Visualizing Harmony

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ICMC 2001

Havana, Cuba

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
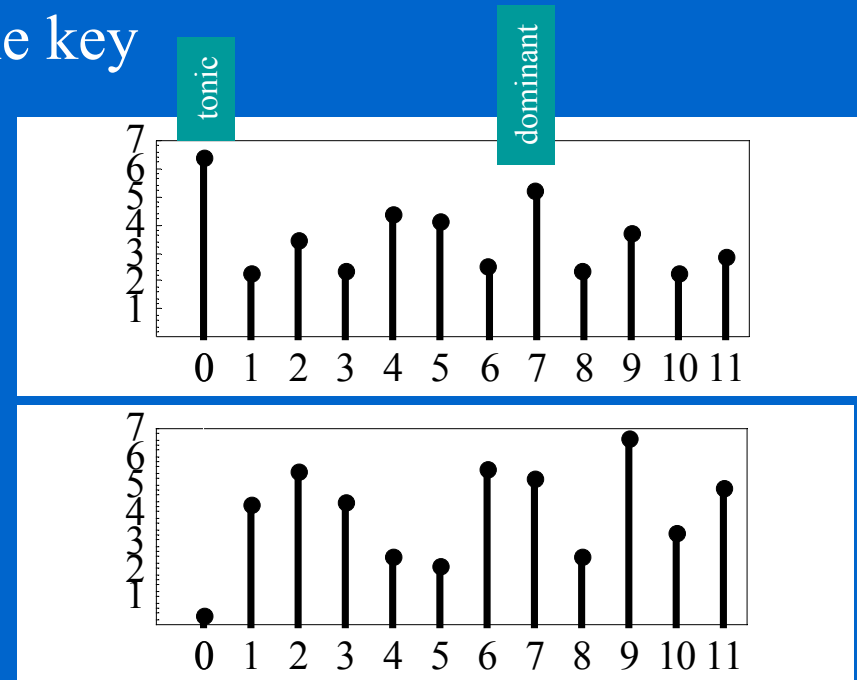
Krumhansl-Schmuckler Algorithm

- Statistical measurement of the key
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Example:

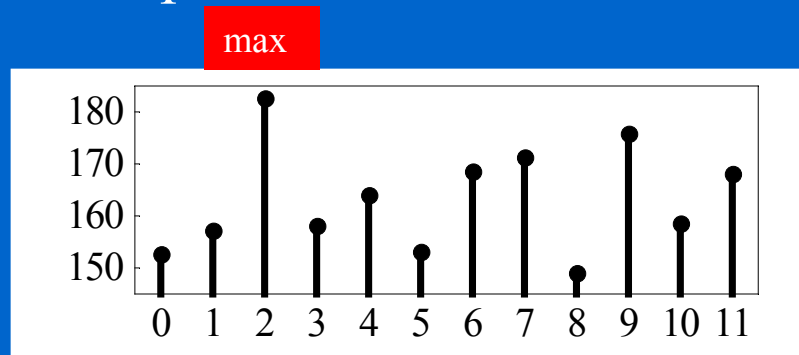Typical major key distribution of notes:
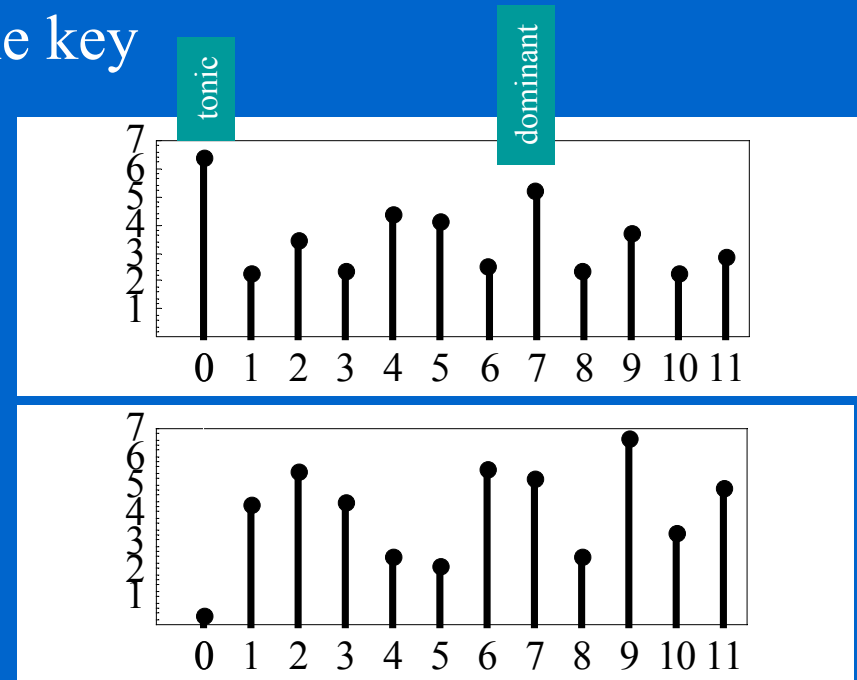

Example data measured from music:

Krumhansl-Schmuckler Algorithm

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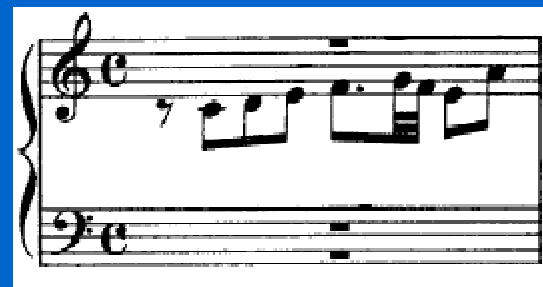- Choose best match as the key

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%
```

Well-Tempered Clavier (2)

Book 1:

```
Fugue 1:   C major        (r=0.8640)   confidence: 22.3%
Fugue 2:   C minor        (r=0.8884)   confidence: 59.1%
Fugue 3:   G# major       (r=0.8238)   confidence: 1.4%
Fugue 4:   C# minor       (r=0.8681)   confidence: 58.2%
Fugue 5:   D major        (r=0.9100)   confidence: 56.6%
Fugue 6:   D minor        (r=0.7905)   confidence: 5.2%
Fugue 7:   E-flat major   (r=0.8332)   confidence: 31.4%
Fugue 8:   D# minor       (r=0.8428)   confidence: 70.9%
Fugue 9:   E major        (r=0.8609)   confidence: 37.3%
Fugue 10:  E minor        (r=0.7586)   confidence: 4.1%
Fugue 11:  F major        (r=0.7568)   confidence: 17.7%
Fugue 12:  F minor        (r=0.8022)   confidence: 25.2%
Fugue 13:  F# major       (r=0.8748)   confidence: 39.9%
Fugue 14:  F# minor       (r=0.8248)   confidence: 33.2%
Fugue 15:  G major        (r=0.8575)   confidence: 17.8%
Fugue 16:  G minor        (r=0.9208)   confidence: 82.4%
Fugue 17:  A-flat major   (r=0.8441)   confidence: 25.6%
Fugue 18:  G# minor       (r=0.8228)   confidence: 49.4%
Fugue 19:  A major        (r=0.8351)   confidence: 21.8%
Fugue 20:  A minor        (r=0.7772)   confidence: 13.3%
Fugue 21:  B-flat major   (r=0.8539)   confidence: 37.6%
Fugue 22:  B-flat minor   (r=0.8432)   confidence: 63.3%
Fugue 23:  B major        (r=0.8589)   confidence: 19.3%
Fugue 24:  B minor        (r=0.8266)   confidence: 40.8%
```

Well-Tempered Clavier (3)

Book 2:

```
Fugue  1: C major        (r=0.9382)   confidence: 59.2%
Fugue  2: C minor        (r=0.9380)   confidence: 70.1%
Fugue  3: C# major       (r=0.9524)   confidence: 78.0%
Fugue  4: C# minor       (r=0.7937)   confidence: 38.9%
Fugue  5: D major        (r=0.8226)   confidence: 15.1%
Fugue  6: D minor        (r=0.8729)   confidence: 56.5%
Fugue  7: E-flat major   (r=0.8961)   confidence: 15.8%
Fugue  8: D# minor       (r=0.7776)   confidence: 44.2%
Fugue  9: E major        (r=0.8248)   confidence: 8.8%
Fugue 10: E minor        (r=0.8239)   confidence: 45.4%
Fugue 11: F major        (r=0.9037)   confidence: 39.9%
Fugue 12: F minor        (r=0.7862)   confidence: 51.4%
Fugue 13: F# major       (r=0.7834)   confidence: 15.6%
Fugue 14: F# minor       (r=0.8283)   confidence: 52.1%
Fugue 15: D major        (r=0.8537)   confidence: 18.5%
Fugue 16: G minor        (r=0.7928)   confidence: 44.8%
Fugue 17: A-flat major   (r=0.8958)   confidence: 33.5%
Fugue 18: G# minor       (r=0.8473)   confidence: 62.1%
Fugue 19: E major        (r=0.7938)   confidence: 3.8%
Fugue 20: A minor        (r=0.8704)   confidence: 87.0%
Fugue 21: B-flat major   (r=0.8659)   confidence: 44.7%
Fugue 22: B-flat minor   (r=0.8329)   confidence: 57.5%
Fugue 23: B major        (r=0.8621)   confidence: 16.3%
Fugue 24: F# minor       (r=0.7644)   confidence: 0.8%
```

Window Size

- Compositions are usually not all in one key

Window Size

- Compositions are usually not all in one key
- How much music to consider when determining key?
