AUTOMATED STRUCTURAL REPRESENTATION AND ALGORITHMIC AUTHENTICATION OF MUSICAL STYLE AND AUTHORSHIP

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Abstract

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This dissertation describes the design of an expert system called ISAS (Integrated Style Authentication System). It uses a language called IMCL (Inverted Music Composition Language), which is based on weak second-order predicate calculus. This enables a structural representation of music which captures those stylistic attributes that are useful for identifying and authenticating musical authorship. IMCL was adapted from a language originally intended for composition of music. ISAS enables the formation of this representation by parsing the music in accordance with a collection of user-supplied characteristics and relations at various hierarchical levels. These properties, stored in predicate libraries, embody the "rules" of the system. Although ISAS can be used to authenticate any composer's works, this dissertation specifically demonstrates ISAS's ability to capture the style of the expositions of Mozart's piano sonatas and distinguish them from those written by his contemporaries. Its use in assigning likely authorship to certain compositions whose authors are in doubt is also demonstrated.

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Chapter 1 - Introduction

1.1 Introduction

This dissertation describes the design for an expert system called ISAS (Integrated Style Authentication System), whose purpose is automated style authentication. It automates the analysis and representation of the syntactic structure of a musical work from various perspectives (such as its melodic, rhythmic, and cadential structure, and its internal form), so that a hierarchical representation results. This is done in order to detect the presence of those of the composer's structural preferences, stylistic signatures, and "gestures" that are useful in authenticating authorship. In particular, we here show that the system, as designed, can recognize and authenticate the style of Mozart's piano sonatas. This design can be adapted for the authentication of other composers as well. Style is conceived here in terms of properties typically found in various segments of a composer's work. Sets of properties have been discovered that can distinguish Mozart from his contemporaries and imitators. ISAS is based upon a language called IMCL (Inverted Music Composition Language), which is an adaptation of a language originally intended for use in computer-assisted musical composition.[1] This language enables the properties to be expressed conveniently, and automates their application to musical scores.

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[1] (Rothenberg, 1975, 1)

ISAS first parses the work to determine its stylistic structure, and represents the structure as a parsing diagram that depicts the syntactic elements found and their salient characteristics and relationships with one another. This graph is then analyzed for the presence, as well as the frequency of use, of a variety of Mozartean signatures and gestures on multiple levels. Works of dubious origin can be similarly represented and examined for authenticity.

1.2 IMCL Language

The system uses a nonprocedural language based on "weak" (in the sense that quantification over finite sets is permitted), second-order predicate calculus, called IMCL (Inverted Music Composition Language). This music description language is adapted from a language originally intended for music composition,[2] and is here used in a system that instead focuses on musical analysis. This language was used because of its ability to represent concisely, easily, and intuitively the syntactic structure of music (in terms of both its style-specific and general musical elements). The basic structural unit manipulated by the language is a segment, which, for example, could be a note ("level-0 segment"), a motif ("level-1 segment", which is a collection of level-0 segments), a phrase ("level-2 segment", which is a collection of level-1 segments), and so forth. The language then allows musical structure to be

[2] (Rothenberg, 1975, 1)

described in terms of segments, their individual characteristics, and their relations with other segments. The hierarchical nature of this segment-oriented language enables it to more readily represent and manipulate the hierarchical musical structure of a work. These representations of various musical compositions can then be analyzed and compared with one another to determine the presence of those properties of their representations that are specific to different composers' works.

The music description language used by the system represents only the syntactic structure of a work. No attempt was made to represent the semantic elements of a work, which may be culturally specific and not amenable to straightforward encoding.

1.3 ISAS System

The user first supplies a collection of logical formulae that define the various segment characteristics and relations he expects are musically and stylistically important. These characteristics and relations (called "properties") define a variety of musical attributes (for example, melodic, rhythmic, harmonic, textural, cadential structure, etc.) that may or may not apply to portions of the music. These can be used to extract from the music those segments (usually of maximal length) to which they apply (i.e., that satisfy the properties). (Such a property may apply to (i.e., satisfy) a segment defined by another property.) A library of predicates is formed. This library includes many properties that, depending upon the setting of a parameter, can characterize the music of different 18th-century composers. (For example, the parameter might specify the maximum number of different note durations in a measure contained in an initial phrase.) These are called 'style-independent' predicates. This name is also applied to characteristics and relations that are component parts of other properties that characterize specific composers (for example, the characteristic that two phrases are adjacent).

Other predicates (called 'style-dependent' predicates) are defined so as to characterize the differences between Mozart's keyboard style and those of his contemporaries. (For example, in Section 3.6.2, the characteristic rep_dur(X), property 6 describes the existence of substantial repetition of a single duration.) The nature and design of the properties were based on direct intensive listening to and performance of all 20 piano sonatas of Mozart and all 62 piano sonatas (Volumes I, II, III) of Haydn, as well as other related works of Mozart and other composers of the classical period. Although the system in this project recognizes and authenticates Mozart, when using a different library of properties, it can be applied to other composers as well.

The system then parses the work so as to represent its stylistic structure in terms of the various segment characteristics and relations. A parsing diagram (hierarchical graph) results that shows which segments contain others, and the properties used in each case. The presence or absence of specific combinations of properties and their frequency determines if the purported authorship of a work is judged to be authentic.

This authentication system is designed to distinguish a composer's work in the following four situations:

a) Distinguish a composer's work from works of his contemporaries. Thus, it should be able to distinguish a Mozart sonata from works of his contemporaries (for example, Haydn, Clementi, Dussek, Hummel, Clementi, and C.P.E. Bach);

b) Distinguish a composer's work from imitations of that composer's style. For example, Mozart's Sonata in B-Flat Major, K. 498a is of doubtful origin, with differing reports of the authenticity of the sonata as a whole or its various movements. It has, for example, been attributed and printed under the name of Auguste Eberhard Müller. David Cope's EMI-composed "Mozart sonata"[3] is an example of a machine-composed imitation;

c) Distinguish a composer's works from those with portions borrowed from that composer but put together by another. Thus, although the segments borrowed

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[3] (Cope 1991, 158)

might exhibit some characteristics and relations typical of that composer, the manner in which they were seamed together would lack such properties. For example, the second movement of Mozart's Sonata in B-Flat Major, K. 498a has its main theme and other portions of the movement borrowed from the second movement of Mozart's Piano Concerto in B-Flat Major, K. 450;

d) Identify those of a composer's works in which portions of the work are borrowed from other works of the same composer. For example, the first movement of Mozart's Sonata in F Major, Anhang, No. 135 is borrowed from the second movement of Mozart's Sonata for Piano and Violin, K. 547. The properties for the ISAS system were designed to distinguish these four categories.

1.4 Information Density

In the course of designing this system, certain issues were discovered to be of interest in authentication of style. One issue that proved to be of significance is the information density of a work (or segment of a work).[4] Information density can be defined as the ratio between the number of notes and number of different characteristics and relations in which each segment participates. Thus, information density is a measure of the efficiency with which notes are used to convey structural information. The parsing diagram, to some extent, indicates the degree of information density and enables it to

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[4] (Rothenberg, 1975,3)

become more tangible because all significant relations and characteristics are marked.

1.5 Intelligibility

Another issue found to be of interest in style authentication is intelligibility. Intelligibility of a work can be defined as the degree to which educated listeners can perceive the structural patterns within the music - - that is, make sense of the music. It seems likely that the greater the degree of intelligibility, the more concisely the music can be described in the music description language of this system. Music that has a low percentage of pattern and therefore could be looked at (in a mathematical sense) as more random, could be perceived as less intelligible and would require a longer description. (The randomness of a series of symbols could be mathematically defined as the length of its shortest description in IMCL.) Then its intelligibility could be defined as the degree to which it is not random. Without a considerable amount of perceptible structural pattern, and an innately perceptible sense of its syntax, a work might sound less intelligible. For example, contrast, climax, and repetition are some of the elements that contribute to a well-crafted melody. Those elements create patterns that involve feelings of expectation and surprise, which aid listeners' reception of and response to a work. The style-specific predicates created for this system were designed to capture those properties that would be intelligible to educated listeners.

1.6 Alternative Systems

Alternative systems for style identification were considered. Primary among these was David Cope's style replication system. Cope's system attempts to recognize the stylistic patterns of a composer. This is done primarily for the purpose of recreating works in that style. Cope's "Experiments in Musical Intelligence" (EMI) program[5] attempts to replicate musical style through "recombinant" use of patterns found recurrently in a database of selected works. To identify stylistic patterns ("signatures"), individual works are analyzed using a hierarchical pattern matcher that extracts frequently used patterns from the work and, as far as possible, represents the work in terms of these patterns. These are superimposed to identify commonly used patterns, which are then stored in a style dictionary along with their frequency and location. They are then used to compose music that is, hopefully, similar in style to that which has been analyzed.

The works selected for a particular style database must all be similar in style. These works are then "clarified", that is, put into similar format, prior to being pattern matched. This clarification process includes: transposing all the

[5] (Cope, 1991,18)

works into the same key (usually C Major); giving them similar textures by removing or adding many doubling notes; removing ornaments (which, Cope felt, caused problems in pattern matching and functional analysis); changing ties that cross bar lines into repeated notes; and establishing metrical equivalencies -- for example, enabling an accompaniment using a pattern of 4 eighth notes (as in Mozart's K. 545, first movement, measure 1) to be compared with a similar accompaniment pattern of 4 sixteenth notes (as in Mozart's K. 332, second movement, measure 1) by altering one of them to rhythmically resemble the other.

Cope's EMI program clarifies data not only to facilitate pattern matching, but also to allow signatures to be more easily connected to newly composed music that could precede or follow it. The EMI program is quite dependent on this clarification process, and on the selection of proper works to insert in this database. EMI's program is not provided in advance with the patterns to be matched. The EMI program itself determines what patterns constitute stylistic signatures based on their frequency of occurrence in particular locations in the music.

Unfortunately, clarification, in an attempt to give a uniform format to the music in the EMI database, inevitably produces alterations and loss of stylistic information. The fact that a pattern occurs with high relative frequency and in a particular location apparently does not guarantee that it actually characterizes the composer's work. Repetition alone appears not to be a sufficient cause to establish a pattern as a signature (when distilling the essence of a composer's style). Certain patterns that recur less frequently than others get overlooked by EMI, even though they are musically significant. In looking, for example, at a sample of Cope's EMI composition "Schumann Childhood Scene"[6] -- his attempt to replicate the style of German romantic-era composer Robert Schumann --one finds that it lacks Schumannesque melodic contour (such as romantic leaps followed by scale-like motion).

The EMI program is unique in its ambitiousness and in the degree to which it is somewhat successful in composing music in styles defined by its idiosyncratic analysis. However, music, which is intended primarily to be listened to, is best analyzed on the basis of how it is heard. If analysis (and, in particular, style analysis) rather than style replication is the goal, that analysis ideally should reflect the perception of the educated listener. In this connection, the EMI program seems unable to detect not only more subtle and abstract patterns that are apprehended by a listener, but also relations among these patterns, which could affect how they could be reused in varying form in a newly composed work. That is, the EMI program cannot reliably detect all

[6] (Cope, 1996, 75)

significant patterns of a work, if by pattern one means a musically distinctive property as opposed to a more obviously repeated structure. This is one among many reasons why the patterns that were used here for the ISAS project to characterize musical works were derived by introspective analysis of its author's pianist's perception of those works. This resulted from study of the 20 Mozart keyboard sonatas, the 62 Haydn keyboard sonatas, and other related works of Mozart's other contemporaries (Clementi, Dussek, Hummel, and C.P.E. Bach).

1.7 Style Considerations

Style has been defined as the manner of expression of an author, composer, period, etc. The word style is derived from the word "stylus", which is the Latin term for an ancient writing implement. Musical style can thus be considered to be the distinctive "handwriting" that a composer uses to express his musical ideas. In particular, style can be described as certain distinctive characteristics (that is, patterns) found consistently in a composer's works. These patterns are musical hallmarks which may appear in several variant forms but are nonetheless recognizably similar. Some of these hallmarks are common to the composer's works as a whole; others may be distinctive in the context of a particular genre. In this dissertation, an investigation is made to determine if Mozart's style can be captured by a set of properties. It also determines how intuitively it can be represented by IMCL.

The observation has been made that well-crafted melodies (as well as other forms of art) generally display similar basic laws of logical structure. This refers, for example, to balance between variety and repetition, and the sense of unity achieved by a departure leading to an eventual return, with a "climax" (central focus) prior to that return. In addition to this tripartite division (departure, climax, and return), a sense of proportioned structure is included. In this dissertation, an exploration is made to determine if the set of properties found to distinguish Mozart's sonatas reflect his own unique application of these laws.

1.8 Organization of This Dissertation - - A Reader's Guide

In the next chapter, the music description language IMCL will be described. In Chapter 3, Sections 3.1 and 3.3 through 3.5 describe the types of predicate libraries used by ISAS. Section 3.6 gives a brief overview of the style-specific predicate library used for distinguishing Mozart. A very detailed, complete description of the style-specific predicates follows in Sections 3.6.1 through 3.6.8. Chapter 4 then describes how the properties listed in Chapter 3's style-specific predicate library are applied to the expositions of the keyboard sonatas of Mozart and his contemporaries. It also describes some results of this analysis. A larger, more complete set of results is provided in Appendix A.

