This is to certify that the

dissertation entitled

Methods of Computer-Assisted Music Analysis: History, Classification, and Evaluation

presented by

Nico Stephan Schuler

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Music Theory

Mark Sullivan
Major professor

Date May 5, 2000

METHODS OF COMPUTER-ASSISTED MUSIC ANALYSIS: HISTORY, CLASSIFICATION, AND EVALUATION

By

Nico Stephan Schuler

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

School of Music

2000

ABSTRACT

METHODS OF COMPUTER-ASSISTED MUSIC ANALYSIS:

HISTORY, CLASSIFICATION, AND EVALUATION

By

Nico Stephan Schuler

Computer-assisted music analysis, which emerged almost 50 years ago, provides analytical tools that help solve problems, some of which may be unsolvable without the assistance of the computer. Unfortunately, most research in the area of computer-assisted music analysis has been carried out, again and again, without any explicit review of preceding attempts and accomplishments. Even the most recent research bears traces of two fundamental flaws that have plagued most research carried out to date: there is no classification of analytical methods within a comprehensive historical framework, and there is no critical evaluation of those methods.

This dissertation is an attempt to solve the problems related to these two flaws. Chapters 1 and 2 lays out a historical framework for computer-assisted music analysis, showing how it has been related to the development of computer technique and information theory, and how it has been applied to aesthetics. The source materials for these chapters consist of about 1,700 published and unpublished writings, including dissertations and internal research papers from many countries, that were collected and analyzed over the past several years.

Chapter 3 presents, within this historical framework, a general system of classification for computer-assisted music analysis. It gives specific characteristics of each classified category of analysis, showing the components and strategies of the methods, as well as developmental trends within the category.

All three of these chapters (1, 2, 3) that present the history and classification of computer-assisted music analysis draw not only on music theory and music history, but also consider related developments in linguistics, computer science, aesthetics, psychology, and artificial intelligence.

Chapter 4 presents a computer program *MUSANA* that has been developed by the author and the German physicist Dirk Uhrlandt for the analysis of music, as well as for the simulation and evaluation of music-analytical methods. The chapter presents the results created by using the program to evaluate the premises of a few of the analytical methods described in chapters 2 and 3, and shows how the program revealed limitations of some of the analytical methods. It also shows, in one case, how to formulate a new, more successful method. Still, overall, the chapter shows that the most important contribution of the program is the way it enables reflection on the methods used and the awareness it engenders of how those methods effect the outcome and the goal of the analysis.

Finally, the dissertation (chapter 5) suggests new kinds of evaluation and new methodologies that could be fruitfully employed in the area of computer-assisted music analysis in the future. An extensive bibliography is provided, comprising the 1,700 published and unpublished writings on computer-assisted music analysis, collected as source material for the dissertation.

For My Loving Parents, Karin & Dr. Jürgen Schüler

ACKNOWLEDGMENTS

I gratefully acknowledge with deep appreciation the criticism and guidance of my dissertation advisor, Professor Mark Sullivan. He not only taught me many aspects of music and of English language, but also of reality and life.

I am indebted to the members of my committee for their helpful comments: Professor Bruce Campbell, Professor Charles Ruggiero, Professor Bruce Taggart, Professor Michael Largey.

Special recognition is given to my former teachers (in Germany) who always, and fully, supported my research interests and ideas: Prof. Dr. Manfred Vetter (†), Prof. Dr. Gerd Rienäcker, Prof. Dr. Reiner Kluge, Dr. Lutz Winkler, and UMD Ekkehard Ochs.

I am extending a very special word of gratitude to my wife, Sunnie, for her love, moral support, and extreme patience.

May 5, 2000 Nico Schüler

PREFACE

This dissertation makes use of author-date citations, i.e. the author's last name and the year of publication are given in running text. For direct quotations, the page number is added after the year, separated by a comma. "Author" means here the name under which the work is alphabetized in the list of references and may, thus, refer to author(s), editor(s), compiler(s), etc. (See *The Chicago Manual of Style*, 14th edition, Chicago: The University of Chicago Press, 1993. p. 641.)

German research plays an important role in computer-assisted music analysis. If not specified otherwise, all German quotations in this dissertation are translated by the author.

The most frequently used terminology of measurements derived from statistics and information theory is defined in Appendix A. Appendix B gives a general overview of the history of computers and computing and provides a thorough background for readers unfamiliar with these developments. Finally, Appendix C reproduces the score of the Mozart pieces analyzed in chapter 4.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Music analysis, including computer-assisted music analysis, is often practiced and taught without any reference to, or reflection on, the premises of the methods employed. One of the few writings acknowledging methodological concerns in the area of music analysis (Wolfgang Horn 1996) points out that analysis is not possible without language and concepts, which means that there is nothing like 'pure cognition.' If 'pure cognition' of composition does not exist, then practicing analysis and teaching analytical methods must include some reflection on its purposes. Music analysis is not an independent discipline—and it depends on very specific theoretical systems—, nor is it an activity to be defined once and for all. Rather, music analysis is a *method*, which means it is a *way* to reach specific goals, it is a means to an end.

One way to handle these methodological problems of music analysis is to examine the premises of different methods; methods of music analysis need to be classified and described. While this task is partially completed for 'traditional' methods of music analysis (e.g., by Hermann Beck 1974, Diether de la Motte 1987, and Jonathan Dunsby & Arnold Whittall 1988), classifications and descriptions are still lacking for new (especially computer-assisted) methods of music analysis. (An exception are, certainly, the classifications and descritions in Ian Bent's monograph *Analysis* from 1987.) A critical evaluation is also urgently needed, but the question why a *methodological* approach to music analysis is necessary? must be answered after introducing other theoretical considerations.

For Wolfgang Horn (1996, 12), analysis is, first of all, neither a doctrine

nor a theory. It is not a formal-logical activity, but it has to do with the application of concepts to objects of experiences. This is the reason why analytical activity is so hard to understand and formalize. The activity 'analyzing' is characterized by examining musical objects that are supposed to be resolved "into simpler constituent elements" (Bent 1987, 1), and by the *manner* of resolving them.

But what is 'music analysis' supposed to resolve? Ian Bent's definition continues: "Music analysis is the resolution of a musical structure into relatively simpler constituent elements, and the investigation of the functions of those elements within that structure." (Bent 1987, 1) But the "resolution of a musical structure" into "constituent elements" is *not* the resolution of an *unknown object*, but of an *internalized experience*: Acoustical events, or their notation, function as a result of experiences and concepts. (Horn 1996, 12)[1]

Analytical resolutions are usually communicated via language. Here, language rules need to be applied. The product, the analytical text, can be verified with the help of logic. Also important, the choice of the concepts on which the analysis is based needs to conform to the goals of the analysis. The (logical) terminological frame as well as the conceptional frame are most crucial and must be explained in the analytical text.

Wolfgang Horn distinguishes between two main approaches: The first

---

[1] Horn writes there: "Die 'Auflösung einer Struktur' in 'konstitutive' Elemente bedeutet nicht das Zerlegen eines uns fremd gegenüberstehenden Objektes, sondern einer bereits 'verinnerlichten' Erfahrung. Akustische Ereignisse bzw. ihr schriftlicher Niederschlag fungieren gleichsam nur als Substrat für Erfahrungen und Begriffe."

answers the question "How is this done?"; the second answers the question "What is this?". "The results have, in both cases, only illustrative character, because the theory 'knows' concepts," and you *apply* concepts, but do so within a framework relating to a specific object. These kinds of analyses are important in historical research for getting an overview, but they are better used to catalogue compositions and relate them to types. Generally, analyses are dependent on their methodological basis: "Only if the basis of an analysis is discovered, can you ask about the relevance of the analysis, and even if the question is only about the relevance to my subjective, current interest."[2] (Ibid., 13-14)

In summation, analyzing music should not only be done "right" and "logically," but the framework of the analysis needs to be *justified*. "We should not only talk about analysis, but also, and especially, about its terms and conditions!"[3] (Ibid., 16) Reflections on the framework of music analysis, its purposes, and its goals are most important, because they determine which methods can, and should, be applied.

Music analysis can be classified with regard to the kind of music analyzed, the methods used, the general approach taken, etc. Any classification needs to be

---

[2] "Erst dann, wenn man den Rahmen einer Analyse erkannt hat, kann man nach ihrer Relevanz fragen, und sei es auch nur nach derjenigen Relevanz, die eine Analyse für mein subjektives gegenwärtiges Interesse hat."

[3] "Nicht nur über Analysen, sondern auch und gerade über ihre Voraussetzungen lohnt es sich zu reden."

based on a logical framework; that means that a level of classification (level of abstraction) has to group characteristics on the same epistemological level.[4]

Dieter de la Motte (1987), for example, distinguishes the following analytical categories:

a) Large-Scale Form → Detailed Structure
b) Measure-by-Measure Analysis
c) Analysis of a Vocal Music
d) Category Analysis
e) Comparative Analysis
f) Special Analysis
g) Tendency Analysis
h) Statistical Analysis
i) Analytical Details
j) Analysis with no Prerequisites

Here, different epistemological levels are mixed, such as classifying with regard to musical categories (e.g., form, structure), with regard to the kind of music (e.g., vocal music), with regard to certain methods (statistics), etc.

---

[4] Epistemology is the study of the methods and grounds of knowledge, especially with regard to its limits and validity. "Epistemological level" refers, here, to a level (in a system of classification) in which all 'members' have one main common characteristic, e.g. all 'members' of that level refer to *either* a method of analysis, *or* to musical categories, *or* to kinds of music, etc.

Ian Bent and his analytical categories offer a more consistent example. Bent's categories of analysis are within the same epistemological level, since he only aims at specific theories. To support that notion, he mentions the author of each theory in parentheses:

a) Fundamental Structure (Schenker)
b) Thematic Process (Réti) and Functional Analysis (Keller)
c) Formal Analysis
d) Phrase-Structure Analysis (Riemann)
e) Category and Feature Analysis (Lomax; LaRue)
f) Musical Semiotics (Ruwet and Nattiez)
g) Information Theory
h) Set Theory

However, if Bent wishes to consider all existing, specific theories, his list is far too short and eclectic. Other theories would have to be added: different theories of harmony, melody, rhythm, and so on.

For this reason, another means of classifying music analysis, one characterized by its categories of musical elements and the relation of the approach to its goals shall be suggested here:

a) Form Analysis

b) Melodic Analysis

- Thematic Analysis
- Motivic Analysis
- Phrase Structure Analysis

c) Harmonic Analysis

d) Contrapuntal Analysis

e) Rhythmic Analysis

f) Analysis of the Relations Between Text and Music

g) Analysis of Instrumentation

Each of these categories can be sub-divided. Musical categories such as range, type of motion, type of patterns, timbre, texture, sound, etc. are included.

To complete the classification by relating the approach to the goal of the analysis—the following categories could be distinguished:

a) Schenkerian Analysis

b) Transformational Grammar Analysis

c) Comparative Analysis

d) Measure-by-Measure Analysis

e) Statistical Analysis

f) Information Theoretical Analysis

g) Semiotic Analysis

h) Category and Feature Analysis

i) Cognitive and AI Analysis

j) Process Analysis

This list is certainly not complete. Some of these categories refer to specific theories; other categories are very broad and refer to established categories of music analysis. A sub-category could be created which would distinguish the basis of the analysis: whether it is notational-based or performance-based (i.e. is the object to be analyzed notated music or performed music).

Another kind classification is conceivable within an epistemological level that would refer to the "kind of presentation" and to the logical order of the analytical text. (Here, de la Motte's 'Special Analysis' would fit in, which does not seek to prove something postulated in the beginning but to discover something unknown by following a specified procedure.) However, there are so many different kinds of presentation possible that a classification in this respect does not seem productive. A more interesting question is whether there is a productive classification that refers to the *goals* of analyses, since this is the ultimate aim of any analytical work. However, a classification of analytical goals has yet to be done as does the integration of classificational levels mentioned above in *one* system of classification.

Another methodological point needs to be made, relating to the use of technology: All analytical methods can be supported by the use of computers in music analysis. Computer-assisted music analysis provides analytical tools to

help solve problems which cannot be solved with traditional methods of music analysis. For instance, it may clarify stylistic characterizations and questions of unclear authorship, it helps investigate (historical) musical developments, it is useful for developing new theoretical systems, for research on acoustics and performance, as well as for cognitive and artificial intelligence research.

Introductory reading material about the history of computer-assisted music analysis, such as the overview articles by Bo Alphonce (1980, 1989) are highly selective; dozens of dissertations and numerous American and European articles are excluded, and most of these articles fail to reflect on the subject critically. More specifically, they do not show the limits of the applications discussed. They do not show, for example, how some of the first experiments with computer-assisted music analysis are not complex enough and do not use enough musical material to support their findings.

Coming back to the twin problems of creating a history of computer-assisted approaches to music and of creating a system of classification for them leads to the main epistemological problem of this dissertation. Even though computer-assisted music analysis has been conducted for only four and a half decades, it has been conducted under various premises, using a variety of methodologies. For that reason, it is almost impossible to talk about a real "history" of computer-assisted music analysis. For now, the best approach is to place computer-assisted music analysis within a classificational system based on methods, while developing the a system of classification through a thorough study of all existing

approaches.

The dissertation covers both: Chapters 1 and 2 lays out a historical framework for computer-assisted music analysis, including its relationship with developments in aesthetics that draw on information theory and computer representations of music. Chapter 3, then, elaborates a system of classification and shows analytical trends that pertain to each category. Although chapters 1, 2, and 3 include some evaluative statements, chapter 4 evaluates, using the analysis program *MUSANA*, selected statistical and information-theoretical methods that have been widely used for computer-assisted approaches to music analysis. Chapter 4 also proposes a new, successful method. Finally, chapter 5 suggests directions for further evaluation of methods of computer-assisted music analysis as well as directions for new methodologies. An extensive bibliography is provided, comprising the 1,700 published and unpublished writings on computer-assisted music analysis, collected as source material for the dissertation.

In music analysis, most important is the reflection on the methods used and the awareness of how they affect the outcome and the goal of the analysis. Every method of music analysis has its advantages for certain goals of the analysis. But every analytical method has also its limits. It is most crucial to know both, advantages and limits; this would include knowledge of when to apply which method. For methods of computer-assisted music analysis, the integration of traditional *and* computer-aided methods seems to be most crucial.

Chapter 1

PHILOSOPHICAL AND REPRESENTATIONAL ASPECTS OF COMPUTER-ASSISTED MUSIC ANALYSIS

> "Information Theory may well prove generally useful for studying the creative process of the human mind. I don't think we have to worry that such analysis will make our art more stilted and mechanical. Rather, as we begin to understand more about the property of creativeness, our enjoyment of the arts should increase a thousandfold." (Richard C. Pinkerton 1956, 86)

1.1. The Philosophical Rationale of Computer-Assisted Music Analysis: Information Theory and Aesthetics

The results predicted by Richard C. Pinkerton have hardly been realized. But especially with regard to certain developments in the area of Artificial Intelligence during the 1990s, research has produced results that came much closer to Pinkerton's vision of the usefulness of information theory for studying creative processes. (See 2.6.)

Pinkerton was one of the first to explore the application of information theory to music, specifically to music analysis. The philosophical rationale, however, was ultimately provided by several people: George D. Birkhoff (1931, 1950), Abraham Moles (1956a, 1956b, 1958, 1962, 1966), and by Max Bense

(1954, 1966, 1969) and his disciples Helmar Frank (1964, 1968), Rul Guntzenhäuser (1962), Siegfried Maser (1971), and Frieder Nake (1974). Using information theory, all of those people sought either to explain some aspects of aesthetic reflection and artistic cognition, or both, or to analyze or synthesize 'artistic artifacts'.

Information theory itself was based on a model, partly mathematical and partly physical, relating to the transmission and reception of messages ('information'). In this context, information was related to the potential variety of messages in contexts and the probabilities of messages. For instance, if a melodic phrase in a piece of music occurs for the first time, it is an unexpected event, i.e. it has a probability of zero; hence, it has a high degree of originality and it "modifies the behavior of the receptor" (Moles 1967, 22). If a melodic phrase occurs many times, its probability increases, and the originality, the degree of 'information', decreases. In 1949, Claude E. Shannon defined a measure of information, called 'entropy', as a logarithmic function of the statistical probabilities of different messages. (See Shannon and Weaver 1949, 49 ff.) Thus, information was considered measurable to the extent that it could determine how predictability and unpredictability relate to the variety of a system.

Taking a different tact, Bense's aesthetics had its origin in the theory of signs. His attempts to create a mathematical notion of aesthetics, a quantitative, descriptive notion he called 'information aesthetics' ['Informationsästhetik'], came out of his interest in cybernetics, and was based on the analytical procedures described by the US-mathematician and physicist George David Birkhoff. In the

1920s, Birkhoff had tried to develop a formula for dealing with aesthetics, defining *aesthetic measure* (M) as a quotient of the *order* (O) of an 'aesthetic object' and its *complexity* (C): M=O/C. (See Birkhoff 1950, 288-306, and 320-333.) Moles, on the other hand, in his 'aesthetic perception theory', based his theory on the evaluation of experimental data and statements, evaluation in which the relation of innovation and redundancy was very important. (See Moles 1958.) Moles distinguished between semantic information and aesthetic information, a distinction based on the insight that Shannon's information theory was hardly applicable to the analysis of art works in terms of their artistic value ('aesthetic information'), but instead was related to what he called the 'inner structure' of these art works ('semantic information').[5]

Responding to the aesthetic theories of Bense and Moles, Helmar Frank proposed an 'exact information theory' (Frank 1964, 1968). He combined automata theory, system theory, and sign theory, with information theory and theories drawn from experimental psychology. To define his 'subject model' mathematically, using theories of automata (i.e., the subject is viewed as the addressee of the message, which is the work of art), he needed such categories as 'surprise value' ['Überraschungswert'] and 'conspicuousness value' ['Auffälligkeitswert']. Frank's integration of empirical research and experimental psychology in his theory is even more important than his theory per se. In this sense, his theory can be seen as an early case of cognitive research like that

[5] An overview of "Aesthetics of Music and Information-Theory", mainly based on Moles' theory, was also given by Jan L. Broeckx (1979, 105-125).

done in the 1980s and 1990s.

A follower of Bense, Siegfried Maser (1971), proposed the creation of a 'numerical aesthetics', derived from Baumgarten's definition of aesthetics as the science of the critical assessment of beauty. Maser interpreted Baumgarten's model of aesthetics as an objective, scientific aesthetics, based on three sciences: the 'science of the real' ['Realwissenschaft'], the 'science of the formal' ['Formalwissenschaft'], and the 'science of the intellect' ['Geisteswissenschaft']. He proposed distinctions between 'macro aesthetics'[6] ['Makroästhetik'] and 'micro aesthetics'[7] ['Mikroästhetik'] in the process of formulating a 'complete aesthetic analysis'[8] ['vollständige ästhetische Analyse'] (Maser 1971, 91). Maser's method of an 'aesthetics by measurement' ['Maßästhetik'] is based on the precise quantitative description of objects, which he sees as the 'rational basis' for an 'aesthetics of value' [Wertästhetik']. He thinks that the more rigorously the rational basis for the formulation of values is defined, the more convincing will be the speculations and conceptions derived from this basis.[9]

---

[6] The formula for calculating the 'Macro Aesthetics' is: Macro Aesthetic Measure (M_{AE}) = Order / Complexity.

[7] The formula for calculating the 'Micro Aesthetics' is: Micro Aesthetic Measure (M_{ae}) = Entropy / Redundancy.

[8] The formula for calculating the 'Complete Aesthetic Measure' is: Macro Aesthetic Measure (AE) = [(M_{AE} + M_{ae}) / 2] birk.

[9] "Je präziser aber diese rationale Basis formuliert wird, desto überzeugender wirken die darauf begründeten Spekulationen und Wertkonzeptionen." (Maser 1971, 125).

All of the attempts mentioned above, which tried to describe aesthetic artifacts with mathematical methods, specifically with methods derived from information theory, were relatively unsuccessful in formulating meaningful philosophical generalizations about works of art. The failure to distinguish different levels of aesthetic information contained in art works was one of the main reasons for the lack of success (see, for instance, Kasem-Bek 1978). Although the mathematical description of complex aesthetic processes and attempts to calculate aesthetic values produced few significant results, the application of information theory to the analysis of structural norms of art works, specifically of motives and phrases, did produce some significant results.[10] Since repetition of musical structures is responsible for creating musical form, the analysis of musical structures based on the measurement of redundancy was fruitful, particularly when it was embedded in observations of musical form.[11]

---

[10] Regarding aesthetic perception, Coons and Kraehenbuehl (1958, 128) call this the level of concept formation. It goes beyond the level of simple perception. In the same article, they also suggest defining information as a quotient of 'nonconfirming tests of predictions' and 'predictions tested' (ibid., 139). See also Kraehenbuehl and Coons 1959.

[11] This notion was already supported in the theoretical articles (i.e. with no practical analyses of music) by Leonard B. Meyer (1957) Joel E. Cohen (1962), Fritz Winckel (1964), and later by Alfred Huber (1974) and others.

1.2. On Developments of Music Encoding[12]

While aesthetics deals with how to structure productive and meaningful analysis, encoding of music deals with the means to carry that analysis out. Both areas are fundamental for discussing methods of computer-assisted music analysis.

Computers can be employed as a tool in composition, in bibliographic research, to create thematic indices, and to scan, transcribe, print, and analyze music, and so forth. Historically, the first computer applications in music spanned two areas, composition and analysis (see 2.2.), but in all the applications that subsequently developed one thing was required: a representation of the music in a digital form. Since the first use of computers in the field of music, different digital codes for representing musical relationships have been developed, and recurrent problems relating to encoding have emerged. F. P. Brooks et al. (1957), for instance, used a simple numeric representation of pitch and tone duration. On the other hand, MUSIC V[13], which developed in several different

[12] Christoph Schnell (1985) and Eleanor Selfridge-Field (1997) presented a detailed description of the problem. — For general information on the history of computing, see Appendix B.

[13] Generating sound samples was part of a research project carried out in the mid-1950s at Bell Telephone Laboratories. (The goal of this research project was the transmission of telephone conversations in a digitized form.) The Bell engineer Max Mathews explored the calculation and generation of sound, coming up with the two experimental programs MUSIC I (1957) and MUSIC II (1958), which were able to synthesize simple sounds via a limited number of triangle-wave functions. For this, Mathews used an IBM 704 computer. The first

"dialects," used several kinds of representations, many of which are still in use today. These include the file format of SCORE, which substituted spatial placement parameters for time-ordered parameters. MUSIC V's differentiation of global parameters and its event list also prefigured the Standard MIDI file format.

The several hundred codes, developed over the last four decades, correspond to a wide range of demands: from simple statistical applications to complex cognitive ones. However, most of them suffer from one or more kinds of problems: technical problems of their implementation, problems in the flow of information, problems inherent in a certain type of notation, or the problems in the limitations of the relation between the system and the user. (Schnell 1985, 289 f.) Fortunately, the means of entering the digital representation into the computer are independent of the purpose of the code and has posed few problems. Christoph Schnell (1985, 44) distinguished the following fundamental, most frequent input possibilities:

- input from a special keyboard,
- input with the help of a mechanized music editor,
- input from a conventional computer keyboard,

---

comprehensive synthesis program, MUSIC III, was completed on an IBM 7094 in 1960. Soon after, James Tenney became involved in the project, followed by Hubert Howe, Godfrey Winham, and Jim Randall. In the mid-1960s, MUSIC IV was re-written in the high-level language FORTRAN, and re-organized and extended as MUSIC V in 1969 at Bell Laboratories, featuring more global sound-control, the possibility of representing individual notes and note-patterns, and supporting the simulation of performance nuances (like ritardando, crescendo, etc.).

- input from a piano keyboard,
- input from a direct recording of analog acoustical information, and
- input from direct scanning of optic-musical information.

These alternatives relate to two basic goals: first, encoding acoustical information as completely as possible, and, second, to encoding abstract musical information. The latter usually involves converting the graphical information (symbols of acoustical events, the notation) into a digital representation. In most cases, musical information outside the score is not converted, but sometimes—depending on the application—even notated parameters, such as dynamics or phrasing, are omitted.

Another factor that has often been a problem, particularly in any complicated analysis, is related to the amount of computer memory needed for carrying out any complex analysis. If, for instance, the analysis involved several parameters of musical events (i.e., not only pitch and tone duration), a relatively large amount of memory was necessary. In the past, the amount needed was often more than common computers had available.[14] Until smaller computers with large amount of memory and higher computation capacities were available (i.e., until about the mid-1980s), most applications were developed on mainframe computers or workstations. Using these computers for musical purposes required a high degree of technical understanding, which meant that the musicologists or music theorists could not use their native methodology, but instead, had to use methods native to the computer and only *adapted* to musical purposes.

[14] See Appendix B for some examples of memory capacities of early computers.

Finally, understanding several key and related problems and solutions require a brief discussion of some of the most widely used codes for digital representation of music.

The Plaine and Easy Code was initially developed by Murray Gould (sometime before 1964), and then expanded and improved by Gould and Berry S. Brook. It was intended to enable the transfer of musical bibliographic data to electronic data-processing equipment (see Brook and Gould 1964, 142). The Plaine and Easy Code enabled the replacement of conventional, purely monolinear notation with ordinary typewriter characters. Thereby, not only tempo, key signature, meter, pitches, and durations could be encoded, but also some phrasing marks and embellishments.

Starting in 1962, Jerome Wenker developed the comprehensive music description code MUSTRAN (see Byrd 1984, and Wenker 1972c, 1974, 1978). It included all common symbols of traditional music notation, and assigned them an alphanumeric code which was translated by the computer into an internal machine-oriented notation. MUSTRAN was mainly used for the analysis of (single-voice) folk songs, and went through various developments on a number of platforms.

In the middle of the 1960s, Murray Gold also co-authored the ALMA code (Alphanumeric Language for Music Analysis) together with George W. Logemann (see Gould and Logemann 1970). ALMA evolved from the Plaine and Easie Code and was based on characters available on the IBM 029 Keypunch. It enabled the encoding of data relating to the following categories: composer, title,

instruments, movement, tempo, clef, key signature, time signature, dynamics, expressions (e.g., morendo), pitches, durations, texture markings, and instrumental techniques. ALMA influenced the development of other early musical codes and, later, was absorbed into the object-oriented program *MScore*.

The Digital Alternative Representation of Musical Scores (DARMS) begun being developed in 1963 by Stefan Bauer-Mengelberg under the name "Ford-Columbia Input Language" (see Bauer-Mengelberg 1970) and was developed further by Raymond Erickson and others. DARMS is strongly print-oriented, and it includes all information of traditional music notation written for any number of voices. DARMS "is the earliest encoding language still in use. . . . DARMS offers a paradigm that is rarely present in the other codes discussed here: namely, that all files stored in DARMS code may be converted to an unambiguous 'canonical' version." (Selfridge-Field 1997, 163) It is entirely based on relative spatial placement and not on sounding pitches. Today, DARMS exists in several different dialects (see Selfridge-Field 1997a).

In the 1960s, Michael Kassler developed IML (Intermediary Musical Language), together with the programming language MIR (Musical Information Retrieval). IML represented common music notation and accompanying text on punched cards, and was designed to represent and solve problems of music theory.

Finally, MIDI (Musical Instrument Digital Interface) was developed in the mid-1980s as the result of collaborations between several synthesizer companies. MIDI filled the need for a universal digital representation of performed music. It originally was intended to be a real-time protocol enabling communication between different digital hardware devices. Its format is described in detail in Selfridge-Field 1997a. Since MIDI was exclusively designed for the creation of performances of sound, MIDI is limited when used for music theoretical applications. To overcome certain insufficiencies (e.g., MIDI's failure to represent rests), MIDI extensions have been developed which provide both performance information and score information. (See ibid.)

Musical representations were usually developed with regard to specific tasks. Even though musical encoding is one of the bases for computer-assisted music analysis, there are close relationships between the development of digital encoding of music and the development of methods of computer-assisted music analysis (as one of the many computer applications in music). In the next chapter, the focus will be on methodological developments of computer-assisted analysis. However, the problems of encoding, and the codes used, will be discussed only when when they are important to methodological developments and when the information was available in the literature.

Chapter 2

HISTORICAL ASPECTS OF COMPUTER-ASSISTED MUSIC ANALYSIS

> "I should like to suggest that computer analysis will become one of the most important directions in musicology for the next generation. One hears frequently the comment that computers will make musicology mechanistic. Bear in mind, however, that the computer does what it is told: even its most sophisticated procedures depend on the imagination of the researcher for instructions; and the final results always require further interpretation. In these two functions -- instruction and interpretation -- the researcher controls the fundamental musicality of the investigation. If the results are mechanistic, he cannot blame the computer." (Jan LaRue 1970a, 197.)

2.1. Predecessors and 'Relatives' of Computer-Assisted Music Analysis

This chapter focuses on applications of statistical and information-theoretical measurements to music analysis and on other computational approaches to music analysis which did not include the use of electronic computers.[15] In most

---

[15] Joseph Schillinger (1948) provided detailed descriptions of mathematical relationships in music, but he was not primarily trying to provide a methodology for music analysis or for composition. For that reason, Schillinger's work will not be discussed here.

cases, those approaches were direct models for computer-assisted applications, and an understanding of the development of computer-assisted analysis is not possible without the knowledge of these early approaches that used no computer.

Otto Ortmann was an important pioneer of statistical analysis of music. His article from 1937, still virtually unnoticed, involved an analysis—certainly conducted without an electronic calculator—that was restricted to interval frequencies of song melodies by R. Schumann (48 songs), J. Brahms (38 songs), and R. Strauss (40 songs). No distinction was made between ascending and descending intervals; intervals of equal distance but different nomenclature (e.g. augmented second and minor third) were grouped together. Ortmann calculated the interval distributions of each song and an interval average for all the songs by each composer, the percentage of songs by each composer in which every specific interval was present, and the range of positions which every interval holds—with regard to its frequency—in most of the songs. No matter what the specific results[16] may be worth, and no matter how the question of what

---

[16] Some parts of each distribution, based on songs by different composers, were similar to each other. Others were different, and thus interpreted as "characterizing" for the composer's style. For Schumann, the predominance of unisons, the relative absence of wide intervals and of chromatic inflection, and the consistency with which the frequency order unison - major second - minor second is found (in 65 % of the songs) was characteristic (Ortmann 1937, 7). Characteristics of Brahm's songs were the relative absence of unisons, the preference for thirds (especially minor thirds), the frequency order major second -

validity these results hold generally for songs written by these composers, Ortmann must be given credit for initiating a new form of analysis and for being self-critical enough to point out the disadvantages of disregarding other musical (and non-musical) parameters.

In 1949, Bertrand Bronson described a procedure for using an electro-mechanical calculator—not a 'computer'—to carry out a comparative study of British-American folk-tunes. He used punched cards for encoding general information (publication, collector, singer, etc.), regional information, and musical characteristics, such as range, mode, time signature, number of phrases, phrasal scheme, final tone, initial interval between the upbeat and the first strong accent, etc. Then, the sorting machine was able to automatically pick out cards with desired characteristics. Thereby, certain musical characteristics could be matched with certain geographical origins, etc. Results of this theoretical procedure were published ten years later (Bronson 1959).

A similar, but much more sophisticated, system called *cantometrics* was developed by Alan Lomax. It is a system for rating song performances by

---

minor second - unison (in 45 % of the melodies), and—"not very pronounced"—the preference for chromatic inflection (ibid., 6 ff.). Finally, characteristics in Strauss' melodies based on interval frequency (except a slightly predominant use of sixths) were not found (or, in other words: a uniformity is typical); in different ways, the distributions were similar to the songs by both of the other composers, Schumann and Brahms (Ibid., 8 f.). This certainly shows the limitations of this approach, which Ortmann himself was aware of. — In general, Ortmann concluded a "chronological tendency towards an increase in pitch-motion" (ibid., 9).

qualitative judgements.[17] Rhythmic, melodic, instrumental, tempi, and other performance characteristics, as well as text characteristics, were initially encoded with a 37 digit rating scale, i.e. the number of slots on an IBM punch card. The system became, later, the model for further computer-assisted studies (as, for instance, described in Grauer 1965).

Even though Pinkerton (1956, 84) claimed that Allen I. McHose (1950) was one of the first to use "modern techniques" for analyzing music, McHose did not mention any use of computers in his analyses. However, his statistical analyses of the chord structure of Bach chorales are of importance for later computer applications in harmonic analysis. In his study from 1950, McHose calculated the frequency of chord types, harmonic functions, inversions, etc., as well as the frequency of non-harmonic tones. He also compared root movements and types of chords in works by Bach, Händel, and Graun. But while computer technique, at the time, was not advanced enough to handle McHose's calculations, this kind of study became the direct predecessor of the kind of computer-assisted harmonic analysis which evolved in the 1960s.

---

[17] Lomax' system is based on the hypothesis that "music somehow expresses emotion; therefore, when a distinctive and consistent musical style lives in a culture or runs through several cultures, one can posit the existence of a distinctive set of emotional needs or drives that are somehow satisfied or evoked by this music." (Lomax 1962, 425) See also Lomax 1976. However, Lomax's theory is not undisputed; see, for instance, Kongas-Maranda 1970, Henry 1976, Kolata 1978, Berrett 1979, Locke 1981, and Oehrle 1992.

H. Quastler reported in 1956[18] that Fred and Carolyn Attneave had analyzed cowboy songs and obtained the transition probabilities for every note preceding a particular note. Based on the analytical results, they tried to synthesize "a few dozen" new songs in the same style, but only two of them were "perfectly convincing" (ibid., 169).

Until the mid-1950s only simple statistical calculations were applied to music analysis, but Linton C. Freeman and Alan P. Merriam in 1956 used a more complex statistical method for the differentiation of two bodies of music: the discriminant function. The discriminant function uses multiple measurements to discriminate between two groups of music. In this case, the two groups of music were songs of Trinidad Rada and of Brazilian Ketu. Three characteristics were examined: the mean values of frequencies of (1) major seconds and (2) minor thirds in proportion to the lengths of the song, as well as (3) the total interval use. While each separate characteristic showed insufficient discrimination of the two groups of songs,[19] the use of the discriminant function reduced the probability of misclassifying a single song. However, only 3 measures each of interval use from a very small sample of only 20 songs diminished the statistical value of the

---

[18] Quastler's report is part of the discussion, following the article of Fucks 1955, pp. 168-169. For F. and C. Attneave themselves, the results were probably not satisfactory enough for publication.

[19] The mean differences for major seconds and minor thirds were each significant beyond the one percent level of confidence, but not in the total interval use. However, the overlaps between the two groups of songs in each separate characteristic were too large.

results. Nevertheless, using a complex statistical method was innovative in that it provided a method useful for a more sophisticated, computer-assisted analysis of music that took place in the following decade.

In 1956, Richard C. Pinkerton published a study on "Information Theory and Melody." In this article, he discussed entropy analysis (i.e., the analysis of the statistical degree on 'information' in music) and redundancy analysis[20] and how each related to the analysis of 39 nursery songs. Even though all calculations were done manually, his approach was already designed to make use of computer assistance (see ibid., 86). Based on the analytical results of pitch and rhythm probabilities, Pinkerton designed a network of tone relations which enabled him to define a compositional procedure to create similar tunes. (However, his 'composed' melodies were "highly monotonous" [Ibid., 84].) Pinkerton's network and transition patterns could be seen as early implementations that relate to concepts that have emerged recently in neural network research: "Thinking of our network scheme, it is fun to speculate that a composer's individual style may reflect networks of nerve pathways in his brain." (Ibid., 86)

Joseph E. Youngblood's applications of information theory to music analysis (Youngblood 1958, 1960) were probably the most extensive studies of all those that could be called the direct 'predecessors' of computer-assisted

---

[20] Pinkerton calculated specifically entropy and redundancy of single tones as well as transition probabilities. See Appendix A for a more detailed explanation of these concepts drawing on information theory.

music analysis. His ambitious calculations showed the need for computer-assistance. Youngblood's attempts to identify and define musical styles was based on the assumption that musical style can be characterized by a stochastic process, specifically a process that can be characterized using a "Markov chain"[21] (Youngblood 1960, 14-15). Youngblood selected song melodies by Schubert, Schumann, and Mendelssohn, and calculated frequencies and probabilities of each scale degree, tone entropies and redundancies, as well as first-order-transition-probabilities for each melody. Some of the results showed, for example, that Mendelssohn used chromatic tones less frequently than Schubert or Schumann, and that Mendelssohn's music was more redundant. Youngblood also compared those results to analyses of samples of Gregorian Chant. Almost all of Youngblood's results did not show statistical differences clearly enough. Due to the number of songs sampled and due to the false assumption that redundancies of melodies alone could characterize a musical style, Youngblood's results were not very significant.[22]

The analyses of musical rhythm by John G. Brawley (1959) were intended to provide a means to characterize style. Assuming music to be a discrete system of communication and assuming that music is an ergodic stochastic process that has the structure of a stationary Markov chain, Brawley calculated entropy and redundancy of selected pieces from different time periods. However,

---

[21] See " Markov Chains" in Appendix A.

[22] In comparison with Youngblood, Joel E. Cohen (1962, 152) applied the same analytical methods to the analysis of two Rock and Roll songs. However, the critique given here for Youngblood's research is especially true for Cohen's.

Brawley stated himself—with regard to an analysis of a Bach invention—"that this analysis employing information theory is not very valuable. At best, it may tell us a little about this particular invention, but hardly more than we could arrive at by a less exhaustive and less painstaking analysis." The number of samples used was too small to warrant drawing general conclusions. However, Brawley's conceptual approach became the basis for more successful rhythm research that followed years later.

Just as philosophical generalizations derived from information theory were applied in a highly limited way (see 1.1.), mathematical (statistical) approaches were applied to the analysis of simple 'aesthetic objects' in a similar limited manner:

Wilhelm Fucks' "mathematical analyses of the formal structure of music"[23] became an important precedent for the devenlopment of computer applications (although Fucks' calculations were still made without the computer)[24], as well as for the elaboration of the application of information theory to aesthetics (see, e.g., Bense 1969). Fucks' music analytical attempts were connected with his attempts to analyze language (e.g., Fucks 1956, 1964). His analyses of musical compositions were usually limited to the analysis of pitch and tone duration in selected voices. Even though his list of publications is long, most of Fuck's

---

[23] See, for instance, Fucks 1975, 1958, 1962, 1963, 1964 and 1968, as well as Fucks and Lauter 1965.

[24] Even though Lejaren Hiller (1964, 10) mentioned that Fucks used already a computer for his study in 1958, there is no indication for the use of computers in any of Fucks' writings themselves.

writings are based on the same, or similar, data. Fucks usually calculated probabilities, transition probabilities, averages, standard deviations, kurtosis and skewness of distribution curves, as well as entropies. In Fucks' analysis from 1958, for instance, his musical materials were limited to the first violin parts of some concertos, symphonies and symphonic poems, and to the soprano parts of some masses (Fucks 1958, 9 f.). While results of his earlier research showed a correlation between composer, time of composition, and frequencies of pitch and tone duration, later publications, especially Fucks' analyses of 1963, demonstrated that standard deviation and entropy of pitches (independent of each other) increases monotonously with the time of composition. Transition matrixes of pitches and transition matrixes of intervals provided information on the probabilities of pitches and intervals following each other. Based on the transition matrixes, Fucks calculated correlation ellipses. Finally, W. Fucks and J. Lauter (1965) calculated auto-correlations of pitches and intervals.

At the time, Fucks' methodological approach was already quite complex in its mathematical form, especially with regard to the comparison of different frequency distributions (pitches, tone durations, intervals, and tone pairs) and its comparison to stochastically-generated music. As such, Fuck's approach revealed the significant potential of mathematical analysis of style. However, Fucks' conclusions were very restricted to specific selections of compositions, and his generalizations of epoch characteristics were far-fetched. An important factor for the restricted analytical outcome was the missing distinction between genre characteristics and personal style in music.

Fucks' methods and analytical results were harshly criticized and shown to be erroneous by Günther Wagner (1976). Wagner noticed "that relative interval-frequencies of consecutive tones cannot be seriously considered either for the question of authenticity or for the proof of a historical development" (ibid., 67)[25]. He pointed out "that the standard deviation in compositions of the same genre and the same composer might vary as much as between compositions of different genres by composers, which belong to different epochs" (ibid.)[26]. And finally, he showed "that the relative pitch distribution is completely ruled out as a method for answering questions about authenticity or chronology" (ibid., 69)[27]

A more reliable music theoretical foundation was provided by Walter Reckziegel (1967a, 1967b, 1967c), a disciple of Fucks, in an extension of Fucks' notion of 'exact scientific' ['exaktwissenschaftlichen'] methods. In his analyses, Reckziegel included the calculation of metrical units and of musical intensity. For this purpose, Reckziegel defined formulas for calculating the entropy of the metrical unit and the 'total entropy', which is the product of the entropy value (H) of u different pitches and v different tone durations [H(u,v)] and of the different

---

[25] ". . . daß relative Intervallhäufigkeiten konsekutiver Töne weder für Echtheitsfragen noch für den Nachweis einer historischen Entwicklung ernsthaft in Frage kommen können."

[26] ". . . daß die Sigmawerte [Standardabweichung, N.S.] in Werken ein und derselben Gattung des gleichen Komponisten ähnlich schwanken können, wie zwischen Werken unterschiedlicher Gattungen von Komponisten, die unterschiedlichen Epochen angehören."

[27] ". . . daß die relative Tonhöhenverteilung als Mittel zur Lösung von Fragen der Echtheit oder Chronologie gänzlich ausscheidet."

pitches u: $u \cdot H(u,v)$.[28] Furthermore, he calculated the 'Bewegtheit' [kind of motion] out of the impulse frequency per metrical unit, 'intensity' and 'density' (arithmetic mean of metrical units). Sound structures and 'complexities' were analyzed (deliberately) without considering harmonic progressions. Reckziegel's attempts show the desire to formulate methods that can deal with a musical complexity greater than that attempted by Fucks' analyses. However, Reckziegel's analyses were still limited with regard to the number and kind of mathematical calculations.

About ten years later, Christian Kaden (1978) discovered an interesting connection between statistical (not computer-assisted) and traditional music analysis, including psychological and sociological aspects. Analyzing the second movement (Allegretto scherzando) of Beethoven's symphony No. 8 op. 93, Kaden tried to verify his intuitive analytical judgment by statistically calculating dependencies of elementary structures (*Gestalt* units), mathematically describable as tone probabilities of higher orders.[29] Kaden's approach was very successful, and his methodology could have been easily adopted for computer-assisted analyses.

Generally, researchers interested in non-computer-assisted approaches to music analysis drawing on mathematics, statistics, and information theory developed an important repertoire of analytical methods that could easily be formalized in

---

[28] The exact formulas can be found in Reckziegel 1967a, 16-17.

[29] The basis for this approach, the structural segmentation of music, was already described and explained in detail by Kaden in 1976.

computer programs. From today's point of view, most of these approaches have to be evaluated very critically, but without them computer-assisted music analysis could not have emerged.

2.2. Computer-Assisted Music Analysis in the 1950s

Even in the beginning of the 'computer age' of music analysis, communication between scholars was very slow. At one of first early conferences on computer applications in music (1965), Edmund Bowles phrased this problem as follows: "There exists no clearinghouse, no center of information, no means of intercommunication between scholars in the humanities using the tools of data processing. Currently existing journals and learned societies are reluctant to assume this additional burden, especially outside their own discipline. We need more scholarly convocations such as this one. We need to avoid needless duplication of effort." (Bowles 1970a, 38.) Since then, some journals have come into being, and more and more conferences on the topic have been organized. However, after looking at the publications in the area of computer-assisted music analysis, it seems that not much has changed since the 'beginning': scholars know little about the history of their area, previous successes and failures are hardly known. Thus, mistakes are duplicated, and prejudices florish. Ultimately, a detailed history of computer-assisted music analysis is needed. This study will fill in gaps, but applications are already too numerous and varied to describe them comprehensively here. For now, only selected approaches can be discussed which are representative in their use of methods. [30]

In the previous chapter, some applications which claimed to be the first application of computers to music analysis were mentioned. However, the first

[30] However, the bibliography is as complete as possible.

extensive, systematic use of an electronic computer for analytical purposes was described by the mathematician Frederick P. Brooks et al. in 1957. Brooks conducted an analysis-synthesis-project at the Computation Laboratory at Harvard University[31]. For this project, high-order probabilities of 37 hymn tunes were calculated. Those probabilities were then used for the synthesis of new melodies, using Markov chains of orders one through eight. Even though this experiment was limited to (melodic) samples that were not structurally complex, this procedure "permitted the production of a significant number of acceptable tunes within a reasonable time." (Ibid., 180)[32]

While Brooks' experiment is rarely mentioned in the literature, the work of Lejaren A. Hiller and Leonard Isaacson has been extensively noted, specifically their work on the *Illiac Suite* (String Quartet No. 4) is mentioned in almost every textbook on electronic music.[33] The *Illiac Suite* was composed with the ILLIAC computer in 1956 at the University of Illinois. Even though the computer was not primarily used for analysis but for the generation and selection of random values in a type of stochastic modeling (known as the "Monte Carlo Method")[34], Hiller's and Isaacson's importance for computer applications in music goes beyond

---

[31] Youngblood 1960 also mentioned an unpublished term paper from 1955 by F. P. Brooks, which lets assume that Brook's project was already realized in 1955. The computer used was the Harvard MARK IV. See Youngblood 1960, 23, footnote 42. In addition, see Neumann and Schappert 1959.

[32] For sample melodies see ibid.

[33] Brooks' paper was not widely available, whereas Hiller's and Isaacson's book (1959) became available in almost every library.

[34] See Appendix A.

composition. In their book (Hiller and Isaacson 1959), they suggest several computer applications to music analysis:

- statistical and information theoretical applications,
- analysis of musical similarity,
- pattern search,
- analysis of sounds and their physical constitution,
- optical music recognition,

and based on analytical results:

- realization of *continuo* and figured bass and to complete part writing,
- missing parts could be reproduced based on statistical style analysis,
- systematic generation of musical materials for teaching purposes.

(See ibid., 165-170.) All of these suggestions were realized later on.[35]

With the applications described in this chapter, not many attempts were made during the 1950s to use new computer technique in music analysis. Computers were, at the time, rarely available for music research. However, the few attempts of the 1950s gave directions for more sophisticated computer-assisted analysis of the 1960s.

---

[35] See Hiller 1964, discussed in chapter 2.3.

2.3. Computer-Assisted Music Analysis in the 1960s

Available hardware severely restricted the computer applications of the 1960s. However, early applications of statistics and of information theory to music analysis (see 2.1.)—especially in the US—as well as music-philosophical reflections (see 1.1.)—especially in Europe—, spurred the boom of computer-assisted methods of music analysis. To show specific tendencies of those methods, some trendsetting applications will be discussed.

In his studio for experimental music at the University of Illinois, Lejaren A. Hiller collaborated in several analytical research projects. Three of these projects are described in Hiller 1964.[36] The first project (Bean 1961; see also Hiller and Bean 1966) involved a comparison of four sonata expositions (by Mozart, Beethoven, Hindemith, and Berg), mainly based on first-order entropies of pitches and intervals as well as on the "speed of information" (i.e., of entropy), which was calculated via note density and tempo. But while Bean's project was not computer-assisted, Baker's research (Baker 1963)—the second project mentioned in Hiller 1964—was partly carried out with the assistance of ILLIAC, the first electronic computer at the University of Illinois.[37] (Thus, this study is the

---

[36] There, Hiller gives the impression that those projects were mainly his own research projects. However, he rather collaborated in the dissertation research of his students Calvert Bean (1961), Robert A. Baker (1963), and Ramon C. Fuller (1965).

[37] However, exactly how the computer was used was not described in Baker's dissertation.

first dissertation project in the area of computer-assisted music analysis.) Modulation-free passages of 16 string quartets by Mozart, Haydn, and Beethoven were analyzed with regard to transition probabilities of harmonies and of pitches as well as their relationships.[38] Finally, the third project discussed in Hiller 1964 (Fuller 1965; see also Hiller and Fuller 1967) involved the analysis of the first movement of Anton Webern's Symphony op. 21. Here, entropy and redundancy calculations (of higher orders) of pitches and intervals revealed, among others, the formal structure of the piece.

William J. Paisley chose a quite different approach to computer-assisted music analysis. Based on communication theory, Paisley (1964) made a fundamental contribution to identifying authorship (and with it, stylistic characteristics) by exploring "minor encoding habits", i.e. details in works of art (which would be, for instance, too insignificant for imitators to copy).[39] To take an example from a different field, master paintings can be distinguished from imitations by examining details like the shapes of fingernails. Similarly, Paisley showed that there are indeed significant minor encoding habits in music. He analyzed note-to-note pitch transitions in the first six notes of each of the 320 themes by Bach, Haydn, Mozart, Beethoven and Brahms. He chose the parameter 'pitch', because pitches can be easily coded for computer processing and because some research on tonal transitions had already been reported.

---

[38] However, the harmonic analysis itself was done traditionally, not computer-assisted.

[39] For a general discussion on this topic, especially with regard to text analysis, see also Paisley 1969.

In his first analysis[40], Paisley calculated interval frequencies of up to six semitones within the first 6 notes of two 160-theme-samples. Furthermore, he calculated the Chi Square Test for Goodness of Fit of those interval distributions for the two samples. While these results could not significantly distinguish Haydn, Mozart, and Beethoven, Paisley claimed a successful distinction between these composers with his second analysis, in which he calculated frequencies and chi squares of two-note transitions between the classes tonic, third, fifth, all other diatonic tones and all chromatic tones. In both analyses, the results of the chi square test were then compared with results from "unknown samples" (Mozart, Beethoven, Händel, and Mendelssohn). The results from analyzing themes by Mozart and Beethoven could (in the second analysis) be successfully matched with the "known" Mozart- and Beethoven-samples, while Händel and Mendelssohn were significantly different. But even though only a modest amount of data was involved in this investigation, and even though a reduction of the number of possible intervals to seven (based on inversions as well as on neglecting the direction) seems to be questionable, Paisley's study was well documented and its results were, considering the time of the study, very impressive. Several other authors referred later to Paisley's approach.

In 1969, Stefan M. Kostka wrote a set of FORTRAN-programs[41] for analyzing string quartets by Paul Hindemith[42], following William J. Paisley's

---

[40] Paisley performed the analyses on the Stanford University 7090 computer.

[41] These programs were implemented on a CDC 3600 computer.

[42] The music was coded in ANON, an alphanumeric coding system developed in the course of a seminar at the University of Wisconsin, conducted by Roland

definition of "minor encoding habits". His task was "to test the hypothesis that Hindemith's style shows a consistency in his use of certain 'hidden communicators' of which Hindemith himself may or may not have been aware. On the other hand, since Hindemith's style did not remain unchanged throughout his life, it was considered worthwhile to see if his employment of some of these communicators showed a noticeable and consistent change from the early quartets to those written in the 1940s." (Kostka 1969, 173) Kostka analyzed roots and classes of chords[43], treating each vertical event equally (regardless of their duration or regardless of whether they contained non-harmonic tones etc.). In his explanations, Kostka referred to Gabura (1965), who found—analyzing music by Brahms and Bartók—only small differences in the result of weighting chords by frequency as opposed to weighting chords by duration. Kostka tried to verify this for Hindemith's music on the example of the first movement of his Fifth String Quartet[44] by letting the computer calculate frequencies and percentages of chords. Other algorithms counted frequencies of all chords (both by treating inversions as independent chords and by dealing with "normal forms") and their harmonic contexts. Finally, in horizontal analyses, various kinds of melodic

---

Jackson. Since the code originally remained unnamed and untested, Kostka named it for his study. (See Kostka 1969, 112 ff.)

[43] Here, the definition of "roots" and "chords" goes back to Hindemith's theoretical system itself, described in Hindemith 1945, 94 ff. Another system of chord classification, which Kostka applied, was based on the distinction between Intervallic, Tertian, Quartal and Whole-Tone chords.

[44] The number of pieces for such a verification remained certainly questionable.

intervals were calculated[45], and the program searched for melodic patterns which had been defined by the analyst, including permutations. Even though Kostka found stringent regularities in the interval frequencies and frequencies of chord classes in all quartets, one can hardly interpret these distributions as "Hindemith's melodic style" (Kostka 1969, 263); analyses of other genres used by Hindemith or other quartets by other composers would be necessary for a verification. The inconsistencies Kostka found in other analyses (e.g. root movements, tonality, etc.) led to the conclusion that either those characteristics are not important for Hindemith's style or the analytical method would need to be changed.

Kostka's study (1969) also showed a limitation of his computer-aided approach to music analysis: the enormous volume of data (the huge number of punched cards) made it impossible to extract, examine and compare the data "for every theoretical question that came to mind" (ibid., 250). But Kostka's dissertation is very important in so far as it is based on the study of former approaches as well as on ('traditional') music-theoretical and musicological writings pertaining to the style in the music by Paul Hindemith. Some 'traditional' explorations of Hindemith's style could be verified by Kostka's computer-aided

[45] These included: A) every single interval; B) minor with major intervals combined; C) minor with major and their inversions combined (e.g. descending second and ascending seventh); D) all inversions combined: all seconds with all sevenths etc.; E) intervals with their mirror inversions combined (minor seconds up and down, major seconds up and down, etc.); F) all major and minor seconds, all major and minor thirds, etc., combined.

study.

The possibility of quickly processing a large amount of data with new computer techniques was recognized in the 1960's, especially by US-scholars in musicology and music theory. In 1966, Gerald Lefkoff (1967a) and Allen Forte (1967a) addressed this topic at the "West Virginia University Conference on Computer Applications in Music". Forte gave 'good' reasons for applying the computer to music analysis: "The computer can be programmed to deal with complex structures—such as musical composition—very rapidly. . . . A second reason for using the computer derives from the requirements of completeness and precision that form the basis of every computer program. . . . The design of an algorithm, the formulation of a decision-structure to solve a problem, the careful checking out of a malfunctioning program—all these activities provide clarifications and insights which would be difficult, perhaps impossible, to obtain otherwise." (Ibid., 33-34.) Without going into details, Forte also described a computer project[46] for the (set theoretical) determination of similarities and differences of sets, for the interpretation of those with respect to characteristics of the environments in which they occur, and for the design of a structural model in terms of set-complex theory (ibid., 39).[47] Gerald Lefkoff (1967b), on the other hand, described a system "for the study of computer-residing, score-derived

---

[46] His set of computer programs was written in MAD.

[47] A similar program, written in the computer language SNOBOL 3, was described in Forte 1966.

musical models" (ibid., 45). Written in FORTRAN, Lefkoff's 'model' saved musical information in time-indexed arrays: pitch, rhythmic values, vocal text, figured bass symbols, dynamics, articulations, and editorial comments. Lefkoff then extracted, along with data relating to other relationships, "a complete list of melodic fragments from a group of compositions, with frequency distribution data for the fragments within each composition and . . . [then] compare[d] the relative frequency of occurrence of each fragment in selected groups of compositions." (Ibid., 55.) The value of Lefkoff's model can be seen in its ability to generalize such analytical procedures and thereby discover stylistic trends. However, Lefkoff did not describe any concrete analyses; and thus, it is questionable if his theoretical model was indeed functioning and reaching the envisioned goals.

Milton Babbitt (1955, 1960, 1961), with his analytical approaches to dodecaphonic and set structures, was of outstanding importance for music theoretical developments in the US. His research provided the basis for the manifold (US-) discussions on the use of logic-mathematical procedures in music analysis (and likewise in composition). Since the mathematical part in set theoretical analyses is very suitable for implementations in computer programs, many computer applications in music theory and musicology after the mid 1960s (Babbitt 1965) are related to set theory.

Donald M. Pederson (1968), for instance, described a computer-assisted, analytical project that used set theoretical and statistical approaches. After the transformation of the musical data (contained in the scores) into a suitable code for music analysis[48], a program computed subset and superset relations of a given set within the score. All set types found were also examined with regard to interval vector and number of occurrences. Finally, another program computed frequencies of pitch classes and generated graphic displays that showed pitch patterns within specific voices and showed the interaction between them; it also found instances of fixed registration, found other pitch patterns, and displayed the registral use of each pitch-class. Pederson analyzed Anton Webern's string quartet op. 28 in two ways: at first, 'traditionally' "to provide a description of the structure and the use of the twelve-tone set and to establish the formal sectioning of the composition" (ibid., 73), and then, after this contextual analysis, non-traditionally, using a computer-aided analysis of the harmonic content applying the methods described above. Pederson concluded, that "even though the two approaches examine different aspects of the music, the relationship found between sections in the contextual analysis are born out by the result of the computer processing" (ibid., 75). Even though the weaknesses of Pederson's approach were the—more or less unexplained—segmentation of the score by the program (to find subsets or supersets of the one set which was identified by himself) and the use of only very basic statistical measurements, Pederson did not only combine traditional and computer-aided analysis in general, but also set

---

[48] Pederson used the "Ford-Columbia Digital Alternate Representation of Musical Scores" (DARMS), which was developed by Stefan Bauer-Mengelberg. Since this code was not specifically developed for music analytical investigations, Pederson modified it slightly. (See Pederson 1968, especially pp. 5-16.)

theoretical and statistical approaches.

In 1970, Allen Forte (Forte 1970a, 1970b) described two computer programs: one calculated set complex relations (with regard to Forte 1964 and 1966), and the second program calculated set class memberships for arbitrary sets of pitch classes.

A pilot study that began as an attempt to automate the collection of bibliographic data from five percent of the 17th century chanson repertory (about 300 pieces) by Lawrence F. Bernstein and Joseph P. Olive (1969) ended up as a computer-assisted project in stylistic analysis.[49] Eleven types of stylistic data were calculated, each falling into one of the three categories: routine analysis, statistical analysis, and numeric representation. While routine analysis included standard harmonic analysis (determination of the roots of all triads)[50], measurement of the rate of harmonic rhythm, and determination of the range of the vocal parts, the statistical calculations—also designed to aid in harmonic analysis—were directed at the number of relatively strong or weak root

---

[49] For the music representation of this project, the Chicago Linear Music Language was developed, which especially takes notational necessities of the 16th century chanson into account. The program was written in FAP for an IBM 7094 computer.

[50] "In the performance of harmonic analysis, the chords had to be examined each time a note changed in any of the voices. A chord was rejected for either of the following reasons: (1) if it contained less than three notes; or (2) if it included intervals other than thirds and fifths. If neither of these conditions prevailed, the root of the chord was determined by examining the intervals, concentrating on the interval of the fifth, and designating its lower member the root." (Ibid, 159)

movements, the degree to which inversions were used, the ratio of complete and incomplete chords, and the frequency of recurrent harmonic adjacencies (Bernstein and Olive 1969, 158). Numeric and graphic representation involved ascertaining textural complexity by analyzing the interaction of several (weighted) parameters of style (number of voices, the amount of coordinated rhythmic activity among the voices, the number of separate rhythmic attacks across the polyphony, duration of the notes; ibid., 159). The authors also expressed the need for improving the computer program for further research: The program should determine more than just the roots of complete triads and it should also distinguish between structural and ornamental harmonic motion.

Astonishing for such a project in the 1960s was the (positive) reservation towards the possibilities of using computers for analyzing music: The authors were never "deluded into believing that the computer was in any way capable of analyzing a piece of music. Rather, we used the information made available by the computer as a means of substantiating or explaining the insights into a given composition that we gained by means of a direct confrontation with the music." (Ibid, 160)[51] Thus, the analyses were indeed 'only' computer-*assisted*! The information, which was electronically derived, was only 'helpful' for setting up stylistic profiles of the composers. Even though all analytical operations could have been done without the assistance of a computer, the compilation of the

---

[51] It continues: "In this way, the data supplied by the computer proved to be very useful in explaining why a particular portion of a chanson generates a sense of tension, while another section of the same piece creates a feeling of rest." (Ibid.)

statistical data would have taken too much time to be considered feasible. (See ibid.)

Michael Kassler (1966) developed a special-purpose programming language named MIR—an acronym for "musical information retrieval". Since MIR is both a programming language and a language for musical information retrieval, music theoretical functions are directly expressible within the program; at the same time, the program functions as an evaluation tool. MIR was usually used in connection with the IML (Intermediate Music Language) music code. As such a connection between music code and information retrieval language, the acronym IML-MIR was used.[52]

Arthur Mendel (1969) applied, together with Lewis Lockwood[53], the IML-MIR system to the analysis of the style of Josquin des Prez. This included primarily calculations of frequencies of all simultaneities.[54] Using the ratio between the percentages of all the four-part simultaneities that constitute complete triads and the percentages of complete triads, Mendel tried to show that one mass subsection was not composed by Josquin des Prez, as scholars originally assumed. However, the main problem with Mendel's project was the

[52] For a relatively detailed introduction see Robison 1967.

[53] Lockwood already presented a progress report on this project at a »Musicology and the Computer I« conference in 1965 (see Brook 1970a), which was published five years later (Lockwood 1970).

[54] Future plans included calculations of interval frequencies and of correlations between the primary accent of a Latin word and the duration of the note set to the syllable that is immediately following. (See Mendel 1969, 51.)

machine-dependent implementation: Because the author had to switch computers, the project could not be continued as planned.

Maurita P. Brender and Ronald F. Brender (1967) developed a program for the transcription and analysis of the Bamberg Codex, notated in Franconian notation. The digital representation of the music included pitch and tone duration. The output of the transcription program, punched cards, was used as input for the analytical programs.[55] The analyses focussed on occurrences of part or voice crossing[56], on melodic intervals in each part, on the "average rate of movement"[57], and on vertical intervals occurring in the three positions: strong, weak, and off beats. The output of the program also included a graphic description of the chord usage in every piece. With regard to existing theories of musical practice of the Middle Ages (and specifically, during the time of the Bamberg Codex), Brender and Brender tried to verify traditional assertions, concerning the usage of consonances and dissonances.[58] In addition to the

---

[55] But here, only five motets with Portare tenors from the Bamberg Codex were analyzed.

[56] Thus, parts of the analyses were aimed at the determination "to what extent the motets, tenor, and triplum could be associated with a fixed position in the chord structure" (Ibid., 206).

[57] "Each melodic interval is divided by the duration of the first note of each pair and the average taken over the whole melodic line." (Ibid., 206) A surprising result was that decreasing intervals were used more commonly than increasing intervals, i.e. "that descending lines tend to change or move faster and over larger intervals than ascending lines. The motetus was normally the most negative, followed by the triplum, then the tenor." (Ibid.)

[58] Even though, the assertions could be verified, "the most general fact . . . is that

analytical attempts, a formal (context free and only right branching) grammar of Franconian notation was formulated. Successful translations (transcriptions) verified the grammar.

Benjamin Suchoff selected transcriptions of Bartok's Serbo-Croatian Folk Songs (a small collection of 75 women's songs) as a pilot project for lexicographical orderings by computer. After dividing and numbering the melodies in accordance with Bartók's determination of the content structure in every melody section, and after coding[59], the computer extracted string interval sequences[60] coded as sequences of positive and negative integers, and sorted and compared the derived sequences.[61] This made further statistical analyses possible. However, in several short articles (Suchoff 1967a, 1968a, 1968b, 1969, 1970a), the analytical part was mentioned only briefly and only the indexing approach was described in detail. The purpose of using the computer for the analysis remained unclear, at least with regard to the identification of melodic

---

the number of exceptions is considerable. In particular, the assertion that a consonance should begin every perfection is, at best, true only in a simple majority of cases." (Ibid., 207)

[59] The calculations were executed by an IBM 1130 computer (Suchoff 1967a), later by an IBM 360 computer (Suchoff 1968). Most programs of this project were written in FORTRAN, some in PL/1, and the music was encoded in the Ford-Columbia code. The indexing system was devised by Harry B. Lincoln (see Lincoln 1967a, 1967b, 1968a, 1968b, 1969a, 1969b).

[60] Repeated notes, interval quality, and rhythmic character were omitted from consideration.

[61] Thus, a melodic section of a Serbo-Croatian folk song could be presented, for instance, as "-2 +2 -2 +2 -2 -2".

variants, since they were probably realized 'traditionally'. Only in Suchoff's 1968a article, the "machine analysis of a string content for frequency occurrences" (Ibid., 6) get mentioned, but without further details. Later, Suchoff (1969) suggested the use of 'skeleton models' in the search for variants and orders. In the explanation of a melodic skeleton, Suchoff referred to Bartók; but it remains unclear in Suchoff's writings if the skeleton models were actually derived with the computer or by hand. In Suchoff 1970a, some analytical results were included, e.g., prevalent types of identical interval sequences, interval frequencies, and frequencies of phrases with a certain interval structure. Suchoff's research certainly provided an important impulse for folksong research on the American continent.

Richard E. Joiner (1969) conducted comparative analyses of eleven Gregorian chants from the early period (approximately 600-1000 A.D.) and twelve from the late period (approximately 1000-1300 A.D.). His analyses were based on frequency counts and relative frequencies of the notes, intervals, and phrases, and on the average length of phrases per chant. The computer program also examined each chant for repeated patterns with the length of two to eight notes. Even though the results—in general formulated by the author himself—'sounded' characteristic of the music,[62] the standard deviations of all results were too large for a computational model of authentication based on the

[62] "On the basis of this limited study, Early chant as opposed to Late chant can be said to be shorter, have more phrases, shorter phrases, be more limited in range (of notes), use smaller intervals, and have less shorter repeated patterns but more longer patterns." (Joiner 1969, 213)

statistical calculations mentioned above. Furthermore, no validity check was described in Joiner's paper.

In Europe, Roland Mix (1967) extended Wilhelm Fuck's methods of entropy analysis. Having chosen the first movement of Haydn's string quartet, op. 76 No. 3, and the first movement of Schoenberg's third string quartet, op. 30, Mix analyzed entropy dependencies of higher orders of pitches, harmonies, dynamics and rhythm. Among others, Mix discovered that the values of entropies of chords and pitches are much higher in Schoenberg's composition than in Haydn's. However, the relative 'contribution' of the rhythm to the total entropy is larger in Haydn's piece than in Schoenberg's. The dependencies among the parts are larger in Haydn's string quartet than in Schoenberg's. In a different experiment, Mix calculated entropies of pitches (up to order six) of the first violins of three Haydn quartets and compared them. But even though Mix's approaches represent great enhancements of information-theoretical analyses in their complex application to several musical parameters, his results were limited by the computer hardware. Methodically, Mix's approaches showed the limits of using only one measurement for comparative analyses. But while Fucks and Reckziegel (see 2.1.) focussed on only one voice of multi-voice compositions, Mix had already attempted a 'vertical' analysis.

The East-German Reiner Kluge (1974)[63] analyzed similarities among

[63] Even though his dissertation was published in 1974, the (dissertation) research was conducted between 1965 and 1968, and defended in 1968.

Altmark[64] folk songs. More than 130 syntactic characteristics were discovered and then used to determine similarities of pairs of melodies (out of random samples with each about 40 melodies[65]). Kluge's research was outstanding, because he developed a similarity measurement, based on the formula r = -cos A/N, "whereby A is the number of the coincidences of two elements j, k within N characteristics, relating to the totality of elements"[66] (Kluge 1974, 31). Using factor analysis, Kluge identified pseudo-individuals, out of which 12 different types and mixed types were derived. The results of Kluge's analyses were limited in several ways:

- the hardware available for his research was too limited in speed and memory,
- the number of musical characteristics was not large enough,
- the definition of his measurement of similarity was insufficient,
- the criteria to describe melodic types were insufficient, and
- the number of random samples was too small.

However, Kluge's work became very valuable for further research in this area, because he found several characteristics and groups of characteristics as suitable for comparative analyses of folk songs.[67] Furthermore, Kluge's study

---

[64] Altmark is an area in Southeastern Germany.

[65] The restrictions to limited samples were necessary because of on the low efficiency of the computer used (ZRA1).

[66] ". . . wobei A die Anzahl der Koinzidenzen zweier Individuen j, k in N betrachteten Merkmalen in bezug auf die betrachtete Individuengesamtheit ist."

[67] Those valuable musical characteristics include, for instance, 'inner melody shape', 'melodic incipits', 'pitch repertory contains the leading tone', 'the lowest pitch occurs after the highest', 'number of changes of melodic direction in the first

showed that a successful comparative analysis is only possible if many musical characteristics are analyzed in relation to each other.

Besides numerous articles, partly reviewed above, sources of computer-assisted music analysis of the 1960s include also three major publications on the use of computers in music research—Heckmann 1967a, Lincoln 1970a, and Brook 1970a—, each containing several analytical articles.

