

Musical Notation & Representation

Music 253/CS 275a

Stanford University

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5 Jan 2016

Representing Music

Two main categories:

- For **Performance** (used as memory aid and for non-aural transmission)

Usually not a complete representation (some discretion left to performer)

- Usually written, but also Guidonian hand is a spatial representation of music for education and memorization.

Scores for computational performance (usually no discretion left to computer)

- MIDI files, Record, CD, MP3, Data sonification

- For **Analysis**

Usually highlights a specific aspect of the music (reductive)

- Graphical representations (visualizations)
- Digital representations (computational analysis)
- Audio-based analysis (such as spectrograms)

Oldest Known Music Notation

Old Babylonian cuneiform musical notation. 2000-1700 BC



2 double columns, each of 7 ruled lines with numbers in Old Babylonian cuneiform tablature notation, with headings, "intonation" and "incantation", respectively.

Two ascending 7-note scales to be played on a 4-stringed lute tuned in ascending fifths.



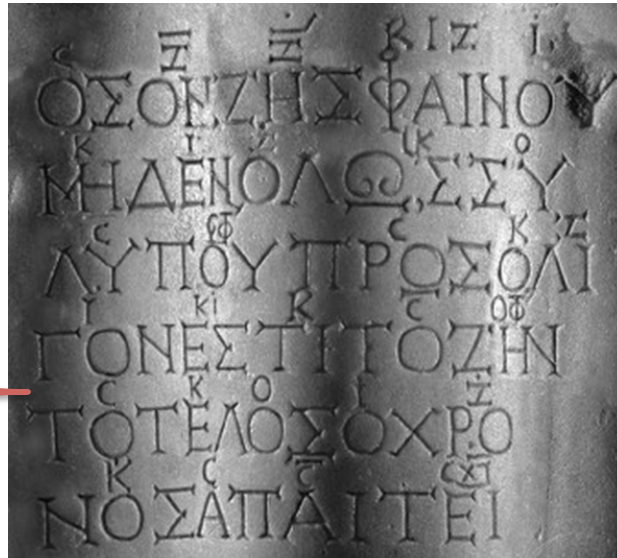
http://www.schoyencollection.com/music_files/ms5105.jpg

<http://www.schoyencollection.com/music.html>

Music Notation in Ancient Greece

Oldest complete notated song (~1st century AD)

Seikilos epitaph



σ τ κ ι ζ $\dot{\iota}$
 Ὅ σον ζῆς φαί νου

$\bar{\kappa}$ $\dot{\iota}$ $\dot{\zeta}$ $\dot{\iota}\bar{\kappa}$ $\bar{o}$ $\bar{\sigma}$ $\bar{\phi}$
 μη δέν ὄ λως σὺ λυ ποῦ

σ κ ζ $\dot{\iota}$ $\dot{\kappa}\dot{\iota}\kappa$ $\bar{\sigma}$ $\bar{\phi}$
 πρὸς ὀ λί γον ἐσ τὶ τὸ ζῆν

σ κ $\bar{o}$ $\dot{\iota}$ $\dot{\zeta}$ $\dot{\kappa}$ $\bar{\sigma}$ $\bar{\sigma}$ $\bar{\chi}$ $\bar{\tau}$
 τὸ τέ λος ὀ χρό νος ἀπ αι τεῖ.

Music Notation in Ancient Greece

C $\bar{Z}$ $\dot{\bar{Z}}$ K I Z $\dot{\bar{I}}$

Ὁ σον ζῆς φαί νου
While you live, shine

$\bar{K}$ I $\dot{Z}$ $\dot{\bar{I}}\bar{K}$ O $\bar{C}$ $\bar{O}\Phi$

μη δὲν ὄ λως σὺ λυ ποῦ
Have no grief at all

C K Z $\dot{I}$ $\dot{\bar{K}}\bar{I}$ $\bar{C}$ $\bar{O}\Phi$
πρὸς ὀ λί γον ἐσ τὶ τὸ ζῆν

Life exists only for a short while

C K O $\dot{I}$ $\dot{Z}$ $\dot{\bar{K}}$ C $\bar{C}$ $\bar{C}\dot{X}\bar{\Gamma}$

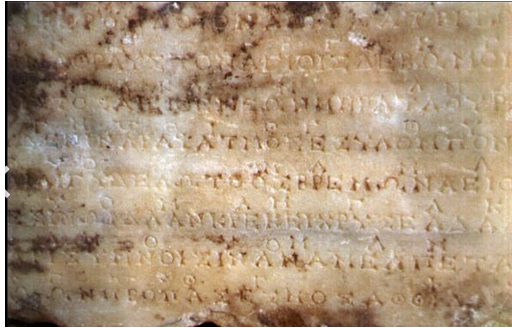
τὸ τέ λος ὁ χρό νος ἀπ αι τεῖ.
And time demands its toll



http://en.wikipedia.org/wiki/Seikilos_epitaph

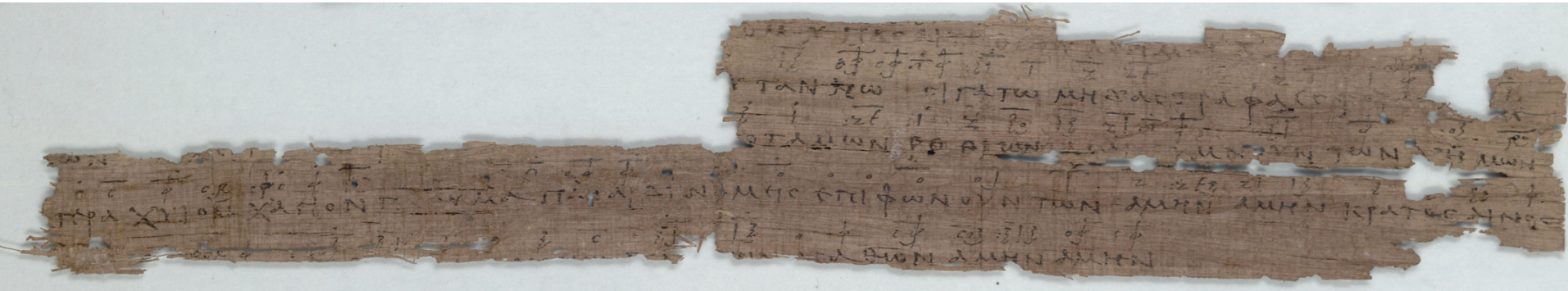
Performed on a *hydraulis*: https://www.youtube.com/watch?v=P4_iWkP24Ww#t=7

Music Notation in Ancient Greece



2nd century BC
Earliest surviving composition
with a known composer
(Athenios son of Athenios)

http://en.wikipedia.org/wiki/Delphic_Hymns



http://en.wikipedia.org/wiki/Oxyrhynchus_hymn

3rd century AD

http://en.wikipedia.org/wiki/Music_of_ancient_Greece

Tonic Sol-Fa

The Lamb.

WILLIAM BLAKE.

GEORGE HENSCHEL.

VOICE.



Lit - tle lamb, who made thee? Dost thou know who
KEY C. { | m .m :m .s | s :r | m .s :d^l .l }

PIANO.



Byzantine Music Notation

(10th – 15th centuries)

interval notation



Romania, 1823

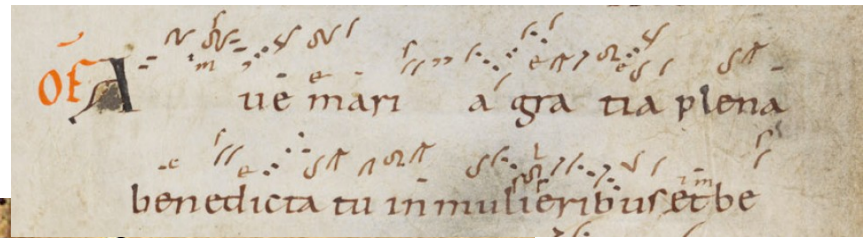
http://en.wikipedia.org/wiki/Musical_notation#Byzantine_Empire



Дѣѡ - те ꙗко - ма ꙗко - ѡ - менъ каѡ - ѡнъ оуѡ ѡ ѡ ꙗко - те

http://www.musicportal.gr/byzantine_music_system/?lang=en

Gregorian Chant



http://www.schoyencollection.com/music_files/ms1681.jpg

Comm.
I.