Chapter 2

IMCL Music Description Language

2.1 The IMCL Language

The IMCL language (Inverted Music Composition Language) is based on a language NPCL (Non-Procedural Composition Language) originally conceived for purposes of music composition.[1] That language has been adapted for use in style analysis to aid in authentication of authorship. They are both non-procedural languages that use weak (in the sense that quantification over infinite sets is not permitted), second-order predicate calculus to describe musical characteristics and relations. NCPL approached the description of music from a multilevel structural standpoint. In contrast with a more linear concept of composition, it described music only in terms of those properties deemed relevant, thereby facilitating an efficient, hierarchical description.

Unlike many music composition languages, this language permits partial specification of the notes of a musical segment, which are determined from specifications of the segment's desired properties. Then several possible realizations that match this description are output for examination and analysis. Commercial "sequencer" programs such as Performer, by contrast, require complete specification of musical segments.

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[1] (Rothenberg, 1975, 1)

Both NPCL and IMCL allow lower-level segments to be succinctly defined and constrained by descriptions of higher-level segments. In effect, both languages view musical composition from an analytical perspective. The fact that NPCL was built from elements useful for analysis made it an appealing candidate for adaptation to style analysis.

The basic object manipulated by IMCL is the segment. This choice of data structure was based on the observation that music is not conceived note by note in a linear, score-like fashion, but in larger sections (that is, fragments, or segments). Moreover, these segments often are not conceived of in isolation, but in relation to other segments (which are not necessarily adjacent). Likewise, music perception and style recognition in particular, generally involve larger units, rather than individual notes, of a score. A hierarchical, segment-oriented language therefore seemed an intuitive choice for use in a style authentication system. It enables the syntax of a work to be described clearly and manipulated in an intuitive fashion so that the elements of style can be systematically identified.

2.2 Representation of Musical Structure

In the ISAS system, the music is initially input using a MIDI system, and then parsed into labeled segments.

2.2.1 Segments

The IMCL language allows musical structure to be described in terms of segments. The atomic unit of which all other segments are comprised is called a level-0 segment. Therefore, a note, the smallest musical building block, is considered to be a level-0 segment. Higher-level musical segments can then be formed in hierarchical fashion. A level-1 segment, for example, consists of a collection of level-0 segments that are either concurrent or consecutive. For example, a chord (a simultaneous occurrence of several notes), a rhythmic pattern (a series of two or more durations), or a cadence (a closing harmonic progression) are examples of a level-1 segment. The decision as to which structural groupings will serve as level-1 segments is dependent on the particular work being analyzed and authenticated, and the particular stylistic patterns that are the objects of interest.

Segments are assigned names (labels) so that they can be referenced in formulae (temporarily stored) or stored as files for later use. Level-0 segments (notes) generally are labeled using a lowercase letter followed by a number (for example, b1), Segments that are level-1 or greater are labeled using uppercase letters or uppercase letters followed by a number (for example, E1).

Segments can be defined in several ways. For example, they can be defined by listing their component segments in brackets (for example, A1={b1, b2}, which defines a level-1 segment A1 consisting of two notes, b1 and b2. Likewise, $A=\{a_1(B),a_2(B),a_3(B)\}$ defines a level-1 segment consisting of the first three notes of segment B. Segments can also be defined using set theoretic operations. For example, the union operator can be used for segment definition (for example, C2=B1 U B2). Also, a segment can be defined by removing one or more parameters from a preexisting segment. (For example, a segment X, which is similar to segment Y except for the omission of the last element of segment Y, could be defined as follows: $X=Y-a_L(Y)$, where the subscript L identifies the last note of segment Y. The statement $E1=D1-a_1(D1)$ indicates that E1 consists of the notes of segment D1, excluding its first note (or rest).

Moreover, a segment can be defined by defining the properties it satisfies. For example, a subsegment A of another segment X that consists entirely of sixteenth notes and is in the uppermost voice can be expressed as follows:

$$A=\{a_{i,1}(X) \mid d_{i,1}(X)=25\}$$

(where i indexes notes $a_{i,1}$ within the top voice of X, $d_{i,1}(X)$ is the duration of that note, and 25 denotes a duration of a sixteenth note). Likewise, a subsegment Y of a segment X that consists of all notes struck simultaneously with note $a_k(X)$ can be defined as follows:

$$Y=\{a_i(X) \mid t_i(X)=t_k(X) \wedge d_i(X)>0 \wedge i\neq k\}$$

(where $t_i(X)$ represents the 'struck time' of the i^{th} element of X (the subscript indicating "voice" is omitted for brevity), and a duration greater than 0 represents nonrests (notes)).

2.2.2 Sets

In order to facilitate the formation of nonatomic formulae, the IMCL language allows the definition of sets of objects (such as numbers) other than segments. For example, a set could be defined by listing its domain as follows:

$$M = \{1..16\}$$
$$D = \{-400..400\}$$

(where M is a set of allowable values for meter, and D is a set of values for duration). Also, a set can be defined by listing its component values. For example, the set representing the pitch class "d" could be defined as follows:

$$Pc_3 = \{26, 38, 50, 62, 74, 86, 98, 110\}$$

(where 62 represents the "d" above middle C, Pc_1 is the set representing the pitch class "c", and pc_{12} is the set representing the pitch class "b"). Likewise, the set of major and minor intervals of a sixth could be represented as:

$$I_6= \{8, 9\}$$

(where intervals are represented in terms of half steps, and I_6 is the sixth of several interval sets that are defined). I_1, for example, might then represent the set consisting of the unison interval, I_2 would represent the set of major and minor seconds, and I_8 would represent the set consisting of the octave interval.

A set can also be defined by describing the properties of its elements. Thus, a set Y consisting of all rests in segment X that occur on the first beat of a segment can be defined as follows:

$$Y = \{a_i(X) \mid d_i(X)<0 \wedge b_i(X) = 1\}$$

(where $d_i(X)$ is the duration of the i^{th} element of X, a negative duration denotes a rest, and $b_i(X)$ is the index of the "beat" on which $a_i(X)$ occurs. (The "a_i" is omitted for brevity.) Likewise, the set of all durations occurring between two notes $a_{i,1}(X)$ and $a_{j,1}(X)$ in the uppermost voice, can be defined as follows (where $a_{i,1}(X)$ and $a_{j,1}(X)$ are the i^{th} and j^{th} elements, respectively, of segment X in the uppermost voice):

$$Y = \{d_{k,1}(X) \mid t_{k,1}(X) > t_{i,1}(X) \wedge t_{k,1}(X) < t_{j,1}(X)\}$$

(where $t_{j,1}(X)$ and $t_{k,1}(X)$ are the "struck time" of the j^{th} and k^{th} elements, respectively, in the uppermost voice of segment X).

Also, the 'duration classes' of a segment, which group together all durations conventionally notated in terms of the same fraction of a "beat" into a single set (for example, eighth and dotted eighth notes), can be defined as follows:

$$Y = \{n \mid d_i(X) \in dc_n\}$$

(where Y is a set of numbers representing the indexes of the duration classes to which the notes belong). Dc_1, for example, is the set of all durations relating to sixty-fourth notes. Likewise, Dc_5 is the set of all durations relating to quarter notes. It could be defined as follows:

$$Dc_5 = \{100, 150, 175\}$$

(where 100 represents a quarter-note duration, 150 a dotted quarter note, and 175 a double-dotted quarter note).

2.3.1 Hierarchical Segment Levels

Level-2 segments can be formed from level-1 segments in the same hierarchical fashion as discussed in Section 2.2.1 for level-0 and level-1 segments. For example, a three-measure "rhythmic sequence" consisting of three occurrences of a one-measure rhythmic pattern (level-1 segments labeled A1, A2, and A3) would be considered a level-2 segment (B1={A1, A2, A3}). (A rhythmic sequence is defined here as the occurrence of one or more adjacent repetitions of a rhythmic pattern.) It is helpful to assign label names that show how segments are interrelated. Thus, in the example above, the four component level-1 segments use labels that all contain an "A". Likewise, level-3 segments can similarly be defined recursively in terms of level-2 segments, and so forth. Segments of level 2 or greater can be represented with superscripts appended to the segment names to indicate segment level. One can create as many levels as required for multilevel structural analysis. Leveled segments (of level 1 and higher) enable structured objects to be handled efficiently.

2.3.2 Level-n Points

A level-n segment's ($segment^n$) type n-1 component segments are called type-n points ($point^n$). These are indexed for use in referring to those constituent segments. Thus, if a level-2 segment E1 ($segment^2$) consists of four level-1 segments D1, D2, D3, and D4, then $a_3(E1^2)$ refers to the third element of $E1^2$, specifically, D3. $L(E1^2)$ is used to refer to the index of the last element of the segment (in this instance, the fourth element). These points are organized hierarchically, like segments. Thus, in the example above, the level-2 segment E1 consists of four level-2 points which are the level-1 segments. Points act like array references for leveled segments containing multiple subsegments. Segments can be referenced with two indexes, when required. For example, $a_{i,v}(X)$ is a point representing the i^{th} element in voice v of segment X. A first subscript of L identifies the last element of a segment. Thus, in the example above, $a_L(E1^2)$ refers to segment D4.

2.4 Regions

A segment refers to elements that are either concurrent or consecutive. In contrast, a "region" is used to define a set of elements that need be neither concurrent nor adjacent. Thus, a region might consist of the first note of measure 1 and the last note of measure 4 of a work. For example, a region W consisting of the last note of segment X and the first note of segment Y can be defined as follows:

$$W = \{a_L(X),\ a_1(Y)\}$$

Regions, like segments, can be grouped in hierarchical fashion. A collection of nonadjacent, nonconcurrent notes is a level-1 region (as in the example above). Likewise, level-1 regions can be grouped to form level-2 regions ($region^2$). Hierarchically ordered regions could be useful, for example, for clearly representing a Schenkerian analysis.

2.5.1 Characteristics

Segments can have a variety of individual characteristics. Characteristics are represented by predicates having one free set variable, which is the name of the segment. Each level of segmentation can have its own set of characteristics. For example, a note (level-0 segment) can be described in terms of its pitch, duration, 'struck time', or voice. These characteristics are considered to be level-0 properties. Likewise, a phrase can be described in terms of its number of notes, total duration, and the musical "scale" to which its notes belong. (These are considered level-1 characteristics.)

2.5.2 Atomic Formulae

Atomic properties are those basic properties in terms of which all other properties are defined. The choice of atomic properties to be included in the library of predicates is significant in determining the power of the IMCL language. These atomic predicates are defined by an atomic formula (or several atomic formulae combined with logical operators). For example, $d_i(X)=k$ is an atomic formula that states that the duration of a note is k beats. Likewise, $p_{i,v}(X)=k$ is an atomic formula stating that the pitch of the i^{th} note of segment X in voice v is k. An atomic formula specifies a segment (which may be a note), a particular parameter (for example, "d"), a value for that parameter (for example, 25}, and the relation between them (for example, =). The primitive relations that can be used in these formulae are "=", "<", and "ε".

2.5.3 Nonatomic Formulae

Formulae used to define properties in terms of other properties or atomic predicates are called "defined formulae". These formulae define properties that are either style-independent or style-dependent. (For example, the characteristic Tnote(X) = k states that the total duration of notes (nonrests) of a segment has the value k, and rpat(X) states that segment X is a "rhythmic pattern" (i.e., it contains at least two different durations). Tnote is discussed in Section 3.4. The formulae listed in the sections that follow are all defined formulae.

2.5.4 Level-n Characteristics

Level-0 segments (notes) can display various level-0 properties (for example, duration - - $d_i(X)$, and pitch - - $p_i(X)$). Level-1 segments (a collection of notes) can also exhibit numerous characteristics (for example, the occurrence of the same pitch repeated more than four times (r-ptch(X) - - Section 3.6.3), and the occurrence of two or more 'peak points' in a melodic line (pkpt>2(X) - - Section 3.6.4). These characteristics of level-1 segments are called level-1 properties. Functions can be defined that return Boolean values in addition to other types of constants and can be used in defined formulae. (The characteristic apg_d(X), which indicates the fact that segment X is an appoggiatura, or the characteristics r-ptch(X) and pkpt>2(X) above, are examples of such functions.) Level-1 properties (and higher-level properties) sometimes require the use of the (weak) second-order predicate calculus. (Otherwise, only first-order statements are used.) This results from the fact that some of these property definitions require quantification over (finite) set variables. An example where quantification over set variables is required is the definition of the characteristic that all subsequences of a segment which have a repeated pitch are less than two beats in duration. When set variables range only over defined subsegments, they will be labeled with a caret over the variable name.

Labels are assigned using the symbol "≡ ". Free variables are placed in parentheses after the property name, and the scope of a quantifier is indicated below and above that quantifier. For example, the characteristic that the total interval span of a segment is k semitones can be defined as follows:

$$(\text{tot\_span}(X)=k) \equiv \underset{i=1}{\overset{L(X)}{\forall i}} \ \underset{j=1}{\overset{L(X)}{\forall j}} \ (|\, p_i(X)-p_j(X)| \leq k)$$

2.5.5 Functions

The IMCL language allows numerical functions to be defined in a manner similar to most programming languages. For example, the function int(i)=k returns the integer value of a real number. Likewise, the function sum(i,k) returns the sum of two numbers, i and j. This function can also be converted into a predicate form.