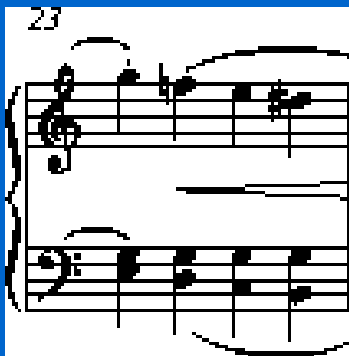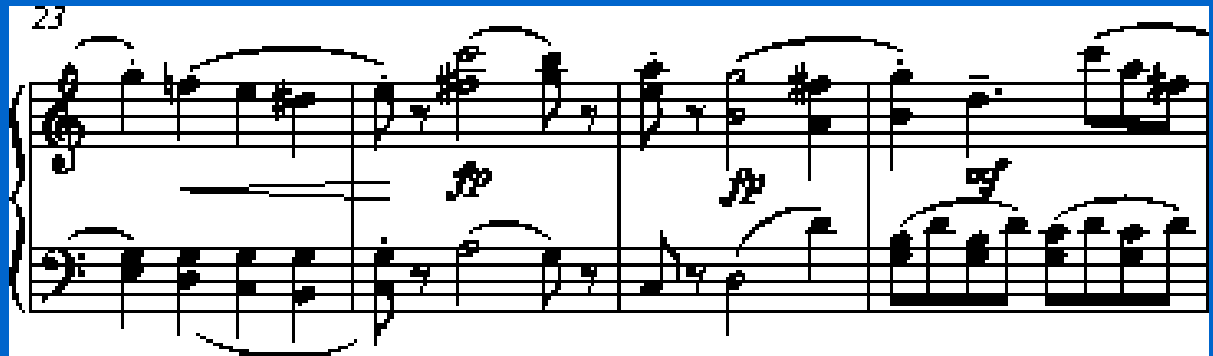
Window Size

- Compositions are usually not all in one key
- How much music to consider when determining key?
  - 1 measure is usually not enough

One measure:
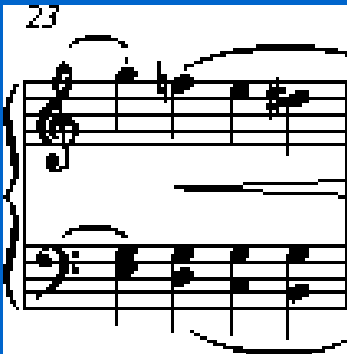
Window Size

- 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:
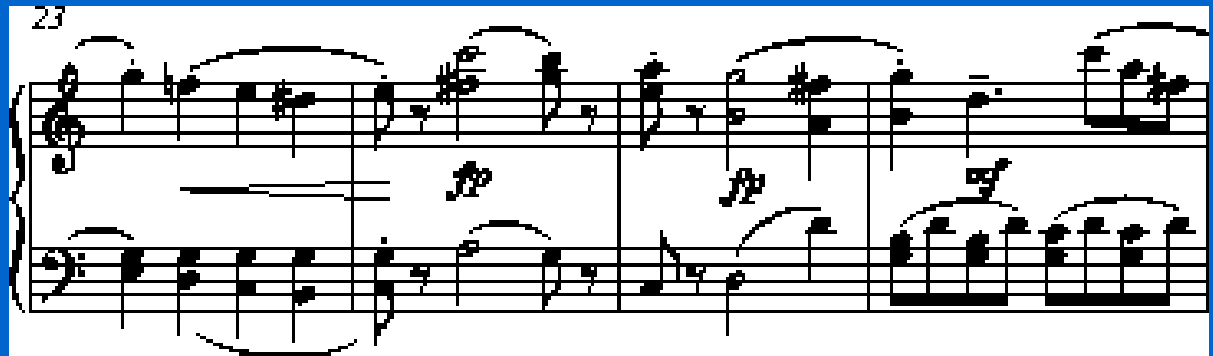
Window Size

- 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:
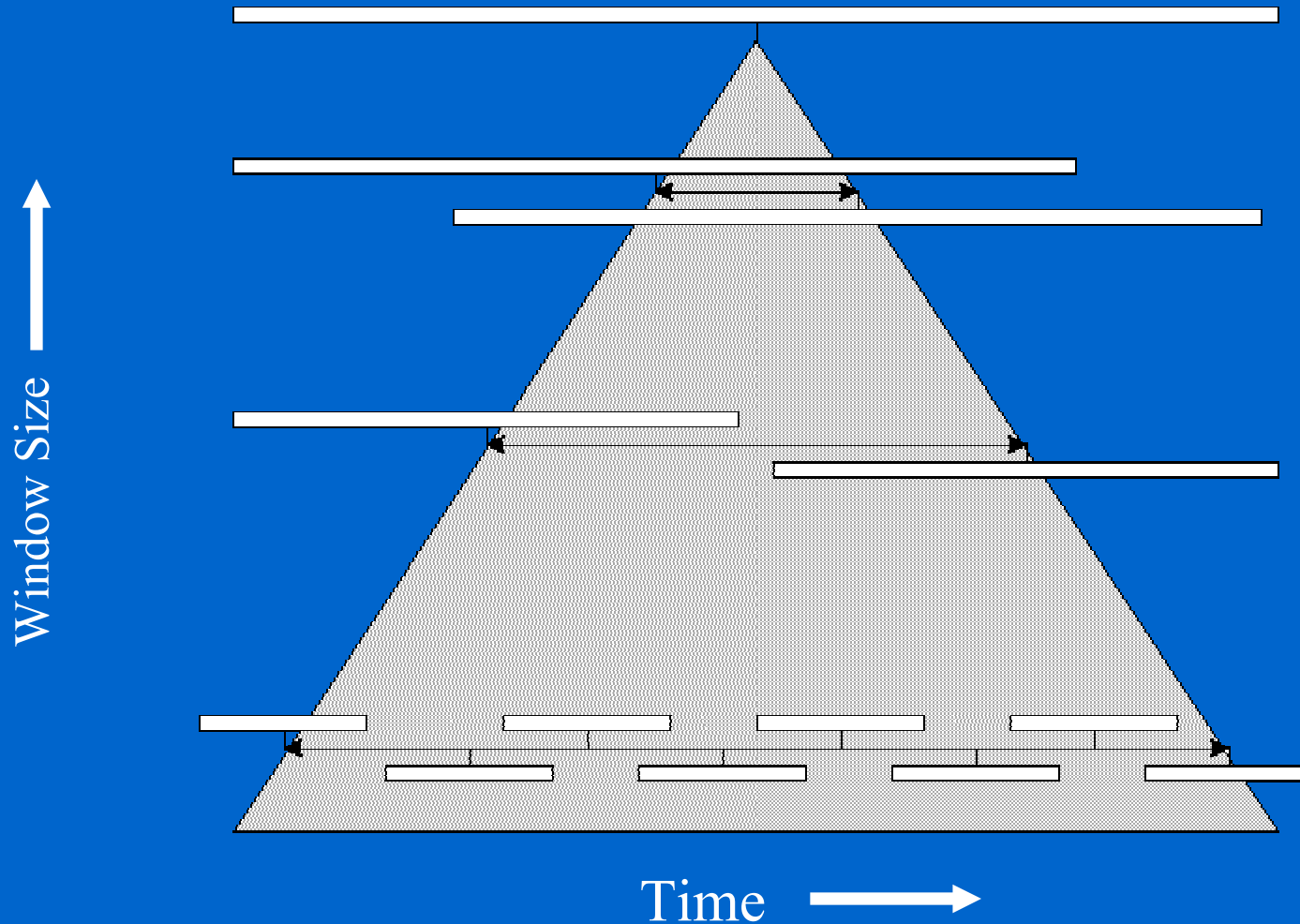
2D Plot for Key Analyses

2D Plot for Key Analyses

Window Size

Start of piece

Time

End of piece

2D Plot for Key Analyses

One pixel for analysis result

Entire piece analyzed

Window Size

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.

