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

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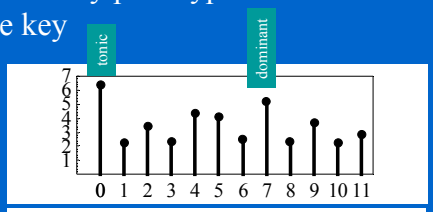
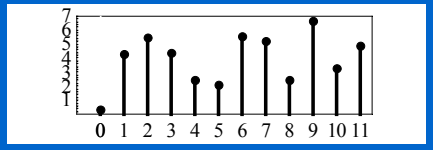
Example:

Typical major key distribution of notes:



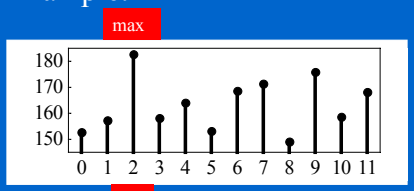
Example data measured from music:



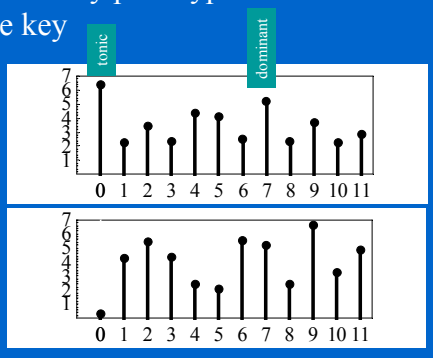
Krumhansl-Schmuckler Algorithm

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

Example:

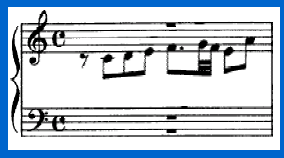


D Major is best fit



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

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- How much music to consider when determining key?

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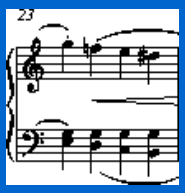
- How much music to consider when determining key?
  - 1 measure is usually not enough

One measure:

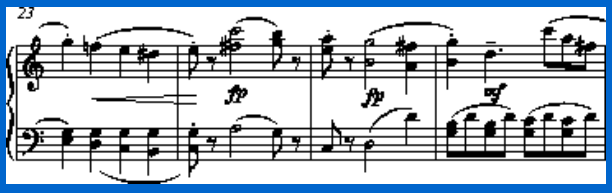


Window Size

- 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:

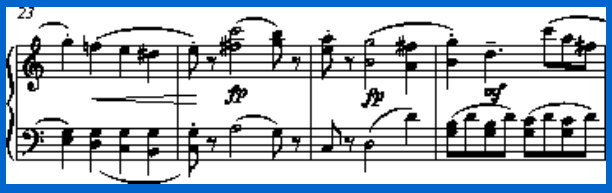


Window Size

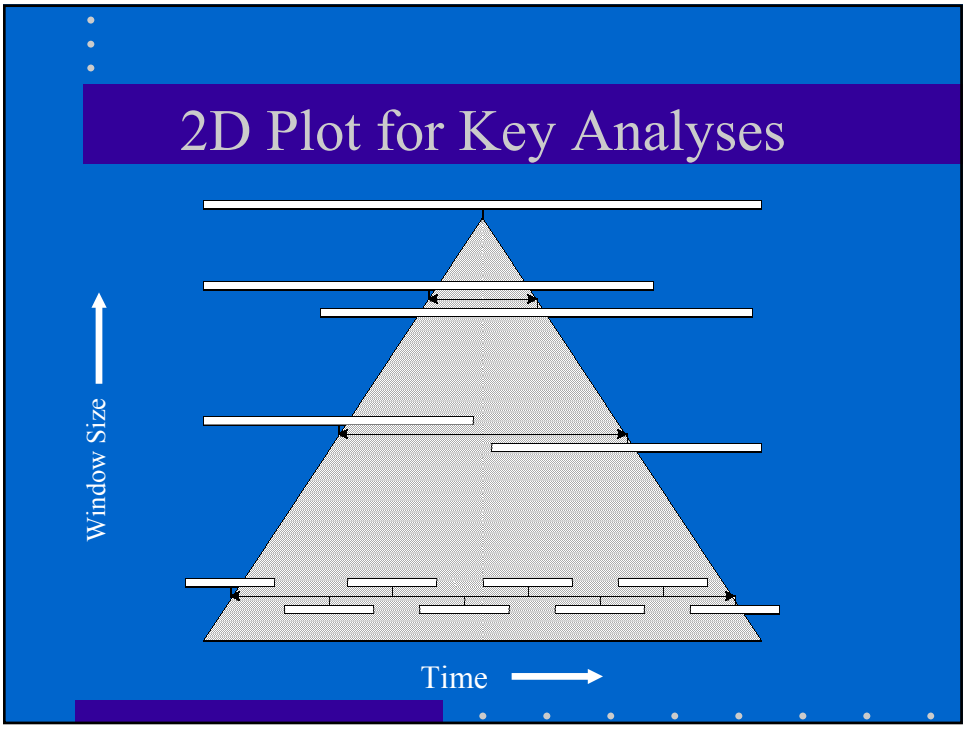
- Compositions are usually not all in one key
- How much music to consider when determining key?
  - 4 measures is often good
  - depends on meter, rhythm, etc.
- Safe way is to consider all window sizes for analysis

One measure:

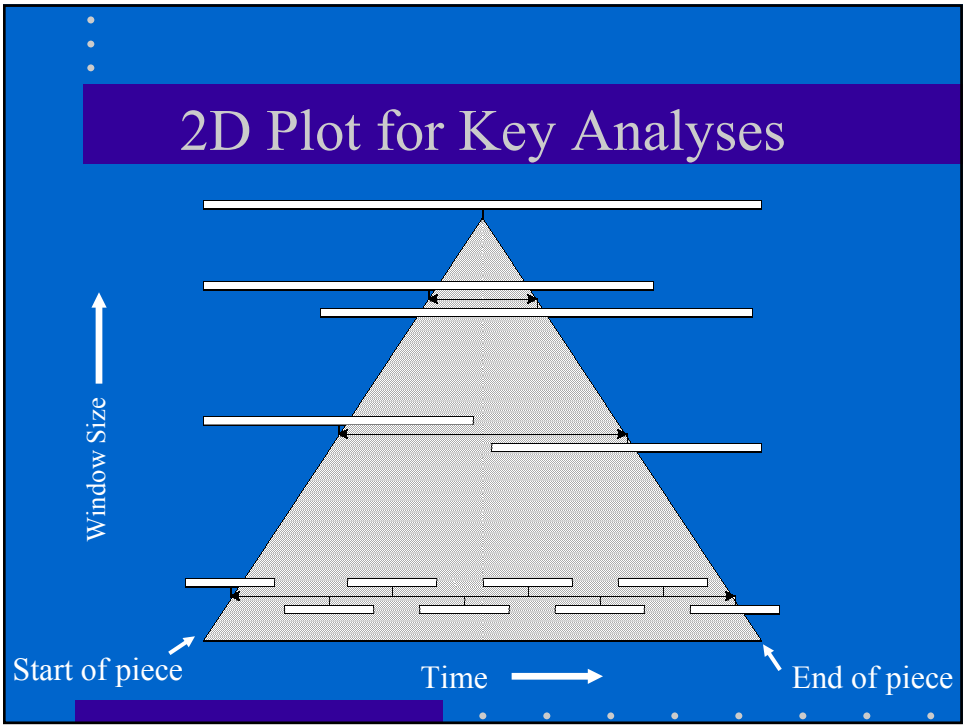
Four measures:



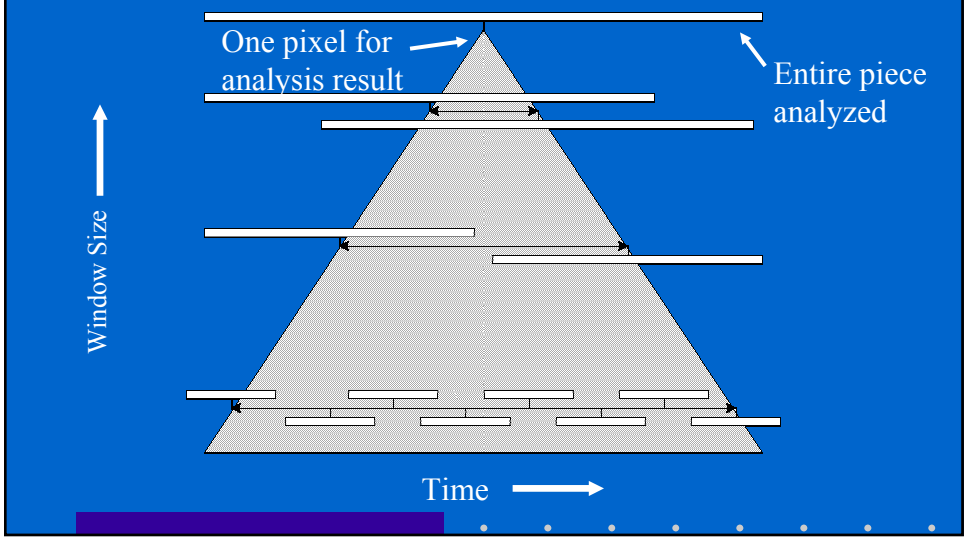
2D Plot for Key Analyses



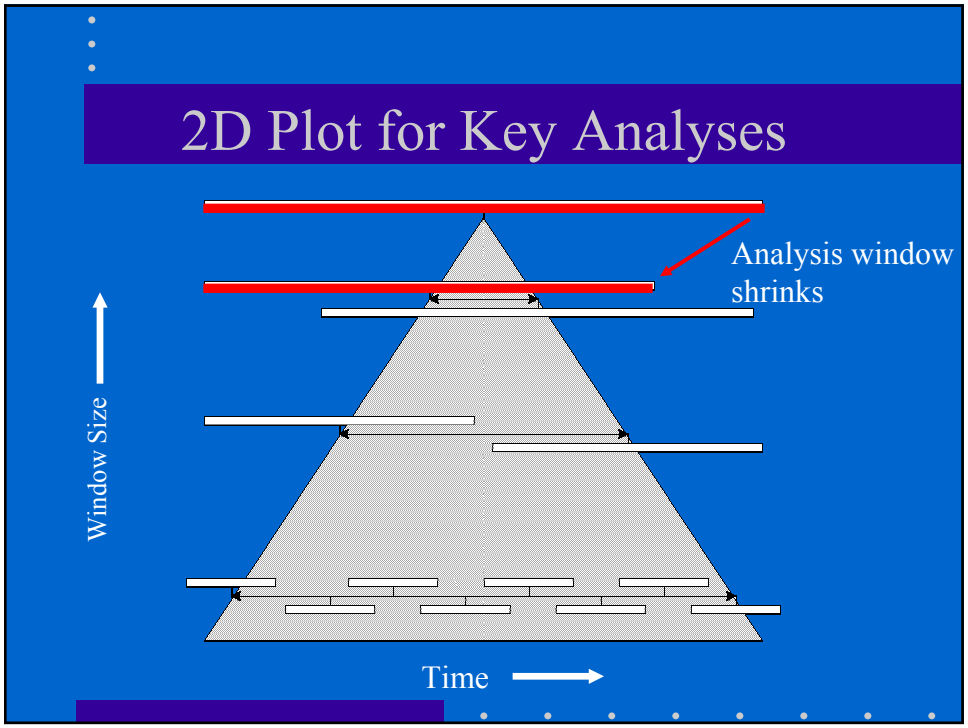
2D Plot for Key Analyses



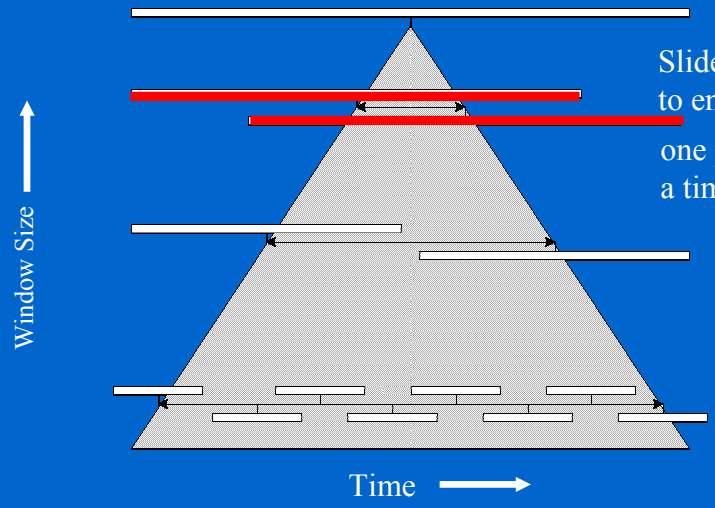
2D Plot for Key Analyses



2D Plot for Key Analyses

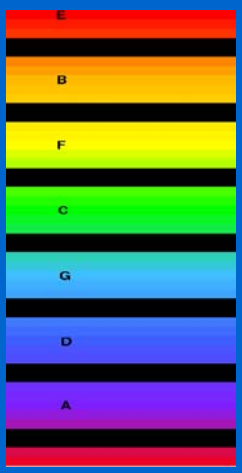


2D Plot for Key Analyses