2.5.6 Numerical Quantification

The predicate calculus has been extended to include a numerical quantifier $Q^{j}X$ (that is read, "for j percent of segment X").[2] This permits segments to be defined in terms of the fraction of their elements that exhibit a particular property. This is particularly useful for authentication of style characterized by a preponderance of certain characteristics because it permits but constrains the number of exceptions. Thus, the characteristic that 75 percent of a segment has a full chord texture (that is, has chords or nonsimultaneous harmony that contain all three tones of a chord or three out of four tones of a seventh chord) could be defined as follows:

$$\text{f\_tex}(X) \equiv Q^{.75}(\text{fb\_ch\_tex}(X))$$

(where fb_ch_tex(X) is a formula that defines the characteristic 'full block chord texture' - i.e., a texture with at least one full chord per half measure if the chord changes). The language also includes quantification of set variables.

2.5.7 Relations

The IMCL language allows segment structure to be described not only in terms of individual characteristics, but also in terms of relations between

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[2] (Rothenberg, 1975, 9)

segments. Relations are called "bondages"[3] because they establish a bonding connection between two segments. Relations are predicates that have at least two free set variables. Properties that describe a relation between individual notes (level-0 segments) are considered level-0 properties and are represented by atomic formulae. For example, the interval between two notes having the particular value of k semitones could be defined by the following level-0 relation:

$$(\mathrm{intrvl}(a_i(X),a_j(X)) = k) \equiv |p_i(X) - p_j(X)| = k$$

2.5.8 Level-n Relations

Relations between two collections of notes (level-1 segments) are called level-1 properties. For example, the fact that segment X forms an exact rhythmic sequence with an adjacent segment Y could be expressed by the following level-1 property:

$$\mathrm{rseq\_x}(X,Y) \equiv \mathrm{rpat}(X) \wedge \mathrm{adj}(X,Y) \wedge \overset{L(X)}{\underset{i=1}{\forall}} i\, (d_i(X)=d_i(Y))$$

(where rpat(X) is a characteristic describing the fact that segment X contains at least two different durations, and adj(X,Y) is a relation stating that segments X and Y are adjacent). Higher-level segments similarly can have a variety of relations between them. Thus, two level-2 segments $B1^2$ and $B2^2$, each

[3] (Rothenberg, 1975, 18)

consisting of 2 two-measure half phrases (B1={A1, A2} and B2={A3, A4}) could have the relation that both end with a V - I resolution.

2.6 Metalanguage for Properties

This language also permits properties to be treated as entities. They can be collected like segments into hierarchically ordered groups, and properties of these groups can be defined. This is potentially useful in style analysis, where the patterned use of properties is of prime importance.

2.6.1 M-segments, M-formulae

A set J^* of properties (called an m-segment, or meta-segment) can be defined as follows

$$J^*=\{P1, P2, P3, P4\}$$

The superscript asterisk symbol is used to distinguish sets whose elements are properties. This is useful, for example, for defining the sets of properties used in the vector tables discussed in Chapter 4. A set of properties can be defined not only by listing the properties in braces as above, but also by describing its relation to another already defined set of properties. Sets of properties can be used to define relations between segments. For example, the relation s_pat(X,Y) could be defined as indicating that segment Y satisfies the same properties of J^* as segment X:

$$s\_pat(X,Y) \equiv \overset{L(J^*)}{\underset{i=1}{\forall}} i\,(X \models (a^*_i(J^*) \rightarrow Y \models a^*_i(J^*))$$

(where $\models$ is read as "satisfies").

Properties, as entities, can themselves have properties (characteristics and relations). Formulae to define such properties have quantifiers that range over properties. These formulae that describe formulae are called m-formulae. Thus, a set of properties K^* could have the characteristic $TC^*(K^*)$ that each of its properties is a textural or cadential property. Likewise, a set of properties D^*could have the characteristic $C^*(D^*)$ that each of its constituent properties is a relation. This could be useful, for example, in describing aspects of the properties in the vector tables (ordered sets) discussed in Chapter 4.

2.7 Weights

Properties can be distinguished in terms of their relative importance. This order of importance can be established, for example, by assigning weights. The statement $w(P5) = 3$ indicates that property P5 is assigned a weight of 3. Likewise, the statement $(\Sigma\ (w(a^*_i(J^*)) = 6))$ indicates that the sum of the weights of all properties in J^* is 6. This is useful, for example, in distinguishing those properties in the vector tables that have greater significance than others. For example, the following formula assigns a weight of 1 to all properties in the set of properties J^*:

$$\overset{L(J^*)}{\underset{i=1}{\forall i}} \; (w\,(a^*_i(J^*)=1))$$

Chapter 3

Predicates for Style Analysis - - Library of Predicates

3.1 Predicate Libraries

Three basic sublibraries were created: the 'atomic predicate' library (basically consisting of predicates that are MIDI-encoded); the 'nonatomic predicate' library consisting of 'style-independent' predicates; and the 'nonatomic predicate' library consisting of 'style-dependent' predicates (that is, predicates describing properties specific to a particular style). The lower-level, style-independent predicates (Section 1.3) determine the nature and degree of sophistication of higher-level, style-dependent properties that can be represented. That is, they provide a vocabulary for efficiently describing higher-level, style-specific properties. They therefore determine the ease and degree of intuitiveness by which these style-specific properties can be represented. It is important to keep the libraries compact but powerful. Attempts were made to strike a balance between the clarity of longer, more descriptive property names, and the ease of using shorter names. Properties were given optional abbreviated names for expedient use in graphs and formulae, as needed.

The style-dependent predicate library, listed in Sections 3.6.1 through 3.6.8, contains a variety of style-specific characteristics and relations pertaining, for example, to such aspects as melody, melodic topology, rhythm, duration, and harmony. Selected style-dependent properties from this library were used to form binary vectors whose elements specify the truth values ("1" or "0" for "true" and "false", respectively) of each of the correspondingly selected properties. These style-vectors contain subsets of properties useful for identifying stylistic patterns of various aspects and locations in a work. (For example, there is a vector for the opening four measures of the main theme, and a cadential vector for the cadential pattern of the exposition.) The formulae for the properties in these vectors are then used separately and in combination to parse the work in question. Vector tables and hierarchical parsing diagrams can then be formed. These individual results, as well as an evaluation of their combined profile, are useful in making a decision regarding style authenticity.

3.2 ISAS Segments and Sets

Segments, the basic data structure of IMCL, can refer either to notes or collections of notes (Chapter 2). Segments of notes in formulae for ISAS are labeled using uppercase letters. (For example, the characteristic rep_dur(X) refers to the use of substantial repetition in segment X.) To refer to specific elements of segments, points with one or two point variables are used. For example, $a_3(X)$ (in which point a is indexed by the point variable 3) refers to the third element of segment X. If segment Y is a collection of notes (for example, a short rhythmic pattern), a_3 would refer to the third note of segment

Y. Segment Y would be considered a level-1 segment consisting of level-0 elements (Chapter 2). Likewise, if segment Y is a collection of four phrases, $a_3(Y)$ would refer to the third phrase of segment Y. Segment Y could then be considered a level-2 segment consisting of four level-1 segments. The point variable enables the next lower-level components of level-n segments to be accessed. Also, $a_L X)$ refers to the last element of segment X. Two indices are used when reference to voice is also required. Thus, $a_{2,1}(X)$ would refer to the second element of segment X in the uppermost voice. $A_{4,v}(Y)$ refers to the fourth element of segment Y in the lowest voice.

A number of sets were defined for use in the formulae that defined properties. For example, set T represents the acceptable values for a continuous time line of beats. It was defined as follows:

$$T=\{-2..n\}$$

Negative values are included in T because an initial upbeat is represented as having negative time values equivalent to its number of beats. Thus, in a 4/4 time signature, a quarter-note upbeat would have a 'struck time' of -1, and an eighth-note upbeat would have a 'struck time' of -0.5 (Section 3.3). For example, the 'struck time' $t(a_i(X))$, which represents the number of elapsed "beats" (defined later) from the beginning of a work, must be confined to an element of T.

Durations are represented in terms of their relation to whole notes. A whole note is represented by a value of 200). Rests are represented by the negative values of the equivalent durations. The set D of durations was defined as follows:

$$D=\{-400..400\}$$

Also, sets of duration classes have been defined. These duration classes group all durations conventionally notated in terms of the same fraction of a beat (e.g., quarter note or eighth note) into separate sets of duration classes. Thus, an eighth note and a dotted eighth note would be in the same duration class. For example, Dc_1 refers to the duration class of 64^{th} notes, and Dc_6 refers to the duration class of half notes, which can be defined as follows

$$Dc_6 = \{200,300,350\}$$

Thus, there are a total of seven duration classes.

A set of pitches for the keyboard works is defined as followed:

$$P=\{21..108\}$$

Pitch classes, which group instances of the same pitch in various registers, are defined as sets. (There are a total of 12 pitch classes.) The pitch class "F" is defined as follows:

$$Pc_6=\{29,41,53,65,77,89,101\}$$

Sets of intervals have also been defined for use in formulae. For example, I_1 is the set consisting of the unison interval, and I_8 the set consisting of the interval of an octave. Intervals are measured in terms of the number of semitones between the two notes. Thus, the set of major and minor thirds would be defined as follows:

$$I_3=\{3,4\}$$

Scales have also been defined by specifying their component notes, starting with "middle C", which is represented by the number 60. For example, S_3, which represents the notes of the D major scale, can be represented as follows:

$$S_3=\{62,64,66,67,69,71,72\}$$

Scales are defined here only in the range starting with middle C. In formulae, scales beginning on other notes can be compared with them by using the mod operator.

A set for meter is defined for the upper numeral of the time signature. (The lower numeral is represented as a duration, rather than in terms of beats.) Thus, a time signature of 3/4 is seen as three beats of a quarter note's worth in duration (which is represented by the values 3 and 100). The set M is defined as follows:

$$M=\{1..6\}$$

Also, a set V for voices is defined as follows:

$$V=\{1..maxv\}$$

(with maxv representing the maximum number of voices).

3.3 Atomic Predicates

Atomic predicates are those basic properties in terms of which all other properties are defined. These are the basic building blocks for all formulae. For example, $d_i(X)=k$ states that the duration of the i^{th} element of segment X is k. The second index is omitted if there is no doubt as to which voice is being referenced (for example, if the segment has been defined previously as a bass-voice segment). Also, $d_{i,v}(X)=k$ states that the duration of the i^{th} element of X in the v^{th} voice of X is k (indexed from the top).

A continuous measurement of elapsed time in beats is maintained. $T_i(X)=k$ states that the 'struck time' (the time when this element is struck on the keyboard) of the i^{th} element of segment X is k (with k an element of the set T of time values, defined in the Section 3.2). $T_{i,2}(X)$ is the 'struck time' of the i^{th} element of segment X in voice 2. As mentioned previously in Section 3.2, an initial upbeat at the beginning of the exposition is considered to have negative values. Thus, in a time signature of 4/4, an upbeat of an eighth note is considered to be struck at time -0.5. The predicate $ts(X)=\langle U,L\rangle$ represents the time signature as an ordered set, where U is an element of set M (the set defining values for meter), and L is an element of set D (the set defining values for durations). Thus, if the time signature were 3/4, U would have the value 3, and L would have the value 100.

The predicate $p_{i,v}(X)=k$ states that the pitch of the i^{th} element of the v^{th} voice of segment X is k. The value of k should be an element of set P of pitches (defined in Section 3.2). (For example, $p_{3,2}(X)$ refers to the pitch of the third note in the second voice of segment X.) Also, the predicate $v_{i,v}(X)=k$ states that the voice of the i^{th} element of the v^{th} voice of segment X is k (where k is an element of set V, defined in Section 3.2). "L" is used to represent the last element of a segment. (For example, $v_L(X)=4$ states that the last element of segment X is in the fourth voice.)

3.4 Defined Predicates: Style-Independent Predicates

Nonatomic predicates (defined predicates) are used to define properties (characteristics and relations) in terms of other properties or atomic predicates. These include formulae with an unspecified parameter (i.e., "free variable") which is instantiated when used in formulae that distinguish different composers' works. ('Style-independent' properties are defined in Section 1.3.) A sample of these style-independent properties is provided here. In order for the names assigned to these to be intuitive, the symbol "=", rather than "," will be used in the name of these properties; when this is done, the name will be enclosed in parentheses. For example, (tnote(X)=k) is a characteristic stating that the total duration of notes (nonrests) in a segment is k. That is, it can be defined as follows:

$$(\text{tnote}(X)=k) \equiv \sum_{i=1}^{L(X)}(d_i(X)|\ d_i(X)>0) = k$$

Other 'style-independent' properties that are used in the subsections of Section 3.6 include those below. Their verbal descriptions are followed by defining formulae in order to illustrate how this is accomplished in IMCL. (For brevity, this is not done in the subsections of Section 3.6.) (Maxdur(X)=k) is a predicate stating that the longest duration of X is k. It can be defined as follows:

$$(\text{maxdur}(X)=k) \equiv \underset{i=1}{\overset{L(X)}{\exists i}}\ (d_i(X)=k) \wedge \underset{j=1}{\overset{L(X)}{\forall j}}(d_j(X)\leq k)$$

Also, (cdur($a_i(X)$,$a_j(X)$)=k) is a predicate stating that the 'composite duration' of two pitches is k. The 'composite duration' of two pitches is considered to be the sum of their durations if the two pitches are in the same pitch class and adjacent (referred to, for example, in Subsection 3.6.5, property 31). It can be defined as follows:

$$\begin{aligned}(cdur(a_i(X),a_j(X))=k) \equiv (&adj(a_i(X),a_j(X)) \wedge \\ &p_i(X) \bmod 12 = p_j(X) \bmod 12 \rightarrow \\ &k=d_i(X) + d_j(X) \text{ else} \\ &k=d_i(X))\end{aligned}$$

(where $adj(a_i(X),a_j(X))$ is a predicate stating that two pitches are adjacent, defined a few paragraphs below, and assuming that else is defined as in standard programming languages).