Window Size

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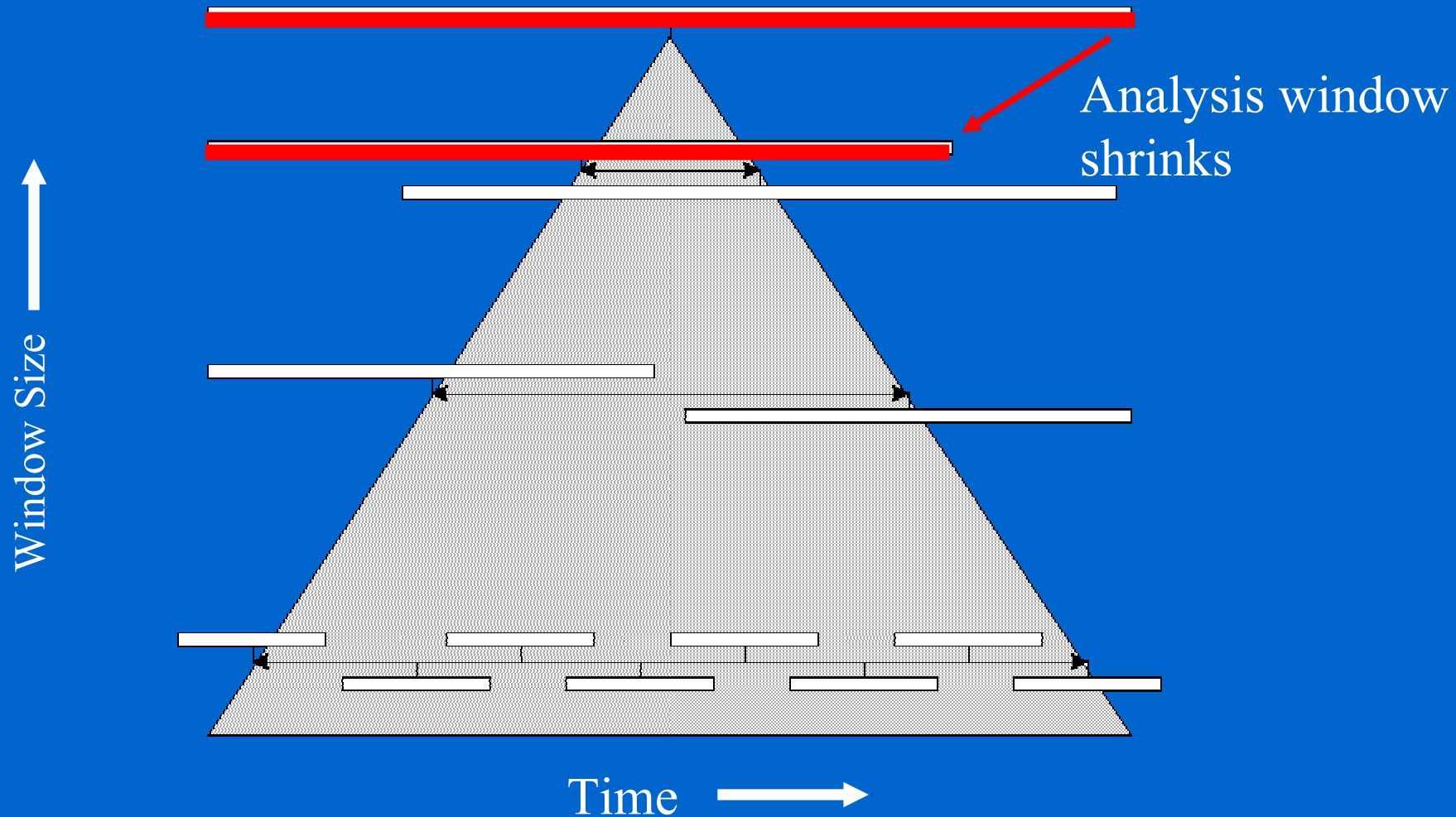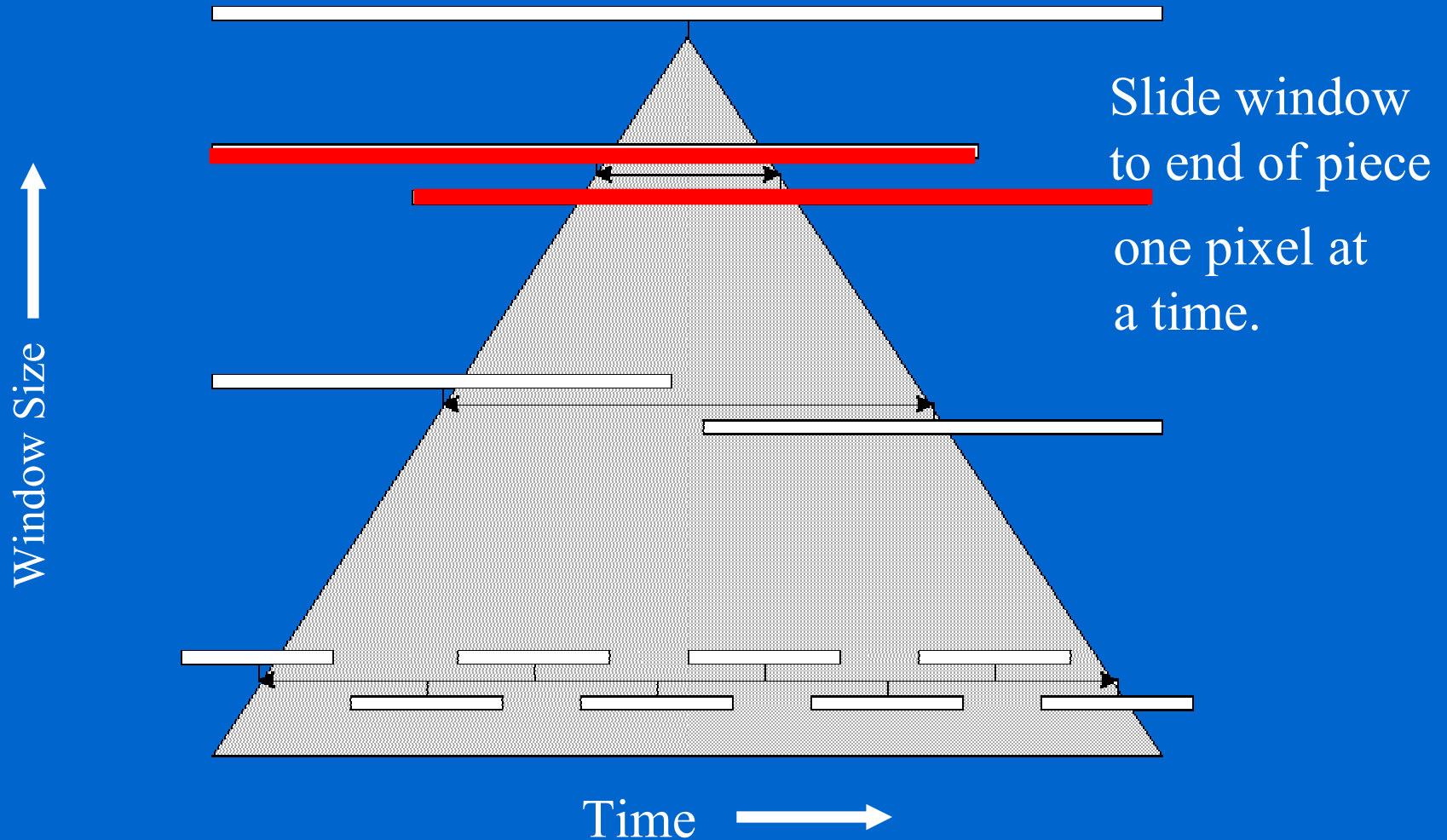
Key to Color Mapping
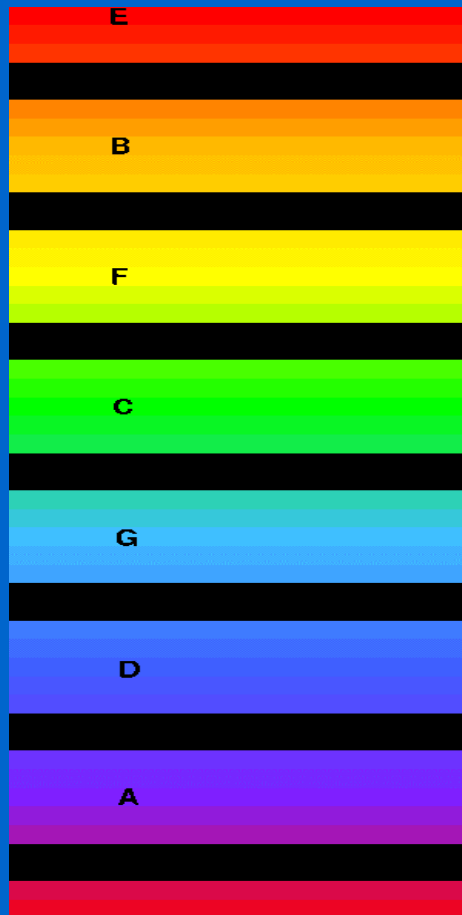
- Rainbow mapped to circle of fifths
- Mostly a diatonic mapping
- Sufficient for tonal harmony