Harald Heckmann's book on "Elektronische Datenverarbeitung in der Musikwissenschaft" contained five articles on (computer-assisted) music analysis. George W. Logemann (1967), for instance, described a system for finding the positions in which the second voices of Bach canons from the *Musical Offering* begin; he tried all possible entry points and matched arising interval structures. Eric Regener (1967) introduced a transcription system as the basis for analytical research[68]; however, this system was not fully in operation at the time. Tobias D. Robison's (1967) article introduced IML-MIR, but did not include any practical application of MIR. Walter Reckziegel (1967) wrote on the use of measurements for inner tempo and individual tempo[69], and Nanna Schoidt and Bjarner Svejgaard (1967) reported an analysis of Byzantine Sticherarion

---

melodic line', 'unusual melodic intervals', 'unusual transition of tone durations', and 'time signature'. See Kluge 1974, 155-157.

[68] His system was called SAM, "System for Analysis of Music", and was specifically written for the IBM 7090 computer. The transcription code used was LMT (Linear Music Transcription).

melodies. The latter project is of special importance and will be discussed here in more detail. It is of special importance, because it was, together with the research by Brender and Brender (1967; see above), one of the first projects of computer-assisted music analysis aimed at Medieval music. The task was to find musical formulas in Gregorian chant, whereby neumes were encoded with a special alphanumerical code. The computer program found all commonly used formulas, whereby the authors verified the results via conventional analytical methods. However, one of the most important results of this study relates to the proportion of expenditure to benefit. In most computer applications to music analysis—to this day—the coding and input process takes much too long, i.e. the proportion of expenditure to benefit is unsatisfactory. On the contrary, the analysis of Byzantine neumes seems to be much faster with the help of a computer: "After half an hour you have learned the code so well that you can type the code symbols a little faster than you can write the neumes out by hand. If you want to study the hymns 'by hand' they have to be written out in different ways in any case. Sometimes you may have to write them out in a new way for each new detail you want to study. Working with the computer you only need to write the hymns out once. Afterwards you put the punched paper tape in the machine and you can ask whatever question concerning the encoded material that might enter your mind. . . ." (Ibid., 194.)

Harry B. Lincoln's edition (1970a) of many papers on computer-assisted

---

[69] Thus, Reckziegel's research included further developments of his measurements introduced already in chapter 2.1.

music analysis[70] include several statistical and combinatorial approaches to the analysis of atonal music. Mary E. Fiore (1970), Ramon Fuller (1970), and Roland Jackson (1970) made use of frequency counts of pitches, intervals, types of dissonances, and chord types (with a certain interval structure). Gerald Lefkoff (1970) analyzed twelve tone rows and computed the 48 permutations as well as similar segments within these permutations. A computer program by Ian Morton and John Lofstedt (1970) calculated frequencies of chordal roots (in tonal music) and their relation to certain beats of a measure. Joseph Youngblood (1970) tried to determine whether a composer's style is characterized by the distribution of root progressions; mathematical measurements applied were frequency, probability, redundancy, and chi-square probability. However, the most important paper in Lincoln's volume with regard to computer-assisted music analysis was probably the paper on analyzing Javanese music by Fredric Lieberman (1970)[71]. This research is a classic example of dissatisfaction with results that are only partially acceptable. While the synthesis of Javanese-style melodies on the basis of analytical results retained by a 'nearest-neighbor Markov process' was not completely satisfactory, a complex system of interacting variables was developed, which could characterize Javanese music much better than just Markov chains by themselves. This complex system of variables included, among others, frequencies of pitches, transition frequencies of higher orders, and

[70] They all used either FORTRAN or SNOBOL as programming languages.

[71] See also Hood 1967.

various (melodic) cadence forms.[72]

Barry S. Brook's book (1970a) is of importance in so far as it is a collection of papers presented at three Greater New York Chapter meetings[73] of the American Musicological Society, two of which were on the topic "Musicology and the Computer". There, Allen Forte, Lewis Lockwood, Barry S. Brook, Murray J. Gould, and many others presented research on new developments in computer-assisted music analysis.[74] These two conferences as well as the "West Virginia University Conference on Computer Applications in Music" in 1966 (Lefkoff 1967a) were the only conferences in the 1960s specifically on the topic of computer applications in music.

A passage in Jan LaRue's article in the volume "Musicology 1960-2000" (Brook 1970a) represents a common way of thinking during the 1960s in the area of computer-assisted music analysis: "May I recommend the computer to you as an instrument without human prejudices. It has its own prejudices, numerical and procedural. But these often act as stimulants and correctives, as healthy balances and supplements to human attitudes. With this new aid, the coming generation of musicologists should develop a style analysis that is comprehensive rather than selective, broad rather than personal, and rich in

---

[72] Other articles in this volume (Lincoln 1970) referring to computer-assisted music analysis (in one way or the other) are by Frederick Crane and Judith Fiehler (1970), James Gaburo (1970), Barton Hudson (1970), W. Earle Hultberg (1970), Theodore Karp (1970), and Michael Kassler (1970b).

[73] Two meetings took place in 1965, and the third one in 1966.

[74] This research has been discussed already earlier in this chapter.

musical insight." (LaRue 1970a, 197.) LaRue was certainly right in his implication that, at least up to the end of the 1960s, computer-assisted analysis of style was anything but comprehensive and rich in musical insight. Moreover, the goal of a comprehensive and inter-personal, computer-assisted analysis could not even be reached in the following decade.

2.4. Computer-Assisted Music Analysis in the 1970s

From its beginning, computer-assisted music analysis was frequently used in folk song research. The statistical methods used to analyze art music did not differ from those which were most commonly applied to the analysis of folk songs. However, folk music is smaller in scope and less complex, often involving only a single voice. These are the main reasons computer-assisted analysis continued to be centered on folk songs up to the end of the 1970s, even though computers became more and more powerful, easily capable of handling the greater complexity of multi-part art music.

Many approaches of computer-assisted analysis, applied to folk songs, followed Bartók's methods of analysis and classification. Bartók's cataloging of East-European melodies not only was based on melody and text incipits, but also on different inner-musical characteristics. Bartók's methods of classification were then further developed by Alica Elschekova (1966, 1975) and Ludwig Bielawski (1973). Hereby, 'classification' means "the division of a great variety [of songs] into sub-groups on the basis of similarity with regard to certain characteristics and the arrangement of the sub-groups"[75] (Jesser 1991, 39).[76] The main focus of

---

[75] ". . . das Einteilen einer Vielfalt in Unterabteilungen aufgrund von Ähnlichkeit in bestimmten Eigenschaften und das Ordnen der so gewonnenen Gruppen".

[76] The problem of similarity of musical structures cannot be discussed here, because it goes far beyond the question of using the computer as an analytical tool. Instead, it must be referred to such extensive and specialized publications like Kluge 1974, Steinbeck 1982, and Jesser 1991. See also the literature cited in

computer-assisted analysis of folk music was the search for rules that put melodies into a specific category and the search for procedures that determined melodic variants. This, in turn, led to the development of analytical methods that investigated single or combined characteristics of music.

Dalia Cohen and Ruth Katz (1973, 1977), for instance, analyzed Arabic and Israeli folk songs, attempting to construct a stylistic comparison. Calculations included pitch frequencies and their relation to specific modes (major, Dorian, Mixolydian, and hedjaz), transition frequencies, frequencies of certain tone groupings, and pitch distributions in certain contexts of the songs (opening notes, final notes, phrase endings). Furthermore, the characteristics related to style included tone durations and rhythmic groupings. Finally, the occurrences of certain musical characteristics were matched with each other to find specific correlations. Findings of this research were discriminations of songs in different modes, e.g. with regard to the existence of non-immediate repetition, the location of the *finalis*, the appearance of upbeats, the existence of exceptional meters, the appearance of specific metric patterns, the maximum number of time values, the maximum proportion between the longest and the shortest note, etc. Cohen's and Katz' approach was successful, or at least has not been falsified up to this point, because of the combination of many musical characteristics and the calculation of correlations between them.

---

these monographs. In Jesser 1991, see also detailed comments and references regarding classification of melodies in general and regarding rules to bring the melodies in a specific order.

Deborah and Philip Scherrer (1971) developed a measurement of melodic variation by correlating melodic contour with rhythmic movement. The degree of 'alikeness' between two graphs of melodic motion was calculated, whereby a 'lag' could shift the graphs horizontally to avoid calculation errors in case of differences in tone durations between the two melodies. Thus, the computer program[77] was able to calculate correlation coefficients of the contour of two melodies, even if the rhythmic structures of the two melodies were very divergent.

With regard to the computer-assisted analysis of *art music*, one important project of the 1970s was Dorothy Susan Gross' dissertation research and her subsequent investigations. Her dissertation (Gross 1975a) was more or less 'only' a *description* of a new "set of computer programs to aid in music analysis"[78], which had the goal "to duplicate the more routine aspects of analysis"

---

[77] The computer program was written in FORTRAN IV. The computer used was the CDC 6600 computer at the Space Science Laboratory of the University of California.

[78] The CAL SNOBOL programs were written for a CDC 6600 computer. The music was encoded with MUSTRAN; besides tone duration and pitch, this alphanumerical code also included all the dynamic and articulation markings as well as descriptive words. The software included programs for translating the input data (i.e., music, encoded in MUSTRAN) into an internal numerical code (on which the calculations were based) and for checking the data for errors. The 'dialog' between user and computer was realized mostly via punched cards. A later version was developed in SPITBOL for an IBM 370/168 computer; see Gross 1975b and 1981 (which are still only *descriptions* of the programs without presenting fundamental analytical, and musicologically useful, results, based on

(Ibid., 165). Since Gross' research was not primarily directed at analyzing a great number of compositions, the value of her research should be seen in her methodological ideas and in the potentials as well as the structure of the programs. The latter will be described here in more detail, as they were unique at the time for their complexity and interactivity. The following lists of procedures and "switches"[79] also show the great variety of characteristics analyzed. The software included the following programs:

- Linear Grouping Program (looking for linear patterns formed by up to 12 consecutive events in the same voice),
- Vertical Grouping Program (listing and counting the vertical structures in a piece of music without identifying them),
- Program for Thematic Analysis (searching for themes submitted by the user),
- Program for Harmonic and Set Analysis (labeling the chords [roots and quality][80] and/or sets in a piece, using the list of groups from the Vertical Grouping Program as reference), and
- Program for cumulative counting (accumulating data from two or more pieces).

Each program used switches for specifying and 'individualizing' the analytical

---

an acceptable amount of compositions).

[79] Those "switches" would select one of two sets of instructions.

[80] Incomplete chords, which could not be identified, were labeled "ambiguous". (Gross 1975a, 109.)

process.[81] Switches of the "Linear Grouping Program" comprised

- interval calculations (included; not included; diatonic; measured upwards in semitones),
- rhythmic and metric calculations (disregard rhythmic positions; calculate rhythmic positions; calculate metric positions),
- minimum number of occurrences in order for a pattern to be printed, parameter to be grouped (pitch; rhythm; articulation; dynamics; chords; sets),
- inversion and retrograde (no consideration of both; scan for inversions; scan for inversions, retrogrades, and retrograde inversions),
- setting the minimum number of occurrences lower, for patterns found in the top voice in order to be printed out (or count equally),
- treatment of rests and repeated notes (no elision over rests or repeated notes; ignoring rests and repetitions of a note; ignoring deviations of a certain number of semitones from the previous note),
- largest number of notes in a group,
- punching cards for the cumulative counting program (no cards; punching captions and information; punching information). (Ibid., 77)

Switches of the "Vertical Grouping Program" comprised

❖ margins (in beats and/or fractions of beats),

---

[81] These user-controlled switches represent a feature, developed mainly in the 1970s for a rather controlled dialog between analyst and computer program. Unfortunately, most descriptions of music analysis programs did not include such details, so that a reconstruction of the history of this methodological feature is not possible.

- minimum number of occurrences in order for a pattern to be printed,
- ordering of groups (unordered groups; ordered groups of struck notes; ordered groups of sounding notes),
- parameters to be printed (pitch; rhythms; articulation; dynamics),
- storing results for use in the "Harmonic and Set Analysis Program" (yes; no),
- octave reduction of pitches (yes; no),
- interval calculation (yes; no),
- punching cards for the "Cumulative Counting Program" (no cards; punch captions and information; punch information). (Ibid., 88)

The "Thematic Analysis Program" had switches for

- interval calculations (included; not included; diatonic; measured upward in semitones),
- rhythmic and metric calculation (disregard rhythmic positions; calculate rhythmic positions; calculate metric positions),
- parameter to be scanned (pitch),
- treatment of rests and repeated notes (no elision over rests or repeated notes; ignoring rests and repetitions; ignoring deviations of a certain number of semitones from the previous note). (Ibid., 101)

Switches of the "Harmonic and Set Analysis Program" were

- style of analysis (chords including ninth, eleventh, and thirteenth chords; chords excluding ninth, eleventh, and thirteenth chords; sets in optimal normal order),
- treatment of dissonances (no skipping of non-chords; disregard non-chords if

there is a chord nearby; disregard non-chords). (Ibid., 110)

The accuracy of the set of computer programs was demonstrated by analyzing one piece each by J. S. Bach, J. Haydn, F. Chopin, and L. Dallapiccola. However, Gross' project was important because of the combination of melodic, harmonic, as well as set theoretical analyses within a comprehensive set of programs.

Already in the early 1970s, Ian A. Morton (1974) modeled a FORTRAN-program[82] for the analysis of tonal music on the level of perception, whereby the program was based on a musical-psychological, 'auditory harmony model'.[83] Program data included key signature, letter names of the notes, as well as their time value and octave. The program supplied every note in a composition with at least one numeric that relates to the key signature, to the tones that sound with it, and to those that precede and follow it. These numerics were "obtained solely on the basis of relational context within a stringently defined architecture of musical structures and keys" (Morton 1974, 265). From the numerics, the following information could be extracted: the melodic relationships between consecutive notes in each voice, the harmonic relationships between consecutive events, summaries of compound events, summaries of ambiguous events, durations of harmonies, and a graphic representation of the harmonic flow of the composition

---

[82] The program was executed on a CDC 6600 computer. — See also Morton 1967 and Morton and Lofstedt 1970.

[83] This model was proposed by J. C. R. Licklider and was applied to several features of tonal music by P. C. Boomsliter and W. Creel; see Morton 1974, 262.

(ibid.). Using this program, Morton analyzed Bach chorales as well as the first two harmonized measures of *Tristan*. In the Bach chorales, an unexpected number of (harmonic) ratios of greater complexity, such as 81/80, 128/105 or 160/147 (besides the classic diatonic ratios 3/2, 5/4, 5/3 etc.), were found, and even such unusual relationships as 1323/1280 and 1701/1600 (ibid.). The analysis of the first two measures of *Tristan* also reflected the complexity of human perception. With this research, Morton developed an early cognitive approach to computer-assisted music analysis, and was, thus, one of the heralds of the cognitive boom in the 1980s and 1990s.

In 1974, Bo Alphonce presented a computer-assisted foundation of set theoretical analyses and provided, with it, a basis for later approaches in this field. He developed a new algorithm for computing prime forms of sets from cardinality 0 to 12 over a binary exponential series and their transformations, based on all (4095) transpositions and inversions of every prime form.[84] Another (SNOBOL3-) computer program produced a complete list of subsets for all prime forms of the twelve-tone-system. Furthermore, Alphonce developed an analytical approach for invariance relations of sets or subsets: the results can be mathematically represented (and visualized) in invariance matrices and used as analytical tools. Different possibilities of interpreting similarity relations were described as a power of his analytical model. Alphonce' two analytical

[84] Alphonce was interpreting the pc integers as exponents to the base 2 and summing up the corresponding powers of 2. — The program was written in FORTRAN.

programs[85], using this methodological framework, were for either monophonic or polyphonic/homophonic input (in the latter case, for pieces in which the set cannot be assumed to be mostly linearly). These programs which, as Alphonce points out, require interaction between the analyst and the program, could be used for either calculating characteristics of sets or twelve-tone rows or for analyzing—even tonal—pieces of music with regard to their inner structure of subsets.

Later on, the invariance matrices calculated by Alphonce were used as databases for several other analytical programs drawing on set theory. But Alphonce also reached the limits of his computer applications, especially concerning computer-aided segmentation: "In some early runs I came dangerously close to the proverbial truckload of output. Measure 1 of Schoenberg's op. 23 no. 4 generated a pile of output about an inch thick when scanned for all equivalent pitch-class collections. . . . Clearly, some output segments would quickly strike me as analytically convincing, but the price was too high, wading through large numbers of irrelevant and coincidental finds. . . . In general, however, I had to turn to human pre-segmentation."[86]

David Stech (1976, 1981) went a different methodological direction in that he developed a FORTRAN-program for the analysis of small musical models. His goal was to detect different types of rhythmic, melodic or intervalic patterns and

[85] These programs were written in FORTRAN for an IBM 370 computer. About the history of those programs see Alphonce 1974, 171.

[86] Bo Alphonce in a personal communication with Peter Castine, cited after Castine 1994, 17.

their inversion, retrograde and retrograde-inversion in strictly linear music, i.e. in music in which a fixed number of voices is defined. The objects of Stech's analyses were John Dunstable's isorhythmic motet "Veni Sancte Spiritus", Paul Hindemith's "Fuga nona in B-flat" (from *Ludis Tonalis*) and Edgar Varése's "Density 21.5". Stech demonstrated, that the computer can process such analyses very fast and accurately, but he did not take perceivable variations of such patterns into account, i.e. he did not pay attention to the problem of variation and similarity.

Norbert Böker-Heil (1974) developed forms of graphical representation for interpretative analysis. He used different graphs showing the progress

- of sound-density (how many voices participate, in average, in sound events in every measure),
- of the dissonant behavior[87],
- of the melodic activity (tone progressions or sizes of intervals), and
- of tone durations.

Böker-Heil also introduced three-dimensional diagrams, in which different conditions were connected with each other. Based on this, it was possible to determine "style-specific forming constants" ["stilspezifische

---

[87] "Here, every vertical 'chord' is considered to be 'dissonant', which does not belong to the group of perfect consonances (two-voices) of the major or minor triads or of corresponding sixth chords." ["Als dissonant gilt hier jede Tonschichtung, die nicht zur Gruppe der vollkommenen Konsonanzen (zweistimmig), der Dur- bzw. Moll-Dreiklänge oder der entsprechenden Sextakkorde gehört."] (Ibid., 109).

Formungskonstanten"] (Ibid., 111) of polyphonic music, which could practically not be found in any other way.

In the Soviet Union, music theorists also developed unique approaches to mathematical and computer-assisted music analysis. M. I. Rojterstejn (1973), for instance, calculated graphs and matrices of pitch-transition probabilities of compositions by Bach and Shostakovich. Using statistical analysis, Moisej G. Boroda explicated "metric-rhythmic melody units" (Boroda 1977) as well as (purely) rhythmic units (Boroda 1978), which can be found in a variety of musical styles. Boroda (1977) showed that the segmentation of every melody is dependent on the metric-rhythmical structure, specifically their interrelations. Boroda also showed that the average length of a "metric-rhythmic melody unit" can be compared to the length of words in language. Citing compositions from different style periods, Boroda gave examples for the arrangement of melodic fragments as "metric-rhythmic melody units". M. A. Iglickij (1973) developed an algorithm for stepwise modulation between any major and minor key; he suggested using this system for analyzing strategies of modulations and their frequencies. B. M. Gasparov (1974) developed a structuralist approach to music analysis; as a specific application of his approach, Gasparov analyzed harmonic distributions in early compositions by Beethoven. Finally, T. P. Karlina and V. K. Detlovs (1968) analyzed sequences, and melodic shiftings, in melodies and harmonies; these sequences and shifting were then classified, depending on interval and pitch repertoire. Karlina and Detlovs analyzed works by Bach, Haydn, and Tchaikovsky, and showed that the application of statistical measurements (e.g., mean, standard deviation) made it possible to identify personal characteristics as well as evolutionary tendencies in the use of certain melodic or harmonic sequences.

Fred T. Hofstetter (1979) developed a different approach to the analysis of tonal music: Referring to earlier investigations by William Paisley, especially referring to procedures for extracting a database in studies of style, Hofstetter modified Paisley's model for analyzing natural language as shown in Figure 1. This model shows how different norms, i.e. sources of variation, influence a message:

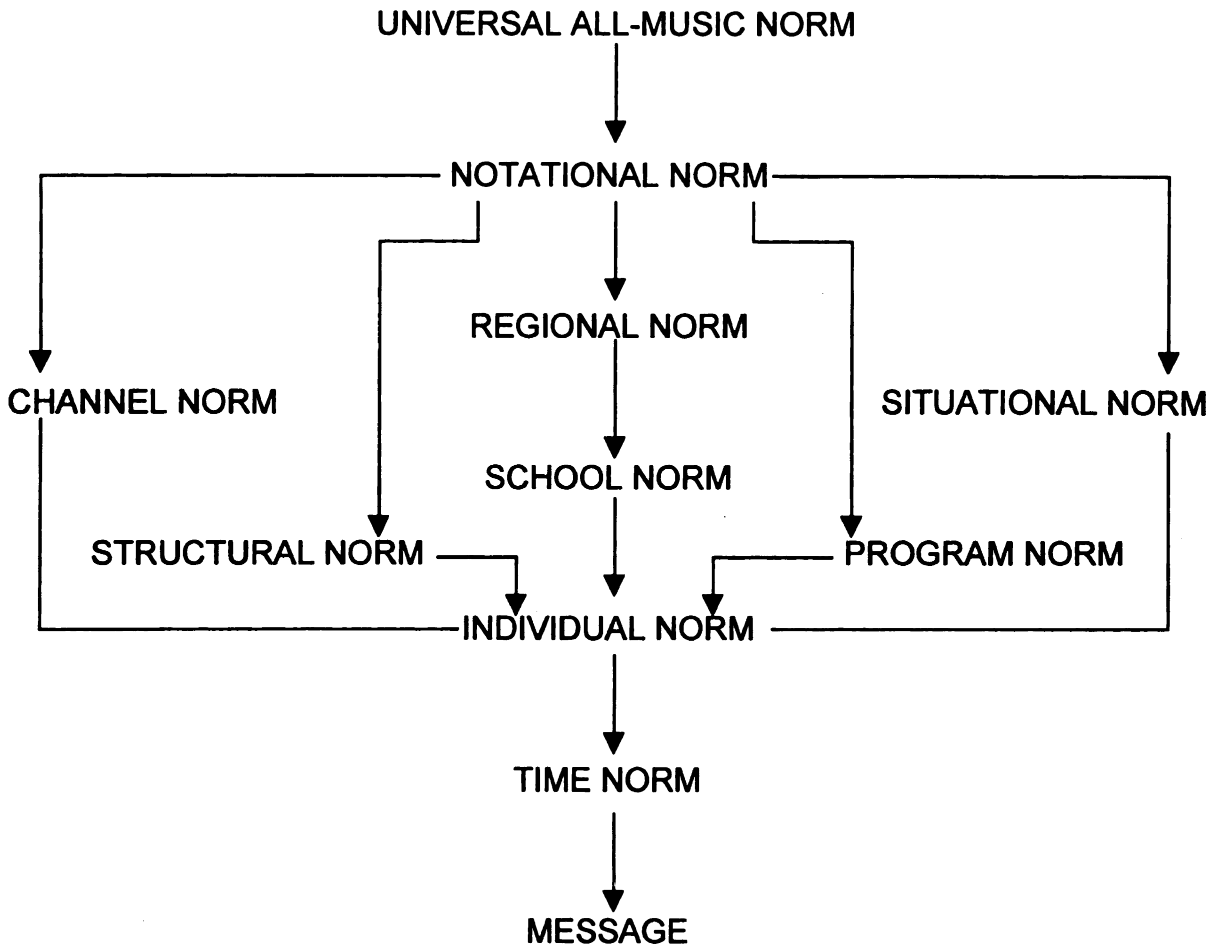


Figure 1: Modified Paisley Model for Selecting a Controlled Database in Studies of Style (Hofstetter 1979, 111)

Hofstetter's methodical procedure was characterized by isolating national influences on 130 'melodies' from 16 string quartets by Czech, French, German and Russian composers of the 19th century. Isolating national influences was accomplished by specifically choosing two string quartets each by Dvorak, Smetana, D'Indy, Saint-Saens, Mendelssohn, Schumann, Borodin and Tschaikowski. Thus, time norm (19^{th} century), notational norm (traditional Western notation), "channel norm" (only string quartets were analyzed), situational norm (all quartets chosen for the study were mature works), and program norm (no extra musical associations) were each controlled. Through quantitative analyses of the interval repertory (using the chi-square-test of independence), it was possible to verify 'qualitative' analyses[88]. Hofstetter could show that, first, national differences between Czech, French, German and Russian chamber music exist, second, French chamber music was influenced by German music, and third, Russian chamber music shows the greatest national influence. With this method, Hofstetter demonstrated, furthermore, similarities between Czech and Russian chamber music. These similarities were probably due to geographical dependencies.

While Hofstetter's study can be criticized with regard to insufficient verification of his method and insufficient musical material analyzed, his study is a great advance compared to most of the studies carried out during the 1960s and early 1970s: different normative levels (see figure 1) are acknowledged. This seems especially important for the categorization of different genres, but also of different voices; not only different genres have different structural characteristics, but also different voices within a composition are characterized by such structural features.

In the 1970s, the search for a musical grammar was probably the most important development in computer-assisted music analysis. The basis for this search was provided by the insight that specific compositions could be represented in terms of a list of grammatical production rules. One of these forms

[88] Here, Hofstetter referred to Cobbett 1929.

of representation is the parse tree which graphically represents the syntactic structure of a composition. One of the first attempts of applying Schenker's theory of tonality to computer-assisted analysis of music was made by Michael Kassler (1975a, 1975b, 1977; see also Kassler 1964). He explicated the middleground of Schenker's theory and programmed[89] the decisions procedures for formalized languages that constitute this explication (see Kassler 1975b, 7). A LISP-based system for the study of Schenkerian analysis was developed by Robert E. Frankel, Stanley J. Rosenschein, and Stephen W. Smoliar (1976, 1978). Since the programmed procedures were essentially a description of Schenker's hearing of the musical works, this approach was one of the first to model musical perception on a digital computer. Schenker's tonal and transformational hierarchies were represented within the context of a symbol-manipulation system in terms of tree transformations. A data structure was implemented that modeled the process by which the hierarchy was (supposedly) created. To demonstrate their computerized modeling, Frankel, Rosenschein, and Smoliar analyzed parts of Beethoven's "Ode to Joy". They summarized their work as follows: "Although we have not yet reached the axiomatisation stage, our LISP-based system may prove of immediate value to the musicologist and the composer. Computer-aided musicological and compositional projects have a long history. We feel our formalism of Schenker's notions of musical structure could significantly effect future developments of both fields. In almost all documented

[89] Kassler wrote his programs in the APL programming language and used IBM 360/50 and CDC Cyber 72 computers.

attempts to use the computer as a tool for stylistic analysis, the data structures employed represented musical information in the form of strings of characters. . . . The representations fail to capture any hierarchical structure internal to a composition. . . . We have, in fact, the capabilities for modeling such a growth process in our LISP system as shown above by our analysis. By contrast, those data and control structures which are based entirely on string manipulation are inadequate in this respect. In fact, with a LISP-based model the musicologist may more readily ask questions about 'deep structure' and its transformations which he may use to establish criteria for stylistic analysis." (Frankel, Rosenschein, and Smoliar 1976, 29-30)

Already in the early 1970s, Otto Laske's search for a grammar of music was an exploration of a "generative theory of music" (Laske 1972, 1973, 1974, 1975). But Laske's grammar concept was based not on notated music, but on a formal model of empirically acquired musical *activity*. Thus, Laske's studies were early studies in musical cognition. He was interested in formal properties of cognitive tasks that process musical input. "Instead of producing a taxonomic analysis of musical structures, Laske has turned to what is essentially a project in cognitive psychology." (Roads 1979, 52) Laske's understanding of 'sonology' expressed "the relationship between the syntactic structure of a music and its physical representation in so far as this relationship is determined by grammatical rules" (Laske 1975, 31). Laske tried to explicate musical grammars as computer programs in so far as they, more or less, relate to musical activity, such as composing or listening. This provided the basis for a unique analytical approach developed in the early 1980s (Laske 1984; see 2.5.).

The 1970s were a rich decade for computer-assisted music analysis. Existing (statistical and information-theoretical) methods were refined, separate measurements were converted into complex, multi-factor analyses, and, most importantly, the core of computer-assisted, analytical methods was extended by psychological and set theoretical approaches as well as approaches drawing on Schenkerian analysis and generative grammars.

2.5. Computer-Assisted Music Analysis in the 1980s

Many research projects conducted during the 1980s aimed at the development of new methods of computer-assisted music analysis. Some projects discovered new possibilities related to using computers to simulate human cognition and perception, drawing on cognitive musicology and artificial intelligence, areas that were themselves spurred on by new technical developments and by developments in computer program design. Approaches that had already established historical precedents, those drawing on statistics and information theory, also developed further.

Manfred Leppig (1987a), for instance, analyzed selected folk songs, using new, and in many ways more productive, analytical criteria, such as 'affinities of tone sequences' ['Tonfolgeaffinitäten'], 'tone identities' ['Tonidentitäten'], 'parallel affinities' ['Parallelaffinitäten'] and 'affinities of tone environment' ['Ton-Umgebungsaffinitäten']. Leppig also examined melodic similarities; for example, he deleted one note in a melody and calculated statistical differences between the original and its variation. Furthermore, with his 'phrase-analysis', he looked for phrases or partial phrases and their retrograde, inversion or retrograde inversion within the melodies. In other writings (Leppig 1987b, 1987c), he described procedures that could be used to search for certain patterns and forms like 'cascades', 'plateau-cascades', 'linearities', 'roofs', 'stairs', 'terraces', 'chains', 'rows', etc. However, Leppig did not perform complex analyses of extensive song material or any other existing music.

More complex research—with regards to the analytical objects and with regards to the methods used—was carried out by Wolfram Steinbeck (1982), who attempted a "classification of 500 melodic segments" of German folk songs. This sample of 500 melody segments was randomly selected from a stock of 4500 melodies. Steinbeck described 35 characteristics. The catalog of characteristics comprised statistical frequencies relating to pitch (tones; repeated tones; foreign tones to the scale; tones above, on and under the tonic; change of direction), statistical frequencies relating to duration and proportions (change in duration, duration sequences short-long, long-short and equal as well as dotted and half-long transitions), pitch attributes (ambitus, minimal and maximal pitch; mean pitch and standard deviation; key tone position within ambitus; maximal and mean size of intervals and standard deviation; mean ascent), and duration qualities (mean duration and standard deviation; mean duration interval; duration share and mean duration as well as proportion of duration mean values of measure emphasis or of unaccented tones). (Ibid., 132 ff.). The classifications were finally made by hierarchic cluster analysis using the correlation coefficient $r_{jk}=s_{jk}/(s_j s_k)$ as a measure for similarity, whereby s_{jk} is the covariance of the characteristic values or pitch values of the melodies j and k, and s_j as well as s_k are standard deviations of each melody (ibid., 253 f.). However, Steinbeck (as Reiner Kluge; see 2.3.) could not solve the problem of determining the similarity between melodies in a manner that is relevant to the actual perception and cognition of the melodies. (For such a determination of melodic similarity that is relevant to cognition and perception, computer-assisted analyses would need to be combined with empirical, psychological studies.) Instead, the characteristics of different classes of melodies were illustrated by the trend of melodic direction (contour): ascending or descending melody, roof form, V-form etc.

Norbert Böker-Heil (1981) wrote a program that searched for melodic idioms, i.e., melodic phrases that are widely used and characteristic of a group of melodies. His goal was to determine by analysis of these characteristics the specific region of Southern Tyrolean folk songs in which a song originated. He used the analytical criteria of range, melodic contour, tone duration, rhythmic groups, and phrase design. The main result of Böker-Heil's project was that 92 melodies out of 192 Southtirol folk songs (48%) could be assigned to the correct region of origin.

Reiner Kluge (1987) presented an application of his theory of active (complex) musical systems to the analysis of (Afro-Cuban and Algerian) ostinato rhythms. Using the model of a 'complex system', which includes hierarchic structures, self regulation, accidental effects, etc., the analyses were directed at the statistical evaluation of the rhythms (specifically by calculating correlations) and at the psychological and historical-cultural structures that were involved in the creation of these rhythms.[90] The analysis was also directed at the "inner time organization," i.e. the time that is 'experienced' by the listener. Thus, Kluge's analytical approach could only be carried out by linking the statistical calculations (and their procedures) with interpretative activities of the musicologist. Even

[90] ". . . 'dahinter' sichtbar werdende psychisch und physisch repräsentierte, geschichtlich-kulturell bedingte Erzeugungsstrukturen" (ibid., 26).

though not actually realized with the aid of a computer, Kluge's approach to complex data processing was an important step towards further research in the field of Artificial Intelligence.

Alda de Jesus Oliveira (1986) used a computer program to determine, which musical traits best characterize folk songs from Bahia (Brazil).[91] Her ultimate goal was to formulate a model that would allow music educators to teach music using characteristics of Bahian folk music. Oliveira's calculations included statistical frequencies related to several musical elements found in a sample of 56 folk songs.[92] Based on her interpretations of the statistical results, Oliveira claimed to have found characteristics specific to Bahian folk song. This claim, however, does not hold: the standard deviations of the statistical means (averages) were too large to characterize any selection of folk songs, and Oliveira even stated that the "results across genres seemed to indicate more differences than similarities" (Oliveira 1986, 131). Surprisingly, Oliveira did not even try to verify her results using other statistical measurements and procedures for verification. Mere statistical frequencies that are derived without applying complex statistical measurements (e.g., multi-variate analysis or cluster

[91] These characteristics included various beat contents, anacruses, rhythmic textures, tempi, melodic ranges, intervals, melodic directions, modes / scales, last note of phrases, and formal structures of melodies.

[92] The songs belonged to the genres "play songs", "work songs", "religious songs", and "dance songs". Oliveira analyzed 14 songs of each genre. The computer program was written in BASIC and machine language for a home computer with 64 KB memory. The encoding system used was M-PARC (see Kostka 1984).

analysis), are not sufficient to characterize any group of songs, and Oliveira did not compare Bahian folk songs with songs from other geographic areas. Without such a comparison, and without other forms of verification, the statement that she found "several unique characteristics of folk songs from Bahia-Brazil" (ibid., 149) cannot be justified. In the pedagogical conclusions, her study accomplished little more than the general assertion that regional musical characteristics are important for the development of music educational curricula.

Another group of studies conducted during the 1980s was centered upon the analysis of works of *art music*. Ann K. Blombach (1982) analyzed the relationship between harmonic and contrapuntal elements in Bach chorales. To determine whether harmonic or contrapuntal elements are more important in Bach chorales, Blombach organized computer-assisted analyses of fifty randomly selected chorales.[93] This selection was limited to chorales in major keys to provide a consistent set of data which is necessary for comparisons. The computer-assisted portion of the analyses was intended to measure the (degree of) equality of the voices and the relative musical interest (which was equated with 'musical variety') of each voice. After transposing all chorales to C, a variety of calculations were performed: statistical frequencies of tones (diatonic or chromatic), duration values, first-order-intervals, pitch patterns, duration patterns, rhythmic elements, average range of each voice, etc. Blombach used the chi-square test to determine significant differences between the voices (i.e. at the .001 level of the chi square test). The results showed that the settings were

[93] The programs were written in Spitbol for an Amdahl 470 computer.

neither purely harmonic nor contrapuntal[94]. Furthermore, Ann K. Blombach used the computer— without describing the process in detail—for frequency calculations of scale changes in each voice, since frequent scale changes, especially within the bass, have a primarily harmonic function.[95] Blombach found a clear contrapuntal influence in the harmonic structure of Bach chorales, because two or more voices made frequent use of different scales at the same time.[96] The success of Blombach's study can be explained by her focus upon the musical significance of the computational results rather than on issues of programming; thus, she focussed on achieving an insightful combination of computer assistance and traditional music theoretical research.

Using a concept derived from C. P. E. Bach's concept of the harmonic circle of fifths and its two primary relationships (that between tonic and dominant

---

[94] The voices were not as equal as in strong harmonic settings: the soprano voices (i.e., the tunes) showed the greatest deviations from all other parts (because most of them were written by other composers), but the remaining voices were significantly different from each other, too. On the other hand, the bass line showed—especially through frequent intervals of fourths and fifths—strong harmonic evidence. Also, the alto and the tenor seemed to be less 'interesting' and more alike than the other voices.

[95] "Usually a change of scale does not make a voice more interesting, but rather a chromatically altered note is usually part of a harmonic structure with a specific harmonic purpose -- for example, a secondary dominant." (Blombach 1982, 87)

[96] "Bach's chorales are an ingenious combination of harmonic and contrapuntal elements in a harmonic framework, and both elements are vital to the chorale settings' musical success. Similarly, a careful consideration of the two elements,

and that between the tonic and its relative key), C. G. Marillier (1983) developed a computer-assisted, statistical method for quantifying "tonal distance" (including a graphical representation) and for extracting the norms of tonal structure of classical symphonies. After creating traditional (by-hand) harmonic analyses of all symphonies by Joseph Haydn, computer programs calculated, for instance, the mean average duration of key areas, standard deviations and the most remote keys reached (in means of modulation). The results showed, for example, an outward expansion of the most remote keys reached by modulation throughout Haydn's symphonic career (while the outward expansion is more pronounced and consistent on the flat side), a decreasing mean tonal level, and an upward trend in the standard deviation from the means of tonal levels. Thus, Marillier verified his hypotheses that there is "a tendency to balance time spent in keys sharper than the tonic with a similar time spent in flatter keys, and, that, in the case of sonata form movements, this flattening is most noticable in development sections" (Marillier 1983, 192). After further comparative analyses of symphonies by Haydn, Mozart, Beethoven, C. P. E. Bach and Sammartini, Marillier suggested "that tonal architecture can be quite idiosyncratic and could possibly aid in ascription disputes, given large enough numbers of authenticated works for statistically meaningful comparisons to be made" (Ibid. 199),[97] his point

---

and the interactions between them, is vital to the music theorist's success in analyzing and understanding this music." (Ibid.)

[97] Marillier continued: "Mozart, for instance, visits flat-side keys in his early symphonies noticably less often than Haydn does. C. P. E. Bach is different from all the others in his nervous habit of lengthily delaying key-establishment,

being that the tonal architecture may be used for solving questions of unclear authorship.

Another example of stylistic characterization of art music based on statistical analysis is the research by Alison Crerar (1985). Crerar analyzed 105 incipits of compositions by Valentini, Corelli, Vivaldi, Bach and Beethoven (especially with the goal to compare Valentini with Corelli and Vivaldi), following W. J. Paisley's earlier research (Paisley 1964). After refining and extending Paisley's procedures by statistical calculations of pitch, intervals, and scale degrees etc., Crerar showed that it is possible thereby to distinguish between the works of different composers and to clarify the authorship of specific compositions.

Dean Keith Simonton's research was also based on Paisley's analytical attempts. Simonton (1980a) combined computer-assisted analyses of two-note transitions within the first 6 notes of 5046 classical themes (by ten well-known composers) with broader, more encompassing, analyses of psychological and sociocultural factors. His goal was to find musical characteristics that make a musical theme 'famous.' 'Thematic fame' was defined, on the one hand, with regard to the frequency of performances, recordings, and citations (ibid., 210). On the other hand, "melodic originality was operationalized as the sum of the rarity scores for each of the theme's 5 transitions" (ibid., 211). Chromaticism and dissonant intervals played an important role in the statistical calculations. But

---

resulting in a characteristic histogram of percentage incidence of key levels." (Ibid., 199)

Simonton neither calculated note transitions of higher orders (beyond two-note transitions), nor did he calculate transitions related to duration or rhythm. Even though some of his results[98] are still valid, most of them are not, especially those dealing with the empirical determination of 'thematic fame'[99] and with the correlation of 'creativity' and Simonton's calculations of 'melodic originality' (interpreted as 'novelty'). Recent research on musical creativity[100] does not support Simonton's understanding of 'melodic originality'. Nevertheless, within a

---

[98] Simonton's main results were: 1. 'thematic fame' is a positive linear function of melodic originality; 2. melodic originality of themes increases over historical time; 3. melodic originality of a theme increases when composed under stressful circumstances in a composer's life; and 4. melodic originality is a curvilinear inverted backwards-J function of the composer's age. (Ibid., 213-215.)

[99] The recognition and 'fame' of a composer and/or of some of his/her themes, for instance, varies within different historical periods. Composers, whose themes were very famous and recognized as 'creative' at the time, can be forgotten today (as, for instance, the Austrian song and chanson composer Ralph Benatzky [1884-1954]; see Schüler 1998b). However, Simonton's empirical sources were even mostly sources of our time. Today's 'fame' of composers and their music can also depend on political situations (see, for instance, the German composer Hanning Schröder [1896-1987]; Schüler 1996c), on the influence of mass-media, on traditions in music research (see the discussion on the 'music history of heros'; Schüler 1998a) etc. etc. Even the "stressful circumstances in a composer's life", which supposedly increase the creativity, cannot be 'compressed' into 5-year age periods as Simonton did.

[100] See, for instance, Gardner 1993 as well as Feldmann, Csikszentmihalyi, and Gardner 1994.

history of computer-assisted music analysis, the attempt of combining psychological and sociocultural factors and statistical analyses was an important step.

Later on, Simonton (1980b, 1983) refined his approach usimg 15,618 musical themes by 479 classical composers, and he considered further analytical variables, e.g. "zeitgeist melodic originality", which is "the degree to which the structure of a given theme departs from contemporaneously composed themes" (Simonton 1980b, 974). With this approach, he gained more detailed and more accurate results.[101] In 1984, Simonton presented two-note transition tables from his former studies as well as three-note transitions and more thorough interpretations of them to support his (earlier) results. Finally, one of the goals of Simonton's studies was to stimulate further research in music psychology and aesthetics. However, only a few of further research projects in music psychology and aesthetics followed Simonton's methodology, and those who did produced

---

[101] Simonton corrected, for instance, that "thematic fame" was then represented by an inverted-J function of "repertoire melodic originality" (i.e., unusual melody in comparison to the entire repertiore of music listening) and that "thematic fame" was also represented by a J function of "zeitgeist melodic originality" (ibid., 977). Furthermore, the "thematic fame" was a curvilinear inverted-U function of a composer's age (Ibid., 979). Simonton stated, that "as the thematic richness of a work increases, the fame of any single theme within the work becomes less dependent on the intrinsic properties of melodic originality and becomes more dependent on associations with other themes via the formal structure of the piece" (ibid, 979); this shows also the problem of the definition of "theme" and the differentiation between 'theme' and 'motive'.

insignificant results.

Norbert Böker-Heil (1989) tested whether compositions belonged to the literature making up the *ars subtilior* (a style of late 14th century music), using a computer-algorithm, which included calculations of several characteristics[102]. In conjunction with a 'significance' function based on the relative frequency of these characteristics, Böker-Heil noticed, for instance, that the motive C-B-C-A that was often used by Guillaume de Machaut was also used beyond and after Machaut (ibid., 13), but not in the *ars subtilior*.

Another direction of computer-assisted music analysis during the 1980s involved the application of set theory. J. Timothy Kolosick (1981) carried out "a computer-aided, set-theoretical investigation of vertical simultaneities in selected piano compositions by Charles Ives"[103]. The main computer program, written in APPLESOFT[104], was a "Time Slicer" which extracted all simultaneous events

---

[102] Those characteristics are: number of all different tone durations; number of all different pitches; number of all notes, which have a higher duration than a dotted eighth note (this is an arbitrary threshold); number of different 'attack-moments' ['Einsatz-Zeitpunkte'], at which the sonority changes through the entry of an 'event' within a voice or within several voices simultaneously; number of different distances, which can be observed between two successive attack-moments; number of active voices at a specific time; (fictitious) duration of the composition; total number of all 'events'; etc. Hereby, an 'event' is defined as an 'entry' of a note within a voice or the beginning of a rest. (Ibid., 11.)

[103] Ives' compositions analyzed here were: *The Anti-Abolitionist Riots*, *Some Southpath Pitching*, *Study Number 22*, *Three-Page Sonata*, *Varied Air and Variations*.

[104] APPLESOFT is a BASIC-dialect. The programs were written for an Apple II

(chords) from the score[105]. After translating the pitches into pitch classes and eliminating duplicated pitches—the durations of the chords were also stored— a program derived prime forms (based on Forte's principles). Since the names of all prime forms were stored in the program, the output also included all set names as well as the interval vectors. Another program searched for each Kh-related subcomplexes and printed out their location in the composition. Also, any two adjacent sets were compared with regard to the interval vector, and a degree of similarity was calculated (based on Morris 1980[106]). Thus, with "some refinement" of the theory[107], Kolosick wanted to show the "flow of similarity"

Plus Microcomputer with one disk drive. (See ibid., 21.)

[105] The music was coded in DARMS and stored in DATA statements of the "Time Slicer" program.

[106] There, Morris suggested, among others, an "absolute similarity index" ("ASIM") based on the sum of the differences between the absolute frequencies of each interval class. This sum is to be divided by the total number of intervals of both sets. The result is a value between 0 and 1 (inclusive), whereby 1 indicates total dissimilarity and 0 identical interval vectors. The fact that divisions by larger numbers (larger sets) reduce the similarity index (indicating higher similarity) is explained with the perceptive assessment that larger sets are more similar to each other than smaller sets. Thus, in contrast to Forte's similarity relation, the sets to be compared need not be of the same cardinality. However, Bo Alphonce (1974, 151 ff.) originally had the idea of calculating a difference vector. But neither Kolosick nor Morris mentioned Alphonce' fundamental work even in their bibliography.

[107] Kolosick's critique of Morris' similarity measure—after the analyses of Ives' compositions—was based on principles of music perception: for instance, register or spacing have a major effect on the aural perception of chord

within entire compositions (Kolosick 1981, 36). Finally, a program compared any two adjacent "time slices", where one pitch was added to an existing set to form the next set, with regard to the Kh relationship. Then, the probability of the Kh-relation to such sets was calculated.[108] As these few examples could show, the methodology of computer-assisted analysis based on set theory—in constrast to all other methodologies developed for computer-assisted music analysis—did not differ from the methodology of the original set theory at all. Here, the computer 'only' extended the capabilities of the original methodology in speed and practicality.

Based on set theory, Mary Hope Simoni (1983) developed another computer program[109]. While the segmentation had to be done by hand by the music theorist, the purpose of the program was to reduce the probability of human error and the amount of time required for finding prime form sets with cardinalities two to ten, their vectors, set complements, "basic interval succession" patterns, set complex relations, similarity relations and invariances for all pairings of sets. The program used two databases: one for all prime forms, their set names, vectors and set complements (derived from "Appendix One" of Forte 1973 with the addition of sets with cardinalities two and ten), and one for all subsets and supersets of each set from the first database (obtained from "Appendix Nine" of Alphonce 1974). Simoni used the program to analyze *Five*

---

similarities as well as the manner of changes within the interval vector.

[108] For this, Kolosick used the "sign test".

[109] The program was written in the programming language BASIC-PLUS 2 for the computer "DEC VAX 11/780".

Pieces for Piano by George Crumb; she showed the usefulness and flexibility of horizontal and vertical set-theoretical analyzes.

Probably the first commercially available set theory program for Macintosh computers was the "*Computer-Assisted Set Analysis Program*" (*CASAP*) by Charles H. Ruggiero and James P. Colman (1984/1990)[110]. It is based on Forte's atonal set theory as described in "The Structure of Atonal Music" (Forte 1973).[111] The program allows the user to enter sets by pitch classes (integer, note names) or as whole sets (using Forte names). The segmentation needs to be done in advance. Every entered set receives an internal reference number so that, later on, those sets are tracked. The calculations comprise prime forms (identified also by Forte names), number of occurences, as well as (Forte's) similaritiy and set complex relations (taken from Forte's Appendices). All entered sets can be saved in an editable file. Hence, *CASAP* is a useful tool for the purely mathematical part of Allen Forte's theory.

Craig R. Harris' and Alexander R. Brinkman's "Contemporary Music Analysis Package" (CMAP; Harris/Brinkman 1987) can be seen as the most powerful of the set theory programs. The input is pitch class sets which can have the size of cardinality zero to twelve. All information about set classes and set class membership is pre-calculated and stored in a database. The set of

---

[110] The first version became available in 1984. The latest version is version 1.13 from 1990.

[111] But Forte's lists of possible pitch class sets are extended by sets with cardinalities 2 and 10.

computer programs, developed for UNIX- and DOS-computers[112], can calculate:

- prime forms (one may choose between Forte's and John Rahn's prime form algorithms),
- ordered or unordered interval class vectors,
- invariance,
- adjacent interval vectors,
- transpositions,
- inversions,
- complementations,
- similarity, and
- sub set and set complex relations.

Optional filters could reduce the output to certain set representations (e.g., names, vectors, pitch class contents). The access to the set class database allows users to write their own functions for tasks, which are not directly provided by CMAP. In the early 1990s, Peter Castine adapted CMAP to Macintosh computers (see Castine 1994) and implemented MIDI support.

The development of new models of syntactic structures in linguistics suggested new ways to describe syntactic structures in musical compositions. Specifically the application of concepts derived from Noam Chomsky's generative-transformational grammar[113] to the analysis of music was of special importance to several developments in music theory. A generative grammar is

---

[112] The program was written in C.

[113] See Chomsky 1965, 1969, and 1972.

based on a theory that could specify a *structural description* for any (grammatically correct) syntactic structure and the rules for creating variations of it (no matter whether the structure occurs in a sentence or a phrase of music), instead of enumerating which sentences or pieces of music are possible. And just as Chomsky was concerned, while developing his grammar, with with the cognitive representation and the perception of language, those who applied Chomsky's grammar to music theory also wanted to understand musical cognition. As used in linguistics or music theory, a generative-transformational grammar involves the application of a number of transformational rules and rules for constructing phrase structures to a set of elementary relationships. Since the model was mostly restricted to structures that are hierarchical in nature, structural trees were often used to visualize structural dependencies, and have become a useful concept in various aspects of (computer-assisted) music analysis.

Fred Lerdahl and Ray Jackendoff (1983) developed another model of the analysis of hierarchical structures; they extended the notion of a generative grammar into a notion of "a generative theory of tonal music". Lerdahl and Jackendoff distinguished four structural components of music: 'grouping structure' (hierarchical segmentation into motives, phrases and sections), 'metrical structure' (hierarchical beat levels), 'time-span reduction' (hierarchy of 'structural importance') and 'prolongational reduction' (hierarchical harmonic and melodic levels). All structural components are described by rules of the following three types: 'well-formedness rules', 'preference rules', and 'transformational rules'. Applying this theory to computer-assisted analysis, Leilo Camilleri described grammatical structures of the melodies of Schubert's Lieder. Camilleri developed a methodology for analyzing phrases of songs taken from *Die schöne Müllerin*, *Winterreise*, and *Schwanengesang*. This methodology was based on the following principles:

- "generation of a possible 'initial phrase' of a melody of a Schubert Lied by means of a syntactically structured grammar with rewriting rules, based on previous observation, subjective knowledge, etc.;
- verification of the suitability of the grammar through examination of the corpus;
- adjustment of the grammar by means of the formulation of other rules which permit a correct description and generation of the phrases." (Ibid., 229.)

A LISP program was entrusted to verify Camilleri's model, which showed that specific rules (transition rules, cadence rules, and ornamentation rules) could indeed be explicated to describe the grammatical structure of music.

Stephen W. Smoliar (1980) applied a different concept of musical grammars to computer-assisted music analysis. Already at the beginning of the 20th century, Heinrich Schenker worked out a specific concept of musical grammar, in which hierarchical subdivisions of the 'Vordergrund' ['foreground'], 'Mittelgrund' [middleground] and 'Hintergrund' ['background'] were analyzed. In Schenker's theory, the surface structure was obtained through the extension of smaller structural units (of the background). The aim of the analytical process was to find an 'Ursatz' [fundamental structure]. Based on this theory, Stephen W.

Smoliar discussed the establishment of a system for experiments in computer-assisted Schenkerian analysis. Structural levels were represented through logical combinations of elements (tones, chords). Smoliar's system embodied successful Schenkerian transformations. The program provided analytical tools in the form of macro definitions of constructs and transformations (within different levels). Smoliar's goal was to fill a database of analyses, which can be used for analyzing other compositions.

Other approaches to computer-assisted music analysis in the 1980s were derived from Artificial Intelligence, an interdisciplinary area which uses computer models to examine the intellectual capabilities of humans and the nature of their cognitive activity. Already in the 1970s, Otto Laske founded a "cognitive musicology" that was directed at musical activities. The goal of Laske's cognitive musicology was an empirically supported theory of musical intelligence (Laske 1977). The computer is the most important tool in formulating theories of musical actions which are empirically verifiable. As Laske pointed out, musical artifacts should not only be analyzed as pure syntactic structures, but also with regard to the underlying human competence involved in the performance of music. In this case, *competence* is defined as knowledge concerning the structure of the medium in which a communicative act takes place; *performance*, on the other hand, is understood as knowledge concerning the ways in which this competence is utilized in the act of communication (Laske 1975, 1). In making such a distinction, music is conceived as a series of tasks; its cognitive structure and processes need to be analyzed. To develop this methodology, Laske drew on linguistics, psychology, computer science, and artificial intelligence, and adopted the premise that the understanding of music requires an understanding both of structures of musical tasks and of musical processes.[114] Thus, for instance, the reading of a score by a conductor, by a musicologist, or by a music analyst are different tasks (performance), although they require a common music-analytical competence.[115]

In 1984, Otto Laske described the set of computer programs he developed, called "KEITH," as a rule-based system generating musical discoveries. A number of distinctions evolved from his work with this system. He began to distinguish between three kinds of musical representations: 'what is heard' ('sonological representation'), 'what is understood' ('music-analytical representation'), and what is said ('linguistic or music-analytical representation'), and saw each as a component of the analytical project. Given that Laske sought to model both the analytical concepts of his test subjects and the problem solving behavior involved in their music-analytical behavior, it is not surprising that in the realm of computer-assisted analysis he would be specifically interested in what a

---

[114] An introduction to (Laske's) cognitive musicology was provided by Nico Schüler (1995a). There, a complete bibliography of Laske's writings can also be found. See also Balaban, Ebcioglu and Laske 1992, Schüler 1995, 1997, 1998c, 1999, and Tabor 1999a, 1999b. For further developments in cognitive musicology see Laaksamo and Louhivuori 1993 and Seifert 1993a.

[115] In this sense, musicology itself becomes a task; the understanding of its structure and process is one goal of cognitive musicology. See Schüler 1994, 3-4.

computer program had to 'know' to pursue an analysis of a specific composition. Perhaps the most unique aspect of Laske's approach to music analysis was that he developed a theory of analytical processes: He pointed out that a theory of product, the kind of theory formulated by most music theorists, can be, and should be, complemented by a theory of process. Laske conceived of music analysis "as a discovery process that generates new concepts and conceptual linkages between them, in a search based on systematically derived examples." (O. Laske in Schüler 1999, 148.) His theories have much to offer for new efforts in the realm of computer-assisted music analysis.

An approach to musical analysis that draws on Artificial Intelligence first began to develop in the late 1980s. It is characterized by the use of a programming concept called neural networks. Neural networks are programs with units connected in networks, analogous to the network of neurons in the nervous system. Specifically, neural networks are a class of dynamic computer programs that are used by theorists (including music theorists) to analyze some activity by simulating the behavior of the nervous system.[116] It involves the study of how massive numbers of various kinds of elementary units, governed by relatively simple rules, can generate complexity and change within a large, dynamic system. Although the approach was promising, it was not until the 1990s that important contributions to music analysis started to be made.

---

[116] Mark Leman (1991) gave, for instance, an introduction to artificial neural networks and their applications in musicology.

2.6. Computer-Assisted Music Analysis in the 1990s

The 1990s ushered in revolutionary methods of music analysis, especially those drawing on artificial intelligence research. Some of these approaches started to focus on musical sound, rather than scores. They allowed music analysis to focus on how music is actually perceived. In some approaches, the analysis of music and of music cognition merged. But statistical and the other mathematical approaches also continued to develop in substantial and sometimes astonishing ways.

Barbara Jesser (1991) investigated an 'interactive' approach to the analysis of folk songs, i.e., the program user was able to influence the analysical process while the program was running. She concentrated on characteristics that could be used to classify folk songs, e.g. the set of pitches used, the mode or tonality, the repertory of intervals, durations, range, rhythmic incipits, accented tones, and finally, cadence tones. In addition to her own computer program, Jesser used a commercial database system (STAIRS)[117]. She tested her theoretical conjectures on several collections of German folk songs: a large one containing the same 4000 19th century folk songs Steinbeck had already used

---

[117] The manner of representation of folk songs in database systems used in Jesser's approach goes back to Helmuth Schaffrath's investigations on the use of databases for ethnomusicological tasks (Schaffrath 1984, 1985a, 1986, and 1987). Jesser's research was conducted as part of Helmuth Schaffrath's research project on the analysis of German and Chinese folk music at the Universität-Gesamthochschule [University of] Essen.

(see 2.5.) and some smaller ones based on German ballads. Her goal was to define and describe different folk song types. The results of the research were disappointing in two ways: no satisfactory measure of the degree of similarity between songs was computed, and the songs themselves were not sufficiently differentiated. Nevertheless, Jesser's approach was successful in developing an interactive computer program, which allowed a further refinement in the formulation of the complex problem of song classification.

Dirk Uhrlandt and Nico Schüler wrote the (TURBO-PASCAL-) program *MUSANA*[118] to analyze statistical and information related aspects of traditionally notated music, especially Western art music.[119] The statistical measurements and measurements of information used in this program include several standard, and a few unique, measures: mean, standard deviation, frequency, correlation, auto-correlation, entropy (including those of higher orders), as well as complex measurements, like entropy profiles and entropy progressions (see chapter 4). The program enables comparative analyses of personal style, genre, or period styles. *MUSANA* takes an interactive approach and includes 'traditional' methods

---

[118] The program is available as freeware and documentated by Schüler and Uhrlandt 1994/1996. The version 1.1 was exhibited at the International Computer Exhibition "CeBIT '96" in Hannover / Germany in March 1996. — *MUSANA* makes use of a unique music code, but a program procedure allows the conversion of MIDI files into the *MUSANA* code.

[119] See Schüler 1992. There, statistical and information-theoretical calculations could verify discoveries, that had been made 'traditionally', and could partly represent them more plausibly and clearly, oftentimes confirm the mere guesswork. —See also Uhrlandt and Schüler 1992.

of music analysis in addition to more computationally oriented methods.

David Leon Butts (1992) also used methods of statistical analysis in a study of the solo guitar compositions of Fernando Sor. The statistical procedures included frequency counts, percentages, and variances, and were directed at the keys, time signatures, forms, tempo indications, measure lengths, ornaments, harmonics, tuning, etc. Applying the method of multi-variate analysis, several parameters were weighted, and cross-classification tables were compiled, correlations, and multivariate comparisons of means were utilized. Butt's results establish Sor's compositional preferences: he liked the key of C major, the tempo andante, but his preferences also included such complex manifestations related to the density of activity, concentrated in certain parts of the measure. These results were then used to draw didactic conclusions for the pedagogical use of Sor's compositions in a logical fashion.

The Swiss mathematician Guerino Mazzola (1985, 1990) is one of the advocates of a mathematical theory of music. The most important distinctions he made are those involving mathematical descriptions of local musical structures and those involving mathematical descriptions of global structures in music. He developed a theory of musical modules which are in specific mathematical relationships with each other. While Mazzola used mathematical formulas for detailed descriptions of the manifold modular relationships, his computer system RUBATO is able to manipulate single musical components within each complex structure of music. (See also Stange-Elbe 2000.) He, thus, has access to audible results of slight mathematical changes in his analytical descriptions of music.

Continuing a trend that had already started in the 1980s, computer-assisted analytical methods shifted from statistical methods to methods drawn from artificial intelligence and cognitice sciences. This shift can be exemplified by several important research projects. John Schaffer (1992, 1994), for instance, proposed and developed a PROLOG-based computer program[120] that enabled the user to define and change analytical criteria while the program was running, i.e. without having to rewrite the program itself. Thus, "the user interacts with the program by repeatedly asserting sets of criteria that the program tests, refines, and feeds back as relevant information to the user – or, if deemed significant, to itself, for further examination. . . . The power of the system comes not from what it does, but from how it does it. In the best sense, it emulates the human processes of heuristic exploration, but it does it much more quickly, more consistently, and, more importantly, in an interpretative manner. The computer is no longer relegated solely to the role of user-interpreted data generation and manipulation, instead it is empowered with the ability to assess and adjust continuously to new information while continuously interacting with the human analyst." (Schaffer 1992, 147.) Using the concept of nodes and spines, Schaffer formalized a flexible PROLOG data structure for expert systems. Nodes represent all discrete dynamic objects such as notes and rests. All discrete nodes are linked by spines, creating sequentially ordered lists. The advantage of

---

[120] PROLOG is a programming language for rule-based or logic programming, oriented to action when declared conditions are met. It is based on the first-order predicate calculus of mathematical logic.

this system is that all analytical structures need to be created only once; editing the event lists is made very easy. The program, then, is able to "use various programmer-defined concepts to begin inferring relationships and refining search strategies without significant user input. . . . In this sort of exploration, the program begins by examining all combinations of event groupings employing a forward-referencing depth-first search heuristic intrinsic to the *Prolog* environment." (Ibid., 153.) Schaffer used this system to analyze selected atonal music, in a manner related to analysis based on set theory. He used fuzzy logic to include certain degrees of uncertainty. Schaffer found this procedure especially useful with respect to searching for the manifold hierarchies and interrelationships in music. Through inclusion of fuzzy logic, the program "could gain the ability to evaluate and assess musical materials in a manner enhanced by continuous reassessment and adjustment based on the ever-changing vagueness weights of previously observed" phenomena (ibid., 155-156). To exemplify the value of his new analytical procedures, Schaffer analyzed Anton Webern's *Six Bagatelles*, op. 9.

Marc Leman (1995a) designed a psycho-acoustical model for "tone center recognition and interpretation" drawing on research in musicology, psychology, computer science, neurophysiology, and philosophy. Leman used his model to analyze perceivable tone centers in music, using musical sound as the program input, thereby avoiding symbol-based paradigms in which music is conceived as a set of symbols (like in a score). Instead, he developed a "subsymbolic" representation of music, that is a representation of the sound. Leman's computer program is strongly grounded in psychoacoustic research and includes, for instance, self-organization and the ability to learn. The main approach is based on "schemas" in that the perception of specific incoming (perceived) images might be actively controlled. His approach allows for the notion of context sensitivity. "The role of an active schema is particularly relevant in cases where previous semantic images are reconsidered in the light of new evidence. Consider a sequence containing the chords IV-V-I. After hearing the first chord, the tone center will point to the tonic that corresponds with degree IV. It is only after hearing the rest of the sequence that the first chord can be interpreted in terms of its subdominant function. The schema should thus control the matching process and adapt the semantic images in view of new evidence." (Leman 1995a, 126) The output of the computer analyses was compared with 'traditional' analyses by a musicologist. Using what he calls "tone center recognition analysis" and "tone center interpretation analysis", Leman discussed differences between analyzing mere melodic pieces and analyzing predominantly harmonic pieces. While Leman's approach to tone center recognition was less successful in analyzing melodic pieces, his results also suggested that tone center recognition and rhythmic grouping are interrelated.

Similar to Leman's connectionist model, i.e. a model that makes use of brain-style computation[121], Don L. Scarborough, Ben O. Miller, and Jacqueline A.

[121] Connectionist systems make use of 'brain-style' computation, i.e. making use of a large number of interconnected processors operating in a strong parallel distributed fashion. Connectionist approaches embody learning, constraint

Jones (1991) suggested a connectionist model for tonal analysis. Unlike other, similar, approaches to tonal analysis that fail to deal with aspects of human perception of music and that fail to explain musical similarity, the approach of Scarborough et al. included the design of a network for "tonal induction," which simulates the perception of tonal relations and similarity. In their network, the "key node" that is most active controls the mapping of the notes, i.e. the various relationships between the keys. "Singling out one key node and disabling the others can be accomplished by letting the output of key nodes be a non-linear sigmoidal function of the input, and by adding inhibitory connections between key nodes." (Ibid., 58) Unfortunately, the model described has neither been tested on a large amount of musical data nor has it been compared to a psychological experiment that could demonstrate how well the networks simulate human perception.

Ilya Shmulevich (1997), while carrying out dissertation research on properties and applications of monotone boolean functions and stack filters, designed a computer system to recognize and classify musical patterns. His goal was to create a system which could minimize pitch and rhythm recognition errors produced when trying to match a scanned pattern with a corresponding target pattern. To recognize perceptual errors, Shmulevich applied (a modified version of) Carol L. Krumhansl's key-finding algorithm, which provides a most likely tonal

---

satisfaction, feature abstraction, and intelligent generalization properties. (See especially Todd and Loy 1991.)

context for given musical patterns.[122] Based on this algorithm, the computer calculated a sequence of maximum correlations. The results were then weighted for perceptual and absolute pitch errors. Other parts of the program computed the complexity of rhythm patterns with the goal of weighting possible pitch errors. Shmulevich concluded that a future application of this system could be the computerized search for compositions containing the closest match with a memorized melody (target pattern).

David Cope (1991, 1996) developed the LISP-computer system "Experiments in Musical Intelligence" (EMI), which combines analysis and composition processes. His goal was to write music in a specific musical style. Cope's analyses are based on hierarchical analysis, drawing on Schenkerian analysis and on Chomsky's generative grammar of natural languages. Cope's EMI as well as his "Simple Analytic Recombinancy Algorithm" (SARA) can analyze each component of a composition for its hierarchical musical function, match patterns for "signals" of a certain composer's style, and reassemble the parts sensitively, using techniques drawing on natural language processing (Cope 1996, 28). Part of the analysis process involves a pattern searching algorithm that, in contrast to pattern-searching algorithms by other authors, seek patterns without any preconceived notion of their content. That means, the analyst does not need to know which patterns are supposed to be matched. "EMI

---

[122] See Krumhansl 1990 and Takeuchi 1994. This key-finding algorithm is based on the observation that tones that are sounded most frequently are, in a specific tonal context, the ones with a high probe of tone ratings. See also Shmulevich 1997, 65.

employs a limited set of variables called controllers, which affix musical parameters to vague outlines within which patterns are accepted as viably recognizable." (Ibid., 36.) Many compositions generated on the basis of analytical results are proof of Cope's success.

Mira Balaban (1992) described computational procedures that focus on hierarchical relationships in musical activities and on the aspect of time in such activities. The formalisms used in this approach support the following descriptions of music:

- partial descriptions (musical structures and patterns of a composition),
- complete descriptions (fully specified pieces),
- implicit descriptions (some processing is needed to find out the denoted structured piece), and
- explicit descriptions (explicitly specifies the sound properties).

Balaban's representation allows grouping of musical structures (hierarchies) over time, without implying conclusions about the "grouped object". Balaban's formalism was intended to explore musical *activities* in a standardized form. Analysis is only one of these activities that the system can support. Others are composition and tutoring. However, the *analytical* extension of this system has not completely been realized yet.

H. John Maxwell (1984, 1992) developed a rule-based expert system that performed harmonic analysis of tonal music. One of the main problems of this project was the distinction between vertical sonorities that are "chords", i.e. sonorities that have a harmonic function, and other sonorities that don't: "IF a sonority consists of only one note, OR it consists of two notes that form a consonant interval other than a perfect fourth, OR it contains of three or more notes forming only consonant intervals, THEN it is a *consonant vertical*, OTHERWISE it is a *dissonant vertical*" (Maxwell 1992, 337.) Maxwell distinguished between several dissonance levels, several strengths of beats for various meters, and several strengths of harmonic functions. All rules were implemented in a LISP-program. But while some rules could be transformed into a relatively simple LISP-syntax, others required extensive programming, for instance, a rule on finding pivot chords for modulations. "The rules are interpreted by a forward-chaining inference engine that uses a prioritized agenda to control conflict resolution. The rule base is partitioned into various phases of analysis such as non-harmonic tone identification, chord recognition, determination of cadence and modulation, and functional analysis of chords. This partitioning, along with priorities that are assigned to individual rules, helps to focus the activity of the system. In addition, the mechanism that matches rules against the musical network uses a list of currently active nodes called a 'focus of attention' to restrict the size of the conflict set. Several control-oriented rules were added which manipulate the agenda and the focus of attention." (Ibid., 345.) Maxwell analyzed three movements of J. S. Bach's *Six French Suites*. While most parts of the analyses were correct, a few failures helped clarify some problems inherent in building a knowledge base for musical analysis.

