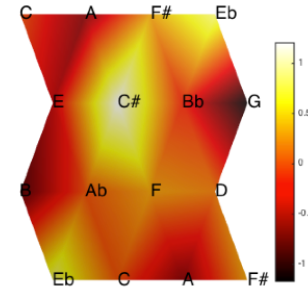


Theme : Human and Artificial Creativity (HAC)

Mathemusal Morphologies

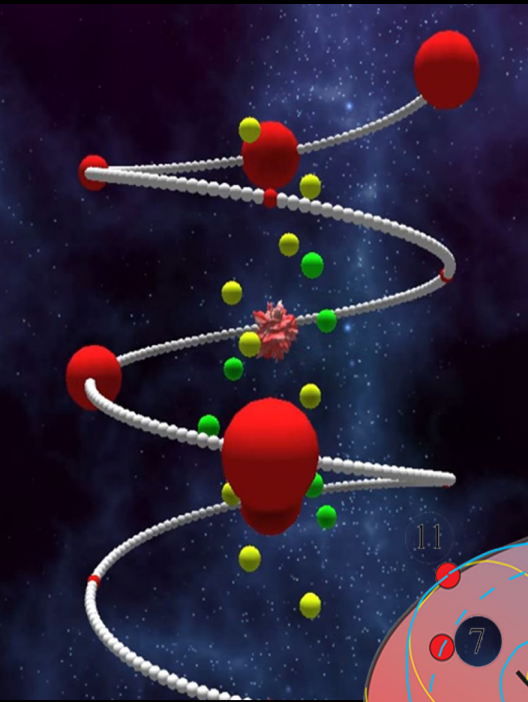


Moreno ANDREATTA¹, Jean-Louis GIAVITTO² *et al.*³

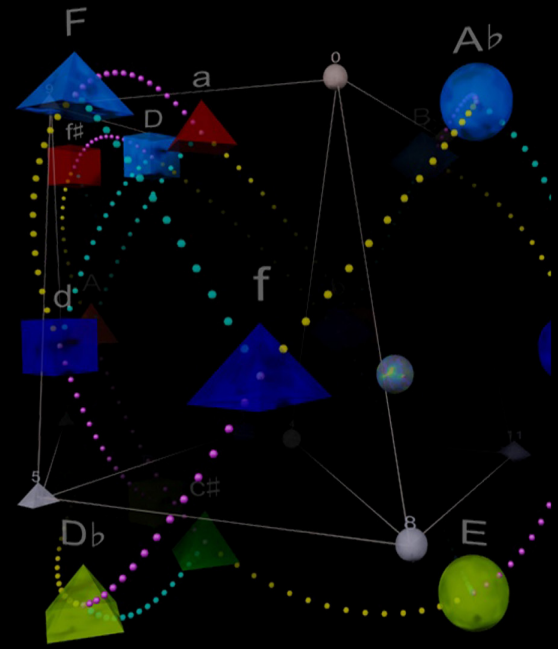
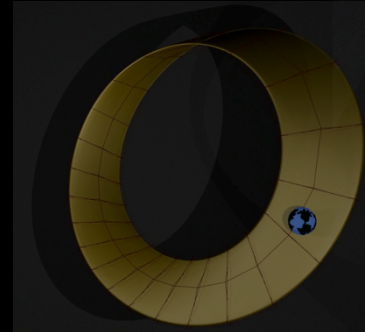
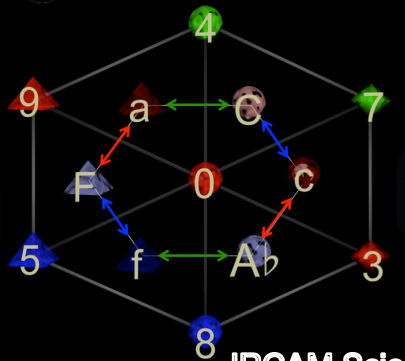
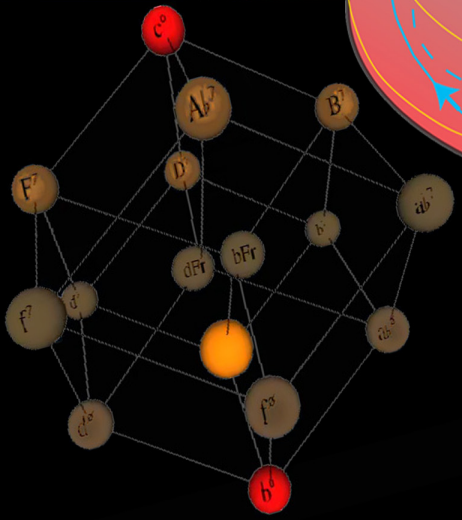
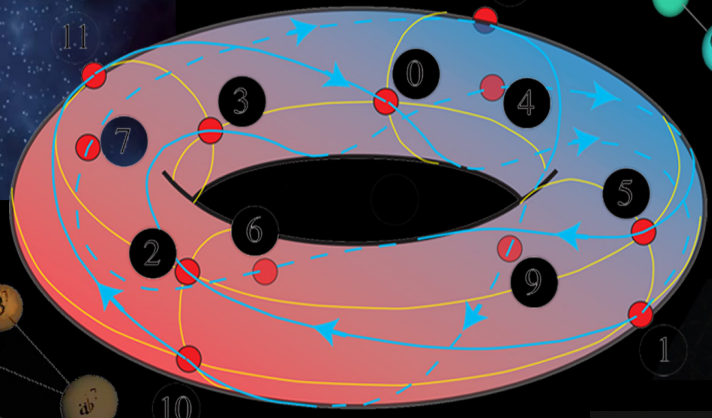
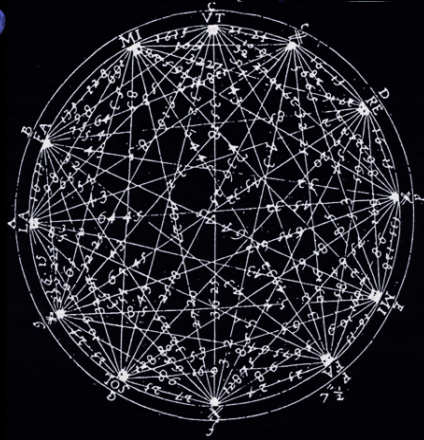
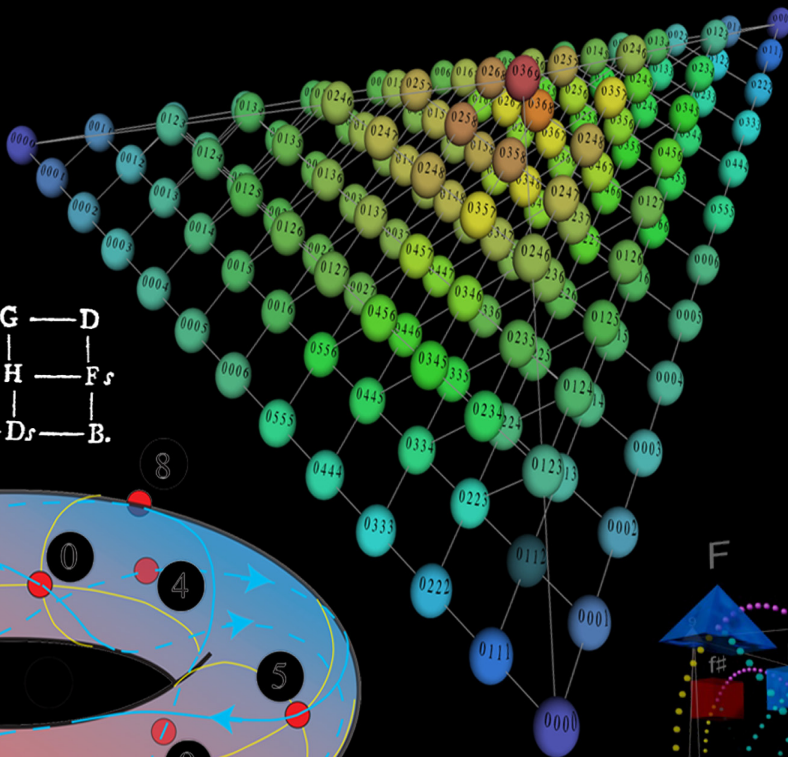
¹CNRS / UPMC / Equipe Représentations Musicales

²CNRS / INRIA / Equipe MuTanT

³RepMus, Institut of Algebra (TU-Dresden), IReMus (Sorbonne Universités), GDR ESARS, SMCM, ...



F	—	C	—	G	—	D
A	—	E	—	H	—	F _s
C _s	—	G _s	—	D _s	—	B.



