Computational Music Analysis

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Editor

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Springer

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ISBN 978-3-319-25929-1 ISBN 978-3-319-25931-4 (eBook)
DOI 10.1007/978-3-319-25931-4

Library of Congress Control Number: 2015954606

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media
(www.springer.com)

Preface

The idea of putting together a book on computational music analysis emerged from a discussion that I had with Ronan Nugent (Senior Editor at Springer) at the Fourth International Conference on Mathematics and Computation in Music, held in Montreal in June 2013.[1] We talked about the fact that using mathematics and computing to advance our understanding of music (and, indeed, our understanding of how music is understood) would probably be considered a tiny niche area by most. However, those of us who devote our lives to this activity find ourselves split up into even tinier subdisciplines with names like "mathematical music theory", "computer music", "systematic musicology", "music information retrieval", "computational musicology", "digital musicology", "sound and music computing" and "music informatics". It must be almost incomprehensible to those working outside of the field that such a relatively small research area has become splintered into so many even smaller subdisciplines. What is more remarkable is how little communication and interaction takes place between these subdisciplines and, indeed, how much disagreement can arise when such interaction does occur.[2]

Ronan and I therefore agreed that the community would benefit from a book that gathered together papers by researchers from as many of these subdisciplines as possible, representing a wide range of current mathematical and computational approaches aimed at advancing our understanding of music. Such a book could showcase the technical and philosophical sophistication of these approaches, while also providing in-depth introductions to particular topics.

Work on this book started in April 2014 and it has taken seventeen months to get it into its final form. It consists of seventeen chapters, authored by thirty-two researchers from Europe and Japan. Each of the chapters was single-blind reviewed by at least two reviewers and the editor. The chapters are grouped into six parts: methodology, chords and pitch class sets, parsing large-scale structure (form and

[1] http://www.music.mcgill.ca/mcm2013

[2] See, for example, the special issue of the *Journal of Mathematics and Music* (Volume 6, Issue 2, July 2012), dedicated to a debate between leading figures in three of these subdisciplines.

voice separation), grammars and hierarchical structure, motivic and thematic analysis, and classification and distinctive patterns.

In the opening chapter, Alan Marsden explores the fundamental underpinnings of computational music analysis. He examines the nature of what exactly it is that we analyse, what the end result of an analysis should be and how one can evaluate a musical analysis. These issues are relevant to all aspects of music analysis and therefore prepare the ground for the remainder of the book.

Part II consists of three chapters focusing on chords, harmonic structure and pitch class set analysis. This part begins with a chapter by Emilios Cambouropoulos (Chap. 2), in which he challenges the usual assumption that the input to an analytical method should be a representation of a piece in terms of *notes*. Cambouropoulos argues that, from the perspective of music perception, it makes sense to start instead with a musical surface that encodes *chords* or 'vertical' pitch collections that are fused into Gestalts. Cambouropoulos proposes two novel, idiom-independent encoding schemes that can help with achieving this. The second chapter in Part II (Chap. 3), by Louis Bigo and Moreno Andreatta, also focuses on chords, but this time from a neo-Riemannian perspective in which relations between chords are represented geometrically and the chords themselves are modelled as pitch class sets represented as *simplices*. More specifically, they represent sets of chords closed under transposition and inversion (i.e., classes of T/I-invariant chords) as *simplicial complexes*. Pieces can then be represented as trajectories through such complexes and features of such trajectories can be used for analysis and classification. In the final chapter in Part II (Chap. 4), Agustín Martorell and Emilia Gómez present a complete method (implemented in software) for carrying out a multi-scale set-class analysis of a piece of music. They consider the problems of segmentation, description and representation, and introduce new data structures and visualization techniques to support their method.

Part III of the book is devoted to the analysis of large-scale structure. The two chapters in this part present methods for parsing whole pieces, on the one hand, into streams or voices and, on the other, into large-scale sections. In the first of these chapters (Chap. 5), Mathieu Giraud, Richard Groult and Florence Levé review the work that has been done on the computational analysis of musical form. They summarize the results they have obtained with systems designed for analysing fugues and movements in sonata form and they discuss the challenges associated with evaluating such systems. This is complemented by the second chapter in Part III (Chap. 6), by Tillman Weyde and Reinier de Valk, which focuses on parsing music into concurrent streams, that is, voice separation. Weyde and de Valk present and evaluate two contrasting approaches to voice separation: the note-to-note approach, where each note is assigned individually to a voice; and a chord-to-chord approach, where chords are treated as the basic units to be processed (as they are in the approach to harmonic analysis proposed by Cambouropoulos in Chap. 2).

Part IV consists of four chapters, presenting different aspects of and approaches to the analysis of hierarchical structure in music. In Chap. 7, Samer Abdallah, Nicolas Gold and Alan Marsden provide an in-depth introduction to the use of probabilistic grammars for analysing melodic structure. They review previous grammar-based approaches to music analysis as well as the foundations of their work in generative linguistics and information theory. They also present the results of experiments on learning the probabilities for simple grammars from two kinds of symbolic music corpora.

An important aspect of a reductive analysis of the hierarchical structure of a piece of music is identifying the relative structural importance of notes and the ways in which notes depend upon each other. The problem of designing an interactive tool that allows an analyst to do this effectively is addressed in Chap. 8 by David Rizo, Plácido Illescas and José Iñesta. Their proposed system learns from a user's corrections to an automatically generated analysis that classifies notes in a melody as either harmonic or one of six different types of non-harmonic elaboration (e.g., 'passing note' or 'neighbour note').

