MATHEMATICS AND COMPUTATION IN MUSIC CONFERENCE (MCM 2011) & RELATED EVENTS

MCM 2011 & RELATED EVENTS

IRCAM – CENTRE POMPIDOU – PALAIS DE LA DÉCOUVERTE
JUNE 11-18, 2011

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PLANNING FOR MCM 2011 AND RELATED EVENTS

SATURDAY JUNE 11

- **3.00PM–5.00PM:** (Palais de la Découverte, Salle des conférences) – "Les mathématiques dans l'univers musical" (*lit. Mathematics in the Musical Universe*), by Moreno Andreatta & Carlos Agon (IRCAM/CNRS), in collaboration with Robin Jamet and Pierre Audin, scientific team of the Palais de la Découverte
  (In French. Free entrance).

WEDNESDAY JUNE 15

- **8.30AM–9.30AM:** (Centre Pompidou) – Welcome and Registration of the Participants

- **9.30AM–11.15AM:** (Centre Pompidou, Petite salle) – Welcome by Hugues Vinet (IRCAM Scientific Director) / Paper Session 1: **Word and Scale Theory I**
  - Karst De Jong, Thomas Noll – Fundamental Passacaglia: Harmonic Functions and the Modes of the Musical Tetractys
  - Norman Carey – On a Class of Locally Symmetric Sequences: The Right Infinite Word Λ_θ
  - David Clampitt – Sensitive Interval Property for Scales as Words in the Free Group F2

- **11.30AM–1.00PM:** (Centre Pompidou, Petite salle) – Paper Session 2: **Word and Scale Theory II**
  - Marek Zabka – Introduction to Scale Theory over Words in Two Dimensions
  - Julian Hook – Spelled Heptachords
  - David Meredith – Tonal Scales and Minimal Simple Pitch Class Cycles

- **1.15PM–2.15PM:** (IRCAM, Salle Stravinsky) – Meeting of the Editorial Board of the *Journal of Mathematics and Music*

- **2.30PM–3.30PM:** (Centre Pompidou, Petite salle) – Paper Session 3: **History, Philosophy and Epistemology**
  - Tito M. Tonietti – Music Between Hearing and Counting (A Historical Case Chosen Within Continuous Long-lasting Conflicts)
  - Dmitri Tymoczko – Mazzola's Model of Fuxian Counterpoint

- **4.00PM–5.30PM:** (Centre Pompidou, Petite salle) – Panel Session "Bridging the Gap: Computational and Mathematical Approaches in Music Research". With the participation of Alan Marsden, Guerino Mazzola, Geraint Wiggins. Organizers: Anja Volk and Aline Honingh.

- **6.30PM–7.30PM:** (IRCAM, Espace de projection) - Welcome by Frank Madlener (IRCAM Director). Pierre Boulez / Alain Connes: La créativité en musique et en mathématiques (encounter led by Gérard Assayag, director of the IRCAM/CNRS Lab). Simultaneous translation French/English. Free Entry, limited seating available.

- **8.30PM:** (IRCAM, Espace de projection) - "Math/Music Concert", ensemble Musikfabrik. Works by Daniele Ghisi (*abroad*, World Premiere), Karim Haddad (*Ce qui dort dans l'ombre sacrée…*), György Ligeti (*Monument. Selbstportrait. Bewegung*), Karlheinz Stockhausen (*Kontakte*).

- Cocktail (IRCAM)

THURSDAY JUNE 16

- **8.30AM-9.30AM:** (Centre Pompidou) – Welcome and Registration of the Participants

- **9.30AM-10.30AM:** (Centre Pompidou, Petite salle) – Paper Session 4: **Geometrical, Topological and Computational Models I**
  - Andrew J. Milne, Martin Carlé, William A. Sethares, Thomas Noll, Simon Holland – Scratching the Scale Labyrinth
  - Nicholas Stylianou – Exploding the Monochord: An Intuitive Spatial Representation of Microtonal Relational Structures

- **11.00AM-12.00PM:** (Centre Pompidou, Petite salle) – Paper Session 5: **Geometrical, Topological and Computational Models II**
  - Louis Bigo, Jean-Louis Giavitto, Antoine Spicher – Building Topological Spaces for Musical Objects
  - Agustín Martorell, Emila Gómez – Two-Dimensional Visual Inspection of Pitch-Space, Many Time-Scales and Tonal Uncertainty Over Time

- **12.30PM-2.30PM:** (IRCAM, level -2) – Buffet sandwiches and First Session of Selected Posters:
  - Franck Jedrzejewski – Plactic Classification of Modes
  - Maximos A. Kaliakatsos-Papakostas, Michael G. Epitropakis, Michael N. Vrahatis – Feature Extraction Using Pitch Class Profile Information Entropy
  - Thomas Hedges, Martin Rohrmeier – Exploring Rameau and Beyond: A Corpus Study of Root Progression Theories
  - Richard Parncutt, Fabio Kaiser, Craig Sapp – Historical Development of Tonal Syntax: Counting Pitch-Class Sets in 13^{th}-16^{th} Century Polyphonic Vocal Music
  - Jocelyn Ho – From 2D to 3D: Using Geometry and Group Theory to Model Motivic Structure in Musical Composition
  - Fani Kosona, Leontios Hadjileontiadis – Catastrophe Theory: An Enhanced Structural and Ontological Space in Music Composition

- **2.30PM-3.30PM:** (IRCAM, Salle Stravinsky and Studio 5) – Around *A Geometry of Music*. An open discussion on the foundation of American and European math/music-theoretical traditions. With the participation of Dmitri Tymoczko (Princeton University). Session chairs: Emmanuel Amiot (mathematician, université de Perpignan, France) and Julian Hook (music theorist, Indiana University, USA).

- **4.00PM-5.30PM:** (IRCAM, salles Shannon, Stravinsky and Studio 5) – Parallel Workshops:
  - Nori Jacoby – Reinforcement Learning and Computational Methods in Music Cognition
  - Jack Douthett, Richard Plotkin, Richard Krantz, and Peter Steinbach – Maximal Even Sets
  - Gilles Baroin – From Circle to Hyperspheres: when the Tonnetze go 4D

- **6.30PM-7.30PM:** (Centre Pompidou, Grande salle) – Alain Badiou (philosopher): mathématiques / esthétiques / arts (*Lit. Mathematics/Aesthetics/Arts*). Simultaneous translation French/English. Free entry, limited seating available.

- **8.30PM** (Centre Pompidou, Grande salle) – Concert, Ensemble Remix. Works by Emmanuel Nunes (*Einspielung 1*; *Wandlungen*), Anton Webern (*Concerto, op. 24; Symphonie, op. 21*) and Bruno Maderna (*Juilliard Serenade*).