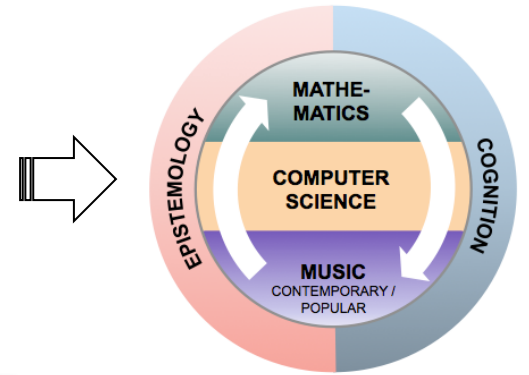
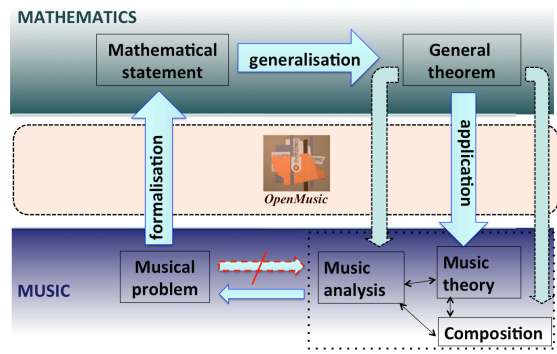
Mathemusical research within the STMS Lab

Rhythmic Tiling Canons

Set/Transformation Theory and Categorical Music Analysis

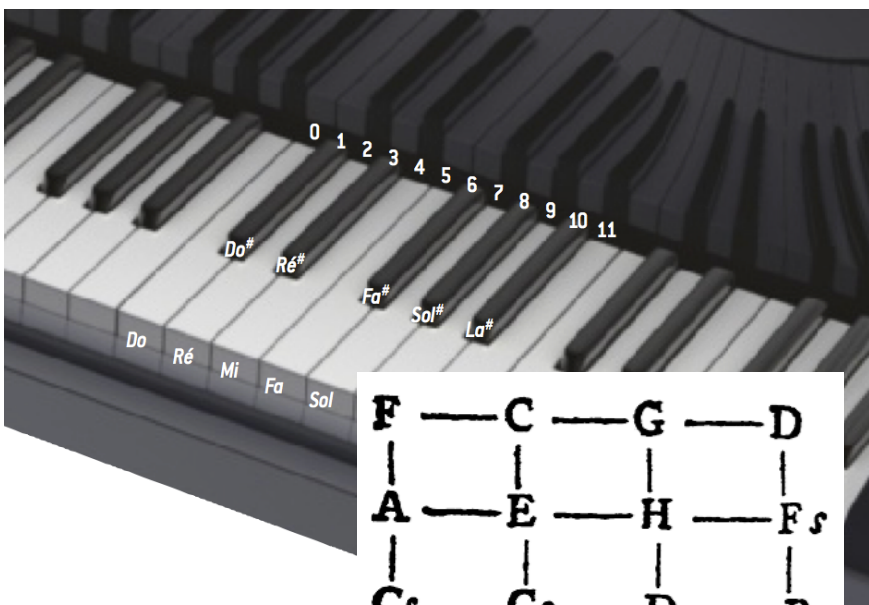
Z-Relation, Homometric Sets and Dynamical Systems

Neo-Riemannian Theory, Spatial Computing and FCA



Programming paradigms for music	Computational Musicology	Symbolic Interaction Systems	Sign-signal articulations
Specialized Languages (OpenMusic)	MISA Modélisation Informatique des Structures Algébriques en Musique	Improvisation modeling	Signal/Symbolic Unified Representations
Computer-Human Interfaces		Tempo and Rhythm extraction	Synthesis Control
Music Algorithmics (PhD H. Cauré)	Musicologie cognitive	Interactive Scores (PhD D. Ghisi)	Computer-assisted Orchestration
Representation of temporal processes (PhD G. Genuys, K. Haddad)	Computer-aided music analysis and complex systems (PhD Ch. De Paiva)		
Spatial Computing, Homology Persistency and Formal Concept Music Analysis (Master A. Freund, PhD L. Bigo, M. Bergomi)			

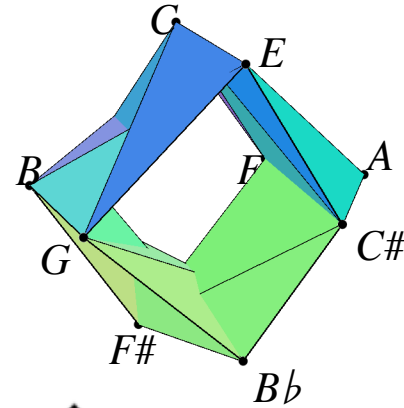
Generalizing the topological Structure of the Tonnetz



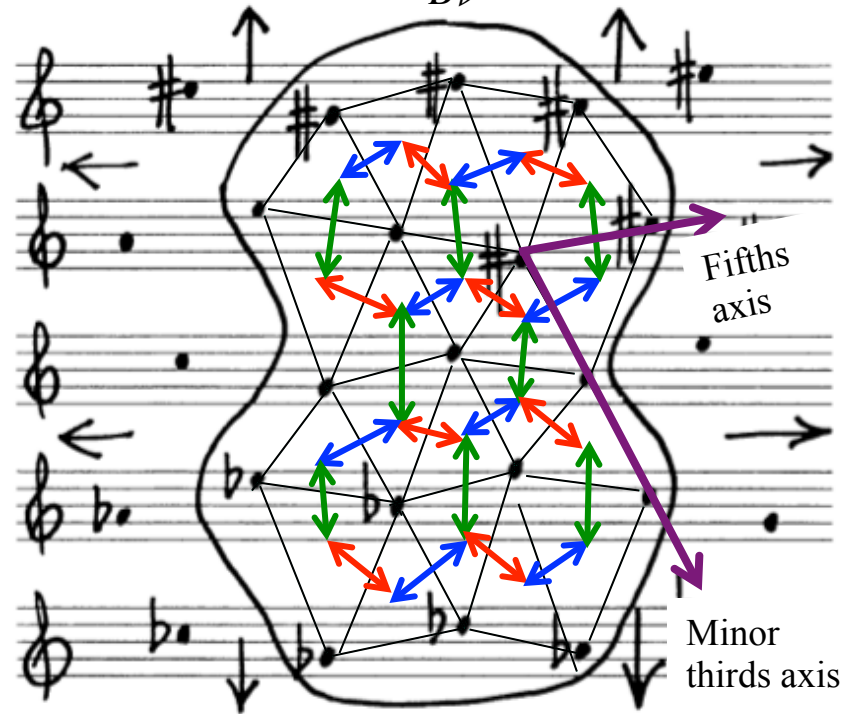
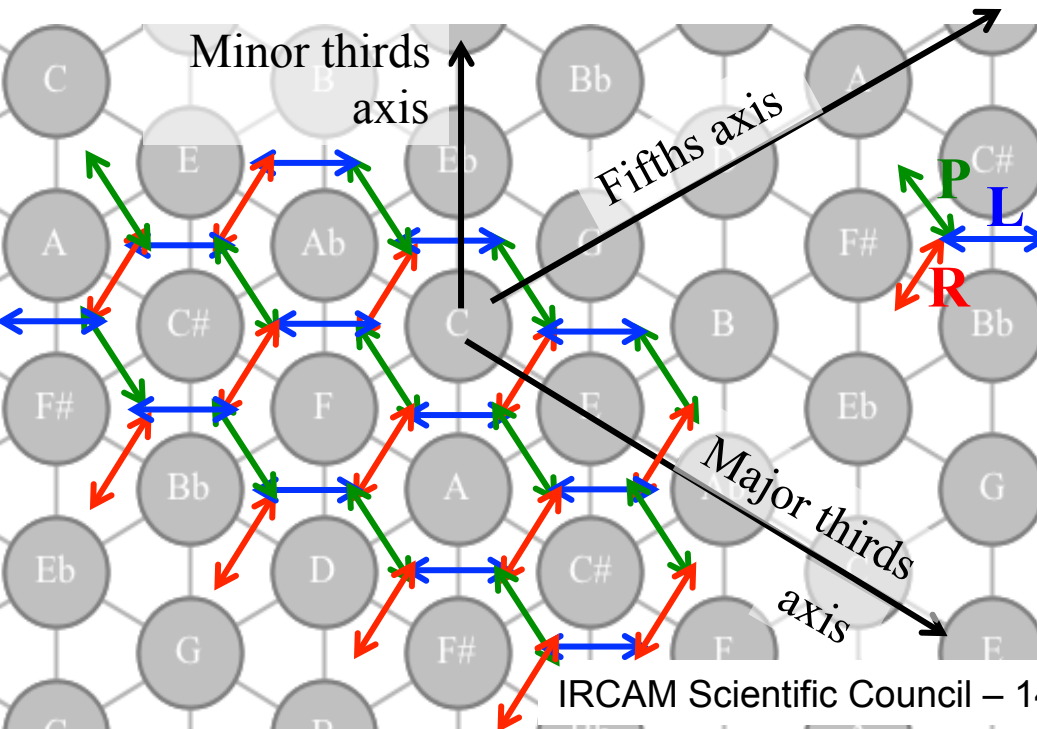
Speculum Musicum (Euler, 1773)