E C-CE virgo concí-pi- et, et pá- ri- et fi- li-

← Messine notation

← Modern chant notation

← St. Gall notation

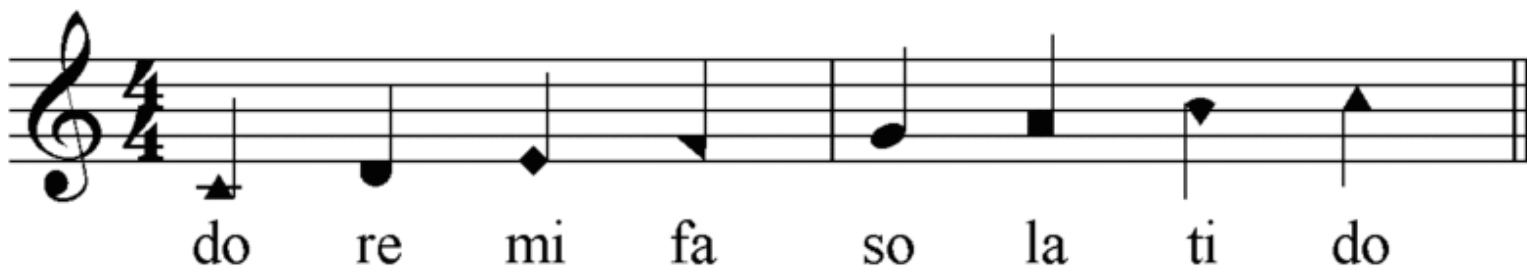
<http://euouae.com/category/transcription/>

http://en.wikipedia.org/wiki/Gregorian_chant

<http://en.wikipedia.org/wiki/Neume>



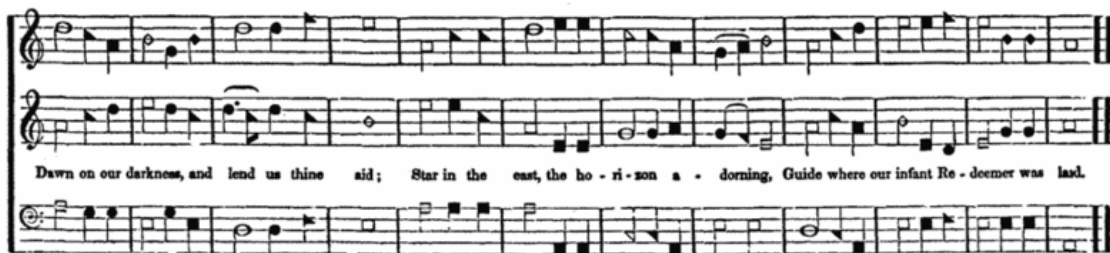
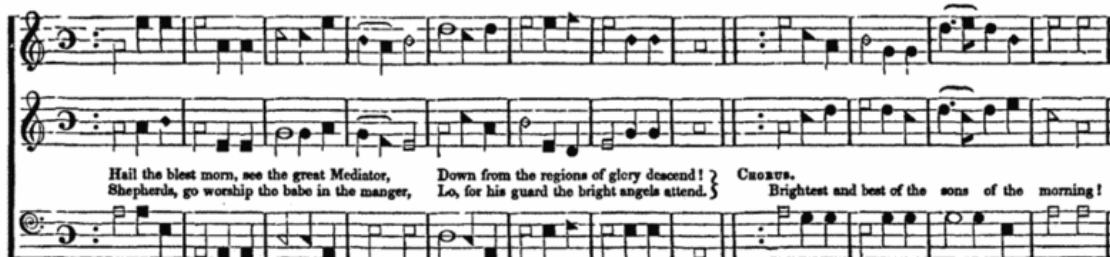
Shape Notes



16

STAR IN THE EAST 10, 11.

Baptist Harmony, p. 35



2 Cold on his cradle the dew-drops are shining;
Low lies his bed, with the beasts of the stall;
Angels adore him, in slumbers reclining,
Wise men and shepherds before him do fall.
Brightest and best. &c.

3 Say, shall we yield him, in costly devotion,
Odours of Eden, and offerings divine,
Gems from the mountain, and pearls from the ocean,
Myrrh from the forest, and gold from the mine?
Brightest and best. &c.

4 Vainly we offer each simple oblation,
Vainly with gold we his favour secure,
Richer by far is the heart's adoration:
Dearer to God are the prayers of the poor
Brightest and best. &c.

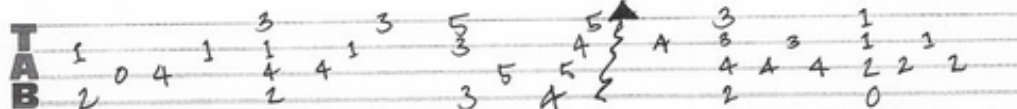


Tablature

Indicates *how* to play the pitches, not an abstracted/neutral concept of pitch.

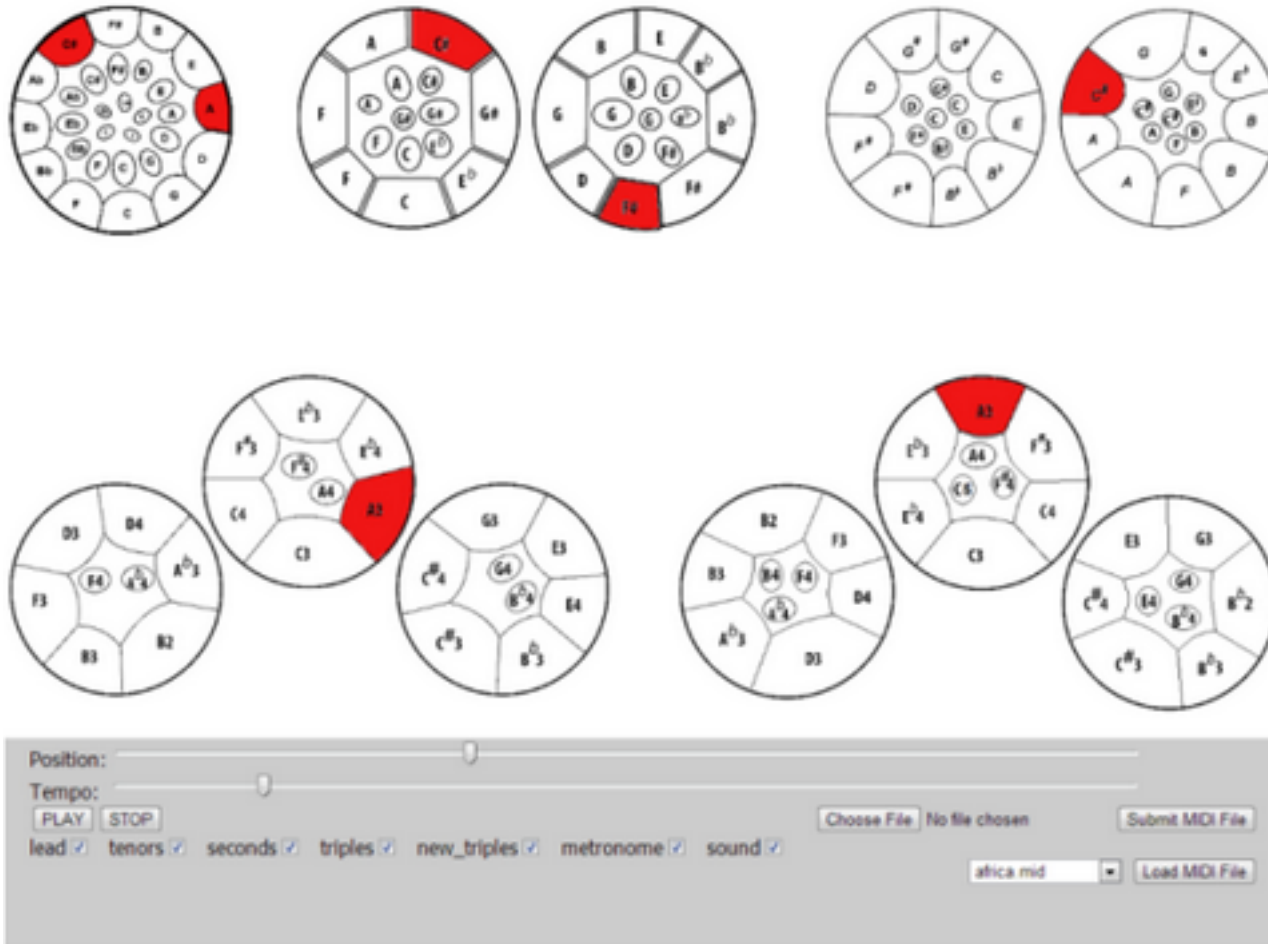


lute



E - 5 - 3 - - - 5 - 3/5 - - -
B - 7 - 7 - - - 7 - - - 7 - - -
G - - - 7 - 7 - 0 - - 0 - 7 - 7 -
D - 0 - 0 - - - - - - - - - -
A 0 - - - - - - - - - - - -
E - - - - - - - - - - - -

