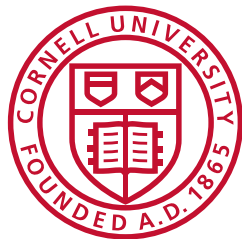


# Musical Information Retrieval

Mark Gotham  
Cambridge, 17 January 2019



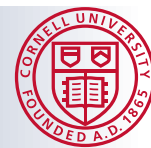
Cornell University

# Talk Contents (you are here ...)

1. Scores: Metrical position usage
2. Audio: 'Attractor tempos'
3. Teaching-led: Species or specious?
4. Teaching Resources: 'Cut outs'

# Talk Contents (you are here ...)

- 1. Scores: Metrical position usage**
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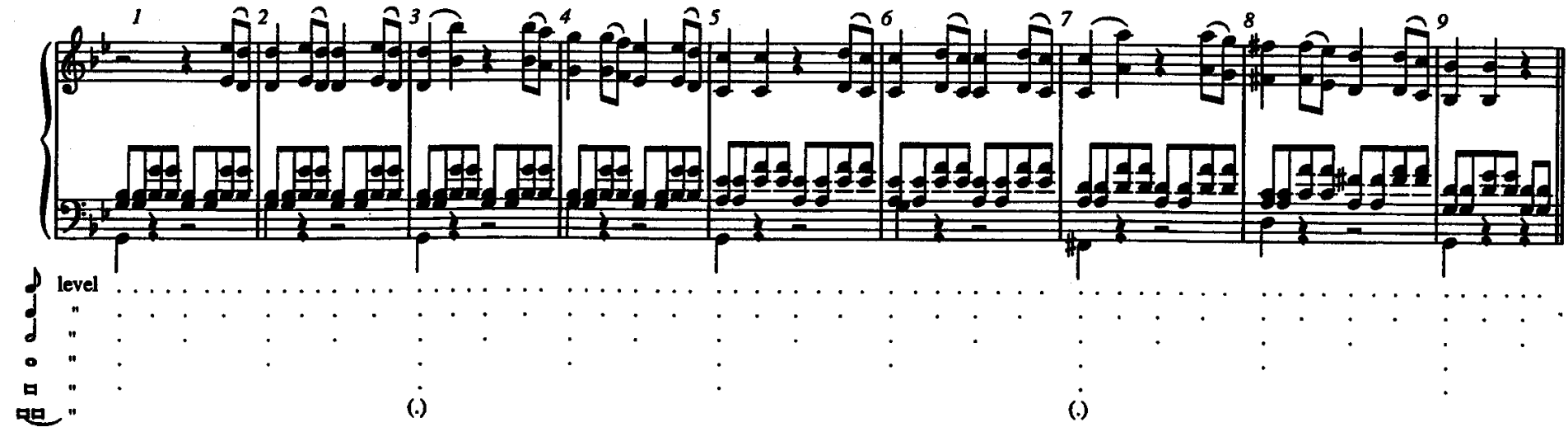
# 1. Scores

## Hierarchies

- ‘Important’ notes / beats

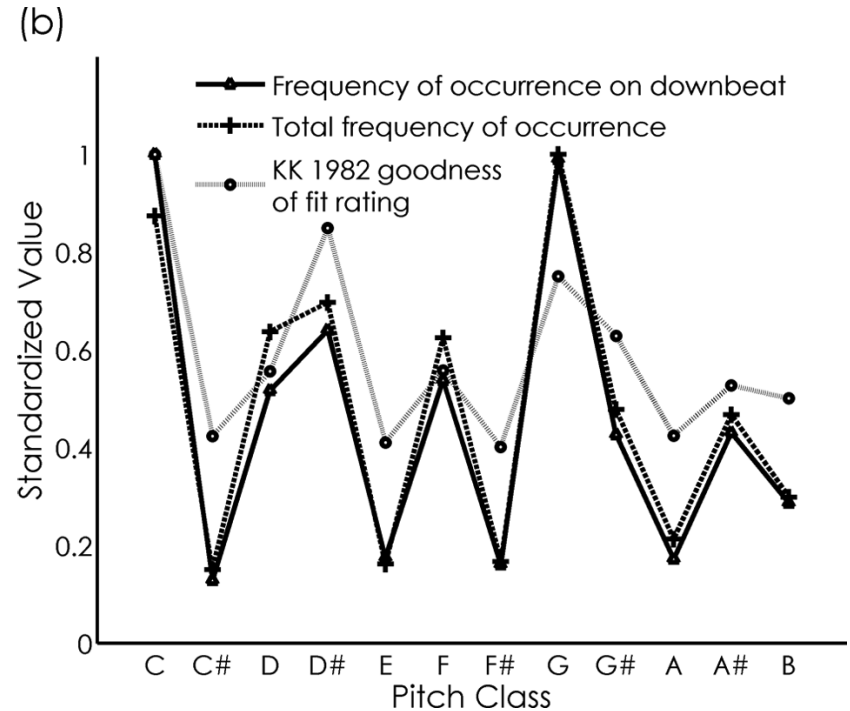
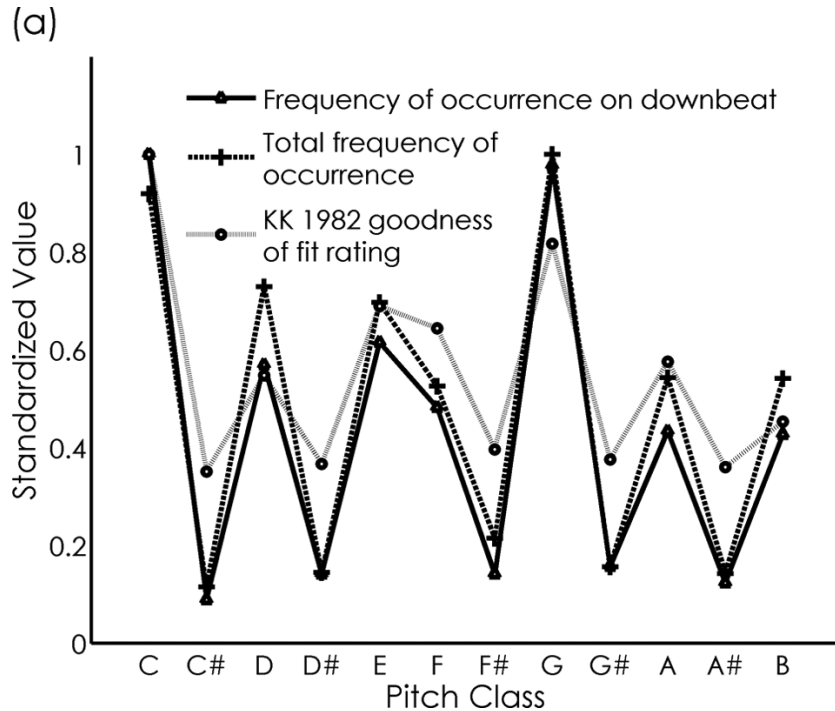
## Assess:

- Perceptual: ‘Goodness of fit’
- Empirical: Extent of usage



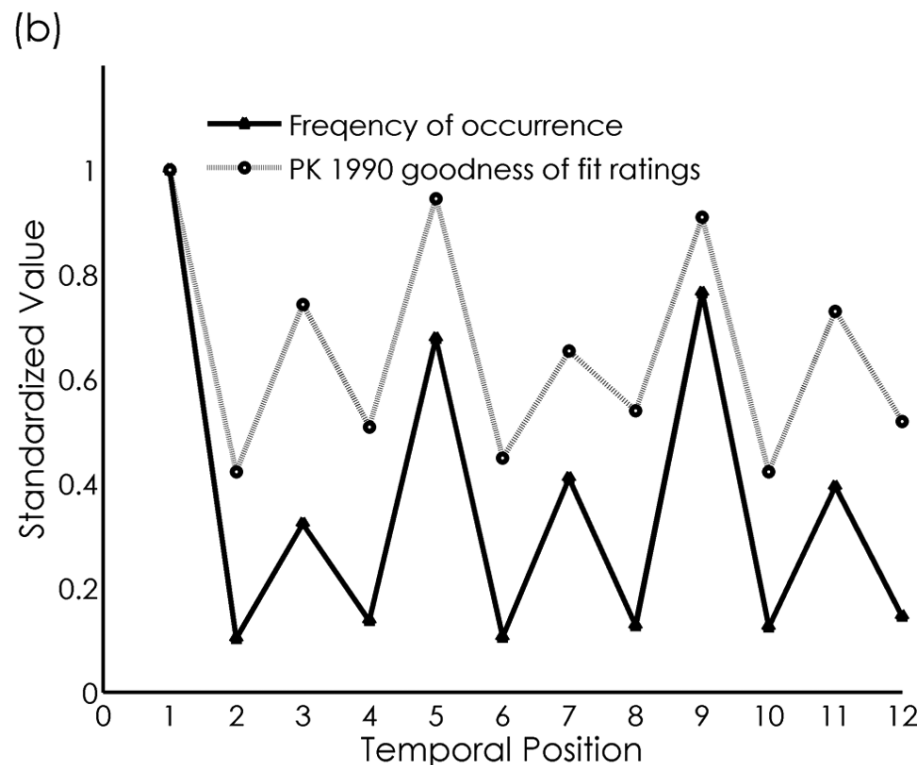
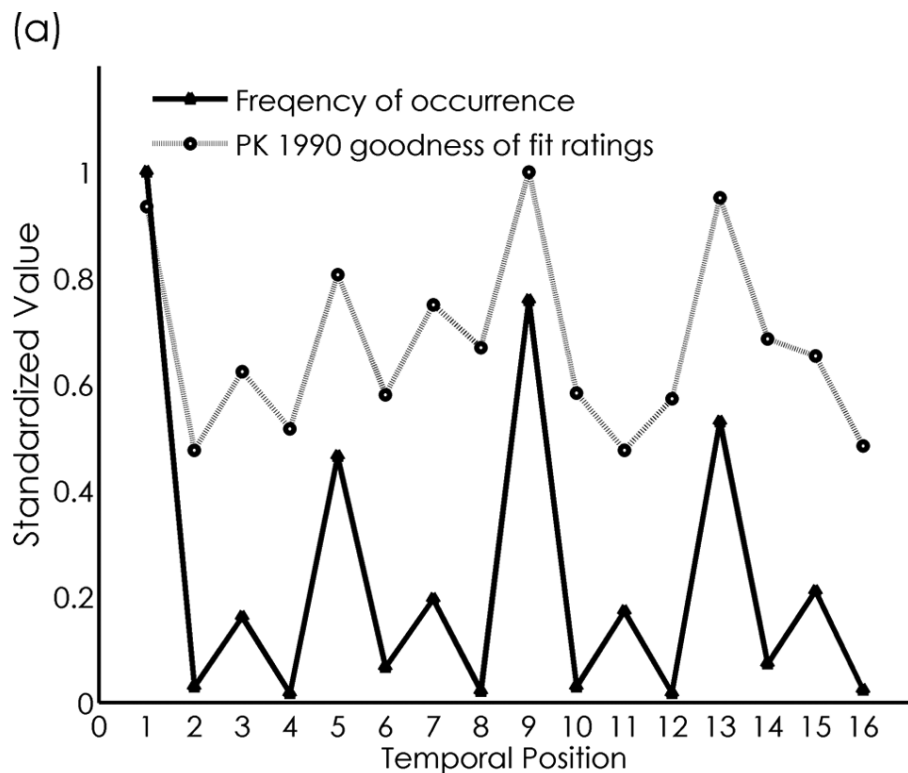
The image displays a musical score for a piano piece, consisting of two staves: a treble clef staff and a bass clef staff. The score is divided into nine measures, each numbered from 1 to 9. The melody in the treble staff features eighth-note patterns with various articulations such as slurs and accents. The bass staff provides a rhythmic accompaniment with chords and single notes. Below the musical notation is a Braille transcription of the score. The Braille is organized into two rows, with the word 'level' written in Braille at the beginning of the first row. The transcription uses Braille characters to represent the notes and rests of the music.