(L. Euler)



(J.-Ph. Rameau)

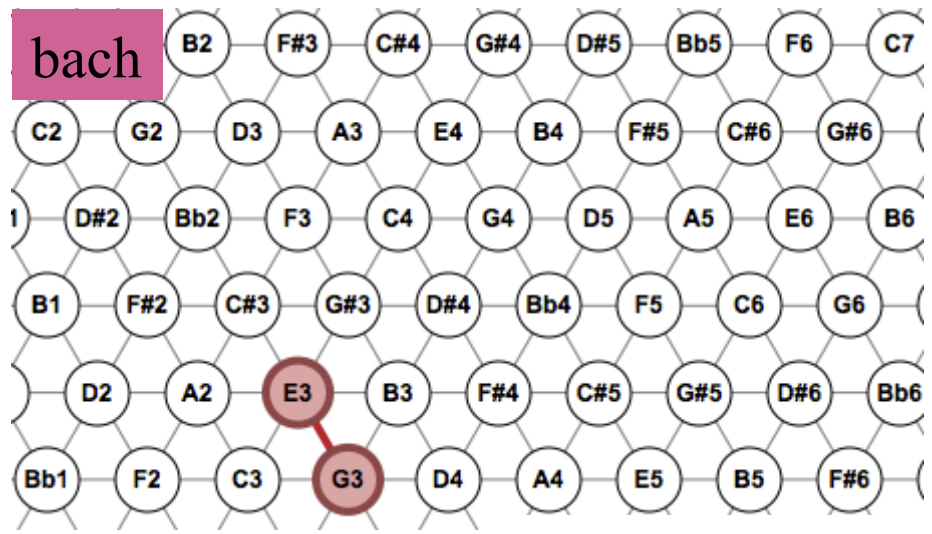
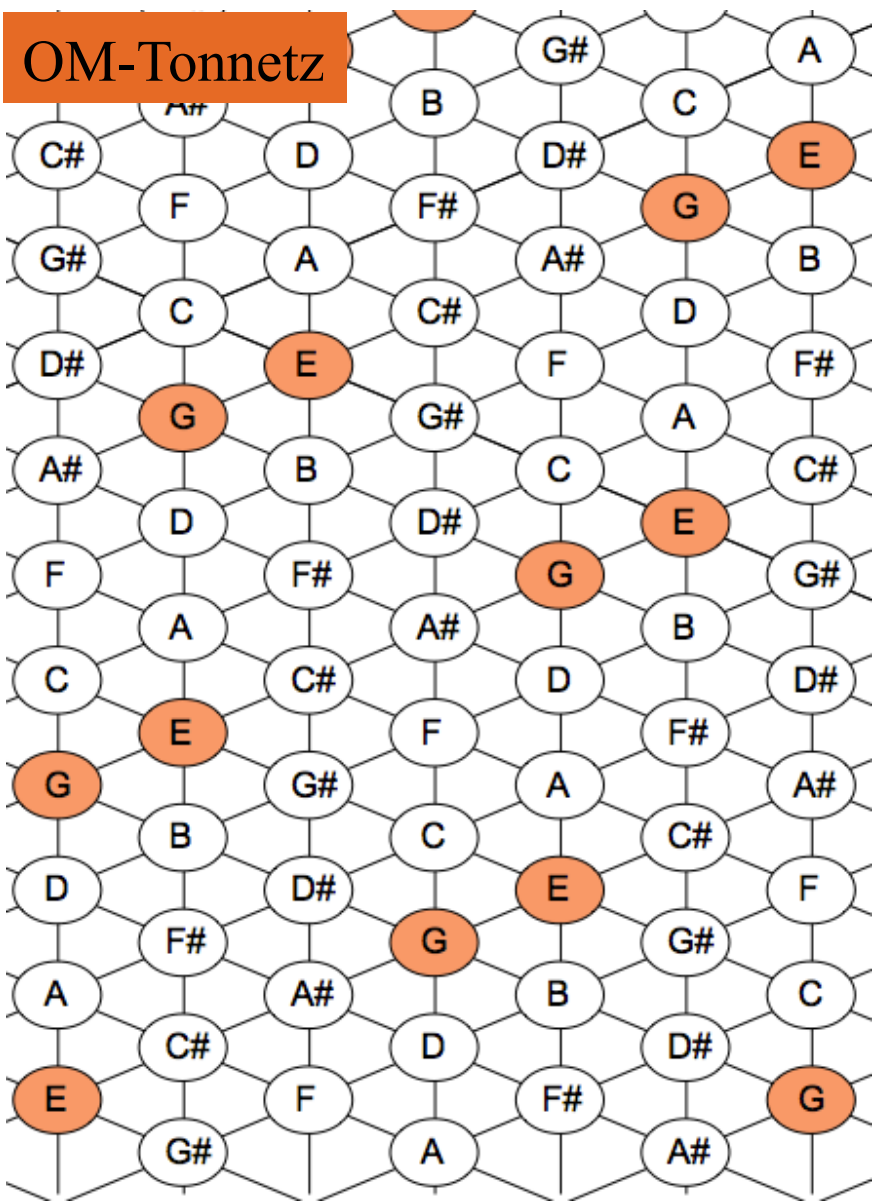


Three environments for a Tonnetz-based Analysis

The screenshot shows the Plex Viewer interface with several components:

- Plex Viewer:** A 3D visualization of a Tonnetz network as a green and blue polyhedron.
- Tonnetz - K[3,4,5]:** A 2D grid of notes with a path highlighted in yellow.
- InfoBox:** A control panel with a tempo slider (0-20), play/stop buttons, and options for chromatic complexes (K[2,3,7]), heptatonic complexes (CM), and path transformation (Origin complex: K[3,4,5], Destination complex: K[3,4,5]).
- Tonnetzs network:** A graph showing nodes like K[1,1,9], K[1,2,9], K[1,3,8], K[1,4,7], K[1,5,6], K[2,2,8], K[2,3,7], K[2,4,6], K[2,5,5], K[3,3,6], K[3,4,5], and K[4,4,4].
- Chart:** A bar chart titled "bwv0281" showing 2-compactness values for various complexes. The x-axis lists complexes from K[1,1,10] to K[4,4,4]. The y-axis ranges from 0.0 to 0.9. A legend indicates "bwv0281" (red) and "random chords" (blue).

Hexachord



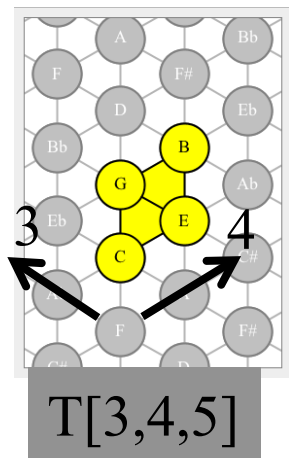
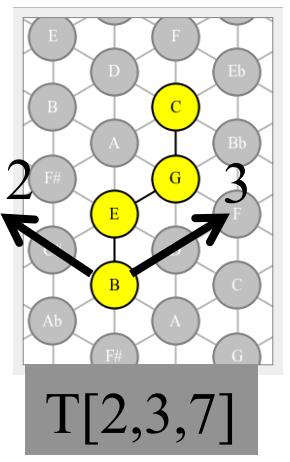
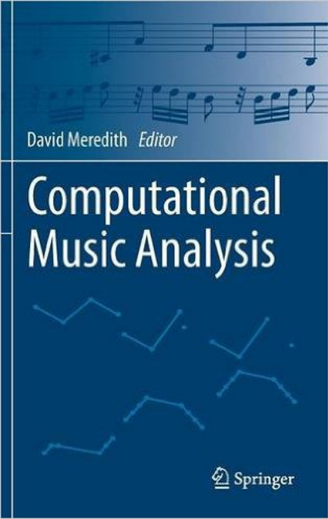
Spatial music analysis via *Hexachord*

The screenshot displays the Hexachord software interface, which is used for spatial music analysis. It consists of several windows:

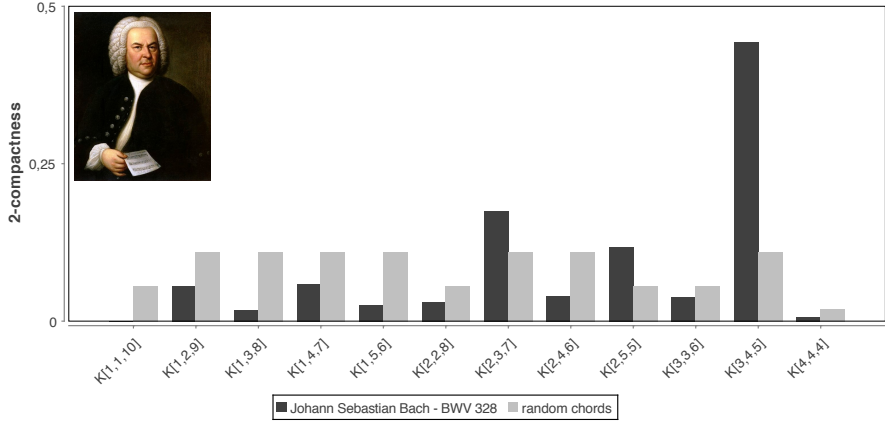
- Plex Viewer:** Shows a 3D visualization of a plex, a geometric structure representing the space of chords.
- Tonnetz : K[3,4,5]:** A grid of 12-tone chromatic complexes (K[3,4,5]) where a specific path is highlighted in yellow.
- InfoBox:** Controls for the analysis, including a tempo slider (set to 10), play/stop buttons, a "Select midi file" button, and options for chromatic and heptatonic complexes. It also includes settings for vertical compactness (2-compactness) and path transformation (Origin complex: K[3,4,5], Destination complex: K[3,4,5]).
- Tonnetzs network:** A window showing the cover of *Computer Music Journal*, Volume 39, Number 3, Fall 2015, ISSN 0148-9267, \$18.00. The cover features a diagram of a plex and a tonnetz grid.
- Chart:** A bar chart titled "bww0281" showing the 2-compactness of various complexes. The y-axis ranges from 0 to 0.8. The x-axis lists complexes: K[1,1,10], K[1,2,9], K[1,3,8], K[1,4,7], K[1,5,6], K[2,2,8], K[2,3,7], K[2,4,6], K[2,5,5], K[3,3,6], K[3,4,5], and K[4,4,4]. The K[3,4,5] complex has the highest compactness, around 0.8.
- Chart:** A bar chart titled "2-compactness : bww0281" showing the complex compliance over time (0 to 35,000). The y-axis ranges from 0 to 1. The chart shows a series of vertical bars, with a legend indicating different complexes: K[1,1,10] (red), K[1,2,9] (blue), K[1,3,8] (green), K[1,4,7] (yellow), K[1,5,6] (cyan), K[2,2,8] (magenta), K[2,3,7] (black), K[2,4,6] (grey), K[2,5,5] (dark red), K[3,3,6] (dark blue), K[3,4,5] (dark green), and K[4,4,4] (orange).

→ <http://www.lacl.fr/~lbigio/hexachord>

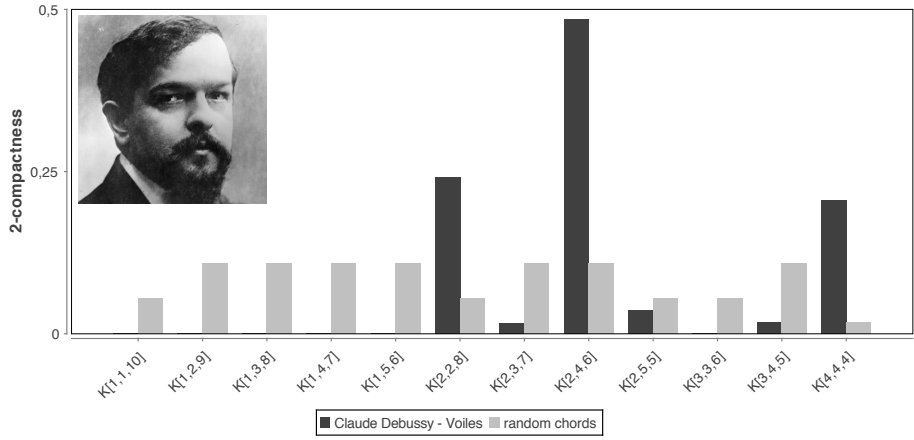
The geometric character of musical logic



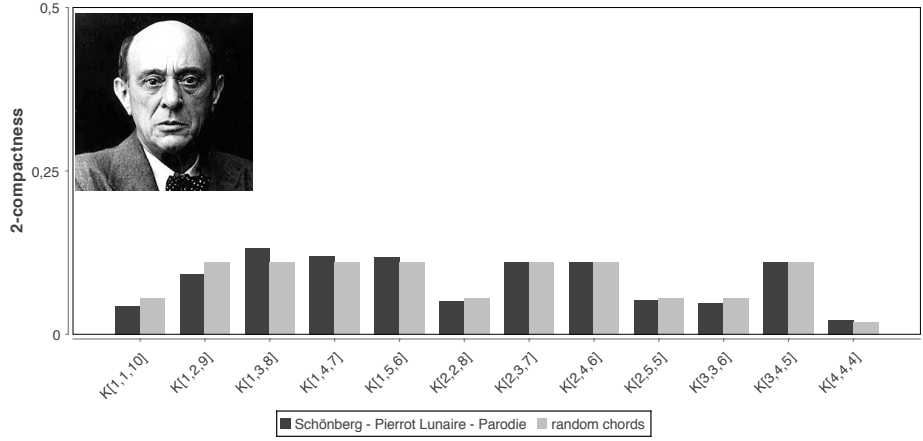
Johann Sebastian Bach - BWV 328



Claude Debussy - Voiles

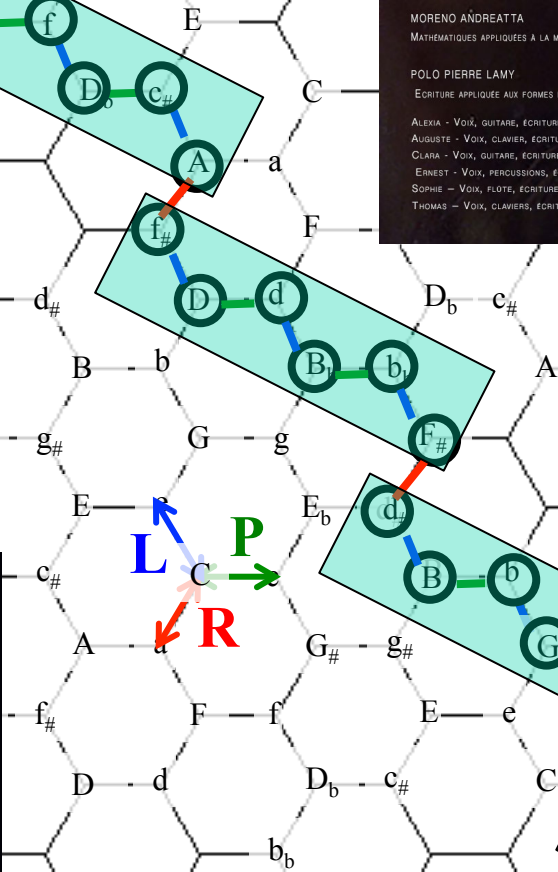
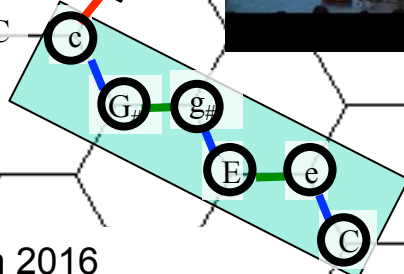
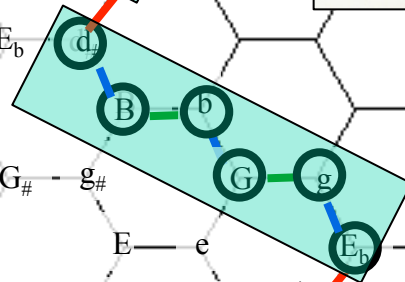
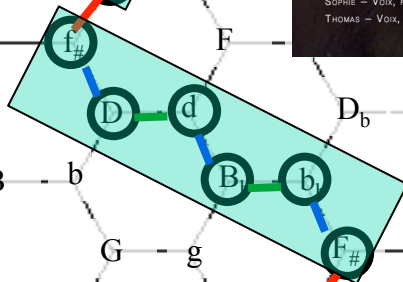
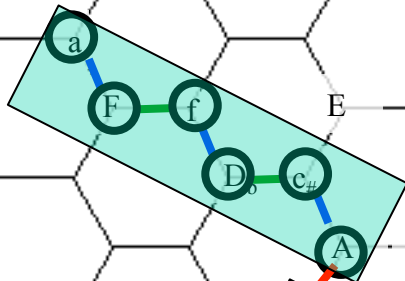
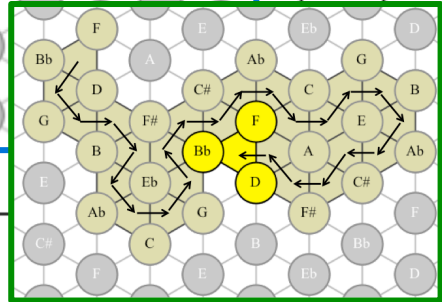
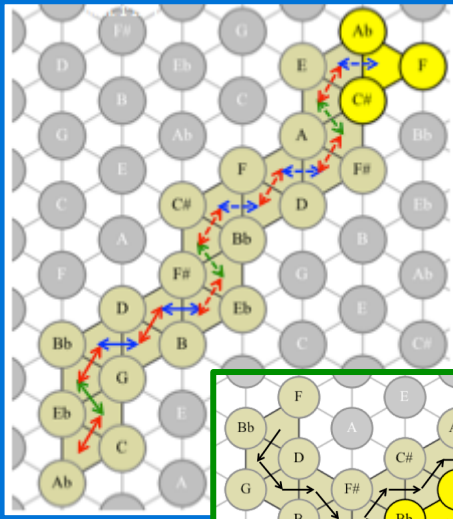