- Any mapping is possible
- Brightness/Contrast can also be used

For example:

Major/Minor => Bright/Dark

Example: Mozart Sonatina

Linear Picture of Key

C   G   D F   C
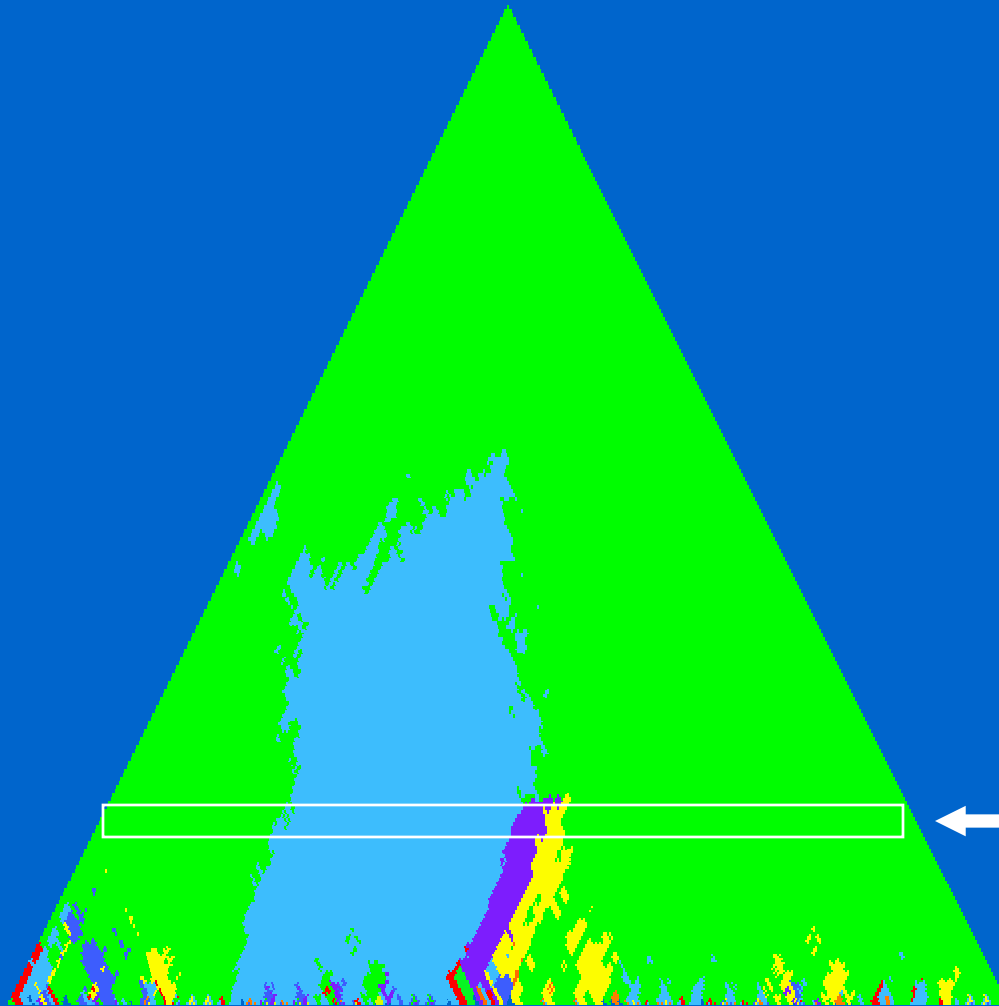
Linear Key

Logarithmic Scaling

Key of Piece

Strong Keys

Weak Keys

Tonicizations

Cadences

Chords