For her dissertation research, Judy Farhart (1991) developed a GCLISP-computer program that could identify keys. It was a knowledge-based (expert) system with rules of musical syntax and syntactic procedures, and was written to simulate intelligent behavior, specifically learning processes as well as interactive and interpretative procedures. The input data (MIDI) were interpreted to identify note names by reiterating possible paths in a tree structure, applying the knowledge rules of recognizing the tonality in a specific key. Farhart's artificial intelligence procedures of key identification had its potential to identify proper note names, matching them with all other notes within a specific key.

At the University of Nijmegen in the Netherlands, Peter Desain and Henkjan Honing launched one of the most extensive research projects that involves research on music cognition and that applies means of artificial intelligence.[123] Some of the projects and procedures, developed as part of this broad research project, named "Music, Mind, Machine," are related to computer-assisted music analysis.[124] All of their analytical procedures are part of the LISP-based POCO software package (see, for instance, Honing 1990). Most of the projects within "Music, Mind, Machine" use digital sound as the source of the analyses, aiming at performance practice and related issues, including structures of performed music.

---

[123] This research is based on preceding studies by Peter Desain and Henkjan Honing, published partly in Desain and Honing 1992. The large-scale project was lounched in 1996/97 with several post-doctoral and other positions, which initially were filled by Peter Desain, Henkjan Honing, Rinus Aarts, Hank Heijink, Ilya Shmulevich, Renee Timmers, and Luke Windsor. In 1998, Huub van Thienen and Paul Trilsbeek joined the team; Ilya Shmulevich and Luke Windsor left.
[124] A detailed description of the research projects, many of the published articles, and the software package are available on-line at http://www.nici.kun.nl/mmm/.

As part of the "Music, Mind, Machine" studies, a current project deals with matching performences (in the form of digital sound) with their printed score (see Desain 1998a). Hereby, the timing is of special interest, since expressions in timing (of performed music) can vary by up to multiples of the original (notated) value of notes. The program developed was able to extract patterns of expressive timing and calculate local tempi. The matching editor made use of structural information, taken from the score, and produced better results than already existing 'structure-matcher.'[125] However, more detailed knowledge of the wide variety of musical structures is necessary to make the program more robust and more successful.

Another project of the "Music, Mind, Machine" studies is related to vibrato. The project's goal is to investigate empirically the relationship between vibrato, musical instruments, and global tempo. The digital audio of several commercial recordings of "Le Cygne" by Saint-Saens as well as performances of the same piece with different instruments have been analyzed specifically regarding expressions in vibrato. The knowledge obtained from these analyses was condensed into a formal computational model that can predict the nature of vibrato performed on different instruments in different structural relationships.

---

[125] Those existing 'structure-matchers' are developed and used in different contexts and for different tasks. Some focus on real-time matching (Dannenberg 1984; Vercoe 1984; Vantomme 1995), others on off-line analyses, for which the analysis is more important than the efficiency of the program. Most of the 'structure-matchers' match primarily pitch, sometimes in combination with time information. The "Music, Mind, Machine" matcher matches pitch and time.

Furthermore, it can be applied to make synthesizers more 'intelligent' in their implementation of vibrato to signals. (See Desain 1998a; Desain, Honing, Aarts, and Timmers 1998.)

Another project within "Music, Mind, Machine" is directed at the perception and performance of grace notes. Results of analyses suggested that not only tempo but also the structural function of a grace note might influence its duration. From the musicological literature, the research team drew several hypotheses about the structural classification of grace notes and the effect of this classification on their durations. They found that, although grace notes in certain structural categories are consistently played longer than grace notes in other categories, the major influence on grace note timing seems to be stylistic. They also found that some grace notes get longer as the tempo decreases, while others retain approximately the same duration. The authors considered this as strong evidence against the notion of relational invariance across different tempi. (Desain 1998a, 8; see also Windsor, Desain, Honing, Aarts, Heijink, and Timmers 1998.)

The quantization of temporal patterns[126], i.e. their subdivision into small finite increments that are measurable, is another project within the "Music, Mind, Machine" studies. Objects of this project are the actual tone durations in performed music, which deviate considerably from the notated durations. The

[126] Quantization of temporal patterns is the subdivision of these temporal patterns into small finite increments. These increments are also called "grids." In this project, quantization is used to objectively measure deviations of performed note values from the notated tone durations.

research shows that those deviations are related to the musical structure. Several elementary models for tempo deviation and for grid-based quantization have been developed. The research is ongoing, like many other projects within "Music, Mind, Machine." (See Desain 1998a; Trilsbeek and Thienen 1999; Cemgil, Desain, and Kappen 1999.)

Another computer program that was used in several research projects is David Huron's Humdrum toolkit (Huron 1993c, 1995, 1999a). It makes use of the *kern* (alphanumerical) music representation. The capabilities of Humdrum's toolkits, a collection of more than 70 interrelated software tools, are broad and range from statistical analysis regarding pitches, tone durations, and intervals to classifications of musical events, melodic search procedures, and harmonic analysis. Several researchers have used Humdrum for specific music analytical tasks. Denis Collins and David Huron, for instance, collaborated in a project on voice-leading in cantus firmus-based canonic compositions. They specifically analyzed the canonic compositional rules of Zarlino, Berardi, and Nanino. The study showed how well described musical practice is in theoretical treatises (Collins and Huron 2000).

Unjung Nam (1998) analyzed pitch distributions in Korean court music. Using Humdrum, Nam found evidence (similar scale intervals, similar phrase-ending tones, and similar tone-duration distributions) that a genre-related tonal hierarchy may exist in traditional Korean court music.

Analyzing 75 fugues by J. S. Bach with the Humdrum toolkit, David Huron and Deborah Fantini (1989) provided music theoretical evidence for the experimentally observed phenomenon that, in polyphonic music, entries of inner voices are more difficult to perceive than entries of outer voices. The study showed that Bach was allegedly much more reluctant to use inner-voice entries in five-voice textures than in three- or four-voice textures. Huron and Fantini hypothesized that Bach tried to minimize perceptual confusion in compositions with a higher textural density.

A different approach to computer-assisted music analysis is taken at the University of Karlsruhe in Germany in a research project on information structures in music. Scholars there are currently trying to model musical structures with rule-based systems. Stylistic characteristics are of special interest. As part of this research, Dominik Hörnel (2000) described a neural network system for analyzing chorales, in which 'harmonic expectations' are central measurements. The analyses are based on probability calculations. Hörnel showed how this neural network system could be used to falsify the authorship of a chorale attributed to Johann Sebastian Bach.

2.7. Synopsis

Computer-assisted music analysis developed rapidly since first attempts during the 1950s and 1960s. While analytical methods drawn from statistics and information theory dominated up to the end of the 1970s, other approaches became more important around 1980 and thereafter: set theoretical analyses, transformational and Schenkerian analyses as well as cognitive and artificial intelligence approaches. During the 1990s, computer-assisted music analysis became more oriented towards performance-based analyses in connection with cognitive and artificial intelligence.

However, communication among the researchers appears to have been minimal. At least before the 1990s, many attempts of computer-assisted music analysis were not recognized by researchers in the same field. Thus, music theorists were unable to learn from one another's mistakes. One reason could be the lack of a journal related to the problems of computer-assisted music analysis. Journals like *Computers in the Humanities* and the *Computer Music Journal* were much broader in their orientation. In 1973, Jerome Wenker tried to establish the *Computational Musicology Newsletter*; he wrote in the Editorial Foreword of the first issue: "During the past few years the number of individuals active in the applications of computers to musicology has greatly increased. As a result of this, it seems that an attempt to distribute information on activities in this field would, even on a relatively informal basis, be of general assistance. . . . The major emphasis is on increasing communications in order to minimize wasted time and resources caused by duplication of efforts. This will make it possible for individuals beginning projects to obtain assistance from -- while also providing fresh insights to -- more experienced researchers and for individuals of all levels of experience to exchange ideas and approaches in the forum of a continuous conversation." (Wenker 1973b, 1) However, the *Computational Musicology Newsletter* was short-lived. More successful in publishing new methods of computer-assisted music analysis and establishing a basis for communication were, later, the series *Computing in Musicology* (successor of the *Directories of Computer Assisted Research in Musicology*, founded in 1985 by the Center for Computer Assisted Research in the Humanities), the journal *Computers in Music Research*, founded in 1989, and the *Journal of New Music Research* which grew out of *Interface* in 1994.

Another problem of the recognition of research has been the acceptance of dissertation research as a valuable source for the methodological discourse within the field of computer-assisted music analysis. In general, American dissertation research has often been influenced and stimulated by the research of faculty members, by existing software, or by theoretical systems. But even though some dissertations have been indispensable for spurring further developments in this area, many of them had little academic value. On the contrary, European dissertations, though infrequent, have had usually much more impact on academic research. But the more recent research in cognition and artificial intelligence has intensified interest in computer-assisted music analysis. The main reasons for American dissertations not yet having been widely disseminated is that, unlike European dissertations, they are not routinely published. Thus, they are excluded from historical overviews and other research papers.

From today's point of view, the first approaches to computer-assisted music analysis seem relatively simplistic, as they strongly emphasized the computer and less the research (i.e. the music theoretical problems). They usually dealt with only a few compositions, or single voice melodies, or even with short phrases of single voices. This limitation obviously effected the outcome of the research and its academic value. However, the simplistic nature of the research was mainly determined by the capacities of the computers in these early years. Negative evaluations of computer-assisted music analysis during the 1960s and 1970s were responsible for reservations against computer applications in music research. Our field still has to recover from this negative image.

A few conclusions can be drawn from studying the history of computer-assisted music analysis:

- Though many publications are of little value, some of them make important contributions and deserved to be more widely disseminated. However, even with newest cognitive research and research in the area of artificial intelligence, the proportion of expenditure to benefit is in most cases unsatisfactory.

- The productive use of different methods in computer-assisted music analysis seems to be independent of the musical genre. Most methods have been applied to many different musical genres.

- More complex analyses in the sense of interactive methods—comprising traditional, sociological, psychological, and historic-cultural aspects—show that neither a pure 'traditional' nor a pure computer-assisted analysis produce valuable results. Instead, computer-assisted music analysis needs to use both computational *and* traditional analytical methods.

- Several studies showed that the application of methods drawn on statistics and information theory is only successful when the greatest possible number of numerical characteristics are used as discriminators.

- Using methods derived from linguistics, from theories of structural levels, and from set theory, computer-assisted music analysis is based on 'traditional' music theory—in the sense of studying musical structures. Some successful research showed that the computer makes it possible to verify the analytical results and algorithms by using the reverse process, generating compositions.

- Finally, computer-assisted music analysis in the field of artificial intelligence is much more interdisciplinary. Especially the strong integration of psychological and cognitive aspects of music allows theorists to focus on basic human activities: on the creation of knowledge as well as on processes of composition and perception. This kind of research then focuses more on the philosophical question: How can I know / discover myself and the world?

Chapter 3

CLASSIFICATION OF METHODS OF COMPUTER-ASSISTED MUSIC ANALYSIS

"Bear in mind, however, that the computer does what it is told: even its most sophisticated procedures depend on the imagination of the researcher for instructions. . . ." (Jan LaRue 1970a, 197.)

3.1. Design of a System of Classification

The history of computer-assisted music analysis includes a great number of approaches. As was mentioned earlier, an important step to handle the methodological problems of music analysis involves reflecting on different methods. That includes the necessity of designing a system of classification. Up to this point, a classification of methods of computer-assisted music analysis was not possible, because neither a history of computer-assisted music analysis nor a complete bibliography were available. Both have been provided here.

Like 'traditional' methods of music analysis, methods of computer-assisted music analysis can be classified with regard to the kind of music analyzed, the methods used, the general approach taken, and so forth. But any classification needs to be based on a logical framework, which means that a certain classificational level (level of abstraction) has to be on an identical epistemological level (see Introduction). For the various approaches to, and studies of, computer-assisted music analysis, we can distinguish three main epistemological levels which would be important for a system of classification:

❖ the analytical methods applied,

❖ the form in which the music is analyzed, and

❖ the kind of music analyzed.

The kind of music analyzed refers to general 'types' of music, which can be distinguished from each other by either musical characteristics or the sociological function of the music. Those general kinds of music are Western art music, not Western art music excluding popular music (that can be either Western folk music or non-Western music), and popular music.

The form in which the music is analyzed refers to either notated music or performed music. Furthermore, notated music can be classified with regard to different types of notation.

The analytical methods, applied to computer-assisted music analysis, are statistical methods, information theoretical methods, set theoretical methods, other mathematical methods, hierarchical / transformational methods, spectral analysis, and methods drawn from cognitive sciences and artificial intelligence. All these general approaches can then, again, be divided into specific methods, as statistical methods comprise measurements for frequencies, probabilities, the chi square test, etc.

Since the outcome of any music analysis is strongly dependent on the methods applied, general methodological approaches need to be—in a system of classification of computer-assisted music analysis—on the highest epistemological level. Divisions into sub-methods are possible. The methods applied strongly depend on the representation in which the music is analyzed; thus, notation-based analysis and performance-based analysis should create the second highest epistemological level in a system of classification. That would leave the kind of music analyzed as a basis for the third epistemological level:

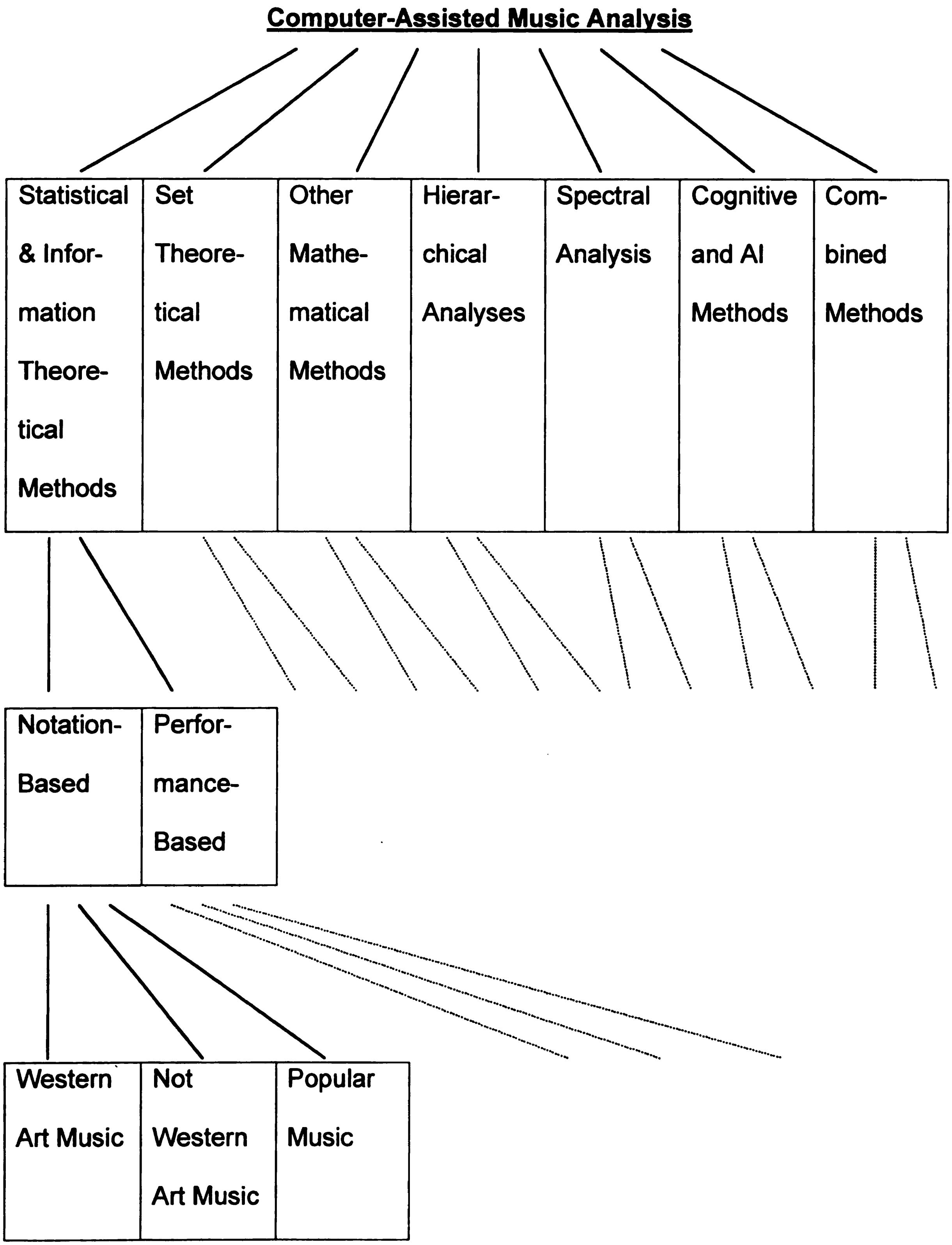


Figure 2: System of Classification of Computer-Assisted Music Analysis

3.

C

In

de

3.2

Sta

me

me

con

and

vari

Mar

infor

meas

enha

and

mus

use

stat

the

3.2. Approaches to Computer-Assisted Music Analysis and their General Characteristics

In the following, each category of the general methodological approaches will be defined and characterized. Most commonly used sub-methods will be named.

3.2.1. Approaches Drawing on Statistics and Information Theory

Statistical and information-theoretical approaches were (historically) the first methods applied to computer-assisted music analysis. Even though statistical methods and information-theoretical methods are distinct from each other, in computer-assisted music analysis they are usually applied together. Statistical and information-theoretical approaches comprise frequency, mean (average), variance, standard deviation, correlation, regression, the chi square test, entropy, Markov chains, probability, redundancy, and other measurements.

As was stated earlier, the application of methods drawing on statistics and information theory to music analysis is only successful when many different measurements are used. Positive correlations between these measurements enhance their efficiency as discriminators. While some approaches of the 1980s and 1990s included such a complex view on the use of statistical methods in music analysis, many did not. This led to false assumptions about the validity and usefulness of statistical methods in music analysis. Since the application of statistics and information theory to music analysis is not only the oldest, but also the historically most extensive, branch in computer-assisted music analysis, further verifications and evaluations of these methods are urgently needed. Chapter 4 of this text will contribute to this task.

3.2.2. Analyses Drawing on Set Theory

For the analysis of atonal music, a number of computer programs draw on Allen Forte's set theory and on further developments of Forte's theory. Most of these programs comprise such standard procedures as calculating prime forms (most often using Forte names), interval vectors, number of occurrences, as well as similarity and set complex relations.

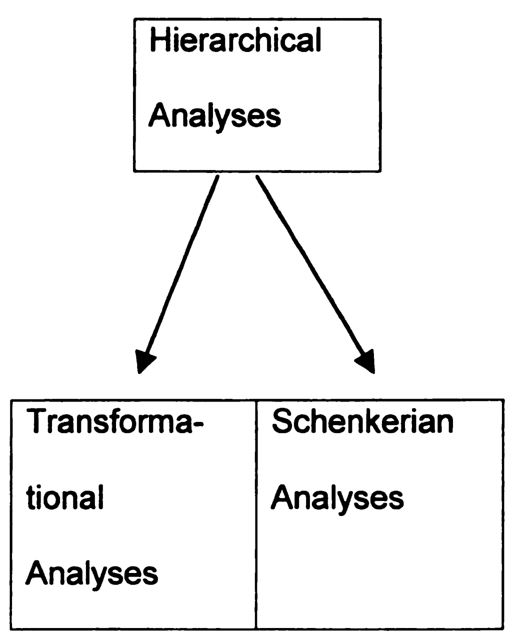
Within the limits of set theory, specifically within the limits of each function of similarity or set relation, computer-assisted music analysis drawing on set theory is doubtless a useful tool, because it is based on the same mathematical procedures that 'traditional' set theoretical analyses are based on. Computers reduce the time needed for calculation, and thus provide more time for the more important part of the analysis: the interpretation of the results of set theoretical data.

3.2.3. Other Mathematical Approaches

In some approaches, mathematical procedures, other than those mentioned already in 3.2.1. and 3.2.2., are applied to music analysis. Structural relationships can be explicated in many mathematical ways, some of which are fractal-like descriptions, formulas for symmetrical structures or for the relationships between groups of motives (describing their characteristics), as well as formulas for calculating the inner tempo of a composition, depending on meter, metrical relationships, and rhythmical structures, etc.

3.2.4. Hierarchical Approaches

Hierarchical approaches to music analysis try to apply reduction procedures to music in a sense that different hierarchies of musical structures show certain dependencies as well as, on a remote and abstract level, large-scale relationships (especially melodic and harmonic relationships). The basis for hierarchical approaches to music analysis is twofold: linguistic methods, especially those from the structuralistic grammar developed by Noam Chomsky, and Heinrich Schenker's concept of musical grammar. Regarding those two main approaches, "hierarchical approaches" can be divided into "transformational analyses" and "Schenkerian analyses":



Both methodological approaches comprise different abstraction levels, which can be obtained by applying certain abstraction rules (see 2.5.).

3.2.5. Spectral Analysis

In some cases of performance-based music analysis, spectral analysis is involved. Usually in those approaches, the sound spectrum is broken up to identify, for instance, the chord structure. While spectral analysis has been used in pure sound analysis for several decades, it became part of structural analysis of music in the late 1980s and early 1990s.

Spectral analysis is most often combined with other methods of computer-assisted music analysis.

3.2.6. Cognitive and Artificial Intelligence Approaches

Computer-assisted approaches of music analysis that draw on cognitive research and artificial intelligence use computer systems to simulate functions that are usually associated with human intelligence. Those functions include reasoning, learning, and self-organization (or self-improvement). Approaches of artificial intelligence to music analysis can exist in forms of neural network systems (see 2.6.) or expert systems[127]. The goal of expert systems is to solve problems by drawing inferences from a knowledge base acquired by expertise; expert

[127] The terms 'expert system' and 'knowledge-based system' are often used synonymously.

systems process information pertaining to a particular application and perform functions in a manner similar to that of a human who is an expert in that field.

Approaches drawing on artificial intelligence and cognitive research are, towards the end of the 20^{th} century, more and more part of interactive music systems that combine both analysis and composition.

3.2.7. Synopsis: Combined Methods

In some applications of computer-assisted music analysis, several methodological approaches are combined in one computer system. Those systems are oriented towards interactivity, so that the user can choose in real time, which methods of music analysis to apply. These choices depend strongly on the goal of the specific research.

Chapter 4

THE ANALYSIS PROGRAM *MUSANA* AS AN EVALUATION TOOL FOR STATISTICAL AND INFORMATION-THEORETICAL APPROACHES

> "In these two functions -- instruction and interpretation -- the researcher controls the fundamental musicality of the investigation. If the results are mechanistic, he cannot blame the computer." (Jan LaRue 1970a, 197.)

4.1. *MUSANA*: Possibilities, Use, and Structure

After constructing a historical account of the development of computer-assisted music analysis, and then developing a system for classifying the methods applied in computer-assisted music analysis, the claims of analytical methods need to be evaluated. One way of evaluating the claims of analytical methods involves using a computer program to formalize certain aspects of the methods of music analysis, aspects that then can be falsified[128] or verified.[129] It was exactly for this

---

[128] Falsification is the act of showing one instance of something to be false or erroneous to reflect on the potential of a theory. If such an instance is falsified, then its falsification also falsifies the theory from which it was logically deduced. (See Popper 1959, 33.)

[129] Verification is the act of showing one or more instances of something to be true or acceptable to reflect on the potential of a theory. Such a verfication is only temporary, for subsequent falsification(s) may overthrow it.

purpose that the computer program *MUSANA* was developed by the author and the German physicist Dirk Uhrlandt. *MUSANA* can be used for the actual analysis of music, as well as for the simulation and evaluation of analytical methods that can be applied to music, particularly those methods that draw on statistics and information theory. And in fact, *MUSANA* was used to evaluate premises of a few of the analytical methods described in chapter 2. The analytical results revealed the limitations of some analytical methods (and/or their implementation), while also showing the strengths and potentials of others. Reformulating the methods that emerged during the last few decades succeeded in two ways: it allowed a useful modification towards more successful methods, and it allowed other methods to merge into a new method.

In the following passages, *MUSANA*'s potentials, its musical representation (code), its organization of memory, and its program structure will be briefly described to provide the significance of *MUSANA*'s statistical and information-theoretical measurements. Then, four analytical studies are summarized. The statistical and information-theoretical methods embedded in them are evaluated, and finally another method is proposed, one that draws on information theory and that extends the methods to new domains.

4.1.1. *MUSANA*'s Music-Analytical Possibilities and Use

The first version of the computer program *MUSANA* was developed in 1992. It has been refined since, and various means of obtaining statistical and information-theoretical measurements have been added. *MUSANA* is written in the programming language Turbo-Pascal[130], specifically the Borland-Pascal version. *MUSANA* makes use of Borland-Pascal's procedure and unit concept. Furthermore, the program makes extremely efficient use of memory, especially since it uses dynamic memory when compiled in the 'protected mode'. When the *MUSANA* program was created, memory was very limited, so that almost all the memory available to the program—including the computer memory beyond the memory supported by the operating system DOS[131]—was used to store the encoded representation of music pieces. As more memory became available with new computers, more complex measurements drawn from information theory could be added.

MUSANA allows each separate voice to be entered via the standard computer keyboard and also allows standard MIDI files to be converted into the musical representation used in *MUSANA*. Standard notation can be displayed on the screen and edited, and the composition can be listened to via the internal loudspeaker of the computer. The methods of analysis help carry out stylistic analysis and classification of the music. The program creates histograms (of pitch and tone duration), searches for melodic or rhythmic patterns, calculates mean values of pitch and duration (as well as their standard deviations), computes correlations, and finally calculates different kinds of entropy.

---

[130] Pascal is a high-level programming language based on ALGOL. It emphasizes aspects of structured programming. Standard Pascal and Turbo-Pascal are different dialects of Pascal.

[131] *MUSANA* runs on all IBM compatible computers under DOS, in the DOS window of Windows, or under Virtual PC on a Macintosh computer.

MUSANA extends traditional methods of music analysis by computer-assisted methods, it does not replace them. It is crucial for the outcome of computer-assisted analysis to integrate both, computer-assisted and traditional methods of music analysis.

4.1.2. Encoding and Organization of Memory

MUSANA encodes only pitch, tone durations, and bar lines. Phrasing marks, dynamics, and other musical information are not included in *MUSANA*'s code. For *MUSANA*, a *numeric* code was developed which can easily be processed by procedures drawing on statistics and information theory.

After the input of each note (from a standard computer keyboard or from a converted standard MIDI file), pitches are assigned to integers in ascending order, not differentiating between enharmonic equivalents:

Octave									
	Sub-contra	Con-tra	Great	Small	One line	Two line	Three line	Four line	Five line
C	1	13	25	37	49	61	73	85	97
C#	2	14	26	38	50	62	74	86	98
D	3	15	27	39	51	63	75	87	99
D#	4	16	28	40	52	64	76	88	100
E	5	17	29	41	53	65	77	89	101
F	6	18	30	42	54	66	78	90	102
F#	7	19	31	43	55	67	79	91	103
G	8	20	32	44	56	68	80	92	104
G#	9	21	33	45	57	69	81	93	105
A	10	22	34	46	58	70	82	94	106
A#	11	23	35	47	59	71	83	95	107
B	12	24	36	48	60	72	84	96	108

Table 1: Pitch Code in *MUSANA*

In the *MUSANA*-code, the smallest possible tone duration is the 1/64-triplet, which is assigned two 'time units'. Following the mathematical relationships between the tone durations, all tone durations have the following values:

V
H
Q
E
S
1/
1/

To

are

3, 4

Wh
Hal
Qua
Eig
Six
1/32
1/64

It w

us

	Double dotted	Dotted	Normal	Triplet
Whole note	---	---	192	---
Half note	168	144	96	64
Quarter note	84	72	48	32
Eighth note	42	36	24	16
Sixteenth note	21	18	12	8
1/32 note	---	9	6	4
1/64 note	---	---	3	2

Table 2: Tone Durations in their Mathematical Relationship

To reduce the amount of memory required to store the encoded data, all values are encoded a second time via a field (2, 3, 4, 6, 8, 9, ..., 192) with the indices 2, 3, 4, ..., 23:

	Double dotted	Dotted	Normal	Triplet
Whole note	---	---	23	---
Half note	22	21	20	19
Quarter note	18	17	16	15
Eighth note	14	13	12	11
Sixteenth note	10	9	8	7
1/32 note	---	6	5	4
1/64 note	---	---	3	2

Table 3: Tone Duration Indices

It was already mentioned earlier that all musical data are saved dynamically by using all the memory that is available, that means beyond the 640K limit of the

DOS operating system. Hereby, each note is assigned to a 2-byte-variable (word). In the "High-byte" of the word element, measure line (if needed) and pitch (the value for rests is 127) are saved, whereby ties (if needed) and tone duration index are saved in the "Low-byte" of the word element:

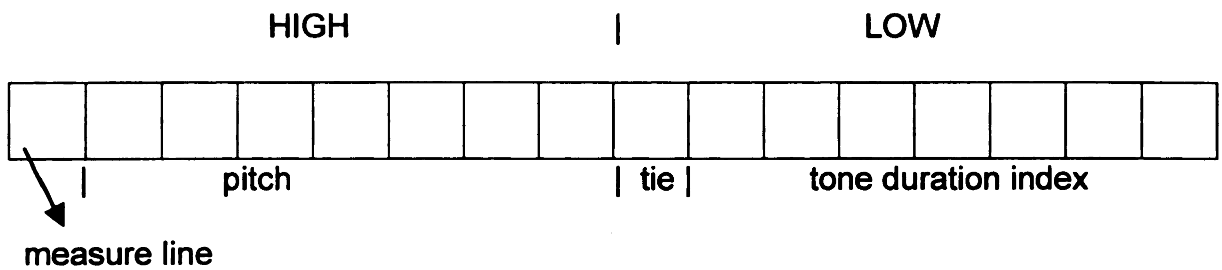
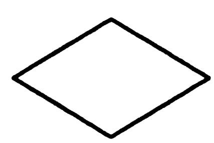


Figure 3: Word-element in *MUSANA*

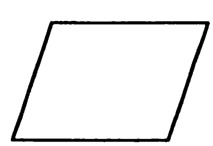
4.1.3. Partial Flowcharts of *MUSANA* and its Procedure "Analyzing"

The flowcharts below show the structure of the main program and the procedure "analyzing" in *MUSANA*. Hereby, the following shapes are used:

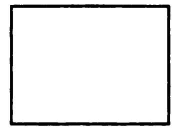
- Decision:



- Data input expected:



- Procedures, which aim at, or prepare, output:



- Start / End:

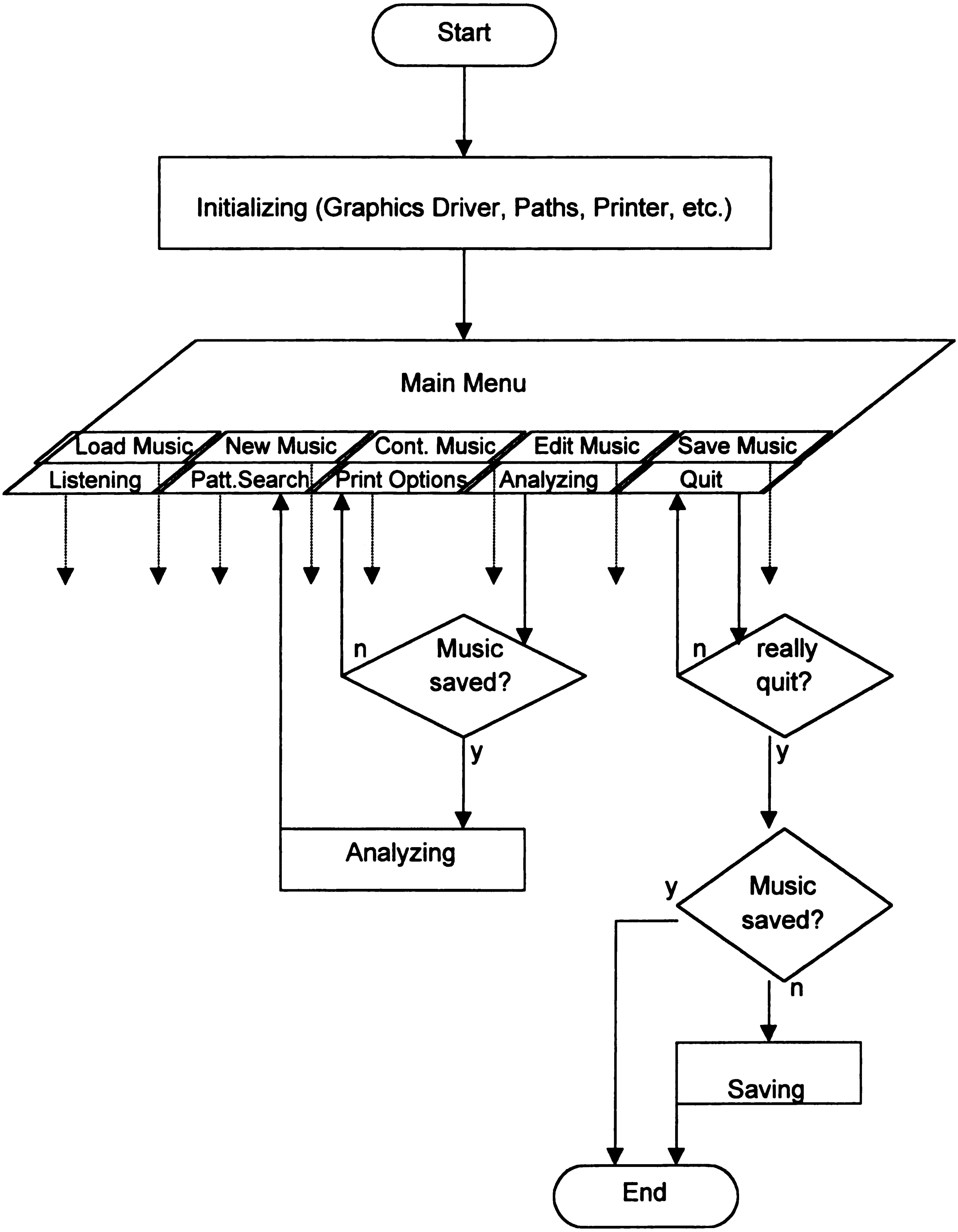


Figure 4: Partial Flowchart of *MUSANA*

Procedure "Analyzing":

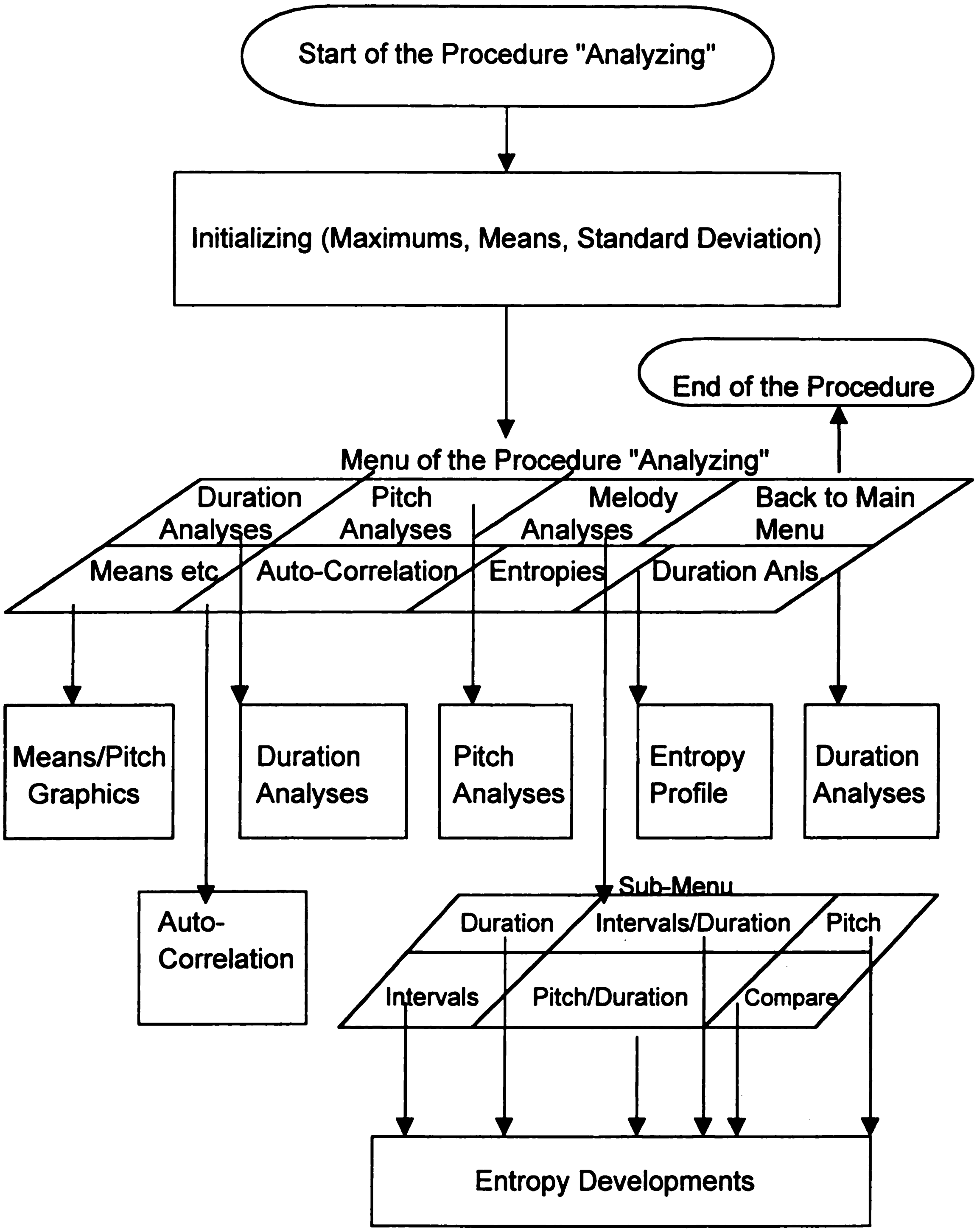


Figure 5: Flowchart of the Procedure "Analyzing"

4.2. Computer-Assisted Comparative Analyses of Haydn and Mozart Trios via Selected Statistical and Information-Theoretical Methods

The goal of the following studies was to evaluate some of the methods that have occupied a prominent position in the history of computer-assisted music analysis. The main methodological approach taken here (in evaluating certain analytical procedures) is falsification. Falsification, the act of showing one instance of something to be false or erroneous to reflect on the potential of a theory, is a powerful tool for evaluating methods of computer-assisted music analysis for two reasons: it neither requires analyzing a large number of compositions nor carrying out extensive verification. In addition, one of the studies will also introduce a new method (drawing on information theory) and show its effectiveness and its potential.

All of the following studies are based on analyses of Wolfgang Amadeus Mozart's *25 Pieces (five Divertimenti) for Bassett Horns* KV 439^{b}. Limiting the pieces to be analyzed to those of a specific composer and in a specific genre is necessary to eliminate distinguishing musical characteristics that are deduced by the following stylistic differences:

- the differences between styles from different periods,
- the differences between different personal styles, and
- the differences between different genres.

Focussing on analyzing only *one* set of compositions (in the same genre) allows one to reduce the probability of error, which could occur when different characteristics of style or genre influence the outcome of statistical and information-theoretical analyses. Analyses that focus on differences between genres, personal styles, or time periods can only be carried out *after* successfully applying certain measurements to analyzing music with a reduced number of distinguishing characteristics. If such an analysis with a reduced number of distinguishing characteristics did not precede, characteristics of time, style or genre can hardly be distinguished, i.e. personal style, for instance, can influence analyses of genre characteristics, and so forth.

Mozart's *25 Pieces (five Divertimenti) for Bassett Horns* KV 439^{b} were composed in 1783; the original instrumentation is not certain.[132] With the selection of divertimenti, a musical form was chosen that was historically a continuation of the suite; the character of the divertimento belongs to *Gebrauchsmusik*. All five divertimenti in this group of compositions have five movements.

4.2.1. *MUSANA* Study No. 1

Historically, many attempts to analyze music with a computer have concentrated only on the beginnings of compositions (incipits), making these the object of their

---

[132] See Köchel 1964, 471 ff., but especially 474. The *Neue Mozart Ausgabe* (Mozart 1975) assigned three bassett horns in F. The *Neue Mozart Ausgabe*, Serie VIII (Kammermusik), Werkgruppe 21 (Duos und Trios für Streicher und Bläser) was used for the analyses in this chapter. All pieces analyzed in this chapter are reprinted in Appendix C.

analyses. This was usually justified by the insufficient memory capacity of the computer. However, the authors usually did not reflect on the possible effects that the length of the musical excerpts has on the analytical results. *MUSANA* Study No. 1 will compare analyses performed with different lengths of the excerpts (incipits).

Each part of the first movements (Allegro) of both, Divertimenti I and II, of KV 439^b are analyzed in the following lengths:

- only the first 10 notes (and rests)
- only the first 20 notes (and rests)
- only the first 40 notes (and rests)
- only the first 60 notes (and rests)
- the whole piece.

The task is to compare the following statistical values, most often used in the past to supposedly characterize a certain musical style:

- average pitch (using the internal numerical code [of *MUSANA*] and considering the duration of each note) and its standard deviation
- the average interval size (disregarding the direction; half step = 1)
- the average tone duration (statistically, here, as a partial of a whole note)
- first order entropy (considering the duration of each note, not just their number of appearances)

The *MUSANA* results of the analyses are as follows:

	10 notes	20 notes	40 notes	60 notes	All (834)
Average Pitch & Stand. Deviation	57.0 ± 2.7 (g#')	58.2 ± 3.6 (a')	57.8 ± 3.0 (a')	58.4 ± 3.4 (a')	58.2 ± 3.6 (a')
Average Interval Size	0.8	1.1	1.8	2.1	2.4
Average Tone Duration & Stand. Deviation	0.2125 ± 0.0976	0.1776 ± 0.0843	0.2279 ± 0.2089	0.2255 ± 0.1836	0.2386 ± 0.2106
First Order Entropy	0.95604	1.65300	1.89431	2.01050	2.47483

Table 4: Allegro from Divertimento I, upper voice

	10 notes	20 notes	40 notes	60 notes	All
Average Pitch & Stand. Deviation	48.5 ± 3.7 (c#')	52.1 ± 5.8 (d#')	53.4 ± 4.1 (e')	53.6 ± 4.2 (f')	52.9 ± 4.2 (e')
Average Interval Size	1.3	1.4	1.7	1.9	2.5
Average Tone Duration & Stand. Deviation	0.2125 ± 0.0976	0.1776 ± 0.0843	0.2286 ± 0.1650	0.2052 ± 0.1418	0.1922 ± 0.1302
First Order Entropy	0.95604	1.75553	2.00176	2.06143	2.47987

Table 5: Allegro from Divertimento I, middle voice

	10 notes	20 notes	40 notes	60 notes	All
Average Pitch & Stand. Deviation	36.9 ± 5.3 (c)	36.7 ± 5.8 (c)	41.1 ± 6.6 (e)	38.7 ± 7.0 (d)	41.6 ± 6.1 (f)
Average Interval Size	4.0	4.5	3.0	5.2	3.8
Average Tone Duration & Stand. Deviation	0.2125 ± 0.0976	0.1964 ± 0.0911	0.2311 ± 0.0821	0.2170 ± 0.1333	0.1976 ± 0.1258
First Order Entropy	1.21820	1.46880	2.35662	2.20022	2.71846

Table 6: Allegro from Divertimento I, lower voice

	10 notes	20 notes	40 notes	60 notes	All (416)
Average Pitch & Stand. Deviation	57.1 ± 3.7 (g#')	57.6 ± 3.5 (a')	57.8 ± 3.3 (a')	59.2 ± 3.8 (a#')	58.8 ± 3.8 (a#')
Average Interval Size	2.8	2.2	2.1	2.1	2.4
Average Tone Duration & Stand. Deviation	0.2222 ± 0.1534	0.1776 ± 0.1169	0.1757 ± 0.1179	0.178 ± 0.1332	0.1812 ± 0.1368
First Order Entropy	1.95212	2.04701	2.09673	2.35861	2.40463

Table 7: Allegro from Divertimento II, upper voice

	10 notes	20 notes	40 notes	60 notes	All (410)
Average Pitch & Stand. Deviation	48.1 ± 2.2 (b)	51.0 ± 4.3 (d')	50.0 ± 4.0 (c#')	51.8 ± 4.3 (d#')	52.3 ± 4.6 (d#')
Average Interval Size	1.9	1.8	2.0	2.0	2.3
Average Tone Duration & Stand. Deviation	0.2344 ± 0.1159	0.1806 ± 0.0952	0.1786 ± 0.0958	0.1838 ± 0.1190	0.1826 ± 0.1231
First Order Entropy	1.68077	2.27938	2.34430	2.3097	2.51913

Table 8: Allegro from Divertimento II, middle voice

	10 notes	20 notes	40 notes	60 notes	All (486)
Average Pitch & Stand. Deviation	40.8 ± 3.6 (e)	41.4 ± 3.4 (e)	41.2 ± 3.2 (e)	40.1 ± 3.6 (d#)	39.9 ± 4.9 (d#)
Average Interval Size	1.3	1.8	1.9	2.3	3.0
Average Tone Duration & Stand. Deviation	0.1250 ± 0.0000	0.1324 ± 0.0294	0.1326 ± 0.0298	0.1297 ± 0.0238	0.1288 ± 0.0240
First Order Entropy	0.32508	1.18372	1.13290	1.53338	2.14939

Table 9: Allegro from Divertimento II, lower voice

Evaluative results of the few calculations presented above provide an astonishing picture of the value of such calculations, at least taken separately, i.e. not as one component of more complex statistical measurements as multi-variate analysis, cluster analysis, or factor analysis. The interpretation of the test results can be summarized as follows:

- While the mean values of pitch do not vary much, their standard deviations may vary by more than 100%. In the middle voice of the Allegro from Divertimento II, for instance, the standard deviation from the pitch average for the first 10 notes is 2.2, but for the entire piece 4.6.

- Similarly, the average interval size varies considerably. The values for shorter incipits (10 and 20 notes/rests), in particular, are far from being close to the average of the entire voice. The upper voice of the Allegro from Divertimento I, for instance, shows 0.8 as the average interval size for the first 10 notes and 1.1 for the first 20 notes, but the average interval size of the entire voice is 2.4, i.e. three times more than the value for the first 10 notes.

- Not only can incipits not accurately characterize the entire piece, but even the values of the same parts (voices) within different pieces are not comparable. The average tone durations of the lower voices of both Allegros are 0.1976 and 0.1288, respectively—a difference of more than a sixteenth note.

- The calculations with regards to the lower voice of the Allegro from Divertimento II demonstrate the falseness of the assumption that an incipit's standard deviation from the average tone duration can be used to characterize a larger part of the piece or the whole piece. While the standard deviation of the first 10 notes is zero, the standard deviation of the first 20 notes is already 0.0294.

- First-order entropies seem not to be significant for a 10-note incipit. The entropies of all larger excerpts show a natural, and consistent, growth when the incipits become longer.

Using incipits as if they were representative of the whole composition has been common practice in computer-assisted music analysis since its beginning. Since evaluations of this practice have not been available, even during the 1990s, calculations based on incipits were put forth as adequate characterizations of compositions or even of a composer's style. The data provided in this study clearly show that there is no statistical basis for the assumption that incipits have a sufficient size for discriminatory tasks or style characterizations.

4.2.2. *MUSANA* Study No. 2

In the overwhelming majority of statistical analyses of music, researchers used the number of instances of tones as the statistical basis for calculating values like average (e.g., of pitch) and its standard deviation, without considering the durations of the tones. However, characterizing the lengths of tones provides structurally important information. For that reason, Study No. 2 focuses on the differences between using just the *number* of tones and the number of tones along with their *durations*. The analytical objects of this study were, again, each of the first movements (Allegros) of Divertimenti I and II of KV 439[b] by W. A. Mozart. The task was to compare the following measurements derived from statistics and information theory:

- average of pitch (using the internal numerical code) and its standard deviation, considering the duration of each note,
- average of pitch (using the internal numerical code) and its standard deviation, considering the number of appearances of each note,
- first-order entropy, considering the duration of each note,
- first-order entropy, considering the number appearances of each note.

The *MUSANA* results of the analyses are as follows:

	Average Pitch (duration)	Average Pitch (number)	Entropy (duration)	Entropy (number)
Allegro I, upper voice	58.2 ± 3.6 (a')	58.3 ± 3.9 (a')	2.47483	2.45432
Allegro I, middle voice	52.9 ± 4.2 (e')	53.1 ± 4.5 (e')	2.47987	2.52007
Allegro I, lower voice	41.6 ± 6.1 (f)	42.0 ± 5.9 (f)	2.71846	2.72288
Allegro II, upper voice	58.8 ± 3.8 (a#')	58.3 ± 3.6 (a')	2.40463	2.33449
Allegro II, middle voice	52.3 ± 4.6 (d#')	52.7 ± 4.7 (e')	2.51913	2.48277
Allegro II, lower voice	39.9 ± 4.9 (d#)	40.0 ± 4.9 (d#)	2.14939	2.26933

Table 10: Allegro I and II. Pitch Averages and Entropies

The results above do not show major differences between the values based on tone durations and those based on the number of occurrences. On the contrary, the results not only show a strong correlation between the values based on tone durations and those based on the number of occurrences, but also a strong correlation between the same voices of each Allegro (except for the entropy values of the lower voices). Based on the results shown above, it can be assumed that the statistical measurements average, standard deviation, and entropy may be useful for characterizing the harmonic and contrapuntal function of each voice within the three-voice texture.

While the attempt failed to falsify the statistically equivalent use of

weighting average, standard deviation, and first-order entropy by either number or duration, the results above can be compared to results of analyzing other pieces in order to falsify the assumption. Hence, the second movement and the fourth movement of the first Divertimento (both are Menuettos with Trios) shall be analyzed in the following:

	Average Pitch (duration)	Average Pitch (number)	Entropy (duration)	Entropy (number)
Menuetto I (2) upper voice	59.1 ± 3.4 (a#')	58.8 ± 3.3 (a#')	2.42058	2.42907
Menuetto I (2) middle voice	52.1 ± 3.9 (d#')	51.6 ± 4.5 (d#')	2.43248	2.50914
Menuetto I (2) lower voice	40.2 ± 5.8 (d#)	40.0 ± 6.0 (d#)	2.52766	2.53871
Menuetto I (4) upper voice	57.7 ± 4.6 (a')	57.8 ± 4.0 (a')	2.50437	2.39214
Menuetto I (4) middle voice	49.1 ± 5.5 (c')	48.9 ± 5.1 (c')	2.62501	2.56372
Menuetto I (4) lower voice	39.2 ± 5.5 (d)	40.3 ± 5.2 (d#)	2.45548	2.57779

Table 11: No. 2 and No. 4 from Divertimento I. Pitch Averages and Entropies

These results also show no large differences between the values based on tone durations and those based on the number of occurrences. The only exception is the lower voice of the the second Menuetto (no. 4), which shows a difference of a little bit more than a half step in the average of pitch. No. 4 also shows, in both upper and lower voices, a larger difference in the entropy value. However, no meaningful generalization could be made about the closeness of the values.

Within the framework of the chosen methodology (of falsification), the attempt failed to falsify the assumption that weighting average, standard deviation, and first-order entropy by either number or duration are equivalent. However, this failure certainly does not mean an automatic verification of the assumption. Such verification would require a much more extensive analytical foundation.

4.2.3. *MUSANA* Study No. 3

Earlier in this paper, a historical account of the development of computer-assisted music analysis was compiled. One unevaluated assumption could be found whenever the average size of intervals was used as a discriminatory characteristic. The authors usually did not consider the effect of the direction of the interval on the average interval size. Showing the differences between the general average of the interval size and the averages of ascending and descending intervals would require the calculation of all three values:

- the average interval size, disregarding the direction (half step = 1)
- the average size of all ascending intervals (half step = 1)
- the average size of all descending intervals (half step = 1).

Those values will be compared as follows, analyzing all voices of both, Allegro I and Allegro II:

	Average interval size	Average of descend. intervals	Average of ascend. intervals
Allegro I, upper voice	2.4	2.7	3.2
Allegro I, middle voice	2.5	2.6	3.1
Allegro I, lower voice	3.8	4.4	4.4
Allegro II, upper voice	2.4	2.7	2.5
Allegro II, middle voice	2.3	2.5	2.7
Allegro II, lower voice	3.0	5.2	5.7

Table 12: Allegro I and II. Average Interval Sizes

In some cases, the averages for both, descending and ascending intervals, show major deviations from the general average of the interval size. The extreme case is the lower voice of Allegro II, for which the difference between any of the averages of ascending or descending intervals is larger than a whole step. But even other voices show differences of up to a half step. The analyses of No. 2 and No. 4 of Divertimento I show similar results:

	Average interval size	Average of descend. intervals	Average of ascend. intervals
Menuetto I (2) upper voice	2.4	2.4	2.7
Menuetto I (2) middle voice	2.5	2.6	3.1
Menuetto I (2) lower voice	2.8	4.6	3.7
Menuetto I (4) upper voice	2.8	2.9	3.2
Menuetto I (4) middle voice	4.0	4.7	3.6
Menuetto I (4) lower voice	3.6	3.7	3.6

Table 13: No. 2 and No. 4 from Divertimento I. Average Interval Sizes

It can be concluded that the differences are too large to use the general interval size, separately from the averages of ascending and descending intervals, as a discriminatory characteristic.

4.2.4. *MUSANA* Study No. 4

The last study draws on information theory. In the past, the authors of many projects in computer-assisted analysis verified the idea that entropy is a useful tool for giving syntactical information about, and characterizing the structure of, musical compositions. If the measure of information, the entropy, is an expression of the syntactical structure of the music, then it must be possible to find the length of structurally important units in each piece of music by calculating the entropy for each order, i.e. for all possible lengths of such structural units. Then, the mathematical difference between the entropy of order n and the entropy of order n-1 should be the essential measurement for finding lengths of structurally important units in music. This difference is the growth of the entropy value for the next higher order (i.e. with one more tone):

$$(\text{growth of entropy})_n = \text{entropy}_n - \text{entropy}_{n-1}$$

This growth ("entropy development") can also be explicated by calculating the percentages of the growth of entropy of order n compared to the growth of entropy of order n-1, i.e. always taking the growth of entropy of order n-1 as 100%:

$$(\text{growth of entropy})_{n-1} = 100\%$$

$$(\text{growth of entropy})_n\ \% = (100\% \cdot (\text{growth of entropy})_n) \,/\, (\text{growth of entropy})_{n-1}$$

Defined by the entropy of higher orders, the percentage of $(\text{growth of entropy})_n$ is always smaller than $(\text{growth of entropy})_{n-1}$. But when $(\text{growth of entropy})_n$ suddenly decreases by a large percentage, i.e. whenever only little "syntactical information" is gained by adding one note to the unit, then this order must mark the length of structural units that are used more often throughout the composition.

Some observations on the basis of analyses of the Mozart trios for basset horns KV 439^b may substantiate our hypothesis, which includes

- that there are, in fact, significant changes in the growth of entropy, and
- that the growth of entropy can indeed be used for identifying the length of structurally important units.

Derived from an analysis of the upper voice of Allegro III (i.e., the first movement of the third Divertimento), Tables 14 through 16 display the *MUSANA* results of calculating entropies of orders one through sixteen for three characteristics: entropies of pitches; entropies considering both, pitch and tone duration; entropies of tone durations. For all entropy values, the growth of entropy (i.e. the mathematical difference between the entropy of order n and the entropy of order n-1) as an absolute value as well as in percentage, are calculated:

Order	Entropy (Pitch)	Growth of Entropy	in %
1	2.5264		
2	4.2612	1.7348	
3	5.3100	1.0488	60
4	5.6245	0.3145	**30**
5	5.7596	0.1351	**43**
6	5.8293	0.0697	52
7	5.8780	0.0487	70
8	5.9125	0.0345	71
9	5.9328	0.0203	59
10	5.9478	0.0150	74
11	5.9602	0.0124	83
12	5.9726	0.0124	100
13	5.9814	0.0088	71
14	5.9902	0.0088	100
15	5.9936	0.0034	**37**
16	5.9971	0.0035	103
17	6.0006	0.0035	100
18	6.0041	0.0035	100
19	6.0075	0.0034	97
20	6.0110	0.0035	103

Table 14: Allegro III, upper voice. Entropies (Pitch) and Growths of Entropy

Order	Entropy (Pitch)	Growth of Entropy	in %
1	3.3253		
2	4.9284	1.6031	
3	5.5212	0.5928	**37**
4	5.6921	0.1709	**29**
5	5.7927	0.1006	59
6	5.8545	0.0618	61
7	5.8969	0.0424	69
8	5.9251	0.0282	67
9	5.9428	0.0177	63
10	5.9552	0.0124	70
11	5.9639	0.0087	70
12	5.9726	0.0087	100
13	5.9814	0.0088	101
14	5.9902	0.0088	100
15	5.9936	0.0034	**37**
16	5.9971	0.0035	103
17	6.0006	0.0035	100
18	6.0041	0.0035	100
19	6.0075	0.0034	97
20	6.0110	0.0035	103

Table 15: Allegro III, upper voice. Entropies (Pitch and Duration) and Growths of Entropy

Order	Entropy (Pitch)	Growth of Entropy	in %
1	0.9454		
2	1.5489	0.6035	
3	2.0828	0.5339	88
4	2.5704	0.4876	91
5	3.0134	0.4430	91
6	3.3611	0.3477	**78**
7	3.6064	0.2453	**71**
8	3.7915	0.1851	**75**
9	3.9666	0.1751	93
10	4.1135	0.1469	84
11	4.2424	0.1289	88
12	4.3536	0.1112	86
13	4.4534	0.0998	90
14	4.5424	0.0890	89
15	4.6265	0.0841	94
16	4.7070	0.0805	96
17	4.7771	0.0701	87
18	4.8359	0.0588	84
19	4.8942	0.0583	99
20	4.9520	0.0578	99

Table 16: Allegro III, upper voice. Entropies (Duration) and Growths of Entropy

Considering only tone duration, the values relating to the growth of entropy do not reach below 71%; only three values (of orders 6, 7, and 8) are below 80%. The reason for the insignificance of rhythmic units must be seen in the dominance of long eighth-note runs in this piece and the uneventful rhythmic stucture in general. This is a result of a general characteristic of the genre chosen here (divertimento): the uneventful motivic-thematic structure as an inheritance from the suite.

The growths of entropy considering pitch or pitch *and* tone duration show values that are significantly low (below 50%) for the orders 4, 5, and 15, or 3, 4, and 15, respectively, i.e. for units with 4, 5, and 15, or 3, 4, and 15 notes. *MUSANA* also calculated the actual appearance of the most frequent units with 3, 4, 5, and 15 notes: These units refer to groups of notes with tone repetitions, triadic pitch organization, and a chromatic neighboring figure (ascending minor second - descending minor second). A by-hand-analysis of Allegro III supports the notion that these units are structurally most important for the composition.

Already the few results show the potentials of the proposed procedure of calculating the growth of entropy ("entropy development"). The procedure will especially be helpful in collecting and categorizing melodic and rhythmic units for melody and rhythm databases. (See the proposals in chapter 5.)

4.3. Summary

The music-analytical program *MUSANA* has been introduced here as a tool for music analysis drawing on statistics and information theory. It includes the statistical and information-theoretical measurements most commonly used for computer-assisted music analysis. It can be used for the evaluation of methods of music analysis proposed in the past. Two studies performed with *MUSANA* showed that the use of incipits is not statistically useful for characterizing a whole composition (especially not for characterizing a composer's style) and the general average of interval sizes is not useful without considering the directions of the intervals within these calculations. A third study failed to falsify the assumption that weighting average, standard deviation, and first-order entropy by either number of tones or by tone duration are equivalent. The last study showed how the growth of entropy could be used to identify structurally important melodic and/or rhythmic units by increasing the order (i.e. the size of the units); this procedure seems to be very valuable for further studies in computer-assisted music analysis.

Chapter 5

FINAL REMARKS: DIRECTIONS FOR FURTHER EVALUATION AND FOR NEW METHODOLOGIES

> "I should like to suggest that computer analysis will become one of the most important directions in musicology for the next generation. . . ." (Jan LaRue 1970a, 197.)

A methodological approach that uses falsification in the manner demonstrated in chapter 4 provides a powerful way to evaluate methods of computer-assisted music analysis. However, many questions remain about verification or falsification of methods of computer-assisted music analysis:

- To which kind of music are the chosen methods of analysis applicable?
- Using a specific method of analysis, which musical characteristics can influence the analytical results?
- How does each musical characteristic influence the analytical results?
- How can we separate those musical characteristics that influence the analytical results?
- Which of these musical characteristics are most influential for the chosen method of analysis?
- Is it possible to weight the musical characteristics in order to receive more objective analytical results?

- Which methods of music analysis are less useful and can be eliminated?
- How can we design a more interactive process of analysis, so that traditional methods of music analysis and computer-assisted methods of music analysis can merge in more useful ways?

Bearing in mind that all analytical results are influenced by the method used, answering all of these and similar other questions can help improve methods of computer-assisted music analysis. Some directions will now be suggested, which may be useful for new methodologies in the area of computer-assisted music analysis. Those directions can partly be applied to further research with *MUSANA*; most directions refer to a general methodology of computer-assisted music analysis:

- The studies with *MUSANA* showed that even single measurements drawn on statistics and information theory can be responsible for the success or failure of computer-assisted music analysis. But most measurements are interrelated with others. In future research, it will be necessary to describe in detail the correlations between the measurements applied, and how those correlations affect the analytical results.

- To evaluate different measurements and methodologies, the influence of period style, personal style, and genre on the analytical results should be minimized by conducting comparative analyses of music from only one genre, one composer, etc. In a second step, the comparative analyses can be extended to compositions with more differences in style and genre.

- Measurements like entropy are useful for describing the syntactical relationships within the music. But it is necessary to ask how such measurements and their analytical results relate to actual human perception. Empirical studies are necessary that correlate with structural analyses.

- Some approaches to computer-assisted music analysis were connected with the reverse process: composition. Composition is a powerful tool to verify analytical results, if the analytical results are complete enough to explicate rules for generating music. Not all approaches would allow reversing the analytical process, but if they do, such a reversal should be part of the methodology.

- Different methods of analysis are directed at different elements of music or at different kinds of structural descriptions etc. Combining different methodologies would result in more complete analytical descriptions. While such "combined analyses" have been rare in the past, they should be strongly supported in the future.

- Conducting structural analyses as described in *MUSANA* Study No. 4 show the necessity of databases for the most common melodic and / or rhythmic units in a certain style of music. Such databases are especially useful if they contain information about the style in which the melodic or rhythmic units most commonly occur, by which composers they were written, etc. The process of data collection can be automated by applying the method of analyzing the growth of entropy ("entropy development") and by saving the results in databases.

- The most recent approaches which draw on cognition and artificial intelligence aim at performance practices by analyzing musical sound rather than musical scores. Our knowledge of music and of cognitive processes related to performance would benefit from focussing on the relationships between notated music and performed music. The influence of musical structure on melodic or rhythmic expressions in music would be of special interest. This research may have a very practical goal in that it can make music technology more 'musical'.

- The design of a system of classification of computer-assisted music analysis was an important step for further research in this area. However, a more detailed catalog is needed which lists comprehensively all methods of computer-assisted music analysis that are available, and which lists the goal(s) of analysis that are supported by these methods. Such a catalog should include cross-references to the kind of music to which each specific method can be applied.

*   *   *

At the conference "Musicology 1966-2000: A Practical Program", on May 26, 1966, Jan LaRue speculated "that computer analysis will become one of the most important directions in musicology for the next generation." (Jan LaRue 1970a, 197.) Having reached the year 2000, we have to realize that LaRue's prediction did not come true. The question remaining is twofold: Why did computer analysis not come one of the most important directions in musicology? And: Do we really want computer analysis to become one of the most important directions? The history of computer-assisted music analysis as well as a few attempts of falsifying long-used methods show that:

- Researchers have not sufficiently been working together to advance in computer-assisted analysis.
- Many researchers had, and still have, only little knowledge of the methodological variety and of the vast number of attempts taken in computer-assisted music analysis.
- Results of computer-assisted music analysis have been accepted too easily, without sufficient verifications or falsifications.

While a history of computer-assisted music analysis and a system of classification of its methods have been provided here, researchers still need to become more critical of the methodologies used. Such a critical view should include our general goal: Music is the ultimate object of our profession, which certainly includes the discourse around it. The discourse around music is a specific goal and need of human intelligence. And while artificial intelligence can be used as a tool to observe and to stimulate the human intelligence, it cannot, and should not, replace it.

APPENDICES

APPENDIX A

OVERVIEW OF MEASUREMENTS DERIVED FROM STATISTICS AND INFORMATION THEORY

As a basis for the understanding of specific methodological discussions in this dissertation, some measurements derived from statistics and information theory will be briefly explained here. The measurements most frequently mentioned in this text are listed in the following in alphabetical order. For more detailed information or mathematical formulas see such standard works as Glass and Hopkins 1996, Golden 1952, Shannon and Weaver 1949, or Goldman 1968.

Arithmetic Mean (Average)

The arithmetic mean (sometimes called 'average') is calculated by dividing the sum of all elements (e.g., pitches, coded as a numerical value) by the number of elements.

Auto-Correlation

Auto-correlation gives information about the relation of one characteristic (e.g., pitch) to itself, shifted in time. — See also Correlation.

Chi Square Test for Goodness of Fit

The Chi Square Test for Goodness of Fit can calculate whether two samples (e.g., melodies) are equal or not. Thus, it compares observed and expected frequencies.

Correlation and **Regression**

Correlation gives information on the relationship between two (or more) characteristics, e.g. if two characteristics such as pitch and tone duration are dependent on one another linearly or not. The correlation coefficient is a statistical measure for linear dependence of characteristics.

For example, if the melodic contour of a song tends to move in a certain direction (ascending or descending), then there is a strong linear correlation of pitch and direction. In this case, the correlation coefficient would be either close to the positive maximum, one (ascending), or to the negative maximum, minus one (descending).

If two characteristics are correlated approximately in a linear fashion, it is often useful to estimate the progress of the characteristics through a progression line. The increase of this progression line (regression line) is determined by the regression coefficient.

Discriminant Function

The discriminant function uses multiple measurements to discriminate between two groups (e.g., to disciminate between two groups of folk songs that originate in different areas).

Entropy[133]

Entropy is a form of measurement found in the conceptual methodology of information theory and is not related to semantics but to syntax. It is an index of the degree of 'information' found by analyzing single elements (e.g., pitches or tone durations) or groups of elements taken as a unit. In the latter case, the entropy is of 'higher order'. The entropy is specifically the negative sum of all logarithms of the probability of each event multiplied by the probability of each event. (See Shannon and Weaver 1949, 49 f.) The average entropy of a melody, for instance, is the negative sum of all logarithms of the probability of each note multiplied by the probability of each note. In case of calculating the entropy of the second order, the specific succession of two notes are seen as *one* element.

Entropy Profile[134]

The entropy profile is a measurement for degree of average 'information' found by analyzing a class of elements (i.e., all occurrences of the pitch c' taken as a unit). For example, the entropy profile of pitches would determine the average degree of 'information' of all c' in a piece of music.

---

[133] Entropy, in information theory, was first defined by Claude E. Shannon in 1949. See Shannon and Weaver 1949, 49 f.

[134] For the mathematical basis of the entropy profile see Bandt and Pompe 1993. First applications of the entropy profile in music analysis was described in detail by Uhrlandt and Schüler 1992.

Factor Analysis

Factor analysis is a mathematical tool, which can be used to examine a wide range of data sets. The goal is to find factors which can be used to characterize a group of objects (e.g., songs), i.e. to find a group of objects with common characteristics.

Frequency

There are two types of frequencies: absolute frequency and relative frequency. Absolute frequency is the exact number of a specific class of elements (e.g., pitch class c), while relative frequency is the absolute frequency of a specific element related to the total number of elements. The relative frequency is always smaller or equal to one, because the denominator is always larger than or equal to the numerator. The quotation in percent results from the multiplication with the factor 100.

Kurtosis

Kurtosis refers to the flatnes or peakedness of a (distribution) curve, relative to the size of the standard deviation.

Markov Chains

A Markov Chain is a model for a sequence of events in which the probability of a given event (or grouping of events, i.e. event of 'higher orders') is dependent only on the preceding event (or event of 'higher orders'). For instance, the probability of a sequence of five pitches, i.e. a group of pitches of order five, would be dependent only on the preceding group of five pitches.

