SpringerBriefs in Electrical
and Computer Engineering

For further volumes:
http://www.springer.com/series/10059

Ana M. Barbancho • Isabel Barbancho
Lorenzo J. Tardón • Emilio Molina

Database of Piano Chords

An Engineering View of Harmony

Springer

Ana M. Barbancho
University of Málaga
Málaga, Spain

Isabel Barbancho
University of Málaga
Málaga, Spain

Lorenzo J. Tardón
University of Málaga
Málaga, Spain

Emilio Molina
University of Málaga
Málaga, Spain

Additional material to this book can be downloaded from http://extras.springer.com

ISSN 2191-8112 ISSN 2191-8120 (electronic)
ISBN 978-1-4614-7475-3 ISBN 978-1-4614-7476-0 (eBook)
DOI 10.1007/978-1-4614-7476-0
Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2013937729

© The Author(s) 2013
This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.
The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.
While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

To our families

Preface

Transcription of music can be defined as the process of analysing an acoustic musical signal with the aim of writing down the musical parameters of the sound. Automatic transcription of music has been a subject of increasing interest during the last decades. This task can be faced dividing the targeted musical signals into two main categories: monophonic musical signals, leading to the transcription of music in which single notes sound, and polyphonic musical signals, related to the transcription of music in which several notes sound simultaneously.

One of the first main problems that a researcher in automatic music transcription has to face is that of the availability of an appropriate music database. The database must contain a sufficiently large number of samples to train and test a transcription system. Also, note that the database should provide with the correct annotation of each sample.

Musical instrument databases commonly used only contain individual notes of the instruments considered. This issue easily constitutes a serious drawback for piano-related activities since it is a polyphonic instrument in which the transcription of polyphonic sounds plays an important role.

The purpose of this book is to present a database of piano chords that can be used in research tasks in the context of polyphonic piano transcription.

When we originally conceived this project in the *Universidad de Málaga* (UMA) in 2007, the objective was simple: to design a database of piano chords that could be used in our research activities on polyphonic piano transcription. As time passed, the concept of the database grew larger and larger, as well as the interest in the international community for this sort of resources. Finally in 2011, we decided to look for a publisher for our work. In the IEEE ICASSP2011 Conference in Prague, we finally found that a highly prestigious publisher, Springer, was interested in our work.

Now, we have developed the most complete database of piano chords that exist nowadays and a book that supports it.

This book is mainly intended for researchers and graduate students in automatic music analysis and transcription systems. Sometimes, the knowledge of the researches on Western harmony is limited and the books of harmony are

strongly oriented to musicians. Trying to fill this gap, this book contains an engineering view of harmony. The descriptions included should help researchers to understand the foundations of Western harmony and to comprehend the content of the presented UMA-Piano chord database. Thus, Chap. 2 contains the foundations of harmony. This chapter is self-contained and it can be used to study Western harmony independently of the database developed. Afterwards, Chap. 3 provides a detailed description of the database. This description is completed with the help of Appendix A in which all the types of recorded chords are summarised including musical examples. Finally, Chap. 4 presents the summary and a discussion about the database developed and the possibility of future improvements.

The piano chords database can be found at http://Extras.Springer.com.

The authors are grateful to the many people who have helped both directly and indirectly to write this book and to compile the complete database presented. The database is expanding and the authors will thank collaborations that help to grow and improve the database.

This work has been funded by the Ministerio de Economía y Competitividad of the Spanish Government under Project No. TIN2010-21089-C03-02 and Project No. IPT-2011-0885-430000 and by the Ministerio de Industria, Turismo y Comercio, under Project No. TSI-090100-2011-25.

Málaga, Spain

Ana M. Barbancho
Isabel Barbancho
Lorenzo J. Tardón
Emilio Molina

Contents

1 Introduction 1
1.1 Interest of the UMA-Piano Chord Database 1
1.2 Outline 2

2 Foundations of Harmony 3
2.1 Characterization of Musical Notes 4
2.1.1 Time Domain Characterization of Musical Notes 4
2.1.2 Frequency Domain Characterization of Musical Notes 4
2.2 Physical Basis of Scales and Musical Intervals 6
2.2.1 Just Intonation Scale 9
2.2.2 Equal Tempered Scale 10
2.2.3 MIDI Pitch Number 11
2.3 Physical Basis of Occidental Chords 13

3 Description of the UMA Piano Chord Database 17
3.1 Chord Selection 17
3.2 Naming Convention of Played Notes 19
3.3 Content of the UMA-Piano Chord Database 20
3.3.1 Single Note Recordings 23
3.3.2 Polyphony 2 Recordings 24
3.3.3 Polyphony 3 Recordings 24
3.3.4 Polyphony 4 Recordings 26
3.3.5 Polyphony 5 Recordings 27
3.3.6 Polyphony 6 Recordings 28
3.3.7 Polyphony 7 Recordings 30
3.3.8 Polyphony 8 Recordings 31
3.3.9 Polyphony 9 Recordings 32
3.3.10 Polyphony 10 Recordings 33
3.4 Descriptions of the Recordings 33