Schönberg - Pierrot Lunaire - Parodie



Pedagogical applications in Popular Music

Hamiltonian cycles / Hamiltonian Songs



CABARET HAMILTONIEN

FABRICE GUEDY
FORMALISME DANS LA MUSIQUE SAVANTE

MORENO ANDREATTA
MATHÉMATIQUES APPLIQUÉES À LA MUSIQUE

POLO PIERRE LAMY
ÉCRITURE APPLIQUÉE AUX FORMES MUSICALES

ALEXIA - VOIX, GUITARE, ÉCRITURE
AUGUSTE - VOIX, CLAVIER, ÉCRITURE
CLARA - VOIX, GUITARE, ÉCRITURE
ERNEST - VOIX, PERCUSSIONS, ÉCRITURE
SOPHIE - VOIX, FLOTE, ÉCRITURE
THOMAS - VOIX, CLAVIERS, ÉCRITURE

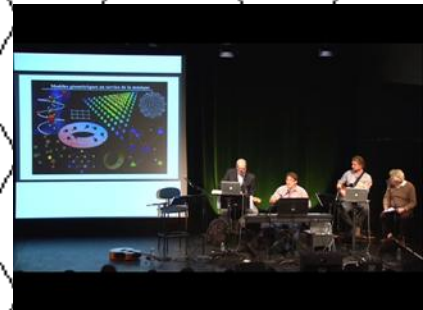
ÉCRIRE SOUS LA CONTRAINTE...
TACHER DU PAPIER SOUS
L'OBLIGATION DE FAIRE
QUELQUE CHOSE...
SALIR DU BOIS CONDITIONNÉ
AVEC LE DEVOIR MORAL DE
TRANSFORMER UN OBJET
INDEFINI...

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Bpi



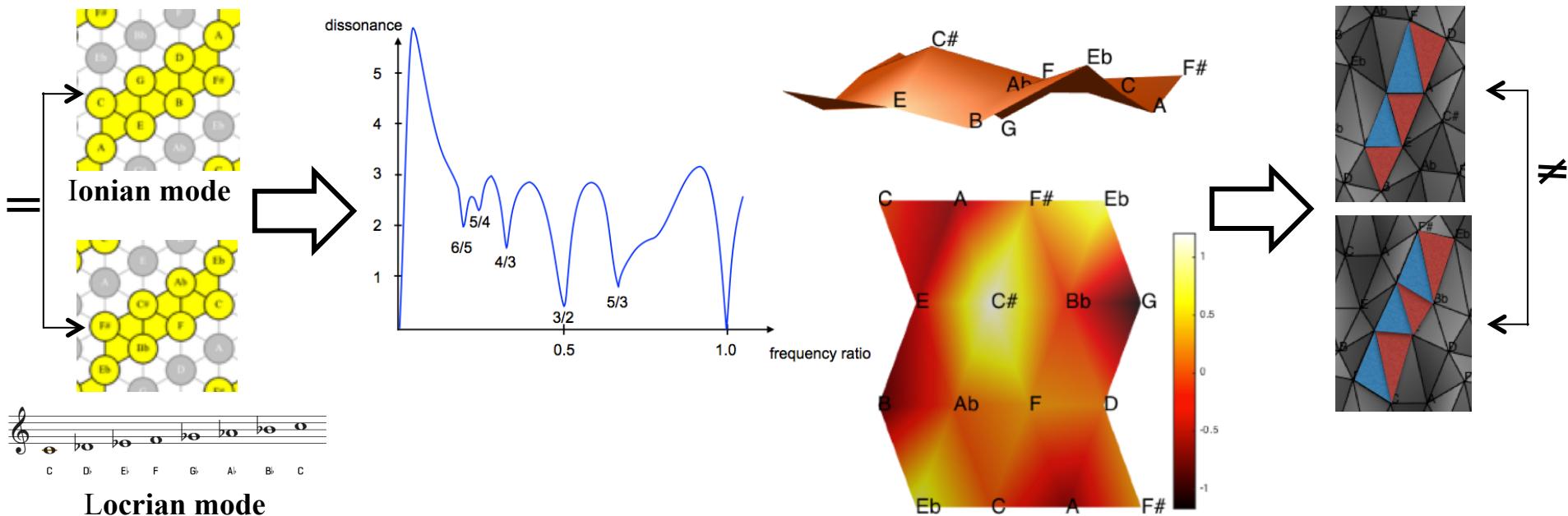
Towards a Tonnetz-computer-aided composition

The image shows a Pure Data patch window titled "test_video". The patch is designed to generate a Tonnetz (chromatic semitone lattice) and visualize it. Key components include:

- Input and Processing:** A "loadbang" triggers a "metro 700" object, which sends a signal to a "shape" object (set to "Hexagon") and a "lattice" object (set to "1: Triangular"). The "lattice" object outputs a signal to a "bach.transcribe" object.
- Chromatic Semitone Lattice (CSL) Table:** A large table of notes is displayed, representing the chromatic semitone lattice. The notes are arranged in a grid and color-coded by pitch class. The notes include: B0, F#1, C#2, Ab2, Eb3, Bb3, F4, C5, G5, D6, A6, E7, B7, F#8, C#9, C#1, Ab1, Eb2, Bb2, F3, C4, G4, D5, A5, E6, B6, F#7, C#8, Ab8, Eb9, Bb0, F1, C2, G2, D3, A3, E4, B4, F#5, C#6, Ab6, Eb7, B7, F8, C9, F0, C1, G1, D2, A2, E3, B3, F#4, C#5, Ab5, Eb6, B6, F7, C8, G8, G0, D1, A1, E2, B2, F#3, C#4, Ab4, Eb5, B5, F6, C7, G7, D8, D0, A0, E1, B1, F#2, C#3, Ab3, Eb4, B4, F5, C6, G6, D7, A7, E8, E0, B0, F#1, C#2, Ab2, Eb3, Bb3, F4, C5, G5, D6, A6, E7, B7, F#8, C#9, F#-1, C#0, Ab0, Eb1, Bb1, F2, C3, G3, D4, A4, E5, B5, F#6, C#7, Ab7, Ab-1, Eb0, Bb0, F1, C2, G2, D3, A3, E4, B4, F#5, C#6, Ab6, Eb7, B7, Eb-1, Bb-1, F0, C1, G1, D2, A2, E3, B3, F#4, C#5, Ab5, Eb6, Bb6, F7, F-1, C0, G0, D1, A1, E2, B2, F#3, C#4, Ab4, Eb5, Bb5, F6, C7, C-1, G-1, D0, A0, E1, B1, F#2, C#3, Ab3, Eb4, Bb4, F5, C6, G6, D7, D-1, A-1, E0, B0, F#1, C#2, Ab2, Eb3, Bb3, F4, C5, G5, D6, A6, A-2, E-1, B-1, F#0, C#1, Ab1, Eb2, Bb2, F3, C4, G4, D5, A5, E6, B6, B-2, F#-1, C#0, Ab0, Eb1, Bb1, F2, C3, G3, D4, A4, E5, B5, F#6, C#7, F#-2, C#-1, Ab-1, Eb0, Bb0, F1, C2, G2, D3, A3, E4, B4, F#5, C#6, Ab6.

The patch also includes a "play" button, a "bach.ezmidisplay" object for visualizing the lattice, and a "bach.transcribe" object that outputs to a "bach.ezmidisplay" object, which is connected to a musical staff. The staff shows a treble and bass clef, but no notes are currently visible. A video player at the bottom left shows a waveform for "CULP_3.aif" and a video frame of a person writing on a board, with the name "D. Ghisi" and the "france musique" logo.

Signal/Symbolic articulation in MIR



M. Bergomi, *Dynamical and Topology Tools for Modern Music Analysis*, PhD, LIM-Milan/UPMC/Ircam, Dec. 2015

➔ Towards a geometric dynamic modeling of a musical piece ?

