



# Two Representations of Music Computed with a Spatial Programming Language

Louis Bigo, Antoine Spicher, Olivier J.J. Michel

## ► To cite this version:

Louis Bigo, Antoine Spicher, Olivier J.J. Michel. Two Representations of Music Computed with a Spatial Programming Language. New Worlds of Computation 2011, May 2011, Orléans, France. pp.1-1. hal-01161289

**HAL Id: hal-01161289**

**<https://hal.science/hal-01161289>**

Submitted on 8 Jun 2015

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Two Representations of Music Computed with a Spatial Programming Language

Louis BIGO<sup>1,2</sup>, Antoine SPICHER<sup>2</sup>, Olivier MICHEL<sup>2</sup>

<sup>1</sup>IRCAM, 1 place Igor Stravinsky, 75004 Paris, France

<sup>2</sup>LACL, Université Paris-Est, 61 rue du Général de Gaulle, 94010 Créteil, France

`louis.bigo@ircam.fr`, `{antoine.spicher,olivier.michel}@u-pec.fr`

## Abstract

In this long abstract, we show how some musical objects and some algorithmic problems arising in musical theory can be rephrased in spatial terms. This leads to the development of meaningful spatial representations and of efficient spatial programs. The corresponding developments have been implemented in MGS, a rule-based spatial programming language.

*Spatial computing* has proven to be a fruitful paradigm for the (re-)design of algorithms tackling problems embedded in space or having a spatial extension. While music can be seen according to various viewpoints, we propose in this paper a few studies of paradigmatic theoretical music problems from a spatial computing perspective.

Musical theory has received much interest by mathematicians that have found a field to develop algebraic methods to solve, in a very elegant way, problems of enumeration and classification of musical structures. Indeed, the algebraic nature of many musical formalizations has been very early assessed: from the equal temperament to combinatorial properties of the integral serialism and modal techniques. However, the topological properties of those objects have been rarely considered (nevertheless, see [M<sup>+</sup>02, Tym06]).

Spatial computing distinguishes spaces in computations either as a *resource* or a *result*. In the following, we propose to illustrate each of these two points of view in the field of theoretical music.

**The MGS Programming Language.** MGS is an experimental programming language (see [GM01b, Gia03]) investigating the use of rules to compute with spatial data structures. MGS concepts rely on well established notions in algebraic topology [Mun84] and have been validated through applications in autonomic computing and in the modeling of complex dynamical systems.

In MGS, all data structures are unified under the notion of *topological collection* [GM02]. A topological collection is a *cellular complex* labeled with arbitrary values. The cellular complex acts as a container and the values as the elements of the data structure. A *cellular complex* is a space built by gluing together more elementary spaces called *cells*. A cell is the abstraction of a space with some *dimension*. In a cellular complex, cells are organized following the *incidence relationship*.

Topological collections are transformed using sets of rules called *transformations*. A rule is a pair *pattern* => *expression*. When a rule is applied on a topological collection, the sub-collections matching with the *pattern* are replaced by the topological collection computed by the evaluation of *expression*. There exists several ways to control the application of a set of rules on a collection but these details are not necessary for the comprehension of the work presented here. A formal presentation of the rewriting mechanism is given in [SMG10].

**Space for Musical Representation.** In this first application, we illustrate how a musical piece can be seen as a computation taking place on specific *resource* space. We focus here on the notion of *Tonnetz* [Coh97, Choa, Chob] and its use for the characterization of tonal music. We show that the topological collection of GBF (Group Based Fields), when carefully defined, makes it possible to describe chords progressions. A GBF [GM01a] is a topological collection that generalizes the usual notion of array, by labeling a cellular complex generated by a mathematical group.

The Neo-Riemannian representation (named after Hugo Riemann, a musicologist) has the ambition to show proximity between notes in terms of consonance instead of chromatism as in the traditional staff. We focus on the strong algebraic structure of musical intervals [Lew87] and suggest a spatial representation of a consonance relationship based on Cayley graphs. The properties of the resulting tone networks depend on the definition of consonance. A musical sequence represented in different networks exhibits more or less regularities. We are interested in formalizing these regularities and understanding if a network can characterize signature of a musical piece or style. More, the exploration of tone networks associated to these representations brings elements on scales generation and instruments conception.