Monte Carlo Method

The Monte Carlo Method is a method of obtaining an approximate solution to a numerical problem by the use of random numbers. In music, this method was first applies to composition by Hiller and Isaacson (1959). Here, random sequences of integers were equated to notes, durations, dynamic values and playing techniques. These random integers were then screened by applying various rules and rejected or accepted, depending on the rules.

Probability

Probability is a measurement for the likelihood of occurrence of a chance event (element).

Redundancy

Redundancy is a measurement, taken from information theory, that gives information about the partial (or complete) repetition of 'message content', i.e. elements. (See also **Entropy**.) For instance, if there is an increasing number of a certain pitch or a certain melodic phrase, the entropy of this pitch or melodic phrase decreases and the redundancy increases.

Regression

See **Correlation**.

Skewness

Skewness refers to a (distribution) curve, which is asymmetrical.

Standard Deviation

The standard deviation is the square root of the **variance** (see also there). It refers to the average distance of elements (e.g., pitches) from their mean value.

Transition Frequency

Transition Frequency is the frequency with which certain elements (e.g., pitches) occur in some places when it is known that certain others occur in previous places.

Transition Probability

Transition probability is the probability of an element (e.g., a note or a group of notes) which follows another specific element (note or group of notes).

Variance and **Standard Deviation**

Variance and standard deviation give information about the distribution of the elements (e.g. pitches, tone durations, or intervals) around the mean, i.e. the average distance of all elements from the mean. The variance is calculated by permanently subtracting the mean from each element, squaring all results, adding them together and dividing them by the total number of all elements minus one. The standard deviation is the square root of the **variance.**

APPENDIX B

THE TECHNICAL BASIS OF COMPUTER-ASSISTED MUSIC ANALYSIS: REMARKS ON THE HISTORY OF COMPUTERS AND COMPUTING

The history of computers and computing cannot be seen as merely a history that starts with electronic calculators in the 1940s. The history of calculating machines and the science of computational strategies goes back hundreds of years. However, a comprehensive history of computing cannot be part of this dissertation. Only a short overview of the development of electronic computers and computing shall be given here, to help understand the history of computer-assisted music analysis.[135] The emphasis on the history of computing between the 1940s and the 1970s is related to the fact that this knowledge is often absent in contemporary discussions of computer applications in music.

The first functioning computer was "Z3," created in 1941 by the German Konrad Zuse. It was a program-controlled computer that used punched tape. However, computers—like the "Z3" —that used the dual system and floating point numerical representation were almost electro-mechanical machines because of their relay technique.

More important than Zuse's computers was the IBM Automatic Sequence Controlled Calculator, usually known as "Harvard Mark I." This computer was

[135] This overview is based on Campbell-Kelly & Asprey 1996, Rechenberg 1991, and Nash 1990.

constructed for Harvard University between 1937 and 1944. Its main designer was the Harvard researcher Howard H. Aiken. Once running, the electro-mechanic computer could store as many as 72 numbers, and "was capable of three additions or subtractions a second. Multiplication took six seconds, while calculating a logarithm or a trigonometrical function took over a minute" (Campbell-Kelly & Asprey 1996, 72-73). The input source for program codes were punched paper tapes. However, the machine was incapable of conditional branching, i.e. causing the program to select an alternative set of instructions, if a specified condition was satisfied, or otherwise to proceed in the normal sequence.

John Presper Eckert and John Mouchly's "ENIAC" (Electronic Numerical Integrator and Calculator; 1946) was the first fully electronic computer. It made calculations about one hundred times faster than calculations by a mechanical differential analyzer. A serious problem of this computer was the time it took to reprogram the machine, since it could not use punched cards for real time operations at the speed of 5,000 operations per second. (Punched cards could only be read at a much lower speed.) Instead, changing the program required re-wiring the computer: hundreds of patch chords connected different units of the computer to each other. Re-programming took between several hours and several days. Other problems were too little storage (only twenty numbers!) and too many tubes. However, after the famous mathematician John von Neumann became a consultant to the ENIAC project in 1944, deficiencies were resolved and a new design was developed. It was one of the most crucial designs for further computer developments: The idea of the "stored-program computer" was born, outlined in a plan for the post-ENIAC "EDVAC" (Electronic Discrete Variable Automatic Computer). Virtually all computers up to the present have been based on the John-von-Neumann-principle of "stored programs"—using the same memory for numbers as well as for instructions—enabling a rapid change from one program to another. After von Neumann's design, computers have had five functional divisions: input, memory unit, control unit, arithmetic unit, and output. Other new features were the use of binary numbers (ENIAC still used decimal numbers), and the serial execution of instructions.

While EDVAC was never actually realized, in 1949 Maurice V. Wilkes' "EDSAC" (Electronic Delay Storage Automatic Calculator) became the first full-scale universal digital computer with saved programs based on John von Neumann's principles. It used delay lines, reducing the number of vacuum tubes by five-sixth compared to ENIAC. Because of its *saved programs*, software design came into being with EDSAC. Eventually, programs were developed which translated other programs into machine code and could, thus, be understood by the hardware. In1950, the developers of EDSAC started to develop a "subroutine library," i.e. a library of programs for solving common problems, such as certain arithmetic calculations, etc. Even today, programming continues to follow the principle of organizing subroutines.

In the second half of the 1940s, IBM became the leading company in the computer industry. The "Card Programmed Calculator" became—in the late 1940s and early 1950s—the most often sold calculating tool. However, by the end of the 1940s, IBM had also developed several full-scale computers. IBM also developed the magnetic drum for the main memory (instead of mercury delay lines or electrostatic storage tubes). After setting up their own computer business, J. P. Eckert and J. Mouchly developed similar devices. After being taken over by Remington Rand, Eckert and Mouchly completed the development of their UNIVAC (UNIVersal Automatic Computer; 1951). It was the world's first commercially available fully electronic computer, and it became a market leader for its type. The UNIVAC was eventually the first computer the broader public had been introduced to during election night 1952, when it accurately predicted Eisenhower's win over Stevenson. After that, 'UNIVAC' became a generic name for computers.

The prediction of the election outcome also showed the great potential for computers in data processing for many business areas. Thus, in the early 1950s, there was a change of the main use of computers: a change from mathematical calculations to data processing. The first music applications date from the mid-1950s. (See chapter 2.2.) Dozens of computer businesses—mainly in the United States—emerged. Most of them were eventually acquired by bigger office-machine firms. But IBM re-entered the market with its IBM model 701 in 1952. The first real data processing computer was announced one year later: the IBM 702. This computer used a more reliable and faster tube technology (memory) and a modular construction; but most important, its magnetic tape systems made the UNIVAC's obsolete. IBM's superior marketing and its customer service helped gain the leadership in this area. The low-cost Magnetic Drum Computer

(IBM 650; 1953) was acquired by many institutions of higher learning. It reflected IBM's total-system view, i.e. the combination of computer development, programming, field service, customer transition, and training, which led to the eventual replacement of the electro-mechanic punched-card accounting machine in the early 1960s. IBM developed the 1401 model with transistors instead of tubes and core memory instead of the magnetic drum; peripherals were new card readers, punchers, high speed printers, and magnetic tape units. To avoid the high cost of machine replacements, IBM developed the programming system RPG (Report Program Generator), a business data processing language designed for analysts familiar with punched-card machines. This programming language is still in use today. Also, IBM itself developed software solutions.

Already by 1953, programming had become a serious research project at IBM. There, John Backus proposed a higher-level programming code, called Formula Translator (FORTRAN). His goal was to develop an automatic programming system which could produce machine code as good as that written by an experienced programmer with only short and logical commands. Finalized in 1957, FORTRAN became the first successful scientific programming language and is still in use today in certain dialects. An improved version, FORTAN II, followed in 1959. By the end of the 1950s, several other languages had been developed by other computer manufacturers or research groups: MAD, IT, ALGOL, etc. However, FORTRAN continued to dominate scientific applications. Last but not least, 'standardizing' FORTRAN made it possible to exchange programs, even if different makes of computers were used. ALGOL was, for several years, more common in Europe; eventually, even there FORTRAN took over a dominating position.

For business applications, the U.S. government initiated the development of COBOL (COmmon Business Oriented Language). It came into life in 1960 as "COBOL 60". This language was based on Business English, rather than on mathematical terms. This allowed non-programmers to understand the code, even though they would not be able to write it themselves. Hundreds of other programming languages were designed in the 1960s, but most of them died out. COBOL and FORTRAN dominated the programming world for the next twenty years.

In the early 1960s, IBM continued with a standardization process to achieve compatibility among all their computer components as well as their software components. The result was their System/360 (1964). However, programming turned out to be more costly than the hardware itself. Further developments were fully integrated circuits, giant number-crunching computers, and time-sharing computer systems (which allowed more than one user to execute programs concurrently).

The military had also played an important role in the emerging computer industry since World-War II. For their needs, the idea of real-time computing for a flight simulator at MIT was most important. For the purpose of real-time computing, computers with a much higher speed and a much higher reliability were needed than existing technology had to offer. Important developments were the core-memory, printed circuits, mass-storage devices, and CRT-graphical displays. Military projects also provided a 'platform' for further developments in software engineering.

The first large civilian *real-time* project was the airline reservation system SABRE (Semi-Automatic Business Research Environment) in the 1950s and early 1960s, and the Universal Product Code (UPC) in the early 1970s. First scanners were manufactured by IBM and NCR. These developments were of great economic importance: the whole manufacturing-distribution network became involved in electronic data tracking and automatic ordering, etc.

While in the early 1950s software was still supplied at no additional cost by the computer manufacturer, 'software contracting' soon developed: Corporations, such as the System Development Corporation (SDC), emerged. In the early 1960s, the software industry was booming. However, in the late 1960s, a software crisis emerged because of the much faster growing hardware industry and the incapability of exploiting the new hardware effectively (since large programs were needed). It took many years, before programming became a real engineering discipline with its "structured design methodology" and its development model as an organic process which would never really be 'finished'. The concept of 'software packages' emerged in the late 1960s; these packages were much more cost-effective than custom software. At the same time, large computer manufacturers decided to price their software and hardware separately.

The 1970s brought faster, and more reliable, integrated circuits, random-access disk storage units, semiconductor memory, more effective time-sharing, communication-based on-line computing, and virtual memory. In 1971, the 4004 microprocessor was announced by INTEL; it was the first "computer on a chip". The microprocessor was initially used for simple control applications and for (emerging) minicomputers, but soon it was used for full-scale computers. The first personal computer came on the market in 1977: the Apple II. The personal computer included a central processing unit, screen, keyboard, floppy disk drives, and a printer. In 1981, IBM announced its entrance into this new market with the IBM PC. Apple responded with the "Macintosh" (famous for its user-friendly point-and-click-software).

With the personal computer, new programming languages became important. BASIC (Beginners All-purpose Symbolic Instruction Code) was developed in 1964 by John Kemeny and Thomas E. Kurtz at Dartmouth College. It superseded FORTRAN not only in its simplicity, but also in its speed (of translation). It became the introductory language for many students, and in the mid-1970s, it became the first widely available programming language for the new personal computers. Pascal (1971) as well as the systems programming language C (1970; originally developed for the implementation of Unix) became more sophisticated and are still two of the most commonly used higher level programming languages. The Unix operating system, developed between 1969 and 1974 by Bell Laboratories, became the—to-date—most widely used operating system for multi-user environments. And while LISP (LISt Processing) was developed already in 1961, it became important decades later, especially in artificial intelligence research.

However, as early as the 1960s, the research of MIT psychologist and computer scientist J. C. R. Licklider suggested that computers could be used to augment the human intellect, but not to supercede it, as AI researchers at the time hoped. Licklider argued that computers should enhance the every-day-work of researchers, since computers spent most of the time not "thinking" but calculating and referencing. Licklider's theories promoted the development of interactive computing with graphical user interfaces, software engineering, and, years later, text processing (1980) and refined calculating software, etc.

During the last three decades, computer hardware costs have fallen dramatically. Changes in the nature of data processing have generally occured invisibly. More sophisticated applications are possible, and real-time systems as well as time-sharing systems have become common in many areas. The IBM PC has set the standard of personal computers up to the present, and Microsoft, contracted by IBM in 1980 to produce of MS-DOS operating system, grew to be the largest software company in the world, later producing Windows, Word, Excel, and other high-quality software products. In the last decade, Microsoft has become the symbol for a major shift from hardware to software. And the World Wide Web is a logical continuation of the demand for universal information and communication.

APPENDIX C

SELECTIONS OF W. A. MOZART'S *FÜNFUNDZWANZIG STÜCKE (FÜNF DIVERTIMENTI) FÜR DREI BASSETTHÖRNER* (KV 439^b)

The following pages reproduce the score of the W. A. Mozart pieces analyzed in chapter 4, i.e. numbers 1, 2, 3, 4, 6, and 11 of *Fünfundzwanzig Stücke (fünf Divertimenti) für drei Bassetthömer* (KV 439^b). The reproduced scores contain page numbers that refer to Mozart 1975.

2. Fünfundzwanzig Stücke (fünf Divertimenti)[*)]

für drei Bassetthörner[*)]

KV 439b[*)]

Divertimento I

1.

Komponiert angeblich zwischen 1783 und 1788[*)]


68
77
86
92
101

2. MENUETTO

Allegretto


16
26
1.
2.
simile
Trio
9
1.
2.
Menuetto
da dapo
3.
Adagio

4. MENUETTO


Trio

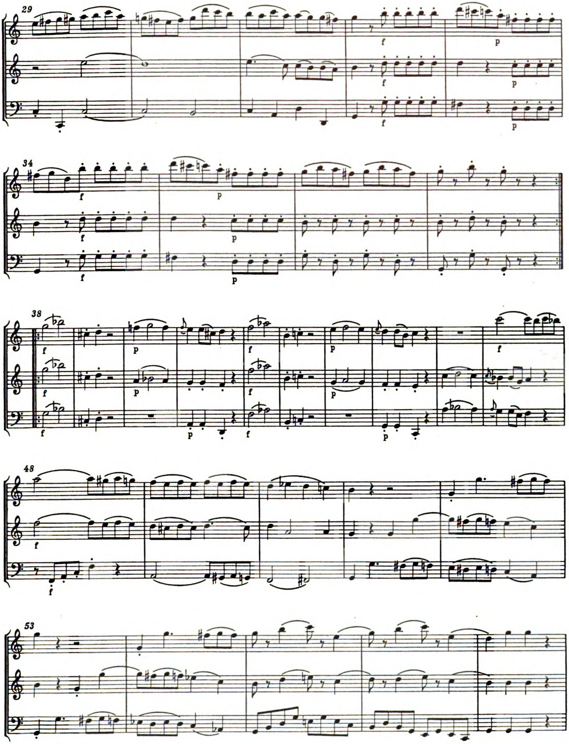

74
21
fp
ossia*):
fp

Divertimento II

6.
Allegro


24
29
33

Divertimento III


29
f
p
34
38
48
f
53


Vi-*)
simile
-de


88
90

BIBLIOGRAPHY

Bibliography

Aarts, Rinus, and C. Jansen. 1999. "Categorical perception of short rhythms," *Proceedings of the 1999 SMPC*. Evanston. 57. (See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Acht, Rob J. M. van. 1985. *De muzikale gebruiken in de oude adellijke abdij van Thorn, 1500-1800*. Gravenhage, Netherlands: author.

Adamo, Giorgio. 1984. "Towards a grammar of musical performance: A study of vocal style," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 245-254.

Adams, Charles R. 1976. "Melodic Contour Typology," *Ethnomusicology* 20 (1976): 179-215.

Agmon, E ytan. 1989. "A Mathematical Model of the Diatonic System," *Journal of Music Theory* XXXIII/1 (1989): 1-25.

__________. 1990. "Music Theory as Cognitive Science: Some Conceptual and Methodological Issues," *Music Perception* VII/3 (1990): 285-308.

__________. 1997. "Musical durations as mathematical intervals: Some implications for the theory and analysis of rhythm," *Music Analysis* XVI/1 (March 1997): 45-75.

Ahlbäck, Sven. 1997. A Computer-Aided Method of Analysis of Melodic Segmentation in Monophonic Melodies," *Proceedings of the Third Triennial ESCOM conference*. Uppsala, Sweden. 263-268.

Albright, Larry Eugene. 1988. Computer Realization of Human Music Cognition, PhD thesis, University of North Texas.

Allen, Paul E., and Roger B. Dannenberg. 1990. "Tracking Musical Beats in Real Time," *Proceedings of the International Computer Music Conference*. Glasgow: International Computer Music Association. 140-143.

Alphonce, Bo H. 1970. "Music theory at Yale - a case study and a project report," *Svensk Tidskrift for Musikforskning* LII (1970): 38-46.

__________. 1974a. The Invariance Matrix. Ph.D. thesis, Yale University.

__________. 1974b. "The invariance matrix as an analytical tool," *International Musicological Society: Report of the Eleventh Congress, Copenhagen 1972*, ed. by Henrik Glahn, Soren Sorensen and Peter Ryom.

Copenhagen: Edition W. Hansen. 228-35.

__________. 1980. "Music Analysis by Computer - A Field for Theory Formation," *Computer Music Journal* IV/2: 26-35.

__________. 1989a. "Computer Applications: Analysis and Modeling," *Music Theory Spectrum* XI/1 (Spring 1989): 49-59.

__________. 1989b. "Computer Applications in Music Research: A Retrospective," *Computers in Music Research* I (1989): 133-159.

Ames, Charles. 1989. "The Markov Process as a Compositional Model - A Survey and Tutorial," *Leonardo* XXII/2 (1989): 175-187.

__________. 1990. "Statistics and Compositional Balance (Computer Music Forum)," *Perspectives of New Music* XXVIII/1 (Winter 1990): 80-111.

__________. 1992. "Quantifying Musical Merit," *Interface* XXI/1 (1992): 53-93.

Anku, William Oscar. 1988. Procedures in African Drumming: A Study of Akan/Ewe Traditions and African Drumming in Pittsburgh. PhD thesis, University of Pittsburgh.

__________. 1992. *Structural Set Analysis of African Music*, vol. 1, Adowa. Legon, Ghana: Soundstage Production.

__________. 1993. *Structural Set Analysis of African Music*, vol. 2, Bawa. Legon, Ghana: Soundstage Production.

__________. 2000. "Circles and Time: A Theory of Structural Organization of Rhythm in African Music," *Music Theory Online* VI/1 (2000).

Aranovskij, Mark G. 1974. "Myslenije, jazyk, semantika," *Problemy muzykalnovo myslenija*. Moskow: Muzyka. 90-128.

__________. *Sintaksiceskaja struktura melodii*. Moskva, Russia: Muzyka.

Arcos, Josep Lluís, Ramon López de Mántaras, and Xavier Serra. 1998. "Saxex: A Case-Based Reasoning System for Generating Expressive Musical Performances," *Journal of New Music Research* XXVII/3 (1998): 194-210.

Ardizzione, E., Antonio Camurri, Marcello Frixione, and Renato Zaccaria. 1993. "A Hybrid Scheme for Action Representation," *International Journal of Intelligent Systems* VIII/3 (1993): 371-403.

Ariyoshi, Yusuke, Shinji Shimojo, and Hideo Miyahara. 1995. "Hyperscore: A

Design of a Hypertext Model for Musical Expression and Structure," *Journal of New Music Research* XXIV (1995): 130-147.

Arnold, Wasiuddin. 1985. "Raga rupa: Computer analysis and sangita-shastra," *Journal of the Sangeet Natak Academy* (India) LXXVI (April-June 1985): 9-35.

Arom, Simha. 1970. "Essai d'une notation des monodies à des fins d'analyse," *Revue de Musicologie* 55 (1970): 172-216.

__________. 1980. "Structuration du Temps dans les Musiques d'Afrique Centrale: Periodicité, Mètre, Rhythmique et Polyrhythmie," *Revue de Musicologie* 70 (1984): 5-36.

__________. 1991. *African Polyphony and Polyrhythm. Musical Structure and Methodology*. Cambridge: Cambridge University Press.

Ashley, Richard D. 1982. Toward a theory of instruction in aural skills. D.M.A. thesis. University of Illinois, Urbana-Champaign.

__________. 1986. "Design Considerations in KSM. A Knowledge System for Music," *CC-AI, Journal for the Integrated Study of Artificial Intelligence, Cognitive Science and Applied Epistemology* III/3 (1986): 269-284.

__________. 1989a. "Computer-based learning: Models and lessons for computer music systems," *Proceedings of the 1989 International Computer Music Conference*, ed. by Peter Desain, Henkjan Honing, and Klaus de Rijk. San Francisco, CA: International Computer Music Association. 9-12.

__________. 1989b. "A computer system for learning analytic listening," *Proceedings of the 1989 International Computer Music Conference*, ed. by Peter Desain, Henkjan Honing, and Klaus de Rijk. San Francisco, CA: International Computer Music Association. 5-8.

__________. 1989c. "Modeling Music Listening: General Considerations," *Contemporary Music Review* IV (1989): 295-310.

__________. 1990. "A computer program for analyzing computer musicians' problem-solving," *Proceedings of the International Computer Music Conference, Glasgow, 1990*. San Francisco, CA: Computer Music Association, 1990. 144-146.

Ashton, Alan Conway. 1971. Electronics, Music and Computer. Ph.D. thesis. University of Utah.

Atteslander, Peter, Christiane Bender, Jürgen Cromm, Busso Grabow, and Gisela Zipp. 1991. *Methoden der empirischen Sozialforschung*, 7th ed. Berlin: de Gruyter.

Auhagen, Wolfgang. 1989. "Ein Beitrag zur musikalischen Grammatik: Grundzüge der Tonalitätswahrnehmung bei Melodien," *Die Sprache der Musik*, ed. by J. P. Fricke. Regensburg: Bosse.

Avenary, Hanoch. 1973. Analysis of Musical Modes on a Quantitative Base," *Computational Musicology Newsletter* I/1 (1973): 13.

__________. 1977. "The Northern and Southern Idioms of Early European Music. A New Approach to an Old Problem," *Acta Musicologica* XLIX/1 (1977): 27-49.

Babbitt, Milton. 1955. "Some Aspects of Twelve-Tone Composition," *The Score and I.M.A. Magazine* 12 (1955): 53-61.

__________. 1960. "Twelve-Tone Invariants as Compositional Determinatns," *The Music Quaterly* 46 (1960): 246-259.

__________. 1961. "Set-Structure as a Compositional Determinant," Journal of Music Theory V/1 (1961): 72-94.

__________. 1965. "The Use of Computers in Musicological Research," *Perspectives of New Music* III/2 (1965): 74-83.

Baffioni, Claudio, Francesco Guerra, Laura Tedeschini Lalli. 1984. "The Theory of Stochastic Processes and Dynamical Systems as a Basis for Models of Musical Structures," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 317-324.

Baggi, Denis L. 1974. Realization of the Unfigured Bass by Digital Computer. Ph.D. thesis, University of California, Berkeley.

Bailey, Robert Lee. 1980. Music and Mathematics: An Interface in the Writings of Leonhard Euler. EDD thesis, State University of New York at Buffalo.

Baily, J. 1988. "Anthropological and Psychological Approaches to the Study of Music Theory and Musical Cognition," *Yearbook for Traditional Music* 20 (1988): 114-125.

Baker, Robert Allen. 1963. A Statistical Analysis of the Harmonic Practice of the 18th and Early 19th Centuries. Ph.D. thesis. University of Illinois.

Baker, Michael J. 1989a. An Artificial Intelligence Approach to Musical Grouping

Analysis," *Contemporary Music Review* III/1 (1989): 43-68.

__________. 1989b. "A Computational Approach to Modeling Musical Grouping Structure," *Contemporary Music Review* IV (1989): 311-325.

__________. 1992. "Design of an Intelligent Tutoring System for Musical Structure and Interpretation," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge, MA: The MIT Press. 466-489.

Bakhmutova, I. V., V. D. Gusev, and T. N. Tikova. 1989. "Repetition and Variation in Melody: Towards a Quantitative Study," *Musikometrika* 2 (1989): 143-168.

Balaban, Mira. 1988a. "A Music-Workstation Based on Multiple Hierarchical Views of Music," *ICMC Proceedings* XIV (1988): 56-65.

__________. 1988b. "The TTS Language for Music Description," *International Man-Machine Studies* XXVIII (1988): 505-523.

__________. 1989a. "The Cross-Fertilization Relationship Between Music and AI (Based on Experience With the CSM Project)," Interface XVIII/1-2 (1989): 89-115.

__________. 1989b. The Cross-Fertilization Relationship Between Music and AI. Technical Report FC-TR-022 MCS-314. Beer Sheva (Israel): Ben Gurion University of the Negev.

__________. 1989c. Music Structures: A Temporal-Hierarchical Representation for Music. Technical Report FC-TR-021 MCS-313. Beer Sheva (Israel): Ben Gurion University of the Negev.

__________. 1991. Music Structures: The Temporal and Hierarchical Aspects in Music. Technical report FC-035 MCS-327. Ben-Gurion University of the Negev.

__________. 1992. "Music Structures: Interleaving the Temporal and Hierarchical Aspects in Music," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge, MA: The MIT Press. 110-138.

Balaban, Mira, et al. Eds. 1988. Proceedings of the First Workshop on AI and Music. Minneapolis / St. Paul: AAAI.

Balaban, Mira, Kemal Ebcioglu, and Otto Laske, eds. 1992. *Understanding Music with AI: Perspectives on Music Cognition*. Cambridge: MIT Press.

Balaban, Mira, and C. Samoun. 1993. "Hierarchy, Time, and Inheritance in Music Modeling," *Languages of Design* I/3 (1993).

Balasubrahmanyan, V. K., S. Naranan, and Saroja Balasubrahmanyan. 1994. "Carnatic music viewed from an information theory perspective," *Journal of the Indian Musicological Society* XXV (1994): 14-26.

Ballova, Luba. 1978. "Algoritmizacia Vyhodnocovania Podobnosti Melodii," *Musicologica slovaca* (Czechoslovakia) VI (1978): 167-174.

Balsach, Llorenç. 1997. "Application of Virtual Pitch Theory in Music Analysis," *Journal of New Music Research* XXVI (1997): 244-265.

Bandt, Christoph, and Bernd Pompe. 1993. "The Entropy Profile - A Function Describing Statistical Dependencies." *Journal of Statistical Physics*, vol. 70, nos. 3/4 (1993): 967-983.

Barbar, Kablan, Anthony Beurivé, and Myriam Desainte-Catherine. 1996. "On the Resolution of Musical Conflicts," *Journal of New Music Research* XXV (1996): 382-397.

Barbar, Kablan, Myriam Desainte-Catherine. 1992. Using Attribute to Find Solutions for Musical Equational Programs. Technical report 92-77. LaBRI. Univ. BX-1.

Barbar, Kablan, Myriam Desainte-Catherine, and A. Beurivé. 1994. "Incremental Evaluation in a Musical Hierarchy," *Proceedings of the I Brazilian Symposium on Computer Music*. 99-105.

Barbar, Kablan, Myriam Desainte-Catherine, and A. Beurivé. 1995. "Structure Hiérachiques et relations temporelles d'une pièce de musique," *Journées d'Informatique Musicale JIM'95*, Paris.

Barbar, Kablan, Myriam Desainte-Catherine, and Alain Miniussi. 1993a. "The Semantics of a Musical Hierarchy," *Computer Music Journal* XVII/4 (1993): 30-37.

Barbar, Kablan, Myriam Desainte-Catherine, and Alain Miniussi. 1993b. "The semantics of musical hierarchies," *Computer Music Journal* XVII/4 (1993): 30-37.

Barbaud, Pierre. 1973. "Methodes d'analyse de textes harmoniques," *Informatique Musicale* (October 1973): 165-176.

Baroni, Mario. 1983. "The Concept of Musical Grammar," *Music Analysis* 2

(1983): 175-208.

Baroni, Mario, Rossella Brunetti, Laura Callegari, and Carlo Jacobni. 1984. "A Grammar for Melody. Relationships Between Melody and Harmony," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 201-218.

Baroni, Mario, and Laura Callegari. Eds. 1984. *Musical Grammars and Computer Analysis*. Florence: Olschki.

Baroni, Mario, and Laura Callegari. 1989. "Analysis of a Repertoire of Eiteenth Century French Chansons," *Musikometrika* 2 (1989): 197-240.

Baroni, Mario, Rossana Dalmonte, and Carlo Jacoboni. 1989. "Relationships Between Music and Poetry in the Arias of Giovanni Legrenzi," *Contemporary Music Review* 4 (1989): 23-44.

Baroni, Mario, Rossana Dalmonte, and Carlo Jacoboni. 1992. Analysis via synthesis: The program Legre," *Secondo Convegno Europeo di Analisi Musicale*, ed. by Rossana Dalmonte and Mario Baroni. Trento, Italy: U. degli Studi, Dipartimento di Storia della Civilta. 599-608.

Baroni, Mario, Rossana Dalmonte, and Carlo Jacoboni. 1992. "Theory and analysis of European melody," *Computer Representations and Models in Music*, ed. by Alan Marsden and Anthony Pople. London: Academic Press. 187-205.

Baroni, Mario, and Carlo Jacobni. 1973. "Four-part Choral Generation," *Computational Musicology Newsletter* I/1 (1973): 10.

Baroni, Mario, and Carlo Jacobni. 1975. "Analysis and generation of Bach's choral melodies," *Proceedings of the First International Congress on Semiotics of Music, Beograd, 17-21 October 1973*. Pesaro: Centro di Iniziativa Culturale. 125-134.

Baroni, Mario, and Carlo Jacobni. 1978. *Proposal for a Grammar of Melody. The Bach Chorales*. Montreal: Les presses de l'Université de Montral.

Baroni, Mario, and Carlo Jacobni. 1979. "Formal Analogies in Different Phrases of a Monodic Composition," *The Third Colloquium on Musical Informatics*, April 1-2, 1979, Padua University, Italy. See abstract in *Computers in the Humanities* XVI/4 (1982): 264.

Baroni, Mario, and Carlo Jacobni. 1993. "Computer Generation of Melodies: Further Proposals," *Computers and the Humanities* XVII/1 (1983): 1-18.

Barth-Wehrenalp, Renate. 1974. Studien zu Adan de le Hale. Ph.D. thesis. University of Vienna.

Battel, Giovanni Umberto, and R. Bresin. 1994. "Analysis by Synthesis in Piano Performance: A Study on the Theme of Brahms' Paganini-Variationen," *Proceedings of the Stockholm Music Acoustic Conference 1993.* Stockholm: KTH. 69-73.

Battel, Giovanni Umberto, and R. Fimbianti. 1997. "Analysis of Expressive Intentions in Pianistic Performances," *Proceedings of the International Kansei Workshop 1997.* Genova: Associazione di Informatica Musicale Italiana. 128-133.

Bauer, Hans-Joachim. 1976. "Statistik, eine objektive Methode zur Analyse von Kunst?" *International Review of the Aesthetics and Sociology of Music* 7 (1976): 249-263.

Bauer-Mengelberg, Stefan. 1968. "'The Truth, the Whole Truth, and Nothing but the Truth'," *Computer Studies in the Humanities and Verbal Behavior* I, no. 2 (1968): 52-54.

__________. 1970. "The Ford-Columbia Input Language," *Musicology and the Computer: Three Symposia*, ed. by Barry S. Brook. New York: The City University of New York Press. 48-52.

Bauer-Mengelberg, Stefan, and Melvin Ferentz. 1965. "On Eleven-Interval Twelve-Tone Rows," *Perspectives of New Music* III, no. 2 (1965): 93-103.

Baumann, Uwe. 1993. "Anforderungen, Möglichkeiten und Grenzen der automatischen Musikanalyse," *Fortschritte der Akustik: Plenarvorträge und Fachbeiträge der 18. Gemeinschaftstagung der Deutschen Arbeitsgemeinschaft fur Akustik.* Bad Honnef, Germany: Deutsche Physikalische Gesellschaft. 896-899.

Baxter, Deborah Elaine. 1989. Women's Voice Classification in Selected Operas of Jules Massenet: Computer Analyzation and Anecdotal Study. DMA thesis, University of Missouri - Kansas City.

Bean, Calvert. 1961. Information Theory Applied to the Analysis of a Particular Formal Process in Tonal Music. Ph.D. diss. University of Illinois.

Beauchamp, James W. 1993. "Unix Workstation Software for Analysis, Graphics, Modification, and Synthesis of Musical Sounds," *Audio Engineering Society Preprint*, No. 3479 (Berlin Convention, March 1993).

Bebbington, Brian. 1968. "Folkmusic and Computers," *African Music* IV/2 (1968): 56-58.

Beck, Hermann. 1981. *Methoden der Werkanalyse in Geschichte und Gegenwart*, 3[rd] edition. Wilhelmshaven: Heinrichshofen.

Beckman, Linda Wilds. 1994. A descriptive analysis of dynamic and articulative nuance in piano performance using MIDI technology. DMA thesis. University of Oklahoma.

Bel, Bernard. 1992. "Symbolic and Sonic Representations of Sound-Object Structures," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge: MIT Press. 64-108.

__________. 1999. "Portrait of an Extraterrestrian," *Otto Laske: Navigating New Musical Horizons*, ed. by Jerry Tabor. Westport, Connecticut: Greenwood. 81-91.

Bel, Bernard, and Jim Kippen. 1992a. "Identifying improvisation schemata with QAVAID," *Computing in Musicology* 8 (1992): 115-119.

Bel, Bernard, and Jim Kippen. 1992b. "Bol Processor Grammars," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge, MA: The MIT Press. 366-400.

Bellgard, Matthew I., and C. P. Tsang 1996. "On the Use of an Effective Boltzmann Machine for Musical Style Recognition and Harmonisation," *Proceedings of the 1996 International Computer Music Conference*. Hong Kong: International Computer Music Association. 461-464.

Bengtsson, Ingmar. 1967a. "On Melody Registration and 'Mona'," *Elektronische Datenverarbeitung in der Musikwissenschaft*, ed. by Harald Heckmann. Regensburg: Gustav Bosse. 136-174.

__________. 1967b. "Numericode -- A Code System for Thematic Incipits," *Svensk Tidskrift för Musikforskning* 49 (1967): 5-40.

__________. 1970. "Studies with the Aid of Computers of 'Music As Performed'," *IMS: Report on the Tenth Congress, Lubljana 1967*, ed. by Dragotin Cvetko. Kassel: Bärenreiter. 443-444.

__________. 1971. "Analysis of Rhythmic Performance," *Computers and the Humanities* V, no. 5 (1971): 310.

Bengtsson, Ingmar, Alf Gabrielsson, and Barbro Gabrielsson. 1978. "RHYTHMSYVARD. A computer program for analysis of rhythmic performance," *Svensk Tidskrift for Musikforskning* LX/1 (1978): 15-24.

Bengtsson, Ingmar, Alf Gabrielsson, and Stig-Magnus Thorsén. 1969. "Empirisk Rytmforskning. En Orientering om Musikvetenskaplig Bakgrund, Utveckling och Några aktuella Projekt," *Svensk Tidskrift för Musikforskning* 51 (1969): 49-118.

Bense, Max. 1954. *Aesthetica*. Stuttgart: Deutsche Verlags-Anstalt.

__________. 1966. "Ästhetik und Programmierung." *IBM-Nachrichten* 16 (1966): 294-296.

__________. 1969. *Einführung in die informationstheoretische Ästhetik*. Reinbek bei Hamburg: Rowohlt.

Bent, Ian D. 1973. "Analysis of Melodic Structure," *Computers and the Humanities* VII/5 (1973): 314.

__________. 1980. "Analysis," *The New Grove Dictionary of Music and Musicians*, ed. by Stanley Sadie, vol. 1. London: Macmillan. 340-388.

__________. 1987. *Analysis*, with a glossary by William Drabkin. London: Macmillan.

Bent, Ian, and John Morehen. 1978. "Computers in the Analysis of Music," *Proceedings of the Royal Musical Association* CIV (1977-78): 30-46.

Berger, Arthur. 1964. "New Linguistic Modes and the New Theory," *Perspectives of New Music* III (Fall 1964): 1-9.

Berger, Jonathan. 1990. "A Theory of Musical Ambiguity," *Computers in Music Research* II (1990): 91-119.

Berger, Jonathan, and Dan Gang 1997. "A Neural Network Model of Metric Perception and Cognition in the Audition of Functional Tonal Music," *Proceedings of the 1997 International Computer Music Conference*. Thessaloniki, Greece: International Computer Music Association. 23-26.

Berggren, Ulf. 1995. *Ars Combinatoria. Algorithmic Construction of Sonata Movements by Means of Building Blocks Derived from W. A. Mozart's Piano Sonatas*. Uppsala: Uppsala Universitet.

Berlind, Gary. 1966. "Writings on the Use of Computers in Music," *College Music Symposium* 6 (1966): 143-152.

__________. 1967. "GRIPHOS: An Interim Report," *Current Musicology* 5 (1967): 149-152.

__________. [no year]. Writings on the Use of Computers in Music. Compiled by Gary Berlind in collaboration with Barry S. Brook, Lejaren A. Hiller Jr., Jan P. LaRue, and George W. Logemann. New York: New York University, Institute for Computer Research in the Humanities. Mimeographed.

Berlind, Gary, and George W. Logeman. 1969. "An Algorithm for Musical Transposition," *Computer Studies in the Humanities and Verbal Behavior* 2 (August 1969): 102-108.

Bernard, Jonathan Walter. 1977. A theory of pitch and register for the music of Edgard Varese. Ph.D. thesis. Yale University.

Bernstein, Lawrence F. 1964. "Data Processing and the Thematic Index," *Fontes Artis Musicae* XI, no. 1 (1964): 159-165.

Bernstein, Lawrence F. and Joseph P. Olive. 1969. "Computers and the 16th-century Chanson: A Pilot Project at the University of Chicago," *Computers and the Humanities* III/3 (January 1969). 153-160.

Bernzott, Philip. 1968. Musical Analysis with Computer: Some Programs and Descriptions. M.M. thesis. Chicago Musical College.

Berrett, Joshua. 1979. "Alan Lomax: Some Reconsiderations," *Journal of Jazz Studies* VI/1 (1979): 54-63.

Bersano, James Richard. 1980. Formalized Aspect Analysis of Sound Texture. PhD thesis, Indiana University.

Bertoni, Alberto, Goffredo Haus, Giancarlo Mauri, and Mauro Torelli. 1978. "A Mathematical Model for Analyzing and Structuring Musical Texts," *Interface* VII (1978): 31-43.

Besson, Mireille. 1997. "Electrophysiological Studies of Music Processing," *Perception and Cognition of Music*, ed. by Irène Deliège and John Sloboda. East Sussex, UK: Psychology Press. 217-250.

__________. 1999. "The Musical Brain: Neural Substrates of Music Perception," *Journal of New Music Research* XXVIII (1999): 246-256.

Besson, Mireille, and F. Faïta. 1995. "An Event-Related Potential (EPR) Study of Musical Expectancy: Comparison of Musicians with Nonmusicians," *Journal of Experimental Psychology: Human Perception and Performance*

XXI (1995): 1278-1296.

Bever, Thomas G. 1988. "A Cognitive Theory of Emotion and Aesthetics in Music," *Psychomusicology* VII/2 (1988): 165-175.

Bevil, Jack Marshall. 1984. Centonization and Concordance in the American Southern Uplands Folksong Melody: A Study of the Musical Generative and Transmittive Processes of an Oral Tradition. PhD thesis. North Texas State University.

__________. 1992a. "MelAnaly," *Computing in Musicology* 8 (1992): 68-69.

__________. 1992b. "Principles and Methods of Element Encoding and Array Formation in the MelAnaly System of Comparative Folktune Analysis," *Computers in Music Research* IV (1992): 77-104.

Bharucha, Jamshed Jay. 1987. "Music Cognition and Perceptual Facilitation: A Connectionist Framework," *Music Perception* 5 (1987): 1-30.

__________. 1993. "MUSCAT: A Connectionist Model of Musical Harmony," *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press. 496-509.

Bharucha, Jamshed Jay, and Carol Krumhansl. 1983. "The Representation of Harmonic Structure in Music: Hierachies of Stability as a Function of Context," *Cognition* 13 (1983): 63-102.

Bharucha, Jamshed Jay, and Keiko Stoeckig. 1986. "Reaction Time and Musical Expectancy: Priming of Chords," *Journal of Experimental Psychology* XII/4 (1986): 403-410.

Bharucha Jamshed J., and Peter M. Todd 1991. "Modeling the Perception of Tonal Structure with Neural Nets," *Music and Connectionism*, ed. by P. Todd and G. Loy. Cambridge, MA: The MIT Press. 128-137.

Bhaskaran, K. 1994. "Can Computers Play a Role in Karnatic Music?" *Journal of the Indian Musicological Society* 25 (1994): 31-39.

Bhave, S. S., S. P. Nawathe, P. V. S. Rao, R. Raveendran, and R. S. Sardesai. 1994. "Computers and Hindusthani Music: A Perspective," *Journal of the Indian Musicological Society* 25 (1994): 1-13.

Binford-Walsh, Hilde Marga. 1992. "The ordering of melody in Aquitanian chant: A study of mode one Introit tropes," *Cantus Planus*, ed. by L. Dobszay. Budapest : Hungarian Academy of Sciences Institute for Musicology. 327-339.

Binkley, Thomas E. 1967. "Electronic Processing of Musical Materials," *Elektronische Datenverarbeitung in der Musikwissenschaft*, ed. by Harald Heckmann. Regensburg: Gustav Bosse. 1-20.

Birkhoff, George David. 1931. "A Mathematical Approach to Aesthetics." *Scientia*, September 1931: 133-146.

__________. 1950. *Collected Mathematical Papers*, vol. 3. New York: American Mathematical Society.

Blacking, John. 1984. "What Languages do Musical Grammars Describe?" *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 363-370.

__________. 1985. "Universal Validity of Musical Analysis," *ICTM UK Chapter Bulletin No 12*. 13-23.

Blevis, Eli Bernard. 1990. An Approach To Interactive Creative Reasoning Systems. PhD thesis, Queen's University at Kongston (Canada).

Blevis, Eli, M. Feret, and Michael Jenkins. 1990. "A Computational Paradigm for Exploring Creative Musical Thought," *Le Fait Musical - Sciences, Technologies, Pratiques*, ed. by Bernard Vecchione and Bernard Bel. Aix-en-Provence / Marseille: CRSM-MIM. 363-382.

Blevis, Eli, Michael Jenkins, and Janice I. Glasgow. 1992. "Motivations, sources, and initial design ideas for CALM: A composition/analysis generation language for music," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge: MIT Press. 140-154.

Blevis, Eli, Michael Jenkins, and Edmund Robinson. 1989. "On Seeger's Music Logic," *Interface* XVIII (1989): 9-31.

Blombach, Ann Kariger. 1976. A Conceptual Framework for the Use of the Computer in Music Analysis. Ph.D. thesis, Ohio State University.

__________. 1982. "Harmony vs. counterpoint in the Bach Chorales," *Computing in the Humanities*, ed. by Richard W. Bailey. Amsterdam: North-Holland Publishing Company. 79-88.

Boggs, Beverly. 1973. "Analysis of Ethnomusicological Transcritions," *Computational Musicology Newsletter* I/1 (1973): 14.

Boggs, J. K. 1973 "Music Ancoding," *Computational Musicology Newsletter* I/1

(1973): 3.

Boon, Jean-Pierre, Alain Noullez, and Corinne Mommen. 1990. "Complex Dynamics and Musical Structures," *Interface* XIX/1 (1990): 3-14.

Böker-Heil, Norbert. 1971a. "Programmierte Musikanalyse," *Computers and the Humanities* V, no. 5 (1971): 314.

__________. 1971b. "DODEK - Eine Computerdemonstration," *Zeitschrift für Musiktheorie* 2 (1971): 2-14.

__________. 1972a. "Weiße Mensuralnotation als Computer-Input und -Output," *Acta Musicologica* XLIII (1971/72): 21-33.

__________. 1973. "Plotting Conventional Music Notation," *Journal of Music Theory* XVI (1973): 72-101.

__________. 1974a. "Der Zustand polyphoner Strukturen: Ein Beispiel Automatischer Stilbeschreibung," *International Musicological Society: Report of the Eleventh Congress, Copenhagen 1972*, ed. by Henrik Glahn, Soren Sorensen and Peter Ryom. Copenhagen: Edition W. Hansen. 108-120.

__________. 1974b. "Musikalische Stilanalyse und Computer. Einige grundsätzliche Erwägungen," *International Musicological Society: Report of the Eleventh Congress, Copenhagen 1972*, ed. by Henrik Glahn, Soren Sorensen and Peter Ryom. Copenhagen: Edition W. Hansen. 45-50.

__________. 1981. "Computer-Simulation eines musikalischen Verstehensprozesses," *International Musicological Society: Report of the Twelfth Congress, Berkeley 1977*, ed. by Daniel Heartz and Bonnie C. Wade. Kassel: Bärenreiter. 324-329.

__________. 1983. *Computer und Notentext*. [Information-Sheets] Berlin: Staatliches Institut für Musikforschung. 3 pages.

__________. 1984. "Klingende Dokumentationen aus dem Synthesizer," *Musikdokumentation gestern, heute und morgen. Harald Heckmann zum 60. Geburtstag am 6. Dezember 1984*, ed. by Wofgang Rehm. Kassel: Bärenreiter. 19-23.

__________. 1985. MUSAN: Ein Program zur elementaren Analyse der Zusammenklänge vorzugsweise des späten Mittelalters. Berlin: Staatliches Institut für Musikforschung. Mimeographed.

__________. 1987. "Klingende Dokumentation aus dem Synthesizer," *Jahrbuch* *des Staatlichen Instituts für Musikforschung Preußischer Kulturbesitz*. Berlin: Merseburger.

__________. 1989. "Ein Lieblingsmotiv der ars subtilior?" *Festschrift Wolfgang Rehm zum 60. Geburtstag am 3. September 1989*, ed. Dietrich Berke and Harald Heckmann. Kassel: Bärenreiter. 9-14.

Böker-Heil, Norbert, and Harald Heckmann. 1979. "Elektronische Datenverarbeitung," *Die Musik in Geschichte und Gegenwart*, vol. 16. Kassel: Bärenreiter. 36-51.

Boltz, Marilyn G. 1991. "The Structural Determinants of Melody Recall," *Melody and Cognition* 19 (1991): 239-251.

__________. 1999. "The Processing of Melodic and Temporal Information: Independent or Unified Dimensions?" *Journal of New Music Research* XXVIII/1 (1999): 67-79.

Bolzinger, Simon. 1992. DKompose: A package for interactive composition in the MAX environment, adapted to the acoustic MIDI Disklavier piano," *Proceedings of the International Computer Music Conference, San Jose, 1992.* San Francisco: International Computer Music Association. 162-165.

Boody, Charles George. 1972. Non-Compositional Applications of the Computer to Music Published in America Through June of 1972. Ph.D. thesis, University of Minnesota.

__________. 1989. Review of Fred T. Hofstetter's *Computer Literacy for Musicians*, *Computers and Music Research* I (1989): 123-131.

Boody, Charles G., and Johannes Riedel. 1981. "A computer aided study of Ecuadorean urban music," *Computers and the Humanities* XV/2 (August 1981): 61-74.

Borin, Gianpaolo, Giovanni De Poli, and Augusto Sarti. 1990. "Formalization of the Sound Generation Process - Structures and Metaphors," *Le Fait Musical - Sciences, Technologies, Pratiques*, ed. by Bernard Vecchione and Bernard Bel. Aix-en-Provence / Marseille: CRSM-MIM. 231-241.

Boroda, Moisej G. 1973. "K voprosu o metroritmiceski elementarnoj edinice v muzyke," *Bulletin of the Academy of Science of the Georgian SSR* 71/3 (1973). 745-748.

__________. 1974. "O castotnoj strukture muzykalnych soobscenij," *Bulletin of the Academy of Science of the Georgian SSR* 76/2 (1974). 178-202.

__________. 1977. "O melodiceskoj elementarnoj edinice," *MAA-FAT-75. Materialy Pervogo Vsesojuznogo seminara po masynnym aspektam algoritmiceskogo formalizovannogo analiza muzykalnych tekstov*. Erevan. 112-120.

__________. 1978. "Ob opredelenii informacionnoj melodiceskoj edinicy tipa frazy v muzyke," *Bulletin of the Academy of Science of the Georgian SSR* 89/1 (1978): 57-60.

__________. 1979. Principy Organizacii Povtorov na Microurovne Muzykalnovo Teksta. Dissertation. Tiblissi.

__________. 1980. "Häufigkeitsstrukturen musikalischer Texte," *Glottometrika 3*, ed. by Wolfhart Matthäus. Bochum: Studienverlag Dr. N. Brockmeyer. 36-96.

__________. 1982. "Die melodische Elementareinheit," *Sprache, Text, Kunst: Quantitative Analysen*, ed. by Ju. K. Orlov, Moisej G. Boroda, and I. S. Nadarejsvilli. Bochum: Brockmeyer. 205-221.

__________. 1988a. "Towards the Basic Semantic Units of a Musical Text," *Musikometrika 1*, ed. by Moisej G. Boroda. Bochum: Brockmeyer. 11-69.

__________. 1988b. "Organizatsiya povtorov v muzykal'nom tekste i universalii muzykal'nogo yazyka," *Applied Linguistics and Automatic Text Analysis. Proceedings of the Conference at the Tartu State University 1988*. Tartu. 15-19.

__________. 1989a. "The Organization of Repetitions in the Musical Composition: Towards a Quantitative-Systemic Approach," *Musikometrika 2*, ed. by Moisej Boroda. Bochum: Brockmeyer. 53-106.

__________. 1989b. "Rhythmical Repetition / Rhytmical Variation in Folk Music and Composed Music: Towards a Quantitative System," *Musikometrika 2*, ed. by Moisej Boroda. Bochum: Brockmeyer. 121-142.

__________. 1991a. "The Concept of 'Metrical Force' in Music: A Computational Approach," *Proceedings of the Conference "Computers in Music Research"*. Belfast: Queen's University. 10-23.

__________. 1991b. "Rhythmic Models in Music: Towards the Quantitative Study," *Musikometrika 3*, ed. by Moisej G. Boroda. Bochum: Brockmeyer. 61-96.

__________. 1992. "Towards a Phrase Type Melodic Unit in Music," *Musikometrika 4*, ed. by Moisej G. Boroda. Bochum: Brockmeyer. 15-82.

Boroda, Moisej G., and Jurij K. Orlov. 1978. "O sravnenii skorostej vosprijatija informacijonnych edinic v muzyke i reci," [*Proceedings of the Conference "The Functioning of Communication Systems"*]. Erevan: Academy of Science. 58-62.

Boroda, Moisej G., and Jurij K. Orlov. 1990. "Zum Vergleich der Wahrnehmungsgeschwindigkeit von Informationseinheiten in Musik und Rede," *Quantitative Linguistics* 43 (1990): 279-283.

Boroda, Moisej G., I. Sch. Nabareyshvili, Jurij K. Orlov, R. Ja. Tshitashvili. 1977. "O Karaktere raspredelenija informatcionnuych edinic maloj tshastotyu v chudoshestvennych tekstach," *Semiotika i Informatika* IX (1977): 23-35.

Boroda, Moisej G., and P. Zörnig. 1990. "Zipf-Mandelbrot's Law in a Coherent Text: Towards the Problem of Validity," *Glottometrika 12*, ed. by R. Hammerl. Bochum: Brockmeyer. 41-60.

Borris, Siegfried. 1971. Review of *Musikalische Stilanalyse auf der Grundlage eines Modelles für Lernprozesse* by Hermann Gerhard Rohrer, *Musik und Bildung* III/11 (November 1971): 567-68.

Boulet, Marie-Michele, Francine Dufour, and Louisette Lavoie. 1992. "Description d'un systeme conseiller en composition musicale," *Recherche en Education Musicale au Quebec* XI (1992): 57-70.

Bowen, Jose Antonio. 1996. "Tempo, duration, and flexibility: Techniques in the analysis of performance," *The Journal of Musicological Research* XVI/2 (1996): 111-156.

Bowles, Edmund. 1970a. "Discussion," *Musicology and the Computer: Three Symposia*, ed. by Barry S. Brook. New York: The City University of New York Press. 37-38.

__________. 1970b. "Musicke's Handmaiden: Or Technology in the Service of the Arts," *The Computer and Music*, ed. by Harry B. Lincoln. Ithaca: Cornell University Press. 3-20.

Brantley, Daniel Lawrence. 1977. Disputed Authorship of Musical Works: A Quantitative Approach to the Attribution of the Quartets Published as Haydn's Opus 3. PhD thesis, University of Iowa.

Braus, Ira Lincoln. 1996. "Making 'impossible' rhythm and figures possible," *Computing in Musicology* 10 (1995-1996): 194-196.

Brawley, John Gray. 1959. An Application of Information Theory to Musical

Rhythm. M.M. thesis. Indiana University.

Brech, Martha. 1991. "Musical analysis of computer music with sonograms," *Proceedings: International Computer Music Conference, Montreal, 1991*. Montreal: McGill University Press, 1991. 550-553.

__________. 1994. *Die Analyse elektroakustischer Musik mit Hilfe von Sonogrammen*. Frankfurt am Main: Peter Lang.

Bregman, Albert S. 1990. *Auditory Scene Analysis: The Perceptual Organization of Sound*. Cambridge: MIT Press.

Brender, Maurita P., and Ronald F. Brender. 1967. "Computer Transcription and Analysis of Mid-Thirteenth Century Musical Notation," *Journal of Music Theory* XI/2 (Winter 1967): 198-221.

Bresin, Roberto. 1993. "MELODIA: A Program for Performance Rules Testing, for Teaching, and for Piano Scores Performing," *Proceedings of X CIM Colloquium on Musical Informatics*. Milano: Associazione di Informatica Musicale Italiana. 325-327.

__________. 1998. "Artificial Neural Networks Based Models for Automatic Performance of Musical Scores," *Journal of New Music Research* XXVII/3 (1998): 239-270.

Bresin, Roberto, Giovanni De Poli, and R. Ghetta. 1995. A Fuzzy Approach to Performance Rules," *Proceedings of the XI CIM Colloquium on Musical Informatics*. Bologna: Associazione di Informatica Musicale Italiana. 163-167.

Bresin, Roberto, and C. Vecchio. 1994. "Analysis and Synthesis of the Performing Action of a Real Pianist by Means of Artificial Neural Networks," *Proceedings of the Third International Conference on Music Perception and Cognition*. University of Liège.

Bresin, Roberto, and C. Vecchio. 1995. "Neural Network Plays Schumann. Analysis and Synthesis of the Performing Action of a Real Pianist," *Proceedings of the KTH Symposium on Grammars for Music Performance*. Stockholm: KTH. 5-14.

Bridger, Michael. 1989. "An Approach to the Analysis of Electroacoustic Music Derived from Empirical Investigation and Critical Methodologies of other Disciplines," *Contemporary Music Review* 3 (1989): 145-160.

Brincker, Jens. 1966a. "Kvantitativ musikanalyse," *Dansk Musiktidsskrift* XLI (1966): 175-178.

__________. 1966b. Review of *Informationstheorie und Computermusik* by Lejaren A. Hiller, *Dansk Musiktidsskrift* XLI (1966): 186.

__________. 1970. "Statistical Analysis of Music. An Application of Information Theory," *Svensk Tidskrift för Musikforsking* 52 (1970): 53-57.

Brinkman, Alexander R. 1978. Johann Sebastian Bach's Orgelbüchlein: A computer-assisted analysis of the in fluence of the cantus firmus on the contrapuntal voices. Ph.D. thesis, University of Rochester, Eastman School of Music.

__________. 1980. "The Melodic Process in Johann Sebastian Bach's *Orgelbüchlein*," *Music Theory Spectrum* II (1980): 46-73.

__________. 1986a. "Representing Musical Scores for Computer Analysis," *Journal of Music Theory* XXX/2 (Winter 1986): 225-275.

__________. 1986b. "A Binomial Representation of Pitch for Computer Processing of Musical Data," *Music Theory Spectrum* 8 (1986): 44-57.

__________. 1987. Review of Wittlich et al. *Microcomputers and Music*, *Integral* I (1987): 141-154.

__________. 1989. "Data Structures for a Note-List Preprocessor," *Computers in Music Research* I (1989): 75-101.

__________. 1990. *Pascal Programming for Music Research.* Chicago: University of Chicago Press.

__________. 1991. "Graphic Modeling of Musical Structure," *Computers in Music Research* III (1991): 1-42.

Brinkman, Alexander R., and Sevan G. Ficici. 1992. "Computational Tools for the Analysis of Rhythm," *Proceedings of the International Computer Music Conference, San Jose, 1992.* San Francisco: International Computer Music Association. 364-365.

Brinkman, Alexander R., and Martha R. Mesiti. 1991a. "Computer-Graphic Tools for Music Analysis," *Proceedings: International Computer Music Conference, Montreal, 1991.* Montreal: McGill University Press. 53-56.

Brinkman, Alexander R., and Martha R. Mesiti. 1991b. "Graphic Modeling of Musical Structure," *Computers in Music Research* III (1991): 1-42.

Broeckx, Jan L. 1979. *Contemporary Views on Musical Style and Aesthetics.*

Antwerp: Metropolis.

__________. 1997. "Beyond Metaphor: Musical Figures or 'Gestalte' as Expressive Icons," *Journal of New Music Research* XXVI (1997): 266-276.

Broeckx, Jan L., and Walter Landrieu. 1972. "Comparative Study of Style, Based on Five Lied Melodies," *Interface* I/1 (1972): 29-92.

Bronson, Bertrand H. 1949. "Mechanical Help in the Study of Folk Song." *Journal of American Folklore* LII (1949): 81-86.

__________. 1959. "Toward the Comparative Analysis of British-American Folk Tunes." *Journal of American Folklore* LXXII (1959): 165-191

Brook, Barry S. 1965a. "The Simplified 'Plaine and Easy Code System," *Fontes Artis Musicae* XII (1965): 156-160.

__________. 1965b. "Utilization of Data Processing Techniques in Music Documentation," Fontes Artis Musicae 12 (May 1965): 112-122.

__________. 1967. "Music Bibliography and the Computer," *Papers from the West Virginia University Conference on Computer Applications in Music*, ed. by Gerald Lefkoff. Morgantown: West Virginia University Library. 9-27.

__________. 1969. "Style and Content Analysis in Music: The Simplified 'Plaine and Easy Code'," *The Analysis of Communication Content*, ed. by George Gerbner et al. New York: John Wiley & Sons. 287-296.

__________, ed. 1970a. *Musicology and the Computer: Three Symposia*. New York: The City University of New York Press.

__________. 1970b. "Music Documentation of the Future," *Musicology and the Computer: Three Symposia*, ed. by Barry S. Brook. New York: The City University of New York Press. 28-36.

__________. 1970c. "The Plaine and Easie Code," *Musicology and the Computer: Three Symposia*, ed. by Barry S. Brook. New York: The City University of New York Press. 53-56.

Brook, Barry S., and Murray Gould. 1964. "Notating Music with Ordinary Typewriter Characters," *Fontes Artis Musicae* XI/1 (January-April 1964): 142-159.

Brooks, Frederick P., A. L. Hopkins, P. G. Neumann, and W. V. Wright. 1957. "An Experiment in Musical Composition." *IRE Transactions on Electronic Computers* VI (1957): 175-182. (An errata see in vol. 7 (1958): 60.)

Reprinted in *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press, 1993. 23-40.

Brown, Charles T. 1968. "To Determine the Melodic Contour of a Melody," *Student Musicologists at Minnesota* III (1968): 87-92.

Brown, Charles T., and Robert D. Oudal. 1969. "The 1968 Introductory Seminar in the Use of Computers in Musical Projects," *Student Musicologists at Minnesota* 3 (1968-1969): 87-92.

Brown, Guy J. 1992. Computational Auditory Scene Analysis: A Representational Approach. Ph.D. thesis. University of Sheffield.

Brown, Guy J., and Martin Cooke. 1994. "Perceptual Grouping of Musical Sounds: A Computational Model," *Journal of New Music Research* XXIII (1994): 107-132.

Brown, Helen. 1988. "The Interplay of Set Content and Temporal Context in a Functional Theory of Tonality Perception," *Music Perception* V/3 (1988): 219-249.

Brown, Judith C. 1992. "Musical Fundamental Frequency Tracking Using a Pattern Recognition Method," *Journal of the Acoustical Society of America* 92/3 (1992): 1394-1402.

__________. 1993. Determination of the Meter of Musical Scores by Autocorrelation," *Journal of the Acoustical Society of America* 94/4 (1993): 1953-1957.

Brown, Matthew Gordon, and Douglas J. Dempster. 1989. "The Scientific Image of Music Theory," *Journal of Music Theory* XXXIII/1 (1989).

Buchanan, Hubert H. 1988. "Bop harmony -- A new interdisciplinary approach: PROLOG, logic and artificial intelligence," *Annual Review of Jazz Studies* IV (1988): 179-188.

Butts, David Leon. 1992. A Computer-Assisted Statistical Investigation of Selected Variables in the Solo Guitar Studies of Fernando Sor: Implications for Pedagogy and Performance. PhD thesis, Texas Tech University.

Byrd, Donald Alvin. 1970a. "Music Notation by Computer," *Computers and the Humanities* V, no. 2 (1970): 111.

__________. 1970b. "Transcription by Plotter," *Random Bits* V/9 (May 1970): 6-8.

__________. 1971. "Humanities Programming for Creative Work," *Random Bits* VI/5 (January 1971): 1, 8-12.

__________. 1974. "A system for music printing by computer," *Computers and the Humanities* VIII/3 (May 1974): 161-172.

__________. 1975. "Music Programs at Indiana University," *Computational Musicology Newsletter* II/1 (1975): 2-4.

__________. 1977. "An Integrated Computer Music Software System," *Computer Music Journal* I/2 (1977): 55-60.

__________. 1984. Music Notation by Computer. Ph.D. thesis. Indiana University.

Calzon, Miguel. 1992. "A program for the reinterpretation of musical input Structures," *Proceedings of the International Computer Music Conference, San Jose, 1992*. San Francisco: International Computer Music Association. 97-100.

__________. 1993. "AREM/ARMS: Reinterpretation of musical structures," *Proceedings of the 1993 International Computer Music Conference*. San Francisco: International Computer Music Association. 357-359.

Cambouropoulos, Emilios. 1996. "A General Pitch Interval Representation: Theory and Applications," *Journal of New Music Research* XXV (1996): 231-251.

__________1997. "Musical Rhythm: A Formal Model for Determining Local Boundaries, Accents and Metre in a Melodic Surface," *Music, Gestalt, and Computing. Studies in Cognitive and Systematic Musicology*, ed. by Marc Leman. Berlin: Springer, 1997. 277-293.

Camilleri, Lelio. 1984. "A Grammar of the Melodies of Schubert's Lieder," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 229-236.

__________. 1986. "The current state of computer assisted research in musicology in Italy," *Acta Musicologica* LVIII/2 (December 1986): 356-360.

__________. 1992a. "Computational Theories of Music," *Computer Representations and Models in Music*, ed. by Alan Marsden & Anthony Pople. London: Academic Press. 171-185.

__________. 1992b. "Analisi Mediante Elaboratore e Analisi della Musica

Elettroacustica," *Musica/Realtáa* XIII/38 (1992): 152-155.

__________. 1993a. "Electroacoustic Music: Analysis and Listening Process," *Sonus. Contemporary Music Materials* 1 (1993): 39-47.

__________. 1993b. "Metodologie e concetti analitici nello studio di musiche elettroacustiche," *Rivista Italiana di Musicologia* 28 (1993): 131-174.

Camilleri, Lelio, David Bencini, and Michele Ignelzi. 1991. "Analisi paradigmatica di repertori monofonici," *IX Colloquium on Musical Informatics / IX Colloquio di Informatica Musicale*, ed. by Antonio Camurri and Corrado Canepa. Genova: Associazione di Informatica Musicale Italiana, 1991. 351-357.

Camilleri, Lelio, David Bencini, and Michele Ignelzi. 1992. "Paradigmatic analysis through the computer," *Secondo Convegno Europeo di Analisi Musicale*, ed. by Rossana Dalmonte and Mario Baroni. Trento, Italy: U. degli Studi, Dipartimento di Storia della Civilta. 609-612.

Camilleri, Lelio, Francesco Carreras, and Chiara Duranti. 1990. "An expert system prototype for the study of musical segmentation," *Interface* XIX/2-3 (1990): 147-154.

Camilleri, Lelio, Francesco Carreras, and Francesco Giomi. 1993. "Sistemi esperti in musicologia: Un prototipo per l'analisi TIME-SPAN reduction," *Atti del X Colloquio di Informatica Musicale*, ed. by Goffredo Haus and Isabella Pighi. Milano, Italy: Associazione di Informatica Musicale Italiana. 36-47.

Camilleri, Lelio, Francesco Carreras, Piero Gargiulo, and Francesco Giomi. "Esempi di applicazione del 'time-span reduction' nell'analisi computazionale della struttura armonica: Sei allemande dall'opera II e dall'opera IV di Corelli," *Studi Corelliani. V: Atti del quinto congresso internazionale*, ed. by Stefano La Via. Firenze: Olschki, 1996. 229-248.

Camilleri, Lelio, Francesco Giomi, and Chiara Duranti. 1992. "Time slices for time-span reductions: An AI environment for the analysis of tonal harmonic structure," *Computing in Musicology* 8 (1992): 90-91.

Camilleri, Lelio, Francesco Giomi, and Chiara Duranti. 1990. "An expert system prototype for the study of musical segmentation," *Interface* XIX/2-3 (1990): 147-154.

Camilleri, Lelio, and Denis Smalley. 1998. "The Analysis of Electroacoustic Music: Introduction," *Journal of New Music Research* XXVII (1998): 3-12.

Campbell, Bruce B. 1990. "A computer assisted approach to music analysis," *Proceedings of the International Computer Music Conference, Glasgow, 1990.* San Francisco, CA: Computer Music Association, 1990. 147-149.

Campbell, Warren Colman. 1970. Computer analysis of musical performance. Ph.D. thesis. University of Connecticut.

Campbell-Kelly, Martin, and William Aspray. 1996. *Computer. A History of the Information Machine*. New York: BasicBooks.

Campos, Arthur Nogueira. 1973. "Music Analysis," *Computational Musicology Newsletter* I/1 (1973): 14.

Camurri, Antonio. Ed. 1990a. Special Issue on Artificial Intelligence and Music," Interface XIX/2-3 (1990).

__________. 1990b. On the Role of Artificial Intelligence in Music Research," *Interface* XIX/2-3 (1990): 219-248.

__________. 1993a. "The Cognitive Level of the Intelligent Music Workstation," *Atti di X Colloquio Informatica Musicale*. AIMI, Universià degli Studio di Milano.

__________. 1993b. "Applications of artificial intelligence methodologies and tools for music description and processing," *Music Processing*, ed. by Goffredo Haus. Madison, WI: A-R Editions. 233-266.

Camurri, Antonio, Corrado Canepa, Marcello Frixione, Carlo Innocenti, Claudio Massucco, Renato Zaccaria. 1991. "A high-level system for music composition," *Proceedings: International Computer Music Conference, Montreal, 1991*. Montreal: McGill University Press. 27-36.

Camurri, Antonio, Marcello Frixione, and Carlo Innocenti. 1994. "A Cognitive Model and a Knowledge Representation System for Music and Multimedia," *Journal in Music Research* XXIII (1994): 317-347.

Camurri, Antonio, Marcello Frixione, and Carlo Innocenti, and R. Zaccaria. 1994. *Representation and Real-Time Processing of Music and Multi-Media.* DIST Technical Report.

Camurri, Antonio, Geoffredo Haus, and R. Zaccaria. 1968. Describing and Performing Musical Processes by Means of Petri Nets," *Interface* XV/1 (1986): 1-23.

Camurri, Antonio, Carlo Innocenti, C. Massucco, and R. Zaccaria. 1992. "A Software Architecture for Sound and Music Processing," *Microprocessing* *and Microprogramming* 35 (1992): 1-5.

Camurri, Antonio, and Marc Leman. 1997. "AI-Based Music Signal Applications - a Hybrid Approach," *Musical Signal Processing*, ed. by Curtis Roads, Stephen Travis Pope, Aldo Piccialli, and Giovanni de Poli. Lisse: Swets & Zeitlinger. 349-381.

Canazza, Sergio, and N. Orio. 1997. How are the Players Ideas Perceived by Listeners: Analysis of 'How High the Moon' theme," *Proceedings of the International KanseiWorkshop 1997*. Genova: Associazione di Informatica Musicale Italiana. 128-133.