# Tonal hierarchy



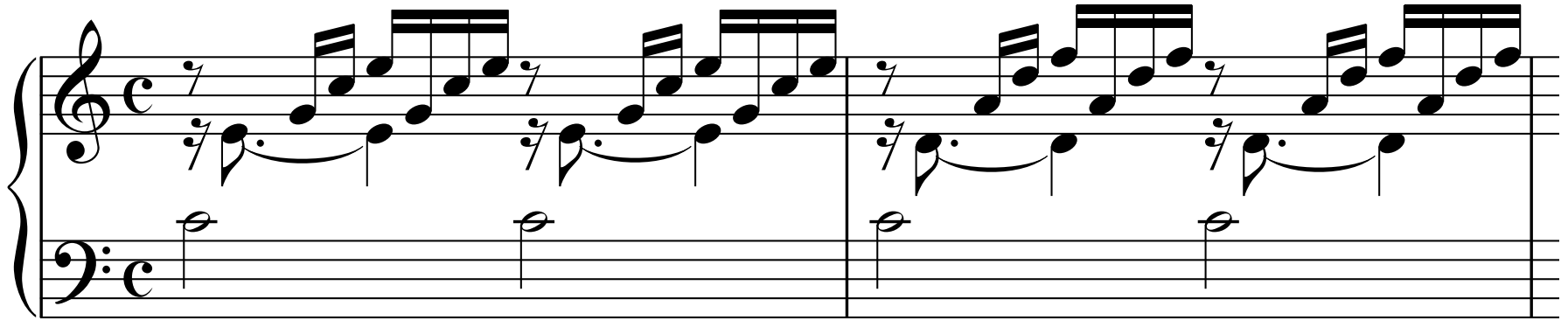
Source: Prince and Schmuckler: 'The Tonal-Metric Hierarchy: A Corpus Analysis' (*Music Perception* 2014). After Kessler and Krumhansl

# Metrical hierarchy

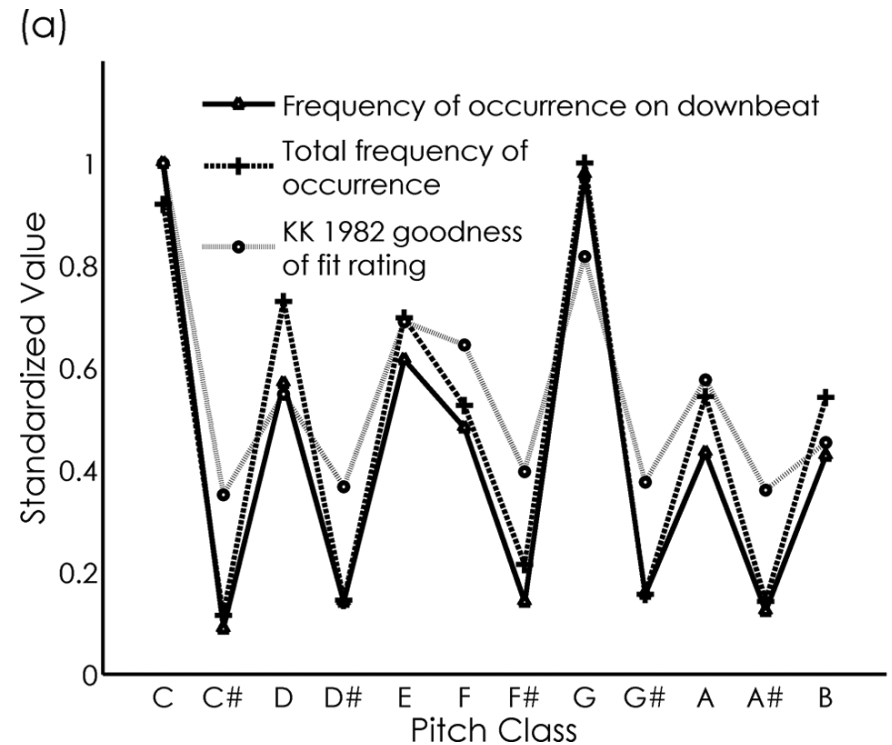
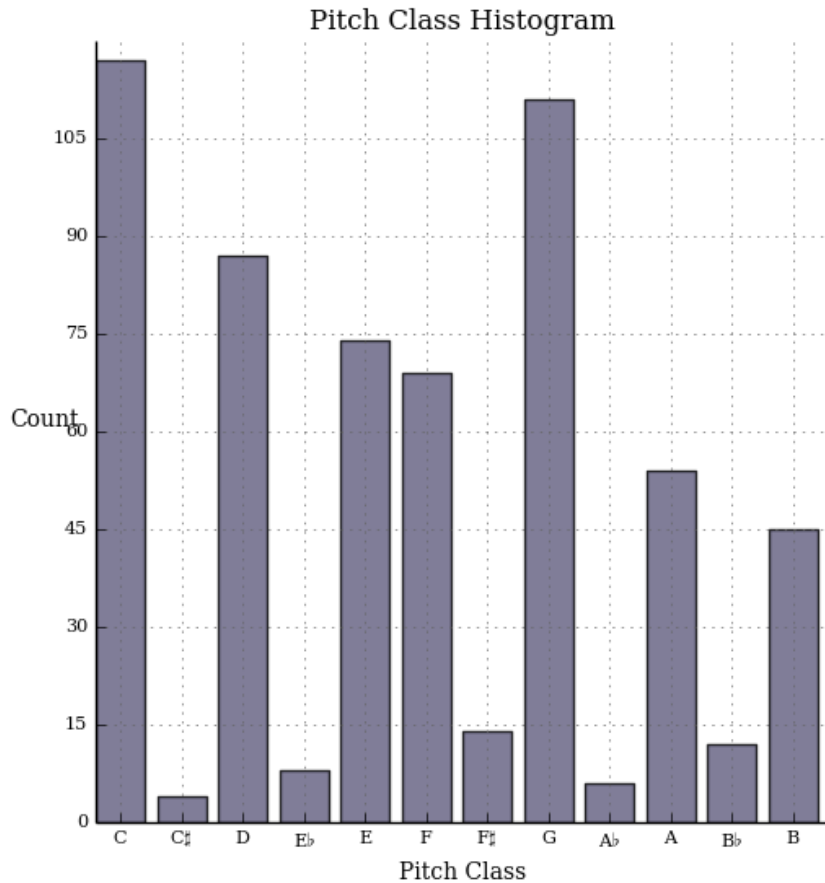


Source: Prince and Schmuckler: 'The Tonal-Metric Hierarchy: A Corpus Analysis' (*Music Perception* 2014). After Palmer and Krumhansl

# Example case: BWV 846



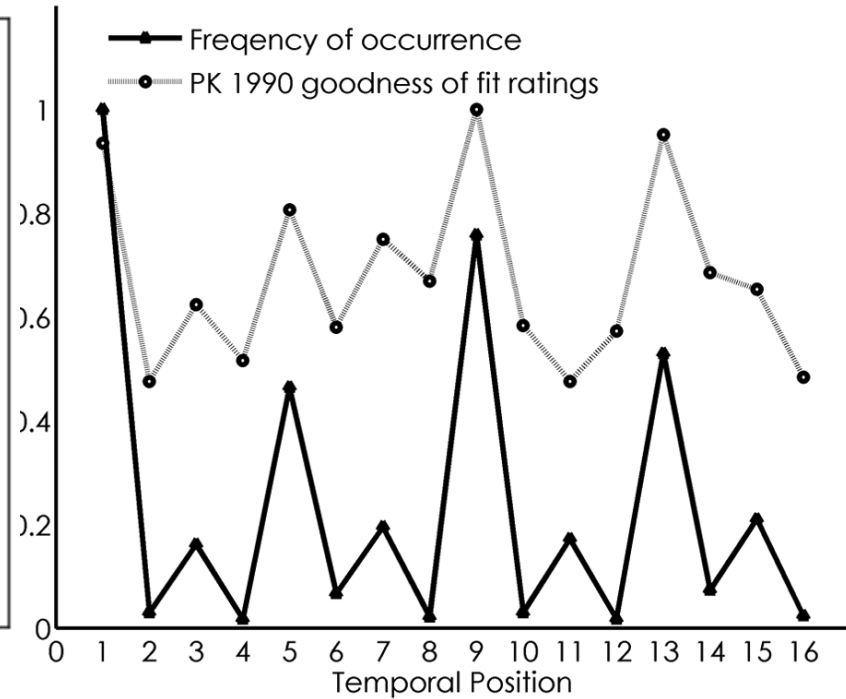
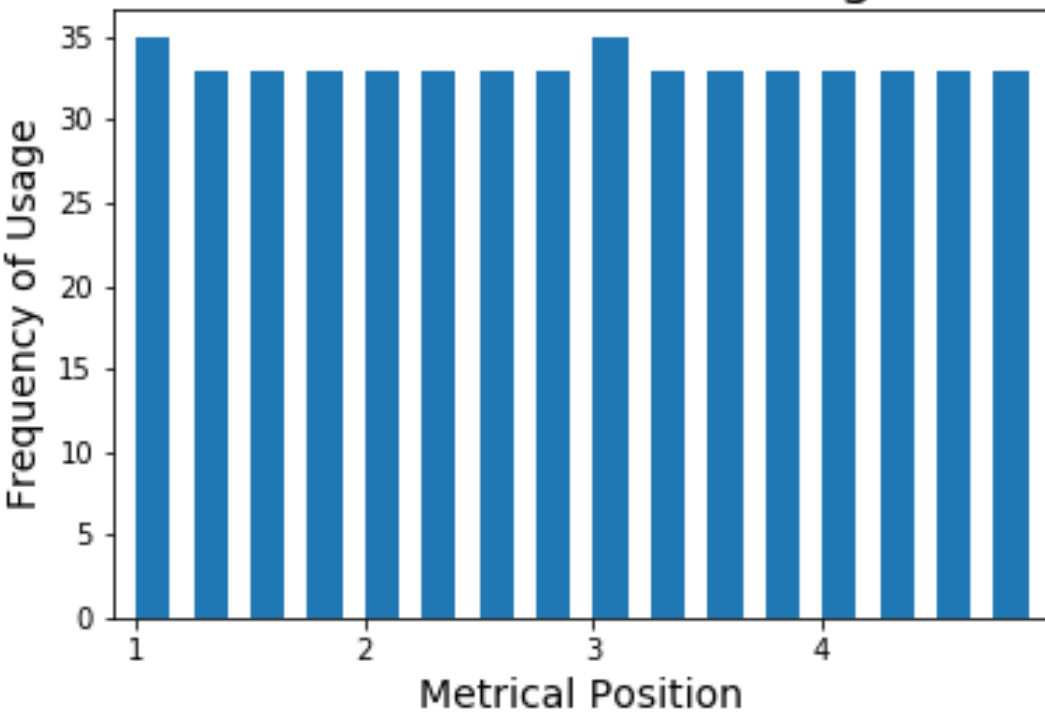
# Tonal hierarchy: YES!