FRIDAY JUNE 17

- **8.30AM-9.30AM:** (IRCAM) – Welcome and Registration of the Participants

- **9.30AM-11.30AM:** (IRCAM, Espace de projection) – Paper session 6: **Set Theory and Transformational Theory**
  - Robert Peck – Nth Roots of Pitch-Class Inversion
  - José Oliveira Martins – Interval Cycles, Affinity Spaces and Transpositional Networks
  - Thomas M. Fiore, Thomas Noll – Commuting Groups and the Topos of Triads
  - Richard Plotkin – Cardinality Transformations in Diatonic Space

- **12.00AM-1.00PM:** (IRCAM, Espace de projection) – Paper session 7: **Computational Analysis and Cognitive Musicology I**
  - Edward Large – Musical Tonality, Neural Resonance and Hebbian Learning
  - Ian Quinn, Panayotis Mavromatis – Voice-Leading Prototypes and Harmonic Function in Two Chorale Corpora

- **1.00PM-3.00PM:** (IRCAM, level -2) – Buffet Sandwiches and Second Session Selected Posters:
  - Aline Honingh, Rens Bod – Clustering and Classification of Music by Interval Categories
  - Mathieu Bergeron, Darrell Conklin – Subsumption of Vertical Viewpoint Patterns
  - Gilles Baroin – The Planet-4D Model: An Original Hypersymmetric Music Space Based on Graph Theory
  - Mika Kuuskankare – Enriched Score Access for Computer Assisted Composition in PWGL
  - Keiji Hirata, Satoshi Tojo, Masatoshi Hamanaka – Melodic Morphing Algorithm in Formalism
  - Chantal Buteau, Christina Anagnostopoulou – Motivic Topologies: Mathematical and Computational Modelling in Music Analysis
  - Atte Tenkanen – Surveying Musical Form through Melodic-Motivic Similarities

- **3.00PM-4.00PM:** (IRCAM, Espace de projection) – Paper Session 8: **Computational Analysis and Cognitive Musicology II**
  - ➤ Benny Sluchin, Mikhail Malt – Open Form and Two Combinatorial Musical Models: The Cases of *Domaines* and *Duel*
  - ➤ Alexandre Popoff – Indeterminate Music and Probability Spaces: the Case of John Cage's *Number Pieces*

- **4.30PM-6.00PM:** (IRCAM, Espace de projection) – Paper Session 9: **Improvisation and Gestures Theory**
  - ➤ Clément Canonne, Nicolas Garnier – A Model for Collective Free Improvisation
  - ➤ Isaac Schankler, Jordan B.L. Smith, Alexandre R.J. François, Elaine Chew – Emergent Formal Structures of Factor Oracle-Driven Musical Improvisations
  - ➤ Guerino Mazzola, Florian Thalmann – Musical Composition and Gestural Diagrams

- **6.15PM-7.00PM:** (IRCAM, Espace de projection) – Stephen Wolfram (video conference from Boston, USA): "Music from the Computational Universe". Session chair: Thomas Noll.

- **8.30PM:** (Cité de la musique, Salle des concerts) Concert "Cantates", Neue Vocalsolisten Stuttgart / Ensemble intercontemporain. Works by Johannes Maria Staud (*Par ici!* World premiere), Ivan Fedele (*Animus anima*), Bruno Mantovani (*Cantate n°1*).

SATURDAY JUNE 18
(MATHEMATICS AND ARTS AT THE PALAIS DE LA DÉCOUVERTE)

- **10.00AM-11.00AM:** (Palais de la Découverte) – Welcome (Free entrance: Registration Required)

- **11.00AM-1.00PM:** (Palais de la Découverte, Salle des conférences) – Round Table around the Creativity in Mathematics and Arts. With the participation of Jean-Marc Lévy Leblond, Yves Hellegouarch, Jean-Paul Allouche, Jean-Claude Risset, Tom Johnson, Jacques Mandelbrojt.

- **3.00PM-6.00PM:** Palais de la Découverte. Guided Tour of the "Math/Art" exhibition and interactive platforms on computer-aided models in music analysis and composition. With the participation of Thomas Noll, Martin Carlé, Gilles Baroin, Jérémie Garcia, P. Beauguitte and Benjamin Lévy (to be confirmed).

- **7.00PM:** (Centre Pompidou, Grande salle) - "Stockhausen Final 1" concert. Works by Karlheinz Stockhausen (*Klang, 6. Stunde - Schönheit*), Helmut Lachenmann (*Mouvement [- vor der Erstarrung]*), Éric Maestri (*Celestografia, musica musicans*, Premiere Cursus 2).

- **9.30PM:** (Église Saint-Eustache) - "Stockhausen Final 2" concert. Works by Karlheinz Stockhausen (*Klang, 5. Stunde – Harmonien*), Francesco Filidei (*Ballata*, Premiere), Franz Liszt (*Fantasy and Fugue on the Theme B-A-C-H* - syncretic version by Jean Guillou), Harrison Birtwistle (*Cortege,a ceremony*).

ABSTRACTS

SATURDAY JUNE 11

Moreno Andreatta (IRCAM/CNRS/UPMC), **Carlos Agon** (IRCAM/CNRS/UPMC), **Robin Jamet** (Palais de la Découverte) and **Pierre Audin** (Palais de la Découverte) – Les mathématiques dans l'univers musical (*lit. Mathematics in the Musical Universe*) (in French).

> An initiation to the relationship between mathematics and music, from undulating phenomena to algebraic structures and geometric representations used in musical composition. Different maths&music concepts will also be explained through a group of paintings hung in the exhibit *Mathématiques et Arts* (Mathematics and the Arts). At the end of the conference, demonstrations created by researchers working on the relationship between mathematics and music will let the public learn more about the subjects presented.

WEDNESDAY JUNE 15

PAPER SESSION 1: WORD AND SCALE THEORY I

Karst De Jong (Royal Conservatoire Den Haag) and **Thomas Noll** (Departament de Teoria, Composició i Direcció, Escola Superior de Música de Catalunya, Barcelona, Spain) – Fundamental Passacaglia: Harmonic Functions and the Modes of the Musical Tetractys

> In this paper we take the three tonal functions *tonic*, *subdominant*, *dominant* out of their usual theoretical domicile—the combinatorics of fifth-related triads enriched by a dialectical interpretation—and redeploy them within an alternative theoretical framework: the combinatorics of the modes of the musical *tetractys*, enriched by musical-theoretical interpretations of selected mathematical facts. Section 1 introduces tonal perspectives of the analysis of the fundamental bass. Section 2 provides a short overview of the combinatorics of the three modes of the musical tetractys. The concluding Section 3 binds the two strands of investigation together.

Norman Carey (CUNY Graduate Center, USA) – On a Class of Locally Symmetric Sequences: The Right Infinite Word Λ_θ

> The Nicomachus Triangle, a two-dimensional representation of powers of 2 and 3, provides a starting point for the development of an infinite class of right infinite *Lambda words*, Λ_θ. The word is formed by encoding differences in the sequence $\{M_\theta\}_i = \{a+b\theta\}_i$, $a,b \in \mathbf{N}$. Although the word is on an infinite alphabet, it is traversable via environments containing no more than three letters. When $\theta = \vartheta = \log_2 3$, the word encodes all well-formed scales and regions generated by the intervals octave and perfect twelfth. The study sheds additional light on the role of palindromes in musical tone structures. Regions are palindromes on two letters, and form the largest palindromes in the Lambda

word, as it develops. The regions have a significant dual representation, connecting them to the palindromic prefixes of a characteristic Sturmian word. The Lambda word is rich in palindromes beyond regions. In particular, a palindrome is formed between any two successive appearances of the same letter. Although Λ_ϑ is of particular importance musically, Lambda words are interesting in their own right as word theoretic objects. The paper ends with a brief look at the Fibonacci Lambda word, Λ_ϕ.