Steel Drum Tablature



— Jonathan Potter, Cardinal Calypso

Ikuta school notation (Kyoto)



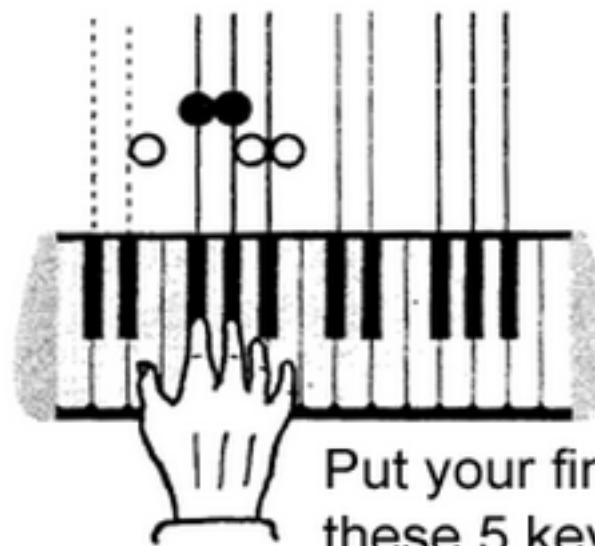
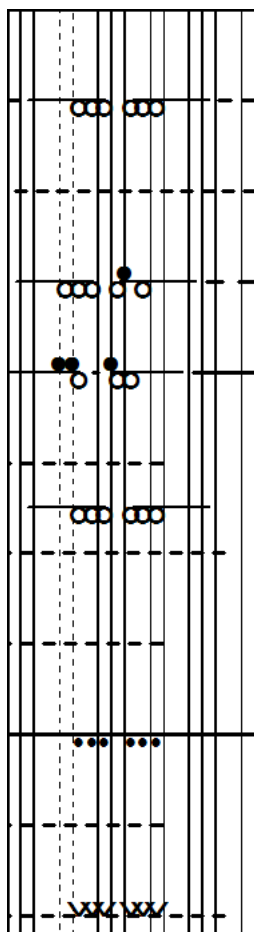
http://en.wikipedia.org/wiki/Koto_%28instrument%29



Piano Tablature

Klavarskribo

“Keyboard script” in Esperanto



Put your fingers above
these 5 keys

<https://www.youtube.com/watch?v=MlolvxunihA&t=659>

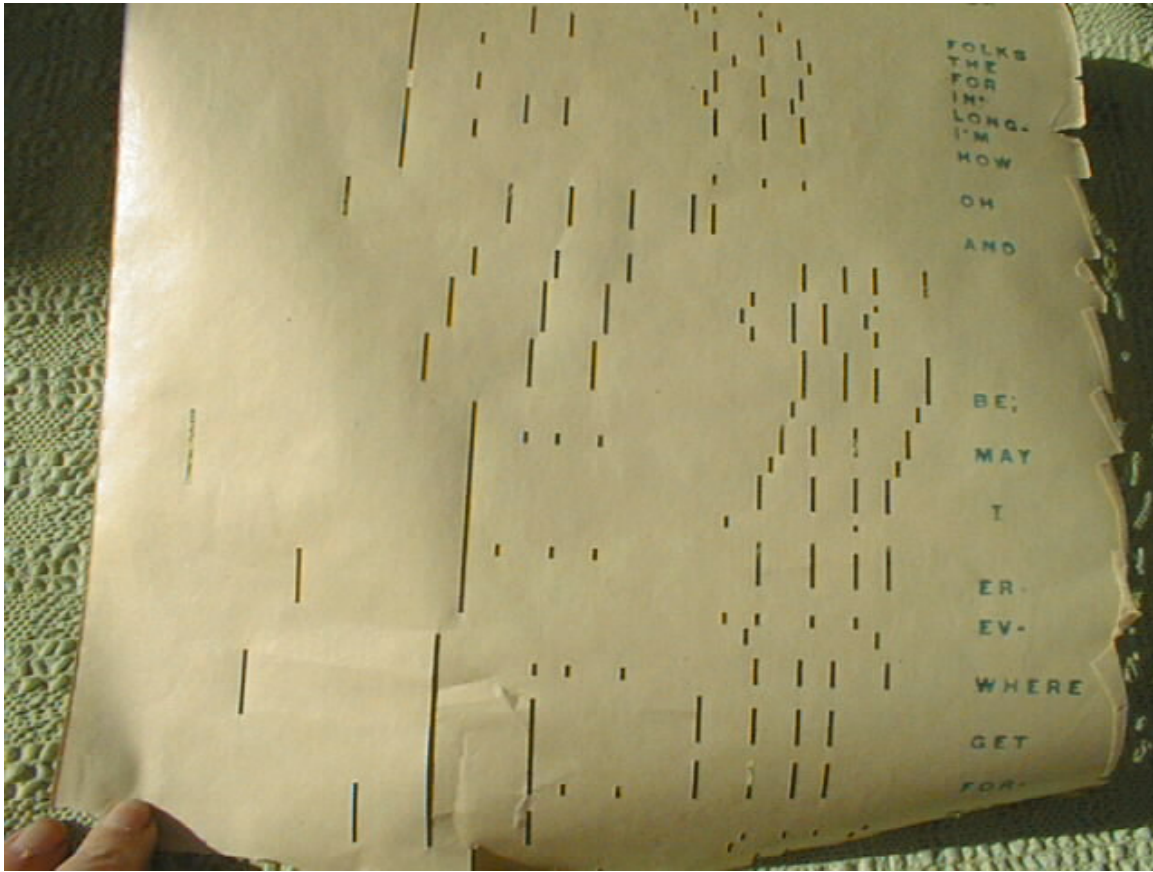
<http://evanlenz.net/blog/2007/11/02/re-discovering-klavarskribo/>

<http://en.wikipedia.org/wiki/Klavarskribo>

<http://www.klavarskribo.nl/en>

Piano Rolls

Mechanical Representation of music



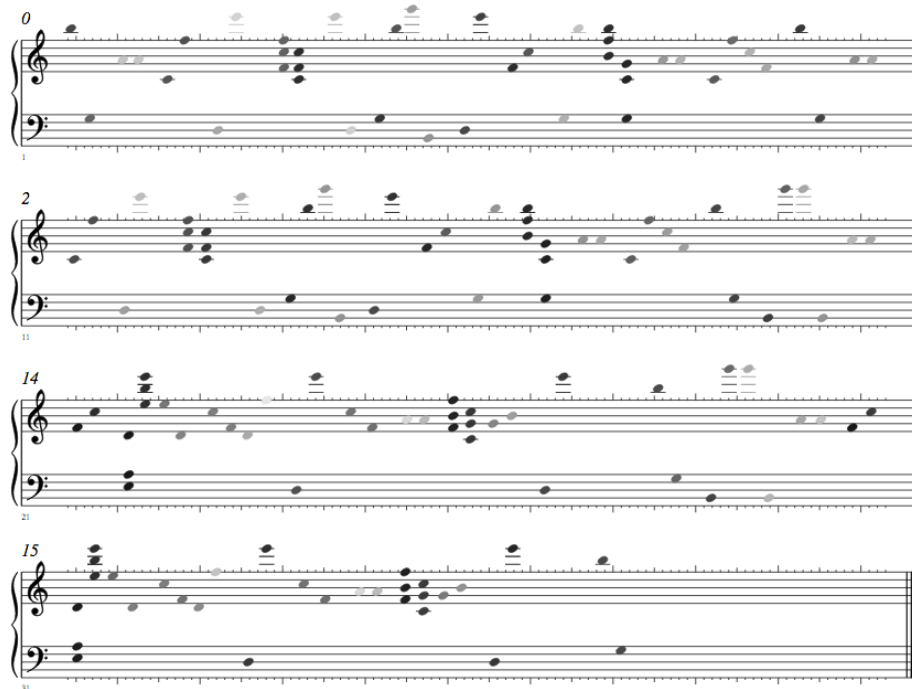
http://en.wikipedia.org/wiki/Piano_roll

<https://www.youtube.com/watch?v=GjpPesy7kIA>

Performance Data Visualization

Webern Piano Variations, mvmt. 2, (Op. 27)