# Metrical hierarchy: NO!

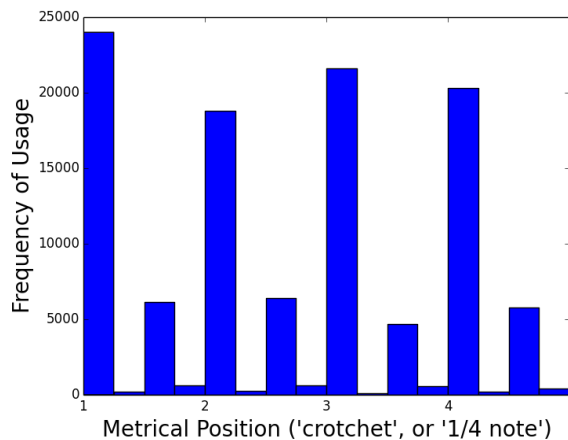
## Metrical Position Usage



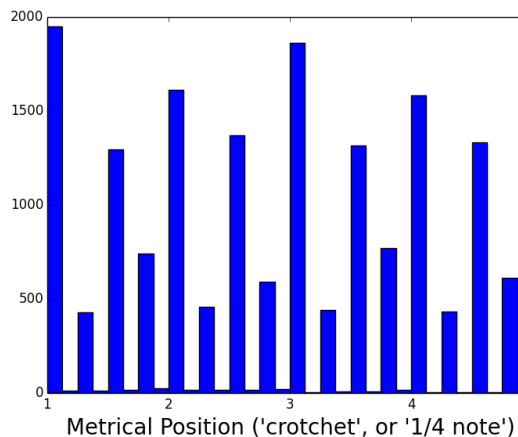
# Sample Size

All:

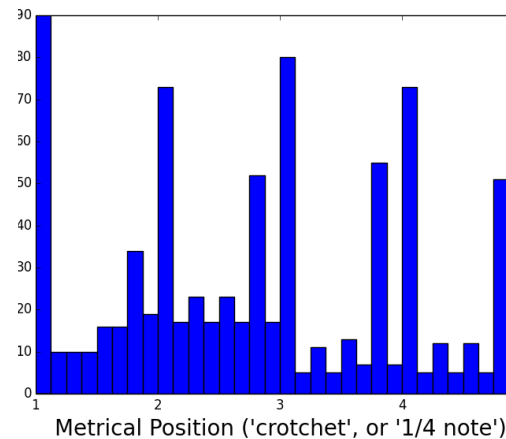
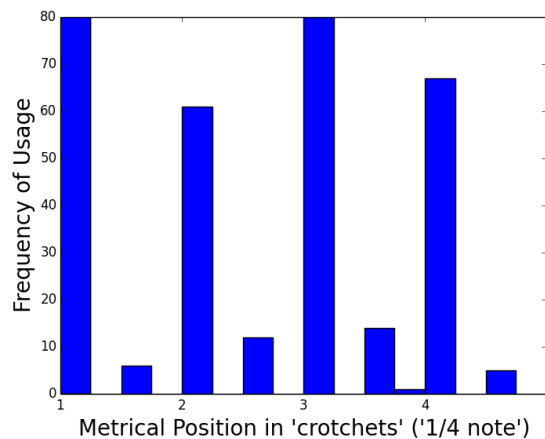
Chorales:



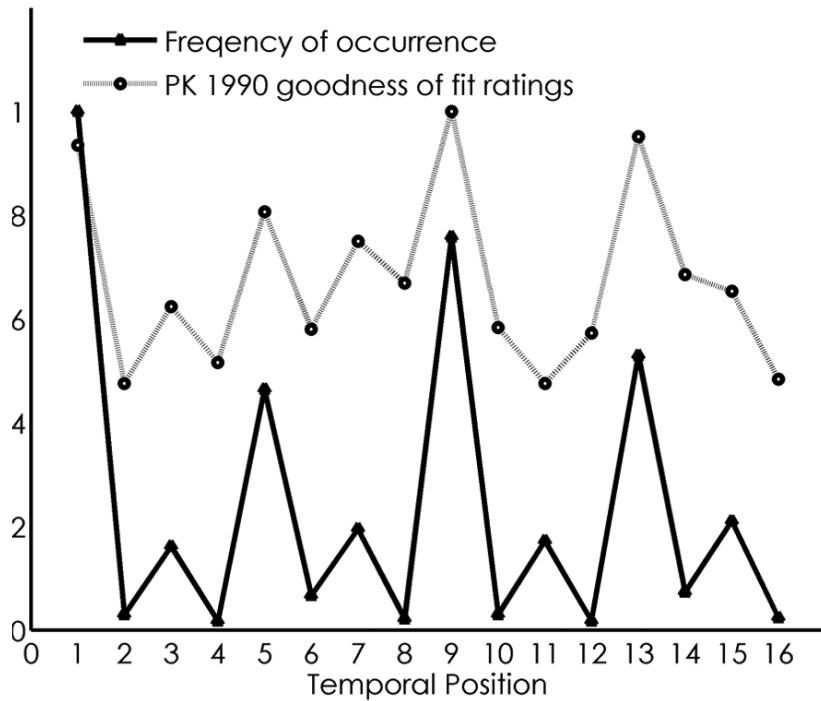
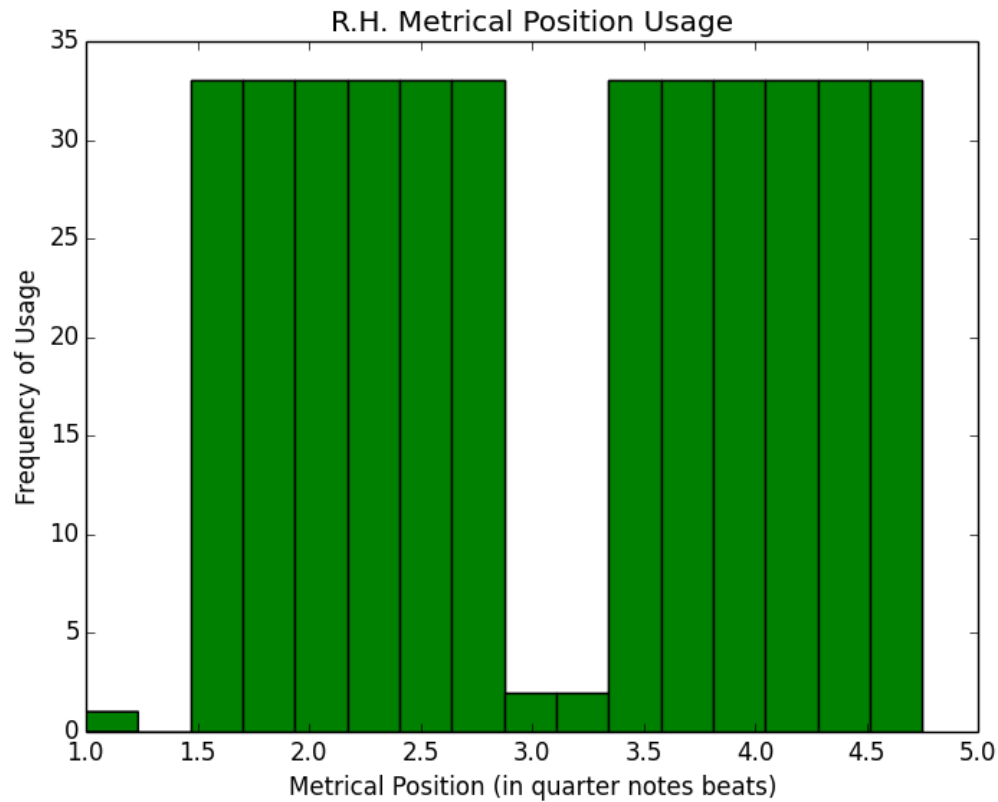
Preludes & Fugues:



One:

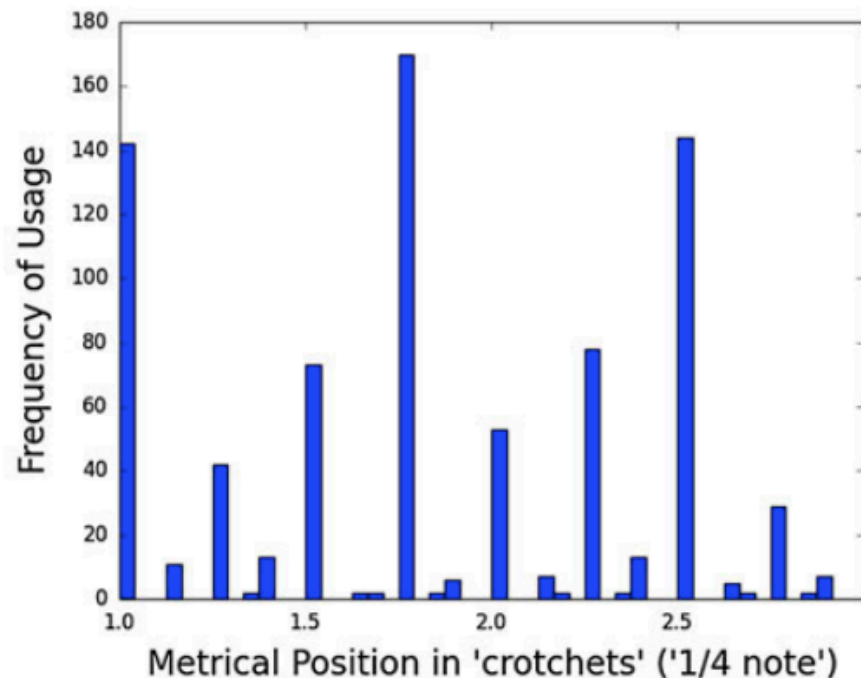


# Hands together?



# Hands together?

## Gershwin Prelude no.1

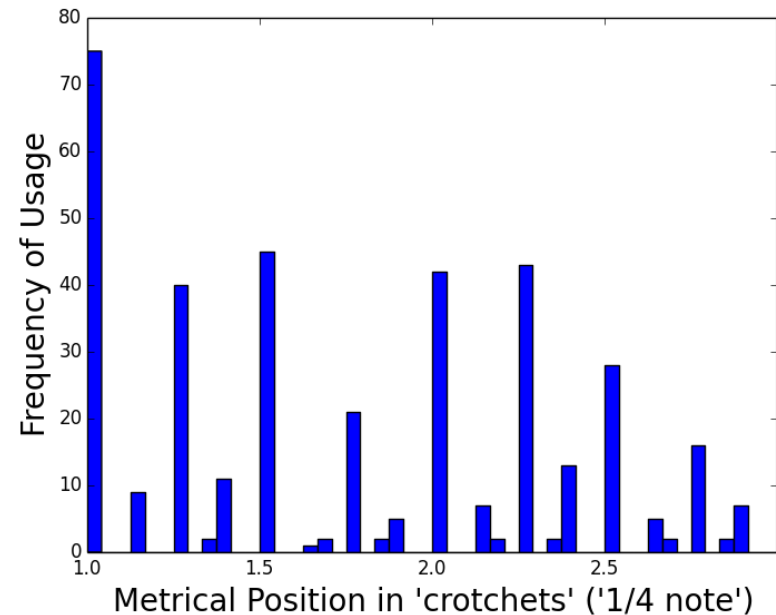
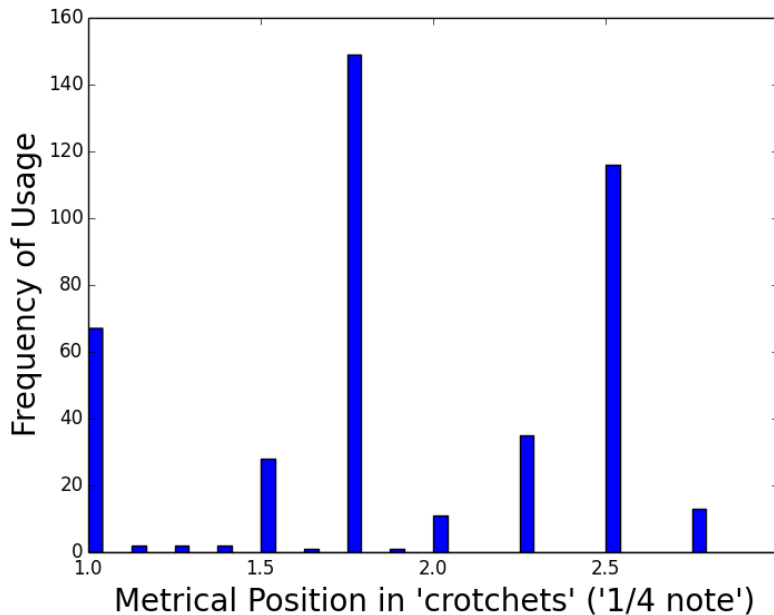


# Hands together?

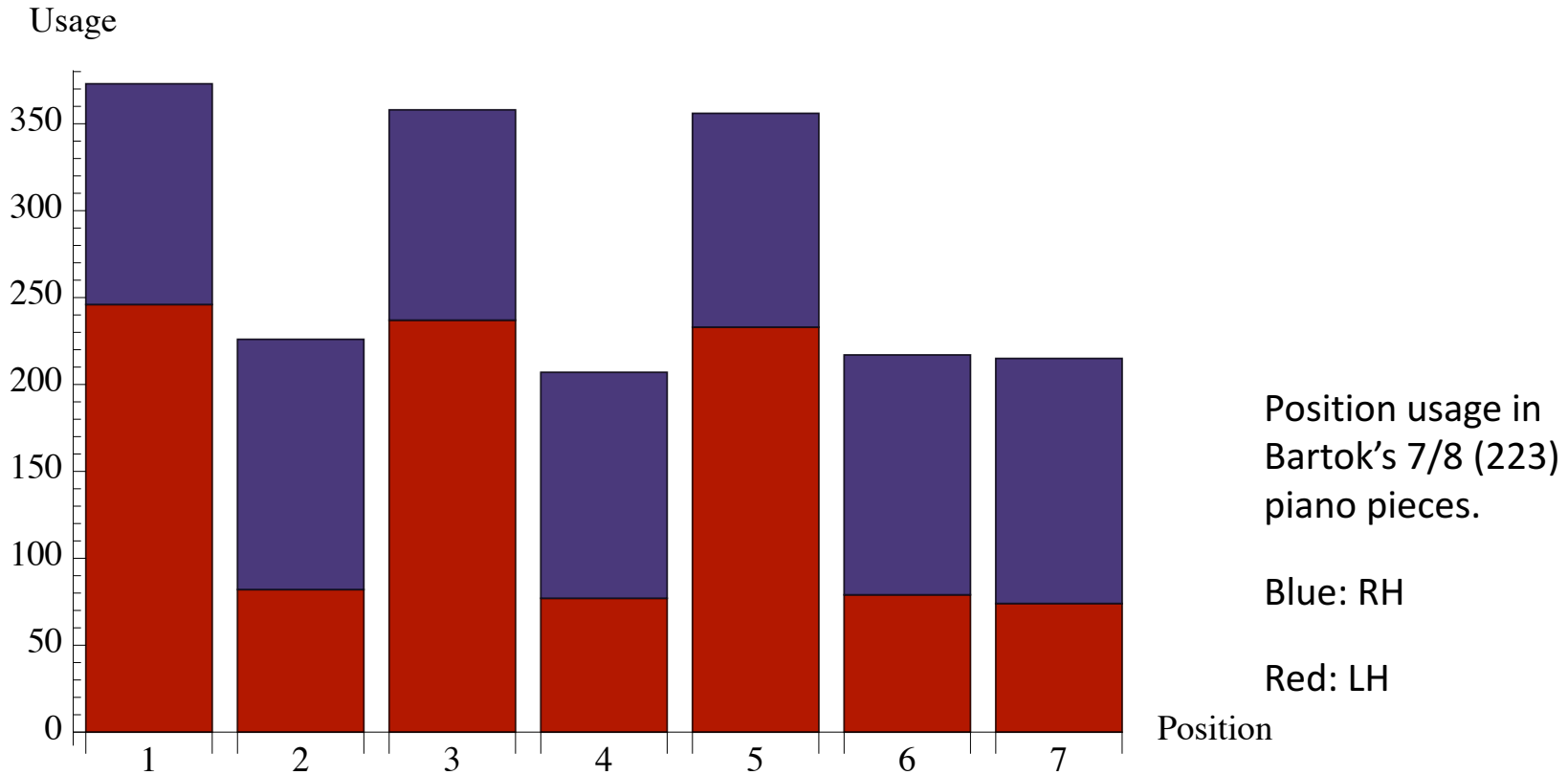
Gershwin Prelude no.1

LH: 3,3,2 'metre'?

RH: 11213 rhythm?



# ‘Mixed’ metrical hierarchy



Source: Gotham 2017: ‘Hierarchy and position usage in mixed metres’  
*Journal of New Musicological Research*, 46/2.

# Part 1: Summary

## Possibilities

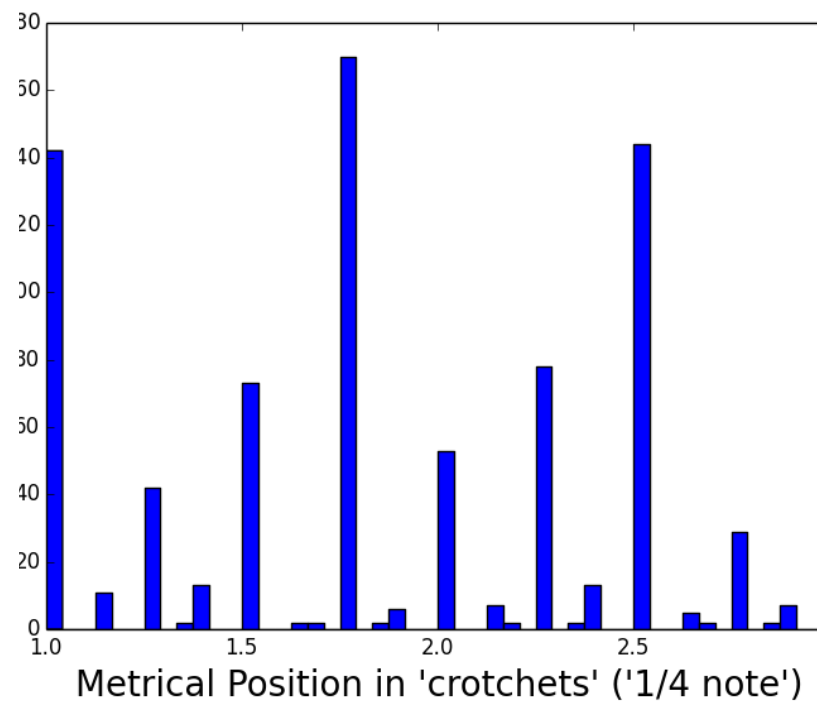
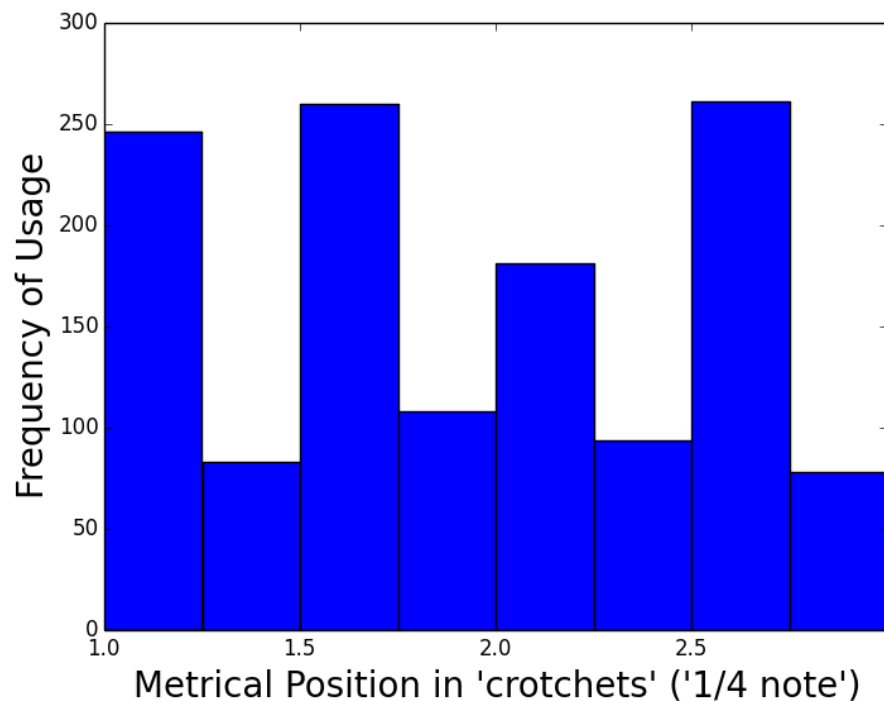
- Insights into cognition and ‘style’
- Automation of search/find/segment

## Pitfalls

- Methodology
- Error spotting

# Style categorization?

Joplin and Gershwin. Similar styles?