WTC1F03

Schubert Variations
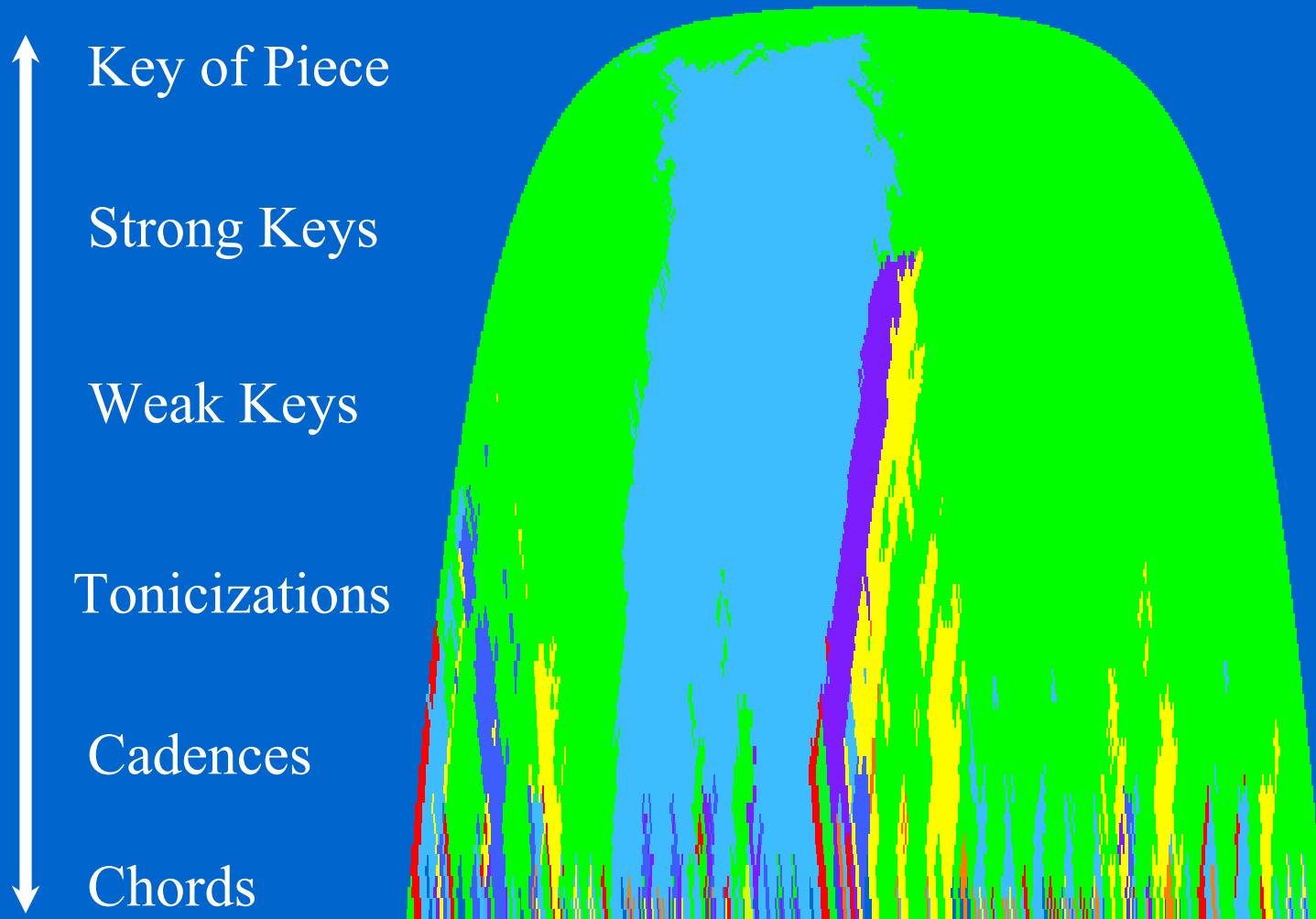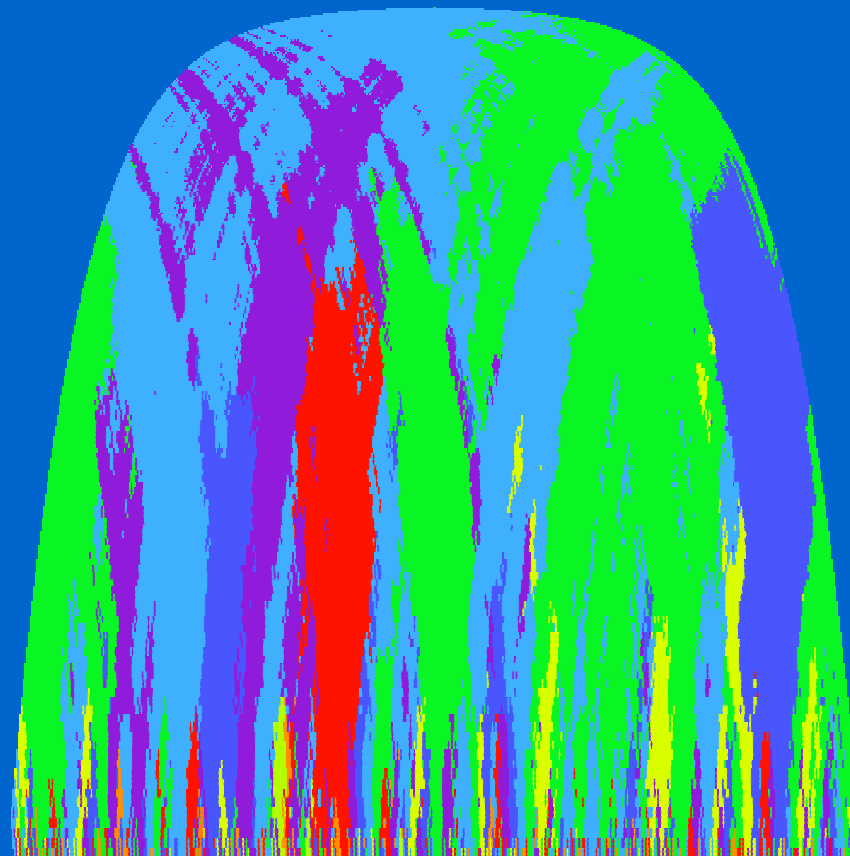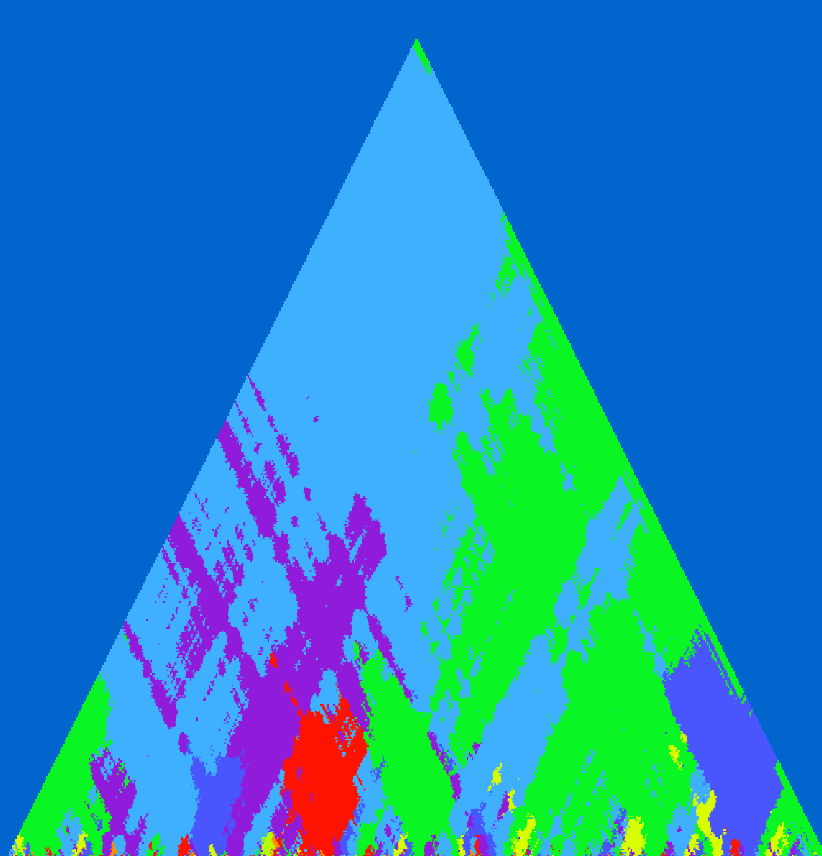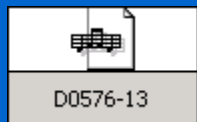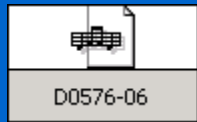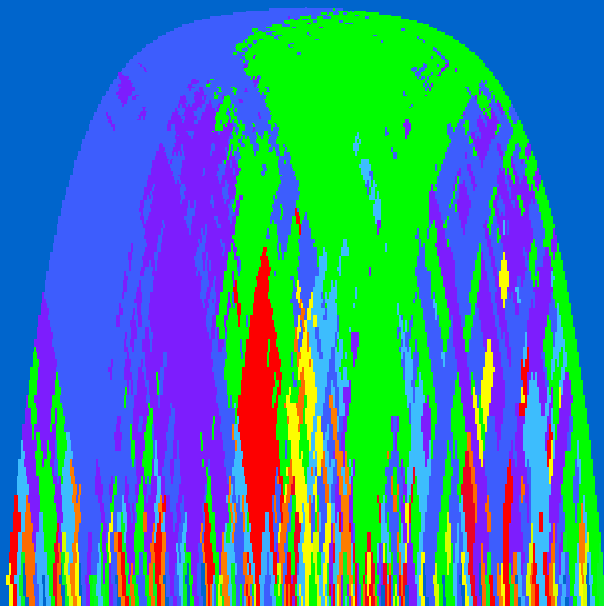
Atonal Music

Webern Op 27, Mvmt. 1