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

Key to Color Mapping

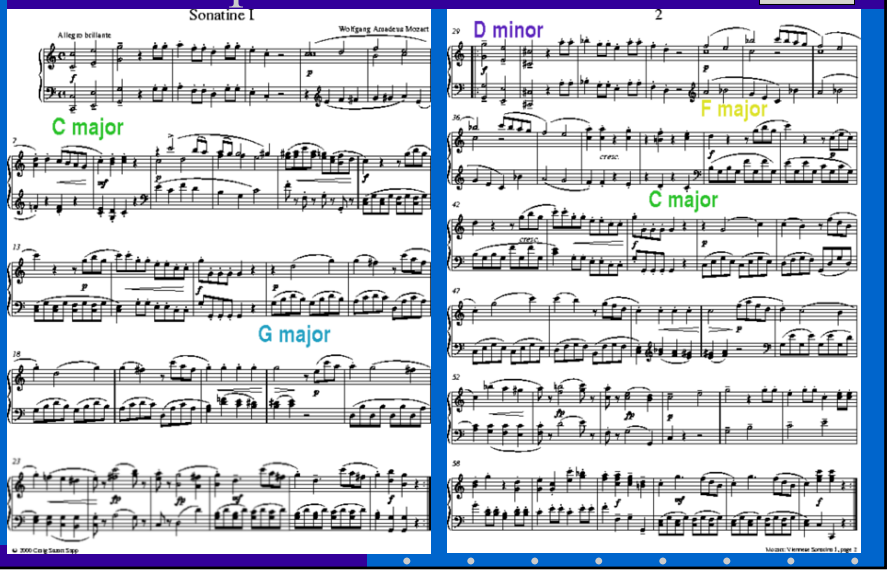


- Rainbow mapped to circle of fifths
- Mostly a diatonic mapping
- Sufficient for tonal harmony
- Any mapping is possible
- Brightness/Contrast can also be used

  For example:

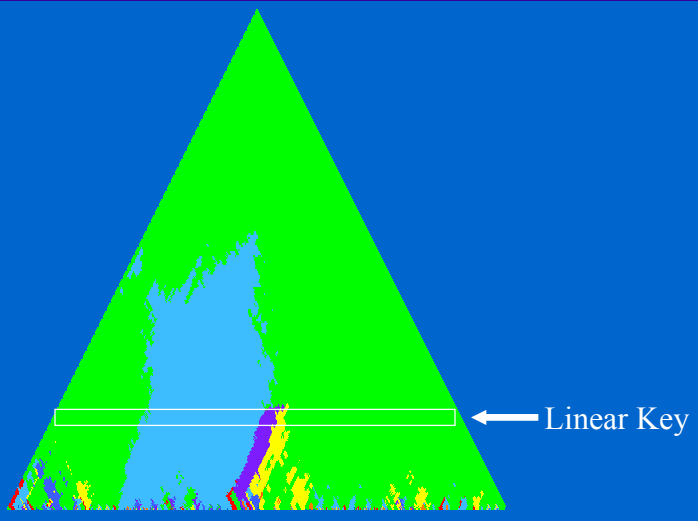
  Major/Minor => Bright/Dark

Example: Mozart Sonatina

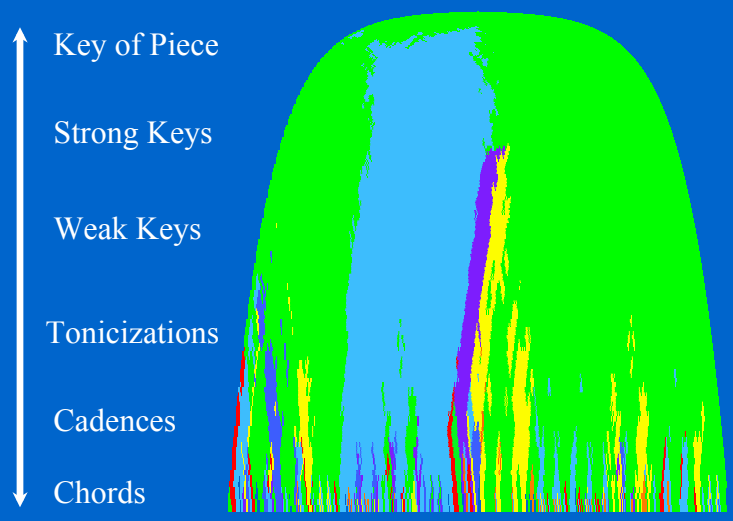


Linear Picture of Key

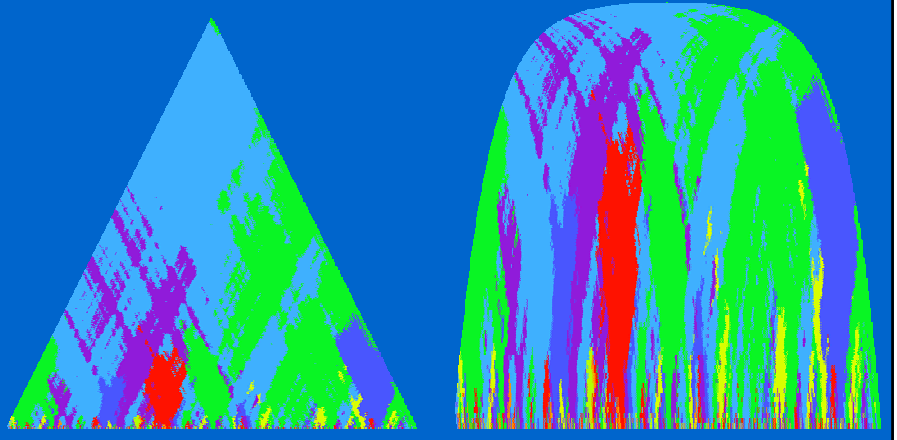
2D Picture of Key



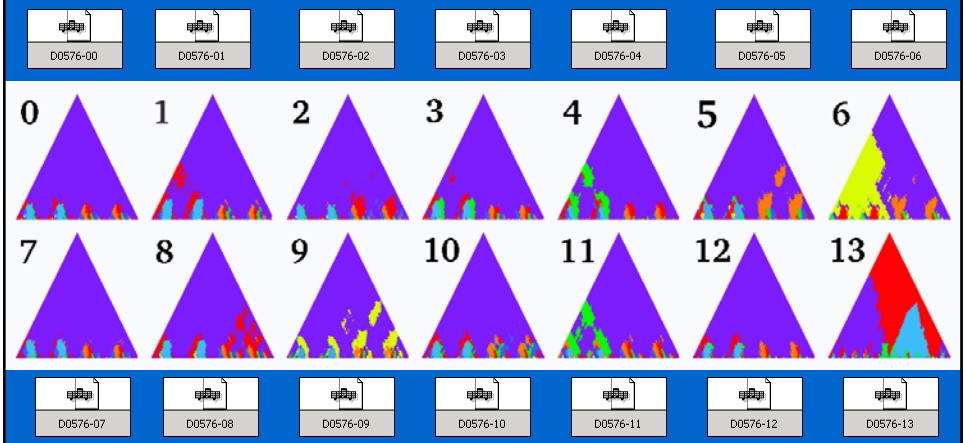
Logarithmic Scaling



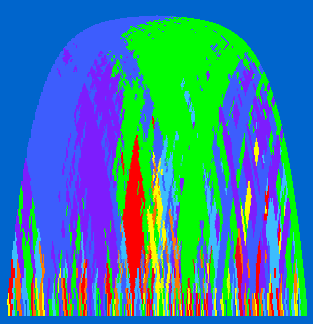
WTC1 Fugue 3



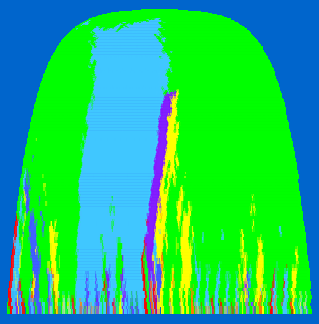