David Clampitt (The Ohio State University, School of Music, Columbus, USA) – Sensitive Interval Property for Scales as Words in the Free Group F2

The sensitive interval property is a special feature of musical scales that generalize the diatonic Ionian (major) and Aeolian (minor) modes: specifically, ascending authentic Ionian and descending plagal Aeolian. This discussion is situated in a music-theoretic interpretation of algebraic combinatorics on words over two-letter alphabets. The present paper provides an introduction to this approach, but relies on results from a number of recent papers in this area. While previous studies have restricted attention to the free monoid of words on two letters, the present one extends consideration to F2, the free group with two generators. This permits treatment of ascending and descending modal varieties of musical scales, together with rising or falling circle-of-fifths presentations (or their generalizations), within a unified mathematical framework. The special property investigated herein positions the diatonic major third (and its generalizations) as of structural significance within the theory.

PAPER SESSION 2: WORD AND SCALE THEORY II

Marek Zabka (Katedra hudobnej vedy, Univerzita Komenského, Bratislava, Slovakia) – Introduction to Scale Theory over Words in Two Dimensions

Recently, an interaction between the mathematical discipline of combinatorics on words and musical scale theory has led to various interesting results. So far, the focus was mainly on scales generated by a single interval. The paper proposes an extension of word scale theory to tone systems of higher dimensions, i.e. generated by more than one interval. It is shown that the number of specific varieties for any non-zero generic interval in n-dimensional comma-demarcated generated tone systems is between 2 and 2^n. Therefore, generating patterns in two-dimensional systems are words over a four-letter alphabet. A concept of *quasi pairwise well-formed* words is introduced as a weakening of Clampitt's pairwise well-formedness. The main result of the paper is that a four-letter word is a generating pattern in a comma-demarcated two-dimensional system if and only if it is quasi pairwise well-formed.

Julian Hook (Indiana University, Bloomington, USA) – Spelled Heptachords

This paper develops a theory of *spelled pitch classes* (spcs) and *spelled pitch-class sets* (spc sets), incorporating pitch spelling into the techniques of pitch-class set theory. The symmetries of spc space are transposition and inversion along the line of fifths. Because of the inextricable link between pitch spelling and diatonic scales, *spelled heptachords*—seven-note spc sets that include each letter name exactly once—occupy a privileged position in this theory. Spelled heptachords

may be regarded as inflected diatonic scales, and possess a number of structural characteristics not shared by other spc sets. The 66 equivalence classes of spelled heptachords without enharmonic doublings or voice crossings are enumerated. A diatonic musical structure together with a spelled heptachord determine an *spc structure* in which the notes of the diatonic structure are inflected by the corresponding accidentals from the heptachord; spc structures arising in this way show promise as powerful tools in analysis of chromatic harmony.

David Meredith (Aalborg University, Denmark) – Tonal Scales and Minimal Simple Pitch Class Cycles

Numerous studies have explored the special mathematical properties of the diatonic set. However, much less attention has been paid to the sets associated with the other scales that play an important role in Western tonal music, such as the harmonic minor scale and ascending melodic minor scale. This paper focuses on the special properties of the class, $\mathbb{T}$, of sets associated with the major *and minor* scales (including the harmonic major scale). It is observed that $\mathbb{T}$ is the set of pitch class sets associated with the shortest simple pitch class cycles in which every interval between consecutive pitch classes is either a major or a minor third, and at least one of each type of third appears in the cycle. Employing Rothenberg's definition of stability and propriety, $\mathbb{T}$ is also the union of the three most stable inversional equivalence classes of proper 7-note sets. Following Clough and Douthett's concept of maximal evenness, a method of measuring the evenness of a set is proposed and it is shown that $\mathbb{T}$ is also the union of the three most even 7-note inversional equivalence classes.

PAPER SESSION 3: HISTORY, PHILOSOPHY AND EPISTEMOLOGY

Tito M. Tonietti (Dipartimento di matematica, Università di Pisa, Italy) – Music Between Hearing and Counting (A Historical Case Chosen Within Continuous Long-lasting Conflicts)

Here is shown Bernhard Riemann's reaction to Helmholtz's *Lehre von den Tonempfindungen*. Then I recall how Joseph Joachim and Johannes Brahms valued Helmholtz's "natural" tuning. In the end, Planck's experiments with a particular new harmonium, and an *a cappella* choir concerning "natural" or tempered tuning are described.

Dmitri Tymoczko (Princeton University, USA) – Mazzola's Model of Fuxian Counterpoint

This paper critiques Guerino Mazzola's derivation of traditional counterpoint rules, arguing that those principles are not well-modeled by pitch- class intervals; that Mazzola's differential treatment of fifths and octaves is not supported musically or by traditional counterpoint texts; that Mazzola's specific calculations are not reproducible; that there are a number of intuitive considerations weighing against Mazzola's explanation; that the fit between theory and evidence is not good; and that Mazzola's statistical arguments are flawed. This leads to some general methodological reflections on different approaches to mathematical music theory, as well as to an alternative model of first-species counterpoint featuring the orbifold $\mathbb{T}^2/\mathcal{S}_2$.

PANEL SESSiON

"Bridging the Gap: Computational and Mathematical Approaches in Music Research". With the participation of **Alan Marsden** (Lancaster Institute for the Contemporary Arts at Lancaster University and editor Journal of New Music Research), **Guerino Mazzola** (University of Minnesota, USA) and **Geraint Wiggins** (Goldsmiths College, University of London). Organizers: **Anja Volk** (Department of Information and Computing Sciences, Utrecht University Institute for Logic) and **Aline Honingh** (Language, and Computation, University of Amsterdam).

Both mathematical and computational approaches to music have thrived over the last decades, with new societies and conferences emerging (such as MCM and ISMIR). At the same time, gaps between different research directions within this multidisciplinary endeavor are noticed, that might hamper the promising utilisation of these new scientific methods for answering essential questions in music research (See Honingh, A. and Volk, A., Mathematische muziektheorie: Nieuwe mogelijkheden voor muziekgerelateerd onderzoek. In: *Dutch Journal of Music Theory*, Vol. 14 no. 3, pp 181-193, 2009). For instance, Cook (see Cook, N., "Towards the complete musicologist". In: Proceedings of the 5th International Conference on Music Information Retrieval, London, 2005) states that we have been standing quite long at a *moment of opportunity* with respect to the relation between computational approaches and musicology, without reaching the full potential of the interdisciplinary enterprise. Likewise, Marsden (see Marsden, A.,'What was the question?': Music Analysis and the Computer. In: Crawford, T., Gibson, L. (eds.) *Modern Methods for Musicology*, pp. 137-148, Ashgate, 2009) discusses possibilities to overcome the existing *gulf* between traditional music analysis and computational approaches to music analysis in order to prevent that this gulf impedes music research. Wiggins et al. (see Wiggins, G., Müllensiefen, D., Pearce, M.T.: "On the non-existence of music: why music theory is a figment of the imagination", *Musicae Scientiae*, Discussion Forum 5, pp. 231-255, 2010) argue that group-theoretic analysis applied to musical phenomena does not really move our understanding forward unless the missing link between musical mental activity and mathematical dynamics is elaborated. Noll and Peck acknowledge a gap between mathematical and computational approaches to music in the first issue of the Journal of Mathematics and Music in 2007 (Noll, T., Peck, R.: 'Welcome', *Journal of Mathematics and Music*, 1(1), pp. 1-6) and express the hope that the dialogue and collaboration between mathematical and computational approaches will be intensified. With respect to the existing gap between both computational and mathematical approaches to music and to more traditional music research, this panel discusses possibilities to strengthen the connections between these different strands of music research to the benefit of all involved disciplines.