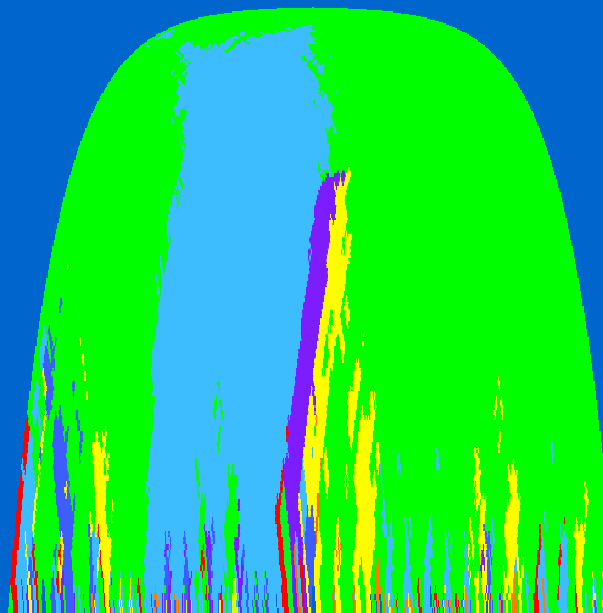
Mozart Sonatina in C, Mvmt. 1

VARIATIO

Pre-Tonal Music
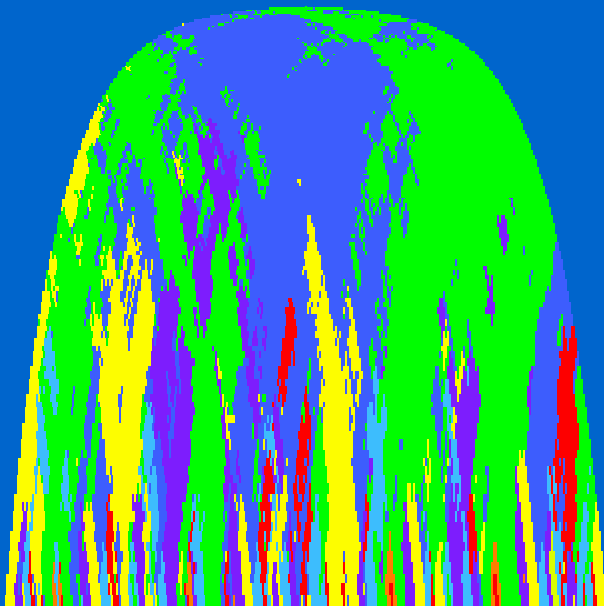
Petrus de Cruce
Motet
(13th century)
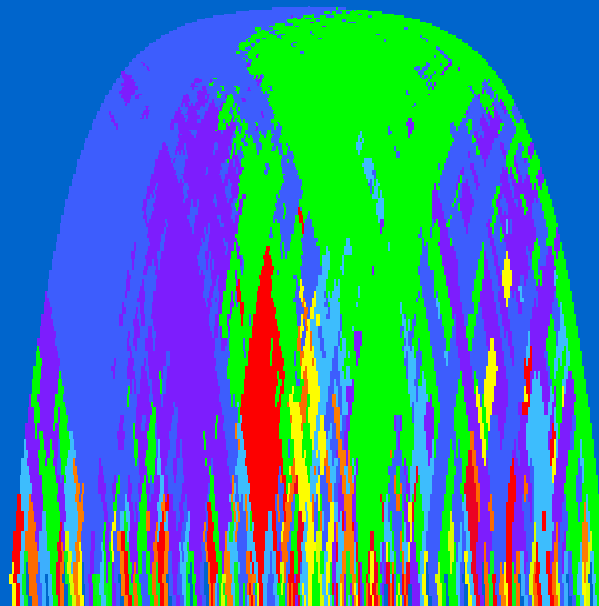
Webern Op. 27
(20th century)

Extended Tonality

Scriabin

Op. 11
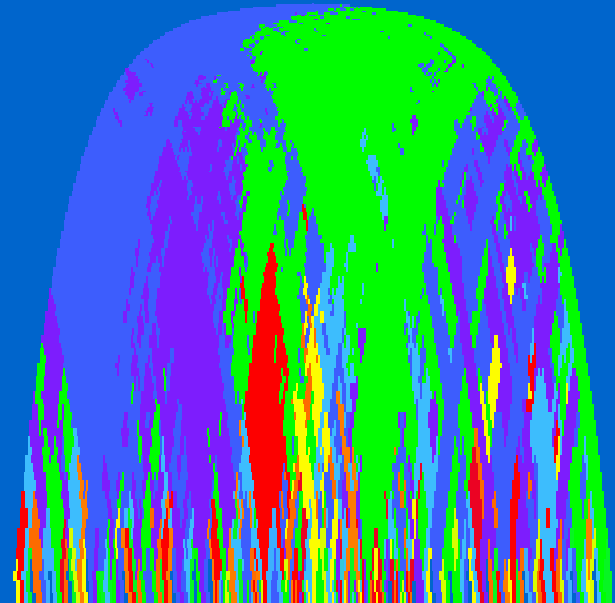Prelude No. 4