4 Summary and Discussion 35
4.1 Summary 35
4.2 Discussion 36

A Types of Recorded Chords 37

References 47

Index 49

List of Figures

Fig. 2.1 Envelope of the piano notes $C1$, $C4$ and $C8$ 5
Fig. 2.2 Waveform of the piano note $C4$ 6
Fig. 2.3 Spectrum of the piano note $C4$ 6
Fig. 2.4 STFT of the piano note $C4$ 7
Fig. 2.5 Western note names in a piano keyboard (only one octave is labeled) 7
Fig. 2.6 Harmonic series for the note $C4$ and the intervals formed in this series 9
Fig. 2.7 Intervals for the just intonation scale in C-major 10
Fig. 2.8 Intervals for the equal tempered scale in C-major 11
Fig. 2.9 Equal tempered frequency, note name and MIDI note number 12
Fig. 2.10 C key: (**a**) Perfect major chord, first inversion (6) and second inversion $\binom{6}{4}$. (**b**) Perfect minor chord first inversion (6) and second inversion $\binom{b6}{4}$ 14
Fig. 2.11 Comparison of the spectrum of (**a**) the perfect major chord $C4E6G5$ and its individual notes (**b**) $C4$, (**c**) $G5$ y (**d**) $E6$ 15
Fig. 2.12 Comparison of the spectrum of (**a**) the perfect major chord $C4Eb6Gb5$ and its individual notes (**b**) $C4$, (**c**) $Gb5$ y (**d**) $Eb6$ 16

Fig. 3.1 Naming convention of sound files 21
Fig. 3.2 General structure of the UMA piano database 22
Fig. 3.3 Basic chords with polyphony 3. (**a**) Group 1. (**b**) Group 2. (**c**) Group 3. (**d**) Group 4. (**e**) Group 5. (**f**) Group 6 ... 25
Fig. 3.4 Basic chords with polyphony 4. (**a**) Group 1. (**b**) Group 2. (**c**) Group 3. (**d**) Group 4. (**e**) Group 5 27
Fig. 3.5 Basic chords with polyphony 5. (**a**) Group 1. (**b**) Group 2. (**c**) Group 3. (**d**) Group 4. (**e**) Group 5 28
Fig. 3.6 Basic chords with polyphony 6. (**a**) Group 1. (**b**) Group 2. (**c**) Group 3. (**d**) Group 4 29

Fig. 3.7 Basic chords with polyphony 7. (**a**) Group 1. (**b**) Group 2. (**c**) Group 3. (**d**) Group 4 30
Fig. 3.8 Basic chords with polyphony 8. (**a**) Group 1. (**b**) Group 2. (**c**) Group 3 31
Fig. 3.9 Basic chords with polyphony 9. (**a**) Group 1. (**b**) Group 2 32
Fig. 3.10 Basic chords with polyphony 10. (**a**) Group 1. (**b**) Group 2 33

List of Tables

Table 2.1 The most conventional names for intervals between notes (blank cells are included for non-existent intervals) 8
Table 2.2 The most consonant intervals of music in descending order of consonance 10
Table 2.3 Comparison between the musical intervals in the just intonation scale and the equal tempered scale 11
Table 2.4 MIDI difference of each interval and a note sample in descending order of consonance 13

Table 3.1 Organization of the tables in which the different recorded chords are presented 18
Table 3.2 Types of recorded chords with three different notes 18
Table 3.3 Types of recorded chords with four different notes 18
Table 3.4 Types of recorded chords with five different notes 19
Table 3.5 Types of recorded chords with six different notes 20
Table 3.6 Types of recorded chords with seven different notes 21
Table 3.7 Names of the notes for the different scale degrees in *C* key 21
Table 3.8 Directories in 'UMAPiano-DB-Poly-2' 23
Table 3.9 Directories in 'UMAPiano-DB-Poly-2-X', where 'X' can be: Second, third, fourth, fifth, sixth, seventh or octave 23
Table 3.10 Directories in 'UMAPiano-DB-Poly-3' 23
Table 3.11 Kinds of intervals considered for polyphony 2 recordings 24

Table A.1 Organization of the tables in which the different recorded chords are presented 38
Table A.2 Types of recorded chords with three different notes 38
Table A.3 Types of recorded chords with four different notes 39
Table A.4 Types of recorded chords with five different notes (I) 40
Table A.5 Types of recorded chords with five different notes (II) 41
Table A.6 Types of recorded chords with six different notes (I) 42

Table A.7 Types of recorded chords with six different notes (II) 43
Table A.8 Types of recorded chords with seven different notes (I) 44
Table A.9 Types of recorded chords with seven different notes (II) 45