Anderszewski 1996



Gould 1954



<http://dl.acm.org/citation.cfm?id=2597179>

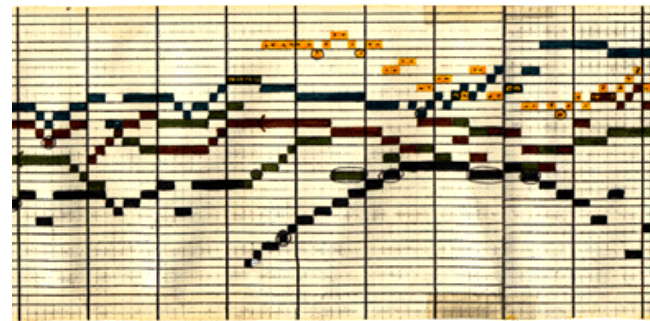
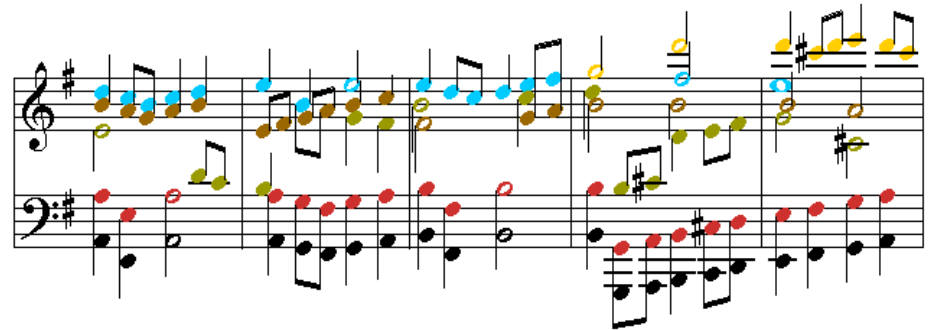
<http://mazurka.org.uk/webern/notation/Anderszewski1996>

<http://mazurka.org.uk/webern/notation/Gould1954>

Music Animation Machine

<http://www.musanim.com>

Stephen Malinowski



<https://www.youtube.com/channel/UC2zb5cQbLabj3U9l3tke1pg>

<https://www.youtube.com/playlist?list=PLMOarqHv8B7P1BuvL2iGqkjS1xNrvTiuX>

Music Animation Machine

Bach, Toccata and Fugue in D minor, organ

https://www.youtube.com/watch?v=ipzR9bhei_o

How are musical
Dimensions mapped
In each visualization?

Mozart, Symphony No. 40 in G minor

<https://www.youtube.com/watch?v=xvtoqE33iZg>

Beethoven, Fur Elise

<https://www.youtube.com/watch?v=o0VwTw1eZ1k>

Beethoven, String Quartet No. 16, 1st mvt. (opus 135)

<https://www.youtube.com/watch?v=Lj4kLPgX5QM>

Paganini, Caprice No. 5 (solo violin)

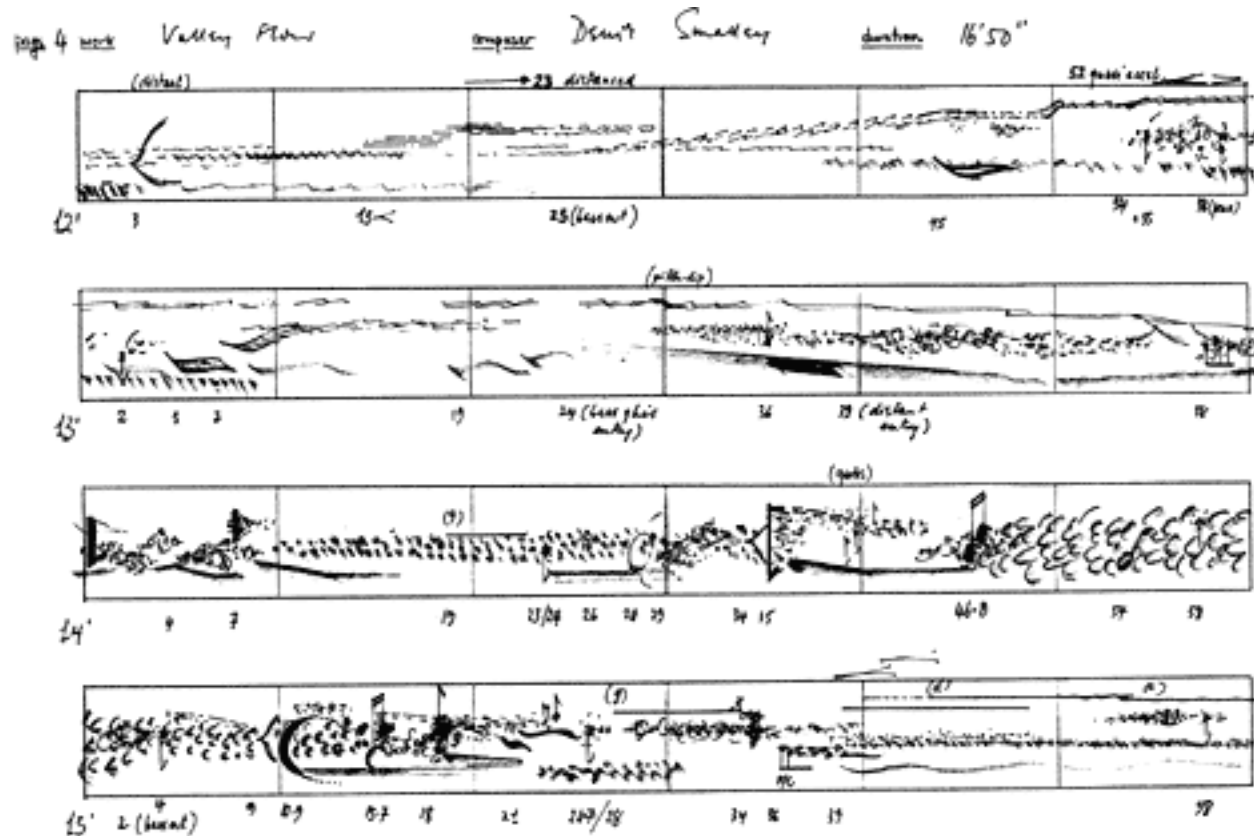
<https://www.youtube.com/watch?v=xhc1PsokFOw>