OP11NO4
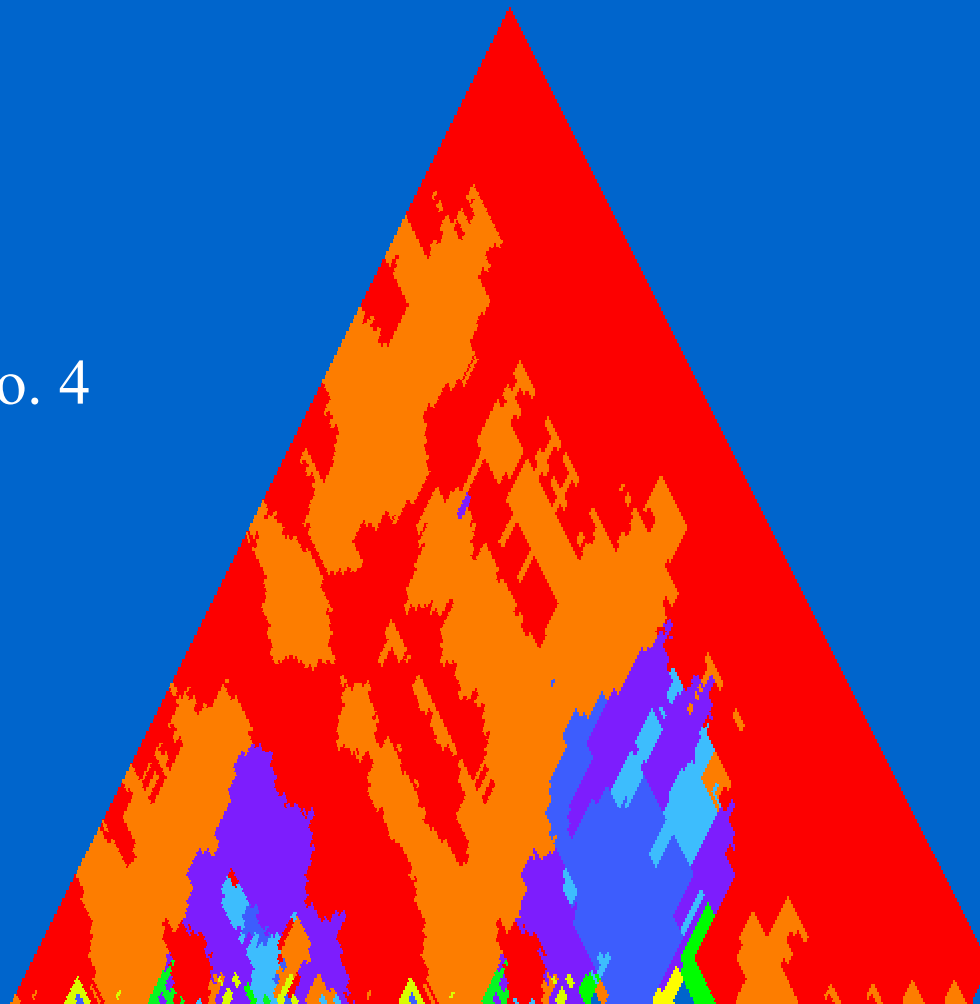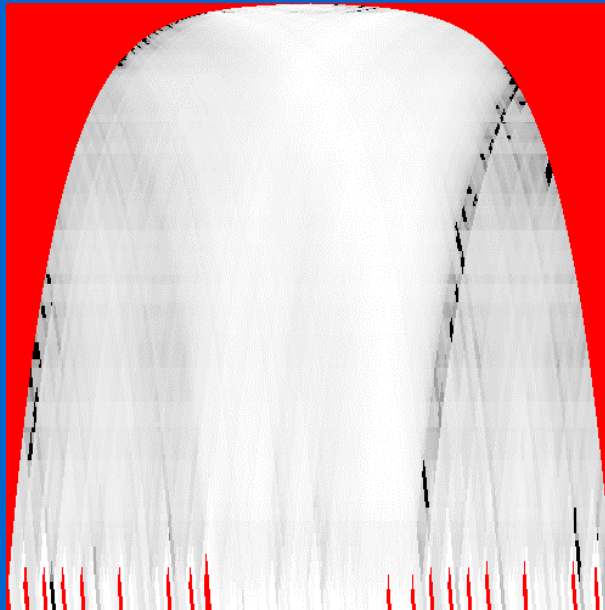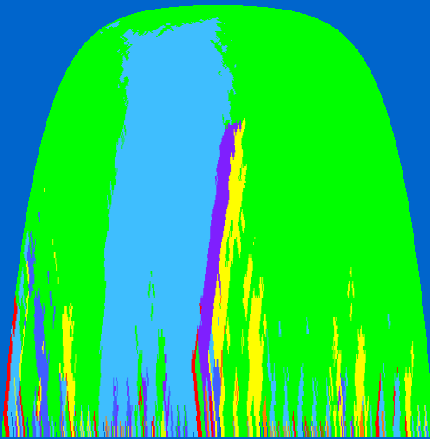
Plot Variations
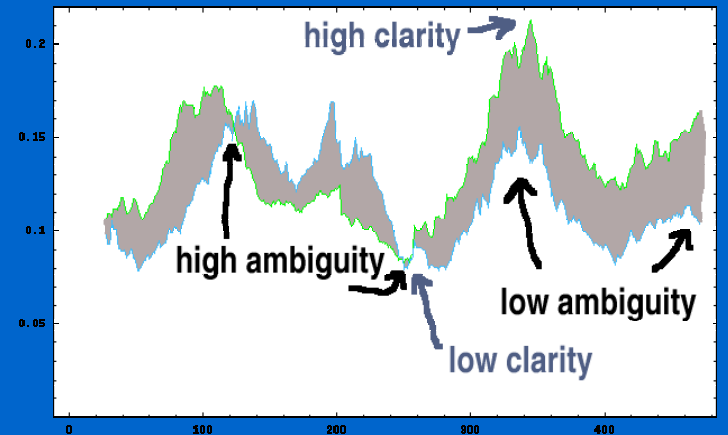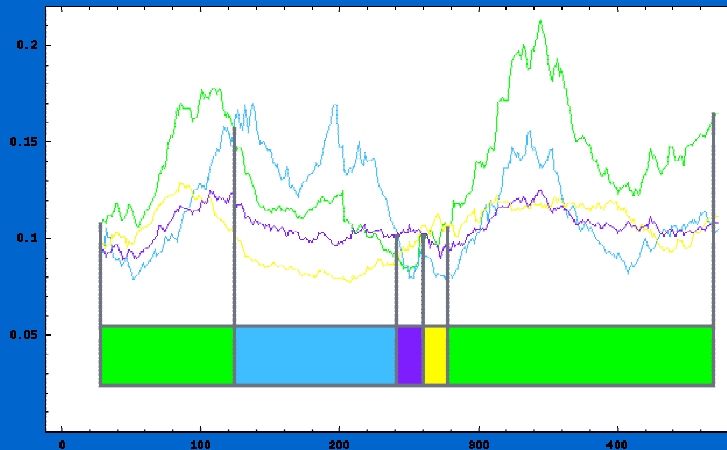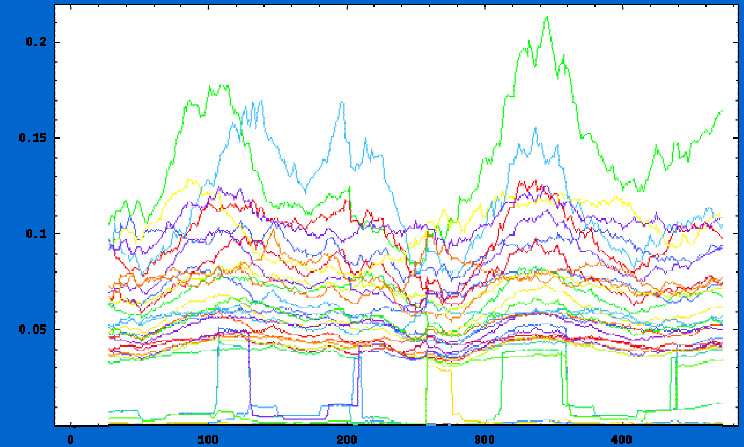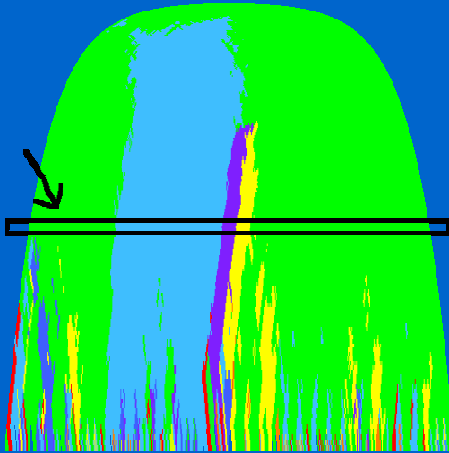