# Part 1: Summary

## Possibilities

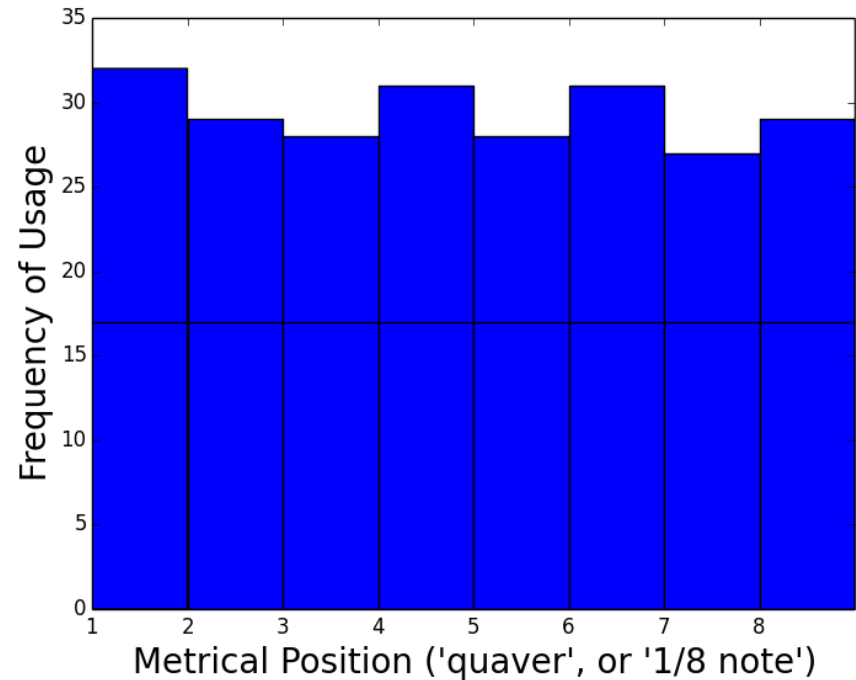
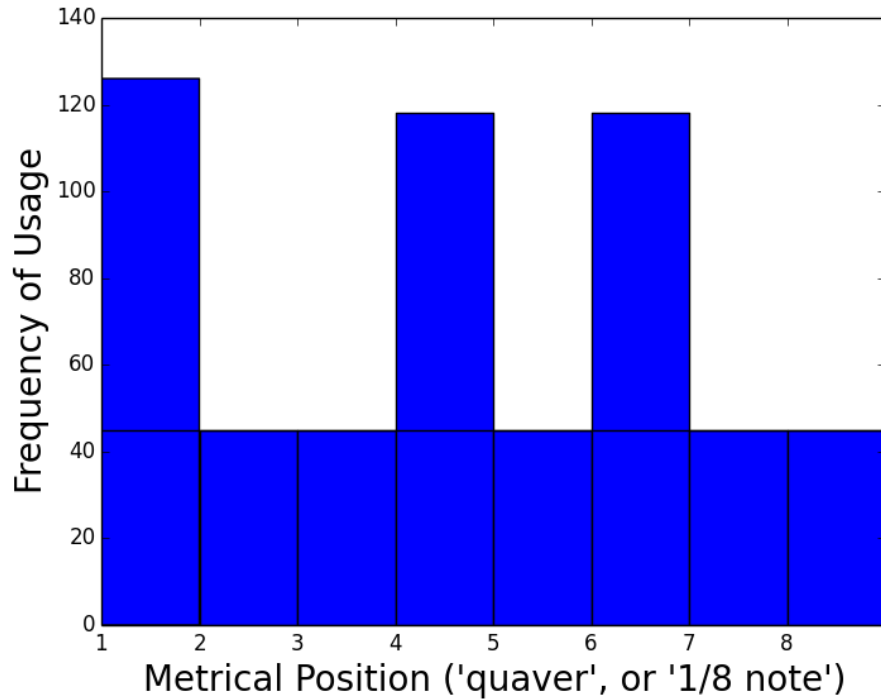
- Insights into cognition and ‘style’
- Automation of search/find/segment

## Pitfalls

- Methodology
- Error spotting

# Section changes

Ligeti. *Fanfares Etude*. Two sections:



# Part 1: Summary

## Possibilities for:

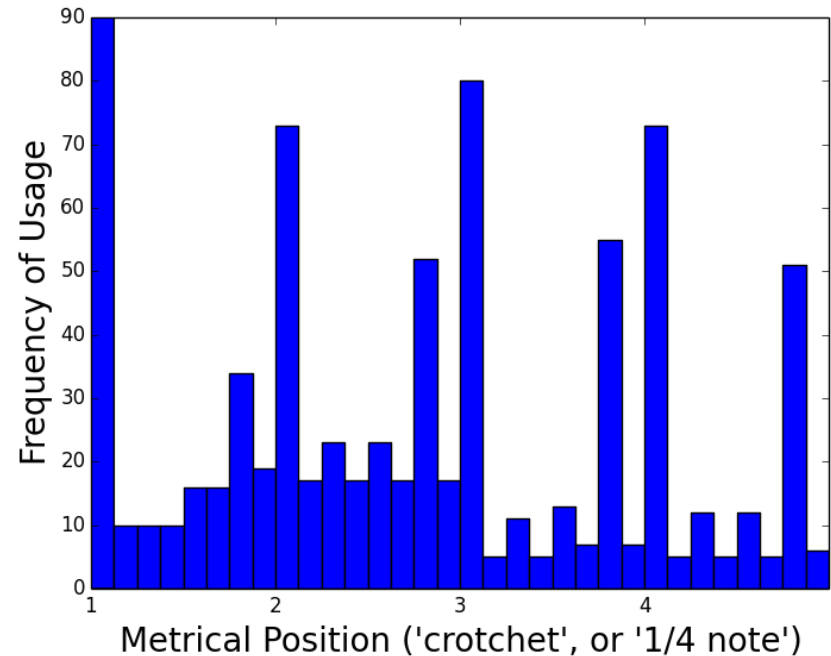
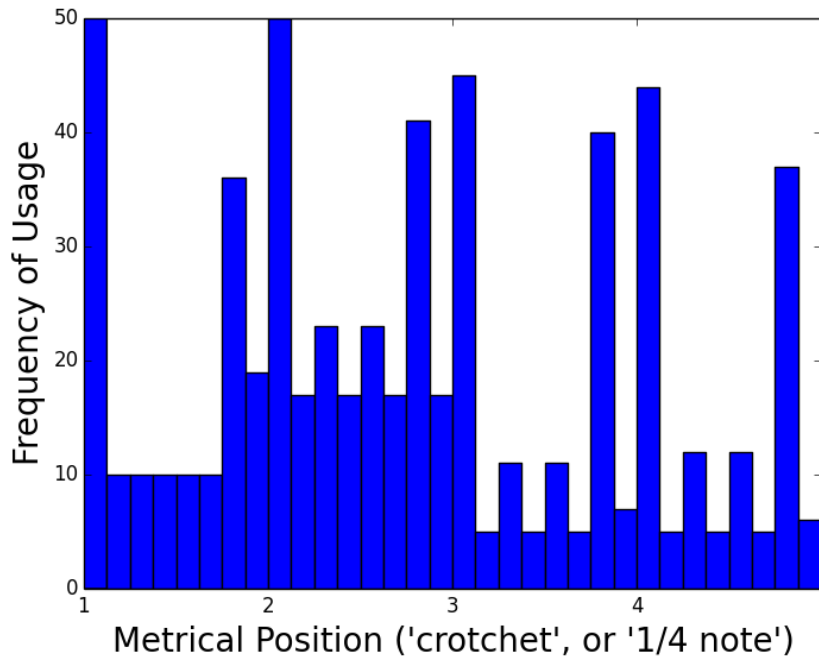
- Insight into cognition
- Automation of search/find/segment

## Pitfalls include

- Methodology
- Error spotting

# How to count (?!)

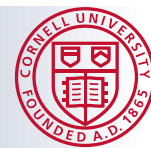
One count per chord (left), or one for each onset /





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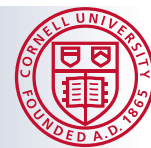


# ‘Attractor Tempos’

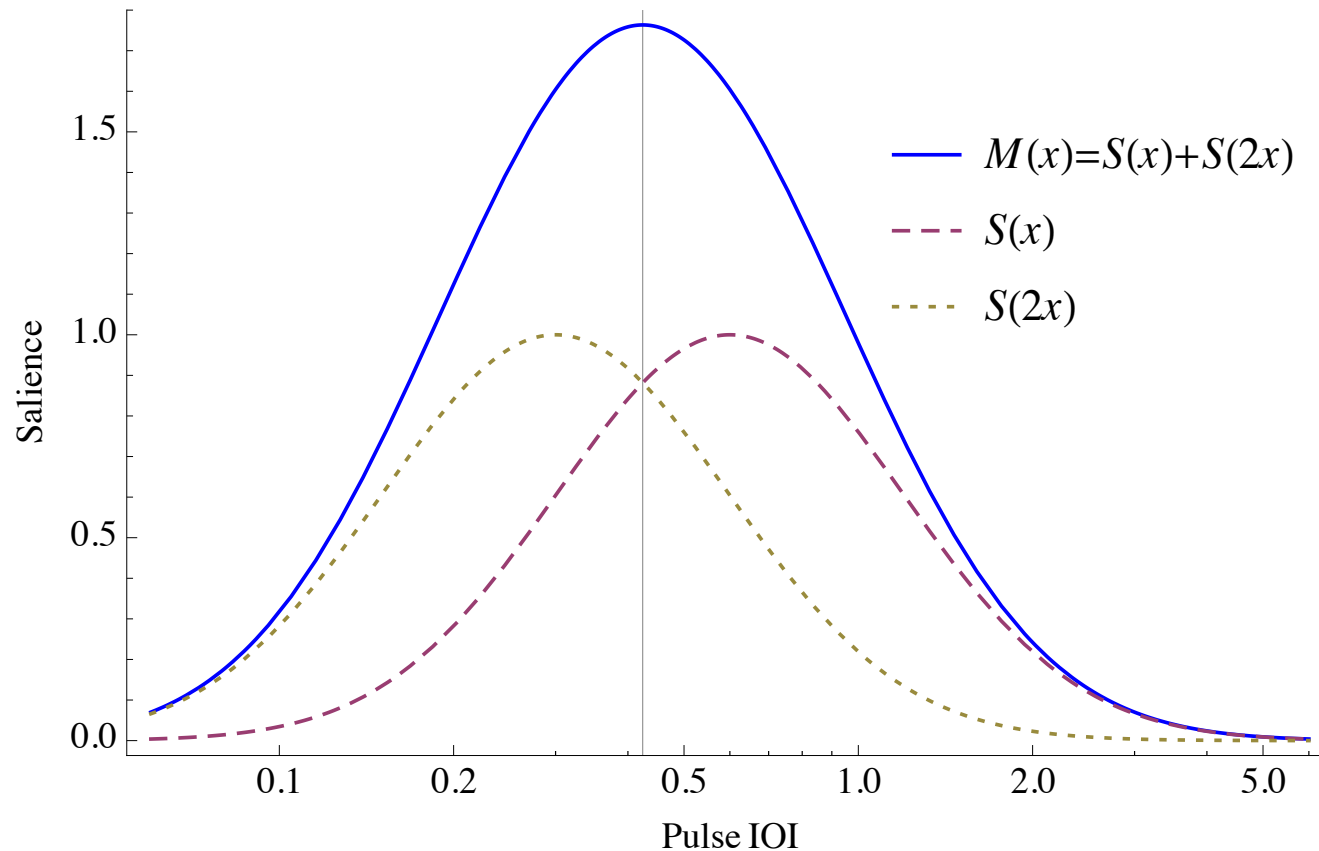
## ‘Attractor tempos’ \*

- Pulse preference in abstract (0.6 seconds);
- Useful range (0.01 – 6 seconds);
- Model based on compromise (max. sum)

\*Source: Gotham ‘Attractor Tempos for Metrical Structures’, *Journal of Mathematics and Music*, 9/1 (March 2015).