Debussy, First Arabesque

<https://www.youtube.com/watch?v=Yt1jfX5C1u0>

Textural Notation

Analytic notation of electro-acoustic music

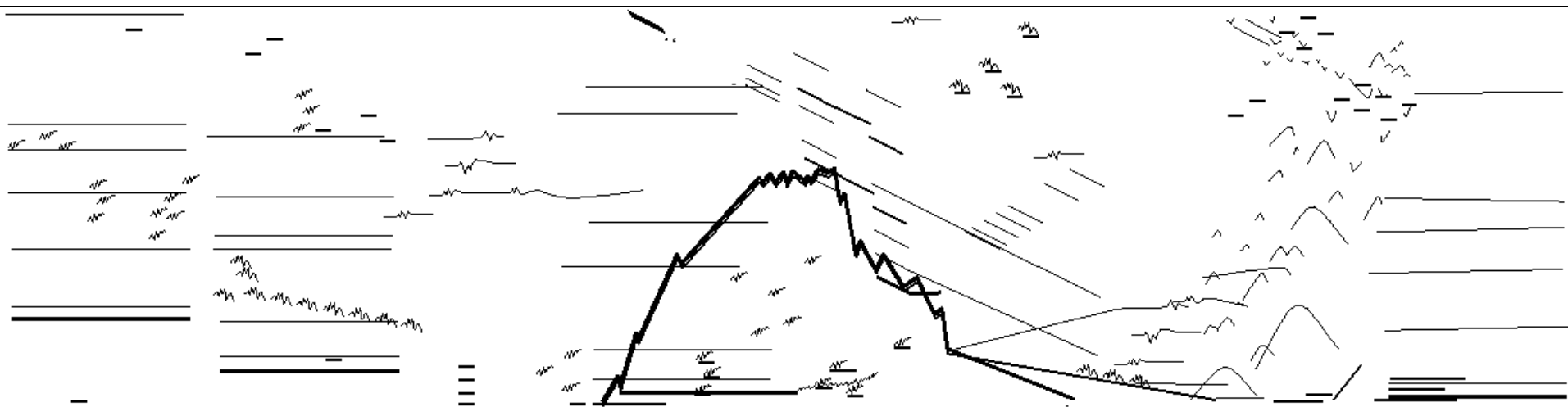


line2sine

Sonification of vector graphics

<http://sig.sapp.org/projects/all/line2sine/line2sine/examples>

Example 6:

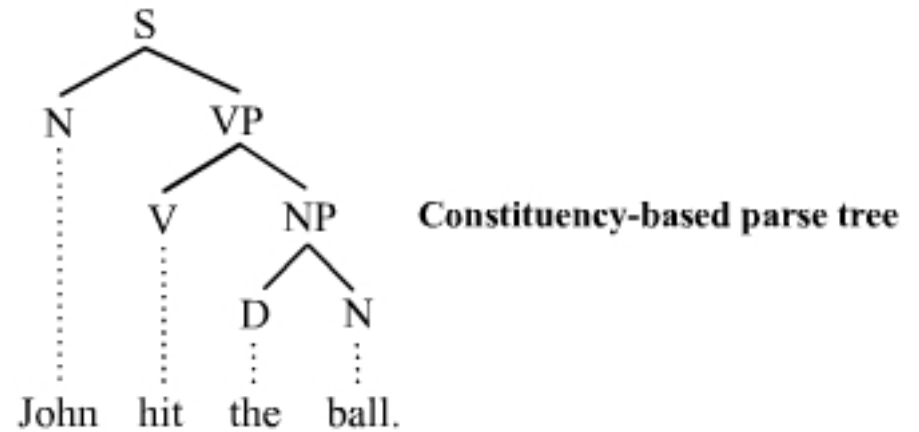
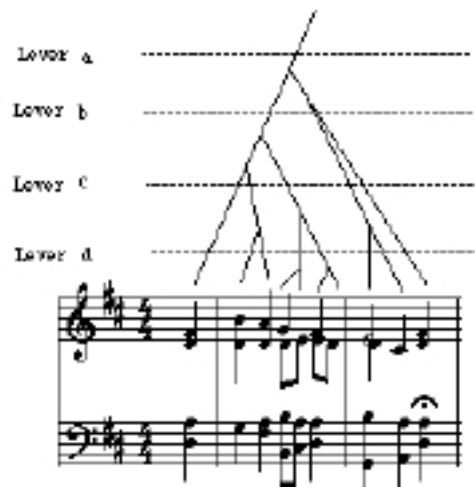


See the music of Iannis Xenakis

http://en.wikipedia.org/wiki/Iannis_Xenakis

http://en.wikipedia.org/wiki/Hyperprism_%28Var%C3%A8se%29

GTTM

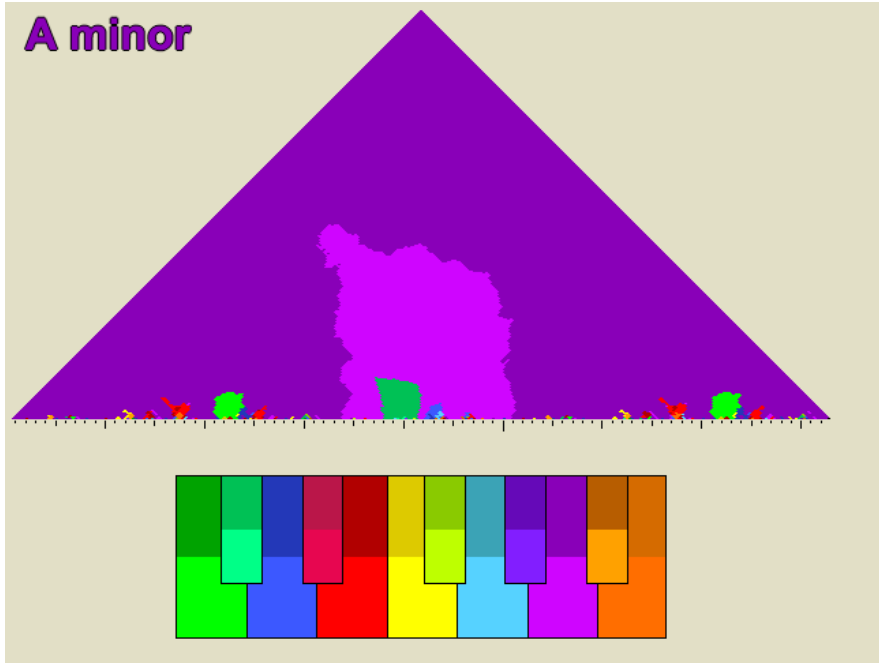


http://en.wikipedia.org/wiki/Parse_tree

http://en.wikipedia.org/wiki/Generative_theory_of_tonal_music

Keyscapes

Graphical display of harmonic structure



Chopin mazurka in A minor Op. 67, No. 4

<https://www.youtube.com/watch?v=AcxZRI6aews>

A major: 1:18

A minor: 2:10

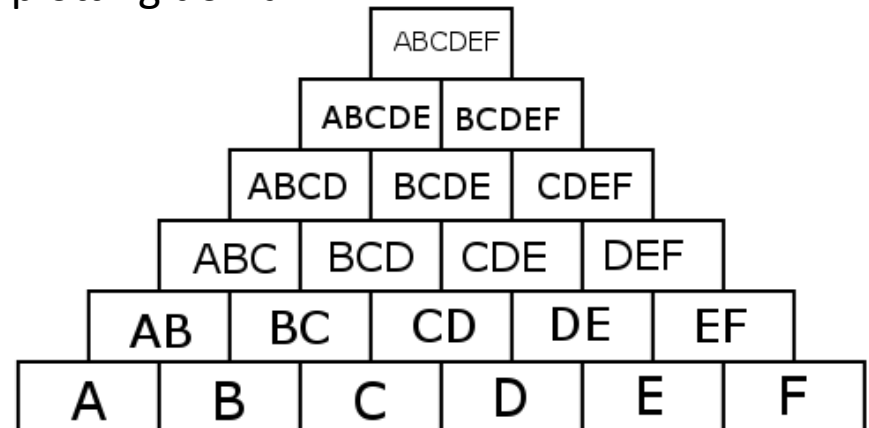
Landscape:

background
large-scale structures
middleground
small-scale structures
foreground
surface features



An Orchard c1896 Henri Rousseau

Scape plotting domain:



Computational Key Identification



<http://extras.humdrum.org/man/keycor>

Computational Key Identification



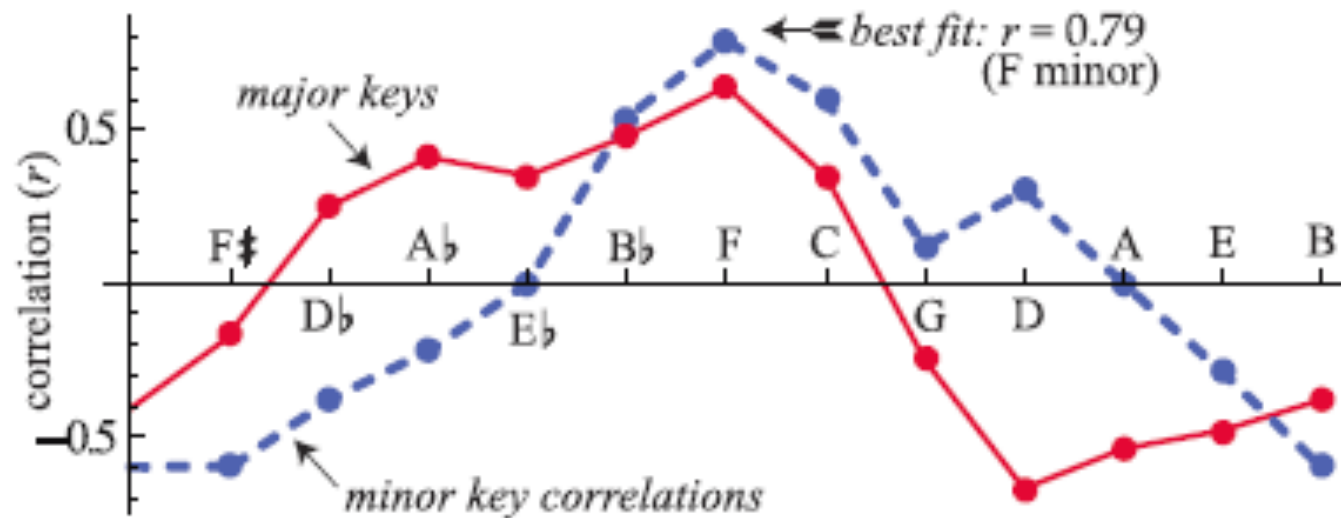
Pearson correlation:

$$r(x, y) = \frac{\sum_n (x_n - \bar{x})(y_n - \bar{y})}{\sqrt{\sum_n (x_n - \bar{x})^2 \sum_n (y_n - \bar{y})^2}}$$

Krumhansl-Schmuckler
key-finding algorithm:

$$\text{key}_k = \arg \max_k r(x, y_k)$$

Computational Key Identification

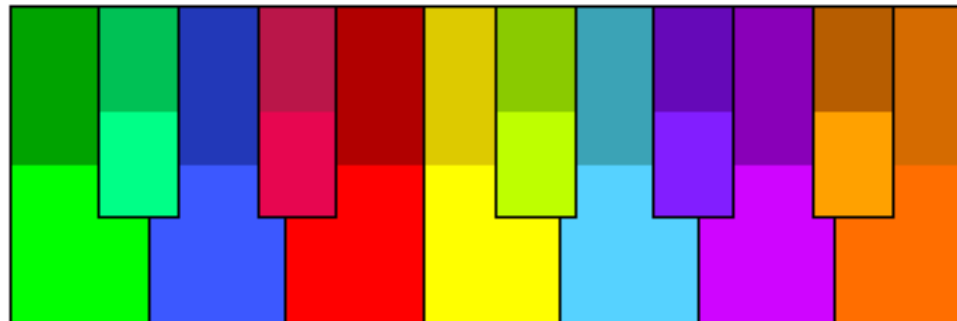
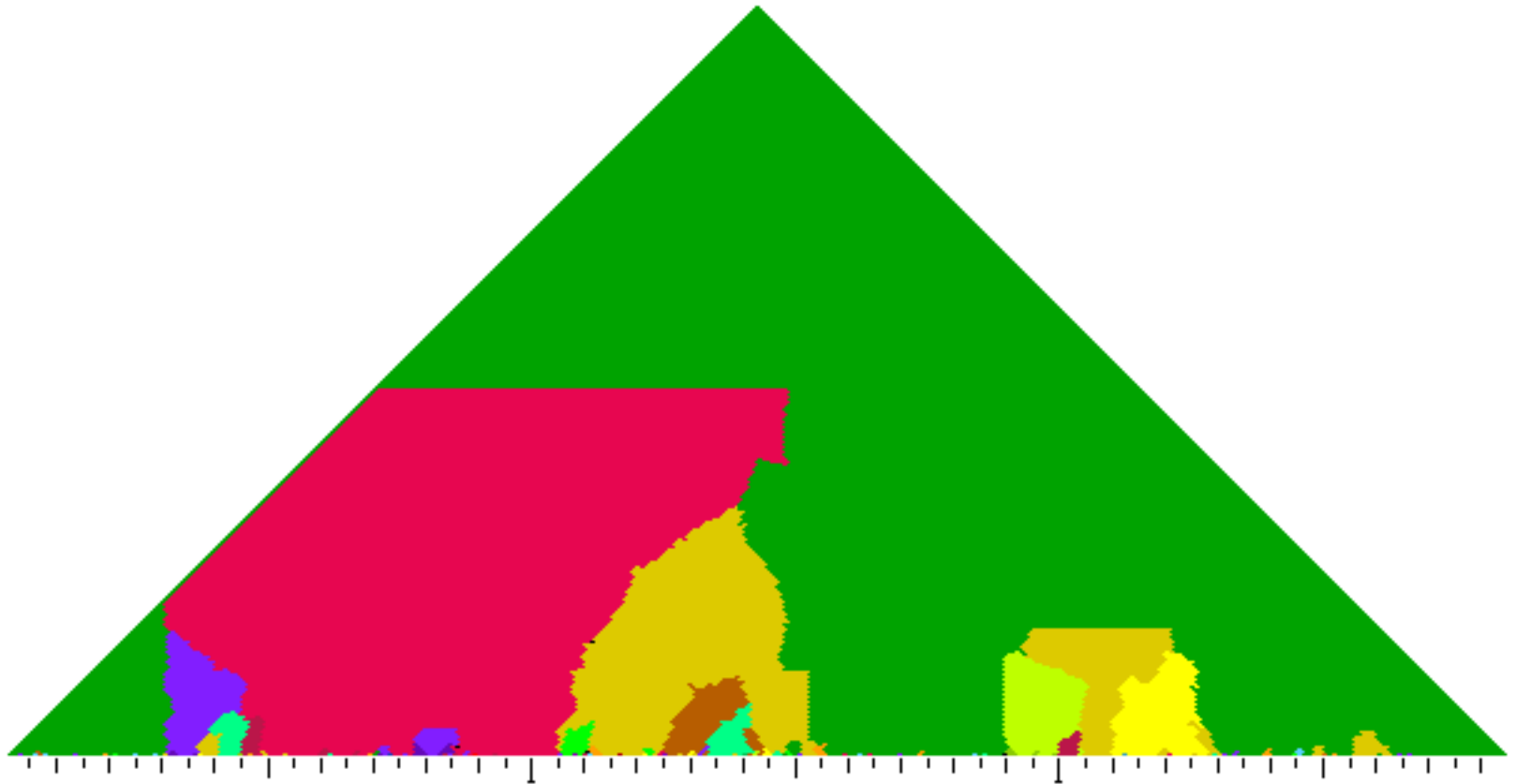


pitch-class histogram: $x = (8, 0, 0, 0, 2, 11, 0, 5, 7, 0, 5, 2)$

major key prototype: $y_M = (2, 0, 1, 0, 1, 1, 0, 2, 0, 1, 0, 1)$

minor key prototype: $y_m = (2, 0, 1, 1, 0, 1, 0, 2, 1, 0, 1, 0)$

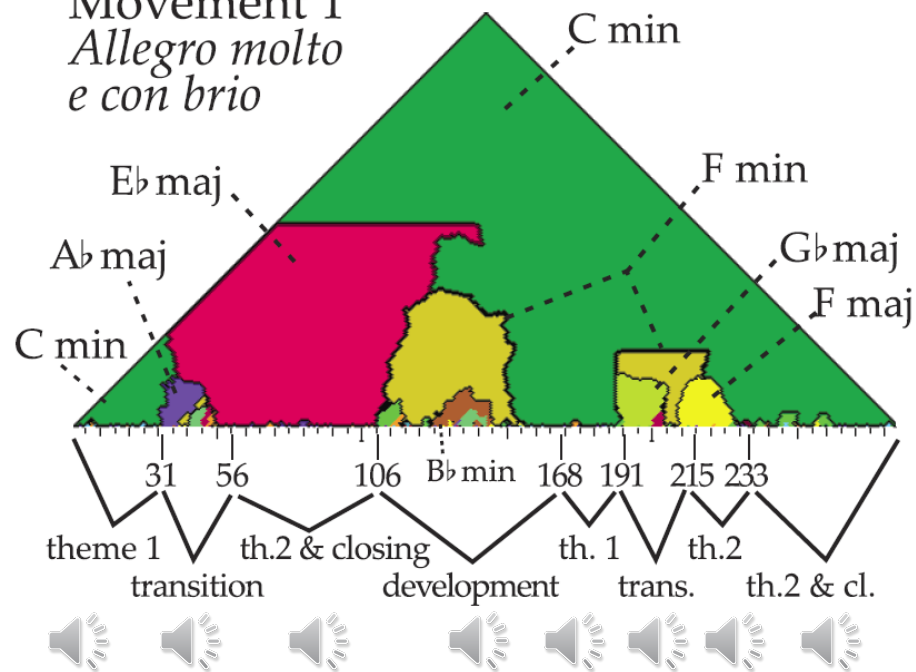
Beethoven Piano Sonata #5 mvmt 1



Sonata No. 5 Internal Key Structure

Theme 1 (C minor):