Canazza, Sergio, Giovanni De Poli, Antonio Roda, and Alvise Vidolin. 1997a. "Analysis by Synthesis of the Expressive Intentions in Musical Performance," *Proceedings International Computer Music Conference 1997*. San Francisco: International Computer Music Association. 113-120.

Canazza, Sergio, Giovanni De Poli, Antonio Roda, and Alvise Vidolin. 1997b. "Sonological Analysis of Clarinet Expressivity," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 431-440.

Canazza, Sergio, Giovanni De Poli, and Alvise Vidolin. 1997. "Perceptual Analysis of the Musical Expressive Intention in a Clarinet Performance," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 441-450.

Cantor, Don. "A Computer program that Accepts Common Musical Notation," *Computers in the Humanities* VI (1971): 103-109.

Carreras, Francesco. 1998. Review of Stan Tempelaars' *Signal Processing, Speech and Music*, *Journal of New Music Research* XXVII/4 (1998): 409-410.

Carrive, Jean. 1995. Analyses de Grilles de Jazz Dans le Système MusES. Master's thesis. Laforia-IBP. University of Paris 6.

Carter, N.P., R. A. Bacon, T. Messenger. 1988. "The requisition, representation, and reconstruction of printed music by computer: A review," *Computers and the Humanities* XXII/2 (1988): 117-136.

Castine, Peter. 1992. "Contemporary music analysis package for the Apple Macintosh (CMAP)," *Secondo Convegno Europeo di Analisi Musicale*, ed. by Rossana Dalmonte and Mario Baroni. Trento, Italy: U. degli Studi, Dipartimento di Storia della Civilta. 613-618.

__________. 1993. "Whatever happened to CMAP for Macintosh?" *Proceedings of the 1993 International Computer Music Conference.* San Francisco: International Computer Music Association. 360-362.

__________. 1994. *Set Theory Objects. Abstractions for Computer-Aided Analysis and Composition of Serial and Atonal Music.* Frankfurt/M.: Peter Lang.

Castine, Peter, Alexander R. Brinkman, and Craig R. Harris. 1990. "Contemporary Music Analysis Package (CMAP) for Macintosh," *Proceedings of the International Computer Music Conference, Glasgow, 1990.* San Francisco, CA: Computer Music Association, 1990. 150-152.

Castrén, Marcus. 1994. *RECREL: A Similarity Measure for Set-Classes*. Helsinki: Sibelius-Akatemia.

Castren, Marcus, and Mikael Laurson. 1989. "Introduction to MacSet, an analysis program for pitch class set theory," *Musiikki* XIX/1-4 (1989): 436-445.

Cemgil, Taylan, Peter Desain, and B. Kappen. 1999. "Rhythm Quantization for Transcription," *Proceedings of the AISB'99 Symposium on Musical Creativity*. 140-146.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Cemgil, Taylan, and Huub van Thienen. 1999. *Quantization for Notation: methods used in commercual musical software*. Mimeographed. Nijmegen, Netherlands.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Ceulemans, Anne-Emmanuelle. 1996. "Les dissonances dans la polyphonie des XVe- et XVIe- siecles: Quelques indications en vue d'une analyse assistee par ordinateur," *Musurgia: Analyse et Pratique Musicales* III/2 (1996): 7-21.

Chadabe, Joel. 1999. "A Brief Overview of Otto Laske's Work," *Otto Laske: Navigating New Musical Horizons*, ed. by Jerry Tabor. Westport, Connecticut: Greenwood. 73-79.

Chafe, Chris, Bernard Mont-Reynaud, and Loren Rush. 1982. "Toward an Intelligent Editor of Digital Audio: Recognition of Musical Constructs," *Computer Music Journal* VI/1 (1982): 30-41.

Chafe, Chris, Bernard Mont-Reynaud, and Loren Rush. 1989. "Toward an Intelligent Editor of Digital Audio: Recognition of Musical Constructs," *The Music Machine*, ed. by Curtis Roads. Cambridge, MA: MIT Press. 537-548.

Chalupka, Lubomir, and Viera Chalupkova. 1978. "Spracovianie Suboru L'udovych Piesni na SP MSP 2A," *Musicologica slovaca* (Czechoslovakia) VI (1978): 203-208.

Chalupkova, Viera. 1978. "Tonalna Analyza Suboru Piesni a Jej Vyhodnotenie," *Musicologica slovaca* (Czechoslovakia) VI (1978): 209-215.

Charnassé, Hélène, and Henri Ducasse. 1971. "De l'emploi de l'ordinateur pour la transcription des trablatures," *Revue de Musicologie* 57/2 (1971): 107-133.

Charnassé, Hélène, and Henri Ducasse. 1975. "Automated Tablature Transcription," *Computational Musicology Newsletter* II/1 (1975): 9-10.

Charnassé, Hélène, and Bernard Stepien. 1991. "Computer and Musicology. Automatic Transcription of 16th century music: german Lute Tablatures," *Computers in the Humanities and the Social Sciences*, ed. by Heinrich Best, Ekkehard Mochmann and Manfred Thaller. München: K. G. Saur. 75-83.

Charnassé, Hélène, and Bernard Stepien. 1992. Automatic Transcription of german Lute Tablatures. An Artificial Intelligence Application," *Computer Representations and Models in Music*, ed. by Alan Marsden & Anthony Pople. London: Academic Press. 143-170.

Chave, George Bidgood. 1988. A Computer-Assisted Analysis of Tonal Relationships in the Third Movement of Roger Sessions' "Second Symphony" (with) "Sapphire". PhD thesis, Washington University.

Chemillier, Marc. 1990. Structure et Méthode Algébriques en informatique Musicale, Ph.D. thesis. University of Paris VII.

Chenoweth, Vida. 1974. *Melodic Perception and Analysis: A Manual on Ethnic Melody.* Ukarumpa: Summer Institute of Linguistics.

Chenoweth, Vida, and Darlene Bee. 1971. "Comparative-Generative Models of a New Guinea Melodic Structure," *American Anthropoligist* 73 (1971): 773-782.

Chesnut, John. 1988. "Affective design in Schubert's Moment musical op. 94, no. 6," *Explorations in music, the arts, and ideas: Essays in honor of Leonard B. Meyer*, ed. by Eugene Narmour and Ruth A. Solie. Stuyvesant, NY: Pendragon. 295-316.

Chmurny, Rudolf. 1978. "DIS, metoda Vyhodnocovania Podobnosti Melodii," *Musicologica slovaca* (Czechoslovakia) VI (1978): 183-186.

Ciamaga, Gustav. 1971. "The Training of the Computer in the Use of New technological Means," *Music and Technology*. Paris: La Revue Musicale, 1971. 143-150.

Citron, Jack. 1966. "MUSPEC," *Computers and the Humanities* I, no. 2 (1966): 52.

Clarke, Eric F. 1986. "Theory, Analysis and the Psychology of Music: A Critical Evaluation of Lerdahl, F. and Jackendoff, R. *A Generative Theory of Tonal Music*," *Psychology of Music* XIV (1986): 3-16.

__________. 1987. "Level of Structure in the Organization of Musical Time," *Comtemporary Music Review* 2 (1987): 211-238.

__________. 1988. "Generative Principles in Musical Performance," *Generative Processes in Music: The Psychology of Performance, Improvisation, and Composition*, ed. by J. Sloboda. Oxford: Claredon Press.

__________. 1989. "Mind the Gap: Formal Structures and Psychological Processes in Music," *Comtemporary Music Review* 3 (1989): 1-13.

__________. 1995. "Expression in Performance: Generativity, Perception and Semiotics," *The Practice of Performance: Studies in Musical Interpretation*, ed. by John S. Rink. Cambridge: Cambridge University Press. 21-54.

Clauß, Günter and Heinz Ebner. 1978. *Grundlagen der Statistik für Psychologen, Pädagogen und Soziologen*, 7th ed. Berlin: Technik Verlag.

Clifton, Thomas. 1973. "Music and the a priori," *Journal of Music Theory* 17(1): 66-85.

Clynes, Manfred. Ed. 1982. Music, Mind, and Brain: The Neuro-Psychology of Music. New York: Plenum.

__________. 1983. "Expressive Microstructures in Music, Linked to Living Qualities," *Studies of Music Performance*, ed. by J. Sundberg. Stockholm: Royal Swedish Academy of Music. 76-181.

__________. 1984. "Secrets of Life in Music: Musicality Realized by Computer," *Proceedings of the 1984 International Computer Music Conference*. Computer Music Association. 225-232.

__________. 1987. "What Can a Musician Learn About Performance From Newly Discovered Microstructture Principles (PM and PAS)? *Action and Perception in Rhythm and Music*, ed. by A. Gabrielsson. Stockholm: Royal Swedish Academy of Music. 201-233.

__________. 1995. "Microstructural Musical Linguistics: Composers' Pulses Are Liked Most by the Best Musicians," *Cognition* 55(1995): 269-310.

Coates, Daran. 1994. "Representations of the MONK Harmonisatzion Systems," *Music Education: An Artificial Intelligence Approach*, ed. by Matt Smith, Alan Smaill, and Geraint A. Wiggins. London: Springer. 77-91.

Cobbett, Walter Willson, ed. 1929. *Cobbett's Cyclopedic Survey of Chamber Music*. London: Oxford University Press.

Cobin, Marian W. 1967a. "Musicology and the Computer in New Orleans," *Computers and the Humanities* I/4 (1967): 131-133.

Cogan, Robert. 1984. *New Images of Musical Sound*. Cambridge: Harvard University Press.

Cohen, Annabel J., Sandra E. Trehub, and Leigh A. Thorpe. 1989. "Effects of Uncertainty on Melodic Information Processing," *Perception and Psychophysics* 46/1 (1989): 18-28.

Cohen, Dalia, and Shlomo Dubnov. 1997. "Gestalt Phenomena in Musical Texture," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 386-405.

Cohen, Dalia, and A. Erez. 1991. "ERP Measurements of Cognitive Components in Response to Pitch Patterns," *Music Perception* 8 (1991): 405-430.

Cohen, Dalia, Roni Granot, Hillel Pratt, and Anat Barneah. 1993. "Cognitive Meanings of Musical Elements as Disclosed by ERP and verbal Experiments," *Music Perception* XI/2 (1993): 153-184.

Cohen, Dalia and Roni Granot. 1993. "Constant and Variable Influences on Stages of Musical Activities. Research Based on Experiments Using Behavioral and Electrophysiological Indices," *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*, ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä. 40-73.

Cohen, Dalia, and Roni Jeger-Granot. 1995. "Constant and Variable Influences on Stages of Musical Activities," *Journal of New Music Research* XXIV (1995): 197-229.

Cohen, Dalia, and Ruth Katz. 1973. "Quantitative analysis of monophonic music: towards a more precise definition of style," *Orbis Musicae* 2: 83-96.

Cohen, Dalia, and Ruth Katz. 1977. *The Israeli Folk Song: A Methodological Example of Computer Analysis of Monophonic Music.* Jerusalem: The Magnes Press.

Cohen, Dalia, and Ruth Katz. 1997. "Attitudes to the Time Axis and Cognitive Constraints: The Case of Arabic Vocal Folk Music," *Perception and Cognition of Music*, ed. by Irène Deliège and John Sloboda. East Sussex, UK: Psychology Press. 31-45

Cohen, Dalia, Joweph Mendel, Hillel Prat, and Anat Barnea. Response to Intervals as Revealed by Brainwave Measurement and Verbal means," *Journal of New Music Research* XXIII (1994): 265-290.

Cohen, Joel E. 1962. "Information Theory and Music," *Behavioral Science* VII/2 (April 1962): 137-163.

__________. 1964. "Teorie informací a hudba," *Nové Cesty Hudby* (1964): 180-215.

Colangelo, William. The Composer-Performer Paradigm in Giacinto Scelsi's Solo Works. Ph.D. thesis. New York University, 1996.

Collins, Walter S. 1965. "A New Tool for Musicology," *Music & Letters* XLVI, no. 2 (1965): 122-125.

Collins, Denis, and David Huron. 2000. "Voice-leading in cantus firmus-based canonic composition: A comparison between theory and practice in renaissance and baroque music," Computers in Music Research. In press.

Colquhoun, Daryl George. 1979. "Computer Piano Concertos," *Computers and the Humanities* XIII/3 (1979): 261.

Conklin, Darrel, and Ian H. Witten. 1991. Prediction and Entropy of Music. Technical Report 91 / 457 / 41. Department of Computer Science. University of Calgary, Alberta, Canda, December 1991.

Conklin, Darrel, and Ian H. Witten. 1995. "Multiple Viewpoint Systems for Music Prediction," *Journal of New Music Research* XXIV (1995): 51-73.

Connor, Aikin Orange. 1967. The perception of musical intervals: the theory of property arrays. Ed.D. thesis. University of the Pacific.

Coons, Edgar, and David Kraehenbuehl. 1958. "Information as a Measure of Structure in Music," *Journal of Music Theory* II (1958): 127-161.

Cooper, David. 1995. Review on Music Education: *An Artificial Intelligence Approach* by Matt Smith et al. (Eds.), *Journal of New Music Research* XXIV (1995): 74-79.

Cope, David. 1987. An Expert System for Computer-Assisted Composition," Computer Music Journal XI/4 (1987): 30-46.

__________. 1988. "Music and LISP," *AI Expert* III/3 (1988): 26-34.

__________. 1989. "Experiments in Musical Intelligence (EMI): Non-Linear Linguistic-Based Composition," *Interface* XVIII/1-2 (1989): 117-139.

__________. 1990. "Pattern Matching as an Engine for the Simulation of Musical Style," *Proceedings of the International Computer Music Conference, Glasgow, 1990*. San Francisco: International Computer Music Association. 288-291.

__________. 1991. *Computers and Musical Style*. Madison, Wisconsin: A-R Editions.

__________. 1992a. "Computer Modeling of Musical Intelligence in EMI," *Computer Music Journal* XVI/2 (1992): 69-83.

__________. 1992b. "On algorithmic representation of musical style," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge: MIT Press. 354-363.

__________. 1996. *Experiments in Musical Intelligence*. Wisconsin: A-R Editions.

Cosi, Piero, Giovanni De Poli, and Giampaolo Lauzzana. 1994. "Auditory Modelling and Self-Organizing Neural Networks for Timbre Classification," *Journal of New Music Research* XXIII (1994): 71-98.

Courtney, David R. 1992. "Introduction to spectrum analysis," *Experimental Musical Instruments* VIII/1 (1992): 18-22.

Courtot, Francis. 1991. CARLA: Acquisition et Induction sur le Matériau Compositionnel. Ph.D. thesis. Université de Rennes I (France).

__________. 1992. "CARLA: Knowledge Acquisition and Induction for Computer Assisted Composition," *Interface* XXI (1992): 191-217.

Coventry, Kenny R., and Tim Blackwell. 1994. "Pragmatics in Language and Music," *Music Education: An Artificial Intelligence Approach*, ed. by Matt Smith, Alan Smaill, and Geraint A. Wiggings. London: Springer. 123-142.

Cramer, Cheryl Lynn. 1986. Musical Paraphrase: A Computer-Based Cognitive Model Derived from Stephen Foster Songs. Ph.D. thesis. University of Pittsburgh.

Crane, Frederick. 1968. "Statistical Comparison of Musical Styles," *Computers and the Humanities* II, no. 5 (1968): 244.

Crane, Frederick, and Judith Fiehler. 1970. "Numerical Methods of Comparing Musical Styles," *The Computer and Music*, ed. by Harry B. Lincoln. Ithaca: Cornell University Press. 209-222.

Crawford, M. D., M. P. Cooke, and Guy J. Brown. 1993. "Interactive Computational Auditory Scene Analysis: An Environment for Exploring Auditory Representations and Groups," *Journal of the Acoustical Society of America* 93 (1993): 2308.

Crerar, Alison. 1985. "Elements of a Statistical Approach to the Question of Autorship in Music," *Computers and the Humanities* XIX/3 (1985): 175-182.

Csébfalvy, K., M. Havass, P. Járdányi, and L. Vargyas. 1965. "Systematization of Tunes by Computers," *Studia Musicologica Academiae Scientiarum Humgaricae* VII (1965): 253-257.

Cuddy, Lola L. 1997. "Tonal Relations," *Perception and Cognition of Music*, ed. by Irène Deliège and John Sloboda. East Sussex, UK: Psychology Press. 329-352.

Cuddy, Lola L., Annabel J. Cohen, and J. Miller. 1979. "Melody Recognition: The Experimental Application of Musical Rules," *Canadian Journal of Psychology* XXXIII/3 (1979): 148-157.

Curry, Jerry L. 1969. A Computer-Aided Analytical Study of Kyries in Selected Masses of Johannes Ockeghem. Ph.D. thesis, University of Iowa.

Czagany, Zsuzsa. 1994. *Corpus antiphonalium officii ecclesiarum centralis Europae*, with an introduction by Laszlo Dobszay. Budapest: Magyar Tudomanyos Akademia.

Czekanowska, Anna. 1969. "Zastosowanie polskicg metod statystycznych do klasyfikacji melodii ludowych," *Muzyka*, Poland XIV/1 (1969): 3-18.

Czekanowska-Kulinska, Anna. 1970. "Polish Mathematical Methods in the Classification of Slavic Folk Songs," *IMS: Report on the Tenth Congress, Lubljana 1967*, ed. by Dragotin Cvetko. Kassel: Bärenreiter. 440-443.

__________. 1977. "Comparative and quantitative methods in international research projects on folk music," *Ethnologia Slavica* VIII-IX (1976-77): 307-18.

Dack, John. 1998. "Strategies in the Analysis of Karlheinz Stockhausen's *Kontakte für elektronische Klänge, Klavier und Schlagzeug*," *Journal of New Music Research* XXVII (1998): 84-119.

Dahlhaus, Carl. 1984. *Die Musiktheorie im 18. und 19. Jahrhundert. Erster Teil: Grundzüge einer Systematik*. Darmstadt: Wissenschaftliche Buchgesellschaft.

Dalmonte, Rossana, and Mario Baroni. Eds. 1992. *Secondo Convegno Europeo di Analisi Musicale*, 2 vols. Trento, Italy: U. degli Studi, Dipartimento di Storia della Civilta.

Dannenberg, Roger B. 1985. "An On-Line Algorithm for Real-Time Accompaniment," *Proceedings of the 1984 International Computer Music Conference*. San Francisco: International Computer Music Association. 193-198.

__________. 1991. "Recent Work in Real-Time Music Understanding by Computer," *Music, Language, Speech, and Brain*, ed. by J. Sundberg, L. Nord, and R. Carlson. London: Macmillan. 194-202.

__________. 1993a. "Music Representation Issues, Techniques, and Systems," *Computer Music Journal* XVII/3 (1993): 20-30.

__________. 1993b. "Computerbegleitung und Musikverstehen," *Neue Musiktechnologie*, ed. by Bernd Enders. Mainz, Germany: Schott. 241-252.

Dannenberg, Roger B., and Istvan Derenyi. 1998. "Combining Instrument and Performance Models for High-Quality Music Synthesis," *Journal of New Music Research* XXVII/3 (1998): 211-238.

Dannenberg, Roger B., Peter Desain, and Henkjan Honing. 1997. "Programming language design for music," *Musical Signal Processing*, ed. by Curtis Roads, Stephen Travis Pope, Aldo Piccialli, and Giovanni de Poli. Lisse: Swets & Zeitlinger. 271-315.

Dannenberg, Roger B., and Bernard Mont-Reynaud. 1987. Following an Improvisation in real Time," *Proceedings of the 1987 International Computer Music Conference*. San Francisco: Computer Music Association. 241-248.

Dannenberg, Roger B., Marta Sanchez, Annabelle Joseph, Ronald Saul, Robert Joseph, Peter Capell. 1990a. "An expert system for teaching piano to novices," *Proceedings of the International Computer Music Conference, Glasgow, 1990*. San Francisco, CA: Computer Music Association. 20-23.

Dannenberg, Roger B., Marta Sanchez, Annabelle Joseph, Peter Capell, Robert Joseph Ronald Saul. 1990b. "A computer-based multi-media tutor for beginning piano students," *Interface* XIX/2-3 (1990): 155-173.

Dauer, Alfons Michael. 1983. "Kinesis und Katharsis. Prolegomena zur Deutung afrikanischer Rhythmik," *Musik in Afrika*, ed. by Artur Simon. Berlin: Museum für Völkerkunde.

__________. 1988. "Derler 1: ein System zur Klassifikation von Rhythmen. Musiktheoretische und Musikhistorische Aspekte," *Jazz-Forschung* 20 (1988): 117-154.

__________. 1989. "Das Derler-System und der Jazzrhythmus. Berichtigung und Ergänzung," *Jazz-Forschung* 21 (1989): 137-151.

David, Eduard. 1989. "Musikwahrnehmung und Hirnstrombild," *Musik - Gehirn - Spiel. Beiträge zum vierten Herbert von Karajan Symposion*, ed. by Hellmuth Petsche. Basel: Birkhäuser. 91-102.

Debiasi, Giovanni B., and Giovanni De Poli. 1982. "Musica: A Language for the Transcrition of Musical Text for Computers," *Interface* XI/1 (1982): 1-27.

Degenhardt, P. 1996. Melodielernen mit neuronalen Netzen am Beispiel von Variationswerken des Barock unter Berücksichtigung größerer musikalischer Zusammenhänge. Diplom thesis. Karlsruhe University (Germany).

Deihl, Ned C. 1971. Computer-Assisted Instruction and Instrumental Music: Implications for Teaching and Research," *Journal of Research in Music Education* XIX/3 (Fall 1971): 299-306.

Delalande, François. 1972. "L'analyse des musiques electro-acoustiques," *Musique en Jeu* (1972): 50-56.

__________. 1986. "En l'absence de partition, le cas singulier de l'analyse de la musique électroacoustique," *Analyse Musicale* 3 (1986): 54-58.

__________. 1987. "L'analyse des conduites musicale: Une étape du programme sémiologique?" *Semiotica* (1987): 66.

__________. 1989. "Essai d'analyse esthésique: La prise en compte des écoutes-types comme points de vue d'analyse," *Analyse Musicale* 16 (1989): 75-84.

__________. 1991. "L'analyse musicale, discipline expérimentale?" *Analyse Musicale* 23 (1991): 11-20.

__________. 1993. "Analyser le style en musique electroacoustique: Approximation et pluralité en analyse comparitive," *Analyse Musicale* 32 (1993): 28-33.

__________. 1998. "Music Analysis and Reception Behaviours: *Sommeil* by Pierre Henry," *Journal of New Music Research* XXVII (1998): 13-66.

de la Motte, Diether. 1987. *Musikalische Analyse.* Kassel: Bärenreiter.

de la Motte-Haber, Helga. 1970. "Die Abhängigkeit des Sonanzeindrucks von der Intervallstruktur," *Bericht über den Internationalen Musikwissenschaftlichen Kongress Leipzig 1966*, ed. by Carl Dahlhaus et al. Kassel: Bärenreiter. 477-482.

__________. 1987. "Historische und ästhetische Positionen der Computermusik," *Musica* 41/2 (1987): 128-143.

Del Giudice, Luisa. 1989. "Computer applications to the analysis of ballad variants," *Ballades et Chansons Folkloriques*, ed. by John R. Porter. Quebec, Quebec, Canada: Universitè de Laval, CELAT. 173-187.

Deliège, Célestin. 1984. "Some Unsolved Problems in Schenkerian Theory," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 71-82.

Deliège, Irene. 1985. "Perception des Formation Élémentaires de la Musiques," *Analyse Musicale* 4 (1985): 20-28.

__________. 1987. Grouping Conditions in Listening to Music: An Approach to Lerdahl and Jackendoff's Grouping Preference Rules," *Music Perception* 4 (1987): 325-360.

Deliège, Irene, and Abdessadek El-Ahmadi. 1990. "Mechanisms of extraction in musical groupings: A study of perception on Sequenza VI for viola solo by Luciano Berio," *Psychology of Music* XVIII/1 (1990): 18-44.

Deliège, Irene, and Marc Mélen. 1997. "Cue Abstraction in the Representation of Musical Form," *Perception and Cognition of Music*, ed. by Irène Deliège and John Sloboda. East Sussex, UK: Psychology Press. 387-412.

De Loos, Ike. 1996. "Ein Beispiel der Computeranalyse mittelalterlicher Neumen: Das Quilisma im Antiphonar U 406 (12. Jh.)," *Musicologica Austriaca* 14-15 (1996): 173-181.

DeMorgon, Jacques. Une communication de masse: la chanson a succes. Essai d'une premiere systematisation de son etude en France de 1946 a 1966. Ph.D. thesis. Department of Sociology. University of Paris V.

Demske, Thomas R. 1993. Recognizing melodic motion in musical scores: Rules and contexts. Ph.D. thesis. Yale University.

__________. 1995. "Relating sets: On Considering a Computational Model of Similarity Analysis," *Music Theory Online* I/2 (1995).

De Poli, Giovanni, Luca Irone, and Alvise Vidolin. 1990. "Music Score Interpretation Using a Multilevel Knowledge Base," *Interface* 19 (1990): 137-146.

De Poli, Giovanni, Aldo Piccialli, and Curtis Roads. Eds. 1991. *Representations of Musical Signals*. Cambridge: MIT Press.

De Poli, Giovanni, Antonio Rodà, and Alvise Vidolin. 1998. "Note-by-Note Analysis of the Influence of Expressive Intentions and Musical Structure in Violin Performance," Journal of New Music Research XXVII/3 (1998): 293-321.

Desain, Peter. 1990a. "LISP as a Second Language: Functional Aspects (Computer Music Forum)," *Perspectives of New Music* XXVIII/1 (Winter 1990): 192-223.

__________. 1990b. "Parsing the Parser: A Case Study in Programming Style," *Computers in Music Research* II (1990): 39-90.

__________. 1992. "A (De)Composable Theory of Rhythm Perception," *Music Perception* IX/4 (1992): 439-454.

__________. 1993. "A Connectionist and a Traditional AI Quantizer, Symbolic Versus Sub-Symbolic Models of Rhythm Perception," *Contemporary Music Review* 9 (1993): 239-254.

__________. 1994. "Taal of teken, stijlen van mens-computer interactie" ["Language or sign, styles of man-computer interaction"], *Mens-Computerinteractie*, ed. by A. A. J. Mannaerts, P. J. G. Keuss, and G. Ten Hoopen. Lisse: Swets & Zeitlinger. 109-129.

__________. 1998a. *Upbeat. Annual Report 1998. Music, Mind, Machine Group.* Nijmegen: Nijmegen Institute for Cognition and Information.

__________. 1998. "Computationeel modelleren van muziekcognitie: waar is de tel?," *Facta* (1998): 20-22.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

__________. 1999a. "The ingredients of a stable rhythm percept: all implicit time intervals plus integer ratio bonding between them," *Proceedings of the 1999 SMPC*. Evanston. 59.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

__________. 1999b. "Vibrato and Portamento, Hypotheses and Tests," *Acustica* 1999. 348.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desain, Peter, Rinus Aarts, Taylan Cemgil, B. Kappen, Huub van Thienen, and Paul Trilsbeek. 1999. "A Decomposition Model of Expressive Timing," Proceedings of th 19999 SMPC. Evanston. 21.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desain, Peter, and Tom Brus. 1993. "What Ever Happened to Our Beautiful Schematics," *Proceedings of the 1993 International Computer Music Conference*. San Francisco: International Computer Music Association. 366-368.

Desain, Peter, and Siebe DeVos. 1990. "Autocorrelation and the study of musical expression," *Proceedings of the International Computer Music Conference, Glasgow, 1990.* San Francisco, CA: Computer Music Association, 1990. 357-360.

Desain, Peter, and Henkjan Honing. 1989a. "The Quantization of Musical Time: A Connectionist Approach," *Computer Music Journal* XIII/3 (1989): 56-66.

Desain, Peter, and Henkjan Honing.1989b. "Report on the First AIM Conference Sankt Augustin, Germany September 1988," *Perspectives of New Music* XXVII/2 (1989): 282-289.

Desain, Peter, and Henkjan Honing.1991. "Toward a Calculus for Expressive Timing in Music," *Computers in Music Research* III (1991): 43-120.

Desain, Peter, and Henkjan Honing. 1992a. *Music, Mind, and Machine: Studies in Computer Music, Music Cognition, and Artificial Intelligence.* Amsterdam: Thesis Publishers.

Desain, Peter, and Henkjan Honing. 1992b. "Time Functions Function Best as Functions of Multiple Time," *Computer Music Journal* XVI/2 (1992).

Desain, Peter, and Henkjan Honing. 1992c. "The Quantization Problem: Thraditional and Connectionist Approaches," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge, MA: The MIT Press. 448-463.

Desain, Peter, and Henkjan Honing. 1993a. "CLOSe to the Edge? Multiple and Mixin Inheritance, Multi Methods, and Method Combination as Techniques in the Representation of Musical Knowledge," *Proceedings of the IAKTA Workshop on Knowledge Technology in the Arts*. Osaka: IAKTA/LIST. 99-106.

Desain, Peter, and Henkjan Honing. 1993b. "Letter to the editor: the mins of Max," *Computer Music Journal* XVII/2 (1993): 3-11.

Desain, Peter, and Henkjan Honing. 1993c. "On Continuous Musical Control of Discrete Musical Objects," *Proceedings of the 1993 International Computer Music Conference*. San Francisco: International Computer Music Association. 218-221.

Desain, Peter, and Henkjan Honing. 1993d. "Tempo Curves Considered Harmful," *Contemporary Music Review* VII/2 (1993): 123-138.

Desain, Peter, and Henkjan Honing. 1994a. "Advanced Issues in Beat Induction Modeling: Syncopation, Tempo and Timing," *Proceedings of the 1994 International Computer Music Conference*. San Francisco: International Computer Music Association. 92-94.

Desain, Peter, and Henkjan Honing. 1994b. "Can Music Cognition Benefit from Computer Music Research? From Foot-Tapper Systems to Beat Induction Models," *Proceedings of the ICMPC 1994*. Liège: ESCOM. 397-398.

Desain, Peter, and Henkjan Honing. 1994c. CLOSe to the Edge? Advanced Object Oriented Techniques in the Representation of Musical Knowledge. Research Report CT-94-13. Amsterdam: Institute for Logic, Language and Computation (ILLC).

Desain, Peter, and Henkjan Honing. 1994d. "Does Expressive Timing in Music Performance Scale Proportionally with Tempo?" *Psychological Research* 56 (1994): 285-292.

Desain, Peter, and Henkjan Honing. 1994e. "Foot-Tapping: A Brief Introduction to Beat Induction," *Proceedings of the 1994 International Computer Music Conference*. San Francisco: International Computer Music Association. 78-79.

Desain, Peter, and Henkjan Honing. 1994. "Rule-Based Models of Initial Beat Induction and an Analysis of Their Behavior," *Proceedings of the 1994 International Computer Music Conference.* San Francisco: International Computer Music Association. 80-82.

Desain, Peter, and Henkjan Honing. 1995a. "Computational models of beat induction: the rule-based approach," *Working Notes: Artificial Intelligence and Music*, ed. by G. Widmer. Montreal: IJCAI. 1-10.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desain, Peter, and Henkjan Honing. 1995b. "Towards algorithmic descriptions for continuous modulations of musical parameters," *Proceedings of the 1995 International Computer Music Conference*. San Francisco: ICMA. 393-395.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desain, Peter, and Henkjan Honing. 1995c. *Music, Mind, Machine. Computational Modeling of Temporal Structure in Musical Knowledge and Music Cognition.* Research proposal (Manuscript).
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desain, Peter, and Henkjan Honing. 1995d. "Computationeel modelleren van beat-inductie," *Van frictie tot wetenschap. Jaarboek 1994-1995.* Amsterdam: Vereniging van Academie-onderzoekers. 83-95.

Desain, Peter, and Henkjan Honing. 1996a. "Modeling Continuous Aspects of Music Performance: Vibrato and Portamento," *Proceedings of the International Music Perception and Cognition Conference*, ed. by B. Pennycook and E. Costa-Giomi. CD-ROM. Montreal.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desain, Peter, and Henkjan Honing. 1996b. "Physical motion as a metaphor for timing in music: the final ritard," *Proceedings of the 1996 International Computer Music Conference*. San Francisco: ICMA. 458-460.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desain, Peter, and Henkjan Honing. 1996c. "Mentalist and physicalist models of expressive timing," *Abstracts of the 1996 Rhtyhm Perception and Production Workshop.*München: Max-Planck-Institut.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desain, Peter, and Henkjan Honing. 1997a. "CLOSe to the edge? Advanced Object Oriented Techniques in the Representation of Musical Knowledge," *Journal of New Music Research* XXVI/1 (1997): 1-15.

Desain, Peter, and Henkjan Honing. 1997b. "Computational Modeling of Rhythm Perception," *Proceedings of the Workshop on Language and Music Perception* France: Marseille.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desain, Peter, and Henkjan Honing. 1997c. "Computationeel modelleren van beat-inductie," *Informatie* (1997): 48-53.

Desain, Peter, and Henkjan Honing. 1997d. "How to evaluate generative models of expression in music performance," *Isssues in AI and Music Evaluation and Assessment. Proceedings of the International Joint Conference on Artificial Intelligence in Nagoya, Japan.* 5-7.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desain, Peter, and Henkjan Honing. 1997. "Music, Mind, Machine: beatinductie computationeel modelleren," *Informatie* (1997): 48-53.

Desain, Peter, and Henkjan Honing. 1997. "Structural Expression Component Theory (SECT), and a method for decomposing expression in music performance," *Proceedings of the Society for Music Perception and Cognition Conference*. Cambridge: MIT. 38.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desain, Peter, and Henkjan Honing. 1998. "A reply to S. W. Smoliar's 'Modelling Musical Perception: A Critical View'," *Musical Networks, Parallel Distributed Perception and Performance*, ed. by N. Griffith and P. Todd. Cambridge: MIT Press. 111-114.

Desain, Peter, and Henkjan Honing. 1998. "Computational Models of Beat Induction: The Rule-Based Approach," *Journal of New Music Research* XXVIII/1 (1999): 29-42.

Desain, Peter, and Henkjan Honing. 2000. "Computational Models of Beat Induction: The Rule-Based Approach," *Journal of New Music Research*. In prep.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desain, Peter, Henkjan Honing, Rinus Aarts, and Renee Timmers. 1998. "Rhythmic Aspects of Vibrato," *Proceedings of the 1998 Rhythm Perception and Production Workshop* 34. Nijmegen.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desain, Peter, Henkjan Honing, Roger B. Dannenberg, D. Jacobs, Cort Lippe, Zack Settel, Stephen Travis Pope, Miller Puckette, and G. Lewis. 1993. "A Max Forum," *Array* 13(1): 14-20.

Desain, Peter, Henkjan Honing, and Hank Heijink. 1997. "Robust Score-Performance Matching: Taking Advantage of Structural Information," *Proceedings of the 1997 International Computer Music Conference*, San Francisco: ICMA. 337-340.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desain, Peter, Henkjan Honing, and P. Kappert. 1995. "Expresso: het retoucheren (en analyseren) van pianouitvoeringen," *Abstracts Congres Nederlandse Vereniging voor Psychonomie*. Egmond aan Zee: Vereniging voor Psychonomie. 20-21.

Desain, Peter, Henkjan Honing, Huub van Thienen, and Luke Windsor. 1998. "Computational Modeling of Music Cognition: Problem or Solution?" *Music Perception* (1998): 151-166.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desain, Peter, and Huub van Thienen. 1997. "Deutsch & Feroe Formalized," *Proceedings of the European Mathematical Psychology Group Conference*. Nijmegen. 18.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Desainte-Catherine, Myriam. 1995. Review of *Music Processing*, ed. by Goffredo Haus, *Journal of New Music Research* XXIV (1995): 392-397.

Detlovs, Vilnis K. 1968. "O statisticeskom analize muzyki," *Latvijskij matematiceskij ezegodnik* [Riga] 3 (1968). 101-120.

__________. 1984. "Oboscennye formalnye motivy," *Algebra i discretnaja matematika*, ed. by E. A. Ikaunieks. Riga.

__________. 1988. "On MicroSegmentation of Tunes. Alternative Units to F-motif," *Musikometrika 1*, ed. by Moisej G. Boroda. Bochum: Brockmeyer. 69-82.

Deutsch, Diana. 1980. "Music perception," *Musical Quarterly* LXVI/2 (April 1980): 165-179.

Diener, Glendon. 1985. Formal Languages in Music Theory. MA thesis, McGill University (Canada).

Dillon, Martin, and Michael Hunter. 1982. "Automated identification of melodic variants in folk music," *Computers and the Humanities* XVI/2 (October 1982): 107-117.

Di Scipio, Agostino. 1990. "Composition by Exploration of Nonlinear Dynamical Systems," *Proceedings of the International Computer Music Conference 1990*. San Francisco: International Computer Music Association. 324-327.

__________. 1993. "Models of Materials and of Musical Design Become Inseparable. A Study in Composition Theory," *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*, ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä. 300-316.

__________. 1995a. "Riflessioni sull'analisi della musica elettroacustica e informatica. Esperienze e spunti teorici," *Proceedings of the Xith Colloquium on Musical Informatics*, ed. by L. Finarelli and F. Regazzi. Bologna: Università di Bologna. 33-36.

__________. 1995b. "Inseparable Models of Materials and of Musical Design in Electroacoustic and Computer Music," *Journal of New Music Research* XXIV (1995): 34-50.

__________. 1995c. "Centrality of *Téchne* for an Aesthetic Approach on Electroacoustic Music," *Journal of New Music Research* XXIV (1995): 369-383.

Doati, Roberto. 1991. "György Ligeti's Glissandi: An Analysis," *Interface* XX/2 (1991): 79-87.

Dobszay, Laszlo. 1988. "The program 'CAO-ECE'," *Studia Musicologica Academiae Scientiarum Hungaricae* XXX/1-4 (1988): 355-60.

Dobszay, Laszlo, and Gabor Proszeky. 1988. *CAO-ECE: Corpus Antiphonalium Officii Ecclesiarium Centralis Europae - A Preliminary Report*. Budapest: Zenetudomanyi Intezet.

Dolson, Mark. 1987. Review of Gary Wittlich, John Schaffer, and Larry Babb's *Microcomputers and Music*, *Music Perception* IV/3 (1987): 306-309.

Donnini, Roberto. 1986. "The Visualization of Music: Symmetry and Asymmetry," *Symmetry: Unifying Human Understanding*, ed. by Istvàn Hargittai. New York: Pergamon Press. 435-463.

Draeger, Hans Heinz. 1964. "Analysis and Synthesis of Musical Structures on the Basis of Information Theory," *Bericht über den neunten internationalen Kongress Salzburg 1964*, ed. by Franz Giegling. Kassel: Bärenreiter. 261-

268.

__________. 1967. "A Quantitative Analysis of Music as Exemplified by Beethoven's Sletches for his Opus 131," *Festschrift für Walter Wiora*. Hamburg: Bärenreiter.

Drake, Carolyn, and Caroline Palmer. 1993. "Accent Structures in Musical Performance," *Music Perception* 10 (1993): 343-378.

Dransch, Detlef O. K., John C. Beatty, and Rhonda S. Ryman. 1985. *ChoreoScribe. A Graphics Editor to Describe Body Position and Movement Using Benesh Movement Notation*. Waterloo, Ontario: Computer Graphics Laboratory.

Ducasse, Henri, and Denys Pages. 1976. "Un systeme de constitution et d'exploitation de donnees pour l'identification et l'analyse de textes musicaux," *Revue de Musicologie* (France) LXII/2 (1976): 292-293.

Duisberg, Robert Adamy. 1980. A digital representation of musical samples and a calculation thereon of autocorrelation as a function of frequency. D.M.A. thesis. Universityof Washington.

Dunsby, Johnathan, and Arnold Whittall. 1988. *Music Analysis in Theory and Practice*. London: Faber Music.

Durbin, Mridula Adenwala. 1971. "Transformational Models Applied to Musical Analysis: Theoretical Possibilities," *Ethnomusicology* XV/3 (1971): 353-362.

Durrenmatt, Hans-Rudolf, Murray Gold, and Jan LaRue. " Die Notierung Thematischer Incipits auf 'Mark-Sense-Cards'," *Fontes Artes Musicae* XVII/1-2 (January-August 1970): 15-23.

Eaglestone, Marry M. 1992. "Extending the Relational Database Model for Computer Music Research," *Computer Representations and Models in Music*, ed. by Alan Marsden & Anthony Pople. London: Academic Press. 41-66.

Eastwood, Tony. 1985. "The Philosophical Implications of the Study of Large and Apparently Homogeneous Repertoires," *Studies in Music* (Australia) XIX (1985): 28-60.

Ebcioglu, Kemal. 1986. An Expert System for Harmonization of Chorales in the Style of J. S. Bach. PhD thesis, State University of New York at Buffalo.

__________. 1988. "An Expert System for Harmonizing Four-Part Chorales," *Computer Music Journal* XII/3 (1988): 43-51. Reprinted in *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press, 1993. 384-401.

__________. 1992. "An expert system for harmonizing chorales in the style of J.S. Bach," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge: MIT Press. 294-333.

Eberlein, Roland. 1986. "Ars antiqua: Harmonik und Datierung," *Archiv für Musikwissenschaft* XLIII/1 (1986): 1-16.

__________. 1997. "A Method of Analysing Harmony, Based on Interval Patterns or 'Gestalten'," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 225-236.

Edworthy, Judy. 1983. "Melodic Contour and Musical Structure," *Musical Structure and Cognition*, ed. by W. Jay Dowling and Dane Harwood. New York: Academic Press.

Eichert, Randolph, Lüder Schmidt, and Uwe Seifert. 1997. "Logic, Gestalt Theory, and Neural Computation in Research on Audotory Perceptual Organization," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 70-

Ellis, Mark. 1980. Linear Aspects of the Fugues of J. S. Bach's "The Well-Tempered Clavier": A Quantitative Survey. Ph.D. thesis. Nottingham University.

Elschek, Oskar. Ed. 1978. "Ludova piesen a samocinny pocitac, II," *Musicologica slovaca* (Czechoslovakia) VI (1978): 163-308.

Elscheková, Alica. 1966. "Methods of Classification of Folk Tunes," *Journal of International Folk Music Council* XVIII (1966): 56-76.

__________. 1969. "Technologie der Datenverarbeitung bei der Klassifizierung von Volksliedern," *Methoden der Klassifikation von Volksliedweisen*. Bratislava: Verlag der Slowakischen Akademie der Wissenschaften. 93-122.

__________. 1972. "Klasifikacie Kratkych Motivickych Usekov Netrofickych i Strofickych Piesni Tradicnymi a Netradicnymi Technikami," *Lidova pisen a samostatny pocitac I*, ed. by Dusan Holy and Oldrich Sirovátka. Brno: Klub uzivatelu MSP. 219-243.

__________. 1975. "Systematisierung, Klassifikation und Katalogisierung von

Volksliedweisen," *Handbuch des Volksliedes*, ed. by R. W. Brednich, L. Röhrich and W. Suppan, vol. 2. München: Fink, 1975, 549-582.

__________. 1978. "Metoda Vyhidnocivania Melodickych Podobnosti Pomocou Klasifikacnych Tabuliek," *Musicologica slovaca* (Czechoslovakia) VI (1978): 217-234.

__________. 1991. "Sucasne systemy analyzy l'udovych piesni," *Cesky Lid* 78/1 (1991): 30-32.

Elsner, Jürgen. 1990. "Der Rhythmus insiraf. Zum Problem quantitativer Rhythmik," *Rhythmik und Metrik in traditionellen Musikkulturen*, ed. by O. Elschek. Bratislava: Verlag der Slovakischen Akademie der Wissenschaften. 239-249.

Engels, Stefan. 1996. "Computerunterstutzte Systematisierung von Neumenzeichen in mittelalterlichen Codices aus Osterreich," *Mitteilungen der Osterreichischen Gesellschaft für Musikwissenschaft* XXX (Sept. 1996): 61-68.

Epstein, David. 1985a. "Tempo Relations: A Cross-Cultural Study," *Music Theory Spectrum* 7 (1985): 34-71.

__________. 1985b. "Mathematics, Structure and Music: Performance as Integrationm" *Musik und Mathematik. Salzburger Musikgespräch 1984 unter Vorsitz von Herbert von Karajan*, ed. by Heinz Götze and Rudolf Wille. Berlin: Springer. 79-80.

__________. 1989. "Time and Timing in Music: Musical Aspects and Neurobiological Aspects," *Musik - Gehirn - Spiel. Beiträge zum vierten Herbert von Karajan Symposium*, ed. by Hellmuth Petsche. Basel: Birkhäuser. 153-162.

Erickson, Raymond. 1968a. "Music Analysis and the Computer," *Journal of Music Theory* XII/2 (1968): 240-263.

__________. 1968b. "Music Analysis and the Computer: A Report on Some Current Approaches and the Outlook for the Future," *Computers and the Humanities* III/2 (1968): 87-104.

__________. 1969. "A General Purpose System for Computer Aided Musical Studies," *Journal of Music Theory* XIII (1969): 276-294.

__________. 1970a. Rhythmic Problems and Melodic Structure in Organum Purum: A Computer-Assisted Study. Ph.D. diss. Yale University.

__________. 1970b. "A Syntax-Directed, Changeable System for Processing Data for Music Analysis," *Computers and the Humanities* IV, no. 5 (1970): 343.

__________. 1970c. "Music and the Computer in the Sixties," *AFIPS* 36 (1970): 281-285.

__________. 1971a. "Rhythmic Problems and Melodic Structure in Organum Purum: A Computer-Assisted Study," *Computers and the Humanities* V, no. 5 (1971): 312-313.

__________. 1971b. "DUPACK (DARMS Utility Package)," *Computers and the Humanities* V, no. 5 (1971): 313.

__________. 1972a. "The Computer and Music," *Journal of the American Musicological Society* XXV/1 (Spring 1972): 102-107.

__________. 1972b. Abstract of *Rhythmic Problems and Melodic Structure in Organum Purum: A Computer-Assisted Study* by R. F. Erickson, *Computers and the Humanities* VI/4 (1972): 254.

__________. 1975a. "'The DARMS Project': A Status Report," *Computers in the Humanities* IX (1975): 291-298.

__________. 1975. "'The Darms Project': A Status Report," *Computational Musicology Newsletter* II/1 (1975): 7-8.

__________. 1977. "MUSICOMP 76 and The State of DARMS," *College Music Symposium* XVII/1 (Spring 1977): 90-101

__________. 1983. "The DARMS project: implementation of an artificial language for the representation of music," *Computers in Language Research*, vol. , II, ed. by Walter Sedelow and Sally Y. Sedelow. Berlin: Mouton. 171-219.

Erickson, Raymond, and Anthony B. Wolff. 1983. "The DARMS Project: Implementation of an Artificial Language for the Presentation of Music," *Computers in Language Research* II (1983): 171-219.

Ermedahl, Gunnar. 1975. "Notskrift och inspelning som underlag for musikalisk analys," *Svensk Tidskrift for Musikforskning* LVII/2 (1975): 65-66.

Evans, James R., Manfred Clynes. Eds. 1986. *Rhythm in Psychological, Linguistic, and Musical Processes*. Springfield, IL: Thomas.

Evarts, John. "Stockholm," *World of Music* XII/3 (1970): 52-56.

Farhart, Judy. 1996. An Expert System Approach to Musical Syntax Analysis. MS thesis, University of Houston.

Federman, Francine. 1996. A study of various representations using NEXTPITCH: A learning classifier system. Ph.D. thesis City University of New York.

Feld, Steven. 1974. "Linguistic Models in Ethnomusicology," *Ethnomusicology* XVIII/2 (1974): 197-217.

__________. 1990. "Linguistic models in ethnomusicology," *Ethnomusicological Theory and Method*, ed. by Kaufman Shelemay. New York : Garland. 183-203.

Feldman, David Henry, Mihaly Csikszentmihalyi, and Howard Garnder. *Changing the World. A Framework for the Study of Creativity*. Westport, Connecticut: Praeger.

Feng, Yin, and Xiang Xhang. 1990. "ESATM: An experimental system for analyzing the tonality of melodies," *Proceedings of the International Computer Music Conference, Glasgow, 1990*. San Francisco, CA: Computer Music Association, 1990. 163-165.

Ferkova, Eva. 1986. *Niektore moznosti vyuzitia vypoctovej techniky v analyze melodie a harmonie*. Bratislava: Slovenska Akademie Vied.

__________. 1989. "Miesto pocitaca v rozlisovani hudobnch stlov," *Hudobny Zivot* XXI/16 (1989): 12.

__________. 1992a. "Computer analysis of Classic harmonic structures," *Computing in Musicology* 8 (1992): 85-89.

__________. 1992b. "CACH: Computer analysis of Classical harmony," *Secondo Convegno Europeo di Analisi Musicale*, ed. by Rossana Dalmonte and Mario Baroni. Trento, Italy: U. degli Studi, Dipartimento di Storia della Civilta. 619-622.

Feulner, Johannes. 1992. "Learning the Harmonies of Western Tonal Music Using Neural Networks," *Proceedings of the International Symposium on Computer and Information Sciences VII 1992*, ed. by E. Gelenbe, U. Halici, and N. Yalabik. Paris: EHEI Press. 303-307.

__________. 1993. "Neural Networks that Learn and Reproduce Various Styles of Harmonization," *Proceedings of the 1993 International Computer Music Conference*. Tokyo, Japan: International Computer Music Association.

236-239.

Feulner, Johannes, and Dominik Hörnel. 1994. "MELONET: Neural Networks that Learn Harmony-Based Melodic Variations," *Proceedings of the 1994 International Computer Music Conference*. Aarhus, Denmark: International Computer Music Association.

Fibich, Friedrich J. 1982. "Mikrocomputer in der Musiktheorie - Anwendungen in der Pädagogik," *Zeitschrift für Musikpädagogik* (November 1982): 37-39.

Ficici, Sevan G. 1991. "Computer analysis of surface detail in tonal music," *Proceedings: International Computer Music Conference, Montreal, 1991*. Montreal: McGill University Press, 1991. 57-60.

Filip, Miroslav. 1964. "Zákonitosti vyvoja harmónie vo svetle základnych myslienok teórie informácie," *Nové Cesty Hudby* (1964): 216-233.

Fink, Michael. 1972. Music analysis: an annotated bibliography. Los Alamitos: Southwest Regional Laboratory for Educational Research and Development. Technical report Vol. 43.

Fiore, Mary E. 1968. "Harmonic Structure in Variation Movements by Webern," *Computers and the Humanities* II, no. 5 (1968): 243.

__________. 1970. "Webern's Use of Motive in the Piano Variations," *The Computer and Music*, ed. by Harry B. Lincoln. Ithaca: Cornell University Press. 115-122.

Fiske, Harold E. *Selected Theories of Music Perception*. Lewiston, NY: Mellen, 1996.

Fleischer, A. 1996. Eine Analyse theoretischer Konzepte der Harmonielehre mit Hilfe des Computers. M.A. thesis. Berlin: Humboldt Universität.

Fodermayr, Franz, and Werner A. Deutsch. 1992a. "Configurazione del tempo e della dinamica nella cadenza della Lucia di Lammermoor nell'interpretazione di tre diverse cantanti," *Secondo Convegno Europeo di Analisi Musicale*, ed. by Rossana Dalmonte and Mario Baroni. Trento, Italy: U. degli Studi, Dipartimento di Storia della Civilta. 43-48.

Fodermayr, Franz, and Werner A. Deutsch. 1992b. "Zur Gestaltung von Zeitachse und Dynamik durch drei verschiedene Sangerinnen in der Kadenz aus Lucia di Lammermoor," *Secondo Convegno Europeo di Analisi Musicale*, ed. by Rossana Dalmonte and Mario Baroni. Trento, Italy: U. degli Studi, Dipartimento di Storia della Civilta. 65-76.

Fornusek, Jaroslav. 1972. "Aplikace zkusenosti z projektovani uloh na samocinnem pocitaci pro oblast lidove pisne," *Lidova pisen a samostatny pocitac I*, ed. by Dusan Holy and Oldrich Sirovátka. Brno: Klub uzivatelu MSP. 11-18.

Forte, Allen. 1964. "A Theory of Set-Complexes for Music," *Journal of Music Theory* VIII/2 (1964): 136-183.

__________. 1966. "A Program for the Analytic Reading of Scores," *Journal of Music Theory* X/2 (Winter 1966): 330-364. Reprinted in *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press, 1993. 55-81.

__________. 1967a. "Computer-implemented Analysis of Musical Structure," *Papers from the West Virginia University Conference on Computer Applications in Music*, ed. by Gerald Lefkoff. Morgantown: West Virginia University Library. 29-42.

__________. 1967b. "Music and Computing: The Present Situation," *Computers and the Humanities* II, no. 1 (1967): 32-35.

__________. 1967c. "Structure of Atonal Music," *Computers and the Humanities* II, no. 2 (1967): 86.

__________. 1967d. *Analytic Reading of Musical Scores*. Cambridge: Massachusetts Institute of Technology, April 1967.

__________. 1970a. "The Domain and Relations of Set-Complex Theory," *Journal of Music Theory* IX/1 (1970): 173-180.

__________. 1970b. "The Structure of Atonal Music: Practical Aspects of a Computer-Oriented Research Project," *Musicology and the Computer: Three Symposia*, ed. by Barry S. Brook. New York: The City University of New York Press. 10-18.

__________. 1973. *The Structure of Atonal Music*. New Haven: Yale University Press.

Franek, Marek, and Jiri Mates. 1997. "Tempo Relations: Is There a Psychological Basis for Proportional Tempo Theory?" *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 253-262.

Frank, Helmar. 1964. *Kybernetische Analysen subjektiver Sachverhalte*. Quickborn bei Hamburg: Schnelle.

__________. 1968. *Informationsästhetik. Grundlagenprobleme und erste Anwendungen auf die mime pure*, 3rd ed. Quickborn bei Hamburg: Schnelle.

__________. 1997. *Ästhetische Information : eine Einführung in die kybernetische Ästhethik*. Berlin: Institut für Kybernetik.

Frankel, Robert E., Stanley J. Rosenschein, and Stephen W. Smoliar. 1976. "A LISP-Based System for the Study of Schenkerian Analysis," *Computers in the Humanities* X (1976): 21-32.

Frankel, Robert E., Stanley J. Rosenschein, and Stephen W. Smoliar. 1978. "Schenker's Theory of Tonal Music - its Explication through Computational Processes," *International Journal of Man-Machine Studies* X (1978): 121-138.

Franzke, Ulrich. 1992. "Die 'Essener Software'," *Musikometrika 4*, ed. by Moisej G. Boroda. Bochum: Brockmeyer. 181-205.

__________. 1993. "Formale und endliche Melodiesprachen und das Problem der Musikdatenkodierung," *Fundamentals of musical language: An interdisciplinary approach*, ed. by Moisej G. Boroda. Bochum, Germany: Brockmeyer. 107-149.

Freeman, Linton C., and Alan P. Merriam. "Statistical Classification in Anthropology: An Application to Ethnomusicology," *American Anthropologist* 58 (1956): 464-472.

Friberg, Anders. 1991. "Generative Rules for Music Performance: A Formal Description of A Rule System," *Computer Music Journal* 15 (1991): 56-71.

__________. 1995a. A Quantitative Rule System for Musical Performance. Ph.D. thesis. Stockholm: Royal Institute of Technology.

__________. 1995b. "Matching the Rule Parameters of Phrase Arch to Performances of 'Träumerei': A Preliminary Study," *Proceedings of the KTH Symposium on Grammars for Music Performance May 27, 1995*, ed. by Anders Friberg and Johan Sundberg. Stockholm: Royal Swedish Academy of Music. 37-44.

Friberg, Anders, Roberto Bresin, Lars Frydén, and Johan Sundberg. 1998. "Musical Punctuation on the Microlevel: Automatic Identification and Performance of Small Melodic Units," *Journal of New Music Research* XXVII/3 (1998): 271-292.

Friberg, Anders, Lars Frydén, L. Bodin, and Johan Sundberg. 1991.

"Performance Rules for Computer-Controlled Contemporary Keyboard Music," *Computer Music Journal* 15 (1991): 49-55.

Friberg, Anders, and Johan Sundberg. 1987. "How to Terminate a Phrase. An Analysis-by-Synthesis Experiment on a Perceptual Aspect of Music Performance," *Action and Perception in Rhythm and Music*, ed. by A. Gabrielsson. Stockholm: Royal Swedish Academy of Music. 81-103.

Frisbie, Charlotte J. 1971. Anthropological and ethnomusicological implications of a comparative analysis of Bushmen and African Pygmy music," *Ethnology* X/3 (July 1971): 265-290.

Fry, Christopher. 1984. "Flavors Band: A Language for Specifying Musical Style," *Computer Music Journal* VIII/4 (1984): 2-34. Reprinted in *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press, 1993. 426-451.

__________. 1989. "Flavors Band: A language for specifying musical style," *The Music Machine*, ed. by Curtis Roads. Cambridge, MA: MIT Press. 295-310.

__________. 1991. "Flavors Band: A language for specifying musical style," *The Well-Tempered Object: Musical Applications of Object-Oriented Software Technologies*, ed. by Stephen Travis Pope. Cambridge, MA: MIT Press. 49-63.

__________. 1993. "Flavors Band: A Language for Specifying Musical Style," *Machine Models of Music*, ed. by Stephan M. Schwanauer and David A. Levitt. Cambridge, MA: MIT Press. 427-451.

Frydén, Lars, and Johan Sundberg. 1984. "Structural Information in Music Performance," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 237-243.

Frydén, Lars, and Johan Sundberg. 1985. "Analysis by synthesis of musical performance," *Trends and perspectives in musicology: Proceedings ofthe World Music Conference of the International Music Council, Oct. 3-5, 1983*. Stockholm: Kungliga Musikaliska Akademien. 165-166

Fucks, Wilhelm. 1956. "Mathematical Theory of Word Formation." *Information Theory*, ed. by Colin Cherry. London: Butterworths Scientific Publications, 154-170.

__________. 1957. "Gibt es mathematische Gesetze in Sprache und Musik?" *Umschau in Wissenschaft und Technik* 1957, no. 2: 33-37.

__________. 1958. *Mathematische Analyse der Formalstruktur von Musik*. Köln: Westdeutscher Verlag.

__________. 1962. "Mathematische Musikanalyse und Randomfolgen. Zufall und Musik." *Gravesaner Blätter* vol. VI (1962): 132-145.

__________. 1963. *Mathematische Analyse von Formalstrukturen von Werken der Musik*. Köln: Westdeutscher Verlag.

__________. 1964. "Gibt es mathematische Gesetze in Sprache und Musik?" *Kybernetik*, ed. by Helmar Frank, 4th ed. Frankfurt am Main: Umschau Verlag, 175-187.

__________. 1968. *Nach allen regeln der Kunst. Diagnosen über Literatur, Musik, bildende Kunst - die Werke, ihre Autoren und Schöpfer*. Stuttgart

Fucks, Wilhelm, and Josef Lauter. 1965. *Exaktwissenschaftliche Musikanalyse*. Köln: Westdeutscher Verlag.

Fugazzotto, Giuliana. 1991. "La trascrizione automatica come strumento di analisi musicale: Una ministoria," *Analisi: Rivista di teoria e pedagogia musicale* II/6 (1991); 19-30.

Fujinaga, Ichiro, Bo Alphonce, Bruce Pennycook. 1989. "Issues in the design of an optical music recognition system," *Proceedings of the 1989 International Computer Music Conference*, ed. by Peter Desain, Henkjan Honing, and Klaus de Rijk. San Francisco, CA: International Computer Music Association. 113-116.

Fujinaga, Ichiro, Bo Alphonce, Bruce Pennycook, and Natalie Boisvert. 1989. "Optical Recognition of Musical Notation by Computer," *Computers and Music Research* I (1989): 161-164.

Fujinaga, Ichiro, Bruce Pennycook, and Bo Alphonce. 1991. "The Optical Music Recognition Project at McGill," *Computers in Music Research* III (1991): 139-142.

Fuller, Ramon Conrad. 1965. An Information Theory Analysis of Anton Webern's 'Symphonie,' opus 21 (with) 'Music for Two Channel Tape and Two Percussionists'. D.M.A. thesis. University of Illinois at Urbana Champaign.

__________. 1970. "Toward a Theory of Webernian Harmony, via Analysis with a Digital Computer," *The Computer and Music*, ed. by Harry B. Lincoln. Ithaca: Cornell University Press. 123-131.

Fyk, Janina. 1997. "Intonational Protention in the Performance of Melodic

Octaves on the Violin," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 421-430.

Gabrielsson, Alf. 1985. "Interplay Between Analysis and Synthesis in Studies of Music Performance and Music Experience," *Music Perception* 3/1 (1985): 59-86.

__________. 1987a. *Action and Perception in Rhythm and Music*. Stockholm: Royal Swedish Academy of Music.

__________. 1987b. "Once Again: The Theme from Mozart's Piano Sonata in A Major (K. 331). A Comparison of Five Performances," *Action and Perception in Rhythm and Music*, ed. by A. Gabrielsson. Stockholm: Royal Swedish Academy of Music. 81-103.

__________. 1993. "The Complexities of Rhythm," *Psychology of Music - The Understanding of melody and Rhythm*, ed. by T. J. Tighe and W. J. Dowling. Hillsdale, NJ: Erlbaum. 93-120.

__________. 1995. "Expressive Intention and Performance," *Music and the Mind Machine*, ed. by R. Steinberg. Berlin: Springer. 37-47.

Gabrielsson, Alf, and Anna Johnson. 1985. "Melodic Motion in Different Vocal Styles," *Analytica: Studies in the Description and Analysis of Music*, ed. by Anders Lönn and Erik Kjellberg. Uppsala: Uppsala University. 277-299.

Gabura, A. James. 1965. "Computer Analysis of Musical Style," *Association of Computing Machinery Proceedings of the 20th National Conference*. New York: Association for Computing Machinery.

__________. 1967. Music Style Analysis by Computer. M.Sc. thesis, University of Toronto.

__________. 1970. "Musical Style Analysis by Computer," *The Computer and Music*, ed. by Harry B. Lincoln. Ithaca: Cornell University Press. 223-276.

Gardikiotis, Spyros K. 1992. "Melody," *Computing in Musicology* 8 (1992): 70-71.

Gardner, Howard. 1993. *Creating Minds. An Anatomy of Creativity Seen Through the Lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Gandhi*. New York, NY: Basic Books.

Garton, Brad. 1992. "Virtual Performance Modeling," *Proceedings of the 1992 International Computer Music Conference*. San Francisco: International Computer Music Association. 219-222.

Gasparov, Boris M. 1972. "Strukturnyj metod v muzykozananii," *Sovetskaya Muzyka* 4 (1972): 42-51.

__________. 1974a. "O nekotorych principach strukturnogo analiza muzyki," *Problemy muzykalnogo myshlenija*. Moskow: Muzyka. 129-152.

__________. 1974b. "Nekotorye Deskriptivnye Problemy Muzykal'noj Semantiki," *Acta et Commentationes Universitatis Tartuensis, Trudy po Znakovym Sistemam* 8 (1974).

Geake, John. 1997. "Individual Differences in the Perception of Musical Coherence," *Journal of New Music Research* XXVI (1997): 201-226.

Gerson-Kiwi, Edith. 1953. "Toward an Exact Transcription of Tone-Relations," *Acta Musicologica* 25 (September): 80-87.

Gilbert, Steven E. 1970. The trichord: an analytic outlook for twentieth-century music. Ph.D. thesis. Yale University.

Giomi, Francesco. 1993. "Analisi musicale e intelligenza artificiale: Problemi metodi ed esempi," Eunomio: Parole di Musica XX (1993): 18-33.

Giomi, Francesco, and Marco Ligabue. 1991. "Computational Generation and Study of Jazz Music," *Interface* XX/1 (1991): 47-63.

Giomi, Francesco, and Marco Ligabue. 1992. "Un Approccio Estesico-Cognitivo alla Descrizione dell'*Objet Sonore*. Dalla Definizione del Paradigma Fonematico alla Individuazione di Strategie Analitico-Computazionali," *Atti des Secondo Convengo Europeo di Analisi Musicale*, ed. by R. Dalmonte and Mario Baroni. Trento: Università di Trento.

Giomi, Francesco, and Marco Ligabue. 1995. "Forme e Strutture nella Musica Elettroacustica tra gli anni Cinquanta e Sessanta," *Atti del XI Colloquio di Informatica Musicale*, ed. by L. Finarelli and F. Ragazzi. Bologna: Università di Bologna.

Giomi, Francesco, and Marco Ligabue. 1998. "Evangelisti's Composition *Incontri di Fasce Sonore* at W.D.R.: Aesthetic-Cognitive Analysis in Theory and Practice," *Journal of New Music Research* XXVII (1998): 120-145.

Gjerdingen, Robert Owen. 1984. A Musical Schema: Structure and Style Change, 1720-1900. PhD thesis, University of Pennsylvania.

__________. 1989. "Using Connectionist Models to Explore Musical Patterns," *Computer Music Journal* XIII (1989): 67-75.

__________. 1991. "Revisiting Meyer's Grammatical Simplicity and Relational Richness," *Cognitive Bases of Musical Communication*, ed. by Mari Riess Jones and Susan Holleran. Washington, D.C.: American Psychological Association, 1991. 225-243.

Glass, Gene V., and Kenneth D. Hopkins. 1996. *Statistical Methods in Education and Psychology*, 3rd edition. Boston: Allyn and Bacon.

Godoy, Rolf Inge. 1997a. Formalization and Epistemology. Oslo: Scandinavian University Press.

__________. 1997b. "Knowledge in Music Theory by Shapes of Musical Objects and Sound-Producing Actions," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 89-102.

Goldberg, Robert P. 1970. "Experimental Music Information System," *Computers and the Humanities* IV, no. 5 (1970): 345-346.

Golden, Cyril H. 1968. *Methods of Statistical Analysis*, 2nd edition. New York: Chapman & Hall.

Goldman, Stanford. 1953. *Information Theory*. New York: Dover.

Goller, Gottfried. 1969. "Zur Bezeichnung der Neumen in der germanischen Choralnotation des 12. bis 14. Jahrhunderts," *Kirchenmusikalisches Jahrbuch*, Germany LIII (1969): 99-100.

Gonzalez, Sanchez, and Francisco Javier. 1989. "Analisis de intervalos y escalas modales," *Revista de Musicologia* XII/1 (1989): 53-78.

Gottschewski, Hermann. 1992. "Graphic analysis of recorded interpretations," *Computing in Musicology* 8 (1992): 93-96.

__________. 1995. "Computergestützte Tempoanalyse: Ein Versuch über Zeitstrukturen in der traditionellen japanischen Musik," *Lux oriente: Begegnungen der Kulturen in der Musikforschung. Festschrift Robert Gunther zum 65. Geburtstag*, ed. by Klaus Wolfgang Niemöller, Uwe Patzold, and Chung Kyo-chul Kassel: Bosse. 377-392.

Gould, Murray. 1967. "A Keypunchable Notation for the Liber Usualis," *Elektronische Datenverarbeitung in der Musikwissenschaft*, ed. by Harald Heckmann. Regensburg: Gustav Bosse. 25-40.

__________. 1968. Review of *Papers from the West Virginia University Conference on Computer Applications in Music* by Gerald Lefkoff (Ed.), *Computers and the Humanities* II, no. 5 (1968): 262-263.

Gould, Murray, and George W. Logemann. 1966. ALMA: An Alphanumeric Language for Music Analysis. New York University: Institute for Computer Research in the Humanities. [Los Angeles: University of California Library / Music Library, calling no. ML 432 G 734a]

Gould, Murray J., and George W. Logemann. 1970. "ALMA: Alphanumeric Language for Music Analysis," *Musicology and the Computer: Three Symposia*, ed. by Barry S. Brook. New York: The City University of New York Press. 57-90.

Granot, Roni. 1996. The Concept of Musical Expectancy Examined by Brainwave Recordings (ERP) and Verbal Responses. Ph.D. thesis. Hebrew University of Jerusalem.

Grauer, Viktor A . 1965. "Some Song-Style Clusters—A Preliminary Study." *Ethnomusicology* IX (1965): 265-271.

Greenhough, Michael. 1986. "A microcomputer system for the real-time exploration of musical structures," *Proceedings of the International Computer Music Conference*, ed. by Paul Berg. San Francisco, CA: International Computer Music Association. 91-93.

Greussay, Patrick. 1973. Modeles de descriptions symboliques en analyse musicale. Ph.D. thesis. University of Paris VIII.

Grey, J. M. 1978. Timbre Discrimination in Musical Patterns," *Journal of the Acoustical Society of America* 64 (1978): 467-472.