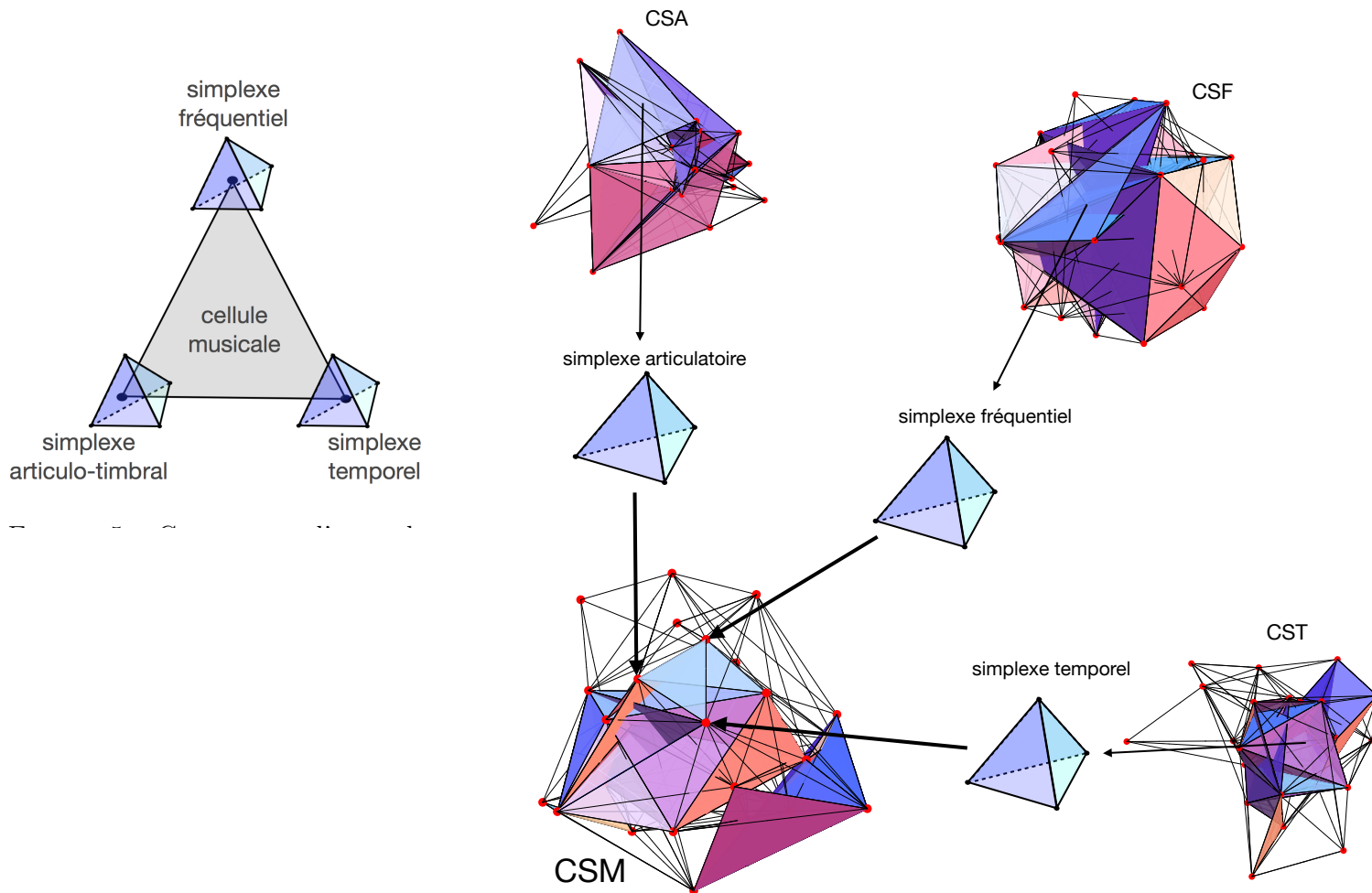
SPACE



MUSIC

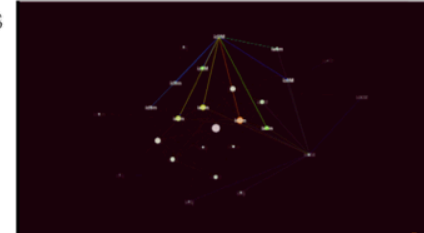
➔ Towards new perspectives on topological compositional spaces ?

Julia Blondeau: Compositional spaces



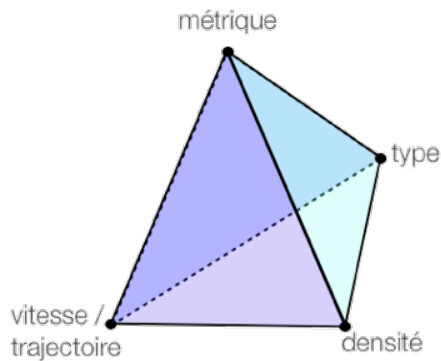
Julia Blondeau: Compositional spaces

Réseau d'intervalles

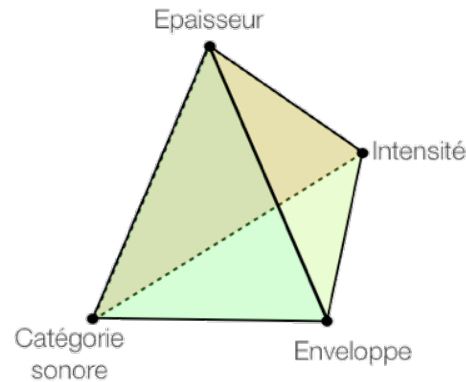


Espaces compositionnels et réseaux intervalliques

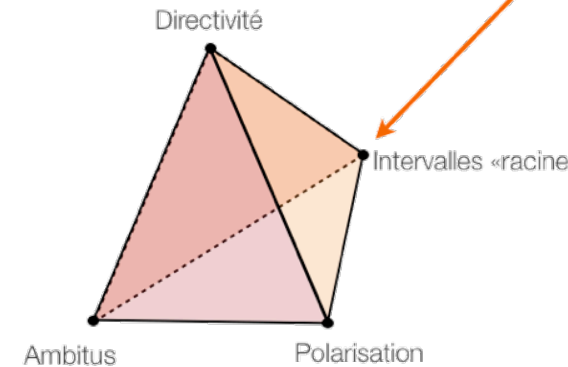
3-simplexe temporel



3-simplexe articulatoire



3-simplexe fréquentiel



métrique	division d'une durée en segments «relatifs» courts ou longs
vitesse	très lent → très rapide, accel, ral, rit ...etc
catégorie	régulier / irrégulier / lisse / strié
densité	faible, moyenne, forte, très forte

enveloppe	Enveloppes => // enveloppes en synthèse <i>Q, trajectoire, fonction d'évolution dyn...</i>
épaisseur	épaisseur «polyphonique» <i>Largeur de bande, champ de propagation....</i>
«catégorie»	pur, mat, bruité, enrichi => liens vers modes de jeu <i>Forme d'onde, nb de partiels, type de filtrage....</i>
intensité	pppp → mp mf → ffff <i>Amplitude moyenne</i>

Directivité	V, Λ, /, \, mixte ...etc.
Intervalles	intervalle(s) racine dans le réseau d'intervalles
Ambitus	restreint, moyen, large, très large
Polarisation	faible, moyenne, forte..

Many musical applications:

classification using topological characteristics: can we catch the notion of style ?

generative power of topological transformation ?

representation of other musical relationships...

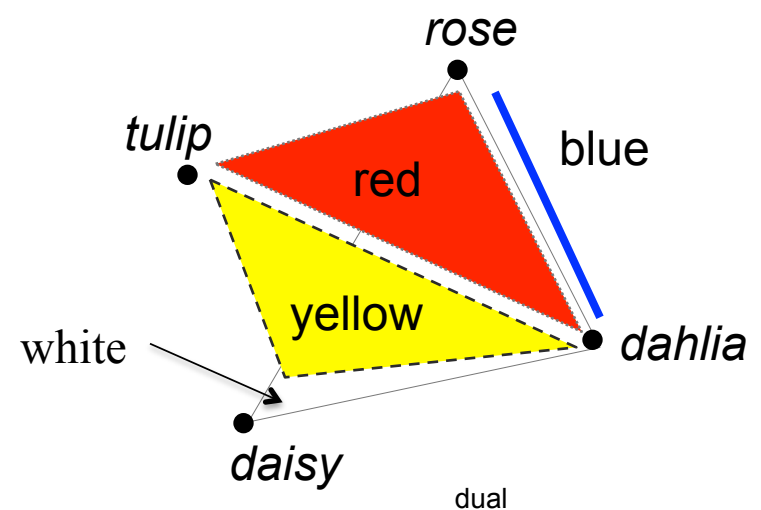
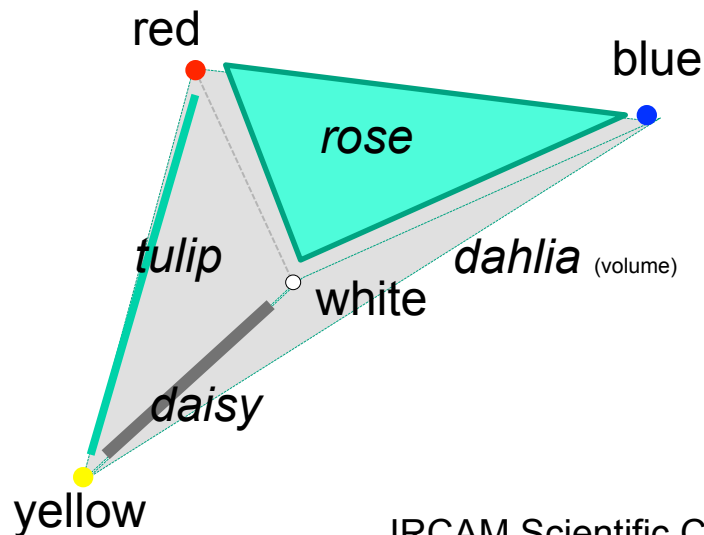
... What kind of relationships ?

