Krumhansl-Schmuckler Algorithm

- Statistical measurement of the key
- Add durations of each pitch class
- Compare duration pattern to key prototype
- Choose best match as the key
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Example:

Typical major key distribution of notes:

Example data measured from music:
Krumhansl-Schmuckler Algorithm

- Statistical measurement of the key
- Add durations of each pitch class
- Compare duration pattern to key prototype
- Choose best match as the key

Example:

D Major is best fit
Well-Tempered Clavier

!!!COM: Bach, Johann Sebastian
!!!XEN: The Well-Tempered Clavier, Volume 1, Fugue 1.
!!!SCT: BWV 846b
**kern **kern **kern **kern
*clefF4 *clefF4 *clefG2 *clefG2
*M4/4 *M4/4 *M4/4 *M4/4
=1 =1 =1 =1
1r 1r 8r 1r
. . 8c .
. . 8d .
. . 8e .
. . 8.f .
. . 32g .
. . 32f .
. . 8e .
. . 8a .
=2 =2 =2 =2

Result of Humdrum key command:

Estimated key: C major (r=0.8640) confidence: 22.3%
<table>
<thead>
<tr>
<th>Fugue</th>
<th>Key</th>
<th>Similarity</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fugue 1:</td>
<td>C major</td>
<td>0.8640</td>
<td>22.3%</td>
</tr>
<tr>
<td>Fugue 2:</td>
<td>C minor</td>
<td>0.8884</td>
<td>59.1%</td>
</tr>
<tr>
<td><strong>Fugue 3:</strong></td>
<td>G# major</td>
<td>0.8238</td>
<td><strong>1.4%</strong></td>
</tr>
<tr>
<td>Fugue 4:</td>
<td>C# minor</td>
<td>0.8681</td>
<td>58.2%</td>
</tr>
<tr>
<td>Fugue 5:</td>
<td>D major</td>
<td>0.9100</td>
<td>56.6%</td>
</tr>
<tr>
<td>Fugue 6:</td>
<td>D minor</td>
<td>0.7905</td>
<td>5.2%</td>
</tr>
<tr>
<td>Fugue 7:</td>
<td>E-flat major</td>
<td>0.8332</td>
<td>31.4%</td>
</tr>
<tr>
<td>Fugue 8:</td>
<td>D# minor</td>
<td>0.8428</td>
<td>70.9%</td>
</tr>
<tr>
<td>Fugue 9:</td>
<td>E major</td>
<td>0.8609</td>
<td>37.3%</td>
</tr>
<tr>
<td>Fugue 10:</td>
<td>E minor</td>
<td>0.7586</td>
<td>4.1%</td>
</tr>
<tr>
<td>Fugue 11:</td>
<td>F major</td>
<td>0.7568</td>
<td>17.7%</td>
</tr>
<tr>
<td>Fugue 12:</td>
<td>F minor</td>
<td>0.8022</td>
<td>25.2%</td>
</tr>
<tr>
<td>Fugue 13:</td>
<td>F# major</td>
<td>0.8748</td>
<td>39.9%</td>
</tr>
<tr>
<td>Fugue 14:</td>
<td>F# minor</td>
<td>0.8248</td>
<td>33.2%</td>
</tr>
<tr>
<td>Fugue 15:</td>
<td>G major</td>
<td>0.8575</td>
<td>17.8%</td>
</tr>
<tr>
<td>Fugue 16:</td>
<td>G minor</td>
<td>0.9208</td>
<td>82.4%</td>
</tr>
<tr>
<td>Fugue 17:</td>
<td>A-flat major</td>
<td>0.8441</td>
<td>25.6%</td>
</tr>
<tr>
<td>Fugue 18:</td>
<td>G# minor</td>
<td>0.8228</td>
<td>49.4%</td>
</tr>
<tr>
<td>Fugue 19:</td>
<td>A major</td>
<td>0.8351</td>
<td>21.8%</td>
</tr>
<tr>
<td>Fugue 20:</td>
<td>A minor</td>
<td>0.7772</td>
<td>13.3%</td>
</tr>
<tr>
<td>Fugue 21:</td>
<td>B-flat major</td>
<td>0.8539</td>
<td>37.6%</td>
</tr>
<tr>
<td>Fugue 22:</td>
<td>B-flat minor</td>
<td>0.8432</td>
<td>63.3%</td>
</tr>
<tr>
<td>Fugue 23:</td>
<td>B major</td>
<td>0.8589</td>
<td>19.3%</td>
</tr>
<tr>
<td>Fugue 24:</td>
<td>B minor</td>
<td>0.8266</td>
<td>40.8%</td>
</tr>
<tr>
<td>Fugue</td>
<td>Key</td>
<td>Confidence</td>
<td>Correlation</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------</td>
<td>------------</td>
<td>-------------</td>
</tr>
<tr>
<td>1</td>
<td>C major</td>
<td>59.2%</td>
<td>0.9382</td>
</tr>
<tr>
<td>2</td>
<td>C minor</td>
<td>70.1%</td>
<td>0.9380</td>
</tr>
<tr>
<td>3</td>
<td>C# major</td>
<td>78.0%</td>
<td>0.9524</td>
</tr>
<tr>
<td>4</td>
<td>C# minor</td>
<td>38.9%</td>
<td>0.7937</td>
</tr>
<tr>
<td>5</td>
<td>D major</td>
<td>15.1%</td>
<td>0.8226</td>
</tr>
<tr>
<td>6</td>
<td>D minor</td>
<td>56.5%</td>
<td>0.8729</td>
</tr>
<tr>
<td>7</td>
<td>E-flat major</td>
<td>15.8%</td>
<td>0.8961</td>
</tr>
<tr>
<td>8</td>
<td>D# minor</td>
<td>44.2%</td>
<td>0.7776</td>
</tr>
<tr>
<td>9</td>
<td>E major</td>
<td>8.8%</td>
<td>0.8248</td>
</tr>
<tr>
<td>10</td>
<td>E minor</td>
<td>45.4%</td>
<td>0.8239</td>
</tr>
<tr>
<td>11</td>
<td>F major</td>
<td>39.9%</td>
<td>0.9037</td>
</tr>
<tr>
<td>12</td>
<td>F minor</td>
<td>51.4%</td>
<td>0.7862</td>
</tr>
<tr>
<td>13</td>
<td>F# major</td>
<td>15.6%</td>
<td>0.7834</td>
</tr>
<tr>
<td>14</td>
<td>F# minor</td>
<td>52.1%</td>
<td>0.8283</td>
</tr>
<tr>
<td>15</td>
<td>D major</td>
<td>18.5%</td>
<td>0.8537</td>
</tr>
<tr>
<td>16</td>
<td>G minor</td>
<td>44.8%</td>
<td>0.7928</td>
</tr>
<tr>
<td>17</td>
<td>A-flat major</td>
<td>33.5%</td>
<td>0.8958</td>
</tr>
<tr>
<td>18</td>
<td>G# minor</td>
<td>62.1%</td>
<td>0.8473</td>
</tr>
<tr>
<td>19</td>
<td>E major</td>
<td>3.8%</td>
<td>0.7938</td>
</tr>
<tr>
<td>20</td>
<td>A minor</td>
<td>87.0%</td>
<td>0.8704</td>
</tr>
<tr>
<td>21</td>
<td>B-flat major</td>
<td>44.7%</td>
<td>0.8659</td>
</tr>
<tr>
<td>22</td>
<td>B-flat minor</td>
<td>57.5%</td>
<td>0.8329</td>
</tr>
<tr>
<td>23</td>
<td>B major</td>
<td>16.3%</td>
<td>0.8621</td>
</tr>
<tr>
<td>24</td>
<td>F# minor</td>
<td>0.8%</td>
<td>0.7644</td>
</tr>
</tbody>
</table>
Window Size

