Musical Information Retrieval

Mark Gotham
Cambridge, 17 January 2019
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**

2. Audio: ‘Attractor tempos’

3. Teaching-led: Species or specious?

4. Teaching Resources: ‘Cut outs’
1. Scores

Hierarchies
• ‘Important’ notes / beats

Assess:
• Perceptual: ‘Goodness of fit’
• Empirical: Extent of usage
Tonal hierarchy

The columns of Table 3 represent temporal positions within the measure, sorted as beats 1 (downbeat), 3, 2 + 4, eighth notes, sixteenth notes, and Other, grouped in accordance with theoretical predictions of beat strength (e.g., Lerdahl & Jackendoff, 1983). That is, the frequency of occurrence of temporal positions is averaged (not summed) within a category of equal metric strength, such that beats 2 and 4 are averaged, becoming 2 + 4, then the remaining 4 eighth note (off-beat) positions, followed by the next lower metric hierarchy level (off-beat sixteenth notes), then “Other” (designating thirty-second notes, sixteenth note triplets, and any non-quantized metric positions).

Finally, Table 4 provides the same data for pieces in the minor mode (4/4 time signature, all composers), also with the rows sorted according to the pitch class distribution of the minor mode on the downbeat. The full data set of all time signatures, modalities, and composers is available upon request from the first author.

Figures 3-8 depict the tonal-metric hierarchies of each time signature as 3-dimensional histograms, separately for major and minor (collapsing across composer). The y axis shows the frequency of occurrence of each combination of pitch class (x axis) and temporal position (z axis). These graphs use the same arrangement as Tables 3 and 4; namely, they sort the axes by frequency of occurrence on the downbeat, as well as averaging across temporal positions with equal metric stability.

These graphs demonstrate that the most common occurrence is a tonally stable pitch (e.g., the tonic) at a metrically stable temporal position (e.g., the downbeat), and that the frequency of occurrence decreases at lower levels of tonal and metric stability. At first glance, the overall tonal-metric hierarchy looks like a replication of the tonal hierarchy at different temporal positions. Closer inspection, however, reveals that the favoring of tonally stable pitch classes is more discernible at the downbeat than at lower levels of metric stability. Indeed, the correlation of the Krumhansl-Kessler major tonal hierarchy with the pitch class distribution decreases across metric category stability: $r = 0.96$ for the downbeat, then $r = 0.92$, $0.90$, $0.88$, and $0.87$ down to the “Other” level. For the same metric categories in the minor mode, the pattern is $r = 0.91$ for the downbeat, then $r = 0.83$, $0.84$, $0.85$, and $0.79$. This change is also evident in Figure 1, as it compares the tonal hierarchy for only downbeat occurrences to the overall total (summing all metric positions).

These figures also demonstrate the remarkable consistency of the tonal-metric hierarchy across time signature and mode. Despite these changes in the metrical framework and major/minor modality, the profile of the tonal-metric hierarchy remains largely the same. This shape is slightly less reliable for Figures 7 and 8, likely due to the small sample size (note the markedly lower scale of the y axis compared to other figures).

Because Figures 3-8 show that notes rarely occurred at fine subdivisions, and in the interest of simplicity, further analyses of the tonal-metric hierarchy used the 16 most common temporal positions (e.g., sixteenth note...
Metrical hierarchy

Note that the exclusion of the least common temporal positions represents a more conservative analysis – the uniformly rare use of the positions of lower metric stability might otherwise artificially inflate correlations between the tonal and metric hierarchies.

Table 5 shows the results of correlating the resulting 12 (pitch class) by 16 (metric stability) tonal-metric matrices across composer, separately for each time signature and modality. Values are the average correlation coefficients of each composer with all other composers. All Table 5 values below .70 are the result of cells with the minimum possible small sample size ($N_{pieces} = 2$).

The strikingly high inter-composer tonal-metric correlations of Table 5 motivated including additional composers, including some from more modern compositional periods; we chose Schubert, Brahms, Liszt, and Scriabin (see Appendix B for the list of included pieces of these composers). These data are not included in the earlier analyses because our corpus had too few pieces of these composers for valid inter-composer comparisons.

We used the 16 most common temporal positions from all time signatures even if it did not correspond to the sixteenth note level (e.g., 3/4) because we were sorting by stability as indexed by frequency of occurrence rather than beat strength.

Example case: BWV 846
Tonal hierarchy: YES!

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Because Figures 3-8 show that notes rarely occurred at fine subdivisions, and in the interest of simplicity, further analyses of the tonal-metric hierarchy used the 16 most common temporal positions (e.g., sixteenth note...
Metrical hierarchy: NO!

Note that the exclusion of the least common temporal positions represents a more conservative analysis – the uniformly rare use of the positions of lower metric stability might otherwise artificially inflate correlations between the tonal and metric hierarchies.

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Sample Size

Chorales:

Preludes & Fugues:

All:

One:
Hands together?

Note that the exclusion of the least common temporal positions represents a more conservative analysis – the uniformly rare use of the positions of lower metric stability might otherwise artificially inflate correlations between the tonal and metric hierarchies.