TOPOLOGICAL vs ALGEBRAIC ANALYSIS OF (MUSICAL) RELATIONS

Q-analysis: a topological representation of a binary relationship

$\lambda \subset \{\text{tulipe, rose, marguerite, dahlia}\} \times \{\text{rouge, bleu, blanc, jaune}\}$

λ	red	blue	white	yellow
<i>tulip</i>	1	0	0	1
<i>rose</i>	1	1	1	0
<i>daisy</i>	0	0	1	1
<i>dahlia</i>	1	1	1	1

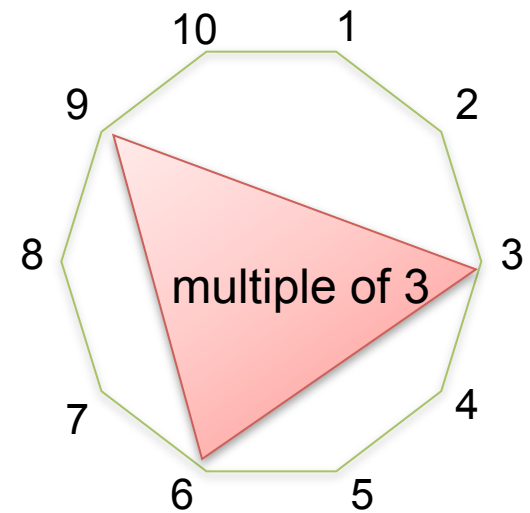
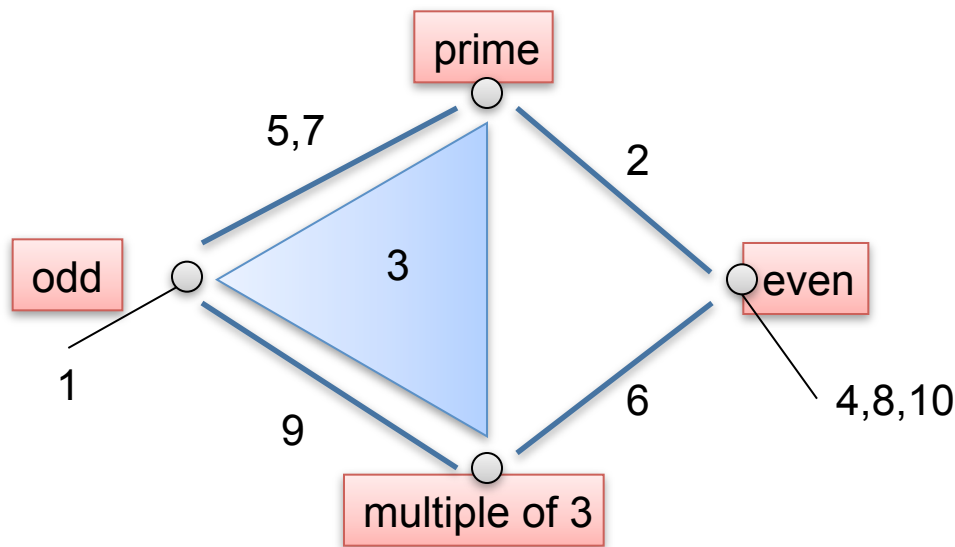


Representation of a set of predicates

$\lambda \subset \text{Objects} \times \text{Predicates} : (o,p) \in \lambda \Leftrightarrow p(o)$

Objects = {1, 2, 3, ..., 10}

Predicates = {prime, even, odd, multiple-of-3}



Formal Concept Analysis (FCA)

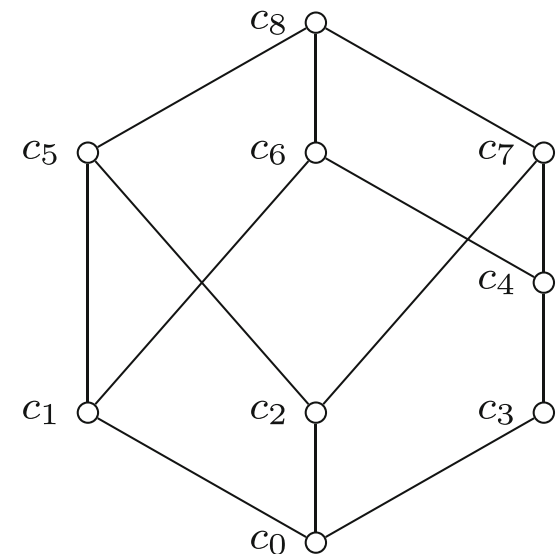
it can also be represented as a lattice

λ : interval g_i appear in a musical motive m_j

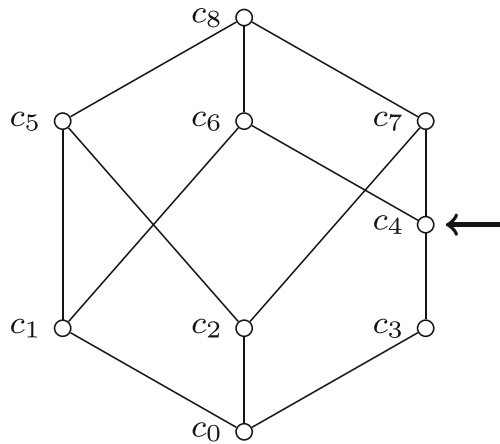
	m_1	m_2	m_3	m_4
g_1	×	×		×
g_2	×	×		
g_3	×		×	
g_4		×	×	
g_5			×	

let $H \in G$ and $N \in M$

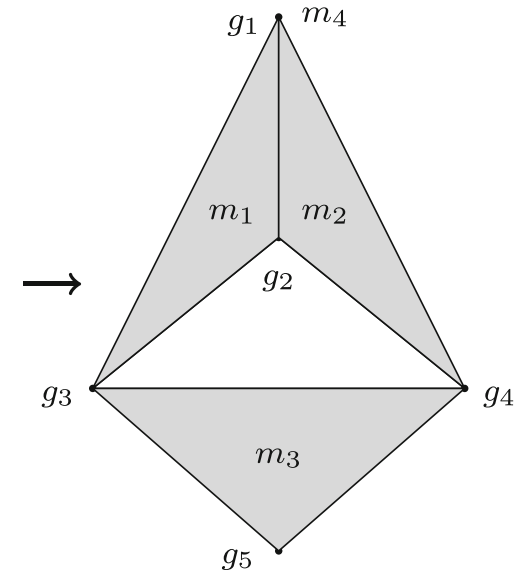
- $H' = \{ m \text{ in } M \mid (h, m) \in \lambda \text{ for all } h \in H \}$
- $N' = \{ g \text{ in } G \mid (g, n) \in \lambda \text{ for all } n \in N \}$
- (H, N) is a *formal concept* iff $H' = N$ and $H = N'$
- formal concept are ordered: $(H, N) < (I, P)$ iff $H \subset I$