Griffith, Niall. 1993. "Representing the Tonality of Musical Sequences Using Neural Nets," *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*, ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä. 109-132.

Gross, Dorothy Susan. 1973. "Music Department," *Computational Musicology Newsletter* I/1 (1973): 14.

__________. 1975a. A Set of Computer Programs to Aid in Music Analysis, Ph.D. thesis, Indiana University.

__________. 1975b. "A computer package for music analysis," *Proceedings of the 2nd Indiana University Computer Network Conference on Instructional Computer Applications*. 6-10.

__________. 1975c. "A Set of Computer Prtograms to Aid in Music Analysis," *Computational Musicology Newsletter* II/1 (1975): 16.

__________. 1980. "A project in computer-assisted harmonic analysis," *Proceedings of the International Computer Music Conference*, ed. by. Hubert S. Howe. San Francisco: Computer Music Association. 525-533.

__________. 1981. "A Computer Project in Music Analysis," *Computing in the Humanities*, ed. Peter C. Patton and Renee A. Holoien. Lexington: Lexington Books. 299-313.

__________. 1984a. "Computer Applications to Music Theory: a Retrospective," *Computer Music Journal* VIII/4: 35-42.

__________. 1984b. "A Study in Rhythmic Complexity of Selected Twentieth-Century Works," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 337-344.

Grueninger, Diana Page. 1990. An Analysis of the Nine Preludes for Piano by Ruth Crawford Seeger. DA thesis, University of Northern Colorado.

Guigue, Didier. 1997. "Sonic Object: A Model for Twentieth-Century Music Analysis," *Journal of New Music Research* XXVI (1997): 346-375.

Guntzenhäuser, Rul. 1962. *Ästhetisches Maß und ästhetische Information. Einführung in die Theorie G. D. Birkhoffs und die Redundanztheorie ästhetischer Prozesse*. Quickborn bei Hamburg: Schnelle.

Gusev, Vladimir D., I. V. Bakhmutova, and Tatiana N. Titkova. 1990. "Repetition and variation in melody: Towards a quantitative study (on the material of composed songs)," *Quantitative Linguistics* 43 (1990): 143-168.

Gutknecht, Dieter. 1972. *Untersuchungen zur Melodik des Hugenottenpsalters*. Regensburg: Bosse.

Haas, Max. 1992. "Chatull Gadol 1.0," *Computing in Musicology* 8 (1992): 63-64.

__________. 1994. "Über einige Möglichkeiten der computergestützten Erforschung liturgischer Einstimmigkeit," *Max Lutolf zum 60. Geburtstag: Festschrift*, ed. by Bernhard Hangartner and Urs Fischer. Basel: Wiese.

Haefer, John Richard. 1971. Selected cantatas of Alan Hovhaness: a linear analysis. M.M. thesis. University of Arizona.

Hall, Thomas B. 1975. "Some computer aids for the preparation of critical editions of Renaissance Music," *Tijdschrift van de Vereniging voor Nederlandse Muziek Geschiedenis* 25(1): 38-53.

Halmos, Istvan. 1973. "Automation of Analysis and Classification of Folk Tunes. Part One: Comparison Note by Note," *Computational Musicology Newsletter* I/1 (1973): 15.

Halperin, David. 1978. A Structural Analysis of Troubadour Music. M.A. thesis. Tel-Aviv University.

__________. 1980. "Distributional structure in troubadour music," *Orbis Musicae* VII (1979-80): 15-26.

__________. 1986. Contributions to a Morphology of Ambrosian Chant: A Computer-Aided Analysis of the pars hiemalis according to the British Museum Manuscript Add. 34209. Ph.D. thesis. Tel-Aviv University.

__________. "A Segmentation Algorithm and its Application to Medieval Monophonic Music," *Musikometrika 2*, ed. by Moisej Boroda. Bochum: Brockmeyer. 107-120.

__________. 1992. "Towards Deciphering the Ugaritic Musical Notation," *Musikometrika 4*, ed. by Moisej G. Boroda. Bochum: Brockmeyer. 101-115.

__________. 1994. "Musical Chronology by Seriation," *Computers and the Humanities* XXVIII/1 (1994): 13-18.

Hamel, Keith A. 1989. "A Design for Music Editing and Printing Software Based on Notational Syntax (Computer Music Forum)," *Perspectives on New Music* XVII/1 (Winter 1989): 70-83.

Hamman, Michael. 1999. "Structure as Performance: Cognitive Musicology and the Objectification of Compositional Procedure," *Otto Laske: Navigating New Musical Horizons*, ed. by Jerry Tabor. Westport, Connecticut: Greenwood. 37-52.

Handelman, Eliot. 1991. Music as a Secondary Consciousness: An Implementation. PhD thesis, Princeton University.

Hansen, Finn Egeland. 1967. "Det gregorianske repertoire i Codex H 159 Montpellier," *Dansk Arbog for Musikforskning* V (1966-67): 181-182.

Hanson, Jens L. 1969. An Operational Approach to Theory of Rhythm. Ph.D. thesis, Yale University.

Hanzelin, Fred Lee. 1978. The Software for Computer Assisted Graphical Representation of Single Instrument Melodic Lines and Harmonic Spectra

Using DARMS Encoding and Acoustical Data. Ph.D. thesis, University of Illinois at Urbana-Campaign.

Harms, H. 1991. Musikalischer Kontrapunkt auf neuronalen Netzen. Diplom thesis. Karlsruhe University (Germany).

Harris, Craig R. 1985. Computer Programs for Set-Theoretic and Serial Analysis of Contemporary Music. Ph.D. thesis. Eastman School of Music.

Harris, Craig R. and Alexander R. Brinkman. *CMAP: Contemporary Music Analysis Package*. Computer program for Unix and MS-DOS. Version 1.0. Rochester: Bitwise Music.

Harris, Craig R. and Alexander R. Brinkman. 1989. "An integrated software system for set-theoretic and serial analysis of contemporary music," *Journal of Computer-Based Instruction* XVI/2 (1989): 59-70.

Harris, Mitch, Alan Smaill, and Geraint Wiggins. 1991. "Representing Music Symbolically," *IX Colloquium on Musical Informatics*, ed. by Antonio Camurri and Corrado Canepa. Genova 1991. 55-69.

Harvey, Todd Dunham. 1993. Keening as a Cross-Cultural Phenomenon. DMA thesis, Ohio State University.

Hasty, Christopher F. 1978. A theory of segmentation developed from late works of Stefan Wolpe. PhD dissertation, Yale University.

Hatano, Giyoo. 1968. "Ongaku eno johoron-teki sekkin," *Ongaku Gaku. Journal of the Japanese Musicological Society* XIV (1968): 54-64.

Haus, Goffredo. 1979. "Musical Text Transformations by Operators," *The Third Colloquium on Musical Informatics*, April 1-2, 1979, Padua University, Italy. See abstract in *Computers in the Humanities* XVI/4 (1982): 264.

__________. 1983. EMPS: A System for Graphic Transcription of Electronic Music Scores," *Computer Music Journal* VII/3 (1983): 31-36.

__________. Ed. 1993. *Music Processing*. Madison, WI: A-R.

Haus, Goffredo, and I. Pighi. 1993. "Stazione di Lavoro Musicale Intelligente: L'ambiente Integrato Macintosh-NEXT," *Atti di X Colloquio Informatica Musicale*. Milano: AIMI, Università degli Studi di Milano.

Haus, Goffredo, and Antonio Rodriguez. 1993. "Formal Music Representation. A Case Study: The Model of Ravel's Bolero by Petri Nets," *Music Processing*, ed. by G. Haus. Madison, WI: A-R Editions. 165-232.

Haus, Goffredo, and Alberto Sametti. 1992. "ScoreSynth: A System for the Synthesis of Music Scores Based on Petri Nets and a Music Algebra," *Readings in Computer Generated Music*, ed. by D. Baggi. Washington: IEEE Computer Society Press. 53-78.

Haus, Goffredo, and Alberto Sametti. 1993. "L'ambiente per l'analisi/re-sintesi di partiture della Stazione di Lavoro Musicale Intelligente," *Atti del X Colloquio di Informatica Musicale*, ed. by Goffredo Haus and Isabella Pighi. Milano: Associazione di Informatica Musicale Italiana. 262-269.

Haus, Goffredo, and Alberto Sametti. 1995. "Score Analysis/Resynthesis Environment of the 'Intelligent Music Workstation'," *Journal of New Music Research* XXIV (1995): 230-246.

Heckmann, Harald. 1964. "Neue Methoden der Verarbeitung musikalischer Daten," *Die Musikforschung* XVII, no. 4 (1964): 381-383.

__________, ed. 1967a. *Elektronische Datenverarbeitung in der Musikwissenschaft*. Regensburg: Gustav Bosse.

__________. 1967b. "Elektronische Datenverarbeitung in der Musikwissenschaft. Eine Einleitung," *Elektronische Datenverarbeitung in der Musikwissenschaft*, ed. by Harald Heckmann. Regensburg: Gustav Bosse. VII-XVII.

__________. 1970. "Elektronische Datenverarbeitung in der Musikwissenschaft," *IMS: Report on the Tenth Congress, Lubljana 1967*, ed. by Dragotin Cvetko. Kassel: Bärenreiter, 1970. 424-427.

__________. 1971. "Katalog 'Deutsches Tenorlied des 16. Jahrhunderts," *Computers and the Humanities* V, no. 5 (1971): 313-314.

__________. 1972. "Informationstheorie und Computer," *Informatik. Vorträge anläßlich der Jahresversammlung vom 14. bis 17. Oktober 1971 zu Halle (Saale)*, ed. by Jocahim-Hermann Scharf. Nova Acta Leopoldina vol. 37/1, no. 206. Leipzig: Barth, 1972. 619-627.

__________. 1973a. "Musik - Dokumentation, Musik - Information," *Neue Zeitschrift für Musik* 134, no. 8 (1973): 479-482.

__________. 1973b. "Musikwissenschaft, Dokumentation, Information," *Musicae Scientae Collectanea. Festschrift Karl Gustav Fellerer zum 70. Geburtstag*, ed. by Heinrich Hüschen. Köln. 219-224.

Heike, Georg. 1961. "Informationstheorie und musikalische Komposition," *Melos*

XXVIII (1961): 269-272.

Heise, Walter. "Über Zwitschermaschinen und andere Kompatible," *"Zum Sehen geboren": Gedenkschrift für Helmuth Hopf*, ed. by Walter Reckziegel, Günther Rötter, and Brunhilde Sonntag. Münster: Lit. 163-172.

Heller, Jack J., and Warren C. Campbell. 1971. "Music Performance Analysis," *Council for Research in Music Education Bulletin* 24 (Spring 1971): 1-9.

Heller, Jack J., and Warren C. Campbell. 1972. *Computer analysis of the auditory characteristics of musical performance*. Washington: U.S. Dept. of HEW, Office of Education.

Helm, Everett. 1971. "UNESCO Report on the Stockholm Meeting," *Music and Technology*. Paris: La Revue Musicale. 193-206.

Helmuth, Mara. 1994. *Meeting the Free Dreamer: Analyses of Three Tape Compositions Created on the Computer and an Exploration of Computer Music Composition*. Ann Arbor, MI: University Microfilms.

__________. 1996. "Multidimensional Representation of Electroacoustic Music," *Journal of New Music Research* XXV (1996): 77-103.

Henckmann, Wolfhart and Konrad Lotter, eds. 1992. *Lexikon der Ästhetik*. München: Beck.

Henriksen, Jon Petter. 1976. Satsteknisk analyse ved hjelp av datamaskin. En musikologisk vinning? M.A. thesis. University of Oslo.

Henry, Edward O. 1976. "The Variety of Music in a North Indian Village: Reassessing Cantometrics," *Ethnomusicology* XX/1 (1976): 49-66.

Hermann, Richard. 1994. A General Measurement for Similarity Relations: A Heuristic for Constructing or Evaluating Aspects of Possible Musical Grammars. Ph.D. thesis. Eastman School of Music.

__________. 1995. "Towards a New Analytic Method for Post-Tonal Music: A Response to Thomas R. Demske," *Music Theory Online* I/3 (1995).

Hessert, Norman Dale. 1971. The Use of Information Theory in Musical Analysis. Ph.D. thesis, Indiana University.

Hewlett, Walter B. 1992. "A Base-40 Number-Line Representation of Musical Pitch Notation," *Musikometrika 4*, ed. by Moisej G. Boroda. Bochum: Brockmeyer. 1-14.

__________. 1996. "A derivative database format for high-speed searches," *Computing in Musicology* 10 (1995-1996): 131-142.

Hewlett, Walter B., and Eleanor Selfridge-Field. 1985. *Directory of Computer Assisted Research in Musicology*. Menlo Park, CA: Center for Computer Assisted Research in the Humanities.

Hewlett, Walter B., and Eleanor Selfridge-Field. 1986. *Directory of Computer Assisted Research in Musicology*. Menlo Park, CA: Center for Computer Assisted Research in the Humanities.

Hewlett, Walter B., and Eleanor Selfridge-Field. 1987. *Directory of Computer Assisted Research in Musicology*. Menlo Park, CA: Center for Computer Assisted Research in the Humanities.

Hewlett, Walter B., and Eleanor Selfridge-Field. Eds. 1988. *Directory of Computer Assisted Research in Musicology*. Menlo Park, CA: Center for Computer Assisted Research in the Humanities.

Hewlett, Walter B., and Eleanor Selfridge-Field. Eds. *Computing in Musicology*. Menlo Park, CA: Center for Computer Assisted Research in the Humanities. 1989 foll.

Hewlett, Walter B., and Eleanor Selfridge-Field. 1991. "Computing in Musicology, 1966-91," *Computers and the Humanities* XXV/6 (1991): 381-392.

Hidaka, I., M. Goto, and Y. Muraoka. 1995. "An Automatic Jazz Accompaniment System Reacting to Solo," *Proceedings of the International Computer Music Conference*. Banff: International Computer Music Association. 167-170.

Hild, Hermann. 1991. Neuronale Netze zur Harmonisierung vierstimmiger Choräle. Diplom thesis. Karlsruhe University (Germany).

Hild, Hermann, J. Feulner und W. Menzel. 1991. "HARMONET: A Neural Net for Harmonizing Chorals in the Style of J.S. Bach," *Advances in Neural Information Processing 4*, ed. by R. P. Lippmann, J. E. Moody, and D. S. Touretzky. San Mateo, CA : Morgan Kaufmann. 267-274.

Hilfinger, John Jay. 1985. A Comparison of some Aspects of Style in the Band and Orchestra Music of Vincent Persichetti. PhD thesis, The University of Iowa.

Hill, John Walter. 1988. "A computer-based analytical concordance of Vivaldi's aria texts: First findings and puzzling new questions about self-borrowing," *Nuovi Studi Vivaldiani: Edizione e Cronologia Critica delle Opere*, ed. by

Antonio Fanna and Giovanni Morelli. Firenze: Olschki. 511-534.

Hiller, Lejaren A., Jr. 1962. Information Theory and Musical Analysis. Mimeographed. Urbana: University of Illinois, Experimental Music Studio. Technical Report No. 5, July 1962. 40 p. (University of Cincinnati Library, MUS ML 3817 .I4 no. 5)

__________. 1964. *Informationstheorie und Computermusik*. Darmstädter Beiträge zur Neuen Musik 8. Mainz: B. Schott's Söhne.

Hiller, Lejaren A., and Calvert Bean. 1966. "Information Theory Analyses of Four Sonata Expositions," *Journal of Music Theory* X (1966): 96-137.

Hiller, Lejaren A., and James W. Beauchamp. 1968. Review of Completed and Proposed Research on Analysis and Synthesis of Musical Sounds by Analog and Digital Techniques. Technical Report No. 19. Urgana, IL: University of Illinois, Experimental Music Studio.

Hiller, Lejaren A., and Ramon Fuller. 1967. "Structure and Information in Webern's Symphonie, Op. 21," *Journal of Music Theory* XI, no. 1 (1967): 60-115.

Hiller, Lejaren A., and Leonard M. Isaacson. 1959. *Experimental Music. Composition with an electronic computer.* New York: McGraw-Hill.

Hiller, Lejaren A., and Burt Levy. 1984. "General system theory as applied to music analysis. I," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 295-316.

Hindemith, Paul. 1945. *The Craft of Musical Composition*, translated by Arthur Mendel. rev. ed. New York: Associated Music Publishers.

Hinderer, Drew Elliott. 1975. Music Analysis and the Genuine Instance Problem. PhD thesis, The University of Michigan.

Hodeir, Andre. 1995. "Deux temps a la recherche," *Musurgia: Analyse et Pratique Musicales* II/3 (1995): 35-42.

Holland, Simon. 1994. "Learning About Harmony Space: An Overview," *Music Education: An Artificial Intelligence Approach*, ed. by Matt Smith, Alan Smaill, and Geraint A. Wiggings. London: Springer. 24-40.

Holtzman, S. R. 1977. "A Program for Key Determination," *Interface* VI/1 (1977): 29-56.

__________. 1981. "Using generative grammars for music composition," *Computer Music Journal* V/1 (Spring 1981): 51-64.

Holy, Dusan, Antonin Bartosik, and Stanislav Zabadal. 1970. "Samocinny pocitac-pomocnik pri analyze a klasifikaci lidovych pisni," *Opus musicum* (Czechoslovakia) II/5-6 (1970): 155-64.

Holy, Dusan, Antonin Bartosik, and Stanislav Zabadal. 1972. "Cil-ukoly-postupy-perspektivy. Za studium lidovych pisni pomoci samocinneho pocitace," *Lidova pisen a samostatny pocitac I*, ed. by Dusan Holy and Oldrich Sirovátka. Brno: Klub uzivatelu MSP. 19-42.

Holy, Dusan, and Oldrich Sirovátka. Eds. 1972. *Lidova pisen a samostatny pocitac I.* Brno: Klub uzivatelu MSP. Mimeographed.

Hörnel, Dominik. 1992. Analyse und automatische Erzeugung klassischer Themen. Diplom thesis. Karlsruhe University (Germany).

__________. 1993. "SYSTHEMA - Analysis and Automatic Synthesis of Classical Themes," *Proceedings of the 1993 International Computer Music Conference*. San Francisco: International Computer Music Association. 340-342.

Hörnel, Dominik, and Wolfram Menzel, 1998. "Learning Musical Structure and Style with Neural Networks," *Computer Music Journal* XXII/4 (1998): 44-62.

Hörnel, Dominik, and T. Ragg. 1996. "Learning Musical Structure and Style by Recognition, Prediction and Evolution," *Proceedings of the 1996 International Computer Music Conference*. Hong Kong: International Computer Music Association.

Hörnel, Dominik, and T. Ragg. 1996. "A Connectionist Model for the Evolution of Styles of Harmonization," *Proceedings of the 1996 International Conference on Music Perception and Cognition*. Montreal, Canada.

Hofstetter, Fred T. 1973. "Computer Applications to Music at OSU," *Computational Musicology Newsletter* I/1 (1973): 2.

__________. 1979. "The Nationalistic Fingerprint in Nineteenth-century Romantic Chamber Music," *Computers and the Humanities* 13 (1979): 105-119.

Honing, Henkjan. 1990. "POCO: an environment for analysing, modifying, and generating expression in music," *Proceedings of the 1990 International Computer Music Conference*. San Francisco: Computer Music Association. 364-368.

__________. 1992. Issues in the Representation of Time and Structure in Music, Music, Mind Machine. Studies in Computer Music, Music Cognition and Artificial Intelligence, ed. by. P. Desain and H. Honing. Amsterdam: Thesis Publishers. 125-146.

__________. 1993a. "A Microworld Approach to the Formalization of Musical Knowledge," *Computers and the Humanities* XXVII (1993): 41-47.

__________. 1993b. "Issues in the Representation of Time and Structure in Music," *Contemporary Music Review* 9 (1993): 221-239.

__________. 1993c. "Report on the International Workshop on Models and Representations of Musical Signals, Capri, Italy, 1992," *Computer Music Journal*, 17/2 (1993): 80-81.

__________. 1994. The Vibrato Problem. Comparing Two Ways to Describe the Interaction Between the Continuous and Discrete Components in Music Representation Systems. Research Report CT-94-14. Amsterdam: Institute for Logic, Language and Computation (ILLC).

__________. 1995. "The vibrato problem, comparing two solutions," *Computer Music Journal*, XIX/3 (1995): 32-49.

Hood, Mantle. 1967. "Improvisation and Music Theory of the Javanese Gamelan," *Computers and the Humanities* II, no. 2 (1967): 88.

Horn, Wolfgang. 1996. "Satzlehre, Musiktheorie, Analyse. Variationen über ein ostinates Thema," *Zum Problem und zu Methoden von Musikanalyse*, ed. by Nico Schüler. Hamburg: von Bockel. 11-31.

Horowitz, D. 1995. "Representing Musical Knowledge in Jazz Improvisation System," *Proceedings of the Fourth Workshop on Artificial Intelligence and Music, IJCAI-95*. Montreal. 16-23.

Hoshovskyj, V. 1965. "The Experiment of Systemizing and Cataloguing Folk Tunes following the Principles of Musical Dialectology and Cybernetics," *Studia Musicologica Academiae Scientiarum Hungaricae* VII (1965): 273-286.

Hosokawa, Shuhei. 1984. "How Saussurian is a Music?" *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 155-163.

Howe, Hubert S. 1965. "Some Combinatorial Properties of Pitch Structures," *Perspectives of New Music* IV, no. 1 (1965): 45-61.

Howell, Peter John, Robert West, and Ian Cross. 1991. "Musical structure and knowledge representation," *Representing Musical Structure*, ed. by Peter John Howell, Robert West, and Ian Cross. London: Academic Press. 1-32.

Hsu, Kenneth J. 1993. "Fractal Geometry of Music: From Bird Songs to Bach," Applications of Fractals and Chaos: The Shape of Things, ed. by A. C. Crilly, R. A. Earnshaw, and H. Jones. Berlin: Springer. 21-39.

Hsu, Kenneth J., and Andrew Hsu. 1991. "Self-Similarity in the "1/f" Noise Called Music," *Proceedings of the National Academy of Sciences of the U.S.A.* 88/8 (April 1991): 3507-3509.

Huber, Alfred. 1974. "Informationstheorie und Musikanalyse," *Melos* XLI/4 (July-August 1974): 207-210.

Hudson, Barton. "Toward a Comprehensive French Chanson Catalog," *The Computer and Music*, ed. by Harry B. Lincoln. Ithaca: Cornell University Press. 277-287.

Hughes, D. 1988. "Deep Structure and Surface Structure in Javanese Music: A Grammar of Gendhing Lampah," *Ethnomusicology* 32 (1988): 23-75.

Hughes, Matt. 1965. Tonal Orientation in Skiabin's Preludes: An Analysis on the Basis of Information Theory. M.A. thesis. University of Texas at Austin.

__________. 1977. "A Quantitative Analysis," *Readings in Schenkerian Analysis*, ed. by Maury Yeston. New Haven: Yale University Press. 144-164.

Huglo, Michel. 1973. "Le classement par ordinateur des listes de repons liturgiques: les problemes musicologiques," *Informatique Musicale* (October 1973): 126-134.

Hultberg, W. Earle. 1970. "Transcription of Tablature to Standard Notation," *The Computer and Music*, ed. by Harry B. Lincoln. Ithaca: Cornell University Press. 289-292.

Humair, Jean-Damien. 1996. "Performance of musical rhythm: An analysis of real polyphonic examples," *Computing in Musicology* 10 (1995-1996): 192-193.

Hummel, Thomas. 1994. *Morton Feldmans Untitled composition (1981) fur Cello und Klavier: Eine computerunterstützte Analyse*. Saarbrucken: Pfau.

Huron, David. 1988. "Error Categories, Detection, and Reduction in a Musical Database," *Computers and the Humanities* XXII (1988): 253-264.

__________. 1989a. "Voice Denumerability in Polyphonic Music of Homogeneous Timbres," *Music Perception* VI/4 (1989). 361-382.

__________. 1989b. "Characterizing Musical Textures," *Proceedings of the 1989 International Computer Music Conference*. San Francisco: Computer Music Association. 131-134.

__________. 1990a. "Crescendo / Diminuendo Asymmetries in Beethoven's Piano Sonatas," *Music Perception* VII/4 (1990). 395-402.

__________. 1990b. "Increment/Decrement Asymmetries in Polyphonic Sonorities." *Music Perception* VII/4 (1990). 385-393.

__________. 1991a. "Tonal Consonance Versus Tonal Fusion in Polyphonic Sonorities," *Music Perception* IX/2 (1991). 135-154.

__________. 1991b. "The Avoidance of Part-Crossing in Polyphonic Music: Perceptual Evidence and Musical Practice," *Music Perception* IV/1 (1991). 93-104.

__________. 1991c. "The Ramp Archetype: A Study of Musical Dynamics in 14 Piano Composers," *Psychology of Music* XIX/1 (1991). 33-45.

__________. 1992a. "Design Principles in Computer-Based Music Representation," *Computer Representations and Models in Music*, ed. by A. Marsden & A. Pople. London: Academic Press. 5-39.

__________. 1992b. "The Ramp Archetype and the Maintenance of Auditory Attention," *Music Perception* X/1 (1992). 83-92.

__________. 1993a. "Chordal-Tone Doubling and the Enhancement of Key Perception," *Psychomusicology* XII/1 (1993). 73-83.

__________. 1993b. "Note Onset Asynchrony in J.S. Bach's Two-Part Inventions." *Music Perception* X/4 (1993(. 435-444.

__________. 1993c. *The Humdrum Toolkit: Software for Music Researchers*. [computer disks and installation guide.] Stanford, CA: Center for Computer Assisted Research in the Humanities.

__________. 1994. "Interval-class content in equally-tempered pitch-class sets: Common scales exhibit optimum tonal consonance," *Music Perception* XI/3 (1994). 289-305.

__________. 1995. *The Humdrum Toolkit: Reference Manual*. Menlo Park, CA: Center for Computer Assisted Research in the Humanities.

__________. 1996. "The Melodic Arch in Western Folksongs," *Computing in Musicology* X (1996). 3-23.

__________. 1997. "Humdrum and Kern: Selective Feature Encoding," *Beyond MIDI: The Handbook of Musical Codes*, ed. by E. Selfridge-Field. Cambridge, Massachusetts: MIT Press. 375-401.

__________. 1999a. *Music Research Using Humdrum: A User's Guide*. Stanford, CA: Center for Computer Assisted Research in the Humanities.

__________. 1999b. Review of *Highpoints: A Study of Melodic Peaks* by Zohar Eitan, *Music Perception* XVI/2 (1999). 257-264.

Huron, David, and Deborah Fantini. 1989. "The avoidance of inner-voice entries: Perceptual evidence and musical practice," *Music Perception*, VII/1 (1989), 43-47.

Huron, David, and Richard Parncutt. 1993. "An Improved Model of Tonality Perception Incorporating Pitch Salience and Echoic Memory," *Psychomusicology* XII/2 (1993). 154-171.

Huron, David, and Matthew Royal. 1996. "What is melodic accent? Converging evidence from musical practice," *Music Perception*, XIII/4 (1996). 489-516.

Huron, David, and Peter Sellmer. 1992. "Critical bands and the spelling of vertical sonorities," *Music Perception* X/2 (1992). 129-149.

Hyde, Martha M. 1989. "Twentieth-Century Analysis During the Past Decade: Achievements and New Directions," *Music Theory Spectrum* XI/1 (Spring 1989): 35-39.

Iglickij, M. A. 1973. "Rodstvo tonalnostej i zadaca ob otyskanii modulajacionnych planov," *Muzykalnoje Iskusstvo i Nauka* II (1973): 192-205.

Imberti, Michel. 1984. "Puo il Concetto di "Grammatica" Esserci Utile per L'elaborazione di una Teoria della Percezione Musicale Presso il Bambino?" *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 255-271.

__________. 1997. "Interwining of the Objectivity of Cognitive Analysis and the Subjectivity of the Oeuvre's Interpretation," *Perception and Cognition of Music*, ed. by Irène Deliège and John Sloboda. East Sussex, UK: Psychology Press. 435-443.

Isaacson, Eric J. 1996. "Issues in the Study of Similarity in Atonal Music," *Music*

Theory Online II/7 (1996).

__________. 1997. "Neural Network Models for the Study of Post-Tonal Music," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 237-250.

Iturbide, Manuel Rocha. 1995. "Unfolding the natural sound object through electroacoustic composition," *Journal of New Music Research* XXIV/4 (1995): 384-391.

Iverson, Eric, and Roger Hartley. 1990. "Metabolizing M usic," *Proceedings of the International Computer Music Conference, Glasgow, 1990.* San Francisco, CA: International Computer Music Association, 1990. 298-301.

Izmirli, Özgür, and Semih Bilgen. 1992. "Classification of Note-Rhythm Complexities," *10th European Conference on Artificial Intelligence. Workshop Notes on AI and Music.* Vienna, Austria.

Izmirli, Özgür, and Semih Bilgen. 1994. "Single and Multi-Part Tonal Context Determination," *Proceedings of the International Conference on Music Perception and Cognition (ICMPC 1994).* Liege, Belgium.

Izmirli, Özgür, and Semih Bilgen. 1996. "A Model for Tonal Context Time Course Calculation from Acoustical Input," *Journal of New Music Research* XXV (1996): 276-288.

Jackendoff, Ray. 1983. *Semantics and Cognition.* Cambridge, MA: MIT Press.

__________. 1987. *Consciousness and the Computational Mind.* Cambridge: MIT Press.

__________. 1991. "Music Parsing and Musical Affect," *Music Perception* IX/2 (1991): 199-230.

Jackson, David L. 1981. Horizontal and Vertical Analysis Data Extraction Using a Computer Program. Ph.D. thesis, University of Cincinatti Conservatory of Music.

Jackson, Roland. 1966. "Harmonic Analysis," *Computers and the Humanities* I, no. 2 (1966): 52.

__________. 1970a. "Harmony before and after 1910: A Computer Comparison," *The Computer and Music*, ed. by Harry B. Lincoln. Ithaca: Cornell University Press. 132-146.

__________. 1970b. "The Computer as a 'Student' of Harmony," *IMS: Report on* *the Tenth Congress, Lubljana 1967*, ed. by Dragotin Cvetko. Kassel: Bärenreiter, 1970. 435-440.

Jackson, Roland, and Philip Bernzott. 1966. "Harmonic Analysis with Computer-- A Progress Report," *ICRH Newsletter* I, no. 9 (1966): 3-4.

Jackson, Roland, and Philip Bernzott. 1970. "A Musical Input Language and a Sample Program for Musical Analysis," *Musicology and the Computer: Three Symposia*, ed. by Barry S. Brook. New York: The City University of New York Press. 130-150.

Jambunathan, Sriram, and Sriram Valavanur. 1991. "How many janya ragas are there?" *The Journal of the Music Academy Madras* 62 (1991): 145-155.

Jammers, Ewald; Bielitz, Matthias; Bender, Iring; Ebenhoh, Wolfgang. 1970. "Das Heidelberger Programm für die elektronische Datenverarbeitung in der musikwissenschaftlichen Byzantinistik," *Sitzungsberichte der Heidelberger Akademie der Wissenschaften, naturwissenschaftliche Klasse* II (1969-70): 3-23.

Janata, Petr. 1995. "EPR Measures Assay the Degree of Expectancy Violation of Harmonic Contexts in Music," *Journal of Cognitive Nueroscience* VII/2 (1995): 153-164.

Janello, David. 1996. "Mathematical randomness in music," *Sonus: A Journal of Investigations into Global Musical Possibilities* XVI/2 (Spring 1996): 12-31.

Järvinen, Topi. 1993. "Key Profiles in Jazz Improvisations," *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*, ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä. 88-103.

Jensen, Richard d'Arcambal. 1985. "A computerized approach to the early Italian lute ricercar," *Journal of the Lute Society of America* XVII-XVIII (1984-85): 106-113.

Jesser, Barbara. 1988. "Rechnergestützte Melodieanalyse - Sackgasse oder Inspiration für die Volksliedforschung" *Musikpädagogische Forschung* IX (1988): 213-228.

__________. 1991. *Interaktive Melodienanalyse. Methodik und Anwendung computergestützter Anaylseverfahren in Musikethnologie und Volksliedforschung: typologische Untersuchung der Balladensammlung des DVA*. Studien zur Volksliedforschung 12. Bern: Peter Lang.

John, Robert W. 1970a. "A Pilot Computer Catalog of Early American Shape-

Note Hymn Tunes," *Computers and the Humanities* IV, no. 5 (1970): 345.

__________. 1970b. "A Pilot Computer Catalog of Early American Sheet Music," *Computers and the Humanities* IV, no. 5 (1970): 345.

Johnson, Christopher M. 1996. "The performance of Mozart: Study of rhythmic timing by skilled musicians," *Psychomusicology* XV (1996): 87-109.

Johnson, Margaret L. 1991. "Toward an Expert System for Expressive Musical Performance," *Computer* XXIV/7 (1991): 30-34.

__________. 1992. "An Expert System for the Articulation of Bach Fugue Melodies," *Readings in Computer-Generated Music*, ed. by D. Baggi. Los Alamitos, California: IEEE Computer, Society Press. 41-51.

__________. 1993. "Neural Networks and Style Analysis: A Neural Network that Recognizes Bach Chorale Style," *Atti del X Colloquio di Informatica Musicale*, ed. by Goffredo Haus and Isabella Pighi. Milano, Italy: Associazione di Informatica Musicale Italiana. 109-116.

Johnson-Laird, Philip N. 1991a. "Jazz Improvisation: A Theory at the Computational Level," *Representing Musical Structure*, ed. by Peter John Howell, Robert West, and Ian Cross. London: Academic Press. 291-325.

__________. 1991b. "Rhythm and meter: A theory at the computational level," *Psychomusicology* VI/2 (Fall 1991): 88-106.

Joiner, Richard E. 1969. "Gregorian Chant," *Computer Studies in the Humanities and Verbal Behavior* II/4 (December 1969): 213-219.

Jones, Jaqueline A., Ben O. Miller, and Don L.Scarborough. 1988. "A Rule-Based Expert System for Music Perception," *Behavior Research methods, Instruments and Computers* II/2 (1988): 225-262.

Jones, Jaqueline A., Ben O. Miller, and Don L.Scarborough. 1990. "GTSM: A Computer Simulation of Music Perception," *Le Fait Musical - Sciences, Technologies, Practiques. Colloque "Musique et Informatique" (MAI 90)*. Marseille, France. 435-441.

Junker, Gerhard. 1995. "An empirical study on the psychoacoustical phenomenon of temporal masking effects," *Systematische Musikwissenschaft /Systematic Musicology* III/1 (1995).

Juslin, Patrik N. 1993. The Influence of Expressive Intention on Electric Guitar Performance," Ph.D. thesis. Uppsala University. Department of Psychology.

Kaden, Christian. 1976. "Strukturelle Segmentierung von Musik - Probleme, Schwierigkeiten, Möglichkeiten," *Beiträge zur Musikwissenschaft* 18 (1976): 149-162 and 293-334.

__________. 1978. "Ludwig van Beethoven, Sinfonie Nr. 8, zweiter Satz, Allegretto scherzando. Ansätze zu einer statistischen Strukturanalyse." *Bericht über den Internationalen Beethoven Kongreß 20. bis 23. März 1977 in Berlin*, ed. by H. Goldschmidt, K.-H. Köhler, and K. Niemann. Leipzig: Deutscher Verlag für Musik, 113-130.

__________. 1981. "Instrumentale Improvisation als stochastischer Prozeß," *Studia Instrumentorum Musicae Popularis* VII (1981): 108-115.

Kaegi, Werner. "Music and Technology," *Music and Technology*. Paris: La Revue Musicale. 11-31.

Kagan, Alan L. 1970. "Computerized Analysis and Classification of Asian Musical Style," *Computers and the Humanities* IV, no. 5 (1970): 347.

Kaipainen, Mauri. 1993. "Simulating Music as Knowledge Ecology," *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*, ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä. 133-158.

__________. 1996. "Representing and Remotivating Musical Processes: Modeling a Recurrent Musical Ecology," *Journal of New Music Research* XXV (1996): 150-178.

Kaipainen, Mauri, Petri Toiviainen, and Jukka Louhivuori. 1995. "A Self-Organizing Map that Recognizes and Generates Melodies," *New Directions in Cognitive Science. Proceedings of the International Symposium*, ed. by P. Pylkkänen and P. Pylkkö. Saariselkä, Finland, 4-9 August 1995.

Kamien, Roger Jaques. 1964. The Opening Sonata-Allegro Movements in a Randomly Selected Sample of Solo Keyboard Sonatas Published in the Years 1742-1774. Ph.D. thesis. Princeton University.

Karkoschka, Erhard. 1972. "Letzter Schreck: der Computer," *Melos* 39/5 (1972): 285-288.

__________. 1979. "On the Analysis of Melodic Activity," *Interface* VIII (1979): 117-127.

Karlina, T. P., and Vilnis K. Detlovs. 1968. "Statisticeskij analiz sekvencij v melodii," *Latvijskij matematiceskij ezegodnik* 4 (1968): 165-173.

Karp, Theodore. 1970. "A Test for Melodic Borrowings among Notre Dame *Organa Dupla*," *The Computer and Music*, ed. by Harry B. Lincoln. Ithaca: Cornell University Press. 293-295.

Kasem-Bek, Jan. 1978. "Informationstheorie und Analyse musikalischer Werke," *Archiv für Musikwissenschaft* 35 (1978): 62-75.

Kasponis, Rimtautas. 1992. *Melodika, Harmonia Litovskoj Muzyki*. Vilnius: Mokslas.

Kassler, Michael. 1964a. A Report of Work, Directed Toward Explication of Schenker's Theory of Tonality, Done in Summer 1962 as the First Phase of a Project Concerned with the Applications of High-Speed Automatic Digital Computers to Music ana Musicology. Princeton, N.J.: Princeton University Music Department. (Mimeographed.)

__________. 1964b. MIR -- A Simple Programming Language For Musical Information Retrieval. Technical Report No. 3, Project 295D, March 1964. Princeton, New Jersey: Princeton University, Department of Music. [University of California at Berkeley: Music Library, calling no. ML 74 .4 M4 K 35 1964 MUSI]

__________. 1966. "Toward Musical Information Retrieval," *Perspectives of New Music* IV/2 (Spring-Summer 1966): 59-67.

__________. 1968. A Trinity of Eassays. Ph.D. dissertation, Princeton University.

__________. 1969. Review of *Kibernetika i muzyka* by R. Kh. Zaripov, *Perspectives of New Music* VII/2 (1969): 115.

__________. 1970a. "An Essay Toward Specification of a Music-Reading Machine," *Musicology and the Computer: Three Symposia*, ed. by Barry S. Brook. New York: The City University of New York Press. 151-175.

__________. 1970b. "MIR—A Simple Programming Language for Musical Information Retrieval," *The Computer and Music*, ed. by Harry B. Lincoln. Ithaca: Cornell University Press. 299-327.

__________. 1972. "Optical Character-Recognition of Printed Music: A Review of Two Dissertations," *Perspectives of New Music* II/1 (1972): 250-254.

__________. 1975a. "Explication of Theories of Tonality," *Computational Musicology Newsletter* II/1 (1975): 17.

__________. 1975b. *Proving Musical Theorems I: The Middleground of Heinrich Schenker's Theory of Tonality*. Technical Report No. 103. Sydney: The University of Sydney, Basser department of Computer Science.

__________. 1977. "Explication of the Middleground of Schenker's Theory of Tonality," *Miscellanea Musicologica* 9 (1977): 72-81.

__________. 1981. "Transferring a tonality theory to a computer," *International Musicological Society: Report of the Twelfth Congress, Berkeley 1977*, ed. by Daniel Heartz and Bonnie C. Wade. Kassel: Bärenreiter. 339-347.

Kassler, Michael, and Hubert S. Howe Jr. 1980. "Computers and Music," *The New Grove Dictionary of Music and Musicians*, ed. by Stanley Sadie, vol. 2. London: Macmillan. 603-615.

Katayose, Haruhiro, T. Fukuoka, K. Takami, and S. Inokuchi. 1990. "Expression Extraction in Virtuoso Music Performances," *Proceedings of the Tenth International Conference on Pattern Recognition*. Atlantic City, NJ. 780-784.

Kawano, Hiroshi. 1969. "Ongaku-teki komyunikeishon no joho-bunseki," *Ongaku gaku: Journal of the Japanese Musicological Society* XV/3-4 (1969): 1-21.

__________. 1975. "The Informational Analysis of Musical Communication," *Computational Musicology Newsletter* II/1 (1975): 15.

Kay, Bruce A., J. A. S. Kelso, I. E. L. Saltzman, and G. Schöner. 1987. "Space-Time Behavior of Single and Bi-Manual Rhythmical Movements: Data and Limit Cycle Model," *Journal of Experimental Psychology: Human Perception and Performance* XIII/2 (1987): 178-192.

Kendall, Jillian Dale. 1991. The Computer is the Prime Symbol of a New Age: The Age of Synthesis. Ph.D. thesis, The University of Texas at Arlington.

Kendall, R. A. 1987. "Model Building in Music Cognition and Artificial Intelligence," *Proceedings of the First Annual Artificial Intelligence and Advanced Computing Conference*. East Wheaton, IL: Tower Conference Management. 137-156.

Kenny, Anthony. 1982. *The Computation of Style*. Oxford: Pergamon Press.

Kessler, Edward J., Christa Hansen, and Roger N. Shepard. 1984. "Tonal Schemata in the Perception of Music in Bali and in the West," *Music Perception* II/2 (1984): 131-165.

Kinzler, Hartmuth. 1993. "Musikalische Analyse und ihre Darstellung mittels kommerzieller Sequencer- und Composersoftware," *Neue Musiktechnologie*, ed. by Bernd Enders. Mainz: Schott. 301-320.

Kippen, Jim. 1987. An Ethnomusicological Approach to the Analysis of Musical Cognition," *Music Perception* V/2 (1987): 173-196.

Kippen, Jim, and Bernard Bel. 1989a. "Can the Computer Help Resolve the Problem of Ethnographic Description?" *Anthropological Quarterly* 62/2 (1989): 131-140.

Kippen, Jim, and Bernard Bel. 1989b. "The Identification and Modelling of a Percussion 'Language', and the Emergence of Musical Concepts in a Machine-Learning Experimental Set-Up," *Computers and the Humanities* XXII (1989): 199-214.

Kippen, Jim, and Bernard Bel. 1992. "Modelling Music with Grammars. Formal Language Representation in the Bol Processor," *Computer Representations and Models in Music*, ed. by Alan Marsden & Anthony Pople. London: Academic Press. 207-238.

Kluge, Reiner. 1967. "Faktorenanalytische Typenbestimmung an einstimmigen Volksmelodien," *Computers and the Humanities* II, no. 2 (1967): 88-89.

__________. 1970a. "Volksliedanalyse und -systematisierung mit Hilfe eines Rechenautomaten," *Bericht über den Internationalen Musikwissenschaftlichen Kongress Leipzig 1966*, ed. by Carl Dahlhause et al. Kassel: Bärenreiter. 158-465.

__________. 1970b. "Zur Automatischen Quantitativen Bestimmung Musikalischer Ähnlichkeit," *IMS: Report on the Tenth Congress, Lubljana 1967*, ed. by Dragotin Cvetko. Kassel: Bärenreiter, 1970. 450-457.

__________. 1974. *Faktorenanalytische Typenbestimmung an Volksliedmelodien*. Beiträge zur musikwissenschaftlichen Forschung in der DDR 6. Leipzig: Deutscher Verlag für Musik.

__________. 1987. Komplizierte Systeme als Gegenstand Systematischer Musikwissenschaft. Zwei Studien. Dissertation (B), Humboldt-University Berlin.

__________. 1993. Review of *Interaktive Melodieanalyse. Methodik und Anwendung computergestützter Analyseverfahren in Musikethnologie und Volksliedforschung: typologische Untersuchung der Balladensammlung des DVA* by Barbara Jesser, *Jahrbuch für Volksliedforschung* 38 (1993): 180-182.

Knoll, Mark William. 1998. Which Bach Wrote What? A Cumulative Approach to Clarification of Three Disputed Works. Ph.D. thesis. University of Michigan.

Knopoff, Leon. 1966. "A Progress Report on an Experiment in Musical Synthesis," *Selected Reports* I/1 (1966): 49-60 (Los Angeles: University of California, Institute of Ethnomusicology).

Knopoff, Leon, and William Hutchinson. 1978. "An Index of melodic Activity," *Interface* VII (1978): 205-229.

Knopoff, Leon, and William Hutchinson. 1983. "Entropy as a Measure of Style: The Influence of Sample Length," *Journal of Music Theory* 27 (1983): 75-97.

Knowlton, Prentise H. 1973. "Capture and Display of Keyboard Music," *Datamation* (1973): 56-60.

Kohonen, Teuvo. 1989. "A Self learning Musical Grammar," *Proceedings of the International Joint Conference on Neural Networks*. Washington, D.C.

Kolata, Gina Bari. 1978. "Singing Styles and Human Cultures: How are They Related?" *Science* CC/4339 (April 1978): 287-288.

Kolinski, Mieczyslaw. 1965a. "The General Dierction of Melodic Movement," *Ethnomusicology* IX (1965): 240-262.

__________. 1965b. "The Structure of Melodic Movement - A New Method of Analysis (revised version)," *Studies in Ethnomusicology* 2 (1965): 96-120.

Kolosick, J. Thimothy. 1980. "SETS: A Program for the Application of Set Theory to Music Analysis," *Proceedings of the Association for the Development of Computer-Based Instructional Systems*. [Bellingham, Wash.]: ADCIS. 209-212.

__________. 1981. A Computer-Assisted, Set-Theoretic Investigation of Vertical Simultaneities by Charles E. Ives. PhD thesis, University of Wisconsin-Madison.

__________. 1986. "A machine independent data structure for the representation of musical pitch relationships: computer-generated musical examples for CBI," *Journal of Computer Based Instruction* XIII/1: 9-13.

Kongas-Maranda, Elli. 1970. "Deep Significance and Surface Significance: Is Cantometrics Possible?" *Semiotica* II/2 (1970): 173-184.

Koozin, Timothy. 1995. "Graphic approaches to musical analysis in a multimedia environment," *Computers in Music Research* V (1995): 103-117.

Kopiez, Reinhard. 1996. "Mensch--Musik--Maschine: Neue Informationstechnologien und ihre Bedeutung für Musikvermittlung und Musikwissenschaft," *Musica* (Germany) 50/1 (Jan-Feb 1996): 20-26.

Koppers, Marius Hendrikus Abraham. 1996. Aanalysis of Music with Information Theory (Pitch). DMus thesis, University of Pretoria (South Africa).

Kornstaedt, Andreas. 1996. "SCORE-to-Humdrum: A Graphical Environment for Musicological Analysis," *Computing in Musicology* X (1996). 105-122.

__________. 1998. "'Themefinder': A Web-ased Melodic Search Tool," *Computing in Musicology* XI (1998). 231-236.

Köster, Lothar. 1988. Die Anwendbarkeit generativer Grammatikmodelle in der Musikanalyse. Eine Diskussion der strukturalistischen, psychologischen und gesellschaftshistorischen Grundlagen von generativen Musikanalysemethoden und den zugrundeliegenden Musik-Modellen. Diplom thesis, Hochschule Hildesheim, Fachbereich Kulturwissenschaften und Ästhetische Kommunikation.

Kostka, Stephan M. 1969. The Hindemith String Quartetts: A Computer-Assisted Study of Selected Aspects of Style. Ph.D. thesis, University of Wisconsin.

__________. 1971. "Recent Developments in Computer-Assisted Musical Scholarship," *Computers and the Humanities* VI/1 (September): 15-21.

__________. 1974. *A bibliography of computer applications in music.* Hackensack, N.J.: J. Boonim.

__________. 1984. "The M-PARC system for musical encoding (Mnemonic pitch and rhythm code, version 3). Unpublished Manuscript, The University of Texas at Austin, Department of Music, Austin.

Kraehenbuehl, David, and Edgar Coons. 1959. "Information as a Measure of the Experience of Music," *Journal of Aesthetics & Art Criticism* XVII/4 (June 1959): 510-522.

Krumhansl, Carol L. 1983. "Perceptual Structures for Tonal Music," *Music Perception* I/1-2 (1983): 28-62.

__________. 1990. *Cognitive Foundations of Musical Pitch*. New York: Oxford University Press, 1990.

__________. 1997. "Effects of Perceptual Organization and Musical Form on Melodic Expectations," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 294-320.

Krumhansl, Carol L., and Edward J. Kessler. 1982. "Tracing the Dynamic Changes in Perceived Tonal Organization in a Spatial Representation of Musical Keys," *Psychological Review* 89 (1982): 334-368.

Krumhansl, Carol L., and Roger N. Shepard. 1979. "Quantification of the Hierarchy of Tonal Functions Within a Diatonic Context," *Journal of Experimental Psychology: Human Perception and Performance* V/4 (1979): 579-594.

Kugel, Peter. 1992. "Beyond Computational Musicology," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge, MA: The MIT Press. 30-48.

Kupper, Hubert. 1970a. *Statistische Untersuchungen zur Modusstruktur der Gregorianik*. Regensburg: Bosse.

__________. 1970b. *Computer und musikalische Kompositionen*. Braunschweig: Vieweg.

__________. 1972. "GEASCOP - Ein Kompositionsprogramm," *Informatik. Vorträge anläßlich der Jahresversammlung vom 14. bis 17. Oktober 1971 zu Halle (Saale)*, ed. by Jocahim-Hermann Scharf. Nova Acta Leopoldina vol. 37/1, no. 206. Leipzig: Barth. 629-655.

Kurkela, Kari. 1986. *Note and Tone: A Semantic Analysis of Conventional Music Notation*. Acta Musicological Fennica 15. Helsinki: Suomen Musiikkitieteellinen Seura.

Kvifte, Tellef. 1981. "On Variability, Ambiguity and Formal Structure in the Harding Fiddle Music," *Studia Instrumentorum Musica Popularis*, ed. by Erich Stockmann. Stockholm: Musikhistoriska Museet. 102-107.

Laaksamo, Jonko, and Jukka Louhivuos. Eds. 1993. *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*. Jyväskylä: The University of Jyväskylä.

Lachartre, Nicole. 1969. "Les musiques artificielles," *Diagrammes du Monde* 146 (April 1969): 1-96.

Laden, Bernice. 1990. "Representation of Pitch Input to Neural Network Models of Music Perception," *Journal of the Acoustical Society of America* 87 (1990): S18.

__________. 1994. "A Parallel Learning Model of Musical Pitch Perception," *Journal of New Music Research* XXIII (1994): 133-144.

Laden, Bernice, and Douglas H. Keefe. 1989. "The Representation of Pitch in a Neural Network Model of Musical Chord Classification," *Computer Music Journal* XIII/4 (1989): 12-26. Reprinted in *Music and Connectionism*, ed. by Peter M. Todd and D. Gareth Loy. Cambridge: MIT Press. 64-83.

Laforest, Serge. 1993. "Le micro-ordinateur et la musique: Ou en sommes-nous?" *Recherche en Education Musicale au Quebec* XII (1993): 19-24.

Lande, Tor Sverre. 1978. "Musikkanalyse med Datamskin," *Studia Musicologica Norvegia* IV (1978): 47-60.

Lande, Tor Sverre, and Arvid O.Vollsnes. 1995. "Object-Oriented Music Analysis," *Computers and the Humanities* XVIII/4-5 (1994-1995): 253-257.

Landy, Leigh. 1983. "Arabic taqsim improvisation: A methodological study using computers," *Informatique et Musique: Proceedings of the Second ERATTO Symposium 1981*. Ivry: Elmeratto. 71-78.

Langmead, C. 1995. A Theoretical Model of Timbre Perception Based on Morphological Representations of Time-Varying Spectra. M.A. thesis in Electro-Acoustic Music. Dartmouth College.

Langner, Jörg, and Reinhard Kopiez. 1995a. "Oscillations Triggered by Schumann's Träumerei; Towards a New Method of Performance Analysis Based on a 'Theory of Oscallating Systems' (TOS)," *Proceedings of the KTH Symposium Grammar for Music Performance*. Stockholm: KTH, Speech Music and Hearing Department. 45-58.

Langner, Jörg, and Reinhard Kopiez. 1995b. "Entwurf einer neuen Methode der Performanceanalyse auf Grundlage einer Theorie oszillierender Systeme (tos)," *Musik Psychologie - Jahrbuch der Deutschen Gesellschaft für Musikpsychologie* XII (1995): 9-27.

Langnickel, J. 1991. Entwurf und Implementierung einer Musikkompositionssystems zur Generierung von Musikstücken im Stile der Klavierwalzer Frederic Chopins. Diplom thesis. Karlsruhe University (Germany).

Lapidaki, Eleni. Consistency of Tempo Judgements as a Measure of Time Experience in Music Listening. Ph.D. thesis. Northwestern University, 1996.

Large, Edward W. 1993. "Dynamic programming for the analysis of serial behaviors: 22nd annual meeting of the Society for Computers in Psychology--Symposium on data visualization," *Behavior Research Methods, Instruments and Computers* XXV/2 (1993): 238-241.

Larnestam, Ulf. 1987. "Explicit musikalisk stilanalys med dator rorande pianosatser i sonatform av W. A. Mozart," *Musikologen* VIII (1987): 40-44.

__________. 1992a. "Det mekaniska som kompositionsprincip hos den unge Mozart," *Musikologen* XIII (1992): 103-106.

__________. 1992b. "Simulation of Keyboard Sonata Movements in the Style of Mozart," *Computing in Musicology* VIII (1992): 13-16.

LaRue, Jan. 1967. "Two Problems in Music Analysis: The Computer Lends a Hand," *Computers in Humanistic Research*, ed. by Edmund A. Bowles. Englewood Cliffs: Prentice Hall. 194-203.

__________. 1968. "Two Options for Input of Thematic Incipits," *Institute for Computer Research in the Humanities Newsletter* IV, no. 3 (1968): 3-6.

__________. 1970a. "New Directions for Style Analysis," *Musicology and the Computer: Three Symposia*, ed. by Barry S. Brook. New York: The City University of New York Press. 194-197.

__________. 1970b. "Some Computer Aids to Musicology," *Bericht über den Internationalen Musikwissenschaftlichen Kongress Leipzig 1966*, ed. by Carl Dahlhause et al. Kassel: Bärenreiter. 466-469.

__________. 1970c. "Future Technological Directions," *IMS: Report on the Tenth Congress, Lubljana 1967*, ed. by Dragotin Cvetko. Kassel: Bärenreiter, 1970. 457-460.

LaRue, Jan, and Marian W. Cobin. 1967. "The Ruge-Seignelay Catalogue: An Exercise in Automated Entries," *Elektronische Datenverarbeitung in der Musikwissenschaft*, ed. by Harald Heckmann. Regensburg: Gustav Bosse. 41-56.

Laske, Otto. 1972. "On Musical Strategies With a View to a Generative Grammar for Music," Interface I/2 (1972): 111-125.

__________. 1973a. "On the Methodology and Implementation of a Procedural Theory of Music," *Computational Musicology Newsletter* I/1 (1973): 15-16.

__________. 1973b. "Toward a musical intelligence system: OBSERVER," *Numus West* IV (1973): 11-16.

__________. 1974a. "In Search of a Generative Grammar for Music," *Perspectives of New Music* XII (Fall-Winter 1973 and Spring-Summer 1974): 351-378. Reprinted in *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press, 1993. 214-240.

__________. 1974b. "Toward a Center for Studies in Musical Intelligence," *Numus West* V (1974) 44-46.

__________. 1975. *Introduction to a Generative Theory of Music*. Sonological Reports. Utrecht: Institute for Sonology.

__________. 1977a. *Music, Memory and Thought: Explorations in Cognitive Musicology*. Ann Arbor: University Research Press.

__________. 1977b. "Toward a Process Model of Musical Structures," *Proceedings of the International Workshop on the Cognitive Viewpoint*. Rijksuniversiteit Gent, Ghent, Belgium: Communication and Cognition. 295-304.

__________. 1980. "Toward an Explicit Theory of Musical Listening," Computer Music Journal IV/2 (1980): 73-83.

__________. 1984. "KEITH: A Rule-System for Making Music-Analytical Discoveries," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Florence: Leo S. Olschki. 165-199.

__________. 1986. "Toward a Computational Theory of Musical Listening," *Communication and Cognition* XVIII/4 (1986): 363-392.

__________. 1988a. "Introduction to Cognitive Musicology," *Computer and Music* XII/1 (1988): 43-57.

__________. 1988b. "Can we Formalize and Program Musical Knowledge? An Inquiri into the Focus and Scope of Cognitive Musicology," *Musikometrika 1*, ed. by. Moisej G. Boroda. Bochum: Brockmeyer. 257-280.

__________. 1989a. "Comments on the First Workshop on A.I. and Music: 1988 AAAI Conference St. Paul, Minnesota," *Perspectives of New Music* XXVII/2 (1989): 290-298.

__________. 1989b. "Composition Theory. An Enrichment of Music Theory," *Interface* XVIII/1-2 (1989): 45-60.

__________. 1991. "Understanding music with AI," *Proceedings: International*

Computer Music Conference, Montreal, 1991. Montreal: McGill University Press, 1991. 188-191.

__________. 1992a. "Artificial Intelligence and Music: A Cornerstone of Cognitive Musicology," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge, MA: The MIT Press. 3-28.

__________. 1992b. "The OBSERVER Tradition of Knowledge Acquisition," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge, MA: The MIT Press. 258-289.

__________. 1993a. "In search of a generative grammar for music," *Machine Models of Music*, ed. by S. Schwannauer and D. Levitt. Cambridge, MA: MIT Press. 215-240.

__________. 1993b. "Understanding Music with AI: Some Philosophical Observations," *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*, ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä. 270-287.

Lee, C. S. 1985. "Rhythm Interpretationof Simple Musical Sequences: Towards a Perceptual Model," *Musical Structure and Cognition*, ed. by Peter John Howell, Ian Cross, and Robert West. London: Academic Press. 53-69.

__________. 1991. "Perception of Metrical Structure: Experimental Evidence and a Model," *Representing Musical Structure*, ed. by Peter John Howell, Robert West, and Ian Cross. London: Academic Press. 59-128.

Leeson, Daniel N. 1995. "Franz Xaver Sussmayr and the Mozart Requiem: A computer analysis of authorship based on melodic affinity," *Mozart-Jahrbuch* (1995): 111-153.

Lefkoff, Gerald, ed. 1967a. *Papers from the West Virginia University Conference on Computer Applications in Music*. Morgantown: West Virginia University Library.

__________. 1967b. "Computers and the Study of Musical Style," *Papers from the West Virginia University Conference on Computer Applications in Music*, ed. by Gerald Lefkoff. Morgantown: West Virginia University Library. 43-61.

__________. 1970. "Automated Discovery of Similar Segments in the Forty-eight Permutations of a Twelve-Tone Row," *The Computer and Music*, ed. by

Harry B. Lincoln. Ithaca: Cornell University Press. 147-153.

Lehr, Mangham D. 1968. "Canon One," *Computers and the Humanities* II, no. 5 (1968): 244.

Leman, Marc. 1989a. "Symbolic and Subsymbolic Information Processing in Models of Musical Communication and Cognition," *Interface* XVIII/1-2 (1989): 141-160.

__________. 1989b. "Introduction to Models of Musical Communication and Cognition," *Interface* XVIII/1-2 (1989): 3-7.

__________. 1990. "Emergent Properties of Tonality Functions by Self-Organization," *Interface* XIX/2-3 (1990: 85-106.

__________. 1991a. "Künstliche Neuronale Netzwerke. Neue Amsätze zur ganzheitlichen Informationsverarbeitung in der Musikforschung," *Computer in der Musik*, ed. Helmuth Schaffrath. Stuttgart: Metzler, 1991. 27-44.

__________. 1991b. "The Ontogenesis of Tonal Semantics: Results of a Computer Study," *Music and Connectionism*, ed. by Peter M. Todd/ Cambridge, Massachusetts: MIT Press. 100-127.

__________. 1991c. Een Model van Toonsemantiek: Naar een Theorie en Discipline van de Muzikale Verbeelding. Ph.D. thesis. Gent: University of Ghent.

__________. 1992a. "Tone Context by Pattern Integration over Time," *Readings in Computer Generated Music*, ed. by D. Baggi. IEEE Computer Sociert Press.

__________. 1992b. "The Theory of Tone Semantics: Concept, Foundation, and Application," *Minds and Machines* 2 (1992): 345-363.

__________. 1992c. "Musiikin Symbolinen ja Alisymbolinen Kuvaus," *Kognitiivinen Misiikkitiede*, ed. by J. Louhivuori and A. Sormunen. Jyväskylä: Jyväskylän Yliopiston Monistuskeskus. 79-127.

__________. 1992d. "Artificial Neural Networks in Music Research," *Computer Representations and Models in Music*, ed. by Alan Marsden & Anthony Pople. London: Academic Press. 165-301.

__________. 1993a. "Symbolic and Subsymbolic Description of Music," *Music Processing*, ed. by G. Haus. Madison, Wisconsin: Oxford University Press.

__________. 1993b. "Tone Context and the Complex Dynamics of Tone Semantics," *Neue Musiktechnologie*, ed. by Bernd Enders. Mainz: Schott. 197-225.

__________. 1994a. "Schema-Based Tone Center Recognition of Musical Signals," *Journal of New Music Research* XXIII (1994): 169-204.

__________. 1994b. "Introduction to Auditory Models in Music Research," *Journal of New Music Research* XXIII (1994): 5-9.

__________. 1995a. *Music and Schema Theory. Cognitive Foundations of Systematic Musicology*. Berlin: Springer.

__________. 1995b. "A Model of Retroactive Tone-Center Perception," *Music Perception* XII/4 (1995): 439-471.

__________. 1995c. Review of *Artificial Perception and Music Recognition* by Andranick S. Tanguiane, *Journal of New Music Research* XXIV (1995): 84-88.

__________. 1997a. "The Convergence Paradigm, Ecological Modelling, and Context-Dependent Pitch Perception," *Journal of New Music Research* XXVI (1997): 133-153.

__________. Ed. 1997b. *Music, Gestalt, and Computing. Studies in Cognitive and Systematic Musicology*. Berlin: Springer.

__________. 1999a. "Relevance of Neuromusicology for Music Research," *Journal of New Music Research* XXVIII (1999): 186-199.

__________. 1999b. "Adequacy Criteria for Models of Musical Cognition," *Otto Laske: Navigating New Musical Horizons*, ed. by Jerry Tabor. Westport, Connecticut: Greenwood. 93-120.

Leman, Marc, and Francesco Carreras. 1995. "Simulation of Listening to Bach's Wohltemperiertes Klavier," *Proceedings of the XI Colloquium on Musical Informatics*, ed. by L. Finarelli and F. Regazzi. Bologna: Associazione di Informatica Musicale Italiana.

Leman, Marc, and Francesco Carreras. 1996. "The Self-Organization of Stable Perceptual Maps in a Realistic Musical Environment," *Proceedings of the Journées d'Informatique Musicale 17-18 Mai 1996*, ed. by G. Assayah. Caen: Univ. de Caen, IRCAM.

Leman, Marc, and Francesco Carreras. 1997. "Schema and Gestalt: Testing the Hypothesis of Psychoneural Isomorphism by Computer Simulation," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 144-168.

Leman, Marc, and Albrecht Schneider. 1997. "Origin and Nature of Cognitive and Systematic Musicology: An Introduction," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 13-29.

Lendvai, Erno. 1990. "Symmetries in music," *Symmetry* I/1-2 (1990).

Leng, Ladislav. 1972. "O niektorych moznostiach vyuzitia SP pri klasifikacii ozdobovanych ludovych instrumentalnych melodii," *Lidova pisen a samostatny pocitac I*, ed. by Dusan Holy and Oldrich Sirovátka. Brno: Klub uzivatelu MSP. 207-213.

Leppig, Manfred. 1987a. "Musikuntersuchungen im Rechenautomaten," *Musica* 41/2 (1987): 140-150.

__________. 1987b. *Computergestützte Musikuntersuchungen: Muster und Formen*. Schriftenreihe des Fachbereiches Mathematik, SU-DU-127. Duisburg: Fachbereich Mathematik.

__________. 1987c. "Tonfolgenverarbeitung in Rechenautomaten: Muster und Formen," *Zeitschrift für Musikpädagogik* 12 (1987): 59-65.

__________. 1987d. "Die Untersuchung musikinterpretierbarer Eigenschaften in Zahl- und Zeichenfolgen. Eine Sachmotivation zum Programmierunterricht," Beiträge zum Mathematikunterricht (1987): 219-222.

Lerdal, Fred. 1988. "Cognitive Constraints on Computational Systems," *Generative Process in Music: The Psychology of Performance, Improvisation, and Composition*, ed. by J. A. Sloboda. New York: Oxford University Press. 231-259.

__________. 1996. "Calculating Tonal Tension," *Music Perception* 13 (1996): 319-363.

Lerdal, Fred, and Ray Jackendoff. 1977. "Toward a Formal Theory of Tonal Music," *Journal of Music Theory* 21/1 (1977): 111-171.

Lerdahl, Fred, and Ray Jackendoff. 1983a. *A Generative Theory of Tonal Musik*. Cambridge: The MIT Press.

Lerdahl, Fred, and Ray Jackendoff. 1983b. "An Overview of Hierarchical Structure in Music," *Music Perception*. Reprinted in *Machine Models of*

Music, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press, 1993. 288-312.

Levitt, David A. 1993. "A Representation for Musical Dialects," *Machine Models of Music*, ed. by Stephan M. Schwanauer and David A. Levitt. Cambridge, MA: MIT Press. 455-469.

Lewin, David. 1968. "Some Applications of Communication Theory to the Study of Twelve-Tone Music," *Journal of Music Theory* 12 (1968): 51-85.

__________. 1987. *Generalized Musical Intervals and Transformations*. New Haven: Yale University Press.

Lewis, Andrew. 1998. "Francis Dhomont's *Novars*," *Journal of New Music Research* XXVII (1998): 67-83.

Lewis, David Sheldon. Two Parameters of Melodic Line as Stylistic Discriminants. Ph.D. thesis. West Virginia University, 1968.

Lidov, David. 1975. *On Musical Phrase*. Montréal: Les Presses de l'Université.

Lidov, David, and Jim Gabura. 1973. "A Melody Writing Algorithm Using a Formal Language Model," *Computer Studies in the Humanities and Verbal Behavior* XIV (1973): 138-148.

Lieberman, Fredric. 1970. "Computer-Aided Analysis of Javanese Music," *The Computer and Music*, ed. by Harry B. Lincoln. Ithaca: Cornell University Press. 181-192.

Ligabue, Marco. 1995. "Some relationships between terminology, analytic strategies, and computational methodologies," *Musical signification: Essays in the semiotic theory and analysis of music*, ed. by Eero Tarasti. Berlin: Mouton de Gruyter. 349-353.

Lincoln, Harry B. 1966. "Incipit Interval Sequence Program," *Computers and the Humanities* I, no. 2 (1966): 52.

__________. 1967a. "Musicology and the Computer: The Thematic Index," *Computers in Humanistic Research*, ed. by Edmund A. Bowles. Englewood Cliffs: PrenticeHall. 184-193.

__________. 1967b. "Some Criteria and Techniques for Developing Computerized Thematic Indices," *Elektronische Datenverarbeitung in der Musikwissenschaft*, ed. by Harald Heckmann. Regensburg: Gustav Bosse. 57-62.

__________. 1967c. "Thematic Index of Sixteenth-Century Italian Music," *Computers and the Humanities* II, no. 2 (1967): 86.

__________. 1968a. "The Thematic Index: A Computer Application to Musicology," *Computers and the Humanities* 2 (1967-68): 215-220.

__________. 1968b. Development of Computerized Techniques in Music Research with Emphasis on the Thematic Index. Washington: Office of Education, U.S. Department of Health, Education, and Welware. 39 p. ERIC No. ED 027 609.

__________. 1968c. "Thematic Index of Sixteenth-Century Italian Music," *Computers and the Humanities* II, no. 5 (1968): 243.

__________. 1969a. "A Computer Application in Musicology: The Thematic Index," *Information Processing 68. Proceedings of the IFIP Congress 1968*, ed. by A. J. H. Morrel. Amsterdam: North Holland. 957-961.

__________. 1969b. Development of Computerized Techniques in Music Research with Emphasis on the Thematic Index. Washington: Office of Education, U.S. Department of Health, Education, and Welware. 15 p. ERIC No. ED 041 031.

__________, ed. 1970a. *The Computer and Music*. Ithaca: Cornell University Press.

__________. 1970b. "The Current State of Music Research and the Computer," *Computer and the Humanities* V, no. 1 (1970): 29-36.