**Space as Musical Representation.** A mathematical analysis of music generally relies on the definition of a *model*, that is a mathematical object, whose specific properties describe faithfully some musical characteristics. In the previous case, we followed this approach by defining topological spaces used to exhibit some musical properties. We focus here on the process used to build such a mathematical model of music. Thus, we consider here spaces as *results* of a spatial computing. In particular, we describe a self-assembly mechanism used to define a spatial representation of a tonality based on triadic chords [M<sup>+</sup>02]. Then, we propose to use this mechanism for the study of a tonality representation based on four-note chords and the analysis of a chord series to F. Chopin.

More detailed applications and other uses of spacial computing for musical analysis are described in [BSM10, BGS11].

**Acknowledgements.** The authors are very grateful to M. Andreatta, C. Agon, G. Assayag and J-L. Giavitto from the REPMUS team at IRCAM, J-M. Chouvel and M. Malt for endless fruitful discussions. This research is supported in part by the IRCAM and the University Paris Est-Créteil Val de Marne.

## References

- [BGS11] Louis Bigo, Jean-Louis Giavitto, and Antoine Spicher. Building spaces for musical objects. In *Mathematics and Computation in Music*, Communications in Computer and Information Science. Springer, 2011.
- [BSM10] Louis Bigo, Antoine Spicher, and Olivier Michel. Spatial programming for music representation and analysis. In *Spatial Computing Workshop 2010*, Budapest, September 2010.
- [Choa] Jean-Marc Chouvel. Analyser l’harmonie – aux frontières de la tonalité.
- [Chob] Jean-Marc Chouvel. Au-delà du système tonal.
- [Coh97] Richard Cohn. Neo-riemannian operations, parsimonious trichords, and their ”tonnetz” representations. *Journal of Music Theory*, 41(1):pp. 1–66, 1997.
- [Gia03] J.-L. Giavitto. Topological collections, transformations and their application to the modeling and the simulation of dynamical systems. In *Rewriting Technics and Applications (RTA’03)*, volume LNCS 2706 of *LNCS*, pages 208 – 233, Valencia, June 2003. Springer.
- [GM01a] J.-L. Giavitto and O. Michel. Declarative definition of group indexed data structures and approximation of their domains. In *Proceedings of the 3rd International ACM SIGPLAN Conference on Principles and Practice of Declarative Programming (PPDP-01)*. ACM Press, September 2001.
- [GM01b] Jean-Louis Giavitto and Olivier Michel. MGS: a rule-based programming language for complex objects and collections. In Mark van den Brand and Rakesh Verma, editors, *Electronic Notes in Theoretical Computer Science*, volume 59. Elsevier Science Publishers, 2001.
- [GM02] J.-L. Giavitto and O. Michel. Data structure as topological spaces. In *Proceedings of the 3rd International Conference on Unconventional Models of Computation UMC02*, volume 2509, pages 137–150, Himeji, Japan, October 2002. Lecture Notes in Computer Science.
- [Lew87] David Lewin. *Generalized musical Intervals and Transformations*. Yale University Press, 1987.
- [M<sup>+</sup>02] G. Mazzola et al. *The topos of music: geometric logic of concepts, theory, and performance*. Birkhäuser, 2002.
- [Mun84] James Munkres. *Elements of Algebraic Topology*. Addison-Wesley, 1984.
- [SMG10] Antoine Spicher, Olivier Michel, and Jean-Louis Giavitto. Declarative mesh subdivision using topological rewriting in mgs. In *Int. Conf. on Graph Transformations (ICGT) 2010*, volume 6372 of *LNCS*, pages 298–313, September 2010.
- [Tym06] D. Tymoczko. The geometry of musical chords. *Science*, 313(5783):72, 2006.