
- Generally singers glided down in descending intervals and up in ascending intervals
  - Rate of change was singer dependent

## **Open Questions**

- Data Analysis Issues
  - How much variation (in cents) is significant across performances?
  - How to determine what is "typical" intonation and what is "expressive"?
- Research Questions
  - How accurately can singers replicate a tuning?
  - What is the effect of training?
  - What is the effect of absolute pitch?
  - What is the effect of a conductor?
  - What happens when there is more than one singer to a part?

# Thank you!

### References

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