__________. 1970c. "Thematic Indexing by Computer, Including Development of Necessary Hardware to Permit Printing of Music by Computer," *Computers and the Humanities* V, no. 2 (1970): 109-110.

__________. 1970d. A Study of Computer Techniques for Music Research. Final Report. Washington: Office of Education, U.S. Department of Health, Education, and Welware. ERIC No. ED 043 650.

__________. 1972. "Uses of the Computer in Music Composition and Research," *Advances in Computers*, ed. by Morris Rubinoff, vol. 12. New York: Academic Press, 1972. 73-114.

__________. 1974. "Use of the computer in music research: a short report on accomplishments, limitations, and future needs," *Computers and the Humanities* VIII/5-6 (September-November): 285-289.

Lindblom, Björn, and Johan Sundberg. 1970. "Towards a Generative Theory of

Melody," *Svensk Tidskrift för Musikforskning* 52: 71-88.

Lindstedt, Iwona. 1996. "Proba zastosowania komputera do analizy serii dodekafonicznej: Opis autorskich programow Serie i Seriean," *Muzyka: Kwartalnik Instytutu Sztuki Polskiej Akademii Nauk* 41/2 (1996): 167-185.

Lindstrom, Erik. 1992. 5 x Oh my Darling Clementine. The Influence of Expressive Intention on Music Performace. Ph.D. thesis. Uppsala University. Department of Psychology.

Linster, Christiane. 1992. "On analyzing and representing musical rhythm," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge: MIT Press. 414-427.

Lischka, Christoph. 1987. "Connectionist Models of Musical Thinking," *Proceedings of the 1987 International Computer Music Conference*. University of Illinois at Urbana-Champaign. 190-196.

Locke, David. 1981. "Cantometrics: An Approach to the Anthropology of Music," *Ethnomusicology* XXV/3 (1981): 527-529.

Lockwood, Lewis. 1966. "MIR ('Musical Information Retrieval')," *Computers and the Humanities* I, no. 2 (1966): 51.

__________. 1970a. "A Stylistic Investigation of the Masses of Josquin Desprez with the Aid of the Computer: a Progress Report," *Musicology and the Computer: Three Symposia*, ed. by Barry S. Brook. New York: The City University of New York Press. 19-27.

__________. 1970b. "Computer Assistance in the Investigation of Accidentals in Renaissance Music," *IMS: Report on the Tenth Congress, Lubljana 1967*, ed. by Dragotin Cvetko. Kassel: Bärenreiter, 1970. 444-449.

Lönn, Anders. 1972. "Trends and Tendencies in recent Swedish Musicology," Acta Musicologica 44/1 (1972): 11-25.

Logemann, George W. 1966a. "Prepare Music Input Data," *Computers and the Humanities* I, no. 2 (1966): 51.

__________. 1966b. "Harmonic and Time-line Input and Statistics," *Computers and the Humanities* I, no. 2 (1966): 51-52.

__________. 1967. "The Canons in the Musical Offering of J. S. Bach: An Example of Computational Musicology," *Elektronische Datenverarbeitung in der Musikwissenschaft*, ed. by Harald Heckmann. Regensburg: Gustav

Bosse. 63-87.

Logrippo, Luigi, and Bernard Stepien. 1986. "Cluster Analysis for the Computer-Assisted Statistical Analysis of Melodies," *Computers and the Humanities* XX/1 (1986): 19-33.

Lomax, Alan. 1962. "Song Structure and Social Structure." *Ethnology* I (1962): 425-451.

__________. 1968. *Folk Song Style and culture*. Washington, D.C.: American Association for the Advancement of Science.

__________. 1976. *Cantometrics: An Approach to the Anthropology of Music*. Berkeley, CA: The University of California Press.

Lonati, F. 1991a. "Guida Opreativa del Modulo 'ScoreSegmenter'," Technical Report M/18. Milan: CNR-PFI2 MUSIC Series.

__________. 1991b. "Note Tecniche del Modulo 'ScoreSegmenter'," Technical Report M/19. Milan: CNR-PFI2 MUSIC Series.

Longuet-Higgins, H. Christopher. Ed. 1983. "All in Theory - The Analysis of Music. Review: A Generative Grammar of Tonal Music by Fred Lerdahl and Ray Jackendoff, MIT-Press 1983," *Nature* 304, 7 July (1983): 93.

__________. 1987. *Mental Processes: Studies in Cognitive Science*. Cambridge: MIT Press. 82-104.

__________. 1993. "The Perception of Melodies," *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press. 470-495.

Longuet-Higgins, H. Christopher, and Christopher S. Lee. 1982. "The Perception of Musical Rhythms," *Perception* XI (1982): 115-128.

Longuet-Higgins, H. Christopher, and E. R. Lisle. 1989. "Modelling Musical Cognition," *Contemporary Music Review* 3 (1989): 15-27.

Longuet-Higgins, H. Christopher, and M. J. Steedman. 1971. "On Interpreting Bach," *Machine Intelligence 6*, ed. by B. Meltzer and D. Michie. New York: American Elsivier. 221-241.

Lönn, Anders, and Erik Kjellberg. 1985. *Analytica: Studies in the Description and Analysis of Music*. Uppsala: Uppsala University.

Lord, Charles Hubbard. 1978. An Explication of Some Recent Mathematical

Approaches to Music Analysis. Ph.D. thesis, Indiana University.

Lorek, Mary Jo. 1991. "Computer analysis of vocal input: A program that simulates college faculty sight singing evaluation," *Computers in Music Research* III (1991): 121-138.

Lospinuso, Margaret F., and Martin Dillon. 1981. "American Shape Note Tunes," *Perspectives on Computing* I/3 (October 1981): 40-48.

Louhivuori, Jukka. 1989. "Computer aided analysis of Finnish spiritual folk melodies," *Probleme der Volksmusikforschung*, ed. by Hartmut Braun. Bern: Peter Lang. 312-323.

__________. 1993. "Generatiivinen vs. konnektionistinen paradigma muuntelun tutkimuksessa," *Etnomusikologian Vuosikirja* (1993): 214-223.

__________. 1995. "Preface [to the special issue on Cognitive Musicology]," *Journal of New Music Research* XXIV (1995): 5-7.

__________. 1997. "Systematic, Cognitive and Historical Approaches in Musicology," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 30-41.

__________. 1999. "Modeling Musical Thinking," *Otto Laske: Navigating New Musical Horizons*, ed. by Jerry Tabor. Westport, Connecticut: Greenwood. 121-132.

Louhivuori, Jukka, and A. Sormunen. 1992. *Kognitiivinen Misiikkitiede*. Jyväskylä: Jyväskylän Yliopiston Monistuskeskus.

Lubej, Emil H. 1987a. Die Gesänge der tenores aus Sardinien: Musikwissenschaftliche Behandlung des cantu a sa seria nebst einer Einführung in den Gesangsstil unter Berücksichtigung allgemein-kultureller und sprachwissenschaftlicher Aspekte. Ph.D. thesis. University of Vienna.

__________. 1987b. "Quantitative Methoden in der vergleichend-systematischen Musikwissenschaft: Automatische Intonationsanalyse über die multimodale Verteilung und deren statistisch-geographische Auswertung am Beispiel der Gesänge der Tenores aus Sardinien," *Musicologica Austriaca* (Austria) VII (1987): 129-155.

__________. 1996. "EMAP (EthnoMusicological Analysis Program) for Windows95 and WindowsNT," *Computing in Musicology* 10 (1995-1996): 151-154.

Lundstrom, Elbjorg Keyn. 1987. The Melodic Structure and Form of Norwegian Lullabies (Bensuller) From the Valleys of Valdres, Gudbrandsdalen, and Osterdalen. MA thesis, Andrews University.

Mala, Hana. 1967. "Statistická srovnávací analyza sboru Leose Janácka a moravskych lidovych písní," *Hudebni Veda* IV/4 (1967): 602-627.

Mandelbrot, Benoit B. 1983. *The Fractal Geometry of Nature*. New York: Freeman.

Manning, Peter. 1993. Review of *Computers and Musical Style* by David Cope. *Music and Letters* 74 (1993): 132-134.

Marillier, Cecil Glyn. 1971. Tonal structure in the symphonies of F.J. Haydn. M.A. thesis. University of Otago.

__________. 1981. "Computer-assisted analysis of tonal structure in the Classical symphony," *Proceedings of the 1981 International Computer Music Conference*. San Francisco, CA: International Computer Music Association. 544-564.

__________. 1983. "Computer Assisted analysis of tonal structure in the classical symphony," *The Haydn Yearbook* XIV (1983): 187-199.

Marsden, Alan A.. 1992. "Modelling the Perception of Musical Voices. A Case Study in Rule-Based Systems," *Computer Representations and Models in Music*, ed. by Alan Marsden & Anthony Pople. London: Academic Press. 239-263.

__________. 1995. "Musical pragmatics and computer modelling," *Musical signification: Essays in the semiotic theory and analysis of music*, ed. by Eero Tarasti. Berlin: Mouton de Gruyter. 335-348.

__________. 1998. Review of Understanding Music With AI: Perspectives of Music Cognition, ed. by M. Balaban, K. Ebcioglu, and O. Laske, *Journal of New Music Research* XXVII/4 (1998): 411-415.

Marsden, Alan, and Anthony Pople. 1989. "Towards a Connected Distributed Model of Musical Listening," *Interface* XVIII/1-2 (1989): 61-72.

Marsden, Alan, and Anthony Pople. Eds. 1992a. *Computer Representations and Models in Music*. London: Academic Press.

Marsden, Alan, and Anthony Pople. 1992b. "Introduction: Music, Computers and Abstraction," *Computer Representations and Models in Music*, ed. by Alan Marsden & Anthony Pople. London: Academic Press. 1-4.

Marsella, Stacy C., and Charles F. Schmidt. 1992. "On the Use of Problem Reduction Search for Automated Music Composition," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge, MA: The MIT Press. 238-256.

Marvin, E. W., and P. A. Laprade. 1987. "Relating Musical Contours: Extensions of a Theory for Contour," *Journal of Music Theory* XXXI/2 (1987): 225-267.

Maser, Siegfried. 1971. Numerische Ästhetik. Neue mathematische Verfahren zur quantitativen Beschreibung und Bewertung ästhetischer Zustände, 3rd ed. Stuttgart: Krämer.

Mason, Robert M. 1969. "An Encoding Algorithm and Tables for the Digital Analysis of Harmony," *Journal of Research in Music Education* 17 (Fall-Winter): 286-300, 369-387.

__________. 1985. *Modern Methods of Music Analysis Using Computers*. Peterborough, NH: Schoolhouse Press.

Massaro, Dominic W. et. al. 1980. "The Role of Tone Height, Melodic Contour, and Tone Chroma in Melody Recognition," *Journal of Experimental Psychology: Human Learning and Memory* VI/1 (1980): 77-90.

Mathews, M. V. 1972. Review of *The Computer and Music* by Harry B. Lincoln, *Computer Studies in the Humanities and Verbal Behavior* III/4 (November 1972): 224-225.

Matteis, Adriano, and Goffredo Haus. 1995. "Formalization of Generative Structures Within Stravinsky's 'The Rite of Spring'," *Journal of New Music Research* XXV (1996): 47-76.

Mattusch, Udo. 1997. "Emulating Gestalt Mechanisms by Combining Symbolic and Subsymbolic Information Processing Procedures," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 469-481.

Maultsby, Portia Katrenia. 1972. "Afro-American Music, 1619-1861: An Analytical Study," *Computers and the Humanities* VII/2 (1972): 125.

__________. 1974. Afro-American Religious Music: 1619-1861. Historical Development and Computer Analysis of one Hundred Sprituals. PhD thesis, The University of Wisconsin.

Maxwell, H. John. 1984. An Artificial Intelligence Approach to Computer-

Implemented Analysis of Harmony in Tonal Music. Ph.D. thesis. Indiana University.

__________. 1992. "An Expert System for Harmonic Analysis of Tonal Musik," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge: The MIT Press. 235-353.

Mazzola, Guerino. 1985a. "Sechs Thesen zur Rolle der Mathematik für die Musik," *Musik und Mathematik*, ed. by H. Götze und R. Wille. Berlin: Springer.

__________. 1985b. "M(2,Z)\Z2-o-scope," *Musik und Mathematik. Salzburger Musikgespräch 1984 unter Vorsitz von Herbert von Karajan*, ed. by Heinz Götze and Rudolf Wille. Berlin: Springer. 75-76.

__________. 1985c. *Gruppen und Kategorien in der Musik*. Berlin: Heldermann.

__________. 1986a. "Die Rolle des Symmetriedenkens für die Geschichte der europäischen Musik," *Symmetrie in Kunst, Natur und Wissenschaft*, vol. 1. Darmstadt: Röther.

__________. Ed. 1986b. *Symmetrie in Kunst, Natur und Wissenschaft*, vol. 3. Darmstadt: Röther.

__________. 1988. "Die Wahl der Zahl - eine systematische Betrachtung des Streichquartetts," *Dissonanz* (Switzerland) 17 (August 1988): 19-22.

__________. 1990. *Geometrie der Töne - Elemente der Mathematischen Musiktheorie*. Basel: Birkhäuser.

__________. 1991. "Mathematische Musiktheorie: Status quo 1990," Jahrbuch des Deutschen Mathematik Vereins 93 (1991): 6-29.

__________. 1994. "Establishing Tempo Hierarchies," *Computing in Musicology* 9 (1993-1994): 103-104.

__________. 1998. "Die schöne Gefangene - Metaphorik und Komplexität in der Musikwissenschaft," *Musikwissenschaft zwischen Kunst, Ästhetik und Experiment. Festschrift Helga de la Motte-Haber zum 60. Geburtstag*. Würzburg: Königshausen & Neumann. 359-369.

Mazzola, Guerino, Vreni Graber-Brunner, and Heinz-Gregor Wieser. "Hirnelektrische Vorgänge im limbischen System bei konsonanten und dissonanten Klängen," *Musik - Gehirn -Spiel. Beiträge zum vierten Herbert von Karajan Symposion*, ed. by Hellmuth Petsche. Basel: Birkhäuser. 135-

152.

Mazzola, Guerino, and Georg Rainer Hofmann. 1989. "Der Music Designer MDZ71 - Hard- und Software für die mathematische Musiktheorie," *Musik - Gehirn -Spiel. Beiträge zum vierten Herbert von Karajan Symposion*, ed. by Hellmuth Petsche. Basel: Birkhäuser. 203-215.

Mazzola, Guerino, and Heinz-Gregor Wieser. 1987. "EEG Responses to Music in Limbic and Auditory Cortices," *Fundamental Mechanisms of Human Brain Function*, ed. by J. Engel. New York: Raven Press.

Mazzola, Guerino, and Heinz-Gregor Wieser, F. Brunner, and D. Muzzulini. 1989. "A Symmetry-Oriented Mathematical Model of Counterpoint and Related Neurophysiological Investigations by Depth-EEG," *Symmetry: Unifying Human Understanding* II. ed. by I. Hargittai, New York: CAMWA / Pergamon Press.

Mazzola, Guerino, and Oliver Zahorka. 1994. "Tempo Curves Revisited - Hierarchies of Performance Fields," *Computer Music Journal* XVIII/1 (1994): 40-52.

Mazzola, Guerino, Oliver Zahorka, and Thomas Noll. 1996. Musical analysis on the RUBATO platform. *Computing in Musicology* 10 (1995-1996): 143-149.

McAdams, Stephen. 1987. "Music: A Science of the Mind?" *Contemporary Music Review* 2 (1987): 1-61.

McArtor, Michael J. 1995. Comparison of design in the finales of the symphonies of Bruckner and Brahms. DMA thesis. Arizona State University.

McGee, Deron L. 1993. Musical Rules: A Knowledge-Based Simulation of an Implication-Realization Model. Ph.D. thesis, The University of Wisconsin.

__________. 1995. "Developing Knowledge-Based Simulations as a Method for Investigating Theoretical Positions," *Computers in Music Research* V (1995): 39-66.

McGee, William F., and Paul Merkley. 1989. "Real-time acoustic analysis of polyphonic music," *Proceedings of the 1989 International Computer Music Conference*, ed. by Peter Desain, Henkjan Honing, and Klaus de Rijk. San Francisco, CA: International Computer Music Association. 199-202.

McGettrick, Paul. 1992. "Style and variation in Irish traditional flute playing," *Computing in Musicology* 8 (1992): 99.

McHose, Allen I. 1950. "Musical Research in the Definition of Bach's Contrapuntal Harmonic Style," *Proceedings of the Music Teachers National Association* 42 (1950): 126-150.

McIntyre, Ryan A. 1994. "Bach in a Box: The Evolution of Four Part Baroque Harmony Using the Genetic Algorithm," *Proceedings of the 1994 IEEE Conference on Evolutionary Computation*. Orlando, Florida.

McLean, Bruce. 1992. "An editing system for analysis of musical scores," *Computing in Musicology* 8 (1992): 133.

McMullen, Patrick T. 1974. "Influence of Number of Different Pitches and Melodic Redundancy on Preference Responses," *Journal of Research in Music Education* XXII (1974): 198-204.

Meeds, Wilfried Vern. 1996. The Hymnody of Barney Elliot Warren. Ph.D. thesis. Claremont Graduate School.

Meehan, James R. 1980. "An Artificial Intelligence Approach to Tonal Music Theory," *Computer Music Journal* IV/2 (1980): 60-65. Reprinted in *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press, 1993. 314-324.

Mendel, Arthur. 1969. "Some preliminary attempts at computer-assisted style analysis in music," *Computers and the Humanities* IV/1 (September 1969): 41-52.

__________. 1976. "Towards Objective Criteria for Establishing Chronology and Authenticity: What Help Can the Computer Give?" *Josquin des Prez. Proceedings of the international Josquin festival-conference held at The Juilliard School at Lincoln Center in New York City, 21-25 June 1971*, ed. by Edward E. Lowinsky. London: Oxford University Press. 297-308.

__________. 1979. "Recension of the Sources of the Works of Josquin Dezpres," *Computers and the Humanities* XIII/3 (1979): 260.

Mesnage, Marcel. 1991a. "Notations et analyse musicale," *Analyse Musicale* 24 (1991): 42-46.

__________. 1991b. "Sur la modelisation des partitions musicales," *Analyse Musicale* 22 (1991): 31-44.

__________. 1992a. "Un modele informatique de 3eme- regard sur l'enfant-Jesus d'Olivier Messiaen," *Musique et assistance informatique*. Marseille: Cite de la Musique. 187-209.

__________. 19992b. "Logique et instrumentation de l'analyse musicale," *Analyse Musicale* XXVIII (1992): 60-68.

__________. 1993. "Morphoscope, a computer system for music analysis," *Interface* XXII/2 (1993): 119-131.

__________. 1994. "Techniques de segmentation automatique en analyse musicale," *Musurgia: Analyse et Pratique Musicales* I/1 (1994): 39-52.

Mesnage, Marcel, and Andre Riotte. 1991. "L'invention a deux voix no 1 de J. S. Bach," *Analyse Musicale* 22 (1991): 46-66.

Metz, Paul Wesley. 1983. Randomness and Correlation in Music: A New Approach to Melodic Analysis. Ph.D. thesis, University of Cincinatti.

Metzler, Wolfgang. 1985. "Schöpferische Tätigkeit in Mathematik und Musik," *Musik und Mathematik. Salzburger Musikgespräch 1984 unter Vorsitz von Herbert von Karajan*, ed. by Heinz Götze and Rudolf Wille. Berlin: Springer. 45-63.

Meyer, Leonard B. 1957. "Meaning in Music and Information Theory." *Journal of Aesthetics & Art Criticism*, vol. XV, no. 4 (June 1957): 412-424.

Meylan, Raymond. 1965. "Utilization des Calculatrices Electroniques pour la comparaison Interne du Repertoire des Basses Danses de Quinzi," *Fontes Artis Musicae* 12 (May 1965): 128-134.

__________. 1966. "Recherche de Parents parmi les Basses Danses du Quinzi," *Acta Musicologica* 38 (January 1966): 46-66.

__________. 1967. "Symbolisierung einer Melodie auf Lochkarten," *Elektronische Datenverarbeitung in der Musikwissenschaft*, ed. by Harald Heckmann. Regensburg: Gustav Bosse. 21-24.

__________. 1968. *L'enigme de la musique des basses danses du quinzieme siecle*. Publications de la Societe Suisse de Musicol Vol. 2/17. Bern: Haupt.

__________. 1970. "Teorie de la Centonisation," *IMS: Report on the Tenth Congress, Lubljana 1967*, ed. by Dragotin Cvetko. Kassel: Bärenreiter, 1970. 427-430.

__________. 1973. "Limites de l'objectivite dans les ecritures instrumentales de la Renaissance," *Informatique Musicale* (October 1973): 1-9.

Millar, Jana Kubitza. 1984. The Aural Perception of Pitch-Class Set Relations: A

Computer-Assisted Investiga PhD thesis, University of North Texas.

Miller, Benjamin, Don L. Scarborough, and Jacqueline A. Jones. 1992. "On the Perception of Meter," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge, MA: The MIT Press. 428-447.

Miller, Ernest John. 1992. Aspects of Melodic Construction in the Masses of Palestrina: A Computer-Assisted Study. Ph.D. thesis. Northwestern University.

Minsky, Marvin. 1981. "Music, Mind, and Meaning," *Computer Music Journal* V/3 (1981): 28-44. Reprinted in *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press, 1993. 326-354.

Minsky, Marvin, and Otto Laske. 1992. "Foreword: A Conversation with Marvin Minsky," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge, MA: The MIT Press. ix-xxx.

Mix, Roland. 1967. "Die Entropieabnahme bei Abhängigkeit zwischen mehreren simultanen Informationsquellen und bei Übergang zu Markoff-Ketten höherer Ordnung, untersucht an musikalischen Beispielen," *Theorien zur Formalanalyse mehrstimmiger Musik*, by Walter Reckziegel. Köln: Westdeutscher Verlag, 39-80.

Moelants, Dirk. 1997. "A Framework for the Subsymbolic Description of Meter," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 263-276.

__________. 2000. "Analysis of Timing in Contemporary Music Performance: some Methods and Observations," *Computer-Aplications in Music Research: Methods, Concepts, Results*, ed. by Nico Schüler. Hamburg: von Bockel. in press.

Moffat, Anne Simon. 1989. "New graphics program debuts in concert hall," *Science* 242 (1989): 1452.

Moisala, Pirkko. 1993. "Cognitive Study of Music as Culture," *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*, ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä. 186-197.

__________. 1995. "Cognitive Study of Music as Culture - Basic Premises for 'Cognitive Musicology'," *Journal of New Music Research* XXIV (1995): 8-

20.

Moles, Abraham A. 1956a. "Informationstheorie der Musik." *Nachrichtentechnische Fachberichte*, vol. 3 (1956): 47-55.

__________. 1956b. "Informationstheorie und ästhetische Empfindung." *Gravesaner Blätter* VI (December 1956): 3-9.

__________. 1958. *Théorie de l'information et perception esthétique*. Paris: Flammarion & C[ie]. American edition: *Information Theory and Esthetic Perception*, translated by Joel E. Cohen. Urbana: University of Illinois Press, 1966.

__________. 1962. "Das neue Verhältnis zwischen Musik und Mathematik," *Gravesaner Blätter* vol. VI (1962): 98-103.

__________. 1964. "Uvedení do soucasného stavu hudby," *Nové Cesty Hudby* (1964): 36-53.

__________. 1966. *Information Theory and Esthetic Perception*, translated by Joel E. Cohen. Urbana: University of Illinois Press.

__________. 1986. "Approche informationnelle de la perception et de la creation Musicale," *International Review of the Aesthetics and Sociology of Music* (Croatia) XVII/2 (December 1986): 273-297.

Moll, Kevin N. 1988. Analyzing Four-Voice Vertical Sonorities in Fifteenth-Century Sacred Polyphony: A Comparison of Selected Ockeghem Kyries According to Contrapuntal Theory of Pietro Aaron. MM thesis, New England Conservatory of Music.

__________. 1996. "Vertical sonorities in Renaissance polyphony: A music-analytic application of spreadsheet software," *Computing in Musicology* 10 (1995-1996): 59-77.

Möller, Hartmut. 1988. "Grenzen der Computerverwendung bei der Erforschung liturgischer Gesangshandschriften," *Florilegium Musicologicum: Hellmut Federhofer zum 75. Geburtstag*, ed. by Christoph-Hellmut Mahling. Tutzing: Schneider. 219-32.

Monelle, R. 1992. *Linguistics and Semiotics in Music*. Chur: Harwood Academic Publishers.

Mont-Reynaud, Bernard and M. Goldstein. 1985. "On Finding Rhythmic Patterns in Musical Lines," *Proceedings of the 1985 International Computer Music Conference*. San Francisco: Computer Music Association. 391-397.

Mont-Reynaud, Bernard, and Emmanuel Gresset. 1990. "PRISM: Pattern recognition in sound and music," *Proceedings of the International Computer Music Conference, Glasgow, 1990*. San Francisco, CA: Computer Music Association, 1990. 153-155.

Moomaw, Charles J. 1973. A PL-1 program for the harmonic analysis of music by the theories of Paul Hindemith and Howard Hanson. M.M. thesis. University of Cincinnati.

Moore, F. 1971. "Musica ed elaboratori elettronici," *Encyclopedia della scienza e della tecnica* (1971): 490-498.

Moorer, James Anderson. 1973. "Segmentation and Analysis of Continuous Musical Sound," *Computational Musicology Newsletter* I/1 (1973): 3-4.

__________. 1975. On the segmentation and analysis of continuous musical sound by digital computer. Ph.D. thesis. Stanford University.

Moraitis, Andreas. 1994. *Zur Theorie der musikalischen Analyse*. Frankfurt am Main: Peter Lang, 1994.

Morehen, John. 1992. "Byrd's manuscript motets: A new perspective," *Byrd Studies*. Cambridge: Cambridge University Press, 1992. 51-62.

Morehen, John, and Ian Bent. 1979. "Computer Applications in Musicology," *The Musical Times* 120/7 (July 1979): 563-566.

Morris, Robert. 1980. "A Similarity Index for Pitch Class Sets," *Perspectives of New Music* 18 (1979/80), 445-460.

__________. 1993. "New Directions in the Theory and Analysis of Musical Contour," *Music Theory Spectrum* XV/2 (Fall 1993): 205-228.

Morris, Robert, and Brian Alegant. 1988. "The even partitions in twelve-tone music," *Music Theory Spectrum* X (1988): 74-101.

Morse, Margaret Beverly. 1974. A quantitative stylistic analysis of the Agnus Dei Mass movements of Guillaume Dufay supporting the doubtful authenticity of the Missa caput. M.M. thesis. Hartt College of Music.

Morse, Raymond William. 1985. Use of Microcomputer Graphics to Aid in the Analysis of Music. DMA thesis, University of Oregon.

Morton, Ian A. 1967. "FORTRAN Music Programs Involving Numerically Related Tones," *Computers and the Humanities* II, no. 2 (1967): 87-88.

__________. 1973. "Analysis of Tonal Music at the Level of Perception," *Computational Musicology Newsletter* I/1 (1973): 16.

__________. 1974. "Analysis of tonal music at the level of Perception," *Computers in the Humanities*, ed. by J. L. Mitchel. Minneapolis: University of Minnesota Press, 1974. 261-266.

Morton, Ian, and John Lofstedt. 1970. "FORTRAN Music Programs Involving Numerically Related Tones," *The Computer and Music*, ed. by Harry B. Lincoln. Ithaca: Cornell University Press. 154-162.

Mozart, Wolfgang Amadeus. 1975. "Fünfundzwanzig Stücke (fünf Divertimenti) für drei Bassetthörner (KV 439^{b})," *Neue Ausgabe Sämtlicher Werke. Serie VIII: Kammermusk. Werkgruppe 21: Duos für Streicher und Bläser*, ed. by Dietrich Berke and Marius Flothuis. Kassel: Bärenreiter. 67-119.

Nake, Frieder. 1974. *Ästhetik als Informationsverarbeitung. Grundlagen und Anwendungen der Informatik im Bereich ästhetischer Produktion und Kritik*. Wien: Springer.

Nam, Unjung. 1998. "Pitch distributions in Korean Court music: Evidence Consistent With Tonal Hierarchies," *Music Perception* XVI/2, 243-248.

Narmour, Eugene. 1977. *Beyond Schenkerianism: The Need for Alternatives in Music Analysis*. Chicago: University of Chicago Press.

__________. 1984. "Toward an Analytical Symbology: The Melodic, Harmonic and Durational Functions of Implication and Realization," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Florence: Leo S. Olschki. 83-114.

__________. 1990. *The Analysis and Cognition of Basic Melodic Structures: The Implication-Realization Model*. Chicago: University of Chicago Press.

__________. 1991. "The Top-Down and Bottom-Up Systems of Musical Implication: Building of Meyer's Theory of Emotional Syntax," *Music Perception* IX/1 (1991): 1-26.

__________. 1992. *The Analysis and Cognition of Melodic Complexity. The Implication-Realization Model*. Chicago: University of Chicago Press.

Nash, Stephen G., ed. 1990. *A History of Scientific Computing*. New York: ACM Press.

Nathan, Hans. 1958. "The Twelve-Tone Compositions of Luigi Dallapiccola," The

Musical Quarterly 44 (July): 289-310.

Nattiez, J. J. 1972. "Is a descriptive seomiotics of music possible?" *Language Sciences* 23 (1972): 1-7.

__________. 1973a. "Musical Semiotics," *Computational Musicology Newsletter* I/1 (1973): 17.

__________. 1973b. "Linguistics: A New Approach for Musical Analysis?" *International Review of the Aesthetics and Sociology of Music* 4 (1973): 51-69.

Nelson, Gary Lee. 1973. "COMPOSE: A Program for Musical Composition," *Computational Musicology Newsletter* I/1 (1973): 11.

__________. 1974. Anton Webern's 'Five Canons' op. 16: A Test Case for Computer-Aided Analysis and Synthesis of Musical Style. PhD thesis, Washington University.

Nettheim, N. 1992. "On the Spectral Analysis of Melody," *Interface* 21 (1992): 135-148.

Nettl, Bruno. 1958. "Some Linguistic Approaches to Musical Analysis," *Journal of the International Folk Music Council* 10 (1958): 37-41.

Neuhoff, Hans. 1996. "Mensch, Musik, Maschine: Das digitale Credo und seine Probleme--Eine Antwort auf Reinhard Kopiez," *Musica Germany* 50/1 (Jan-Feb 1996): 27-32.

Neumann, P. G., and H. Schappert. "Komponieren mit elektronischen Rechenautomaten," *Nachrichtentechnische Zeitschrift* VIII (1959): 403-407.

Ng, Kia Chuan, and Roger Boyle. 1992. "Segmentation of Music Primitives," *Proceedings of the British Machine Vision Conference. Leeds, UK. September 1992*. London: Springer.

Ng, Kia Chuan, and Roger Boyle. 1994. Recognition of Music Scores From Primitives Subsegmentation. Technical Report 94.12, School of Computer Studies, The University of Leeds. U.K.

Ng, Kia Chuan, Roger Boyle, and David Cooper. 1996. "Automatic Detection of Tonality Using Note Distribution," *Journal of New Music Research* XXV/4 (1996): 369-381.

Noorden, Leon van, and Dirk Moelants. 1999. "Resonance in the Perception of

Musical Pulse," *Journal of New Music Research* XXVIII (1999): 43-66.

Norman, P. 1945. *A Quantitative Study of Harmonic Similarities in Certain Specified Works of Bach, Beethoven and Wagner.* New York, NY: Carl Fischer.

Oehrle. Elizabeth. 1992. "Cantometrics: An Approach to the Anthropology of Music," *British Journal of Music Education* IX/1 (1992): 83-86.

Oliveira, Alda de Jesus. 1986. A frequency count of music elements in Bahian folk songs using computer and hand analysis: suggestions in music education. PhD thesis, The University of Texas at Austin.

__________. 1997. "A frequency count of music elements in Bahian folk songs using computer and hand analysis: Suggestions for applications in music education," *16th International Seminar of the Research Commission.* Urbana, IL: U. of Illinois, School of Music. 105-109.

Oliveira, Jamary. 1981. "SERIE: Um programa auxiliar para analise de musica dodecafonica," *Revista da Escola de Musica e Artes Cenicas da UFBA* (Brazil) II (July-September 1981): 113-132.

Oliveiro, Jamari de. 1988. "Educacao atraves de computadores," *Simposio internacional de musica e informatica.* Sao Paulo: Festival Musica Nova. 29-30.

O Maidin, Donncha Sean. 1996. "A programmer's environment for corpus-based musical analysis," *Computing in Musicology* 10 (1995-1996): 150.

__________. 1984a. "Computer Analysis of Irish Music," *Ceol. A Journal of Irish Music* VII/1-2 (1984): 35-39.

__________. 1984b. "Computer Analysis of Irish and Scottish Jigs," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 329-336.

__________. 1992. "Representation of Music Scores for Analysis," *Computer Representations and Models in Music*, ed. by Alan Marsden and Anthony Pople. London: Academic Press. 67-93.

O'Neill, John Charles. 1984. Computer Analysis and Synthesis of a Sung Vowel. DMA thesis, University of Illinois at Urbana-Champaign.

Oppo, Franco. 1984. "Per Una Teoria Generale del Linguaggio Musicale," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 115-130.

Opren, Keith S., and David Huron. 1992. "The Measurement of Similarity in Music: A Quantitative Approach for Non-Parametric Representations," *Computers in Music Research* IV (1992): 1-44.

Orlov, Ju. K. "Unsichtbare Harmonie," *Musikometrika 1*, ed. by Moisej G. Boroda. Bochum: Brockmeyer. 263-270.

Ortmann, Otto. 1937. "Interval Frequency as a Determinant of Melodic Style." *Beabody Bulletin* (December): 3-10.

Osborn, F. E. Ann. 1986. A Computer-Aided Methodology for the Analysis and Classification of British-Canadian Children's Traditional Singing Games. Ph.D. thesis, Ohio State University.

__________. 1988. "Computer-Aided Methodology for the Analysis and Classification of British-Canadian Children's Traditional Singing Games," *Computers and the Humanities* XXII (1988): 173-182.

Osborn-Seyffert, F.E. Ann. 1989. "British-Canadian children's traditional singing games: A computer-aided methodology for analysis and classification," *Ballades et Chansons Folkloriques*, ed. by John R. Porter. Quebec, Quebec, Canada: Universitè de Laval, CELAT. 219-229.

__________. 1992. "Analysis and classification of singing games," *Computing in Musicology* 8 (1992): 72-74.

Oudal, Robert D. 1969. "The 1968 introductory seminar in the use of computers in musical projects: a summary report of reactions, frustrations, and achievements," *Student Musicologists at Minnesota* III (1968-69): 66-109.

Overill, Richard E. 1993. "On the combinational complexity of fuzzy pattern matching in music analysis," Computers and the Humanities XXVII/2 (1993): 105-110.

Ozzola, Vito, Giovanni Melzi, and Azio Corghi. 1984. "Experiments in Stochastic Approximation of Musical Language," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 325-327.

Pachet, François. 1990. "Representing Knowledge Used by Jazz Musicians," *Proceedings of the International Computer Music Conference*. International Computer Music Association. 285-288.

__________. 1991a. "A Meta-Level Architecture for Analyszing Jazz Chord Sequences," *Proceedings: International Computer Music Conference,* *Montreal, 1991*. Montreal: McGill University Press, 1991. 266-269.

__________. 1991b. "Representing Knowledge Used by Jazz Musicians," *Proceedings of the International Conference on Computer Music.* Montréal, Canada. 285-288.

__________. 1994a. "The MusES System: An Environment for Experimenting with Knowledge Representation Techniques in Tonal Harmony," *Proceedings of the First Brazilian Symposium on Computer Music - SBC&M '94*. Caxambu, Minas Gerais, Brazil. 195-201.

__________. 1994b. "An Object-Oriented representation of Pitch Classes, Intervals, Scales and Chords," *Journées d"informatique Musicale*. Bordeaux, France. 19-34.

__________. 1996. "The Embeddability of Production Rules in Object-Oriented Languages," *Journal of Object-Oriented Programming* VIII/4 (1996): 19-24.

Pachet, François, Geber Ramalho, and Jean Carrive. 1996. "Representing Temporal Musical Objects and Reasoning in the MusES System," *Journal of New Music Research* XXV (1996): 252-275.

Pachet, François, and P. Roy. 1994. Mixing Constraints and Objects: A Case Study in Automatic Harmonization," *Proceedings of TOOLS Europe '95*. Versailles: Prentice-Hall. 119-126.

Paisley, William J. 1963. "Identifying the Unknown Communicator in Painting, Literature and Music: the Significance of Minor Encoding Habits," *Journal of Communication* XIV, no. 4 (1964): 219-237.

__________. 1969. "Studying 'Style' as deviation from encoding norms," *The Analysis of Communication Content. Developments in Scientific Theories and Computer Techniques*, ed. by George Gerbner, Ole R. Holsti, Klaus Krippendorff, William J. Paisley and Philip J. Stone. New York: Wiley & Sons. 133-146.

Palmer, C., and Carol L. Krumhansl. 1990. "Mental Representations for Musical Meter," *Journal of Experimental Psychology: Human Perception and Performance* 16 (1990): 728-741.

Parncutt, Richard. 1987. "The Perception of Pulse in Musical Rhythm," *Action and Perception in Rhythm and Music*, ed. by. A. Gabrielsson. Stockholm: Royal Swedish Academy of Music.

__________. 1988. "Revision of Terhardt's Psychoacoustical Model of the Root(s) of a Musical Chord," *Music Perception* VI/1 (1988): 65-93.

__________. 1989. *Harmony. A Psychoacoustical Approach.* Heidelberg: Springer.

__________. 1993a. "Pitch Properties of Chords of Octave-Spaced Tones," *Contemporary Music Review* (1993).

__________. 1993b. Template-Matching Models of Musical Pitch and Rhythm Perception," *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*, ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä. 1-19.

__________. 1994. "Template-Matching Models of Musical Pitch and Rhythm Perception," *Journal of New Music Research* XXIII (1994): 145-167.

__________. 1995. "Response to Demske: Relating Sets," *Music Theory Online* I/3 (1995).

__________. 1997. "A Model of the Perceptual Root(s) of a Chord Accounting for Voicing and Prevailing Tonality," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 181-199.

__________. 1998a. "Listening to Music in the Real World? A Critical Discussion of Marc Leman's (1995) *Music and Schema Theory: Cognitive Foundations of Systematic Musicology*," *Journal of New Music Research* XXVII/4 (1998): 380-408.

__________. 1998b. "Reply to Balsach," *Journal of New Music Research* XXVII/4 (1998): 416-417.

Parncutt, Richard, John A. Sloboda, Eric F. Clarke, Matti Raekallio, and Peter Desain. 1997. "An Ergonomic Model of Keyboard Fingering for Melodic Fragments," *Music Perception* (1997): 341-381.

Paszkowska, Elzbieta. 1977. "Struktura napiecia w klasyoznej formie sonatowej," *Muzyka* (Poland) XXII/4 (1977): 14-37.

Patrick, P. Howard. 1974. "A computer study of a suspension formation in the masses of Josquin Desprez," *Computer and the Humanities* VIII/5-6 (September-November 1974): 321-331.

Patrick, Robert Lee. 1971. A Composer-Based Thematic Index to the Works of Heinrich Sch‸tz. D.M.A. thesis. University of Kentucky.

Patzold, Uwe. 1995. "Ethnomusikologie und Multi-Media-Computersysteme: Perspektiven und Probleme der computergestutzten interaktiven Analyse von Musik und Bewegung am Beispiel der Bewegungskunst "Pencak Silat" (Indonesien/ Malaysia)," *Lux oriente: Begegnungen der Kulturen in der Musikforschung. Festschrift Robert Gunther zum 65. Geburtstag*, ed. by Klaus Wolfgang Niemöller, Uwe Patzold, and Chung Kyo-chul Kassel: Bosse. 393-405.

Pearce, Alastair. 1982. "Troubadours and transposition: a computer-aided study," *Computers and the Humanities* XVI/1 (September 1982): 11-18.

Pederson, Donald Margedo. 1968. Some Technique for Computer-Aided Analysis of Musical Scores. PhD. diss., The University of Iowa.

Peiper, Chad Evan. 1996. "Dissonance and genre in Corelli's trio sonatas: A LISP-based study of opp. 1 and 2," *Computing in Musicology* 10 (1995-1996): 34-48.

Pelinski, Ram6n. 1984. "A Generative Grammar of Personal Eskimo Songs," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 273-286.

Penel, A., Peter Desain, E. Maris, and Luke Windsor. "A Decomposition Model of Expressive Timing," Proceedings of the 1999 SMPC. Evanston. 21. (See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Pennycook, B., D. Stammen, and D. Reynolds. 1993. "Toward a Computer Model of Jazz Improviser," *Proceedings of the 1993 International Computer Music Conference*. San Francisco: International Computer Music Assiciation. 228-231.

Peretz, I., and J. Morais. 1989. "Music and Modularity," *Comtemporary Music Review* 4 (1989): 279-293.

Perry-Camp, Jane. 1986. "Divers marks in Mozart's autograph manuscripts: Census and significance," *Mozart-Jahrbuch 1984-85* (1986): 80-108.

Peters, G. David. 1981. "Hardware development for computer-based instruction," *College Music Symposium* XXI/2 (Fall 1981): 15-21.

Peterson, Don Laurel. 1975. Tonal characteristics in the Kyrie and Sanctus sections of twelve L'homme arme Masses: a computer-assisted study. Ph.D. thesis. University of Wisconsin.

Petroni, Nicola Cufaro, Franco Degrassi, and Guido Pasquariello. 1993.

"Detection of Pitch and Residue Pitch in Random Acoustic Signals," *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*, ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä. 20-39.

Petroni, Nicola Cufaro, and Matteo Tricarico. 1997. "Self-Organizing Neural Nets and the Perceptual Origin of the Circle of Fifth," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 169-180.

Philippot, Michel P. 1970. "Muss es sein," *L'Arc* (France) 40 (1970): 82-95.

Piccialli, Aldo, Pierfrancesco Basile, Mariella Sala, P. Simone, S. Vergara. 1991. "Analysis/synthesis system based on a perceptive model," *IX Colloquium on Musical Informatics / IX Colloquio di Informatica Musicale*, ed. by Antonio Camurri and Corrado Canepa. Genova: Associazione di Informatica Musicale Italiana, 1991. 290-302.

Pickover, Clifford. 1986. "Representation of melody patterns using topographic spectral distribution functions," *Computer Music Journal* X/3 (Fall 1986): 72-78.

Pierce, John R. 1992. *The Science of Musical Sound*. New York: Freeman.

Pikler, Andrew G. 1960. "Automatische Bewertung von Musikaufführungen," *Gravesaner Blätter* V (1960): 137-139.

Pinkerton, Richard C. 1956. "Information Theory and Melody." *Scientific America* 194/2 (Febuary 1956): 77-86.

Pinter, Istvan. 1994a. "Szamitogepes hangmikroszkopia II," *Zenetudomanyi dolgozatok* (1992-1994): 243-258.

__________. 1994b. Transcription versus sound spectroscopy in analyzing folk music performance," *Systematic Musicology* II/2 (1994): 333-346.

__________. 1994c. "The computer as the newest tool of sound microscopy," *Perspektiven der Musikethnologie: Dokumentationstechniken und interkulturelle Beziehungen*, ed. by Bruno B. Reuer and Lujza Tari. München: Südostdeutsches Kulturwerk. 32-37.

__________. 1995. "Computerized Sound Microscopy. Application of Sound Microscopy: Comparison of Notation by Ear and Sound-Microscopic Analysis Data on a Folk Fiddle Music Example," *Studia Musicologica Academiae Scientiarum Hungaricae* XXXVI/1-2 (1995): 151-166.

Piotrowska, Maria. 1968. Wybrane aspekty problematyki Jeux venitiens jako wstep do badan strukturalnych nad tworczoscia Witolda Lutoslawskiego. M.A. thesis. University of Warszawa.

Piotrowski, Zbigniew. 1974. "O zastosowaniu komputerow w muzyce mowi Lejaren Hiller," *Ruch Muzyczny* (Poland) IV (February 1974): 3-4.

Rirard, Emmanuel. 1987. "Reflexion sur l'application des techniques informatiques a l'etude des fondements de la musique," *Belgisch Tijdschrift voor Muziekwetenschap* XLI (1987): 97-102.

Piszczalski, Martin B., and Bernard A. Galler. 1979. "Computer Analysis and Transcription of Performed Music: a Project Report," *Computers and the Humanities* 13/3 (July-September 1979): 195-206.

Piszczalski, Martin B., and Bernard A. Galler. 1982a. "A Computer Model of Music Recognition," *Music, Mind and the Brain*, ed. by M. Clynes. New York: Plenum Press, 1982.

Piszczalski, Martin B., and Bernard A. Galler. 1982b. "Computer-aided Techniques for Understanding Performed Music," *Computing in the Humanities*, ed. Richard W. Bailey. Amsterdam: North-Holland Publishing Company. 89-95.

Piszczalski, Martin B., Bernard A. Galler, R. Bossmeyer, M. Hatamian, and F. Looft. 1981. "Performed Music: Analysis, Synthesis and Display by Computer," *Journal of the Audio Engeneering Society* 29 (1981): 38-46.

Plenckers, Leo J. 1984. "A Pattern Recognition System in the Study of the *Cantigas de Santa Maria*," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 59-69.

Pletka, Vaclav. 1974. "Methodologische Probleme der Arbeiterliedforschung," *Arbeiterklasse und Musik: theoretische Positionen in der deutschen Arbeiterklasse zur Musikkultur vor 1945 : eine Dokumentation des Arbeiterliederarchivs*, ed. by Charlotte Albrecht, Inge Lammel, Ilse Schütt, and Marlene Weller. Berlin: Akademie der Künste der Deutschen Demokratischen Republik. 32-35.

Pohlmann, Ken C. 1987. "Technical overview of the CD-I format," *The Proceedings of the AES 5th International Conference: Music and Digital Technology*, ed. by John Strawn. New York: Audio Engineering Society. 223-232.

Polansky, Larry. 1979. "A Hierarchical Gestalt Analysis of Ruggles' Portals," *Proceedings of the 1978 International Computer Music Conference*, vol. 2, ed. by Curtis Roads. Evanston: Northwestern University. 790-852.

__________. 1987. "Morphological Metrics: An Introduction to a Theory of Formal Distances," *Proceedings of the International Computer Music Conference 1987*. San Francisco: International Computer Music Association. 197-205.

__________. 1996. "Morphological Metrics," *Journal of New Music Research* XXV (1996): 289-368.

Ponsford, Dan, Geraint Wiggins, and Chris Mellish. 1997. Statistical Learning of Harmonic Movement. Technical Reprort RP874. Department of Artificial Intelligence, University of Edinburgh.

Ponsford, Dan, Geraint Wiggins, and Chris Mellish. 1999. "Statistical Learning of Harmonic Movement," *Journal of New Music Research* XXVIII (1999): 150-177.

Pool, Otto Ede. 1996. "The Apollo project: Software for musical analysis using DARMS," *Computing in Musicology* 10 (1995-1996): 123-130.

Pope, Stephen Travis. 1986. "Music Notation and the Representation of Musical Structure and Knowledge," *Perspective of New Music Research* XXIV/2 (1986): 156-189.

__________. 1989. "Machine Tongues. XI: Object-Oriented Software Design," *Computer Music Journal* XIII/2 (1989): 9-22.

__________. Ed. 1991a. *The Well-Tempered Object: Musical Applications of Object-Oriented Software Technology*. Cambridge: MIT Press.

__________. 1991b. A tool for manipulating expressive and structural hierarchies in music," *Proceedings: International Computer Music Conference, Montreal, 1991*. Montreal: McGill University Press, 1991. 324-327.

__________. 1992. "MODE and SMOKE," *Computing in Musicology* 8 (1992): 130-132.

__________. 1997. "Musical Object Representation," *Musical Signal Processing*, ed. by Curtis Roads, Stephen Travis Pope, Aldo Piccialli, and Giovanni de Poli. Lisse: Swets & Zeitlinger. 317-347.

Popovic, Igor. 1989. "The Analytical Object: Computer-Based Representation of Musical Scores and Analyses," *Computers in Music Research* I (1989): 103-116.

Popper, Karl R. 1959. *The Logic of Scientific Discovery*. New York: Basic Books.

Powers, Harold S. 1980. "Language Models and Musical Analysis," *Ethnomusicology* XXV/1 (1980): 1-60.

__________. 1981. "Tonal Types and Modal Categories in Renaissance Polyphony," *Journal of the American Musicological Society* XXXIV/3 (Fall 1981): 428-470.

Prather, Ronald E., and R. Stephen Elliot. 1988. "SML: A Structured Musical Language," *Computers and the Humanities* XXII (1988): 137-151.

Prerau, David S. 1970a. "Computer Pattern Recognition of Standard Engraved Music Notation," *Computers and the Humanities* IV, no. 5 (1970): 344.

__________. 1970b. Computer Pattern Recognition of Standard Engraved Music Notation. PhD dissertation, Massachussetts Institute of Technology.

__________. 1971. "Computer Pattern Recognition of Printed Music," *AFIPS Conference Proceedings* 39 (1971)153-162.

__________. 1975. "DO-RE-MI: A Program that Recognizes Music Notation," *Computers and the Humanities* IX (1975): 25-29.

Pruett, James W. 1966. "The Harpur College Music-Computer Seminar: A Report," *Computers and the Humanities* I, no. 2 (1966): 34-38.

__________. 1968. Review of *Papers of the West Virginia University Conference on Computer Applications in Music* by Gerald Lefkoff (Ed.), *Computer Studies in the Humanities and Verbal Behavior* I, no. 3 (October 1968): 155

Pylkkö, P. 1988. "Tonal Harmony as Formal System," *Essays in the Philosophy of Music. Acta Philosophica Fennica* 43 (1988): 300-322.

Rabson, Carolyn. 1979. "National Tune Index," *Computers and the Humanities* XIII/3 (1979): 261.

Rabson, Gustav, and Carolyn Rabson. 1981. "The National Tune Index: A Systsems Overview," *Computers and the Humanities* XV (1981): 128-137.

Rader, Gary M. 1974. "A Method for Composing Simple Traditional Music by Computer," *Communications of the ACM* November 1974. 631-638. Reprinted in *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press, 1993. 242-260.

__________. 1975. "A Method for Composing Simple Traditional Music by Computer," *Computational Musicology Newsletter* II/1 (1975): 14.

Raffman, Diana. 1993. *Language, Music, and Mind.* Cambridge, MA: The MIT Press.

Rahn, John. 1980. "On Some Computational Models of Music Theory," *Computer Music Journal* IV/2 (1980): 66-72.

__________. 1984. "Teorie su Alcuni Motetti dell' *ars antiqua*, con Relative Considerazioni Metodologiche," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 39-58.

__________. 1989. "Theories for Some Ars Antiqua Motets," *Musikometrika 1*, ed. by Moisej Boroda. Bochum: Brockmeyer. 191-214.

___________. 1989. "Toward a theory for chord progression," *In Theory Only* XI/1-2 (1989): 1-10.

Ramalho, Geber L. 1997. "Pattern Reuse in Tonal Music Improvisation and Accompaniment Systems," *Proceedings of the Ivth Brazilian Symposium on Computer Music*. SBC: Brazilia. 47-58.

Ramalho, Geber L., and Jean-Gabriel Ganascia. 1994a. "Simulating Creativity in Jazz Performance," *Proceedings of the Twelfth National Conference on Artificial Intelligence*. Seattle: The AAAI Press. 108-113.

Ramalho, Geber L., and Jean-Gabriel Ganascia. 1994b. "The Role of Musical Memory in Creativity and Learning: A Study of Jazz Performance," *Music Education: An Artificial Intelligence Approach*, ed. by Matt Smith, Alan Smaill, and Geraint A. Wiggings. London: Springer. 143-156.

Ramalho, Geber L., Pierre-Yves Rolland, and Jean-Gabriel Ganascia. 1999. "An Artificially Intelligent Jazz Performer," *Journal of New Music Research* XXVIII (1999): 105-129.

Randall, J. K. 1964. "A Report from Princeton," *Perspectives of New Music* 3 (Spring 1964): 84-92.

Rapoport, Eliezer. 1996. "Emotional Expression Code in Opera and Lied Singing," *Journal of New Music Research* XXV (1996): 109-149.

__________. 1997. "Singing, Mind and Brain - Unit Pulse, Rhythm, Emotion and Expression," *Music, Gestalt, and Computing. Studies in Cognitive*

Musicology, ed. by Marc Leman. Berlin: Springer. 451-468.

Raskin, Jeffrey F. 1967. A Hardware Independent Computer Drawing System Using List Structured Modeling: The Quick-Draw Graphics Systems. M.S. thesis, Pennsylvania State University.

__________. 1973. "On Keyboard Input of Music to the Computer," *Computational Musicology Newsletter* I/1 (1973): 4.

Rasmussen, Steven C. 1989. "Log of current applications in musical computing," *Computing in Musicology*, ed. by Walter B. Hewlett and Eleanor Selfridge-Field. Menlo Park, CA: Center for Computer Assisted Research in the Humanities. 107-138.

__________. 1996. "Modality vs. tonality in Bach's chorale harmonizations," *Computing in Musicology* 10 (1995-1996): 49-58.

Ratner, L. 1970. "Ars Combinatoria: Chance and Choice in Eighteenth-Century Music," *Studies in Eighteenth Century Music*, ed. by Landon and H. C, Robbins. Allen & Unwin.

Ravnikar, Bruno. 1972. "Nekaj rezultatov proucevanja glasbene folklore z metodami matematicne statistike," *Proceedings of the Rad XVII Kongressa Saveza Udruzenja folklorista Jugoslavije*. 271-286.

Reckziegel, Walter. 1967a. *Theorien zur Formalanalyse mehrstimmiger Musik*. Köln: Westdeutscher Verlag.

__________. 1967b. "Musikanalyse - eine exakte Wissenschaft?" *Elektronische Datenverarbeitung in der Musikwissenschaft*, ed. by Harald Heckmann. Regensburg: Bosse, 203-224.

__________. 1967c. "Musikanalyse und Wissenschaft." *Studia Musicologica Academiae Scientiarum Hungaricae* IX (1967): 163-186.

__________. 1967d. "Die Notenschrift im Computer dargestellt," Studia *Musicologica Academiae Scientiarum Hungaricae* IX (1967): 395-406.

__________. 1968. "Musik im Datenspeicher," *Die Musikforschung* XXI (1968): 427-438.

__________. 1970. "Ein Subjektives Tempomaß," *Bericht über den Internationalen Musikwissenschaftlichen Kongress Leipzig 1966*, ed. by Carl Dahlhause et al. Kassel: Bärenreiter. 457-458.

Rees, Fred J., and Rainer M. Michelis. 1991. "Identifying Musical Performance

Behavior in Instrumentalists Using Computer-Based Sound Spectrum Analysis," *Bulletin of the Council for Research in Music Education* 110 (1991): 53-66.

Regener, Eric. 1967a. "A Multiple-pass Transcription and a System for Music Analysis by Computer," *Elektronische Datenverarbeitung in der Musikwissenschaft*, ed. by Harald Heckmann. Regensburg: Gustav Bosse. 89-102.

__________. 1967b. "Layered Music-Theoretic Systems," *Perspectives of New Music* 5 (1967): 52-62.

Regier, Marvin Paul. 1996. The haute-contre voice: Tessitura and timbre. DMA thesis. University of Oregon.

Reid, John William. 1981. The Treatment of Dissonance in the Works of Guillaume Dufay. A Computer Aided Study. Ph.D. thesis. University of Colorado.

Reinecke, Hans-Peter. 1970. "Anwendung Informationstheoretischer und Korrelationsstatistischer Verfahren für die Analyse Musikalischer Strukturen," *IMS: Report on the Tenth Congress, Lubljana 1967*, ed. by Dragotin Cvetko. Kassel: Bärenreiter, 1970. 430-434.

Reier, Ellen Jane, and Warren Reier. 1976. "The Introit Trope Repertory at Nevers," *Nordiskt Kollokvium III. I Latinsk Liturgiforskning*, ed. by Knud Ottosen. HelsinkiL Helsingfors University. 97-110.

Repp, B. H. 1990. "Patterns of Expressive Timing in Performances of Beethoven Minuett by Nineteen Famous Pianists," *Journal of the Acoustical Society of America* 88 (1990): 622-641.

__________. 1992a. "Diversity and Commonality in Music Performance: An Analysis of Timing Microstructure in Schumann's Träumerei," *Journal of the Acoustical Society of America* 92 (1992): 2546-2568.

__________. 1992b. "Probing the Cognitive Representation of Musical Time: Structural Constraints on the Perception of Timing Perturbations," *Cognition* 44 (1992): 241-281.

__________. 1996. "The art of inaccuracy: Why pianists' errors are difficult to hear," *Music Perception* XIV (1996): 161-183.

Reybrouck, Mark. 1989. "Music and the Higher Function of the Brain," *Interface* XVIII/1-2 (1989): 61-72.

__________. 1997. "Gestalt Concepts and Music: Limitations and Possibilities," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 57-69.

Rhodes, James. 1996. "Musical data as information: A general-systems perspective on musical analysis," *Computing in Musicology* 10 (1995-1996): 165-180.

Rhodes, Willard. 1965. "The Use of Computer in the Classification of Folk Tunes," *Studia Musicologica Academiae Scientiarum Hungaricae* 7 (1965). 339-343.

Rich, Elaine. 1985. "Artificial Intelligence and the Humanities," *Computers and the Humanities* XIX (1985): 117-122.

Richter, Peter H. 1989. "Fraktale-Chaos: Auf der Suche nach Ordnung zwischen Unvorhersagbarkeit und gebrochenen Dimensionen," *Österreichische Musikzeitschrift* 44/6 (1989): 276-279.

Richter, P., H. Petsche, and O. Filz. 1993. "Composing and Perceiving Music Display Different Cortical Activation in EEG Coherence Pattern," *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*, ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä. 344-355.

Riedel, Johannes. 1970. "A Computer-Assisted Study of Ecuadorian Urban Music," *Computers and the Humanities* V, no. 2 (1970): 111.

Riotte, Andre. 1974. "Informatique musicale: jonction nouvelle entre art et science," *Euro-Spectra* XIII/1 (March 1974): 2-15.

__________. 1984. "From Traditional to Formalized Analysis," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Florence: Olschki. 131-153.

__________. 1989. "Les materiaux du clair de lune: Prealables a une etude formalisee du style chez Debussy," *Analyse Musicale* XVII (October 1989): 55-58.

__________. 1992a. "L'utilisation de modeles mathematiques en analyse et en composition musicales," *Quadrivium: Musique et Sciences*. Paris: Villette. 87-103.

__________. 1992b. "Formalisation des echelles de hauteurs en analyse et en composition," *Musique et assistance informatique*. Marseille: Cite de la

Musique. 173-185.

__________. 1995a. "Scrittura intuitiva o ideazione cosciente? Creazione, formalismi, modelli, tecnologie," *Sonus* VII/1-3 (1995): 2-9.

__________. 1995b. "Ecriture intuitive ou conception consciente? Creation, formalismes, modeles, technologies," *Musurgia: Analyse et Pratique Musicales* II/2 (1995): 16-26.

__________. 1996. "Formalismes, modeles: Un nouvel atout pour la composition et l'analyse," *Musurgia: Analyse et Pratique Musicales* III/3 (1996): 90-105.

Riotte, Andre, and Marcel Mesagne. 1988. "Analyse musicale et systèmes Formels: Un Modèle Informatique de la Première pièce pour quatuor à cordes de Stravinsky," *Analyse Musicale* 10 (1988): 51-66.

Riotte, Andre, and Marcel Mesagne. 1989. "Les variations pour piano op. 27 de Webern: Approche cellulaire barraqueenne et analyse assistee par ordinateur," *Analyse Musicale* XIV (1989): 41-67.

Roads, Curtis. 1979. "Grammars as Representations for Music," Computer Music Journal III/1 (March 1979): 48-55.

__________. 1980a. "Artificial Intelligence and Music," *Computer Music Journal* IV/2 (1980): 13-25.

__________. 1980b. "Interview with Marvin Minsky," *Computer Music Journal* IV/3 (1980): 25-39.

__________. 1983a. "Report on the International Conference on Musical Grammars and Computer Analysis," *Computer Music Journal* VII/2 (1983): 36-42.

__________. 1983b. "Musik und Künstliche Intelligenz. Ein Forschungsüberblick," translated and with an afterword by Otto Laske, *Feedback Papers* 30 (1983): 3-36.

__________. 1984. "An Overview of Music Representations," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 7-37.

__________. 1985. "Research in Music and Artificial Intelligence," *ACM Computer Surveys* XVII (1985): 163-190.

__________. 1988a. "Directory of Computer Assisted Research in Musicology," *Computer Music Journal* XII/2 (1988): 63.

__________. 1988b. "Grammars as representations for Music," *Foundations of Computer Music*, ed. by C. Roads, and J. Strawn. Cambridge: MIT Press. 403-442.

Roads, Curtis, Giovanni De Poli, and Stephen Pope. Eds. 1997. *Musical Signal Processing*. Lisse, The Netherlands: Swets & Zeitlinger.

Roads, Curtis, and J. Strawn. Eds. 1988. *Foundations of Computer Music*. Cambridge: MIT Press.

Robison, Brian. 1995. Category Structures and Fuzzy Sets," *Music Theory Online* I/5 (1995).

Robison, Tobias D. n.d. "A Short Description of the MIR Compiler," Princeton: Princeton University Music Department. n.d.

__________. 1967. "IML-MIR: A Data-Processing System for the Analysis of Music," *Elektronische Datenverarbeitung in der Musikwissenschaft*, ed. by Harald Heckmann. Regensburg: Bosse. 103-135.

Rodda, Richard E. 1994. "The CWU Music Scores Application project: Interactive linking of scores, analyses, and recordings," *Computing in Musicology* 9 (1993-1994): 65-69.

Rohrer, Hermann G. 1971. *Musikalische Stilanalyse auf der Grundlage eines Modelles für Lernprozesse*. Berlin: Siemens AG.

Rojterstejn, M. I. 1973. Graf i matrica kakinstrumenty ladovogo analiza," *Muzykalnoje Iskusstvo i Nauka*. Moskva: Muzyka. 175-189.

__________. 1974. "'Muzykalnye' structury v poezii Bloka," *O Muzyke. Problemy analiza*. Moskow: Sovetskij Kompozitor. 323-343.

Rolland, P. Y., and J. G. Ganascia. 1996. "Automated Motive Oriented Analysis of Musical Corpuses: A Jazz Case Study," *Proceedings of the 20th International Computer Music Conference (ICMC '96)*, Hong Kong.

Rolland, P. Y., and J. G. Ganascia. 1999. "Musical Pattern Extraction and Similarity Assessment," *Readings in Music and Artificial Intelligence*. The Netherlands: Harwood Academic Publisher.

Roller, Gilbert H. 1964. The Development of the Methods for Analysis of Musical Composition and for the Formation of a Symmetrical Twelve-tone Row Using the Electronic Digital Computer. Ph.D. thesis, Michigan State

University.

__________. 1965. "Development of a Method for Analysis of Musical Compositions Using an Electronic Digital Computer," *Journal of Research in Music Education* XIII, no. 4 (Winter 1956): 249-252.

Robison, Tobias D. 1967. "IML-MIR: A Data-Processing System for the Analysis of Music," *Elektronische Datenverarbeitung in der Musikwissenschaft*, ed. by Harald Heckmann. Regensburg: Gustav Bosse. 103-135.

Roeder, John. 1993. "Toward a semiotic evaluation of music analyses," *Music Theory Online* 0/5 (1993): 1-22.

Rose, Richard F. 1985. "Computer-Assisted Swing!" *Jazz Educators Journal: Official Magazine of the National Association of Jazz Educators* XVII/3 (1985): 14-15.

Rosenboom, David. 1992. Parsing real-time musical inputs and spontaneously generating musical forms: Hierarchical Form Generator (HFG)," *Proceedings of the International Computer Music Conference, San Jose, 1992*. San Francisco: International Computer Music Association. 186-189.

Rosenthal, D. 1988. "A Model of the Process of Listening to Simple Rhythms," *Proceedings of teh 14th International Computer Music Conference*. Cologne: Feedback Studio. 189-197.

__________. 1992a. Machine Rhythm: Computer Emulation of Human Rhythm Perception. Ph.D. thesis. MIT Media Lab.

__________. 1992b. "Intelligent rhythm tracking," *Proceedings of the International Computer Music Conference, San Jose, 1992*. San Francisco: International Computer Music Association. 227-230.

Rothgeb, John. 1966. "Some Uses of Mathematical Concepts in Theories of Music," *Journal of Music Theory* X (1966): 200-215.

__________. 1967. "Theories of Tonal Bass Harmonization," *Computers and the Humanities* II, no. 2 (1967): 87.

__________. 1968a. "Theories of Tonal Bass Harmonization," *Computers and the Humanities* II, no. 5 (1968): 243.

__________. 1968b. Harmonizing the Unfigured Bass: A Computational Study. Ph.D. thesis. Yale University.

__________. 1969. "Simulating Musical Skills by Digital Computer," IEEE

Transactions on Computers. Reprinted in *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press, 1993. 156-164.

__________. 1971a. "Musical Research by Computer: Some Current Limitations," *Computers in the Humanities* V, no. 3 (1971): 178-182.

__________. 1971b. "Some Early Efforts in Computational Musicology," *Computers in the Humanities* VI, no. 1 (1971): 56-58.

__________. 1971c. Harmonizing the unfigured bass: a computational study. PhD dissertation, Yale University.

__________. 1980. "Simulating Musical Skills by Digital Computer," *Computer Music Journal* 4/2 (1980): 36-40.

__________. 1993. "Simulating musical skills by digital computer," *Machine Models of Music*, ed. by S. Schwannauer and D. Levitt. Cambridge, MA: MIT Press. 157-164.

Rowe, Robert. 1990. "Feature classification and related response in a real-time interactive music system," *Proceedings of the International Computer Music Conference, Glasgow, 1990.* San Francisco, CA: Computer Music Association, 1990. 202-204.

__________. 1991a. Machine Listening and Composing: Making Sense of Music with Cooperating Real-Time Agents. Ph.D. thesis. Massachusetts Institute of Technology.

__________. 1991b. "A self-critical compositional algorithm," *Proceedings: International Computer Music Conference, Montreal, 1991.* Montreal: McGill University Press, 1991. 250-253.

__________. 1993. *Interactive Music Systems: Machine Listening and Composing.* Cambridge, MA: The MIT Press.

__________. 1996. "Incrementally Improving Interactive Music Systems," *Contemporary Music Review* XIII/2 (1996): 47-62.

Roy, Stéphane. 1998. "Functional and Implicative Analysis of *Ombres Blanches*," *Journal of New Music Research* XXVII (1998): 165-184.

Rubenstein, Nancy O. 1969. A Fortran Computer Program for Transcribing Franconian Rhythm. Ph.D. thesis, Washington University.

Ruggiero, Charles and James Colman. 1984/1990. *CASAP User's Guide* (software manual). Okemos, MI: Okemos Music Software.

Russell, Roberta Cram. 1983. A Set of Microcomputer Programs to Aid in the Analysis of Atonal Music. DMA thesis, University of Oregon.

Ruwet, N. 1972. *Language, Musique, Poésie*. Raris.

Saary, Margarete. 1996. "Bibliographie aus Musikanalyse: Ein computergestütztes Projekt des Instituts für Musikanalytik," *Pluralismus analytischer Methoden*, ed. by Gottfried Scholz. Frankfurt am Main, Germany: Peter Lang. 203-205.

Saastamoinen, Ilpo. 1986. "Kolttasaamelainen leu'dd: Sattuman entropiaa vai salattua jarjestysta?" *Etnomusikologian Vuosikirja* (1986): 66-95.

Sabater, J., R. López de Màntaras, and J. L. Arcos. 1998. "Using Rules to Support Case-Based Reasoning for Harmonizing Melodies," *Proceedings of the AAAI98 Spring Symposium on Multimodal Reasoning.*

Sachia, Darzagin, and Milan Rusko. "Dynamic programming approach to time normalized similarity evaluation of melodic structures," *Systematic Musicology* II/2 (1994): 325-332.

Saiwaki, Naoko, Seiji Inokuchi, Tsuyoshi Inouye, Sho Katayama, and Yasuo Hori. 1993. "An Analysis of EEG Responded to Musical Stimuly," *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*, ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä. 356-369.