A 'style-independent' property that does not include an unspecified parameter (Section 1.3) is the characteristic i_upbt(X). This characteristic states that X is an 'initial upbeat' at the opening of a work. It can be defined as follows:

$$i\_upbt(X) \equiv \forall_{i=1}^{L(X)} i(t_i(X)<0)$$

(assuming, as mentioned previously in Section 3.2, that negative elapsed time denotes an upbeat at the beginning of a work). On_bt($a_i(X)$) is a characteristic that states that a note $a_i(X)$ is struck 'on the beat'. It can be defined as follows:

$$on\_bt(a_i(X) \equiv b_i(X) \bmod 1 = 0$$

(where mod is defined as in the programming language Pascal, and noninteger beats denote "off-beat" notes).

With respect to elapsed time, the fact that a segment X is notated as a measure of a work whose time signature is <U,L> can be represented by the characteristic r_meas(X). It is defined as follows:

$$r\_meas(X) \equiv ts(X)=\langle U,L\rangle \wedge b_1(X)=1 \wedge d\_meas(X) = U * L$$

(where ts(X) states that the time signature is U beats of duration L (Section 3.3), and assuming that d_meas is a function that returns the duration of a measure). Thus, if the time signature is 4/4, the time signature would be represented as <4,100>, $b_1(X)$ denotes the first beat of segment X, and the total duration of segment X is 4 * 100, or four quarter-notes' worth).

Adj(X,Y) is a relation describing the fact that segments X and Y are adjacent (i.e., that the first element of Y strikes immediately after the last element of X). This can be defined as follows:

$$adj(X,Y) \equiv t_1(Y)=t_L(X) + |d_L(X)| \wedge id\_voice(X,Y)$$

(where id_voice(X,Y) is a predicate stating that all notes of segments X and Y are in the same voice).

Mesh(X,Y) is a relation describing the fact that segments X and Y "mesh together". Specifically, the last note of segment X is also the first note of segment Y. This property was useful in the definition of certain melodic topological properties (Subsection 3.6.4). This relation can be defined as follows:

$$mesh(X,Y) \equiv id\_voice(X,Y) \wedge t_L(X) = t_1(Y)$$

A sample of melodic style-independent properties would include ascent(X), which states that segment X is an ascending segment that consists of at least two ascending pitches (although some intervening pitches may repeat). This can be defined as follows:

$$ascent(X) \equiv \overset{L(X)}{\underset{i=1}{\forall i}} (p_{i+1}(X) - p_i(X) \geq 0) \wedge \overset{L(X)}{\underset{j=1}{\exists j}} \; \overset{L(X)}{\underset{k=1}{\exists k}} (p_j(X) \neq p_k(X))$$

The characteristic tot_span(X)=k states that the maximum intervallic range of a segment is k semitones. It can be defined as follows:

$$(tot\_span(X)=k) \equiv \overset{L(X)}{\underset{i=1}{\forall i}} \; \overset{L(X)}{\underset{j=1}{\forall j}} (|p_i(X) - p_j(X)| \leq k)$$

Stepw(X) is a characteristic that indicates that all intervals of segment X are major or minor seconds. This can be defined as follows:

$$stepw(X) \equiv \overset{L(X)}{\underset{i=1}{\forall i}} (|p_i(X)-p_{i+1}(X)| \in I_2$$

where $I_2 = \{1,2\}$.

With respect to harmony, Vseg(X) is a characteristic stating that X is a 'vertical segment' (i.e., all of its notes strike simultaneously). It can be defined as follows:

$$\mathrm{Vseg}(X) \equiv \overset{L(X)}{\underset{i=1}{\forall i}} \left(t_i(X)=t_1(X) \right)$$

With respect to voice, the relation id_voice(X,Y) describes the fact that all corresponding notes of segments X and Y are in the same voice. This relation can be expressed as follows:

$$\mathrm{id\_voice}(X,Y) \equiv \overset{L(X)}{\underset{i=1}{\forall i}} \; \overset{L(X)}{\underset{j=1}{\forall j}} \left(v_i(X) = v_j(X) \right)$$

(where $v_i(X)$ is the voice of the i^{th} element of segment X). Upm_v(X) is a characteristic stating that all elements of segment X are in the uppermost voice. This can be defined as follows:

$$\mathrm{upm\_v}(X) \equiv \overset{L(X)}{\underset{i=1}{\forall i}} \left(v_i(X)=1 \right)$$

An example of how the above formulae are used to define the style- dependent properties in the following sections , is ident_pr(X,Y) (property 16, Subsection 3.6.2), which states that the uppermost voice of the two adjacent segments X and Y, each at least half a beat long, are identical in rhythm and pitch (within octave transpositions). The last duration need not match if segment X contains at least 10 notes.

$$\text{ident\_pr}(X,Y) \equiv \text{adj}(X.Y) \;\wedge\; \text{ts}(X) = \langle U,L \rangle \;\wedge$$

$$\forall_{i=1}^{L(X)} (p_{i,1}(X) \bmod 12 = p_{i,1}(Y) \bmod 12) \;\wedge$$

$$(\Sigma\, d_{i,1}(X) + \Sigma\, d_{i,1}(Y) \geq L) \;\wedge$$

$$\exists_{i=1}^{L(X)} i \;\; \exists_{j=1}^{L(X)} j\, (p_{i,1}(X) \neq p_{j,1}(X)) \wedge$$

$$(L(X) \leq 10 \rightarrow$$

$$\forall_{i=1}^{L(X)} i\, (d_{i,1}(X) = d_{i,1}(Y)) \text{ else}$$

$$\forall_{i=1}^{L(X)-1} i\;\; (d_{i,1}(X) = d_{i,1}(Y)))$$

3.5 Overview of Style-Specific Predicate Library

When starting to analyze Mozart's 20 keyboard sonatas in an attempt to discover their characteristics and relations, two issues became clear: First, it was not sufficient to discover only properties that are found consistently in a majority of these sonatas. Properties also had to be included that are likely to be found in no more than a minority of keyboard sonatas by other composers contemporary with Mozart (for example, C.P.E. Bach, Haydn, Clementi, Dussek, and Hummel).

The ISAS system is intended to authenticate Mozart's style not only by distinguishing his sonatas from sonatas written by other composers of his time, but also by distinguishing a sonata that is only 'partially Mozart' from those that are entirely Mozart. Such a work might contain excerpts from authentic Mozart works, but the extracted portions are elaborated and put together by a 'non-Mozart'. Thus, the authentic Mozart passages (which could be quite large) would certainly exhibit various Mozartean properties and statistics, but this would be offset considerably by the non-Mozartean overall design of the work. Excerpts of Mozart, even entire movements, apparently do not work when placed in a foreign context. (Even rearranging the measures of all original Mozartean material produces less artistic, and far less Mozartean, results.)

The second issue that became clear when starting to analyze Mozart's 20 keyboard sonatas was that it was necessary to approach the search for recurring properties (with its wide array of possibilities) from a specific defining perspective. For the ISAS system, this search was deliberately restricted to the perspective of performer and listener as well as computer scientist. The properties found and listed below are those that could be discernible to the educated listener, and felt to be stylistically evident when analyzing the works in preparation for performance. Properties are viewed in terms of their stylistic significance. Segments that possess these properties should be viewed not only as interval patterns, but also in terms of the Mozartean properties that could be heard by the educated listener and felt kinesthetically by the performer. (For example, the cadence at the end of the exposition of Mozart's Sonata in B-Flat Major, K. 281 could also be viewed, for example, in terms of its use in the treble clef with respect to the g-gest property (that is, rounded, graceful gestures such as appoggiaturas, as defined in Subsection 3.6.3).

The keyboard sonatas studied for the ISAS system were further classified within their genre to assure a reasonably homogenous sample. Only one of Mozart's sonatas, Sonata in A Major, K. 331, was found not to fit into the homogenous group of the other 19 sonatas. Its first movement is a theme and variations, which is far removed from sonata form. Likewise, of the 62 Haydn keyboard sonatas, Sonatas No. 5 (Hob. XVIII/ 1), 7 (Hob. XVI/11), 52 (Hob. XVI/39), 54 (Hob. XVI/40), 56 (Hob. XVI/42), and 58 (Hob. XVI/48) are not similar to the others. However, even the one Mozart sonata not in the homogenous group can be shown to demonstrate many Mozartean stylistic properties.

The properties in this library of predicates for authentication of Mozart's style have been subdivided into two categories in terms of the stylistic aspects they represent: namely, "positive properties" and "negative properties". Positive properties are characteristics and relations stylistically evident in Mozart's music. However, Mozart's style can be characterized not only by properties present in his music, but also by those that are noticeably absent (though present in music of several of his contemporaries). These properties are termed negative properties. Internal properties is the term used for defined predicates within formulae that help define these style-dependent properties.

In addition, properties can also be categorized in terms of their basic use in identifying style - - namely, segment-defining properties. Basic segment-defining properties are those that help subdivide the work (that is, establish segment boundaries) into labeled subsegments representing its basic, hierarchical structural framework. These are still style-specific in the sense that they represent the composer's own version of a generic form (for example, sonata-allegro form). Also, "group properties" are composite properties that consist of the disjunction of a series of logically related subproperties (for example, property 24, Subsection 3.6.3, which consist of various types of 'g-gestures' ('graceful gestures'). 'Uni-group properties' consist of properties within the same category (for example, rhythm or melody). 'Multi-group properties' consist of properties from a variety of categories (for example, melody and harmony). The property dim_grp (property 17, Subsection 3.6.2) that comprises all properties involving diminution (rhythmic as well as harmonic) is an example of a multi-group property. This kind of property enables observations to be made regarding aspects common to properties categorized separately. Although individual properties in a style-specific predicate library may not necessarily characterize a composer's style, several properties in combination can do so. Some individual properties may carry more weight than others. Also, certain individual negative properties can be helpful in eliminating nonauthentic works if they are consistently absent in sample data.

The following sections contain numerous properties. It is important to note that specific combinations of relatively few of these effectively distinguish Mozart's keyboard sonatas from those of his contemporaries. Were such not the case, we would be in danger of having "overfit" the data[1] (consisting of the keyboard works discussed in Section 4.1). The property list is a pool from which distinct combinations, each of which accomplish the required

[1] (Rothenberg, 1994, 2-4)

distinctions, are formed. The fact that alternative models are effective, if anything, lessens the likelihood that the favorable results are spurious. In fact, Mozart and Haydn are effectively distinguished using few combinations. A few additional and/or different combinations are required to distinguish Mozart from other contemporaries.

3.6 Style-Dependent Predicate Library

The style-dependent predicate library consist of 55 properties. They are described in detail in Subsections 3.6.1 through 3.6.8. These are the properties for the sonata expositions used by the vector tables in Chapter 4. Although the properties are discussed and illustrated with respect to the exposition, they can be adapted with minor modifications to other parts of the sonata. (Vector tables consist of subsets of these properties for various locations of the exposition. The elements of these tables specify the truth values of each of the correspondingly selected properties.) Subsections 3.6.1 through 3.6.8 include, respectively, properties relating to duration, rhythmic pattern, melody, melodic topology, harmony, cadence, texture, and structure. Listeners' identification of works as being by Mozart is strongly related to their melodic content. Thus, there are many properties essential to authenticating Mozart's style that focus on his approach to melodic design. It was interesting to discover, though not surprising, that Mozart's melodies display many of the properties that constitute well-crafted melodies. Most well-designed melodies follow certain basic rules of form, proportion, shape, subdivision, and rhythm. Moreover, well-formed melodies have the proper balance of repetition and variety. The presence of these elements in Mozart's works will be discussed when the pertinent properties are described.

3.6.1 Duration Properties

1) dtyp5(X)

This characteristic is satisfied when a 4- or 8-measure segment contains between three and five different 'duration types' of notes within its uppermost voice (particularly in the opening four or eight measures of the initial theme and of the exposition). An eight-measure segment exhibiting this characteristic should also have between 3 and 5 duration types in its first four and first eight measures. An eighth note would be considered to be a different duration type than a dotted eighth. A sixteenth note which is a part of a sextuplet is also considered to be a different duration type than a sixteenth note. Durations of rests and ornamentation are not included. For example, in the first eight measures of the main melody of Mozart's Sonata in C Major, K. 279, only three different duration types are used (a quarter note, an eighth note, and a sixteenth note). In contrast, Haydn, for example, in his Sonata No. 47, Hob. XVI/32, uses seven different duration types in the opening eight measures. In the first four measures of the main melody of the first movement of his sonatas, Mozart uses no more than five duration types in approximately 95 percent of his sonatas (Appendix A, Tables 1-1A, 1-1B). Haydn, in contrast, uses five or less duration types in this location in approximately 60 percent of his sonatas (Appendix A, Tables 1-3A through 1-3F).

Mozart is selective in his use of a variety of note values in a particular locality (such as the main melody of the first movements), and tends to use a simple, organized set of duration types that is neither excessively small (repetitive) nor large (varied). This characteristic is particularly useful for distinguishing Mozart's sonatas from Haydn's. A considerable number of Mozart's properties exhibit this attempt to establish a balance between variety and repetitiveness (Sections 1.7 and 4.4). Likewise, approximately one-fifth of Clementi's sonatas have opening main themes (first four measures) lacking this property (Appendix A, Tables 1-4A through 1-4C). Similarly, approximately one-fifth of the Dussek sonatas lack this property in the same location (Appendix A, Tables 1-5A, 1-5B). Also, several of C.P.E. Bach's sonatas have initial main themes in the exposition that lack this property. This property is considered to be a positive property.