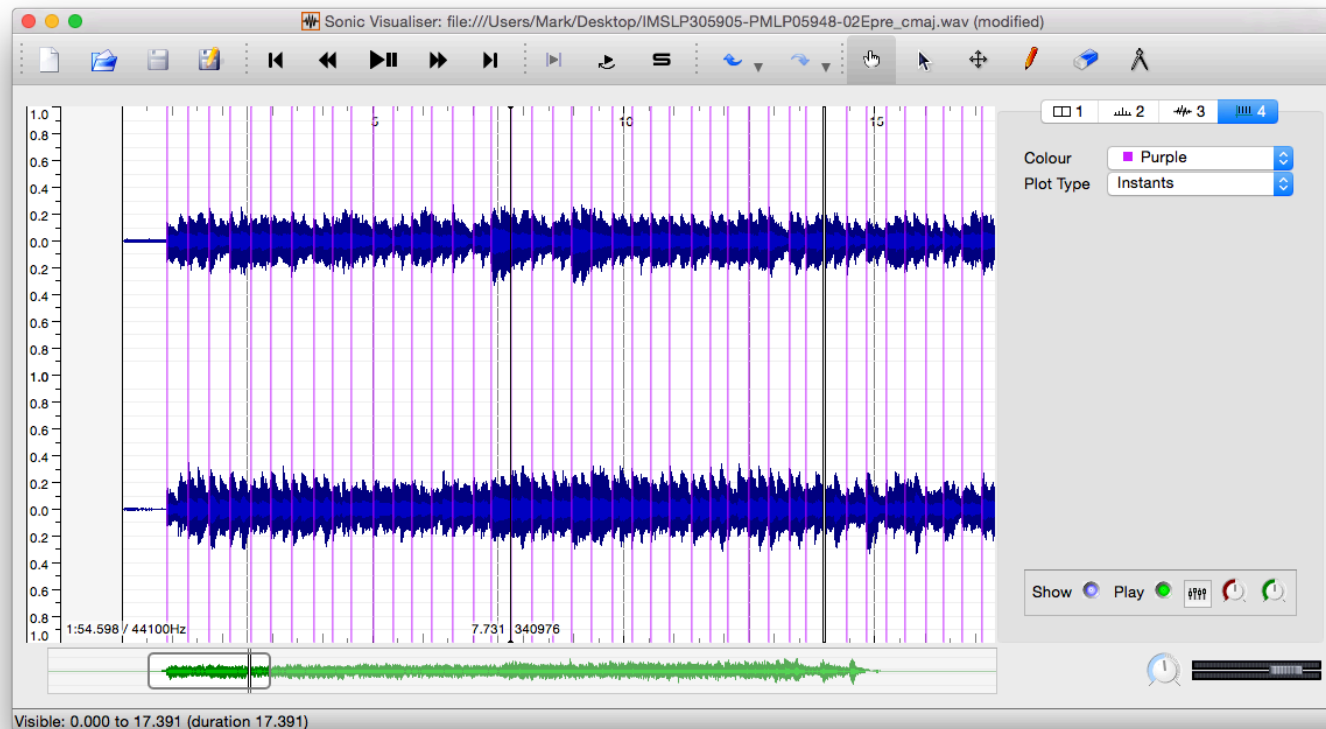


# 'Attractor Tempos'



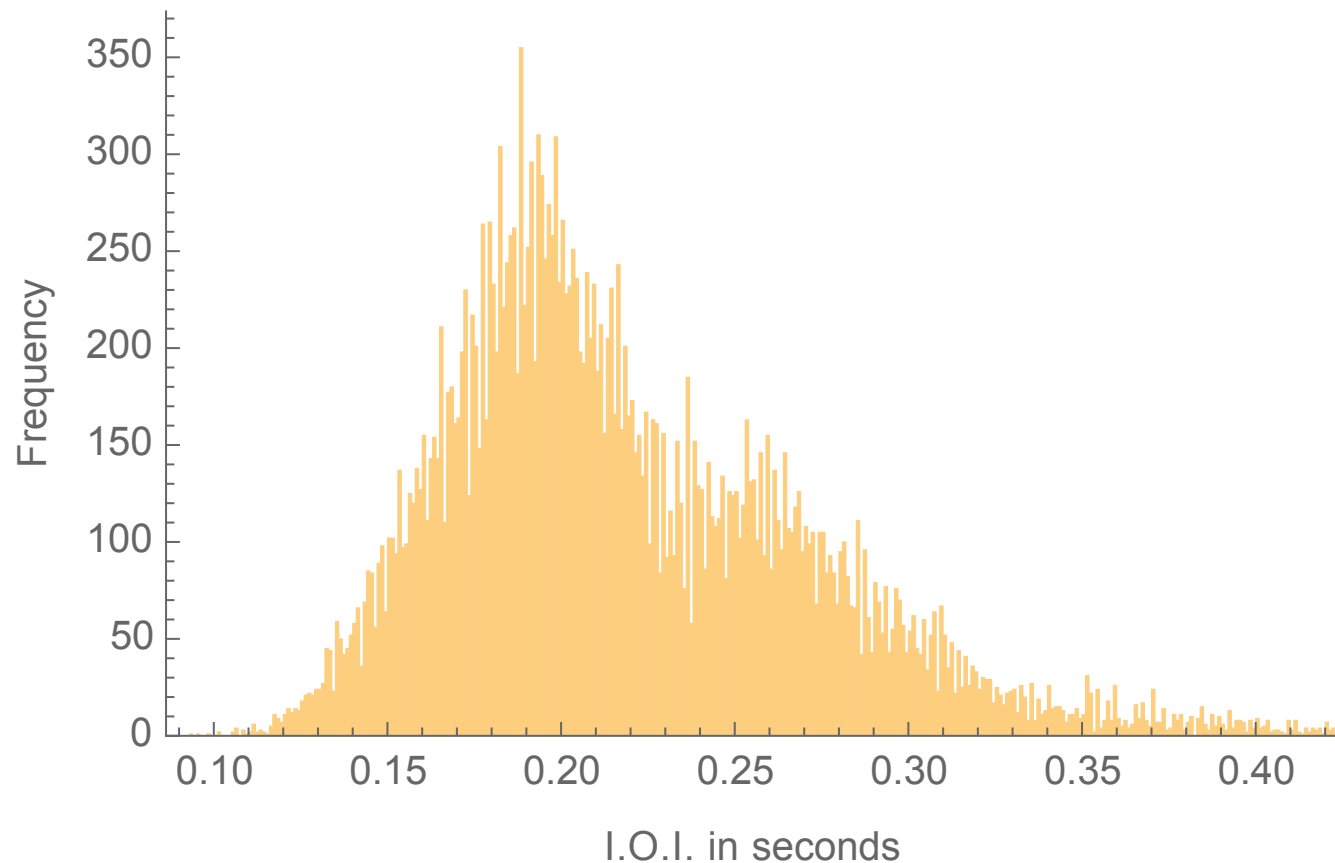


# Method: 'Sonic Visualiser'



Automatic beat recognition in 'Sonic Visualiser' (Cannam et al., QMUL, UK)  
(One recording of the Bach example: BWV 846.)

# Spot 'the' tempo



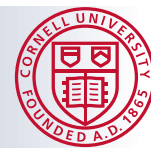
After data from Benadon and Zanette, (M.P.R. vol.7, 2015.)

# ‘Attractor Tempos’ in Brahms

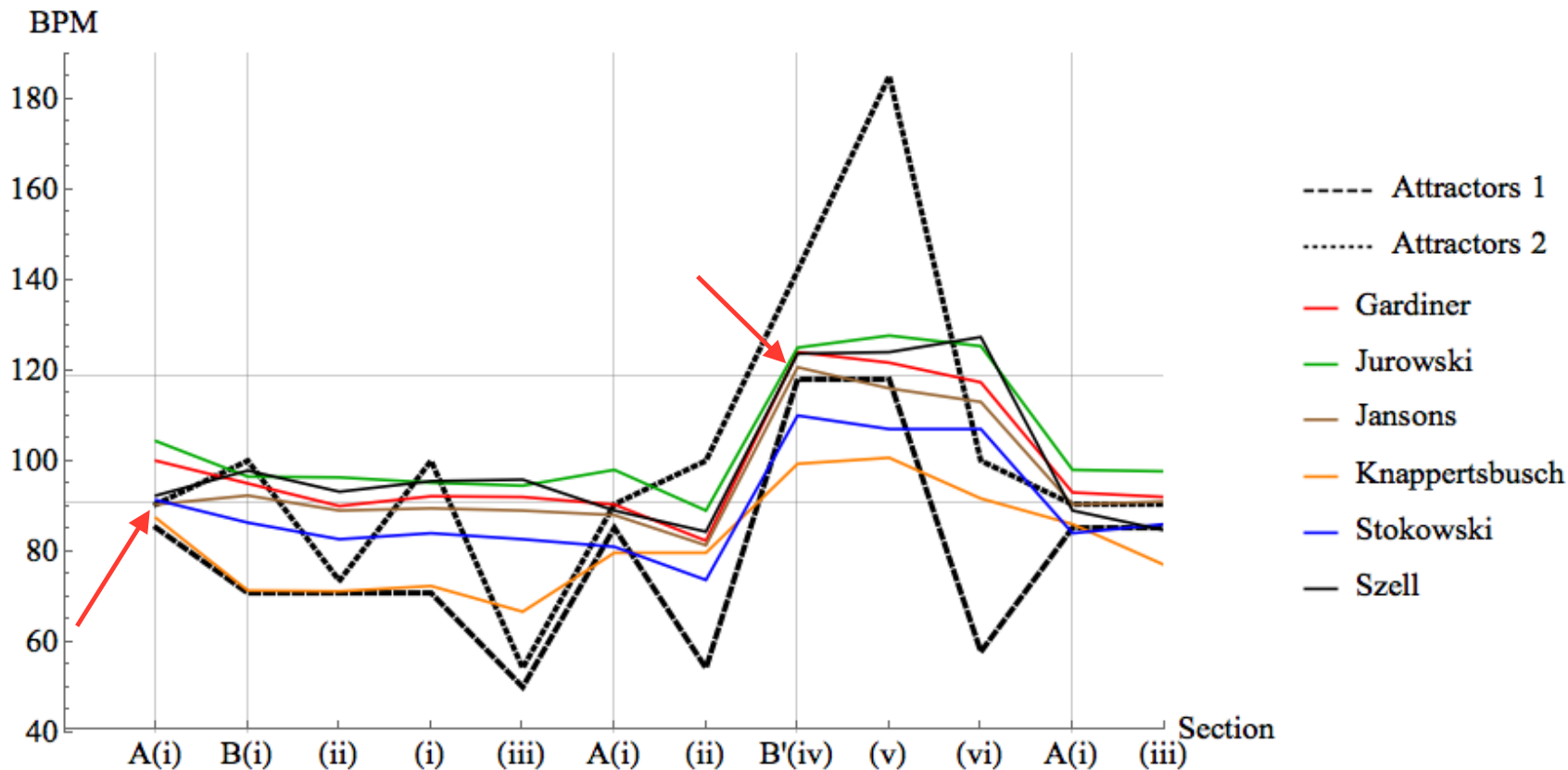
## **Brahms 2/iii: \***

- Frequent changes of metre (and level usage);
- Many of these sections nominally equivalent;
- Two choices of tempo (which may also be related).