- Compositions are usually not all in one key
Window Size

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- How much music to consider when determining key?
Window Size

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- How much music to consider when determining key?
  - 1 measure is usually not enough

One measure:
Window Size

- Compositions are usually not all in one key
- How much music to consider when determining key?
  - 4 measures is often good
  - depends on meter, rhythm, etc.

One measure:  

Four measures:
Window Size

- Compositions are usually not all in one key
- How much music to consider when determining key?
  - 4 measures is often good
  - depends on meter, rhythm, etc.
- Safe way is to consider all window sizes for analysis

One measure:  Four measures:
2D Plot for Key Analyses
2D Plot for Key Analyses

Window Size

Start of piece

Time

End of piece
2D Plot for Key Analyses

Window Size

One pixel for analysis result

Entire piece analyzed

Time
2D Plot for Key Analyses

Analysis window shrinks

Window Size

Time
2D Plot for Key Analyses

Slide window to end of piece one pixel at a time.
Key to Color Mapping

- Rainbow mapped to circle of fifths
- Mostly a diatonic mapping
- Sufficient for tonal harmony
- Any mapping is possible
- Brightness/Contrast can also be used

For example:
Major/Minor => Bright/Dark
Example: Mozart Sonatina

C major

D minor

F major

G major

C major
Linear Picture of Key

C G D F C
Logarithmic Scaling

Key of Piece
Strong Keys
Weak Keys
Tonicizations
Cadences
Chords
WTC1 Fugue 3
Schubert Variations
Atonal Music

Webern Op 27, Mvmt. 1

Mozart Sonatina in C, Mvmt. 1
Pre-Tonal Music

Petrus de Cruce
Motet
(13th century)

Webern Op. 27
(20th century)
Extended Tonality

Scriabin

Op. 11
Prelude No. 4
Plot Variations
Plot Variations

Ambiguity
Plot Variations

Clarity
Plot Variations

Best roots

Interpolation

Next-best roots
Further Information

• Keyscape website:
  http://www-ccrma.stanford.edu/~craig/keyscape

• Written description:
  Presented at ICMC 2001, Havana, Cuba
  http://www-ccrma.stanford.edu/~craig/papers/01