2) dclss4(X)

This characteristic is satisfied when between three and four different 'duration classes' of notes occur in the uppermost voice of a 4- or 8-measure segment (particularly in the first four measures of the first theme (main theme) of the exposition). An eighth note would be considered to be in the same duration class as a dotted eighth. Likewise, a sixteenth note which is part of a sextuplet, for example, would also be part of the same duration class as a regular sixteenth note. Thus, a duration class groups duration types conventionally notated with the same type of duration. This property does not include the durations of rests or ornamentation (except explicitly written first and last notes of trills).

In the first four measures of the main melody of the expositions of his sonatas, for example, Mozart uses no more than four duration classes in approximately 85 percent of his sonatas (Appendix A, Tables 1-1A through 1-1B). It is interesting to note that the three Mozart sonatas lacking this property have less than the lower limit of three duration classes, rather than a number exceeding the upper limit. In contrast, several of the opening main melodies of the expositions of Haydn's sonatas lacking this property exceed the upper limit of 4 (Appendix A, Tables 1-3A through 1-3F). Thus, Mozart seems to consistently use a compact, organized set of duration types and duration classes in his opening main themes. This property is considered to be a positive property.

3) fd_bt(X)

This characteristic is concerned predominantly with the fine subdivision of a beat into all thirty-second notes or less in the uppermost voice of a one-measure segment when the majority of the segment is not so minutely divided. More specifically, this would include, either: (a) a beat consisting of a sudden tuplet (of thirty-second notes or less), with no other such tuplet in any other beat of the measure; or (b) a beat fully subdivided by notes of duration less than or equal to thirty-second notes, with all other beats in that measure having longer durations; or (c) sporadic use of thirty-second notes or less within a measure for no more than a total of a quarter of a measure's worth (excluding ornamentation). For example, in Haydn's Sonata No. 62, Hob. XVI/52, measure 19, there is a grouping of 10 thirty-second notes ('dectuplet') on beat 1, with no other like tuplets in the remainder of the measure in accordance with definition (a). As an example of definition (b), Haydn's Sonata No. 13, Hob XVI/6, measure 3 has 8 thirty-second notes on beat three and none on any other beat. Moreover, in Haydn's Sonata No. 3, Hob. XVI/9, beats one, two, and three of measure 8 each have only 2 sixty-fourth notes suddenly interspersed, thus illustrating definition (c).

Likewise, in Haydn's Sonata No. 18 (Hob. deest), measures 17 and 18, the dotted sixteenth with thirty-second note figures provide two sudden, sporadic thirty-second notes. Mozart does not generally use this kind of dotted rhythm. The sporadic irregular use of fine subdivisions of a beat give all these segments an abrupt, unbalanced, asymmetrical sound. Mozart rarely has segments with the fd_bt characteristic in his sonatas. To begin with, thirty-second notes are not used very frequently in his sonatas, and are particularly absent in his first movements. His Sonata in C Major, K. 330 and Sonata in B-Flat Major, K. 281 are the only two sonatas with expositions that use thirty-second notes in any noticeable way. However, even in K. 281, a relatively small number of measures exhibit the fd_bt characteristic, with many of the measures with thirty-second notes having at least half a measure of them. This property is considered to be a negative property.

4) 2,4mwt(X)

This segment characteristic ('2,4-based measure with tuplets') represents the clearly perceptible use of 3-based rhythms (for example, triplets, sextuplets) or other tuplets in the uppermost voice (for example, quintuplets or septolets) in the same measure containing '2- or 4-based' rhythms in that voice (for example, a triplet or sextuplet in a measure otherwise consisting of eighth notes, as in Haydn's Sonata No. 8, Hob XVI/5, measure 3). It also includes the occurrence of a measure in which a predominantly 2,4-based melody is supported by a predominantly 3-based bass (lowest voice). This property is satisfied if the number of beats of 2- or 4-based note durations (not including rests) is greater than or equal to the number of beats of tuplet notes (with the number of tuplet notes being greater than zero). For example, Haydn's Sonata No. 47, Hob. XVI/32, measure 23 has an equal number of tuplet and nontuplet beats in the uppermost voice, thus displaying the 2,4mwt property. A sonata that begins with an initial triplet upbeat is also considered to exhibit this characteristic.

In the opening four bars of the main theme of Mozart's expositions, only one sonata (5 percent) exhibits this property (Appendix A, Tables 1-1A, 1-1B). Haydn, in contrast, has segments with this characteristic in the opening four measures in over one-third of his sonatas (Appendix A, Tables 1-3A through 1-3F). Likewise, over one-third of the opening four measures of the Clementi sonatas exhibit this property (Appendix A, Tables 1-4A through 1-4C. Thus, Mozart clearly establishes a measure as either 2-,4-based or 3-based. This imparts greater balance and symmetry to his music. The use of 2-,4-based rhythms with 3-based rhythms, however, can result in less pronounced feelings of expectation in the listener. This could be due to a lesser degree of regular, intelligible pattern and greater rhythmic variety. 2,4mwt is considered to be a negative property.

5) b1_Lrest(X)

This characteristic is satisfied if the first beat (initial downbeat) of the opening measure of the sonata exposition has a rest larger than an eighth-note rest in the bass (followed by one or more notes), or a rest of any duration in this location in the treble clef. (Opening segments with one or more full measures of unaccompanied melody would not be considered as exhibiting this property.) None of the main themes of Mozart's expositions exhibit this characteristic (Appendix A, Tables 1-1A, 1-1B). Only one of Mozart's sonata expositions (K. 533) has a rest larger than an eighth-note rest on beat one of the bass of the opening measure. However, it lacks this property because the bass accompaniment does not start later in the measure, but on beat one of measure 4.

In contrast, the expositions of approximately 30 percent of Clementi's sonatas exhibit this property. The b1_Lrest property is considered to be a negative property. The lack of a bass on beat 1 can contribute to a less grounded, more unbalanced sound.

3.6.2 Rhythmic Properties

6) rep_dur(X)

This characteristic describes the repeated use of a single duration within the uppermost voice of a segment X. Durations in an initial upbeat (that is, the upbeat at the opening of the sonata exposition) and rests are not included.

With respect to half notes in the first eight measures of the sonata exposition, over a measures's worth of half notes could be considered as sounding repetitive. Likewise, segments with two or more measures of quarter-note durations are considered to exhibit the rep_dur characteristic. For example, Haydn's Sonata No. 10 (Hob XVI/1) opens with three full measures of quarter notes, which could be heard as a prolonged use of quarter notes. With respect to eighth notes in the opening four measures of the main melody of the exposition, there should be over one measure of eighth notes in segments exhibiting the rep_dur property, and over two and a half measures of eighth notes if they occur in measures 5 through 8 of the exposition. A segment with just one eighth note more than a measure's worth is excluded if the first eighth note occurs on the last beat of a measure. (For example, in Haydn's Sonata, No. 50 (Hob. XVI/37, the first three and a half measures of the exposition consist entirely of eighth notes.) Eighth-note triplets, when used in the initial eight measures of the main theme, can be considered to exhibit the above characteristic if there is more than one measure of them.

Sixteenth notes are frequently used as 'running' figures. Thus, when they occur in the main theme, there should be over three quarters of a measure of them if they occur in the opening four measures; and there should be over two measures of sixteenth notes in measures 5 through 8 for them to be considered as exhibiting the rep_dur characteristic. (For example, in the main theme of Mozart's Sonata in D Major, K. 284, there are continuous sixteenth notes in measures 7 and 8, which would not necessarily sound repetitive.) With respect to sixteenth- or thirty-second note triplets in the first eight measures of the exposition, segments with over one measure of these triplets display this characteristic. Likewise, segments with over half a measure of thirty-second notes in the opening eight measures of the main theme could also sound repetitive and therefore exhibit this characteristic.

In the first four measures of Mozart's expositions, Mozart has only one sonata with this characteristic (Appendix A, Table 1-1B) This is the one sonata (Sonata in B-Flat Major, K. 498a) whose authenticity is disputed. In contrast, however, Haydn has segments with the rep_dur characteristic in over one fourth of his sonatas (Appendix A, Tables 1-3A through 1-3F). Rep_dur is, therefore, a negative property. Thus, Mozart uses his main theme to present fresh ideas, without an excessive use of repeated durations.

Rhythmic Sequence
Properties

Properties 7 through 12 are rhythmic properties that are concerned with rhythmic sequence in the uppermost voice. Properties 13 through 15 include pitch and rhythmic sequence. A rhythmic pattern is defined in the ISAS system as a series of at least two different durations, at least one of which is a note (excluding ornamentation). Rhythmic sequence is defined as the adjacent repetition(s) of a rhythmic pattern (as opposed to repetition of a single duration discussed in property 6). Ornamentation need not match.

7) <=hmrseq(X,Y)

This relation defines the existence of a "<=half-measure rhythmic sequence". Specifically, it refers to exact repetition of a short half-measure or less rhythmic pattern in an adjacent segment in the uppermost voice (particularly in the opening four measures of the initial theme of the exposition). Rhythmic sequences consisting of rhythmic patterns less than half a measure should have a total duration of at least a quarter note (including all occurrences). A rhythmic sequence with a rhythmic pattern ending with a trailing rest should have a total duration of at least three quarter-note beats, not including trailing rests. (For example, in Mozart's Sonata in D Major, K. 576, end of measure 2 to measure 3, the pattern of a sixteenth note, 2 thirty-second notes, and an eighth note followed by an eighth-note rest is repeated once, but the total duration of the two occurrences is not at least three quarter-note beats. In Haydn's Sonata No. 1, Hob. XVI/8, measures 10 - 11, a pattern of a sixteenth-note triplet and an eighth note is repeated three times, for a total of a measure and a half's worth, thus exhibiting the <=hmrseq property.

In the first four measures of the main theme of Mozart's expositions, only approximately 5 percent of the sonatas having pattern repetition exhibit this type of relation (Appendix A, Tables 1-1A, 1-1B). Haydn, in contrast, uses such short patterns in the first four measures in almost half of his sonatas (Appendix A, Tables 1-3A through 1-3F). Likewise, almost one third of the Clementi sonatas exhibit this property in these measures. Approximately one-fourth of the Dussek sonatas also display this property in this location. Thus, Mozart avoids small, choppy patterns in the main theme, and prefers larger-scale repetition with more global, than merely local, significance. This property is considered to be a negative property in the context indicated.

8) 2mrseqL(X,Y)

This relation is used to describe the use of exact repetition of a two-measure rhythmic pattern in the uppermost voice (segment X) in an adjacent segment

(segment Y) (particularly in the uppermost voice of the opening four measures of the exposition). If the pattern consists of at least 10 notes, the last duration can be shortened or lengthened. Only two of Mozart's sonatas exhibit this property in this location (Appendix A, Tables 1-1A, 1-1B). Exact rhythmic repetition is avoided in the opening themes of Mozart's expositions, particularly with sequences formed from patterns consisting of an even number of measures. This property is considered to be a negative property in the context indicated.

9) <=hmrseqL>2(X,Y,Z)

This relation describes the existence of "> 2 occurrences of a <=half-measure rhythmic pattern". Specifically, it defines the use of at least two exact repeats (in adjacent segments Y and Z) of a half-measure or less rhythmic pattern in the uppermost voice (segment X), particularly in the first theme of the exposition. The last duration of the last repeat of a pattern need not be matched exactly in segment Z if it is a note, and the pattern consists of at least three elements, at least two of which are notes. (An element of the pattern is defined here as a note or rest.) If it contains three such elements, segment Z's last duration can appear lengthened. If the pattern contains four or more elements, segment's Z's last duration can appear either shortened or lengthened.

For example, in Mozart's Sonata in C Major, K. 330, the half-measure rhythmic and melodic pattern at the end of measure 54 (appearing in the Bartok-edited edition as 4 thirty-second notes followed by an eighth note) appears three times in succession. However, the third time it appears (at end of measure 55 through beginning of measure 56), the 4 thirty-second notes are followed by another thirty-second note, rather than an eighth. This does not negate satisfaction of the above relation but still constitutes a pattern match, and reflects the fact that this change in the final duration does not detract from its being heard as a repetition of the pattern. (This is represented by the "L" toward the end of the property name, which refers to the last duration.)

In the first four measures of the main theme of Mozart's expositions, not only are short, half-measure or smaller-size rhythmic patterns used relatively infrequently, but they are not repeated more than once (Appendix A, Tables 1-1A, 1-1B). Likewise, in the first eight measures, only one sonata exhibits this characteristic (Appendix A, Table 3-1B). In contrast, almost 25 percent of Haydn's sonatas exhibit this characteristic in the first four measures (Appendix A, Tables 1-3A through 1-3F). In the first eight measures of Haydn's expositions, 50 percent of the sonatas exhibit this characteristic (Appendix A, Tables 3-3A through 3-3F). Over 20 percent of the Clementi sonatas exhibited this property in the first four measures (Appendix A, Tables 1-4A through 1-

4C), and over 25 percent of them displayed this property in the first eight measures of the exposition. Forty percent of the Dussek sonatas exhibited this property in the first eight measures. Also, several of the C.P.E. Bach sonatas displayed such repetition. This property is considered to be a negative property.