In the proposed panel discussions, we intend to address the following key issues:
– Gaps in research topics: What research questions have mathematical and computational approaches to music successfully brought to the agenda that have opened up new research directions? Have they also contributed to investigating open questions in other areas of music research?
– Gaps in objectives: Are there any "grand challenges" on the agenda of mathematical and computational approaches to music - how do they relate to challenges in other areas of music research?
– Gaps between subfields: Music research (e.g. musicology, music theory) in general is split into many subareas. Similarly, mathematical and computational approaches to music research cover a broad area of research, however connections between different approaches are often difficult to

find. Does this result inevitably from the multifaceted nature of music - or do we limit the success of our research by not making the effort to reach across?
– Gaps between theory and experiment: Should we strengthen our efforts to link the more theory-oriented investigations in mathematical approaches to the application of theoretic models to musical corpora within computational approaches to music? What are promising strategies?
We intend to approach these questions by presenting views from three different sides: the musicological, the mathematical and the computational side. The panelists have been chosen because of their interdisciplinary research and their expertise in one of the areas.

FIRST KEYNOTE LECTURE

Pierre Boulez (composer) / **Alain Connes** (mathematician) – Creativity in Music and Mathematics

A meeting of two major figures of musical creation and contemporary mathematical research, Pierre Boulez and Alain Connes. What is the role of intuition in mathematical reasoning and in artistic activities? Is there an aesthetic dimension to mathematical activity? Does the notion of elegance of a mathematical demonstration or of a theoretical construction in music play a role in creativity? What is the status of numbers and of structures? Chairman: Gérard Assayag, head of the CNRS/IRCAM Laboratory for The Science and Technology of Music and Sound.

THURSDAY JUNE 16

PAPER SESSION 4: GEOMETRICAL, TOPOLOGICAL AND COMPUTATIONAL MODELS I

Andrew J. Milne (The Open University, Milton Keynes, UK), **Martin Carlé** (Humboldt-Universität zu Berlin, Germany), **William A. Sethares** (University of Wisconsin-Madison, USA), **Thomas Noll** (Departament de Teoria, Composició i Direcció, Escola Superior de Música de Catalunya, Barcelona, Spain), **Simon Holland** (The Open University, Milton Keynes, UK) – Scratching the Scale Labyrinth

In this paper, we introduce a new approach to computer-aided microtonal improvisation by combining methods for (1) interactive scale navigation, (2) real-time manipulation of musical patterns and (3) dynamical timbre adaption in solidarity with the respective scales. On the basis of the theory of well-formed scales we offer a visualization of the underlying combinatorial ramifications in terms of a *scale labyrinth*. This involves the selection of generic well-formed scales on a binary tree (based on the Stern-Brocot tree) as well as the choice of specific tunings through the specification of the sizes of a period (pseudo-octave) and a generator (pseudo-fifth), whose limits are constrained by the actual position on the tree. We also introduce a method to enable transformations among the modes of a chosen scale (generalized and refined "diatonic" and "chromatic" transpositions). To actually explore the scales and modes through the shaping and transformation of rhythmically and melodically interesting tone patterns, we propose a playing technique called Fourier Scratching. It is based on the manipulation of the "spectra" (DFT) of

playing gestures on a sphere. The coordinates of these gestures affect score and performance parameters such as scale degree, loudness, and timbre. Finally, we discuss a technique to dynamically match the timbre to the selected scale tuning.

Nicholas Stylianou – Exploding the Monochord: An Intuitive Spatial Representation of Microtonal Relational Structures

Microtonality appears in a wide range of historical and ethnomusicological contexts, particularly in theoretical aspects of tuning systems and as intonation in performance. Theoretical concepts of microtonality can be inaccessible due to difficulties arising in the reconciliation of mathematical and musical approaches. The development of sophisticated geometrical representations of pitch cognition has largely been focused on the Western tonal tradition with limited incorporation of microtonality. This paper presents a spatial model of microtonal intervals and their relational structures. The model enhances accessibility of microtonal-theoretic concepts through a visually intuitive representation. It also acts as a unifying framework with respect to the comparative assessment of microtonal schemes and the integration of the different dimensions of pitch cognition. The integrative characteristics of the model demonstrate the psychological emergence of cognitive structures and their potential isomorphism with algorithmic approaches. The comparative features of the model may provide the basis for computational applications of broader scope than a culturally specific model can provide, while the intuitive spatial aspects may inspire improvements in the human-computer interaction of such applications.

PAPER SESSION 5: GEOMETRICAL, TOPOLOGICAL AND COMPUTATIONAL MODELS II

Louis Bigo (LACL/Université Paris-Est Créteil / UMR CNRS STMS 9912/IRCAM), **Jean-Louis Giavitto** (UMR CNRS STMS 9912/IRCAM), **Antoine Spicher** (LACL/Université Paris-Est Creteil) – Building Topological Spaces for Musical Objects

The development of spatial representations of musical objects allows for a reformulation of algorithmic problems arising in musical theory, fosters novel classifications and provides new computational tools. In this paper, we show how a topological representation for n-note chords associated with the degrees of the diatonic scale and for the All-Interval Series (AIS) can be automatically built using MGS, a rule-based spatial programming language. Then, we suggest a new categorization for AIS based on their spatial construction.

Agustín Martorell (Music Technology Group, Universitat Pompeu Fabra, Spain) and **Emila Gómez** (Music Technology Group, Universitat Pompeu Fabra, Spain) – Two-Dimensional Visual Inspection of Pitch-Space, Many Time-Scales and Tonal Uncertainty Over Time

This work explores the representational limitations of toroidal pitch-spaces, when multiple temporal resolutions, tone center ambiguity, and the time dimension are considered for visualization of music pieces. The algorithm estimates key from chroma features, over time at many time-scales, using the key-profile correlation method. All these estimations are projected as tonal

centroids within Krumhansl and Kessler's toroidal space of inter-key distances. These centroids, belonging to a toroidal surface, are then mapped to colours by 3-dimensional geometric inscription of the whole pitch-space in the CIELAB colourspace. This mapping provides a visual correlate of pitch-space's double circularity, approximates perceptual uniformity of colours throughout near regions, and allows for representing key ambiguity. We adapt Sapp's keyscapes to summarize tonal centroids in pitch-space at many time-scales over time, in a two-dimensional coloured image. Keyscapes are linked with higher-dimensional tonal representations in a user interface, in order to combine their informative benefits for interactive analysis. By visualizing some specific music examples, we question the potential of continuous toroidal pitch-spaces in supporting long term analytical conclusions and tonal ambiguity description, when assisted by time vs. time-scale representations.

