# Computational Music Science

**Series Editors**

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# The Rubato Composer Music Software

## Component-Based Implementation of a Functorial Concept Architecture

Springer

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# Foreword

Gérard Milmeister's thesis, which is now published in Springer's innovative series *Computational Music Science*, is a key text for accessing the present version of the RUBATO software. It is also the beautiful trace of a conceptual and technological completion of a development that was initiated in 1992, when Oliver Zahorka and I conceived, designed and implemented the RUBATO sofware for musical performance. This first implementation on NeXT computers, written in Objective C, was driven by the idea to implement Theodor W. Adorno's theory of an analytical performance, i.e., a performance that is defined upon musical analysis of the given score. The original architecture of RUBATO was therefore modular and split into modules for analysis (rhythmical, melody, and harmonic) and modules for performance. These modules, coined rubettes, were only conceived as organic parts of an overall anatomy. However, the successive developments and also research driven investigations, such as Anja Fleischer's work[1] on rhythmical analysis or Chantal Buteau's work[2] on motivic analysis showed that there is also a legitimate interest in rubettes without being necessarily parts of a given fixed anatomy. Successive work by Stefan Göller[3] on geometric concept spaces associated with RUBATO data formats, and Stefan Müller[4] on performance and gesture rubettes proved that there is a different approach to RUBATO, which by far transcends the original "hardcoded" anatomy.

[1] Fleischer, Anja. *Die analytische Interpretation: Schritte zur Erschließung eines Forschungsfeldes am Beispiel der Metrik*. Dissertation, Berlin 2003

[2] Buteau, Chantal. *A Topological Model of Motivic Structure and Analysis of Music: Theory and Operationalization*. Dissertation, Zürich 2003

[3] Göller, Stefan. *Object Oriented Rendering of Complex Abstract Data*. Dissertation, Zürich 2004

[4] Müller, Stefan. *Pianist's Hands—Synthesis of Musical Gestures*. Dissertation, Zürich 2004

The new requirements had to face different conceptual, soft-, and hardware conditions and challenges. To begin with, the NeXT computer had finished to exist, and the platform-dependent strategies, such as the original Objective C implementation had become obsolete by the now standard Java virtual platform environment. The other point of change was that the rubettes had to become a modular construct that would be of any size and would also be of open usage without much predefined larger anatomical preconditions. It turned out that the decisive requirements were defined by component-driven programming. However, this generic setup also entailed a radical redesign of the data format of denotators, which was invented in the early collaboration with Zahorka. The redesign was however not only affected by the component-driven data architecture, but by a meanwhile dramatic urge to step from naive (zero-addressed) denotators to functorial denotators, i.e., to quit the old-fashioned concept of a point and to introduce functorial points, i.e., morphisms defined on variable address modules and with values in not necessarily representable space functors.

All these delicate requirements set up an agenda that could not be realized except by a computer scientist with excellent programming and really solid mathematical competence. Gérard Milmeister was the ideal researcher to bring such a difficult enterprise to its completion. His award-winning doctoral dissertation, which is now in your hands, is the written counterpart of his remarkable programming work, available as a GPL software on `http://www.rubato.org`. The thesis is not only a clear and concise introduction to the conceptual and mathematical architecture of the RUBATO enterprise, but offers also precise and concrete tutorials for the programming of rubettes and their networks.

The success of Milmeister's work is, last, but not least, documented by contributions from Florian Thalmann and myself, which prove that the RUBATO software may now reach out to compositional tasks that were postponed since the early developments of a geometric composition software *presto* in the late 80s. Thalmann's *BigBang* rubette is the long-awaited extension of RUBATO to gestural strategies in composition, and it is the proof that Milmeister's work is not only the completion of a long march through the hard- and software meanders and conceptual revolutions, but also is setting a pointer to creative future music software perspectives.

Minnesota,
October 2008

*Prof. Dr. Guerino Mazzola*

# Preface to the Springer Edition

For this edition published by Springer, I am happy to be able to include as chapter 17 and chapter 18 two contributions by Guerino Mazzola and Florian Thalmann. The first is the description of a sophisticated rubette that provides an extensive gestural interface to manipulate musical structures. The second contribution is the first major application of RUBATO COMPOSER in music theory and computational composition. It resulted in a remarkable piece of music starting from the idea of "analyse créatrice" forwarded by Pierre Boulez. The whole process involves many of the features presented in this book, and, thus, is something of a "proof by construction" of the usefulness of these concepts. I therefore thank both for their energy and ingenuity in putting the RUBATO COMPOSER system to test and exercising its capabilities.