Relation between FCA and Q-analysis

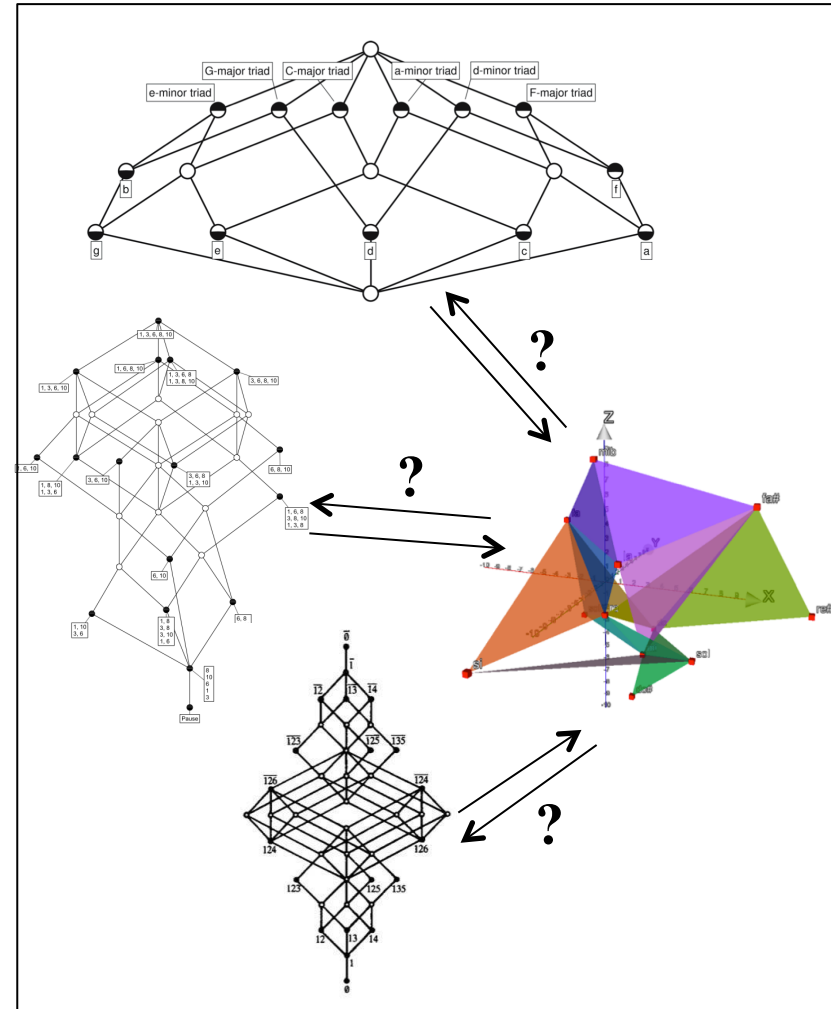
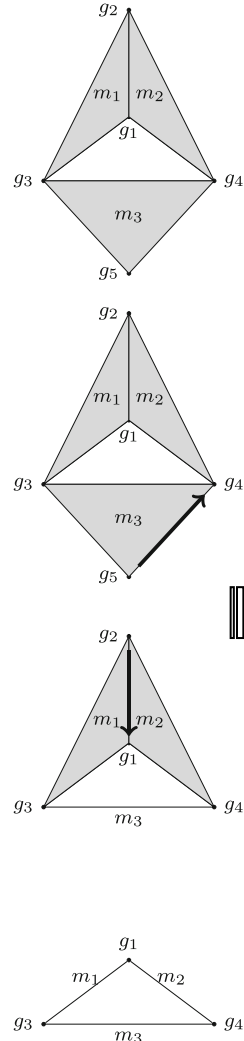
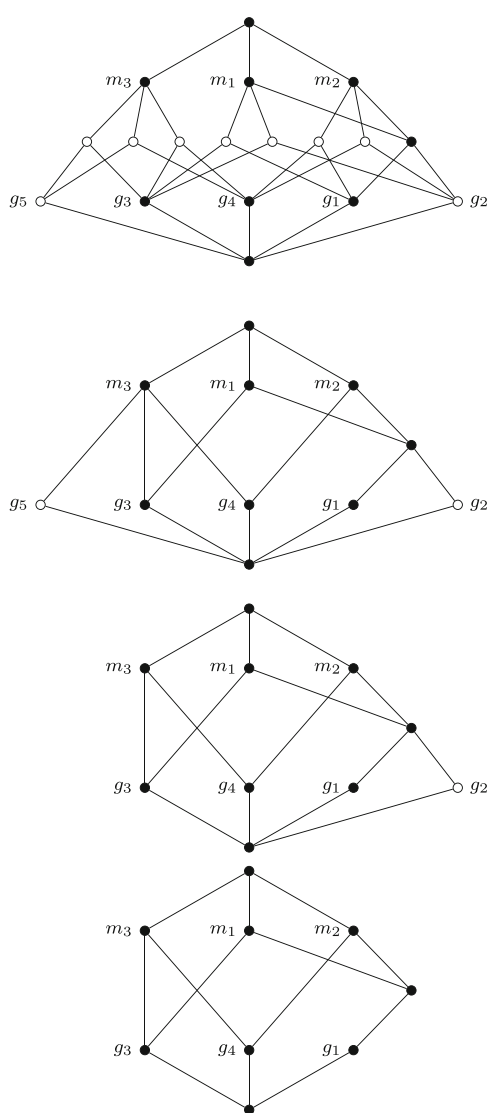


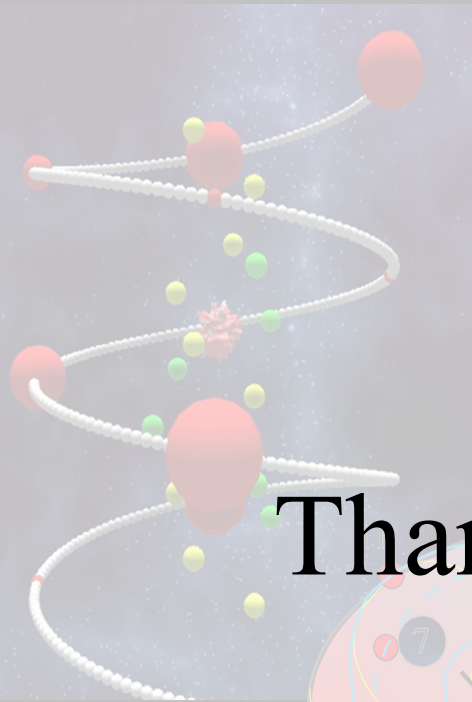
	m_1	m_2	m_3	m_4
g_1	×	×		×
g_2	×	×		
g_3	×		×	
g_4		×	×	
g_5			×	



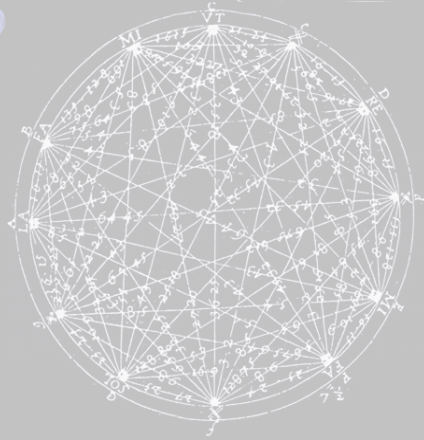
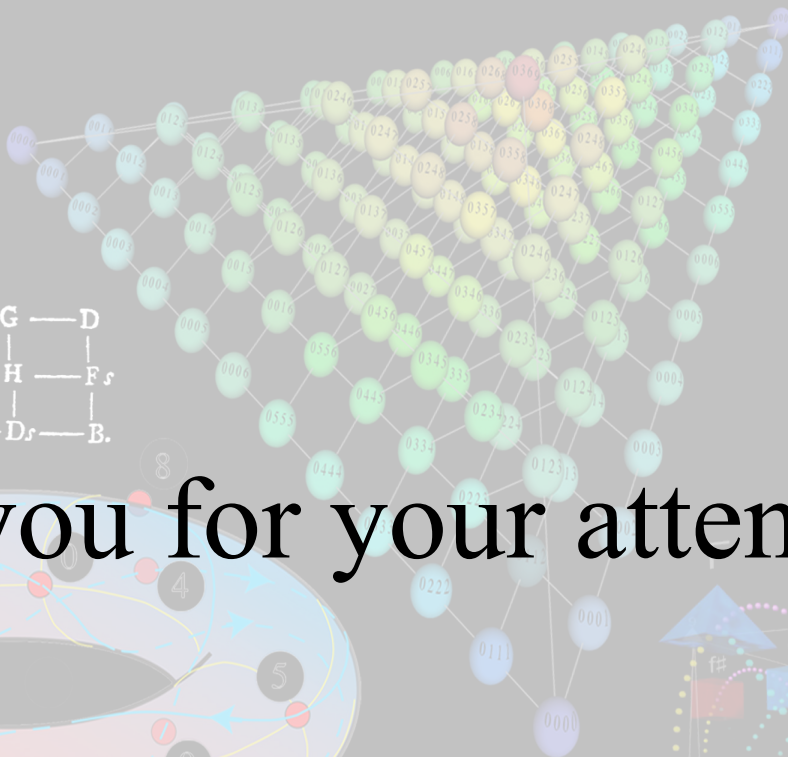
Relation between FCA and Q-analysis

➔ Freund A., M. Andreatta, J.-L. Giavitto (2015), « Lattice-based and Topological Representations of Binary Relations with an Application to Music », *Annals of Mathematics and Artificial Intelligence*





F — C — G — D
 A — E — H — F_s
 C_s — G_s — D_s — B.



Thank you for your attention