FIRST SESSION OF SELECTED POSTERS

Franck Jedrzejewski (CEA Saclay, France) – Plactic Classification of Modes

Classification of scales began to take shape in the nineteenth century through the works of Camille Durutte, Hoëne Wronski, Anatole Loquin and some others, but it really took a new start in the twentieth century. The aim of this paper is to study a new classification of modes based on the plactic congruences. These congruences mimic a small perturbation from one mode to the other by the move of only one note. Two modes are in the same plactic class if they are related by a path of modes which are pairwise linked by plactic congruences. In this paper, a *mode* is an ordered series of musical intervals (or steps).\ A *scale* is an ascending or descending series of notes, representing a class of modes under circular permutations. In traditional Western music, the C major scale represents the circular permutations of the seven usual modern modes (Ionian, Dorian, Phrygian, etc.)

Maximos A. Kaliakatsos-Papakostas, **Michael G. Epitropakis**, **Michael N. Vrahatis** (Computational Intelligence Laboratory (CI,Lab), Department of Mathematics, University of Patras, Greece) – Feature Extraction Using Pitch Class Profile Information Entropy

Computer aided musical analysis has led a research stream to explore the description of an entire musical piece by a single value. Combinations of such values, often called global features, have been used for several identification tasks on pieces with symbolic music representation. In this work we extend some ideas that estimate information entropy of sections of musical pieces, to utilize the Pitch Class Profile information entropy for global feature extraction. Two approaches are proposed and tested, the first approach considers musical sections as overlapping sliding onset windows, while the second one as non-overlapping fixed-length time windows.

Thomas Hedges (Trinity Laban Conservatoire of Music and Dance, London, UK), **Martin Rohrmeier** (Centre for Music and Science, Faculty of Music, University of Cambridge, UK) – Exploring Rameau and Beyond: A Corpus Study of Root Progression Theories

This study empirically explores root progression theories as a differentiator between tonal and pre-tonal music with a statistical corpus analysis of Palestrina Madrigals and Bach Chorales. Results found some quantitative evidence in the corpora for Rameau's rule-based root progression theory and Meeùs' symmetry between "dominant" and "subdominant" root progressions. Further investigation revealed statistically significant differences between the underlying structures of the corpora, suggesting the cycle of fifths as fundamental to tonal music.

Richard Parncutt (Centre for Systematic Musicology, University of Graz, Austria), **Fabio Kaiser** (Centre for Systematic Musicology, University of Graz, Austria), **Craig Sapp** (CCARH, Stanford University, USA) – Historical Development of Tonal Syntax: Counting Pitch-Class Sets in 13^{th}-16^{th} Century Polyphonic Vocal Music

The evolution of tonal-harmonic syntax in European notated music, from the beginnings of polyphony to the emergence of major-minor tonality, has been the subject of intense historical study. Several authors have also attempted statistical analyses of the frequency of occurrence of specific pitch-time patterns in specific periods or composers. But no-one has compared prevalence profiles across different periods. Here, we estimate the frequency of occurrence of pitch-class sets of cardinality three in small samples of vocal polyphony from the 13^{th}, 14^{th}, 15^{th} and 16^{th} centuries. Throughout this period, sonorities that were later identified as major and minor became more prevalent (major more than minor). The rank order of sonorities was more variable in earlier music, where chords such as CDF or $CE_{\flat}F$ were quite prominent; in later music, the third and fourth most common chords were suspended and diminished.

Jocelyn Ho (Department of Music, Stony Brook University, New York, USA) – From 2D to 3D: Using Geometry and Group Theory to Model Motivic Structure in Musical Composition

In this paper, I propose to model motivic development using the concept of manifolds. Compositional space is represented by a manifold that consists of musical "charts", and the music itself is represented by a path. This concept forms the basis of my two compositions, *Torus* and *12 Variations on a Dodecahedron*. In *Torus*, the idea of a path on a two-dimensional manifold in three dimensions is used to manifest different levels of circularity. In *12 Variations on a Dodecahedron*, the elements in the group of rotational symmetries of a dodecahedron are represented musically by exploiting its isomorphism with the alternating group on five elements.

Fani Kosona (Dept. of Music, Ionian University, Corfu, Greece), **Leontios Hadjileontiadis** (Dept. of Electrical & Computer Engineering, Aristotle University of Thessaloniki, Greece / State Conservatory of Thessaloniki, Greece) – Catastrophe Theory: An Enhanced Structural and Ontological Space in Music Composition

The application of catastrophe theory in music composition offers a solid conceptual frame for handling discontinuity, resulting to an enhancement of the structural space, by converting the music work into a dynamical system. In this frame, the structural stability of the form is put under strain by forces as multiple attractors, consequently enlarging the ontological space of the work to contain indeterminist, de-autocorrelative and deconstructive aspects. A case study is briefly discussed.

AROUND A GEOMETRY OF MUSIC

An open discussion on the foundation of American and European math/music-theoretical traditions. With the participation of Dmitri Tymoczko (Princeton University, USA). Session chairs: Emmanuel Amiot (mathematician, université de Perpignan, France) and Julian Hook (music theorist, Indiana University, USA).

A Geometry of Music proposes a new framework for understanding tonality, and with it the history of Western music. The book proposes that there are five musical features that are basic to "tonality" in the broad sense. It then sets out a theoretical apparatus for understanding these five features, focusing on the way they constrain each other. Central to the argument is the use of singular quotient spaces, or "orbifolds," to represent voice leading relationships among chords and scales. The book also proposes new theoretical tools for thinking about scales, voice leading, pitch-class circulation, and "macroharmony." The second half of the book then uses these tools to retell the history of Western music, arguing that there is an "extended common practice" stretching from before the time of Palestrina to the present day. The book provides detailed discussions of passages by Mozart, Beethoven, Chopin, Brahms, Grieg, Debussy, Stravinsky, Schoenberg, Shostakovich, the Miles Davis Quintet, Bill Evans, the Beatles, and many others, arguing that jazz is continuous with the classical tradition.

After shortly presenting the content of the book, Julian Hook and Emmanuel Amiot discuss some aspects of the book respectively from the American and European perspective. Finally a discussion with the audience will try to address more general issues concerning the foundations of music theory, and the similarities and differences between European and the American approaches.

PARALLEL WORKSHOPS

Nori Jacoby (Interdisciplinary Center for Neural Computation, Hebrew University of Jerusalem / Department of Music, Bar-Ilan University) – Reinforcement Learning and Computational Methods in Music Cognition

Listening and performing music involves the ability to make predictions in real time, as we constantly update our cognitive states or actions within an ever-changing musical environment. This predictive process can be modeled using reinforcement learning, a technique taken from the domain of computer science and computational neuroscience. In this tutorial, I will review the basic concepts of reinforcement learning such as states, actions, reward function and values, as well as Bellman equations and Q-learning. I will also link reinforcement learning to other related techniques such as Markov Decision Processes (MDP), Partially Observed Markov Decision Processes (POMDP), and Hidden Markov Models (HMM). I will present current applications of these models in music cognition, with illustrated examples from the domain of sensorimotor synchronization (tapping experiments), and suggest possible research directions in the domains of rhythm, harmony, and music performance and production.

Jack Douthett (Central New Mexico Community College), **Richard Plotkin** (State University of New York at Buffalo), **Richard Krantz** (Metropolitan State College of Denver) and **Peter Steinbach** (Central New Mexico Community College) – Maximal Even Sets

The workshop will be divided into three parts.