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Hands together?

Gershwin Prelude no.1
Hands together?

Gershwin Prelude no.1
LH: 3,3,2 ‘metre’?

RH: 11213 rhythm?
‘Mixed’ metrical hierarchy

Position usage in Bartok’s 7/8 (223) piano pieces.

Blue: RH

Red: LH

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?

```
<table>
<thead>
<tr>
<th>Metrical Position in 'crotchet' ('1/4 note')</th>
<th>Frequency of Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>250</td>
</tr>
<tr>
<td>1.5</td>
<td>275</td>
</tr>
<tr>
<td>2.0</td>
<td>200</td>
</tr>
<tr>
<td>2.5</td>
<td>250</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Metrical Position in 'crotchet' ('1/4 note')</th>
<th>Frequency of Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>40</td>
</tr>
<tr>
<td>1.5</td>
<td>50</td>
</tr>
<tr>
<td>2.0</td>
<td>30</td>
</tr>
<tr>
<td>2.5</td>
<td>40</td>
</tr>
</tbody>
</table>
```
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 /
Technical errors

Spot the mistake ...
1. Scores: Metrical position usage

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4. Teaching Resources: ‘Cut outs’
‘Attractor Tempos’

‘Attractor tempos’ *

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

'Attractor Tempos'

\[ M(x) = S(x) + S(2x) \]

- \( S(x) \)
- \( S(2x) \)

---

Mark Gotham. 2019-1-17
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).

‘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).
Talk Contents (you are here ...)

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3a. Gap-fill VS Regression

median-departing skip
median-crossing skip
median-landing skip
median-approaching skip
median pitch of melody
### 3a. Gap-fill VS Regression

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

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

a) Temporal interval:
b) Pitch interval:
3c. Imitation

a) Temporal interval: 6 beats (strong to strong)
b) Pitch interval: Perfect 5\textsuperscript{th} (down)
3c. Imitation–Temporal

![Bar chart showing frequency of usage over interval numbers.](chart)

Mark Gotham. 2019-1-17
### 3c. Imitation–Pitch

<table>
<thead>
<tr>
<th>Forte Class</th>
<th>#</th>
<th>Source for anomalies</th>
<th>Movement, ref, notes</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Mass. Missa:</strong></td>
<td></td>
</tr>
<tr>
<td>1-1</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-5</td>
<td>341</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-11A</td>
<td>1</td>
<td><em>Sine nomine (1599)</em></td>
<td>Credo(_52_a): ACECE</td>
</tr>
<tr>
<td>3-4A</td>
<td>1</td>
<td><em>Sine nomine (1599)</em></td>
<td>Agnus(_I_46). EAAEF</td>
</tr>
<tr>
<td>3-6</td>
<td>1</td>
<td><em>Sacerdotes Domini</em></td>
<td>Sanctus(_47_b: Pleni sunt). CDE</td>
</tr>
<tr>
<td>3-7B</td>
<td>1</td>
<td><em>Sine nomine (1599)</em></td>
<td>Benedictus(_53_b: Pleni sunt). AEG</td>
</tr>
<tr>
<td>3-9</td>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-14A</td>
<td>2</td>
<td><em>Sacerdotes Domini</em></td>
<td>Credo(_46_a). DADDEF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Agnus(_I_41). DADDEF</td>
</tr>
<tr>
<td>4-22A</td>
<td>1</td>
<td><em>Sacerdotes Domini</em></td>
<td>Kyrie(_52). GDDCDE</td>
</tr>
<tr>
<td>5-23A</td>
<td>1</td>
<td><em>Sacerdotes Domini</em></td>
<td>Gloria(_48). GDAEFA</td>
</tr>
<tr>
<td>5-35</td>
<td>1</td>
<td><em>Sacerdotes Domini</em></td>
<td>Sanctus(_47_a). GDACDE</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
<td><strong>404</strong></td>
</tr>
</tbody>
</table>
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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.*

BWV 369.xml

**Beats to cut**

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

2

**Voices to cut**

*Choose which voices to remove.*

- [ ] Alto
- [ ] Bass
- [ ] Tenor

**Score type**

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

[Reset] [Generate exercise]
Cut Outs: Chorales

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

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

Piano

O Lust, vom Berg zu schauen

weit über Wald und Strom, hoch über sich den blauen, den klaren Himmels-
Song

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

Hensel_Fanny_Mendelssohn__5_Lieder

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).

2

Preserve bass line

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

☐

Additional features  None

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.

1

Reset  Generate exercise
Cut Outs: Lieder

1. Take a score
2. Cut parts out
Cut Outs: Lieder

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

Lust, vom Berg zu schauen weit ü - ber Wald und Strom, hoch ü - ber sich den
Interactive Teaching Resources

Three Examples:

1. **Interactive scores**
2. A Guide to the Pedal Harp
3. A Metre of Metrical Dissonance
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; Vln1 with viola; Vln1 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

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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Final Summary / Outlook

What else is going on in the field?

https://github.com/MarkGotham/MusoRepo
Thank you!

Mark Gotham
Cambridge, 17 January 2019