Schubert Variations



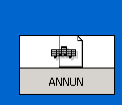
Atonal Music



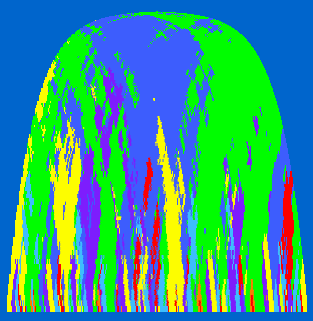
Webern Op 27, Mvmt. 1



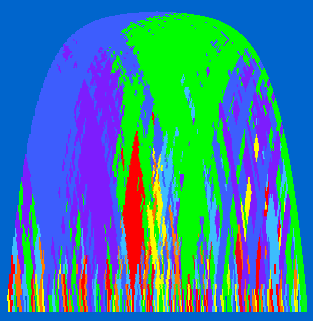
Mozart Sonatina in C, Mvmt. 1



Pre-Tonal Music



Petrus de Cruce
Motet
(13th century)

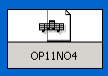


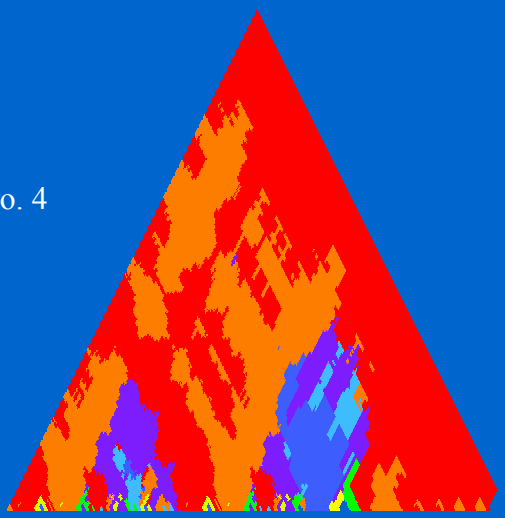
Webern Op. 27
(20th century)