\*Source: Gotham 2018: ‘Attractor Tempos in Brahms 2/iii’,  
*Music Theory Spectrum*



# 'Attractor Tempos' in Brahms



# Part 2: Summary / Outlook

## Summary

- Attractors: ‘tempo dissonance’ heuristic.

## Methodology

- On tempo: ‘average’?
- Of whole or ‘steady-state’?

## Future work

- Measure of relative level usage (weighted).

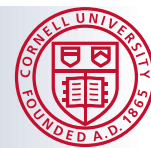
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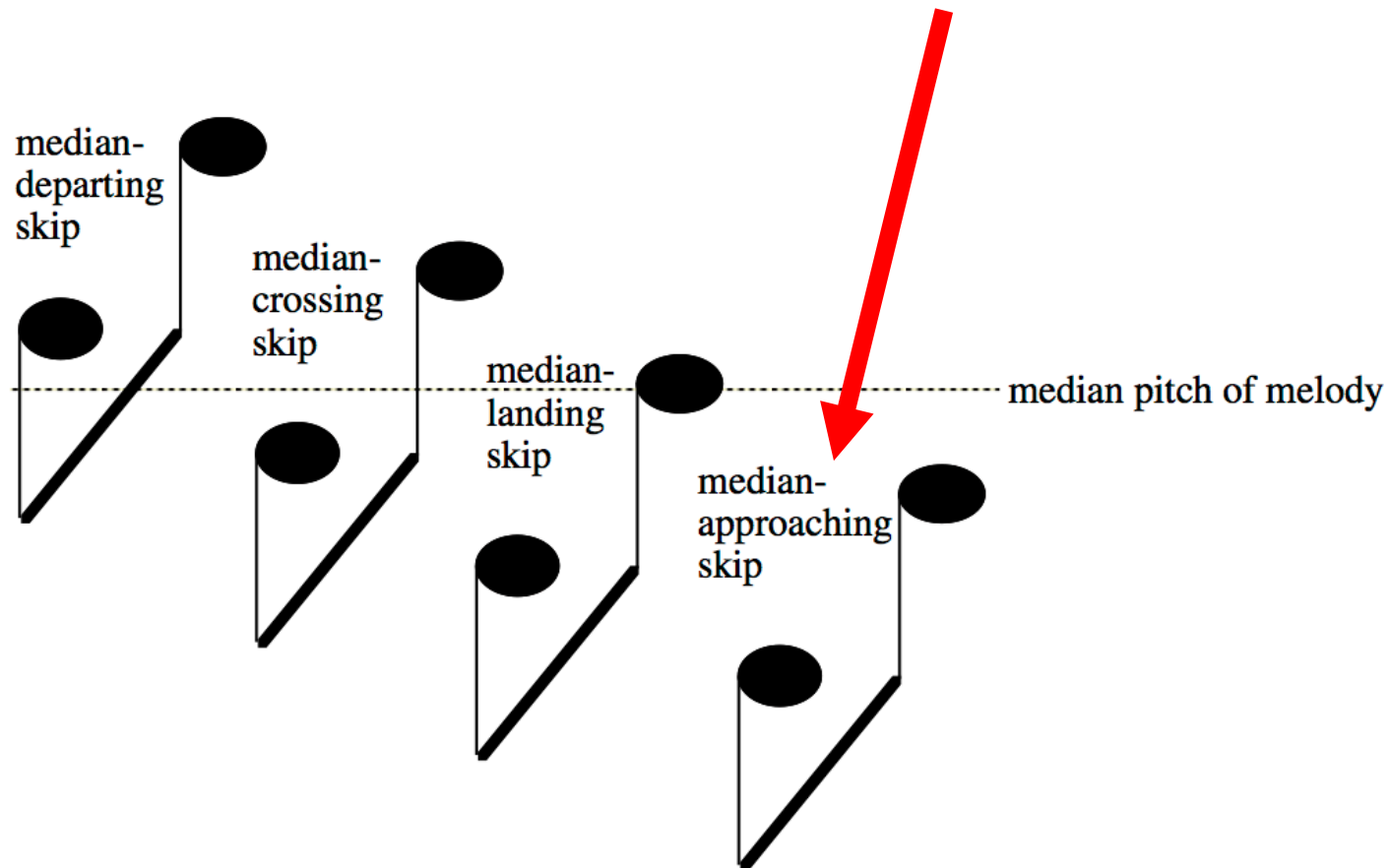
2. Audio: 'Attractor tempos'

**3. Teaching-led: Species or specious?**

4. Teaching Resources: 'Cut outs'



# 3a. Gap-fill VS Regression



# 3a. Gap-fill VS Regression

	Gap-fill	R. to mean	Difference	P value / significance	
Chant	52	254	- 66.0%	e-31	****
Ars Nova	12,961	12,644	+ 1.05%	0.046	*
JRP	19,391	16,708	+ 7.4%	e-45	****
Palestrina	7,761	7,444	+ 2.1%	0.00507	**
Monteverdi	475	389	+10.0%	0.00172	**
Bach Chorales	850	1,262	- 19.5%	e-19	****
German Art Song	1,429	2,657	- 30.1%	e-82	****
Essen minus Han	3,076	8,365	- 46.2%	0 (< e-308)	****
Han Chinese	1,605	4,140	- 44.1%	e-245	****



# 3b. Too large to fall?

Interval (semi-t.)		Proportion	Observations	Rule
First	Second	First:Second	All (Each)	(yes / no)
7	3	10.636	128 (117:11)	Y
4	3	7.284	555 (488:67)	Y
5	4	4.462	142 (116:26)	Y
-4	-5	3.846	126 (100:26)	Y
7	5	3.733	71 (56:15)	Y
5	3	3.057	142 (107:35)	Y
-5	-7	2.027	448 (300:148)	Y
-3	-4	1.425	1552 (912:640)	Y
<b>-7</b>	<b>-3</b>	<b>1.105</b>	<b>120 (63:57)</b>	<b>N</b>
-3	-5	1.064	97 (50:47)	Y

# 3c. Imitation

**TENOR.**

**BASSUS.**

Be - - - ne-di - ctus qui ve - - - -

Be - - - ne - di - ctus qui

The image shows a musical score for Tenor and Bassus. The Tenor part is in 3/4 time, G major, and begins with a half note G4, followed by quarter notes A4, B4, and C5, then a half note B4. The Bassus part begins with a whole rest, followed by a half note G3, then quarter notes A3, B3, and C4, then a half note B3. The lyrics are 'Be - - - ne-di - ctus qui ve - - - -' for the Tenor and 'Be - - - ne - di - ctus qui' for the Bassus. The Tenor part has a slur over the first four notes, and the Bassus part has a slur over the last four notes.

- a) Temporal interval:
- b) Pitch interval:

# 3c. Imitation

**TENOR.**

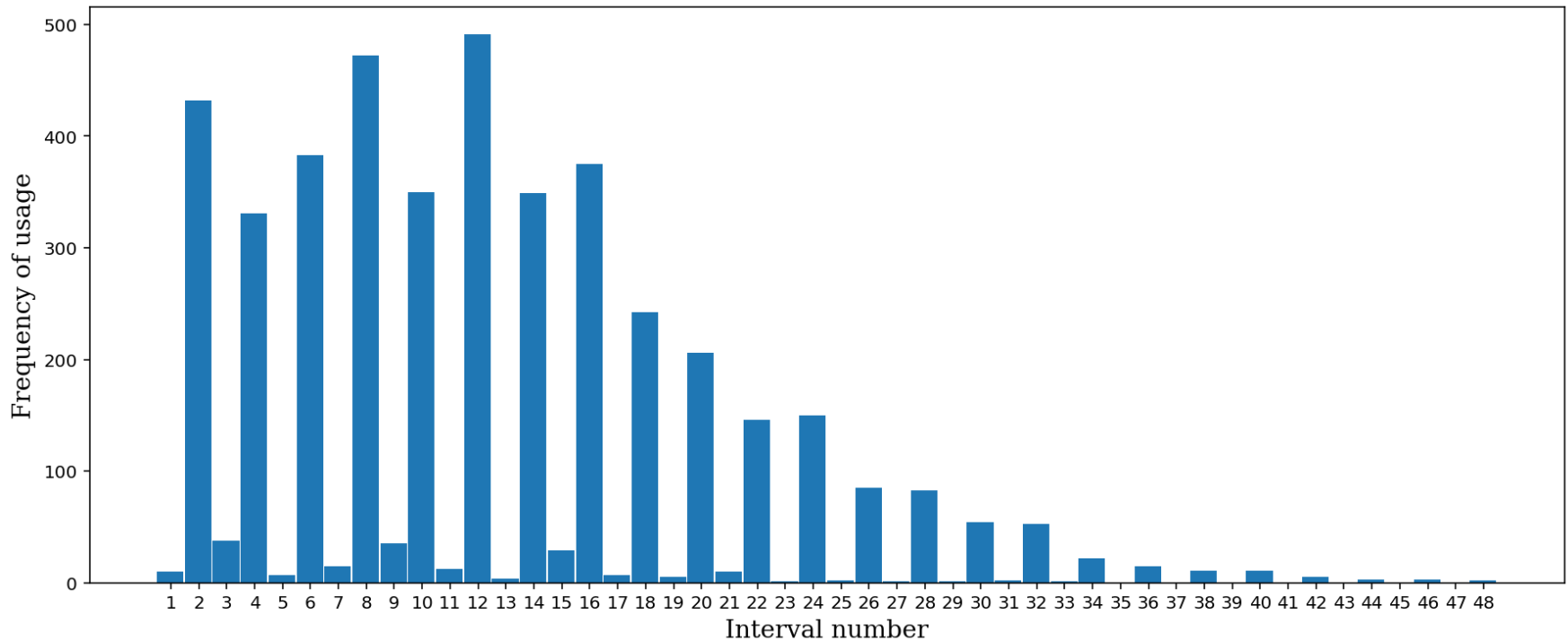
Be - - - ne-di - ctus qui ve - - - -

**BASSUS.**

Be - - - ne - di - ctus qui

- a) Temporal interval: 6 beats (strong to strong)
- b) Pitch interval: Perfect 5<sup>th</sup> (down)