Zurich,
December 2008

*Gérard Milmeister*

# Preface

Trained as a computer scientist, I have always been interested in music and musicology. Therefore I took the opportunity offered by PD Dr. Guerino Mazzola to work with his MusicMedia group, then a part of the MultiMedia Laboratory at the Department of Informatics of the University of Zurich, directed by Prof. Dr. Peter Stucki.

Thus, first and foremost, thanks go to Guerino Mazzola, who introduced me to mathematical musical theory, most of which I had never heard of before. He gave me the conviction of working at the forefront of music research and taught me the use of modern mathematical methods, such as category theory. He supervised my work with all the enthusiasm and competence one could wish for.

I would also like to thank the reviewers Prof. Dr. Bernd Enders of the University of Osnabrück and Prof. Dr. Renato Pajarola of the University of Zurich, who suggested improvements to this thesis.

The thesis could not have been accomplished without the backing by Prof. Dr. Pfeifer, whom I like to thank for his willingness to support it as the responsible member of the Faculty of Mathematics and Natural Sciences.

Finally, I have to thank the staff of the Department of Informatics for helping me with the tedious administrative tasks that a doctoral student and assistant has to manage.

Zurich, *Gérard Milmeister*
November 2006

# Introduction

It is significant that the art and theory of music production and performance have always been connected to the newest developments of the natural and engineering sciences of the time. Indeed, a sophisticated theory of sound and music has been an important part of the earliest mathematics in ancient Greece. The theory of musical intervals set forth by Pythagoras is still a matter of discussion among psychologists of music and theorists alike. On the other hand, since the appearance of digital computers, and the development of computer science as a mathematical and engineering discipline in the late 1940s and early 1950s, music has been among the first applications to appear besides numerical computations on the newly invented machines.

At lot has happened since, and there have always been researchers in mathematics who have been trying to apply the newest trends in their disciplines to the explanation of the principles of music, with various degrees of success. Whatever the outcome of each of these developments, the outlook of music as a whole has been changed forever to the open-minded observer. Unfortunately, it is still the case that the intersection of the set of mathematical music researchers and the set of musicologists or music theorists is vanishingly small compared to the combined number of people active in the field.

To further the penetration of mathematical music theory into the realm of music production, it is vital to offer a computer-based tool to contemporary composers and music theorists that provides the most advanced ideas from mathematics applied to music.

*Category theory* is the field of mathematics that has crept into almost every mathematical domain and reformulated most basic tenets in a modern language. Computer science is another discipline that has benefited enormously from the exposure to category theory, as has mathematical music theory. It is certainly not exaggerated to assert that the colossal volume *The Topos of Music* by Guerino Mazzola has brought music theory to a new

level by infusing it with advanced and recent ideas from category and topos theory, whence the name.

The following work takes the fundamental ideas expounded in that book and describes the design and implementation of a software system, called RUBATO COMPOSER, that provides the tools to work creatively and analytically with those principles. The software system is both an application development framework, targeted at programmers proficient in mathematics or music theory, or both, and a graphical user interface intended for the composer or the theorist who wants to make use of components created by developers to build an application that embodies his or her musical ideas.

The first part presents the concepts and theory. There is neither place nor need for a complete exposition of the theory developed in *The Topos of Music*. Therefore only those parts that have found their way into the implementation are discussed.

The second part is a thorough account of the implementation of the RUBATO COMPOSER software system. Here the high-level organization as well as some details are covered. This chapter is also of importance to the developer who wants to extend and build on the RUBATO framework.

The third part is about the practical aspects of using RUBATO COMPOSER. A tutorial describes a typical use through a step-by-step tour illustrated with screenshots of the running program. Several uses of the framework by external projects are introduced that exemplify the application developer aspect.

The fourth and last part acts as an appendix. The greatest part is taken up by the RUBATO COMPOSER user's manual. This manual is intended as a stand-alone reference and also features many details that are not essential to understanding and therefore are not included in the treatment in the main text.

# Overview

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