Plot Variations
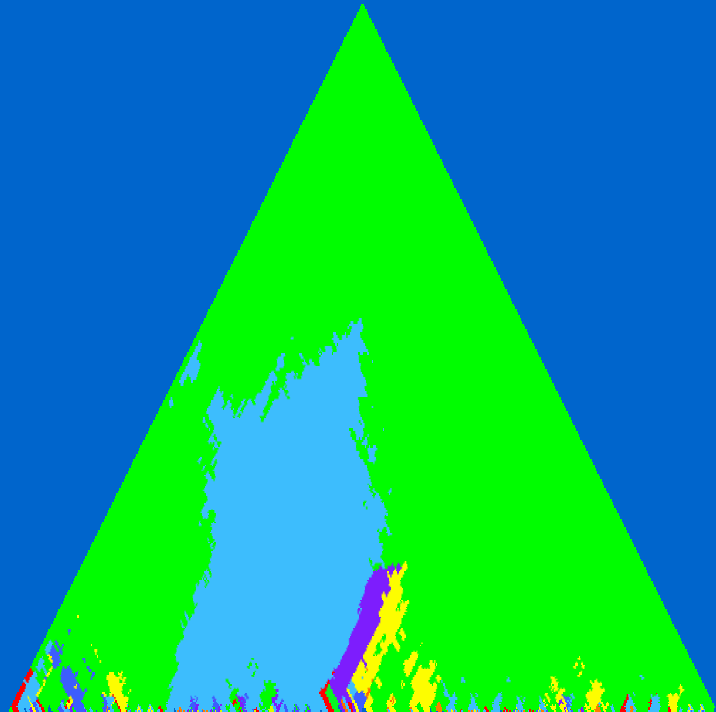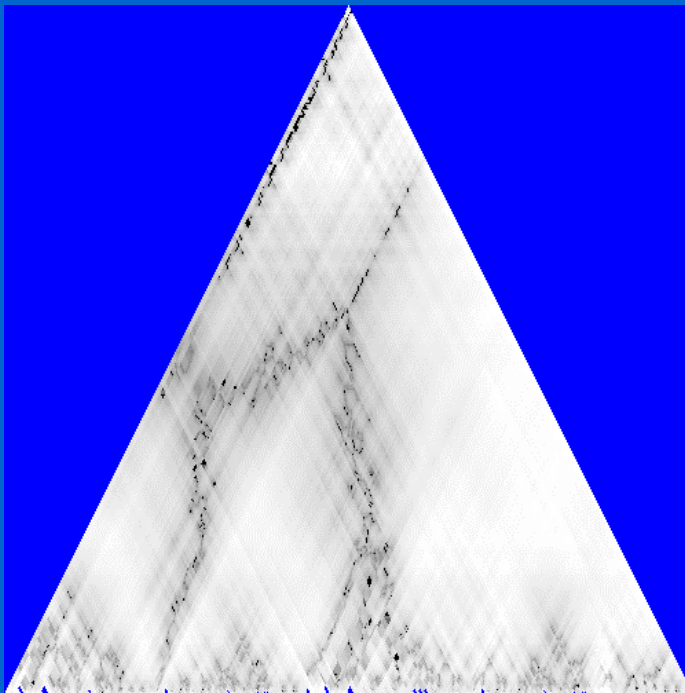
Plot Variations

Plot Variations

Interpolation

Best roots
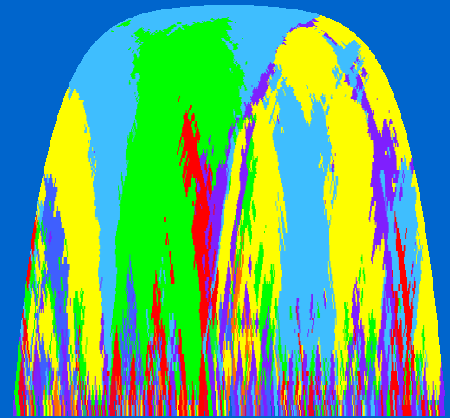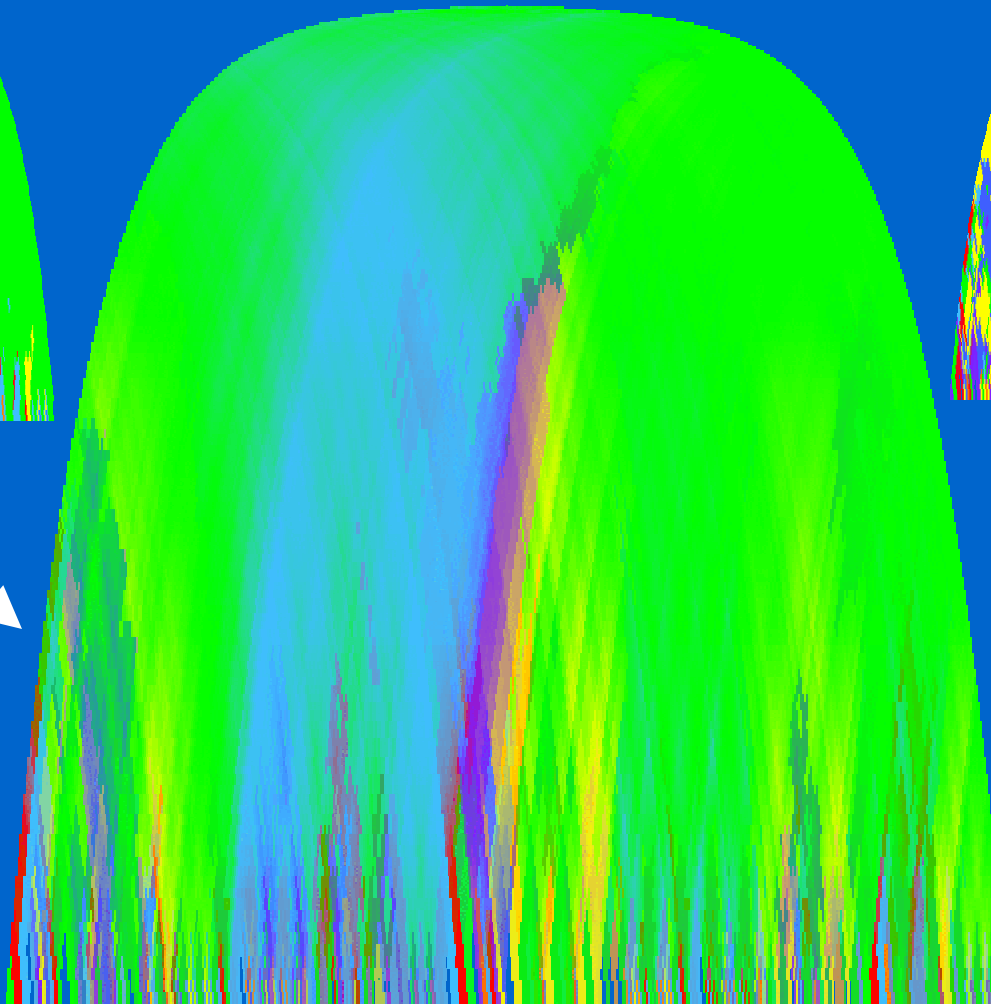
Next-best roots

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