In the last two chapters of Part IV, Masatoshi Hamanaka, Keiji Hirata and Satoshi Tojo review their work on implementing parts of Lerdahl and Jackendoff's highly influential *Generative Theory of Tonal Music* (MIT Press, 1983). In Chap. 9, they present software implementations of Lerdahl and Jackendoff's theories of grouping structure and time-span reduction, that, like the system described by Rizo et al. in Chap. 8, is capable of learning from user-feedback in response to automatically generated analyses. In Chap. 10, the same authors present an algebraic formalization of Lerdahl and Jackendoff's theory of time-span reduction and develop a distance measure for comparing time-span trees, which they then evaluate against human judgements of similarity.

Part V of the book consists of three chapters presenting different approaches to the automatic discovery of repeated patterns in music. In the first of these chapters (Chap. 11), Olivier Lartillot presents an exhaustive approach to the discovery (or 'mining') of closed and cyclic patterns in sets of sequences representing melodies. Lartillot's system is capable of finding not only motives and themes in the conventional sense, but also 'heterogeneous' patterns that consist of sequences of items in several different musical dimensions (e.g., articulation, dynamics, pitch, rhythm). In the second chapter in this part (Chap. 12), Gissel Velarde, Tillman Weyde and I present a computational method for segmentation and clustering of segments, that relates closely to paradigmatic analysis. The method uses the continuous wavelet transform and self-similarity matrices. We also present and discuss the results obtained when the method was used for classifying folk songs into tune families and for identifying the parent pieces of excerpts from Bach's two-part inventions. In contrast to the essentially *sequential* approach adopted in Chaps. 11 and 12, the final chapter in this part of the book presents a *geometric* approach in which the music to be analysed is represented as a set of points in a multi-dimensional space. In this chapter (Chap. 13), I describe and analyse a number of pattern discovery and compression algorithms based on discovering maximal translatable patterns in such point-set representations. I give examples of the output of these algorithms on a Bach fugue and I also present the results of using the algorithms for folk song classification and the discovery of repeated themes and sections in polyphonic music.

The final part of the book concentrates on classification and the discovery of distinctive patterns. In the first chapter in this part (Chap. 14), Dorien Herremans, David Martens and Kenneth Sörensen develop five types of classification model that can successfully distinguish between music by Bach, Haydn and Beethoven. They consider both comprehensible models, such as decision trees and rulesets, and black-box models such as support vector machines. The second chapter in this part (Chap. 15), by Kerstin Neubarth and Darrell Conklin, introduces the task and techniques of contrast pattern mining in the context of folk music analysis. Neubarth and Conklin identify two types of contrast patterns: sequential patterns and global feature patterns. They then recast previous work in quantitative folk music analysis as contrast pattern mining and show how subsumption applies equally to global feature and sequential patterns. In the third chapter in this part (Chap. 16), Darrell Conklin and Stéphanie Weisser report on a study of both frequent and rare motifs in Ethiopian bagana songs. They show that both over- and under-represented patterns can be discovered in a corpus of such songs that correspond with high significance to motifs that are well known within bagana performance practice. Finally, in Chap. 17, Tom Collins, Andreas Arzt, Harald Frostel and Gerhard Widmer present a method that uses geometric pattern discovery in combination with the viewpoint approach, symbolic fingerprinting and techniques from sequential pattern mining to discover patterns in polyphonic music that are distinctive of a particular composer and that are used across many works.

In September 2014, I had the pleasure of organizing a two-day special session on computational music analysis at the European Music Analysis Conference (EuroMAC), at which many of the authors of chapters in this book gave presentations.[3] This proved to be a highly enjoyable event at which researchers from widely different backgrounds were able to interact constructively. My hope is that this book and events like the EuroMAC special session will help to establish computational music analysis as a recognized research area that *intersects* with many of the existing subdisciplines of computational and mathematical music research, and that possibly even assists in gluing these "sherds" back together. I would like to see computational music analysis become a sandbox, where researchers from different backgrounds can collaborate effectively with each other, united by the common goal of achieving a better understanding of music itself and how it is experienced and understood.

Aalborg, Denmark, *David Meredith*
September 2015

[3] http://www.euromac2014.eu/programme/9a

Acknowledgements

As editor, I would like to thank the authors of the chapters in this book for the conscientiousness and diligence with which they worked on their respective chapters. I would also like to thank them for the careful and constructive anonymous reviews that they provided for chapters other than their own.

I would like to thank Teppo Ahonen, Justin Christensen, David Temperley, Costas Tsougras, Andrew Choi and Anna Jordanous for their constructive and helpful reviews of chapters.

I would like to thank Ronan Nugent at Springer for his steadfast support and for the confidence he has shown in me throughout this project.

I would like to thank my wife, Susanne Meredith, for her patience and support while I have been working on this book. I would also like to thank her for her feedback on the first draft of the preface.

Much of the editorial work on this book was carried out as part of the dissemination work package of the collaborative European project, “Learning to Create” (Lrn2Cre8). The project Lrn2Cre8 acknowledges the financial support of the Future and Emerging Technologies (FET) programme within the Seventh Framework Programme for Research of the European Commission, under FET grant number 610859.

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