Part 1: This part will address a variety of distinct, yet equivalent, definitions of maximally even (ME) sets and their applications. Included among these definitions are the ME algorithms, "picture" definitions that require no mathematics, definitions based on interval spectra, convex (concave) interaction definitions, and definitions based on the Euclidean algorithm and Fourier transforms. The relationship between ME sets and musical scales and rhythm, the dinner table problem, the 1-dimensional antiferromagnetic Ising model, and distance metrics will also be addressed in this part.

Part 2: In this part the connection between ME sets and Myhill Property (MP), dual symmetry, cardinality-equals-variety (CV), continued fractions, Chord CV (CCV), and dual CCV will be addressed. The connection between these concepts and unsolved problems including the twin-prime problem (primes that differ by 2) will be discussed.

Part 3: In this part, ME set theory is extended via convex (concave) interactions from essentially a 2-color problem (e.g., men and women distributed as evenly as possible around a circular dinner table) to a 3-color problem (Frenchmen, Germans, and Englishmen distributed as evenly as possible around a circular dinner table). For this extended definition of ME set theory there are more questions then answers.
This workshop is intended for anyone who has a reasonably good mathematical background and is interested in learning more about ME sets and their applications in music and science. We well discuss topics for future research and unsolved problems that relate to ME theory.

Gilles Baroin (Laboratoire LLA Creatis, université de Toulouse de Le Mirail, France) – From Circle to Hyperspheres: when the Tonnetze go 4D

This Workshop shows some chosen geometrical models representing the 12 tone equal tempered system that I've either re-colorized, reconstructed in 3D, or self-created from scratch in 3D or 4D during my PhD. The examples are ordered by geometrical complexity. We start with the simplest circle and end up with a true 4D model that resides on a hypersphere. The pedagogic purpose of this visualization is not to list or prefer any particular existing model but to illustrate the one I have created. We will progressively familiarize the spectator to the concepts of hyper-symmetry and four dimensional spaces.

SECOND KEYNOTE LECTURE

Alain Badiou (philosopher): Mathematics / Aesthetics / Arts

Eminent figure of contemporary thought, playwright, politically committed intellectual, controversial polemicist, Alain Badiou is one of the rare philosophers today that maintains an intense and constant relationship with mathematics, building his logic and his system of the theory of ensembles inherited from Georg Cantor on it. Beginning in 1988, the founding axiom of his philosophy was explained in his work, *L'être et l'événement (The Being and The Event)*: mathematics are the ontology, the philosophy produces a discourse that reveals it to itself. Mathematics take the seat of honor of the poem compared to the history of metaphysics. Under what conditions does a creative oddity become a part of the need to formalize mathematics? Does a history of the work-theorems—from Mondrian to Stockhausen—exist?

Session organized in collaboration with the Département du développement culturel (La Parole) at the Centre Pompidou.

FRIDAY JUNE 17

PAPER SESSION 6: SET THEORY AND TRANSFORMATIONAL THEORY

Robert Peck (School of Music, Louisiana State University, USA) – Nth Roots of Pitch-Class Inversion

In this study, we investigate the square, cubic, and other *n*th roots of inversion in discrete pitch-class spaces. We examine the group-theoretical structures that they inhabit, as well as various multi-dimensional regular polytopes whose symmetries model those structures. Moreover, we determine which nth roots of inversion occur in pitch class spaces of various sizes, and their multiplicities. Because of their relevance to the majority of music in the Western canon, as well as to the transformational theories that engage this repertoire, we focus largely on inversions and their nth roots in mod-7 diatonic space and in mod-12 chromatic space. Our objective is to further the understanding of pitch-class inversion as a gesture, through an exploration of its *n*th roots in discrete transformational music theory.

José Oliveira Martins (Eastman School of Music, University of Minnesota-Rochester, USA) – Interval Cycles, Affinity Spaces and Transpositional Networks

The paper proposes a framework that coordinates several models of pitch space whose constructive features rely on the concept of interval cycles and transpositional relations. This general model brings under a focused perspective diverse pitch structures such as *Tonnetze*, *affinity spaces*, Alban Berg's "master array" of interval-cycles, and several types of transpositional networks (T-nets). This paper argues that applying incremental changes on some of the constructive features of the generic *Tonnetz* (Cohn 1997) results in a set of coherent and analytically versatile transpositional networks (T-nets), here classified as homogeneous, progressive, and dynamic. In this context, several properties of the networks are investigated, including voice-leading and common-tone relations. The paper also explores the music-modeling potential of progressive and dynamic T-nets by attending to characteristic compositional deployments in the music of Witold Lutosławski and György Kurtág.

Thomas M. Fiore (Department of Mathematics and Statistics, University of Michigan-Dearborn, USA) and **Thomas Noll** (Departament de Teoria, Composició i Direcció, Escola Superior de Música de Catalunya, Barcelona, Spain) – Commuting Groups and the Topos of Triads

The goal of this article is to clarify the relationship between the topos of triads and the neo-Riemannian *PLR*-group. To do this, we first develop some theory of generalized interval systems: 1) we prove the well known fact that every pair of dual groups is isomorphic to the left and right regular representations of some group (Cayley's Theorem), 2) given a simply transitive group action, we show how to construct the dual group, and 3) given two dual groups, we show how to easily construct sub dual groups. Examples of this construction of sub dual groups include Cohn's hexatonic systems, as well as the octatonic systems. We then enumerate all $\mathbf{Z}_{12}$-subsets which are invariant under the triadic monoid and admit a simply transitive *PLR*-subgroup action on their maximal triadic covers. As a corollary, we realize all four hexatonic systems and all three octatonic systems as Lawvere--Tierney upgrades of consonant triads.

Richard Plotkin (University at Buffalo, The State University of New York, USA) - Cardinality Transformations in Diatonic Space

This paper introduces a system in which parsimonious and continuous transformations occur seamlessly between triads and tetrachords. Such fluidity is abundant in common practice music, but unprecedented in theoretical literature, largely because there has been no consistent way to approach transformations independent of cardinality. Neo-Riemannian theory elegantly unites harmonic change and voice-leading efficiency, but deals exclusively with set class [037] in a 12-gamut pcset space. Attempts to extend the neo-Riemannian approach to tetrachords in 12-gamut space often fall short; the elegant characteristics of the triadic theory do not carry over. However, when a scalar context arbitrates the parsimoniousness of transformations, triads and tetrachords can be treated in a consistent manner. Within this consistently modeled space, cardinality itself can be transformed. In this paper, we see that filtered point-symmetry is an essential tool for working through the iterated maximally even sets that establish scalar contexts. To understand cardinality transformations, we also extend filtered point-symmetry to model partially symmetric distributions and relatively even sets.

PAPER SESSION 7: COMPUTATIONAL ANALYSIS AND COGNITIVE MUSICOLOGY I

Edward Large (Center for Complex Systems and Brain Sciences, Florida Atlantic University, USA) – Musical Tonality, Neural Resonance and Hebbian Learning

> A new theory of musical tonality is explored, which treats the central auditory pathway as a complex nonlinear dynamical system. The theory predicts that as networks of neural oscillators phase-lock to musical stimuli, stability and attraction relationships will develop among frequencies, and these dynamic forces correspond to perceptions of stability and attraction among musical tones. This paper reports on an experiment with learning in a model auditory network. Results suggest that Hebbian synaptic modification can change the dynamic responses of the network in some ways but not in others.