10) 1mrseqL-e(X,Y,Z,W)

This relation describes the existence of an "even number of exact occurrences of a one-measure rhythmic pattern". Specifically, it refers to the fact that segment X consists of a one-measure rhythmic pattern in the uppermost voice that occurs a total of two (segments X and Y) or 4 times (segments X,Y,Z and W) in succession in the opening four measures of the exposition. Thus, the pattern is heard in total an even number of times. (As mentioned previously, a rhythmic pattern is defined as a series of at least two different durations.) If the pattern occurs four times, the last duration of segment W need not match the pattern exactly if it is a note and the pattern consists of at least three elements (at least two of which are notes). If it contains three such elements, segment W's last duration can appear lengthened. If the pattern contains four or more elements, segment W's last duration can appear either shortened or lengthened.

The initial main theme of Mozart's expositions generally contains rhythmic sequences formed from patterns at least one measure in duration. However, one-measure patterns generally do not occur an even number of times. Specifically, they tend to occur three times, which provides an asymmetry within phrases that are usually evenly divided. This property does not occur in the opening four measures of Mozart's sonatas (Appendix A, Tables 1-1A, 1-1B). It occurs in this location in approximately 20 percent of the Clementi sonatas and in one-third of the Dussek sonatas. 1mrseqL-e is considered to be a negative property in the context indicated.

11) rseqL_odd(X,Y)

This relation describes the fact that a rhythmic pattern in the uppermost voice is repeated at least twice in adjacent segment Y, so that it occurs in total an odd number of times. If the pattern consists of at least three elements (at least two of which are notes), its last duration (if it is a note) need not match exactly in the last repeat. If it contains three such elements, segment Y's last duration can appear lengthened in this final repeat. If the pattern contains four or more elements, segment Y's last duration can appear either shortened or lengthened. Only approximately 15 percent of Mozart's sonatas have patterns that are immediately repeated an odd number of times in the opening four measures of the exposition (Appendix A, Tables 1-1A, 1-1B). Thus, Mozart shows a preference for an even, balanced, symmetrical use of repetition in the main theme. This property is considered to be a negative property in the context indicated.

12) 2mrseq_v1i(X,Y)

This relation represents the fact that two adjacent two-measure segments X and Y in the uppermost voice form a variant (nearly-matching) rhythmic sequence with segment Y ('two-measure rhythmic sequence with one variant'). Two segments X and Y are considered to have this property if every note in segment X is rhythmically matched with the notes of segment Y, not including ornamentation (such as grace notes), except for one nonmatching duration. Segment Y can have one more element (note or rest) than segment X. For example, in the opening of Mozart's Sonata in C Major, K. 330, the two-measure segment in measures 1 and 2 is repeated in measures 3 and 4, with one note in the rhythmic pattern of the melody varied, and one added note. (The mismatched note, on beat 1 of measure 1 (an eighth note), is replaced by two sixteenth notes in the following nearly matching segment.) Also in Mozart's Sonata in C Major, K. 545, the first two measures (segment X) of the exposition exhibit the above relation with the following two measures (segment Y). Segment X has only one duration mismatched in segment Y, with segment

Y having one added note not found in segment X (excluding nonwritten trill notes). Although there are often rhythmic sequences in Mozart's transitions, yet even here, there are subtle differences in many of them to add a touch of newness to a repeated phrase. This property is considered to be a positive property.

13) >=1mrpseqL(X,Y)

This relation describes the occurrence of a rhythmic or pitch and rhythmic sequence in the uppermost voice formed from a pattern that is at least one measure long. It also includes pitch and rhythmic sequences formed from a pitch pattern of only one duration type. Segment Y may contain multiple repeats of the pattern. (Pitch sequence is defined as adjacent segments that form successively ascending or descending instances of a pitch and rhythmic pattern. They are either all a second or a third from the preceding instance). It can form a real or tonal sequence. If there are at least three occurrences of a pattern containing three or more elements (at least two of which are notes), the last duration of its last repeat need not match the pattern exactly if it is a note. If it contains three such elements, the last duration can appear lengthened. If it contains four or more elements, it can appear either shortened or lengthened. It also includes a pitch sequence formed from the uppermost note of each beat of segments X and Y. Mozart's expositions generally contain a predominance of larger-scale patterns. For example, larger-scale sequences with dual repetition of both pitch and rhythmic pattern are commonly found in the transition to the second theme of the exposition (the section that enables a shift from the tonic to the dominant key of the second theme). This property is considered to be a positive property in the context of the transition.

14) rpseqL3(X,Y,Z)

This relation is concerned with three adjacent occurrences in the uppermost voice of a rhythmic or pitch and rhythmic pattern that is at least a measure long. It also includes triple occurrences of a pitch and rhythmic pattern consisting of a single duration type. If the pattern contains at least three elements (at least two of which are notes), the last duration of segment Z need not match the pattern exactly if it is a note. If it contains three such elements, segment Z's last duration can appear lengthened. If it contains four or more elements, segment Z's last duration can appear either shortened or lengthened or have a rest substituted for a note. In Mozart's sonatas, in the remainder of the exposition after the first eight bars of his main theme, there are substantial-sized rhythmic patterns (at least a measure long) that occur three times. In contrast, Haydn uses such pattern repetition to a lesser degree. For example, in Mozart's Sonata in G Major, K. 283, measures 16 through 19, the one-measure pattern that starts in measure 16 occurs a total of three times. This is immediately followed by a melodic sequence (consisting entirely of sixteenth notes) in measures 19 through 21 in which the pattern occurs three times.

Again, in measure 31, there is a one-measure rhythmic pattern that occurs three times. Mozart has a predilection for using multiples of two for such musical elements as phrase divisions, and number of rhythmic patterns in his main theme. However, in the remainder of the exposition (for example, in the transition - - Appendix A, Table 5-1), Mozart uses some triple occurrences of patterns, which create a sense of contrast of "three" versus a more symmetrical "four". This property is, therefore, considered to be a negative property in the opening eight measures of the exposition, and a positive property in certain prescribed locations in the remainder of the exposition.

15) prseqL_mx(X,Y)

This relation is used to describe the fact that a segment X forms a real or tonal pitch and rhythmic sequence with an adjacent segment Y in the uppermost voice, particularly in the opening four measures of the exposition. Segment Y can contain one or more repeats of the pitch and rhythmic pattern in succession. All repetitions of the rhythmic pattern are repeated either a second or third above or below the previous instance of the pattern (forming an ascending or descending sequence). This property also includes pitch sequences involving a single duration. The total duration of the pattern and its repetitions should be at least three quarters of a measure (excluding trailing rests). This enables only more substantial instances of pitch and rhythmic sequence to be included. If a pitch and rhythmic pattern consisting of at least three elements (at least two of which are notes) occurs more than two times, the last duration (if it is a note) need not match the pattern exactly in segment Y's last occurrence of the pattern. If it contains three such elements, its last duration can appear lengthened. If the pattern contains four or more elements, segment Z's last duration can appear either shortened or lengthened.

For example, in Haydn's Sonata No. 40, Hob. XVI/25, measure 3 contains two half-measure segments exhibiting the above relation. Likewise, in Haydn's Sonata No. 55/Hob. XVI/41, the opening eight measures have segments exhibiting this relation in many of the measures. Mozart is very judicious, particularly in his melodies, in the use of exact pitch or rhythmic repetition. He frequently makes sure to vary even a note or two to avoid the plodding quality that can be a consequence of exact repetition. In the opening four measures of the exposition, only one Mozart sonata exhibits this characteristic. In contrast, one quarter of the Haydn sonatas exhibit this characteristic. This is considered to be a negative property in the opening four measures of the sonata exposition.

16) ident_pr(X,Y)

This relation represents the fact that two adjacent segments (segments X and Y) in the uppermost voice are identical in pitch and rhythm (particularly in the opening eight measures of the exposition). Ornamentation is not included. The pitch can be transposed to another octave. One note can be shifted to another octave in any direction. The total duration of both segments should be at least one beat. Segment X should contain at least two different pitches. (The r_pitch property, property 20, is concerned with the repetition of a single pitch.) If segment X contains at least 10 notes, the last duration need not match. For example, in Clementi's Sonata Op. 36, No. 3, measures 1 through 8 exhibit the above relation to the segment extending from measures 9 through 16. Moreover, measures 1 through 6 contain two subsegments exhibiting the same relation. Likewise, in Haydn's Sonata No 47, Hob. XVI/32, end of measure 4 through end of measure 6, there are two one-measure segments exhibiting this relation (Appendix A, Tables 1-3A through 1-3F). This property is a considered to be a negative property with respect to Mozart's sonatas.

17) dim_grp(X)

This characteristic is a 'group' property in that it consists of the logical disjunction of three related characteristics involving diminution, namely: dim_sp(X,Y,Z) ('diminution of spacing', property 17a); dim_durv(X,Y) ('diminution of duration', property 17b); and harm_dim (X,Y) ('harmonic diminution', property 17c).

17a) dim_sp(X,Y,Z)

This relation describes the existence of 'diminution of spacing' in the uppermost voice. Specifically, it refers to the fact that a half-measure or greater pattern that ends with a rest (segment X) occurring in a rhythmic sequence with adjacent segment Y is then repeated in part, at least two times in more rapid succession in adjacent segment Z. Specifically, segment Z contains at least two adjacent repeats of an initial or end portion of segment X's rhythmic pattern (with or without the final rest). Thus, there is a diminution of the original spacing between portions of the pattern. The basic intervallic relations of the pattern repeats in segment Z are maintained in modal fashion, with only two possible variations. Also, diminution of spacing can be achieved not only by omission of a rest but also by shortening the durations of the final two notes of the pattern, and/or by omission of a rest at the beginning or end of the pattern.

For example, in Mozart's Sonata in C Minor, K. 457, the pattern of two eighth notes, a quarter note, and two quarter-note rests starting in the second half of measure 30 is immediately repeated in measures 31 through 32, and then three times in rapid succession, without its final rests, at end of measure 32 through measure 34. Also, in the development of this sonata, there are three successive, somewhat overlapping examples of the dim_sp property in measures 83 through 96. For example, in measures 87 through 88, a two-measure rhythmic pattern (the initial measures of measures 83 through 86) is repeated two times in measures 89 through 94. The ending of two quarter notes and a half-note rest of this pattern appears in both measures 95 and 96, and twice in measure 97 without the rest. This creates a sudden acceleration of melodic motion, and adds to the impact of the cadence. (However, the vector tables in Appendix A illustrate use of style-dependent properties only for the sonata exposition.)

Mozart uses segments with this property as a dramatic means to create and increase tension before cadences (which resolve tension.) It is interesting to note the frequent use of triple repetition within the various segments exhibiting this property (for example, property 14, rpseqL3). Mozart uses triple repetition, particularly after the main theme of the sonata exposition (for example, in the transition to the second theme and development), which contrasts with the 2,4-based symmetry of his main themes. The dim_sp property is considered to be a positive property in these contexts. The juxtaposition of two rhythmic, melodic sequences, the second of which is spun from the first, is an example of the careful architectural craftsmanship in Mozart's sonatas.

17b) dim_durv(X,Y)

This segment relation describes the existence of 'diminution of duration' in the uppermost voice. It is a variant version of the dim_sp(X,Y,Z) property (property 17a). A segment Y exhibiting this relation contains over two repeated occurrences of an initial portion of a half-measure or greater melodic and/or rhythmic pattern (or series of repeated durations). The durations of this initial portion, however, have been uniformly diminished and an initial rest can be removed. There can be no more than two intervallic mismatches of segment X's pitch and rhythmic pattern. For example, in the development of Mozart's Sonata in B-Flat Major, K. 333, measures 86 through 91, a pattern of an eighth-note rest, 7 eighth notes ending with two quarter notes (measure 86) then occurs right afterwards several times, with the eighth-note rest and eighth notes reduced to a sixteenth-note rest followed by 7 sixteenth notes. (However, the vector tables in Appendix A illustrate use of style-dependent properties only for the sonata exposition.) Again, as in the previous diminution property, (dim_sp(X,Y,Z), property 17a, this results in an increase in dramatic tension prior to cadence resolution. This is considered to be a positive property in the context indicated.

17c) harm_dim(X,Y)

This relation describes the existence of 'harmonic diminution'. It represents the fact that a half-measure or greater harmonic progression of at least two chord harmonies which occurs at least twice in succession (segment X), is then repeated in part in closer succession at least twice (segment Y). Specifically, segment Y contains at least the initial two chord harmonies of segment X repeated at least two times, with the rate of harmonic progression uniformly diminished. For example, in Mozart's Sonata in A Minor, K. 310, the progression in measure 20 that occurs three times (measures 20 through the first half of measure 21) occurs at twice the rate of harmonic progression in the second half of measure 21. Also, in the development of Mozart's Sonata in C Major, K.330, measures 84 through 85, the half-measure chord progression occurring three times then appears twice with an accelerated rate of harmonic progression. As with properties 17a and 17b, harmonic diminution increases dramatic tension. It is used, for example, at the end of the transition to the second theme and at certain cadential points of the exposition, as well as in the development. It is interesting to note again the use of triple repetition in each of these examples. This diminution property is considered to be a positive Mozartean property.