Extended Tonality

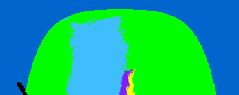
Scriabin

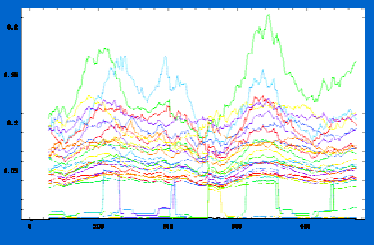
Op. 11
Prelude No. 4

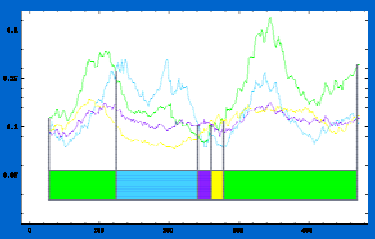


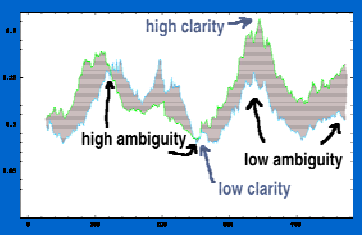


Plot Variations



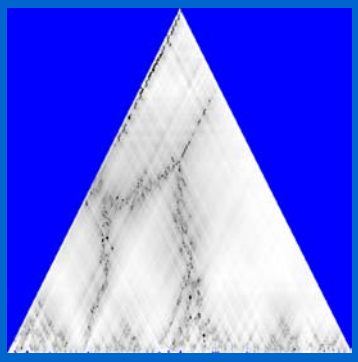


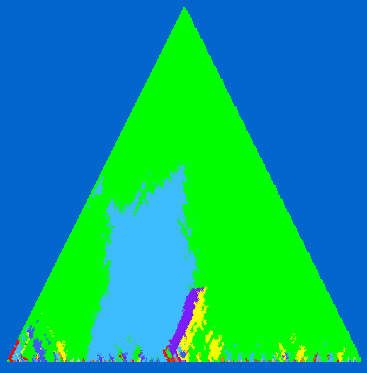




Plot Variations

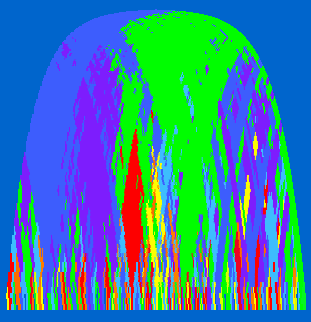
Ambiguity



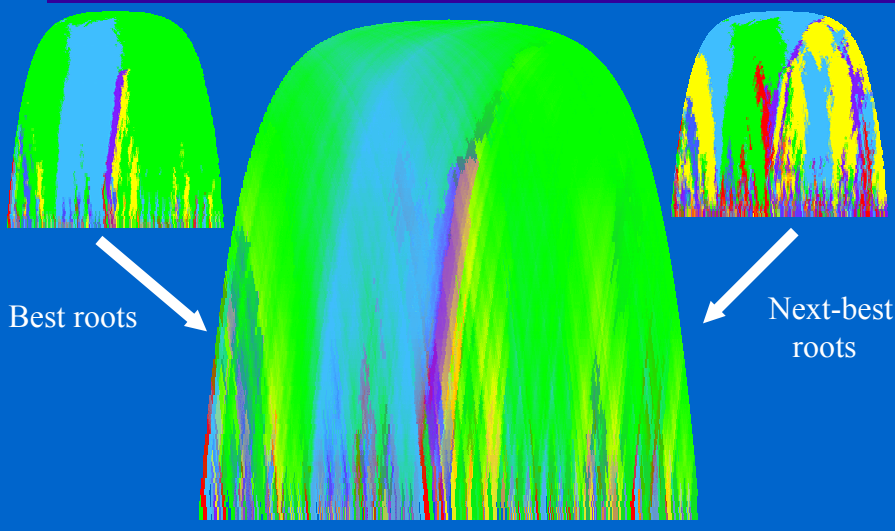


Plot Variations

Clarity



Plot Variations



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