Ian Quinn (Yale University, USA) and **Panayotis Mavromatis** (New York University, USA) – Voice-Leading Prototypes and Harmonic Function in Two Chorale Corpora

> We describe a data representation for voice leading between two sonorities in a chorale texture, and a similarity measure for these voice leadings. These tools are used in an empirical study of the relationship between voice leading and harmonic function in a corpus of Bach chorales and a corpus of Lutheran chorales from a hundred years earlier. Common voice-leading types in the corpora are subjected to a cluster analysis that is readily interpreted in terms of harmonic functional syntax. We are thus able not only to read a theory of harmony directly out of a corpus, but to do so without building in a priori notions of chord structure, rootedness, or even key. The cluster analysis also clarifies important syntactic differences between the pre-tonal (modal) corpus and the Bach (tonal) corpus.

SECOND SESSION OF SELECTED POSTERS:

Aline Honingh (Institute for Logic, Language and Computation, University of Amsterdam) and **Rens Bod** (Institute for Logic, Language and Computation, University of Amsterdam) – Clustering and Classification of Music by Interval Categories

> We present a novel approach to clustering and classification of music, based on the concept of interval categories. Six interval categories exist, each with its own musical character. A piece of music can be represented by six numbers, reflecting the percentages of occurrences of each interval category. A piece of music can, in this way, be visualized as a point in a six dimensional space. The three most significant dimensions are chosen from these six. Using this approach, a successful visual clustering of music is possible for 1) composers through various musical time periods, and 2) the three periods of Beethoven, which illustrates the use of our approach on both a general and a specific level. Furthermore, we will see that automatic classification between tonal and atonal music can be achieved.

Mathieu Bergeron (McGill University, Montreal, Canada) and **Darrell Conklin** (Department of Computer Science and Universidad del País Vasco, San Sebastián, Spain, IKERBASQUE, Basque Foundation for Science, Bilbao) – Subsumption of Vertical Viewpoint Patterns

This paper formalizes the vertical viewpoint pattern language for polyphonic pattern representation. The semantics of patterns is given in terms of a translation to a relational network form. The language supports pattern subsumption, an essential inference for pattern mining, development, and refinement. Though computed in a way entirely different to relational network matching, this paper proves that subsumption inferences are sound and complete with respect to the underlying relational language.

Gilles Baroin (Laboratoire LLA Creatis, University of Toulouse, France) – The Planet-4D Model: An Original Hypersymmetric Music Space Based on Graph Theory

Beside a geometrical part that has been calculated with the help of the graph theory, the Planet-4D model includes twelve ideograms that can either symbolize notes, chords or scales depending on the context. Based on symmetry principles, it presents the following innovations:
1. the hyper spherical environment grants each symbol an equivalent physical position, and involves more symmetries than any 3D model,
2. the concept of bi-dimensional ideograms provides an intuitive understanding of pitch relationships,
3. it contains implicitly the chromatic and fourth circles as well as the original Tonnetz.

NB: the pertinence of this model is effective when demonstrated in motion with colored CGI animations of the 4D Space including sound examples. Videos shown during this conference are available on the web at www.planetes.info.

Mika Kuuskankare (Sibelius Academy, Department for Doctoral Studies in Music and Research, Helsinki, Finland / STMS, IRCAM/CNRS/UPMC, Paris, France) – Enriched Score Access for Computer Assisted Composition in PWGL

PWGL is a visual composition environment that can be used to, among other things, solve musical constraints problems. The constraints system within PWGL, PWGLConstraints, allows us to write rules using a special pattern-matching language. Typically, the assignments use as a starting point a score prepared with the help of Expressive Notation Package (ENP). In this paper we present an extension to the PWGLConstraints pattern-matching language which allows us to access information from ENP to assist with the compositional process. ENP provides a rich library of standard and user-definable expressions called ENP-expressions. They range from standard articulation markings (such as staccatos and slurs) to fully interactive multi-purpose graphical expressions. A special syntax is developed which allows us to retrieve information about and contained by the expressions. In this paper, the syntax and the present state of the system are illustrated using a working example.

Keiji Hirata (NTT/Future University Hakodate, Japan), **Satoshi Tojo** (Japan Advanced Institute of Science and Technology, Japan) and **Masatoshi Hamanaka** (PREST, JST/University of Tsukuba, Japan) – Melodic Morphing Algorithm in Formalism

> We introduce a feature structure, corresponding to a time-span tree of Lerdahl and Jackendoff's *A Generative Theory of Tonal Music*, and represent the reduction of the tree by the subsumption among these feature structures. As the collection of them forms a lattice, we can define the *join* and *meet* operations. We show a melodic morphing algorithm based on these simple operations.

Chantal Buteau (Department of Mathematics, Brock University, Canada) and **Christina Anagnostopoulou** (Department of Music Studies, University of Athens, Greece) – Motivic Topologies: Mathematical and Computational Modelling in Music Analysis

> This paper discusses a mathematical model together with its computational realization, for the motivic analysis of a piece of music. Relations between the mathematical model (motivic topologies), computational counter-part (OM-Melos), and music analysis are presented in the light of general concepts of computational music analysis, stressing the importance of neutrality and scientific rigour in the modelling part, while preserving the freedom of the analyst.

Atte Tenkanen (Department of Musicology, University of Turku, Finland) – Surveying Musical Form through Melodic-Motivic Similarities

The aim of this study is practical: we want to afford useful compositional schemas and insights, for instance, for students who apply counterpoint in order to construct larger musical forms. For that, we inspect by computer the melodic hierarchies in classical contrapuntal textures. The current model is based on mapping the frequencies of melodic-motivic repetitions throughout an entire piece. Our application creates schemas that illustrate how commonly the melodic segments occur in the piece. The results seem to correspond well to our intuitive impressions of thematic hierarchies.

PAPER SESSION 8: COMPUTATIONAL ANALYSIS AND COGNITIVE MUSICOLOGY II

Benny Sluchin (Ensemble intercontemporain, IRCAM) and **Mikhail Malt** (IRCAM, MINT / université Paris-Sorbonne) – Open Form and Two Combinatorial Musical Models: The Cases of *Domaines* and *Duel*

> Two "open" works, composed within a two-year period by Boulez and Xenakis, could be seen as based on a square matrix of order six and share several properties. Their combinatorial attributes, the theory and the practice of their performances are studied and compared. Our main aim is to establish a relationship between the properties of the mathematical model and its use by Boulez and Xenakis in *Domains* and *Duel*.

Alexandre Popoff – Indeterminate Music and Probability Spaces: the Case of John Cage's *Number Pieces*

Indeterminate music is characterized by the use of random outputs, either during the compositional process or during its performance. John Cage's *Number Pieces* are works indeterminate in their realization in which the performer, through a framework of "time-brackets", has control over the temporal limits of fixed sounds. In this paper we analyze John Cage's temporal system of time-brackets using a statistical approach. It is shown that for a single time-bracket a probability space can be defined concerning the choice of the temporal limits of a sound. The performer's attitude toward choice is modelled through different probability distributions over the sample space and the audible quantities (in particular, length) of the sound contained within a time-bracket are calculated. We show how time-brackets can be considered as flexible structures ensuring complex outputs from simple assumptions. The limits of our statistical model as compared to real human behavior are discussed, and perspectives are given concerning the study of complete sets of time-brackets.