3.6.3 Melodic Properties

18) lh_mel(X)

This characteristic represents the fact that the treble clef of a segment X contains low-range melodic notes (particularly in the opening four or eight measures of the initial main melody of the exposition). Specifically, it contains one or more lower-range notes below the "a" below middle c. This property also includes the recurrence in the lowest voice of an initial portion of a pitch and rhythmic pattern in the initial melody in the uppermost voice of the segment. This recurrent pattern should be greater than one beat in duration and consist of at least two notes. There should be no more than three intervallic mismatches. Only 5 percent of Mozart's sonatas exhibit this property in the opening four measures of the exposition (Appendix A, Tables 1-1A, 1-1B). This one exception is his Sonata in B-Flat Major, K. 498a, whose authenticity has been disputed. In contrast, 25 percent of Haydn's sonatas exhibit this property (Appendix A, Tables 1-3A through 1-3F). Over 25 percent of the Clementi sonatas and Dussek's sonatas also display this property (Appendix A, Tables 1-4A through 1-4C). This property also is evident in one third of Hummel's sonatas. This property is considered to be a negative property.

19) nonscal,>3(X)

This characteristic describes the fact that a segment in the uppermost voice is not of very narrow range and does not contain a fairly substantial 'running' scalar passage (particularly in the first four measures of the first theme of the exposition). Specifically, a segment X exhibiting this characteristic contains no continuously ascending or descending scalar passages (with at least 4 different scale notes) a half measure or greater in length containing all sixteenth notes or less. (The last note can be an eighth note or greater if it contributes no more than one fourth of the total duration of the scale.) Also, segment X should contain at least two intervals greater than a third (not including the initial upbeat of the exposition). Moreover, the total interval span of segment X should be greater than a sixth. Approximately 90 percent of Mozart's sonatas exhibit this property in the initial theme of the exposition (Appendix A, Tables 1-1A, 1-1B). In contrast, only approximately half of Dussek's sonatas exhibit this property (Appendix A, Tables 1-5A, 1-5B). This property is considered to be a positive Mozartean property. Mozart's melodies avoid fast, running sixteenths which merely ascend or descend. They generally dart up and down, creating 'corners' instead of a generally smooth terrain. Also, his opening melodies generally span at least an octave.

20) r-ptch(X)

This characteristic is satisfied if a segment X in the uppermost voice consists of a single pitch that is repeated at least four times for a total of at least two beats (particularly in the first theme of the exposition). For example, Haydn's Sonata No. 42, Hob. XVI/27, measures 2 through 4, contains two instances of this kind of repeated pitch. Mozart is judicious in his use of such repetition, particularly in the opening initial theme of his exposition. This would, therefore, be considered a negative property with respect to the main theme.

21) diss_span(X)

This characteristic represents the fact that an ascending or descending motion within the uppermost voice of a segment contains an interval of a major seventh or minor ninth (allowing for octave transposition) between two of its notes (particularly in the opening four measures of the exposition). These notes need not be adjacent. Grace notes are not included. It also can include the vertical occurrence of these intervals on beat 1 (initial downbeat) of the opening measure of the exposition. The use of a diminished fifth in the initial upbeat of the exposition (including the first note of beat 1), an initial upbeat longer than one beat, or an initial upbeat in the bass clef also are elements included in this property. This characteristic occurs in the opening four measures in only 5 percent of Mozart's sonatas (Appendix A, Tables 1-1A. 1-1B). This is the one sonata whose authenticity is in dispute (K. 498a). It occurs in almost one-third of Clementi's sonatas (Appendix A, Tables 1-4A through 1-4C). Diss_span is considered to be a negative property in the context indicated.

22) sym_div(X,Y,Z)

This relation describes the fact that a melodic segment, which is at least three measures long (segment Z), contains a melody that can be subdivided evenly into two phrases (segments X and Y). For example, an eight-measure segment might contain 2 four-measure subsegments, or a six-measure melody might contain 2 three-measure subsegments. This subdivision into segments is done primarily in accordance with the basic harmonic, cadential (or cadence-like resolutions), as well as rhythmic structure of the melody. Mozart has a predilection for using main melodies which are 'symmetrically divided', frequently into 2 four-measure subsegments, which, in turn, can be subdivided evenly into 2 two-measure subsegments. This use of even-numbered symmetrical subdivisions creates a sense of balance and stability.

Segments X, Y, and Z exhibit the sym_div property if the following conditions are satisfied: If segment Z is the opening eight measures of the exposition, segment X would end in measure 3, 4 or beat 1 of measure 5 with a harmonic progression that is one of the following - - $V_{(7)}$- I, or rarely, VII - I with VII in inverted position; a progression to the dominant (I- $V_{(7)}$, II - V, IV - $V_{(7)}$); a progression to the IV (I - IV); a series of harmonies remaining on the tonic; or if the exposition is in a minor key, a progression to the VII (as an inverted seventh chord). Segment Y would end in measure 6, 7, or 8 (or the first beat of measure 9) with a progression to the tonic ($V_{(7)}$ - I, IV - I, or VII - I with the VII in inverted form). It can move to the dominant if it is immediately followed by a repeat of at least the first two measures of segment X. Segments X and Y should be the same length.

If segment Z is the opening four measures of the exposition, segment Y would end in measure 3, 4 or beat 1 of measure 5, as described above for segment X. Segment X would end with a progression to the I chord ($V_{(7)}$ - I, VII - I with the VII chord in inverted position), a progression to $V_{(7)}$ (I - $V_{(7)}$), a progression to the II chord (VI - II), a progression to the VI chord (I - VI), or the harmony merely remains on the I chord. Segments X and Y should be the same length.

The sym_div property considers harmonic subdivision of segment Z into phrases to be supported also by any occurrence of rhythmic sequence. If an end subsegment of segment X (not longer than two measures but not including the entire segment) forms a rhythmic sequence with the beginning of segment Y, these segments do not exhibit the sym_div property. If Z is a four-measure segment and the rhythmic pattern of the last or next to last measure of segment Y occurs in the measure that follows segment Y, then segments X, Y, and Z do not exhibit the above property. Likewise, if Z is an eight-measure segment and the rhythmic pattern of the last measure of segment Y is immediately repeated more than once, or the last two measures are immediately repeated, then segments X, Y, and Z do not exhibit the sym_div property.

If the chord progressions mentioned above, which signal the end of a phrase, extend only partially into a measure, then the algorithm for deciding whether to include that measure in the previous subsegment (rather than the next subsegment) is as follows: If the chord progression extends at least half a measure (including rests), and there is no new melodic pattern starting in the first half of the measure, then that measure counts as part of the previous subsegment. For example, in Mozart's Sonata in B Flat Major, K. 333, the progression to the I chord in measure 4 extends at least half a measure. Likewise, the notes of the next melodic pattern start in the second half of the measure. Thus, this measure is included in the first subsegment, resulting in a four-measure initial subdivision of the main melody. In contrast, in Mozart's Sonata in C major, K. 279, the progression to the I chord that occurs at the end of the first phrase is in measure 5. However, another melodic pattern starts at the beginning of measure 5. Thus, the first subsegment is considered as ending in measure 4, with measure 5 as the beginning of the second main-melody subdivision. In Mozart's Sonata in D Major, K. 311, the progression to the I chord occurs in measure 4. However, the melodic pattern that starts in measure 4 starts less than halfway through the measure. Thus, measure 4 is considered the beginning of the next main-melody subdivision.

Almost 75 percent of the opening four measures of Mozart's sonata expositions exhibit the sym_div property (Appendix A, Tables 1-1A, 1-1B). Also, approximately 85 percent of the first eight measures of the first theme of Mozart's expositions are evenly divided (Appendix A, Tables 3-1A, 3-1B). This is in contrast, for example, with Haydn's sonatas, in which only approximately one third of the opening four measures of his main melodies have this property (Appendix A, Tables 1-3A through 1-3F). Only approximately one third of the opening eight measures of Haydn's sonatas display this property (Appendix A, Tables 3-3A through 3-3F). Likewise, approximately one third of Clementi's sonatas exhibit this property in the opening four measures (Appendix A, Tables 1-4A through 1-4C). Only approximately one fourth of those sonatas exhibit this property in the initial eight measures. This property is also evident in only approximately a third of initial four measures of Dussek's sonatas (Appendix A, Tables 1-5A, 1-5B). Sym_div is considered to be a positive property.

23) y-leap(A,S,T,R)

This melodic characteristic describes the existence of a 'yearning leap' in the uppermost voice. Specifically, it is an unexpected melodic leap in a new direction of at least a fifth, which quickly retreats away from that direction with a small (subdued) interval. This characteristic attempts to make tangible the feeling of 'yearning' and longing that can be felt by a listener of Mozart's melodies. For example, measures 1 - 2 and 2 - 3 of Mozart's Sonata in C Major, K. 545 each contain a 'yearning leap'.

Y-leaps give Mozart's sonatas depth, soaring movement, drama, and a feeling of ever-reaching, ever-yearning passion. They shape the melodies into dynamic curves. Y-leap is, therefore, a positive property. Y-leaps can already be found in the opening eight measures (main melody) in over 35 percent of Mozart's sonatas (Appendix A, Tables 3-1A, 3-1B). In contrast, they can be found in the opening eight measures of only approximately 14 percent of Haydn's sonatas (Appendix A, Tables 3-3A through 3-3F). Only 13 percent of Clementi's sonatas exhibit this characteristic in this location. Likewise, only one of C.P.E. Bach's sonatas exhibited this property in this location. With respect to the remainder of the sonata exposition, y-leaps generally can be found much more often in Mozart's sonatas than in those of his contemporaries. Moreover, they can be found in many of Mozart's melodies in genres other than the keyboard sonatas (for example, the opening of the second movement of his Piano Concerto No. 21 in C Major, K. 467, which contains two overlapping y-leaps ("f c a f" and "a f c b-flat"); in the opening of his Symphony No. 40 in G Minor, K. 550; and in the opening of the overture of his opera Don Giovanni ("f# e b a"). The y-leap property is considered to be a positive Mozartean property.

A y-leap consists of an approach note, a springboard note (both preparation notes for the leap), the target note (the note leaped to), and a retreat note. The rules for recognizing a y-leap are as follows:

a) Approach Note

The approach note (A) is a small interval from the springboard note (between a second and a fourth). In this way, the leap which follows stands out more in contrast. (It only moves a fourth if the springboard note is not a strong beat, and the y-leap's duration is at least a measure's worth). The approach note is greater than or equal to a sixteenth note (for example, Mozart's Sonata in F Major, K. 280, end of measure 2). In this way, the leap is not made too quickly (which would detract from its lingering, 'yearning' quality). The duration of the approach note is less than or equal to the duration of the springboard note or target note (so that either the beginning or end of the leap is emphasized rather than the approach note). Thus, the springboard note or target note (the notes on either end of the leap) should always have the longest duration of the y-leap (That is, no other note duration in the leap exceeds this value.) The y-leap's longest note(s) should be on the beat. For example, the leap in Mozart's Sonata in B-Flat Major, K. 570, beginning of measure 4, would not be a valid approach note since the approach note "f" would be the longest of the three notes that follow. These four notes, therefore, do not form a y-leap. There should be no more than one rest after the approach note, and it should be no longer than an eighth in duration. For example, Mozart's Sonata in F Major, K. 332, measure 4 beat 2, with a quarter-note rest after the approach note, does not have a valid y-leap. Otherwise, the longer rest would slow down the building up of momentum and detract from the compelling, 'yearning' quality of the segment.

b) Springboard Note

The springboard note (S) should be greater than or equal to an eighth note in duration. (This prevents the actual jump from springing forth too quickly, thus maintaining the 'yearning' effect for the listener). However, the springboard note can be a sixteenth note if the target note (the note actually leaped to) is greater than or equal to an eighth note (that is, at least, double its value). The target note would therefore be the longest note. Thus, although the leap is initiated in a quick fashion, the note leaped to is longer and compensates for this (for example, Sonata in A Minor, K. 310, measure 8). If this sixteenth-note springboard note is also preceded by an approach note which is also a sixteenth note, that would doubly speed up the start of the leap. Both notes should then be an upbeat (last beat of the measure); the duration of the retreat note should then be greater than or equal to the duration of the target note (which is at least an eighth note), thus slowing the end of the leap; and the leap size should be greater than a sixth (rather than a fifth) to compensate for the initial acceleration. For example, Mozart's Sonata in F Major, K. 280, end of measure 2 to measure 3, has a valid y-leap. In contrast, his Sonata in D Major, K. 284, end of measure 1 (last two sixteenths) to beginning of measure 2 (first two quarter notes), has a leap of a fifth, which combined with the two sixteenths rushing the leap, makes it invalid as a y-leap.

A springboard note can be followed by no more than a quarter-note rest. This can prolong the actual leap, and yet not remove the restless, 'yearning' quality. (Note that the rest after the approach note was allowed to be only an eighth-note rest or smaller, since a longer rest would stop the initial momentum. For example, Mozart's Sonata in G Major, K. 283, end of measure 3 to beginning of measure 4, has a valid y-leap. There should be no more than a total of a quarter-note's worth of rests in a y-leap. The springboard note can be repeated (or tied) several times, as long as the very last time it is repeated, its duration is at least as long as the duration of any of the other repeated notes, and there is no rest between those repeated pitches, which would slow down the momentum of a segment already slowed by repetition. For example, in his Sonata in F major, K. Appendix III, No. 135, end of measure 11 to the beginning of measure 14, the "f" is repeated three times and tied, but the last iteration of the "f" is worth a total of 4 beats, four times the value of any of the other repetitions of the note (quarter notes).

c) Target Note

The actual leap made from the springboard note to the target note (T) must be at least an interval of a fifth. Leaps which are larger than an octave should be considered equivalent to their interval (number of half steps) mod 12. For example, an eleventh should be considered a fourth), since a leap from "c" to the "f" an octave higher can still be heard as a leap from "c" to "f", which is just a fourth. For example, in Mozart's Sonata in G Major, K. 283, end of measure 1 to measure 2, the four-note segment with a leap of a tenth is not considered a valid y-leap. The leap must be in the opposite direction of that of the first two notes of the potential y-leap.