Movement 1
*Allegro molto
e con brio*



Theme 2 (E♭ major):



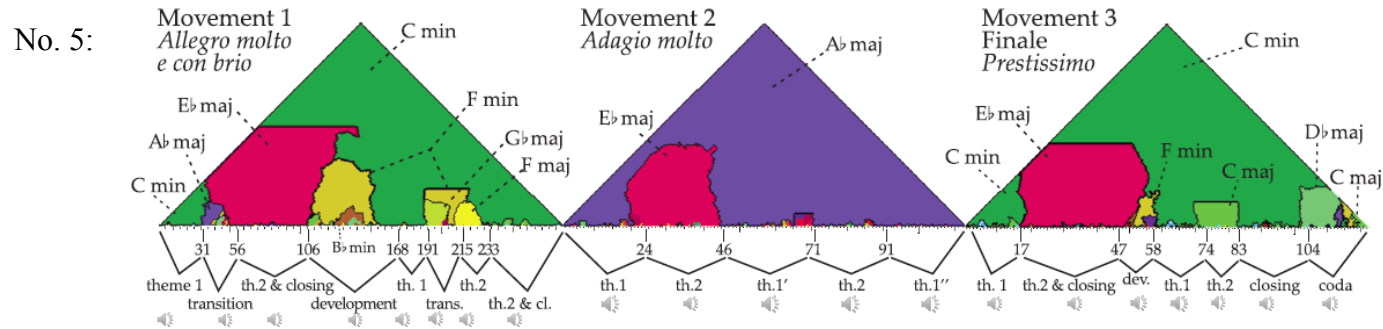
Theme 2 (F major):



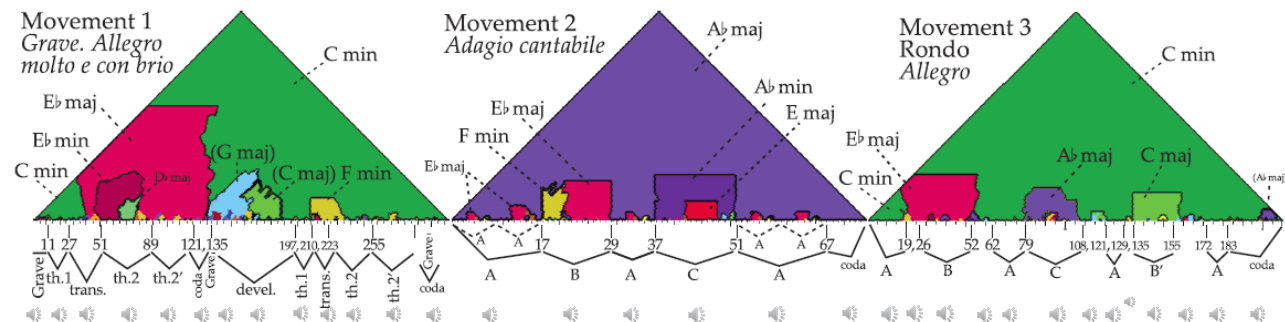
Theme 2 (C minor):



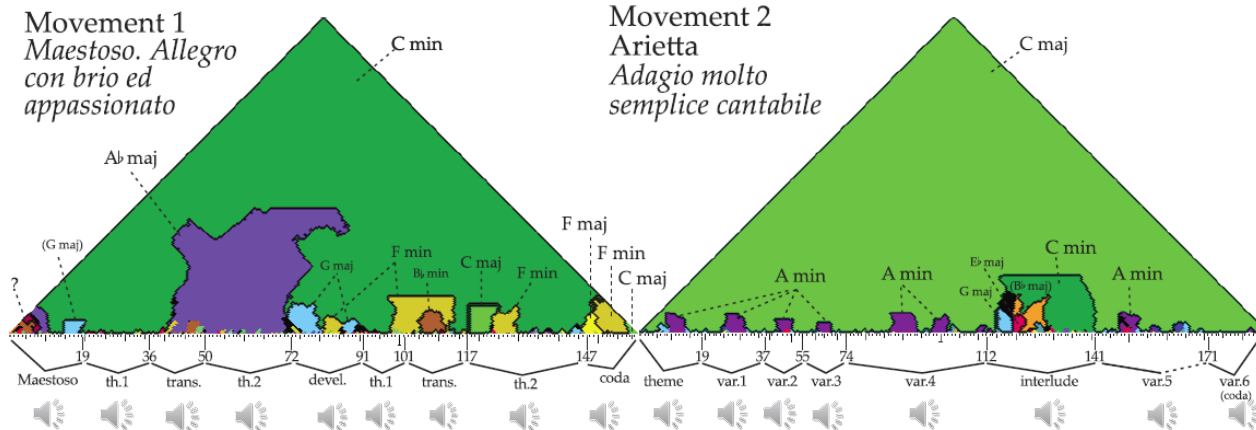
Other C-Minor Beethoven Sonatas



Piano Sonata no. 8 in C minor, op. 13 ("Pathétique")



piano sonata no. 32



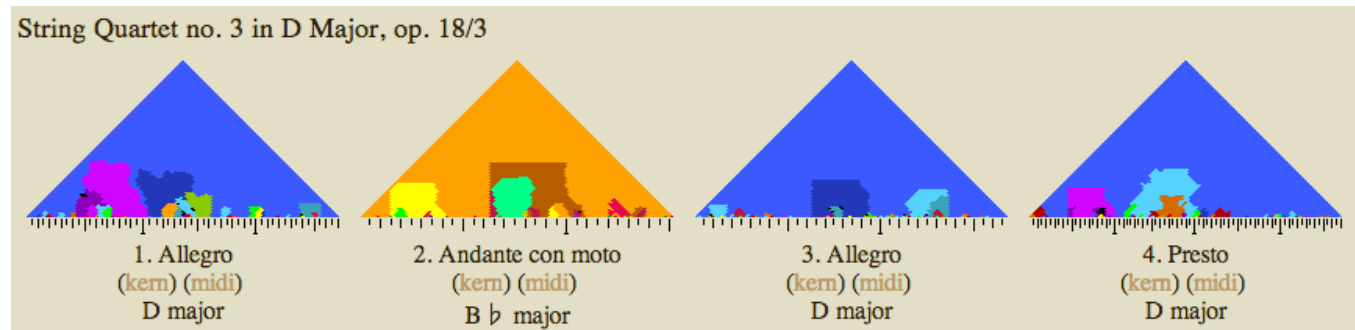
More Info

C++ implementation of KS algorithm and keyscape generator:

- <http://extras.humdrum.org/man/keycor>
- <http://extras.humdrum.org/man/mkeyscope>

See bottom of last link for latest keyscape galleries, such as Beethoven string quartets:

<http://extras.humdrum.org/man/mkeyscope/beet-quartet>



~5000 keyscales of MIDI files:

<https://ccrma.stanford.edu/~craig/keyscape/class>

Form Visualization/Analysis

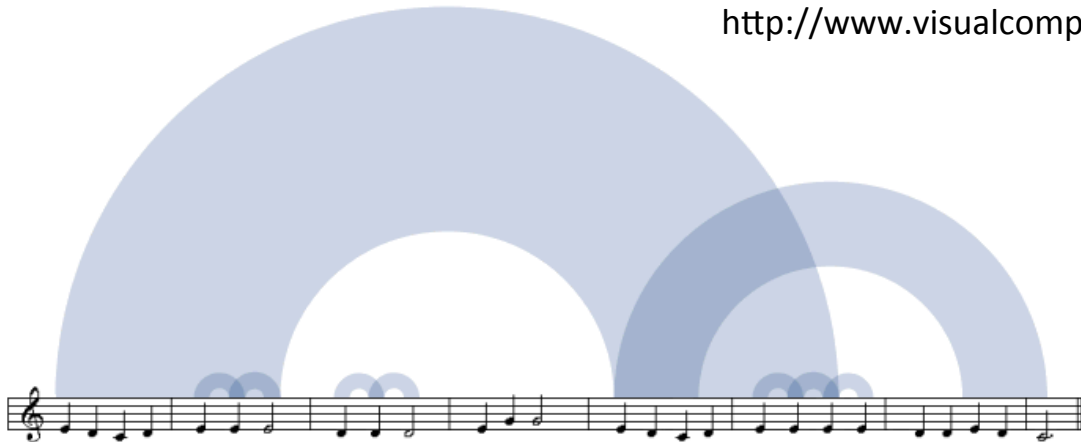
<http://www.bewitched.com/song.html>

<http://hint.fm/papers/arc-diagrams.pdf>

Martin Wattenberg



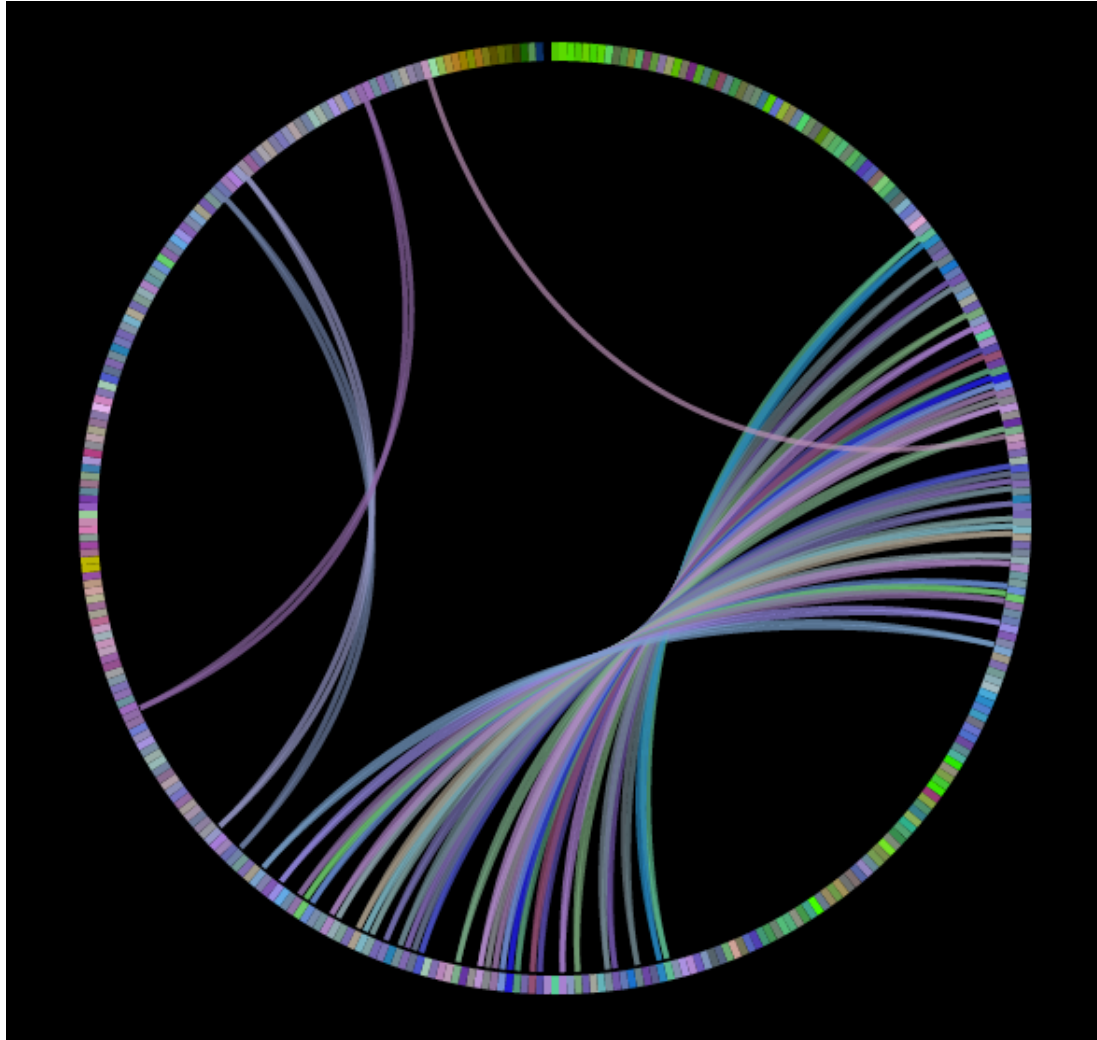
<http://www.visualcomplexity.com/vc/index.cfm?method=Arc%20Diagrams>



Infinite Jukebox

<http://labs.echonest.com/Uploader/index.html?trid=TRORQWV13762CDDF4C>

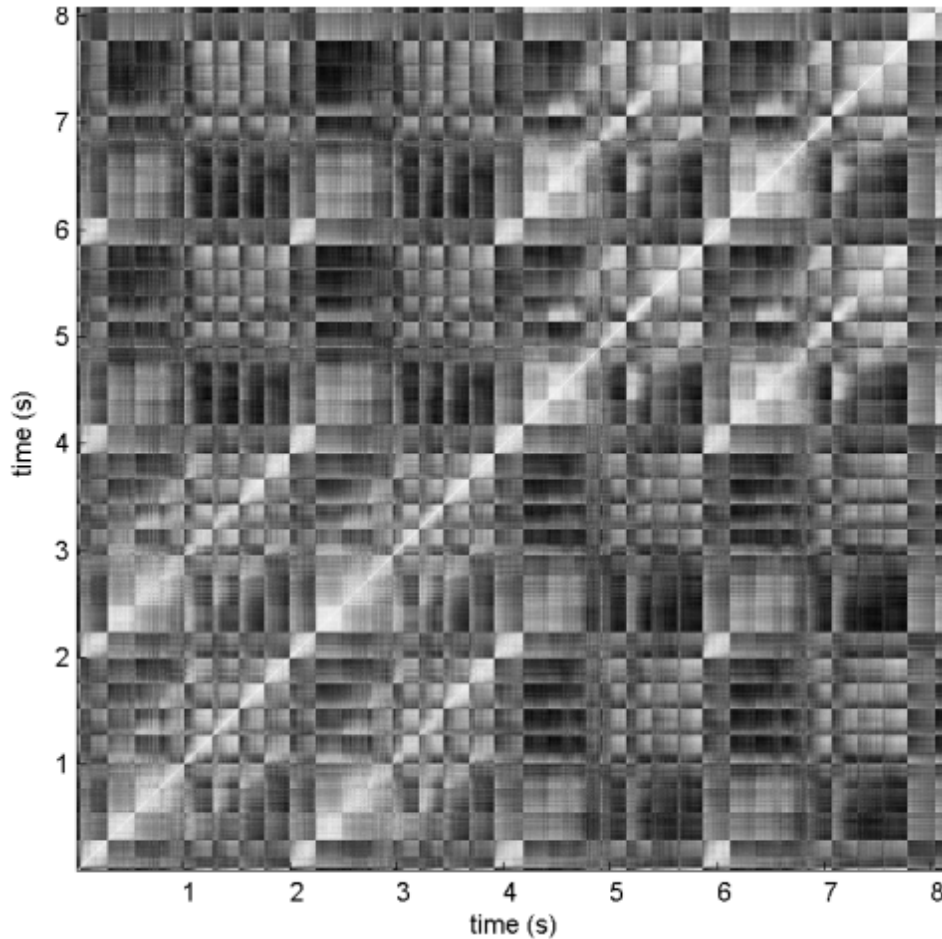
Paul Lamere



Similarity Matrix

Jonathan Foote

<http://www.fxpall.com/publications/visualizing-musical-structure-and-rhythm-via-self-similarity.pdf>



J.S. Bach WTC 1: Prelude #1 in C major