PAPER SESSION 9: IMPROVISATION AND GESTURES THEORY

Clément Canonne (université de Lyon, École Normale Supérieure de Lyon) and **Nicolas Garnier** (université de Lyon, Laboratoire de Physique de l'ENS-Lyon, CNRS UMR 5672) – A Model for Collective Free Improvisation

This paper presents a model for Collective Free Improvisation (CFI), a form of improvisation that can be defined as *referent-free*. While very simple, it captures some interesting mechanisms of CFI. We use two variables: the *intention* and the *objective*. Both variables are used to describe the production and organization of the improvisers' signals. Using a system of Landau equations, we propose a non-linear dynamics for the intention evolving on a short time-scale while the objective evolves on a long time-scale. In this paper, the model is used to determine if, and within which conditions, a collective structure can emerge from CFI.

Isaac Schankler (University of Southern California, Los Angeles, USA), **Jordan B.L. Smith** (University of Southern California, Los Angeles, USA), **Alexandre R.J. François** (Harvey Mudd College, Claremont, USA) and **Elaine Chew** (University of Southern California, Los Angeles, USA) – Emergent Formal Structures of Factor Oracle-Driven Musical Improvisations

In this article, improvisations created with the factor oracle, a commonly used data structure in machine models of musical improvisation, are shown to exhibit certain formal structures independent of the musical content. We posit that these structures are in fact emergent properties of the behavior of the factor oracle itself. An expert improviser (the first author) performed a series of improvisations with Mimi, a factor oracle-driven multimodal system for human-machine improvisation, and the formal structures of each performance was independently analyzed by the performer and an experienced music structure annotator (the second author). Quantitative assessment of the similarity between the performer's and the listener's analyses was carried out using techniques from the field of automatic structure analysis. Supported by a comparison to baseline analysis approaches, the results suggest a high level of agreement between the two

sets of analyses. Drawing upon this foundation of evidence, we discuss these analyses and their relationship to common classical forms, including canon- and rondo-like forms, as well as forms based on the juxtaposition of rhythmic cells.

Guerino Mazzola (School of Music, University of Minnesota, USA) and **Florian Thalmann** (School of Music, University of Minnesota, USA) — Musical Composition and Gestural Diagrams

By an adjoint functor argument, we reinterpret categorical gestures as being "continuous diagrams" with values in topological categories, which we therefore call "gestural diagrams'". This allows to view traditional transformational diagrams as canonical restrictions of gestural diagrams and to reinterpret musical gesture theory in a natural way as a topological extension of transformational theory. We apply these tools to extend the concept of a musical score to a "processual diagrammatic score'". Such a score not only captures the result of a compositional effort but also the poietic process and its underlying gestures. These conceptual extensions can be modeled on the level of denotators and forms so that an implementation for the Rubato Composer software becomes feasible. Recent developments in this software enable the definition of affine transformations using finger gesture input on trackpads. Once such gestures are abstracted in a transformational processual diagram we introduce a Bruhat decomposition argument for $SL_2(\mathbf{Z})$ to reconstruct canonical gestural diagrams. Based on this model, we suggest new ways of graphical software interaction that facilitate dynamic navigation and intervention in the composition's history.

THIRD KEYNOTE LECTURE

Stephen Wolfram (computer-scientist, founder and CEO of Wolfram Research and creator of Mathematica and of Wolfram|Alpha): "Music from the Computational Universe" (videoconference from Boston, USA). Session chair: **Thomas Noll** (ESMuC / TU-Berlin, co-editor en chief of the *Journal of Mathematics and Music*).

SATURDAY JUNE 18
(MATHEMATICS AND ARTS AT THE PALAIS DE LA DÉCOUVERTE)

Round Table around the Creativity in Mathematics and Arts (In French). With the participation of **Jean-Marc Lévy Leblond** (physicist and essayist), **Claude Bruter** (mathematician and president of the ESMA), **Yves Hellegouarch** (mathematician), **Jean-Paul Allouche** (mathematician), **Jean-Claude Risset** (physicist and composer), **Tom Johnson** (composer), Jacques Mandelbrojt (painter and physicist). Round table led by: **Moreno Andreatta** (IRCAM /CNRS).

> Do mathematics have a unique place within scientific disciplines, as music does within artistic practices? This final round-table discussion will raise the issue of the mathematics/music relationship and, more generally, the possible connections between science and art starting with the problem of creativity in mathematics and the arts.

Guided Tour of the "Math/Art" exhibition and interactive platforms on computer-aided models in music analysis and composition. With the participation of **Thomas Noll** (ESMuC / TU-Berlin), **Martin Carlé** (Humboldt University of Berlin), **Gilles Baroin** (université de Toulouse), **Jérémie Garcia** (IRCAM / In Situ – université Paris-Sud 11), **Pierre Beauguitte** (IRCAM / UPMC), **Benjamin Lévy** (IRCAM / université de Paris VI. To be confirmed).

> An opportunity to visit the exhibition "Mathématiques et Arts" presented by ESMA in collaboration with IRCAM and the Palais de la Découverte and to meet the researchers who made computer models of certain musical problems (e.g. Fourier scratching, geometric representations of musical objects, augmented paper, computer-aided improvisation, etc.).

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L'ÉQUIPE

DIRECTION
Frank Madlener

COORDINATION
Suzanne Berthy

CONFÉRENCES
Hugues Vinet
Carlos Agon, Moreno Andreatta, Gérard Assayag, Sylvie Benoit, Jean Bresson

PRODUCTION
Alain Jacquinot, Julien Aléonard, Timothé Bahabanian, Pascale Bondu, Sylvain Cadars, Christophe Egéa, Agnès Fin, François Gibouin, Kristell Guiguen, Anne Guyonnet, Jérémie Henrot, Enora Le Gall, Maxime Le Saux, Frédéric Vandromme

COMMUNICATION
Claire Marquet
Murielle Ducas, Sylvia Gomes, Vincent Gourson, Deborah Lopatin, Delphine Oster, Juliette Tissot-Vidal

BILLETTERIE
Paola Palumbo,
Cyrielle Fiolet, Arnaud Issoulié, Stéphanie Leroy

PÉDAGOGIE ET ACTION CULTURELLE
Cyril Béros
Anne Becker, Fleur Gire, Natacha Moënne-Loccoz

RELATIONS PRESSE
Opus 64
Valérie Samuel, Marine Nicodeau
Eracom
Estelle Reine-Adélaïde

LES PARTENAIRES

- Centre Pompidou, Bpi (Bibliothèque publique d'information) et Département du développement culturel (Parole, Spectacles vivants)
- Centre national des arts plastiques
- Cité de la musique
- Église Saint-Eustache
- Gaîté lyrique
- Le CENTQUATRE
- Le Fresnoy-Studio national des arts contemporains
- Opéra Comique
- Radio France
- Palais de la découverte, un lieu Universcience

AVEC LE SOUTIEN DE

- Afim (Association française d'informatique musicale)
- Arcadi
- Cap Digital
- Centre culturel Calouste Gulbenkian à Paris
- Festival de l'Argos
- Futur en Seine
- Institut Camões à Paris
- Région Île-de-France
- Sacem (Société des auteurs, compositeurs et éditeurs de musique)
- Sfam (Société française d'analyse musicale)
- SMF (Société Mathématique de France)

PARTENAIRES MÉDIAS

- ARTE Live Web
- France Culture
- France Musique
- Télérama

Notes