Saiwaki, Naoko, Kunio Kato, and Seiji Inokuchi. 1997. "An Approach to Analysis of EEGs Recorded During Music Listening," *Journal of New Music Research* XXVI (1997): 227-243.

Saue, Sigurd, and Jan Tro. 1990. "MIDI-based analysis of musical performance," *Studia Musicologica Norvegica* XVI (1990): 125-139.

Sbornik "Problemy taksonomii estonskich runiceskich melodij". Tallin: Academy of Science, 1977.

Sbornik "Tocnye metody i muzykalnoje iskusstvo". Rostov: Rostov University Press, 1972.

Scaletti, Carla, and Kurt J. Hebel. 1991. "An object-based representation for digital audio signals," *Representations of Musical Signals*, ed. by Giovanni De Poli, Aldo Piccialli, and Curtis Roads. Cambridge, MA : MIT Press.

371-389.

Scarborough, Don L., Ben O. Miller, and Jaqueline A. Jones. 1989. "Connectionist Models for Tonal Analysis," *Computer Music Journal* XIII/3 (1989): 49-55. Reprinted in *Music and Connectionism*, ed. by Peter M. Todd and D. Gareth Loy. Cambridge: MIT Press, 1991. 54-63.

Schäfer, Wolf-Dieter. 1982. *Entwurf einer quantitativen Instrumentationsanalyse. Ein Beitrag zur Methodik von Instrumentationsuntersuchungen, dargestellt an Beispielen aus der Wiener Klassik und der Spätromantik.* Frankfurt am Main: Lang.

Schaffer, John Wm. 1992. "A Prolog-Based Program for the Interactive Analysis of Atonal Scores," *Musikometrica 4*, ed. by Moisej G. Boroda. Bochum: Brockmeyer. 145-180.

__________. 1994. "Threader: A Computer Interface for the Graphic Entry, Encoding, and Analysis of Musical Material," *Computer Music Journal* XVIII/1 (1994): 21-29.

__________. 1996. Review of *Set Theory Objects* by Peter Castine, *Music Theory Online* II/6 (1996).

Schaffrath, Helmuth. 1984. "Computer Cataloging. A Database System for Ethnic Music at Essen University, West Germany," *IASA Phonographic Bulletin* 39 (July 1984): 35-39.

__________. 1985a. "Der Umgang mit Information über Musik. Am Beispiel einer Datenbank ethnomusikologischer Schallplatten der Universität Essen," *Musikpädagogische Forschung* 6: 253-263.

__________. 1985b. Review of *Struktur und Ähnlichkeit* by Wolfram Steinbeck, *Jahrbuch für Volksliedforschung* 30 (1985): 163-164.

__________. 1986. "Datenbank zur Erfassung von Musik auf Tonträger 'ETNO'. Universität-Gesamthochschule Essen: Zukunftstechnologie Neue Medien," *Schriften und Berichte* 9 (1986): 59-65.

________. 1987a. "Datenbanksystem zur Dokumentation von Musik auf Tonträgern," *Dokumentationsprobleme heutiger Volksmusikforschung*, ed. by J. Dittmar. Studien zur Volksmusikforschung 2. Bern: Peter Lang. 183-197.

__________. 1987b. "Computer - wozu?" *Musica* 41/2 (1987): 135-139.

__________. Ed. 1991a. *Computer in der Musik. Über den Einsatz in*

Wissenschaft Komposition und Padagogik. Stuttgart: Metzler.

__________. 1991b. "Zum Einsatz von Computern in Musikwissenschaft und - pädagogik," *Computer in der Musik. Über den Einsatz in Wissenschaft Komposition und Padagogik*, ed. by Helmut Schaffrath. Stuttgart: Metzler. 8-26.

__________. 1992a. "The ESAC databases and MAPPET software," *Computing in Musicology* 8 (1992): 66.

__________. 1992b. "Analysis Means Retrieval," *Secondo Convegno Europeo di Analisi Musicale*, ed. by Rossana Dalmonte and Mario Baroni. Trento, Italy: U. degli Studi, Dipartimento di Storia della Civilta. 623-626.

__________. 1992c. "The Retrieval of Monophonic Melodies and their Variants: Concepts and Strategies for Computer-Aided Analysis," *Computer Representations and Models in Music*, ed. by Alan Marsden and Anthony Pople. London: Academic Press. 95-109.

__________. 1993. "Repräsentation einstimmiger Melodien. Computerunterstützte Analyse und Musikdatenbanken," *Neue Musiktechnologie*, ed. by Bernd Enders. Mainz: Schott. 277-300.

__________. 1995. *The Essen Folksong Collection*, ed. by David Huron. Stanford, CA: Center for Computer Assisted Research in the Humanities.

Scharf, Joachim-Hermann. "Einführung in 'Computer und Musikwissenschaft'," *Informatik. Vorträge anläßlich der Jahresversammlung vom 14. bis 17. Oktober 1971 zu Halle (Saale)*, ed. by Jocahim-Hermann Scharf. Nova Acta Leopoldina vol. 37/1, no. 206. Leipzig: Barth, 1972. 563-572.

Scheirer, Eric D. 1997. "Tempo and Beat Analysis of Acoustic Musical Signals," *Journal of the Acoustical Society of America* 103/1 (1997): 288-301.

Scherrer, Deborah K. 1973. "Computer-aided Music Analysis," *Computational Musicology Newsletter* I/1 (1973): 17.

Scherrer, Deborah K., and Philip H. Scherrer. 1971. An Experiment in the Computer Measurement of Melodic Variation in Folksong," *Journal of American Folklore* 84 (1971): 230-241.

Schillinger, Joseph. 1948. *The Mathematical Basis of the Arts*. New York: Philosophical Library.

Schiodt, Nanna. 1965. "Data Processing Applied to Byzantine Chant," *Fontes Artis Musicae* XII/2-3 (1965): 122-123.

__________. 1971. "A computer-aided analysis of thirty-five Byzantine hymns," *Studies in Eastern Chant II*, ed. by Milos Velmirovic. London: Oxford University. 129-154.

Schiodt, Nanna, and Bjarner Svejgaard. 1967. "Application of Computer Technique to the Analysis of Byzantine Sticherarion Melodies," *Elektronische Datenverarbeitung in der Musikwissenschaft*, ed. by Harald Heckmann. Regensburg: Gustav Bosse. 187-201.

Schloss, Walter Andrew. 1985. On the Automatic Transcription of Percussive Music -- From Acoustic Signal to High-Level Analysis. PhD thesis, Stanford University.

Schnell, Christoph. 1985. *Die Eingabe musikalischer Information als Teil eines Arbeitsinstrumentes. Ein Beitrag zur Computeranwendung in der Musikwissenschaft*, Bern, Frankfurt/M., New York: Peter Lang.

__________. 1986. Die Eingabe musikalischer Information in den Computer," *Output* XV/1 (1986): 37-49.

__________. 1986. Eingabe musikalischer Information in den Computer. Ein Neues Verfahren," *Output* XV/5 (1986): 51-60.

__________. 1989. *Ein System zur computergestützten Forschung in den Geisteswissenschaften. Konzeption, Implementierung, Anwendungsbeispiele*. Bern: Peter Lang.

Schot, Joanna Wood. 1962. review of *Experimental Music Composition with an Electronic Computer*, by Lejaren Hiller, Jr., and Leonard M. Isaacson. *Mathematics of Computation* 16, issue 80 (October 1962): 507-508.

Schüler, Nico. 1992. "Methoden und Resultate einer Computergestützten Musikanalyse Mozartscher Werke," *Wolfgang Amadeus Mozart. Referate des wissenschaftlichen Kolloquiums der Greifswalder Mozart-Tage am 3. Dezember 1991*, ed. by Nico Schüler and Lutz Winkler. Greifswald: Institut für Musikwissenschaft. 103-120.

__________. 1995. *Erkenntnistheorie, Musikwissenschaft, Künstliche Intelligenz und der Prozeß. Ein Gespräch mit Otto Laske*, Peenemünde: Dietrich.

__________. 1996a. "Methoden computerunterstützter Musikanalyse - ein historischer Überblick," *Zum Problem und zu Methoden von Musikanalyse*, ed. by Nico Schüler. Hamburg: von Bockel. 51-76.

__________. Ed. 1996b. *Zum Problem und zu Methoden von Musikanalyse.*

Hamburg: von Bockel.

__________. 1996c. *Hanning Schröder. Dokumente. Kritisches Werkverzeichnis.* Hamburg: von Bockel.

__________. 1997. "Otto Laske," *Komponisten der Gegenwart*, ed. by Hanns-Werner Heister and Walter-Wolfgang Sparrer. Munich: edition text+kritik, 11. Nachlieferung. 2 pp.

__________. Ed. 1998a. *Zu Problemen der 'Heroen'- und der 'Genie'-Musikgeschichtsschreibung*. Hamburg: von Bockel.

__________. 1998b. "Von Heroen, Genies, und anderen. Zu Musik und Musikleben im Spiegel einer Brünner-Deutschen Zeitung im Januar 1920," *Zu Problemen der 'Heroen'- und der 'Genie'-Musikgeschichtsschreibung*, ed. by Nico Schüler. Hamburg: von Bockel. 113-146.

__________. 1998c. "Beziehungen von Musik und Literatur im kompositorischen und musikwissenschaftlichen Schaffen von Otto E. Laske. Dimensionen des Literarischen. *Colloquium. Stadt und Region als Schauplätze des Musikgeschehens. Komponist und Literatur im Kulturambiente der Neuzeit, Brno 1994*. Brno: Masarykova Universita, 1998. 249-254.

__________. 1999. "A Composer's Cognitive Musicology," *Otto Laske: Navigating New Musical Horizons*, ed. by Jerry Tabor. Westport, Connecticut: Greenwood. 135-150.

__________. Ed. 2000. *Computer Applications in Music Research: Concepts, Methods, Results*. Hamburg: von Bockel. In Press.

Schüler, Nico, and Dirk Uhrlandt. 1994 / 1996. *MUSANA 1.0 / 1.1 - ein Musikanalyseprogramm. Programmdokumentation*. Peenemünde: Dietrich.

Schwanauer, Stephan M. 1993. "A Learning Machine for Tonal Composition," *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press. 510-532.

Schwanauer, Stephan M., and David A.Levitt. Eds. 1993. *Machine Models of Music*. Cambridge: MIT Press.

Segerman, Ephraim. 1994. "On the measurement of tessitura and movement in music," *FoMRHI Quarterly* 75 (April 1994): 30.

Seifert, Uwe. 1986. Neuere methodische Ansätze in der Musiktheorie seit 1945 unter besonderer Berücksichtigung der Vereinigten Staaten. M.A. thesis.

Universität Hamburg, Germany.

__________. 1993. *Systematische Musiktheorie und Kognitionswissenschaft. Zur Grundlegung der Kognitiven Musikwissenschaft.* Bonn: Verlag für Systematische Musikwissenschaft.

__________. 1992. "Cognitive Science: A New research Program for Musicology," *Interface* 21 (1992): 219-238.

__________. 1993a. *Systematische Musiktheorie und Kognitionswissenschaft. Zur Grundlegung der kognitiven Musikwissenschaft.* Bonn: Verlag für Systematische Musikwissenschaft.

__________. 1993b. "Time Constraints and Cognitive Modelling. Preliminary Remarks on the Methodology of Music Research in Cognitive Musicology," *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*, ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä. 288-299.

Seifert, Uwe, Fabian Olk, and Albrecht Schneider. 1995. "On Rhythm Perception: Theoretical Issues, Empirical Findings," *Journal of New Music Research* XXIV (1995): 164-195.

Selfridge-Field, Eleanor. 1990. "Reflections on Technology and Musicology," *Acta Musicologica* 62 (1990): 302-314.

__________. 1992. Review of *Computers and Musical Style* by David Cope. *Journal of the American Musicological Society* 45 (1992): 535-545.

__________. 1993. "Music Analysis by Computer," *Music Processing*, ed. by Goffredo Haus. Madison, WI: A-R Editions. 3-24.

__________. 1997. "DARMS, Its Dialects, and Its Uses," *Beyond MIDI. The Handbook of Musical Codes*, ed. by Eleanor Selfridge-Field. Cambridge: The MIT Press. 163-174.

__________. 1997a. *Beyond MIDI. The Handbook of Musical Codes*, ed. by Eleanor Selfridge-Field. Cambridge: The MIT Press.

Sellek, John. 1968. "Music Information Retrieval," *Computers and the Humanities* III, no. 2 (1968): 112.

__________. 1970. "Musical Information Retrieval (MIR)," *Computers and the Humanities* V, no. 2 (1970): 110.

Sellek, John, and Roger Bakeman. 1965. "Procedures for the Analysis of Form: Two Computer Applications," *Journal of Music Theory* IX/2 (Winter 1965): 281-293.

Sen, Wang, and Zhou Haihong. 1992. "Scale-Tone Functions and Melodic Structure in Chinese Folk Music," *Computer Representations and Models in Music*, ed. by Alan Marsden and Anthony Pople. London: Academic Press. 111-120.

Sentieri, Alfred Richard. 1978. A Method for the Specification of Style Change in Music: A Computer-Aided Study of Selected Venetian Sacred Compositions from the Time of Gabrieli to the Time of Vivaldi. Ph.D. thesis. Ohio State University.

Shaffer, L. Henry. 1994. "Performing the F-sharp minor prelude op. 28 no. 8," *Chopin studies II*, ed. by John Rink and Jim Samson. Cambridge: Cambridge University Press. 183-198.

Shaouy, William Philip. 1993. MAPLE: A knowledge-based system for computer-aided music composition. MS thesis, Florida Atlantic University.

Shamos, Michael Ian. 1971. "Computer Investigation of Highland Bagpipe Music," *Computers and the Humanities* V, no. 5 (1971): 311-312.

Shannon, Claude E., and W. Weaver. 1949. *The mathematical theory of communication*. Urbana: University of Illinois Press.

Sharp, Michael Durward. 1988. Relationships among model performances and performances by piano majors: Articulation and dynamics in selected Bach fugal excerpts. Ph.D. thesis. Louisiana State University.

Shatzkin, Merton. 1970. "Chords and Chord Progression in J. S. Bach's 371 Chorales," *Computers and the Humanities* IV, no. 5 (1970): 347.

__________. 1973. "Bach Chorales," *Computational Musicology Newsletter* I/1 (1973): 17.

Shea, David Lawrence. 1996. A comparative analysis of interpretive decisions in selected unaccompanied clarinet solos using computer graphics technology. DMA thesis. Indiana University.

Shepard, R. N. 1982. "Structural Representations of Musical Pitch," *The Psychology of Music*, ed. by D. Deutsch. New York: Academic Press.

Shinkai, Ritsuko. 1994. "Koizumi riron ni okeru kakuon no saikento," *Ongakugaku* 40/1 (1994): 16-29.

__________. 1995. "Nagauta shamisen ni okeru hon-choshi, ni-agari, san-sagari, no oto no ugoki no chigai to choshi-gae no koka," *Ongakugaku* 41/3 (1995): 165-177.

Shmulevich, Ilya. 1997. Properties and Applications of Monotone Boolean Functions and Stack Filters. Ph.D. thesis. Purdue University.

Shmulevich, Ilya, and Dirk Povel. 1998. "Complexity Measures of Musical Rhythms," *Proceedings of the 7th Rhythm Perception and Production Workshop*, Nijmegen. 38.

Silverman, Faye-Ellen. 1974. "Report from New York City: Computer Conference, June 1973," *Current Musicology* 17 (1974): 77-80.

Silvia, Dini, Amadeo Gaggiolo, Claudio Martini, and Morando Mauro. 1993. "Man-Machine Interaction in the Study of Melodic Structures," *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*, ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä.169-185.

Simon, Herbert A., and Richard K. Summer. 1968. "Pattern in Music," *Formal Representation of Human Judgement*, ed. by B. Kleinmuntz. New York: Wiley. 219-251. Reprinted in *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press, 1993. 83-110.

Simoni, Mary Hope. 1983. The Computer Analysis of Atonal Music: An Application Program Using Set Theory. Ph.D thesis, Michigan State University.

Simonton, Dean Keith. 1980a. "Thematic Fame and Melodic Originality: A Multivariate Computer-Content Analysis," *Journal of Personality* 48 (1980): 206-219.

__________. 1980b. "Thematic Fame, Melodic Originality, and Musical Zeitgeist: A Biographical and Transhistorical Content Analysis," *Journal of Personality and Social Psychology* 39 (1980): 972-983.

__________. 1983. "Aesthetics, Biography, and History in Musical Creativity," *Documentary Report on the Ann Arbor Symposium on the Application of Psychology to the Teaching and Learning of Music (Session III)*. Reston, Virginia: Music Educators National Conference. 41-48.

__________. 1984. "Melodic Structure and Note Transition Probabilities: A Content Analysis of 15,618 Classical Themes," *Psychology of Music* XII/1

(1984): 3-16.

__________. 1986. "Aesthetic success in classical music: A computer analysis of 1,935 compositions," *Empirical Studies of the Arts* IV/1 (1986): 1-17.

__________. 1994. "Computer content analysis of melodic structure: Classical composers and their compositions," *Psychology of Music* XXII/1 (1994): 31-43.

Simpson, Jasba, and David Huron. 1993. "The Perception of Rhythmic Similarity: A Test of a Modified Version of Johnson-Laird's Theory," *Canadian Acoustics* XXI/3 (1993). 89-90.

Simpson, Jasba, and David Huron. 1994. "Absolute pitch as a learned phenomenon: Evidence consistent with the Hick-Hyman Law," *Music Perception* XII/2 (1994). 267-270.

Sinding-Larsen, Henrik. 1991. "La notation musicale et l'ordinateur: Deux formes d'externalisation du savoir," *Chimeres* 12 (1991): 53-71.

Sitter, Peer. 1995. "Voraussetzungen und Anwendungsmoglichkeiten des Computers in der 'analytischen Werkstatt'," *Systematische Musikwissenschaft /Systematic Musicology* III/1 (1995).

Sloboda, John A. 1983. "The Communication of Musical Metre in Piano Performance," *Quarterly Journal of Experimental Psychology* 35A (1993): 377-396.

__________. 1985. *The Musical Mind: The Cognitive Psychology of Music*. Oxford: Clarendon.

__________. Ed. 1988. *Generative Processes in Music: The Psychology of Performance, Improvisation, and Composition.* Oxford: Claredon Press.

Smaill, Alan. 1994. "Music Representation - Between the Musician and the Computer," *Music Education: An Artificial Intelligence Approach*, ed. by Matt Smith, Alan Smaill, and Geraint A. Wiggins. London: Springer. 108-119.

Smaill, Alan, Geraint Wiggins, and M. Harris. 1993. "Hierarchical Music Representation for Composition and Analysis," *Computers and the Humanities* XXVII (1993): 7-17.

Smalley, Denis. 1987. "Spectro-Morphology and Structuring Processes," *The Language of Electroacoustic Music*, ed. by S. Emmerson. London: Macmillan. 61-96.

__________. 1992. "Can Electro-Acoustic Music be Analyzed?" *Atti des II Convegno Europeo di Analisi Musicale*, ed. by R. Dalmonte and Mario Baroni. Trento: Università di Trento. 423-434.

__________. 1993. "Defining Transformations," Interface 22 (1993): 279-300.

__________. 1995. "La Spectromorphologie: Une Explication des Fornes du Son," *Esthétique des Arts Mediatiques*, ed. by L. Poissant. Vol. 2. Saint-Foy, Québec: Presses de l'Université du Québec. 125-164.

__________. 1996a. "La Spettromorfologia: Una Spiegazione delle Forme del Suono. I Parte," *Musica Pealtà* 50 (1996): 121-137.

__________. 1996b. "La Spettromorfologia: Una Spiegazione delle Forme del Suono. II Parte," *Musica Pealtà* 51 (1996): 87-110.

__________. 1997. "Spectromorphology: Explaining Sound-Shapes," *Organised Sound* 2 (1997): 107-126.

Smith, Beverley G. 1993. "A Computer-Aided Analysis of Early 15th-Century English Music," Ph.D. thesis. University of Sheffield.

Smith, Brian K. 1994. "Uncovering Cognitive Processes in Music Composition: Educational and Computational Approaches," *Music Education: An Artificial Intelligence Approach*, ed. by Matt Smith, Alan Smaill, and Geraint A. Wiggins. London: Springer. 56-73.

Smith, Matt, and Simon Holland. 1992. "An AI tool for the analysis and generation of melodies," *Proceedings of the International Computer Music Conference, San Jose, 1992*. San Francisco: International Computer Music Association. 61-64.

Smith, Matt, and Simon Holland. 1994. "MOTIVE: The Development of an AI Tool for Beginning Melody Composers," *Music Education: An Artificial Intelligence Approach*, ed. by Matt Smith, Alan Smaill, and Geraint A. Wiggins. London: Springer. 41-55.

Smith, Matt, Alan Smaill, and Geraint A. Wiggins. Eds. 1994. *Music Education: An Artificial Intelligence Approach*. London: Springer.

Smoliar, Stephen William. 1972a. A Parallel-Processing Model of Musical Structures. PhD dissertation, Massachussetts Institute of Technology.

__________. 1972b. "Music theory-a programming linguistic approach," *Proceedings of the ACM 25th annual conference*. 100-114.

__________. 1974. Process Structuring and Music Theory," *Journal of Music Theory* XVIII (1974): 308-336. Reprinted in *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press, 1993. 188-212.

__________. 1975a. "Proposal for an Interactive Computer-Music Facility," *Computational Musicology Newsletter* II/1 (1975): 5-6.

__________. 1975b. "Process Structuring and Music Theory," *Computational Musicology Newsletter* II/1 (1975): 17.

__________. 1976. "Music Programs: An Approach to Music Theory Through Computational Linguistics," *Journal of Music Theory* XX/1 (Spring 1976): 105-131.

__________. 1977. "SCHENKER: A Computer Aid for Analyzing Tonal Music," *SIGLASH Newsletter* X/1-2 (1977): 30-61.

__________. 1980. "A Computer Aid for Schenkerian Analysis," *Computer Music Journal* IV/2 (1980): 41-59.

__________. 1981. "Current advances in computer methods. Remarks," *International Musicological Society: Report of the Twelfth Congress, Berkeley 1977*, ed. by Daniel Heartz and Bonnie C. Wade. Kassel: Bärenreiter. 347-352.

__________. 1986. Review of *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari, *Journal of Music Theory* XXX/1 (Spring 1986): 130-141.

__________. 1990. "Lewin's Model of Musical Perception Reflected by Artificial Intelligence," *Computers in Music Research* 2 (1990): 1-37.

__________. 1992a. "Representing Listening Behavior: Problems and Prospects," *Understanding Music with AI: Perspectives on Music Cognition*, ed. by Mira Balaban, Kemal Ebcioglu, and Otto Laske. Cambridge, MA: The MIT Press. 53-63.

__________. 1992b. "Elements of a Neuronal Model of Listening," *In Theory Only* XII/3-4 (1992): 29-46.

__________. 1993. "Process structuring and music theory," *Machine Models of Music*, ed. by S. Schwannauer and D. Levitt. Cambridge, MA: MIT Press. 189-212.

__________. 1995a. "Parsing, Structure, Memory, and Affect," *Journal of New Music Research* XXIV/1 (1995): 21-33.

__________. 1995b. Review of *New Images of Musical Sound* by Robert Cogan, *Music Theory Online* I/3 (1995).

Smoliar, Stephen W., and M. Joseph Willson. 1974a. "Proposal for an Interactive Computer-Music Facility," *Numus-West* V (1974): 39-43.

Snell, James Loftin. 1979. Design for a formal system for deriving tonal music. Master's thesis. State University of New York at Binghamton.

__________. 1985. Review of *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari, *Perspectives of New Music* XXIII/2 (Spring-Summer 1985): 220-234.

Snyder, John L. 1990. "Entropy as a Measure of Musical Style: The Influence of A Priori Assumptions," *Music Theory Spectrum* XII/1 (Spring 1990): 121-160.

Sobrino Sanchez, Ramon, and Maria Encina Cortizo. 1992a. "Rapporti fra intonazione verbale e melodia gregoriana negli introiti del primo modo," *Secondo Convegno Europeo di Analisi Musicale*, ed. by Rossana Dalmonte and Mario Baroni. Trento, Italy: U. degli Studi, Dipartimento di Storia della Civilta. 105-110.

Sobrino Sanchez, Ramon, and Maria Encina Cortizo. 1992b. "Relationships between verbal intonation and Gregorian melody in the first mode Introiti," *Secondo Convegno Europeo di Analisi Musicale*, ed. by Rossana Dalmonte and Mario Baroni. Trento, Italy: U. degli Studi, Dipartimento di Storia della Civilta. 189-202.

Solomon, Larry. *Music Analysis System.* Software 1976, 1982, 1984.

__________. 1982. "The list of chords, their properties and use in analysis," *Interface* XI/2 (1982): 61-107.

Sorensen, Av Olve. 1978. "Metoder og Metodeproblemer ved Harmonisk Analyse med EDB," *Studia Musicologica Norvegica* IV (1978): 201-216.

Sorkin, Robert D. 1990. "Perception on Temporal Patterns Defined by Tonal Sequences," *Journal of the Acoustical Society of America* 87/4 (1990): 1695-1701.

Spagnulo, Antonio. 1991. *La paleografia musicale bizantina e il computer: Analisi del ms. 470 Mt. Athos con programma informatico.* Pavia: Universita degli Studi di Pavia.

Spector, L., and A. Alpern. 1995. "Induction and Recapitulation of Deep Musical Structure," *Proceedings of the Fourth Workshop on Artificial Intelligence and Music, IJCAI-95.* Montreal. 41-48.

Spiesel, Laurie. "Sonic Set Theory: A Tonal Music Theory for Computers. Tools for Algorithmic Composition with an Algorithmim for Chord Selection for Dessert," *1982 Proceedings of the Symposium on Small Computers in the Arts.* Los Angeles: IEEE Computer Society. 15-21.

Springer, G. P. 1956. "Language and Music: Parallels and Divergencies," *For Roman Jakobson*, ed. by M. Halle, H. G. Lunt, H. McLean, and C. H. Van Schooneveld. Den Haag: Mouton. 504-513.

Spyridis, H. C. 1987. "Computer-aided determination of the scale of a musical composition," *Acustica* (Germany) LXIII/2 (1987): 160-161.

__________. 1994. "An application of information theory to the structural study of 'Kalamatianos' Greek folk songs," *Acustica: International Journal of Acoustics* 80/5 (1994): 431-441.

Spyridis, H. C., and D. V. Politis. 1990. "Information theory applied to the structural study of Byzantine ecclesiastical hymns," *Acustica: International Journal of Acoustics* 71/1 (1990): 41-49.

Spyridis, H. C., and J. P. Prinos. 1992. "Computer-aided determination of the genus and the tropos of an extract from the ancient Greek music," *Acustica: International Journal of Acoustics* 77/1 (1992): 1-11.

Srinivasan, R. 1978. "Studies on Indian musical scales. I: Computer analysis of Venkatamakhi's melakarta scheme," *Journal of the Sangeet Natak Academy* (India) 49 (July-September 1978): 33-42.

Srinivasan, R. 1980. "Studies on Indian musical scales. II," *Journal of the Sangeet Natak Academy* (India) 58 (October-December 1980): 27-38.

Stacy, William B. 1969. Style and register as correlated factors in the horn parts of selected symphonies by Joseph Haydn. M.A. thesis. University of North Carolina, Chapel Hill.

Stahl, V. 1964. Informationswissenschaft und Musikanalyse," *Grundlagenstudien aus Kybernetik und Geisteswissenschaft* 5 (1964): 51-58.

Stange-Elbe, Joachim. 2000. "Strukturelle Analyse als Grundlage musikalischer Interpretation," *Computer-Aplications in Music Research: Methods, Concepts, Results*, ed. by Nico Schüler. Hamburg: von Bockel. in press.

Starr, Daniel, and Robert Morris. 1977. "A general theory of combinatoriality and the aggregate (Part 1)," *Perspectives of New Music* XVI/2 (1977): 3-35.

Starr, Daniel, and Robert Morris. 1977. "A general theory of combinatoriality and the aggregate (Part 2)," *Perspectives of New Music* XVI/2 (1977): 50-84.

Stech, David. 1976. A computer-assisted approach to micro-analysis of melodic lines. Ph.D. thesis, Michigan State University.

________. 1981. "A Computer-Assisted Approach to Micro-Analysis of Melodic Lines," *Computers and the Humanities* 15/4 (December 1981): 211-221.

Stedron, Milos. 1971. "Moznosti interavlove a melodicke analyzy," *Opus Musicum* (Czechoslovakia) III/7 (July 1971): 202-08.

__________. 1972. "K Intervalovym Charakteristikam jednotlivych v Janacekovoe Opere Vex Makropulos. Uvahy nad Vysledky Pocitacove Analyzy Vokalni Melodiky," *Lidova pisen a samostatny pocitac I*, ed. by Dusan Holy and Oldrich Sirovátka. Brno: Klub uzivatelu MSP. 263-285.

__________. 1975. "K analyze vokalni melodiky Janackovy opery Vec Makropulos s vyuzitim samocinneho pocitace," *Hudebni Veda* (Czechoslovakia) XII/1 (1975): 46-61.

__________. 1978. "Zjistovani Typicnosti Nekterych Melodickych Struktur ve Vokalni Melodice Janackovy Opery Vec Makropulos Zapomoci SP," *Musicologica slovaca* (Czechoslovakia) VI (1978): 187-198.

Steedman, Mark J. 1977. "The Perception of Musical Rhythm and Metre," *Perception* VI (1977): 555-569.

__________. 1984. "A Generative Grammar for Jazz Chord Sequences," Music *Perception* 2 (1984): 53-77.

Stefani, Gino. 1984. "Musical Competence, Analysis and Grammar," *Musical Grammars and Computer Analysis*, ed. by Mario Baroni and Laura Callegari. Firenze: Leo S. Olschki. 219-227.

Steinbeck, Wolfram. 1976a. "The Use of the Computer in the Analysis of German Folksongs," *Computers and the Humanities* X/5 (1976): 287-296.

__________. 1976b. "Die Liederbank Kiel," *Jahrbuch des Staatlichen Instituts for*

Musikforschung 1976: 94-108.

__________. 1976c. Review of *Faktorenanalytische Typenbestimmung an Volksliedmelodien* by Reiner Kluge, *Jahrbuch für Volksliedforschung* 21. 217-218.

__________. 1976d. Review of *Faktorenanalytische Typenbestimmung an Volksliedmelodien* by Reiner Kluge. *Jahrbuch für Volksliedforschung* 21 (1976): 217-218.

__________. 1978. "Zur Methodik der Analyse deutscher volkstümlicher Lieder mit Hilfe elektronischer Rechenanlagen," *Beiträge zur Musikgeschichte Nordeuropas. Kurt Gudewill zum 65. Geburtstag*, ed. by Uwe Haensel. Wolfenbüttel: Möseler. 323-341.

__________. 1979. "Die Liederbank Kiel," *Computers and the Humanities* XIII/3 (1979): 263.

__________. 1980. "ANTOC. Ein neues Verfahren zur Aufzeichnung von Melodien durch den Computer," *Bericht über den Internationalen musikwissenschaftlichen Kongress Berlin 1974*, ed. by Hellmut Kühn and Peter Nitsche. Kassel: Bärenreiter. 546-553.

__________. 1982. *Struktur und Ähnlichkeit. Methoden automatisierter Melodienanalyse*. Kieler Schriften zur Musikwissenschaft 25. Kassel: Bärenreiter.

__________. 1998. "Zum Verhältnis von Akzent und Dauer im deutschen Volkslied. Eine statistische Untersuchung," *Musikwissenschaft zwischen Kunst, Ästhetik und Experiment. Festschrift Helga de la Motte-Haber zum 60. Geburtstag*. Würzburg: Königshausen & Neumann. 564-571.

Stephan, Claudio. 1971. "Harmonic and Phraseologic Computer Aided Music Analysis," *Computers and the Humanities* VI/2 (1971): 123.

Stinson, John A. 1992. "The SCRIBE database," *Computing in Musicology* 8 (1992): 65.

Stockmann, Doris. 1969a. "Elektronische Datenverarbeitung in der Ethnologie und den ihr nahestehenden Wissenschaften," *Deutsches Jahrbuch für Volkskunde* XV (1969): 134-158.

__________. 1969b. Zur Arbeit der Study Group of Folk Music Systematization des IFMC," *Analyse und Klassifikation von Volksmelodien : Bericht über die 3. Arbeitstagung der Study Group of Folk Music Systematization beim International Folk Music Council vom 24. bis 28. Oktober 1967 in*

Radziejowice, ed. by Doris Stockmann and Jan Steszewski. Krakow : Polskie Wydawnictwo Muzyczne. 9-30.

Stoffer, Thomas H. 1979. *Aspekte einer generativen Syntax zur Beschreibung musikalischer Strukturen für eine kognitive Musikpsychologie*. Berichte des Psychologischen Instituts der Ruhr-Universität Bochum, Arbeitseinheit Kognitionspsychologie, Nr. 11, 1979.

Stoffer, Thomas H., and Moisej G. Boroda. 1980. "Mathematisierungstendenzen in der Musikwissenschaft: Eine Bibliographie zur quantitativ-statistischen und algebraischen Analysie musikalischer Strukturen," *Glottometrika* 3, ed. by Wolfhart Matthäus. Bochum: Studienverlag Dr. N. Brockmeyer. 198-222.

Straus, Joseph N. 1990. *Introduction to Post-Tobal Theory*. Englewood Cliffs: Prentice Hall.

Strawn, John Michael. 1985. Modeling Musical Transitions. Ph.D. thesis. CCRMA / Department of Music, Stanford University.

Stroh, Wolfgang Martin. 1972. "über Schwierigkeiten bei der mathematischen Darstellung musikalischer Sachverhalte," *Neue Zeitschrift für Musik* X (1972): 567-572.

Stroppa, M. 1984. "The Analysis of Electronic Music," *Contemporary Music Review* (1984): 175-180.

Suchoff, Benjamin. 1967a. "Computer Applications to Bartók's Serbo-Croatian Material," *Tempo* 80 (Spring 1967): 15-19.

__________. 1967b. "Computer Applications to Béla Bartók's Serbo-Croatian Material," *Computers and the Humanities* II, no. 2 (1967): 88.

__________. 1968a. "Bartók, Ethnomusicology, and the Computer," *Institute for Computer Research in the Humanities Newsletter* IV/4 (December 1968): 3-6.

__________. 1968b. "Computerized Folk Song Research and the Problem of Variants," *Computers and the Humanities* II/4 (March 1969): 155-158.

__________. 1969. "Some Problems in Computer-Oriented Bartokian Ethnomusicology," *Ethnomusicology* XIII, no. 3 (1969): 489-497.

__________. 1970a. "Computer-Oriented Comparative Musicology," *The Computer and Music*, ed. by Harry B. Lincoln. Ithaca: Cornell University Press. 193-206.

__________. 1970b. "Studies Rekating to Automation of Bartók Archives," *Computers and the Humanities* V, no. 2 (1970): 110.

__________. 1970c. "Aplicarea calculatorelor elektronice la etnomuzicologia Bartokiana," *Musica* XI (November 1970): 10-14.

__________. 1970d. "A Bartoki nepzenekutatas es az elektronikus szamitogepeg," *Muzsika* XIII (July 1970): 6-8; (August 1970): 4-6.

__________. 1971a. "Studies Relating to Automatization of Bartók Archives," *Computers and the Humanities* V, no. 5 (1971): 309-310.

__________. 1971b. "The Computer and Bartók Research in America," *Journal of Research in Music Education* XIX/1 (Spring 1971): 3-16.

__________. 1971c. "The Computer and Bartok Research in America," *Hungarian Musico-Historical Studies* III, ed. by F. Bonis. Budapest, 1971.

__________. 1972. "A national science computer network: a report on the first working seminar," *Computers and the Humanities* VII/2 (November 1972): 96-97.

__________. 1973. "An Application of GRIPHOS to Bartók's Turkish Folk Music Materials," *Computational Musicology Newsletter* I/1 (1973): 18.

__________. 1979. "The COMMPUTE Program," *Computers and the Humanities* XIII/3 (1979): 262.

Sundberg, Johan. 1991. "Music Performance Research: An Overview," *Music, Language, and Brain*, ed. by Sundberg, Nord, and Carlson. London: Macmillan. 173-193.

Sundberg, Johan, Anders Askenfelt, and Lars Frydén. 1983. "Musical Performance: A Synthesis-by-Rule Approach," *Computer Music Journal* 7 (1983): 37-43.

Sundberg, Johan, Anders Friberg, and Lars Frydén. 1991. "Common Secrets of Musicians and Listeners - An Analysis-by-Synthesis Study of Musical Performance," *Representing Musical Structure*, ed. by P. Howell, R. West, and I. Cross. London: Academic Press.

Sundberg, Johan, and Lars Frydén. 1985. "Teaching a Computer to Play Melodies Musically," *Analytica: Studies in the Description and Analysis of Music*, ed. by Anders Lönn and Erik Kjellberg. Uppsala: Uppsala University. 67-76.

Sundberg, Johan, Lars Frydén, and Anders Askenfelt. 1983a. "What tells you the player is musical?" *Studies in Music Performance*. Stockholm: Kungliga Musikaliska Akademien. 61-75.

Sundberg, Johan, Lars Frydén, and Anders Askenfelt. 1983b. "What tells you the player is musical? A study of music performance by means of analysis-by-synthesis," *Speech Transmission Laboratory: Quarterly Progress and Status Report* IV (January 1983): 135-148.

Sundberg, Johan, and Björn Lindblom. 1976. "Generative Theories in Language and Music Descriptions," *Cognition* 4 (1976): 99-122. Reprinted in *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press, 1993. 262-286.

Sundberg, Johan, and Björn Lindblom. 1991. "Generative Theories for Describing Musical Structure," *Representing Musical Structure*, ed. by Peter John Howell, Robert West, and Ian Cross. London: Academic Press. 245-272.

Sundberg, Johan, and Björn Lindblom. 1993. "Generative Theories in Language and Music descriptions," *Machine Models of Music*, ed. by S. Schwanauer and D. Levitt. Cambridge: MIT Press. 263-286.

Sundberg, Johan, and Ronald T. Verillo. 1980. "On the Anatomy of a Ritard: A Study of Timing in Music," *Journal of the Acoustical Society of America* 68/3 (1980): 772-779.

Sundin, Nils-Göran. 1993. "Aesthetical Criteria: Intentional Content in Musical Interpretation in Contemporary Performance," *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*, ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä. 317-321.

Sward, Rosalie La Grow. 1979. "The Computer Assists in Attempting to Solve a Problem of Twentieth Century Music," *Proceedings of the 1978 International Computer Music Conference*, vol. 2, ed. Curtis Roads. Evanston, Ill.: Northwestern University. 853-872.

__________. 1981. An Examination of the Mathematical Systems Used in Selected Compositions of Milton Babbitt and Iannis Xenakis. PhD thesis, Northwestern University.

Sychra, Antonin. "Die Anwendung der Kybernetik und der Informations-Theorie in der Marxistischen Ästhetik," *Beiträge zur Musikwissenschaft* XII/2 (1970): 83-108.

__________. 1964. "Hudba a Kybernetika," *Nové Cestu Hudby* I (1964): 234-267.

__________. 1965. "Möglichkeiten der Anwendung der Kybernetik und der Informationstheorie in der marxistischen Musikwissenschaft," *Beiträge zur Musikwissenschaft* XII (1970): 83-108.

Sykes, Charles E. 1992. A Conceptual Model for Analyzing Rhythmic Structure in African-American Popular Music. DME thesis, Indiana University.

Tabor, Jerry. Ed. 1999a. *Otto Laske: Navigating New Musical Horizons*. Westport, Connecticut: Greenwood.

Tabor, Jerry. 1999b. "A Pioneer in Composition and Research," *Otto Laske: Navigating New Musical Horizons*, ed. by Jerry Tabor. Westport, Connecticut: Greenwood. 1-18.

Tadeusiewicz, Ryszard, and Aleksander Sodo. 1979. "Kompozycje muzyczne z komputera," *Problemy* (Poland) XII (December 1979): 25-30.

Takeuchi, Annie H. 1992. Perception of Tonalness and Rhythmicity in Music. Ph.D. thesis. John Hopkins University, Baltimore, Maryland.

__________. 1994. "Maximum Key-Profile Correlation (MKC) as a Measure of Tonal Structure in Music," *Perception & Psychophysics* 56 (1994): 335-346.

Tanguiane, Andranick S. 1989. "A Principle of Relativity of Perception and its Applications to Pattern Recognition in Analysis of Performed Music," *Proceedings of the First International Conference on Music Perception and Cognition*. Kyoto, Japan. 261-266.

__________. 1990. "A Model of Correlative Perception and its Applications to Certain Problems of Pattern Recognition," *Matematiceskoe Modelirovanie* II/8 (1990): 90-111.

__________. 1991a. "Criterion of Data Complexity in Rhythm Recognition," *Proceedings of the International Computer Music Conference*. Montreal: International Computer Music Association.

__________. 1991b. "Recognition of Chords, Perception Correlativity, and Music Theory," *Musikometrika 3*, ed. by Moisej G. Boroda. Bochum: Brockmeyer. 163-200.

__________. 1992a. "Time Determination by Recognizing Generative Rhythmic Patterns," *Musikometrika 4*, ed. by Moisej G. Boroda. Bochum: Brockmeyer. 83-99.

__________. 1992b. "An Analytical Approach to Musical Performance," *Computer Representations and Models in Music*, ed. by Alan Marsden and Anthony Pople. London: Academic Press. 121-141.

__________. 1993a. *Artificial Perception and Music Recognition*. Berlin: Springer.

__________. 1993b. "Music Recognition Based on Artificial Perception Approach," *Interface* XXII/2 (1993): 133-149.

__________. 1994. "Principle of Correlativity of Perception and its Applications to Music Recognition," *Music Perception* XI/4 (1994): 465-502.

__________. 1995a. "Towards Axiomatization of Music Perception," *Journal of New Music Research* XXIV (1995): 247-281.

__________. 1995b. "Comparative study of recognizability of harmonic and inharmonic tones in chords," *Systematische Musikwissenschaft /Systematic Musicology* III/1 (1995).

__________. 1997. "Technology of Interpretation and Expressive Pulses," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 409-420.

Taube, Heinrich. 1995. "An Object-Oriented Representation for Musical Pattern Definition," *Journal of New Music Research* XXIV (1995): 121-129.

__________. 2000. "Automatic Tonal Analysis: Toward the Implementation of a Music Theory Workbench," *Computer Music Journal* XXIII/4 (2000): 18-33.

Taylor, William Michael. 1996. Humdrum Graphical User Interface. M.A. thesis, Queen's University of Belfast.

Teitelbaum, Richard. 1965. "Intervallic Relations in Atonal Music," *Journal of Music Theory* IX/1 (Spring 1965): 72-127.

Tempelaars, Stan. 1996. *Signal Processing, Speech and Music*. Lisse, The Netherlands: Swets & Zeitlinger.

Temperley, David. 1996. The perception of harmony and tonality: An algorithmic perspective. Ph.D. thesis. Columbia University.

Tenney, James C., and Larry Polansky. 1978. Hierarchical Gestalt perception in music: a 'metric space' model. mimeographed. Toronto: York University Music Department.

Terhardt, Ernst, Gerhard Stoll, and Manfred Seewann. 1982. "Algorithm for Extraction of Pitch and Pitch Salience from Complex Tonal Signals," *Journal of the Acoustical Society of America* 71 (1982): 679-688.

Tervaniemi, Mari. 1999. "Pre-Attentive Processing of Musical Information in the Human Brain," *Journal of New Music Research* XXVIII (1999): 237-245.

Tervaniemi, Mari, and Tita L. van Zuijen. 1999. "Methodologies of Brain Research in Cognitive Musicology," *Journal of New Music Research* XXVIII (1999): 200-208.

Thompson, William F. and Murray Stainton. 1996. "Using Humdrum to Analyze Melodic Structure: An Assessment of Narmou's Implication-Realization Model," *Computing in Musicology* X (1996). 24-33.

Tiits, Kalev. 1992. "Automatic analysis of melody: A computer implementation," *Musique et assistance informatique*. Marseille: Cite de la Musique. 347-353.

__________. 1993a. "Detection of Musical Structure in Time Domain Using Self-Organizing Feature Maps," *Proceedings on the First International Conference on Cognitive Musicology. 26-29 August 1993, University of Jyväskylä (Finnland)*, ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä.159-168.

__________. 1993b. "Laskennallinen musikologia ja kognitiiviset mallit: Historiallinen nakokulma," *Musiikkitiede* V/1 (1993): 123-160.

Timmers, Renee, and R. Ashley. 1999. "Influences of Musical Context and Pianist Stategy on the Timing of a Melody," *Proceedings of the 1999 SMPC*. Evanston. 82.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Tirro, Frank. 1988. "Melody and the Markoff chain model: A Gregorian hymn repertoire," *Explorations in music, the arts, and ideas: Essays in honor of Leonard B. Meyer*, ed. by Eugene Narmour and Ruth A. Solie. Stuyvesant, NY: Pendragon. 229-260.

Tischler, Hans. 1970. "A Complete Edition of the *Magnus Liber Organi*," *Computers and the Humanities* V, no. 2 (1970): 111.

__________. 1973. "Parisian Two-Part Organa," *Computational Musicology Newsletter* I/1 (1973): 18.

Todd, Neil Philip McAgnus. 1985. "A Model of Expressive Timing in Tonal Music," Music *Perception* 3 (1985): 33-58.

__________. 1989a. Computational Theory and Implementations of an Abstract Expression System: A Contribution to Computational Psychomusicology. Ph.D. dissertation, University of Exeter (United Kingdom).

__________. 1989b. "Towards a Cognitive Theory of Expression: The Performance and Perception of Rubato," Contemporary Music Review 4 (1989): 405-416.

__________. 1991. "Communication of Self-Motion in Musical Expression," *Proceedings of the International Workshop on Man-Machine Interaction in Live Performance*. Pisa: CNUCE/CNR. 151-162.

__________. 1992a. "The Dynamics of Dynamics: A Model of Musical Expression," *Journal of Acoustical Society of America* 91 (1992): 3540-3550.

__________. 1992b. "Hierarchical Event Detection," *Journal of the Acoustical Society of America* 91/6 (1992): 3540-3550.

__________. 1993a. "Segmentation and Stress in the Rhythmic Structure of Music and Speech," *Journal of the Acoustical Society of America* 93/4 (1993): 2363.

__________. 1993b. "Wavelet Analysis of Rhythm," *Journal of the Acoustical Society of America* 93/4 (1993): 2290.

__________. 1993c. "Wavelet Analysis of Rhythm in Expressive Musical Performance," *Proceedings of the International Computer Music Conference*. San Francisco: International Computer Music Association. 264-267.

__________. 1993d. "Multi-Scale Analysis of Expressive Signals: Recovery of Structure and Motion," *Proceedings of the Stockholm Music Acoustic Conference*. Stockholm.

__________. 1993. "Analysis and Synthesis of Rhythm," *Journal of the World Intellectual Property Organization*.

__________. 1994a. "The Auditory "Primal Sketch": A Multiscale Model of Rhythmic Grouping," *Journal of New Music Research* XXIII (1994): 35-70.

__________. 1994b. "Metre, Grouping and the Uncertainty Principle: A Unified Theory of Rhythm Perception," *Proceedings of the 3rd International Conference on Music Perception and Cognition*. Liege, Belgium.

__________. 1995. "The Kinematics of Musical Expression," *Journal of the Acoustical Society of America* 97/3 (1995): 1940-1949.

Todd, Peter M., and D. Gareth Loy. 1991. Eds. *Music and Connectionism*. Cambridge, MA: The MIT Press.

Toiviainen, Petri. 1999. "An Interactive MIDI Accompanist," *Computer Music Journal* XXII/4 (1999): 63-75.

Tokumaru, Yoshihiko. 1970. "Joho-riron to ongaku-kodo," *Daigoro Festschrift*. Tokyo: Kunitachi Music College. 195-212.

Topp, Morten. 1987. "Obostemmerne i Handels Messias," *Musik & Forskning* XII (1986-87): 5-139.

Tortiglione, Paolo. 1992. "FLUXUS," *Computing in Musicology* 8 (1992): 102.

Trantham, Gene Starr. 1991. Toward a Theory of the Music Girolamo Frescobaldi Developed Through Computer-Assisted Analysis of Selected Works. Ph.D. thesis, The University of Wisconsin.

__________. 1994. "An analytical approach to sevententh-century music: Exploring Inganni in Fantasia Seconda (1608) by Girolamo Frescobaldi," *College Music Symposium* 33-34 (1993-1994): 70-92.

Trilsbeek, Paul, and Huub van Thienen. 1999. *Quantization for Notation: Methods Used in Commercial Musical Software*. Mimeographed. Nijmegen, The Netherlands: Nijmegen Institute for Cognition and Information.
(See also http://www.nici.kun.nl/mmm/publications/; February 4, 2000.)

Trowbridge, Lynn Mason. 1970. "The Burgundian Chanson: An Index and Analysis of Incipits," *Computers and the Humanities* IV, no. 5 (1970): 343-344.

__________. 1971. "An Analytical and Indexing System for Incipits of Renaissance Polyphonic Compositions," *Computers and the Humanities* V, no. 5 (1971): 310.

__________. 1982. The Fifteenth-Century French Chanson: A Computer-Aided Study of Styles and Style Change. PhD thesis, University of Illinois at

Urbana-Champaign.

__________. 1986. "Style change in the fifteenth-century chanson," *Journal of Musicology* IV/2 (Spring 1985-86): 146-70.

Tsang, C. P., and M. Aitken. 1991. "Harmonizing Music as a Discipline of Constraint Logic Programming," *Proceedings of the International Computer Music Conference 1991*. Montreal: ICMA. 61-64.

Uhrlandt, Dirk, and Nico Schüler. 1992. "Informationsmaße in der computergestützten Musikanalyse." *Kammermusik Heute* 2 (1992): 102-112.

Ulrich, John Wade. 1977. "The Analysis and Synthesis of Jazz by Computer," *Proceedings of the 5th International Joint Conference on Artificial Intelligence 1977 (IJCAI-77)*, vol. 2. Pittsburgh, PA: Carnegie-Mellon University. 865-872.

Ungeheuer, Elena. 1997. "Statistical Gestalts - Perceptible Features in Serial Music," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 103-113.

Ungvary, Tamas, and Simon Waters. 1990. "The Sonogram: A Tool for Visual Documentation of Musical Structure," *Proceedings of the International Computer Music Conference 1990.* San Francisco: Computer Music Association. 159-162.

Ungvary, Tamas, Simon Waters, and Peter Rajka. "NUNTIUS: A computer system for the interactive composition and analysis of music and dance," *Leonardo: Journal of the International Society for the Arts, Sciences and Technology* XXV/1 (1992): 59-68.

Uno, Yayoi, and Roland Hubscher. 1995. "Temporal-gestalt segmentation: Polyphonic extensions and applications to works by Boulez, Cage, Xenakis, Ligeti, and Babbitt," *Computers in Music Research* 5 (1995): 1-37.

Unyk, Anna M. 1990. "An Information Processing Analysis of Expectancy in Music," *Psychomusica* IX/2 (1990): 229-240.

Urup, Henning. 1972. Danske Folkedanse. En beskrivelse og undersogelse af det danske folkelige melodistof med hertil horende dansebeskrivelser. M.A. thesis. University of Kobenhavn, 1972.

Valk-Falk, Maris. 1993. "The Quantitative Structure as a Context," *Proceedings on the First International Conference on Cognitive Musicology. 26-29*

August 1993, University of Jyväskylä (Finnland), ed. by Jonko Laaksamo and Jukka Louhivuos. Jyväskylä: The University of Jyväskylä. 104-108.

Vanpuyvelde, Steven. 1989. Muziekanalyse en de Computer: Overzicht van Inputtalen om Muziek te Representeren. M.A. thesis. Rijksuniversiteit Gent, Belgium.

Vecchione, Bernard, and Bernard Bel. 1992. "Music Sciences and Technologies: New inquiries, New Connections," *Interface* XXI (1992): 185-189.

Vercoe, Barry L. 1971. Reviews of *The computer and music*, ed. Hary B. Lincoln; *Musicology and the computer*, ed. Barry S. Brook. *Perspectives of New Music* IX/1 (1971): 323-330.

__________. 1974. "Music computation conference: a report and summary," *Perspectives of New Music* XIII/1 (Fall 1974): 234-238.

__________. 1997. "Computational Auditory Pathways to Music Understanding," *Perception and Cognition of Music*, ed. by Irène Deliège and John Sloboda. East Sussex, UK: Psychology Press. 307-326.

Vetere, Guido. 1990. "Verso un modello automatizzato per l'analisi musicale tassonomica," *Rivista italiana di Musicologia* XXV/2 (1990): 183-208.

Victor, Michele. 1975. "L'Informatique musicale," *Musique En jeu* (France) XVIII (April 1975): 45-62.

Vikis-Freibergs, Vaira, and Imants Freibergs. 1978. "Formulaic analysis of the computer-accessible corpus of Latvian sun-songs," *Computers and the Humanities* XII/4 (1978): 329-339.

Vollsnes, Arvid, and Tor Sverre Lande. 1988. Music Encoding and Analysis in the MUSIKUS System. Departments of Informatics and Music. University of Oslo. Mimeographed.

von Hippel, Paul Thomas. 1998. Post-Scip Reversals Reconsidered. Ph.D. thesis. Stanford University.

Vos, Piet G. 1976. Identification of metre in Music. Bericht Nr. 76 ON 06. University of Nijmegen.

Wagner, Christoph, Ernst Piontek, and Ludwig Teckhaus. 1973. "Piano learning and programmed instruction," *Journal of Research in Music Education* XXI/2 (Summer 1973): 106-22.

Wagner, Günther. 1976. "Exaktwissenschaftliche Musikanalyse und Informationsästhetik." *International Review of Aesthetics and Sociology of Music* VII, no. 1 (1976): 63-76.

Wagner, Stefan L. 1992. A Textual Analysis of Selected Slovak Folk Songs And Educational Implications. EDD thesis, University of San Francisco.

Walters, Simon, and Tamas Ungvary. 1990. "The sonogram: A tool for visual documentation of musical structure," *Proceedings of the International Computer Music Conference, Glasgow, 1990.* San Francisco, CA: International Computer Music Association, 1990. 159-162.

Warburton, Thomas. 1971. Review of *The Opening Sonata-Allegro Movements in a Randomly Selected Sample of Solo Keyboard Sonatas Published in the Years 1742-1774* by Roger Jaques Kamien, *Current Musicology* XI (1971): 118-121.

Ward, John Anthony. 1992. Theories of Similarity Among Ordered Pitch Class Sets. Ph.D. thesis, The Catholic University of America.

Warren, Richard M., and James A. Bashford. 1993. "When Acoustic Sequences are not Perceptual Sequences: The Global Perception of Auditory Patterns," *Perception and Psychophysics* 54/1 (1993): 121-126.

Warren, R. M., D. A. Gardner, B. S. Brubaker, and J. A. Bashford. 1991. " Melodic and Non-Melodic Sequences of Tones: Effects of Duration on Perception," *Music Perception* VIII/3 (1991): 277-290.

Waters, William Jerome. 1996. The rite of spring by Igor Stravinsky: A comparative performance critique based on sound recordings from 1929-1993. Ph.D. thesis, Florida State University.

Wenk, Arthur B. 1988. "Parsing Debussy: proposal for a Grammar of His Melodic Practice," *Musikometrika 1*, ed. by Moisej Boroda. Bochum: Brockmeyer. 237-256.

Wenker, Jerome R. 1964. A computational Method for the analysis of Anglo-American Folksongs. M.A. thesis, Indiana University.

__________. 1968. "A Music Compiler for Musicologists and Ethnomusicology," *Computers and the Humanities* II, no. 5 (1968): 244.

__________. 1969. "An Analytic Approach to Folk Music," *Computers and the Humanities* IV, no. 2 (1969): 138.

__________. 1970. "A Computer Oriented Music Notation Including Ethnomusicological Symbols," *Musicology and the Computer: Three Symposia*, ed. by Barry S. Brook. New York: The City University of New York Press. 91-129.

__________. 1972a. "A Music Compiler for Musicologists and Ethnomusicologists," *Computers and the Humanities* VII/2 (1972): 124.

__________. 1972b. "An Analytic Approach to Folk Music," *Computers and the Humanities* VII/2 (1972): 124-125.

__________. 1972c. "MUSTRAN II - An Extended *MUS*ic *TRAN*slator," *Computers and the Humanities* VII/2 (1972): 125.

__________. 1973a. "Music Encoding - Keypunch," *Computational Musicology Newsletter* I/1 (1973): 6-7.

__________. 1973b. "Editorial Forword," *Computational Musicology Newsletter* I/1 (1973): 1-2.

__________. 1974. "MUSTRAN II: A Foundation for Computational Musicology," *Computers in the Humanities*, ed. by J. L. Mitchell. Edinburgh: Edinburgh University Press. 267-280.

__________. 1978. A Computer-Aided Analysis of Anglo-Canadian Folktunes. Ph.D. thesis. Indiana University.

Werts, Daniel. 1997. "'Good', 'Fair', and 'Bad' Chord Progressions: A Regression-Analysis of Some Psychological Chord Progression Data Obtaines in an Experiment by J. Bharucha and C. Krumhansl," *Music, Gestalt, and Computing. Studies in Cognitive Musicology*, ed. by Marc Leman. Berlin: Springer. 200-213.

Wessel, David L.1991. Improvisation with highly interactive real-time performance systems," *Proceedings: International Computer Music Conference, Montreal, 1991*. Montreal: McGill University Press, 1991. 344-347.

Westhead, Martin D., and Alan Smaill. 1994. "Automatic characterisation of musical style," *Music Education: An Artificial Intelligence Approach*, ed. by Matt Smith, Alan Smaill, and Geraint A. Wiggins. New York: Springer. 157-170.

Whitney, Thomas G. 1977. "Music analysis: SLAM simplified or how the computer compares 16th century Bourgeois with eighteenth century Bach," *Creative Computing* III/2: 88-89.

Widmer, Gerhard. 1992. "Qualitative Perception Modeling and Intelligent Music Learning," *Computer Music Journal* XVI/2 (1992): 51-68.

__________. 1993. "Understanding Learning Musical Expression," Proceedings of the 1993 International Computer Music Conference. San Francisco: International Computer Music Association. 268-275.

__________. 1994. "The Sunergy of Music Theory and AI: Learning Multi-Level Expressive Interpretation," *Proceedings of the Twelfth National Conference on Artificial Intelligence (AAAI-94)*. Cambridge, MA: MIT Press. 114-119.

__________. 1995a. "Modeling the Rational Basis of Musical Expression," *Computer Music Journal* XIX/1 (1995): 76-96.

__________. 1995b. "A Machine Learning Analysis of Expressive Timing in Pianists' Performances of Schumann's 'Träumerei'," *Proceedings of the Stockholm Symposium on Generative Grammars for Music Performance*, ed. by Johan Sundberg. Stockholm, Sweden: Royal Institute of Technology.

__________. 1996. "Learning Expressive Performance: The Structure-Level Approach," *Journal of New Music Research* XXV (1996): 179-205.

Wiggins, G., E. Miranda, A. Smaill, and M. Harris. 1993. "A Framework for the Evaluation of Music Representation Systems," *Computer Music Journal* XVII/3 (1993): 31-42.

Wild, Jonathan. 1996. A Review of the Humdrum Toolkit: Unix Tools for Musical Research by David Huron, *Music Theory Online* II/7 (November 1996).

Will, Udo. 1991. "Sampling und Musik-Analyse," *Computer in der Musik. Über den Einsatz in Wissenschaft Komposition und Padagogik*, ed. by Helmut Schaffrath. Stuttgart: Metzler. 51-65.

Wille, Rudolf. 1985. "Musiktheorie und Mathematik," *Musik und Mathematik. Salzburger Musikgespräch 1984 unter Vorsitz von Herbert von Karajan*, ed. by Heinz Götze and Rudolf Wille. Berlin: Springer. 4-31.

Williams, James Kent. 1982. Themes Composed by Jazz Musicians of the Bebop Era: A Study of Harmony, Rhythm, and Melody. PhD thesis, Indiana University.

__________. 1985. "A method for the computer-aided analysis of jazz melody in the small dimensions," *Annual Review of Jazz Studies* III (1985): 41-70.

Wilson, Dana. 1986. "Symmetry and its 'Love-Hate' Role in Music," *Symmetry: Unifying Human Understanding*, ed. by Istvàn Hargittai. New York: Pergamon Press. 101-112.

Wilson, Dean C. 1967. An Analytical and Statistical Study of the Harmony in Carl Nielsen's Six Symphonies. Ph.D. thesis, Michigan State University.

Wilson, Frank R. 1992. "Digitizing digital dexterity: A novel application for MIDI recordings of keyboard performance," *Psychomusicology: A Journal of Research in Music Cognition* XI/2 (1992): 79-95.

Wilson, Sarah J., and Roger J. Wales. 1995. "An exploration of children's musical compositions," *Journal of Research in Music Education* 43/2 (1995): 94-111.

Winckel, Fritz. 1964. "Die informationstheoretische Analyse musikalischer Strukturen," *Die Musikforschung* XVII/1 (1964): 1-14.

__________. 1967. "Neue Wege der mathematischen Analyse von Musikstrukturen," *Wiener Akademie Festschrift*. Wien: Lafite. 78-88.

__________. 1975. "Das Wirkgefuge von Musikstrukturen in der Analyse durch Computer und Kybernetik," *Festschrift Kurt Blaukopf*, ed. by Irmgard Bontinck and Otto Brusatti. Wien: Universal Edition. 156-163.

Windsor, Luke, Peter Desain, Henkjan Honing, Rinus Aarts, Hank Heijink, and Renee Timmers. 1998. "Graceful Timing: Ornaments, Tempo and Musical Structure," *Proceedings of the 7th Rhythm Perception and Production Workshop*, Nijmegen. 35.

Winograd, Terry. 1968. "Linguistics and the Computer Analysis of Tonal Harmony," *Journal of Music Theory* XII/1 (1968): 2-49. Reprinted in *Machine Models of Music*, ed. by Stephen M. Schwanauer and David A. Levitt. Cambridge, MA: The MIT Press, 1993. 113-153.

Winograd, Terry, and Fernando Flores. 1986. *Understanding Computers and Cognition. A New Foundation for Design*. Rading: Addison-Wesley.

Winold, A., and J. Bein. 1983. BANALYZE: An Artificial Intelligence System for Harmonic Analysis of Bach Chorales. Unpublished manuscript. School of Music. Indiana University.

Witten, Ian H., Radford M. Neal, and John G. Cleary. 1987. "Arithmetic Coding for Data Compression," *Communications of the ACM* XXX/6 (1987): 520-540.

Witten, Ian H., Leonard C. Manzara, and Darrel Conklin. 1994. "Comparing Human and Computational Models of Music Prediction," *Computer Music Journal* XVIII/1 (1994): 70-80.

Wittlich, Gary E.. 1969. "Programming a Computer for Musical Analysis," *Your Musical Cue* V/6 (1969): 3-13.

__________. 1971. "Music as Information," *Your Music Cue* VII/3 (December 1970-January 1971) 3-9.

__________. 1973a. "Project Score," *Computational Musicology Newsletter* I/1 (1973): 6.

__________. 1973b. "Pattern Structure Studies," *Computational Musicology Newsletter* I/1 (1973): 19.

__________. 1973c. "Scale Index," *Computational Musicology Newsletter* I/1 (1973): 19.

__________. 1980. "Developments in computer based music instruction and research at Indiana University," *Journal of Computer-Based Instruction* VI/3 (February 1980): 62-71.

Wittlich, Gary, Donald Byrd, and Rosalee Nerheim. 1978. "A System for Interactive Encoding of Music Scores Under Computer Control," *Computers in the Humanities* XII (1978): 309-319.

Wittlich, Gary E., John W. Schaffer, and Larry R. Babb. 1986. *Microcomputers and Music*. Englewood Cliffs, NJ: Prentice-Hall.

Wolff, Anthony B. 1972. "Development of a DARMS-to-Canonical DARMS Translator," *Computers and the Humanities* VI/5 (1972): 316.

__________. 1977. "Problems of Representation in Musical Computing," *Computers and the Humanities* XI (1977): 3-12.

Wong, S. F., and K. R. P. H. Leung. 1992. "Melody analysis on centre patterns," *Proceedings of the International Computer Music Conference, San Jose, 1992*. San Francisco: International Computer Music Association. 435-436.

Worz, Otto. 1990. "Ist das Besondere der Klassik beweisbar?" *Musica* (Germany) 44/4 (July-Aug 1990): 220-224.

Wulstan, David. 1992. "Birdus tantum natus decorare magistrum," *Byrd Studies*. Cambridge: Cambridge University Press, 1992. 63-82.

__________. 1995. "Byrd, Tallis, and Ferrabosco," *English Choral Practice c.1400-c.1650: A memorial volume to Peter Le Huray*, ed. by John Morehen. Cambridge: Cambridge University Press. 109-142.

Xenakis, Iannis. 1971. *Formalized Music. Thought and Mathematics in Composition*. Bloomington: Indiana University Press.

Ye, Gan-lin. 1995. "A preliminary study of the numerical characteristics of Chinese folk songs," *Chinese Music* XVIII/2 (1995): 34-38.

Ye, Gan-lin. 1995. "A preliminary study of the numerical characteristics of Chinese folk songs," *Chinese Music* XVIII/3 (1995): 44-49.

Youngblood, Joseph E. 1958. "Style as Information." *Journal of Music Theory* II (1958): 24-35.

__________. 1960. Music and language: some related analytical techniques. Ph.D. thesis, Indiana University.

__________. 1967. "Root Progression and Composer Identification," *Computers and the Humanities* II, no. 2 (1967): 87.

__________. 1970. "Root Progressions and Composer Identification," *The Computer and Music*, ed. by Harry B. Lincoln. Ithaca: Cornell University Press. 172-178.

Zahler, Noel, and Jon Kozzi. 1992. "Music MatrixTM-: A tool for composers / analysts," *Proceedings of the International Computer Music Conference, San Jose, 1992*. San Francisco: International Computer Music Association. 437-439.

Zannos, Ioannis. 1991. "Der Rechner in der Notationsforschung und musikalischen Analyse: Ein Beispiel," *Computer in der Musik: Über den Einsatz in Wissenschaft Komposition und Padagogik*, ed. by Helmut Schaffrath. Stuttgart, Germany: Metzler. 45-50.

Zaripov, Rudolf K. 1969. "Cybernetics and music," translated from the Russion by J. G. K. Russel, wlth commentary by Michael KASSLER, *Perspectives of New Music*, VII/2 (Spring-Summer 1969): 115-54.

__________. 1971. *Kibernetica i Muzyka*. Moscow: Nauka.

__________. 1984. "Construction of Frequency Lexicons of Musical Segments for Analysis and Modelling of Melodies," [in Russian] *Nauka* 41 (1984): 207-252.

Zatorre, Robert J. 1999. "Brain Imaging Studies of Musical Perception and Musical Imagery," *Journal of New Music Research* XXVIII (1999): 229-236.

Zbikowski, Lawrence Michael. 1991. Large-Scale Rhythm and Systems of Grouping. Ph.D. thesis. Yale University.

__________. 1995. "Theories of Categorization and Theories of Music," *Music Theory Online* I/4 (1995).

Zhou, Jinmin. 1992. Timbre, playing technique and structure: A microscopic analysis of samples from two works for the 'qin'," *Musique et assistance informatique*. Marseille: Cite de la Musique. 109-128.

Zhuo, Guo-dong, and Gan-lin Ye. 1993a. "Studying Chinese folk songs by use of a computer," *Chinese Music* XVI/3 (Sept. 1993): 52-59.

Zhuo, Guo-dong, and Gan-lin Ye. 1993b. "Studying Chinese Folk Songs by Use of a Computer II," *Chinese Music* XVI/4 (1993): 66-75.

Zoch, Josef. 1972. "Vztah mezi vokaly a melodii v lidove pisni," *Lidova pisen a samostatny pocitac I*, ed. by Dusan Holy and Oldrich Sirovátka. Brno: Klub uzivatelu MSP. 215-219.

Zwink, Eberhard. 1974. *Paul Hindemiths "Unterweisung im Tonsatz" als Konsequenz der Entwicklung seiner Kompositionstechnik. Graphische und Statistische Musikanalyse*. Göppingen: Alfred Kümmerle.