# 3c. Imitation–Temporal



# 3c. Imitation–Pitch

Forte Class	#	Source for anomalies	
		Mass. <i>Missa</i> :	Movement, ref, notes
1-1	13		
2-5	341		
3-11A	1	<i>Sine nomine (1599)</i>	Credo(_52_a): ACECE
3-11B	1	<i>Inviolata</i>	X. Gloria_77_b. Noise. Really 2-5
3-4A	1	<i>Sine nomine (1599)</i>	Agnus(_I_46). EAAEF
3-6	1	<i>Sacerdotes Domini</i>	Sanctus(_47_b: Pleni sunt). CDE
3-7B	1	<i>Sine nomine (1599)</i>	Benedictus(_53_b: Pleni sunt). AEG
3-9	39		
4-14A	2	<i>Sacerdotes Domini</i>	Credo(_46_a). DADDEF Agnus(_I_41). DADDEF
4-22A	1	<i>Sacerdotes Domini</i>	Kyrie(_52). GDDCDE
4-23	1	<i>Nigra sum</i>	X. Sanctus(_87_c). Noise. Really 3-9.
5-23A	1	<i>Sacerdotes Domini</i>	Gloria(_48). GDAEFA
5-35	1	<i>Sacerdotes Domini</i>	Sanctus(_47_a). GDACDE
<b>Total:</b>	<b>404</b>		

# Talk Contents (you are here ...)

1. Scores: Metrical position usage
2. Audio: 'Attractor tempos'
3. Teaching-led: Species or specious?
- 4. Teaching Resources: 'Cut outs'**

# Cut Outs: Chorales

## 1. Take a score



This generates music theory completion exercises based on Bach chorales.

### Original chorale score

*The chorale score (in MusicXML format) used as a base for the exercise.*

### Beats to cut

*Decide on a number of tactus beats ('crotchet' / 'quarter note') to cut from each phrase.*

### Voices to cut

*Choose which voices to remove.*

- Alto
- Bass
- Tenor

### Score type

- Full score (four staves)
- Short score (two staves)



# Cut Outs: Chorales

1. Take a score
2. Cut parts out (Exercise)



A musical score for a chorale exercise in G major (one sharp) and common time (C). The score consists of four staves: Treble 1, Treble 2, Treble 3, and Bass. The music is in 4/4 time and spans six measures. The first staff (Treble 1) features a melody with a fermata on the final note of each measure. The second staff (Treble 2) has a melody with rests in the first and third measures. The third staff (Treble 3) has a melody with rests in the first and third measures. The fourth staff (Bass) has a steady eighth-note accompaniment. A small blue icon is visible in the top right corner of the score area.

# Cut Outs: Chorales

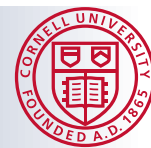
1. Take a score
2. Cut parts out ... or colour them red (solution)



A musical score for a chorale in G major, 4/4 time. The score consists of four staves: Treble clef (top), Treble clef (second), Treble clef (third), and Bass clef (bottom). The key signature is one sharp (F#) and the time signature is common time (C). The score is divided into six measures. The second, third, and fourth staves have several notes highlighted in red, indicating the 'cut parts' or 'solution' mentioned in the text. A small blue icon is visible in the top right corner of the score area.

# Cut Outs: Lieder

## 1. Take a score



5 Lieder, Op.10  
5. Bergeslust

Joseph von Eichendorff

Fanny (Mendelssohn) Hensel

*Allegro molto vivace e leggiero.*

Voice

O Lust, vom Berg zu schau - en

Piano

Piano

8

weit ü - ber Wald und Strom, hoch ü - ber sich den blau - en, den kla - ren Him - mels -


Piano

Piano




### Song

*The original score (in MusicXML format) used as a base for the exercise.*




### Preserve piano part in rests

*Choose whether or not to leave the piano part in for the bars where the voice part is resting.*



### Rest length

*What does 'resting' mean? Choose a length (in 'quarter notes' / 'crotchets') that acts as the benchmark. So, when the combined length of rests in one bar (measure) of the vocal part add up to this value, the 'Preserve piano part in rests' option will be activated (if selected).*




### Preserve bass line

*Whatever else is going on, leave the left hand piano part intact and just work on the right hand.*



Additional features



### Harmonic rhythm for chord hints

*If you chose the Chord Hints feature, what harmonic rhythm should these be based on? Please specify the length in 'quarter notes' ('crotchets') of that harmonic rhythm.*

# Cut Outs: Lieder

1. Take a score
2. Cut parts out

6

Lust, vom Berg zu schau - en weit ü - ber Wald und Strom, hoch ü - ber sich den

# Cut Outs: Lieder

1. Take a score
2. Cut parts out
3. Add parts in

6

Lust, vom Berg zu schau - en weit ü - ber Wald und Strom, hoch ü - ber sich den

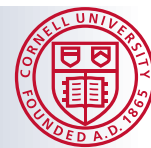
The image shows a musical score for a song in G major (one sharp). It consists of three staves. The top staff is the vocal line, the middle staff is the right-hand piano accompaniment, and the bottom staff is the left-hand piano accompaniment. The lyrics are written below the vocal staff. The score is marked with a '6' in the top left corner.

# More Teaching Resources

## Interactive Teaching Resources

Three Examples:

- 1. Interactive scores**
2. A Guide to the Pedal Harp
3. A Metre of Metrical Dissonance





Clarinet in Bb

Bass Clarinet in Bb

Horn 1 in F

Horn 2 in F

Harp

**Webern: Symphonie op.21, movement 1, opening**

This opening section is a double canon in inversion.

Press 1 to show the first part (dux) of the first canon in red.

Press 2 to show the second part (comes) of the first canon in green.

Press 3 to show the first part (dux) of the second canon in blue.

Press 4 to show the first part (comes) of the first canon in orange.

Throughout, the instruments are paired: clarinet and bass clarinet; the two horns; the two hands (staves) of the harp; Vin1 with viola; Vin1 with VC.

Corresponding material appears in those matching parts.

Press any of 5, 6, 7, 8, 9 to show blocks of that material (in their original colours) in the first canon.

Each pitch class consistently appears in the same octave, for instance, A always sounds as 'A3', just below middle C.

The exceptional pitch class is Eb which appears as both Eb3 and Eb4 (either side of the A3).

This is part of a symmetrical pattern of pitches centred on that A3.

A and Eb have a special, central role for other reasons, for instance, they're the only pitches to be simultaneously by the same instrument.

Press 0 to show each A and Eb in this passage in all parts.

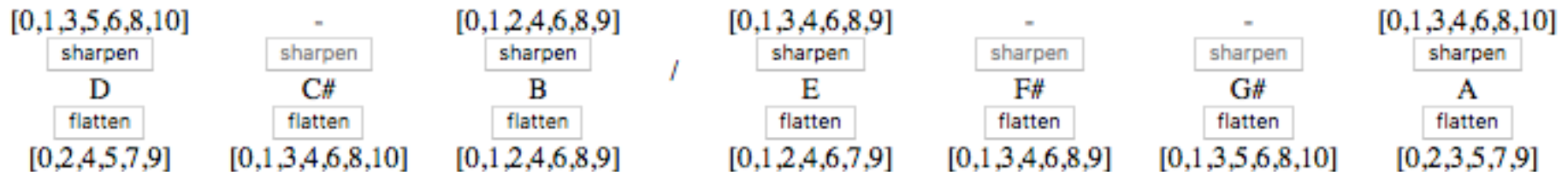
# Teaching Resources

## Interactive Teaching Resources

### Three Examples:

1. Interactive scores

## 2. Pedal Harp



# Teaching Resources

## Interactive Teaching Resources

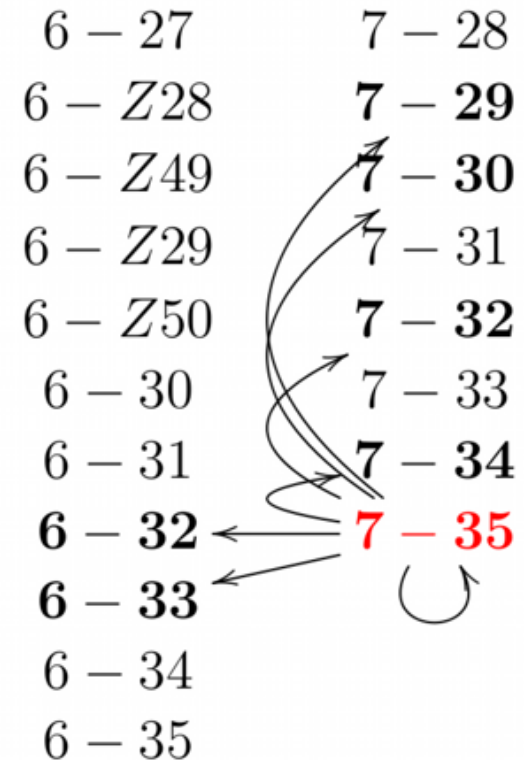
### Three Examples:

1. Interactive scores

**2. Pedal Harp**

3. Metrical Dissonance

Gotham and Gunn 2016: 'Pitch Properties of the Pedal Harp, with an Interactive Guide', *Music Theory Online*, 22/4.



# Teaching Resources

Interactive Teaching Resources

Three Examples:

1. Interactive scores
2. Pedal Harp
- 3. Metrical Dissonance**

Forthcoming: 'Towards a Cognitively-Based Quantification of Metrical Dissonance', in Doffman, Payne, and Young eds *The Oxford Handbook of Time in Music*, O.U.P.

## A: Tempo

Base-level inter onset interval:

0.6  seconds.

Submit IOI

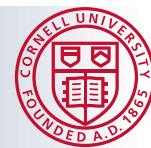
## C: Metre 1, Levels

- 1 (fastest unit, mandatory);  
 2  3;  
 4  6  9;  
 8  12  18  27;  
 16  24  36  54;  
 32  48;

Reset

# Talk Contents (you are here ...)

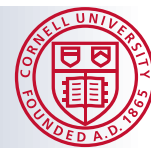
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2. Audio: 'Attractor tempos'
3. Teaching-led: Species or specious?
4. Teaching Resources: 'Cut outs'



# Final Summary / Outlook

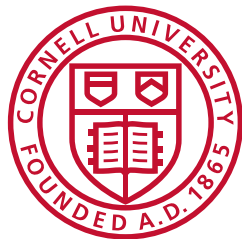
What else is going on in the field?

<https://github.com/MarkGotham/MusoRepo>



# Thank you!

Mark Gotham  
Cambridge, 17 January 2019



Cornell University