Moreover, the target note (the note leaped to) should be greater than or equal to an eighth note. However, it can be a sixteenth note if the springboard note is on the beat, and the springboard note preceding it is at least an eighth note (that is, at least double its value). (For example, Mozart's Sonata in C Major, K. 279, measure 22, has a valid y-leap and the shorter duration of the sixteenth-note leap note "b" is compensated for by the springboard note "d", which is an eighth note.) The longer springboard note slows down the leap, thus maintaining the 'yearning quality' for the listener. The target note can be followed by a rest if it is no longer than a quarter-note rest. (For example, Mozart's Sonata in F Major, K. Anhang III, No. 135, measure 73 to the beginning of measure 75, has a valid y-leap.) The target note can be repeated only once (as in the Sonata in F Major just mentioned above). Otherwise, the retreat from the leap, which is also an important contributor to the 'yearning quality', will be slowed down. If there is both a repeated target note and a rest (which both prolong the leap and delay its resolution), the total duration of both should be no more than a quarter-note's worth. Otherwise, the retreat will be delayed too long, again removing the 'yearning' quality.

d) Retreat Note

The retreat note (R) must be greater than or equal to a thirty-second note. This retreat note should move in a direction opposite to that of the leap that precedes it. The interval between the target note and the retreat note should be either a second or a third.

The y-leap should only have rests between one pair of notes, and should not contain any triplets. Also, the y-leap should have a total duration greater than a quarter note.

24) g-gest(X)

This characteristic describes the existence of 'graceful gestures' (g-gestures) in the uppermost voice of segment X. In the course of analyzing Mozart's sonatas for the ISAS system, it was found that his melodies have a considerable number of 'graceful gestures'. G-gestures are small, slower, more rounded, gentle approaches toward a destination note occurring in the uppermost voice. A performer might approach playing these g-gesture segments with a gentle wrist motion. They include, for example, standard appoggiaturas, accented passing tones, as well as other gestures more uniquely characteristic of Mozart. These are, therefore, positive properties. This characteristic attempts to make tangible some of the gentle, refined grace heard often in Mozart's melodies. Mozart's music embodies civility and courtesy in musical garb.

For example, in the first eight bars of the main themes of Mozart's sonatas, there are g-gestures in almost 85 percent of the sonatas (Appendix A, Tables 3-1A, 3-1B). In contrast, only 31 percent of Haydn's opening main themes have any g-gestures (Appendix A, Tables 3-3A through 3-3F). Only approximately 17 percent of Clementi's sonatas exhibit this characteristic in the same location (Appendix A, Tables 3-4A through 3-4C). Likewise, only approximately 20 percent of Dussek's sonatas (Appendix A, Tables 3-5A and

3-5B), and only one of Hummel's sonatas (Appendix A, Table 3-6), exhibit this characteristic in this location. G-gestures generally are found more often in Mozart's expositions than in those of his contemporaries. Mozart clearly seems to have a greater predilection for use of segments with the g-gesture characteristic. It is, therefore, a positive property.

All g-gestures should have notes with durations of at least a sixteenth note (with the exception of the first note, which can be a thirty-second note), but no longer than a half note. Otherwise, the segment will either sound too sharp-edged (if it has several thirty-second notes) or too slow-moving (if, for example, it has dotted half notes) to sound like 'graceful gestures'. They should not consist entirely of sixteenth notes. They should not contain only rests in the bass clef. G-gest is a 'uni-group property' (Section 3.5) that consists of several properties representing types of g-gestures. G-gestures frequently involve the use and resolution of dissonance. They generally can be organized into two categories: those which are 'on_beat gestures' (properties 24a-1 through 24a-6); and those that are 'rounded gestures' (properties 24b-1 through 24b-4).

24a) On_bt_gest(X)

All 'on_beat' gestures are three- or four-note gestures. The second note should occur on a strong beat, with at least one note sounding beneath it in the bass clef at some point in its duration. In addition, the second note should be at least an eighth note (with the exception of the aptr_r subproperty (property 24a-6i)). The total duration of the gesture should be at least a half measure but less than one measure in duration. (If the meter is 2/4, it can be a measure in duration.) At least two of the gesture's notes should have 'full-chord harmonies'. That is, they have harmonies containing all three notes of a chord's notes, or at least three out of four of a seventh chord's notes, which are not necessarily heard simultaneously.

24a-1) apg-d(X)

A segment exhibiting this characteristic has an appoggiatura in its melodic line. Specifically, it has an initial skip (usually a third) to a note that is dissonant with the resolution chord, which then resolves by step in the opposite direction. It consists of an approach note, an appoggiatura note (the dissonant note which is on the beat), and a resolution note. The approach note is at least a thirty-second note, and the other two notes are between an eighth and a half note in duration. The appoggiatura note should be greater than or equal to the approach note. For example, in the opening of Mozart's Sonata in D Major, K. 576, at the end of measure 7 through the beginning of measure 8, there is a segment exhibiting this characteristic. Likewise, in the opening of Mozart's Sonata in C Major, K. 279, there are segments with this characteristic starting on the second half of beat 2 in measures 5, 6, and 7. The fact that the nondissonant note shies away, usually only an interval of a third from the starting note, and then turns around stepwise for resolution of dissonance, creates a rounded motion that contributes to the sound of leisurely gracefulness repeatedly evident in Mozart's sonatas.

24a-2) apg-v(X)

This characteristic is a variant form of the above subproperty (subproperty 24a-1). A segment X with this characteristic has all the attributes of subproperty 24a-1, with the exception that the note after the approach note (the second note) does not create a dissonance with the harmony beneath it. Also, the third note ('resolution note') can be the seventh of a dominant seventh harmony. (For example, in Mozart's Sonata in B-Flat Major, K. 570, end of measure 4 through beat 1 of measure 5, there is a segment with this characteristic).

24a-3) p-apg(X)

A segment X exhibiting this characteristic contains an appoggiatura in which the dissonance is "prepared for", since the note that creates the dissonance appears an extra time right before it. Thus, it comes as no surprise. The approach note therefore has the same pitch as the following appoggiatura note, which then resolves by step. The appoggiatura note is dissonant with the harmony below it. It is at least an eighth note, with a duration greater than or equal to that of the approach note. (If the gesture starts on the last beat of the measure, the approach note can be the longest note.) For example, in Mozart's Sonata in B-Flat Major, K. 333, end of measure 4 through beat 1 of measure 5, there is a segment exhibiting this characteristic. The delayed resolution of "d" going to "c" contributes to a more gracious sound.

24a-4) p_apgv(X)

This is a variant version of the p-apg characteristic (property 24a-3). This g-gesture has the same basic melodic motion described for that property. However, the second note does not create a dissonance with the harmony beneath it. For example, in Mozart's Sonata in B-Flat Major, K. 332, end of measure 9 through beginning of measure 10, there is a segment exhibiting this characteristic.

24a-5) p_apgr

This characteristic is a variant of the p_apg subproperty described above in property 24a-3. However, it ends with a repeat of the note to which it resolves (resolution note). For example, in Mozart's Sonata in G Major, K. 283, end of measure 5 through beat 2 of measure 6, there is a segment exhibiting this property. The juxtaposition of a standard or variant prepared appoggiatura with a repeat of the resolution note at the end of a segment gives an added gracefulness to the segment.

24a-6) apt-v(X)

This 'uni-group property' (Section 3.5) consists of properties involving an accented passing tone. An accented passing tone consists of three stepwise-moving notes: a starting note, a passing tone that is on the beat, and a resolution note. It consists of the following two subproperties (subproperties 24a-6i through 24a-6ii).

24a-6i) aptr_r(X)

A segment X exhibiting this characteristic can have a passing tone on the beat if the note it moves stepwise to (the resolution note) is immediately repeated. The duration of the passing tone can be a sixteenth note (unlike the second note of the other 'on_beat gestures' - - properties 24a-1 through 24a-6). The repeat note should be at least as long as the other notes. For example, in Mozart's Sonata in F Major, K. 332, end of measure 3 through measure 4, there is a segment with this characteristic. Unlike other 'on-beat' gestures, its maximum total duration is one measure. The requirement of a repeated note (either of the passing tone or the note to which it resolves) adds a graceful shape to the segment, creating a slower, gentler descent. These graceful gestures are characteristic Mozartean touches.

24a-6ii) apt-chr(X)

A segment X exhibiting this characteristic is a 'chromatic accented passing tone'. This segment consists entirely of half-step motion. For example, in Mozart's Sonata in D Major, K. 311, beat 2 through beat 3 of measure 19, there is a segment displaying this property. This use of a single chromatic note is evident in Mozart's sonatas. The gentle half-step chromatic motion in an otherwise nonchromatic unstepwise measure adds a graceful sound to the measure.

24b) rounded(X)

This 'uni-group' property (Section 3.5) consists of four different g-gesture subproperties that create circular or other rounded melodic motions. It consists of the following subproperties (properties 24b-1 through 24b-4).

24b-1) circle(X)

This characteristic describes a melodic segment in which the notes move up or down between a third and a sixth, and then circle back stepwise to the starting note (or the note just after the starting note), thus creating a circular motion. Only one interval can be larger than a second. The first note should be at least a dotted eighth. It should be the longest note and occur on the beat. Otherwise the circling motion would start off too quickly. This is followed by at least two sixteenth notes. This circular motion should be less than a measure in duration. (The term "gesture" implies a certain brevity in duration.) Otherwise, the motion would sound more prolonged, and less like a short, graceful gesture. Moreover it should not consist entirely of notes of the same duration, which gives a more plodding, 'walking', less graceful effect. For example, in Haydn's Sonata, No. 59, Hob. XVI/49, measure 21, the motion from "e" to "e" which takes an entire measure, is too long to be a circular gesture.

In Mozart's Sonata in C Major, K. 545, measure 14, beats 2 through 4, there is a circular motion that starts on "g", rises stepwise up a third, and then returns to the initial "g". Likewise, in measure 2 of the same sonata, there is a segment with this characteristic, in which a brief rise to "d", starting on "b", circles back to "c". The initial note can be repeated once. For example, Mozart's Sonata in C Major, K. 545, second movement, measure 15 illustrates this. In its second movement, which could be considered by some listeners to sound 'quintessentially Mozart', the opening sixteen measures begin and end with a circular gesture.

24b-2) shy_awy(X)

This characteristic represents a g-gesture in which there is a quick, upward, stepwise shying away from an initial note before proceeding downward in the other direction in a stepwise 'walk' spanning at least a perfect fifth from the initial note. The first note should be at least an eighth, followed by all sixteenths. The entire gesture occurs within the same measure. For example, in Mozart's Sonata in F Major, K. 280, measure 2, the progression of "c" down to "f" is initially shied away from when the starting note first goes up to "d" before proceeding down to "f". The brief, hesitant circling motion at the beginning of this segment gives it a gracious sound. (This property can also include a gesture in which an eighth note is followed by two sixteenth notes and two quarter notes.)

24b-3) shy_awy_tr(X)

This characteristic represents a circling, 'shying-away' motion up an interval of a fifth from the direction of a downward, stepwise resolution in the uppermost voice. After this shying away by the second note,, it retreats back this fifth, a third at a time, spelling out the II triad using a triplet. It then proceeds stepwise straight downward a third, ending with a gentle retreat back a second. For example, in Mozart's Sonata in F Major, K. Anhang III, No. 135, starting at the end of measure 57, the resolution that goes from ""d" to "c" is initially shied away from with a leap of a fifth, after which it retreats back with a triplet triad as defined above. This segment clearly exhibits this property. The circling motion, coupled with the appearance of a triplet with its round contour in this context, contributes to a graciousness of sound that is characteristically Mozartean. Segments with this characteristic often appear at cadential points.

24b-4) shy_awy_chr(X)

This characteristic is a variant form of the above shy-awy property (property 24b-2). A segment with this characteristic detours a fifth from its intended downward direction by first stepping through the chromatic note a half step below that fifth. There is no triplet used in the triadic descent. For example, in Mozart's Sonata in F Major, K. Anhang III, No. 135, starting at the end of measure 62, there is a segment exhibiting this property.

25) red_dest(X,Y,Z)

This relation is concerned with the fact that two adjacent melodic segments in the uppermost voice (segments X and Y) which subdivide the melody contained within segment Z into two phrases, have the same 'destination notes'. (Segment Z is at least three measures long. For example, an eight-measure segment may contain 2 four-measure phrases or 2 three-measures phrases.) Destination notes are considered to be those notes occurring on strong beats of the last measure of the phrase that are harmonic with the phrase's final harmony (unless the notes are delayed one beat by nonharmonic motion). The destination note need not be in the same octave. With respect to the opening four measures of the exposition, if the pitch of the destination note of the first phrase (segment X) is identical (within octave transpositions) to that of the second phrase (segment Y), then these segments exhibit this relation. If segments X and Y are melodically and rhythmically identical or similar, the above condition can be ignored.

With respect to the opening eight measures of the sonata exposition, if the pitch of the destination note of the first phrase (segment X) is identical (within octave transpositions) to that of the first note of the second phrase (segment Y), then these segments also exhibit the red_dest relation. The basic melodic subdivisions are determined according to basic harmonic structure and the occurrence of rhythmic sequence in a manner similar (but not identical) to that in the sym-div property (property 22). If at least the first 1-1/2 measures of the second phrase (segment X) are identical to the first phrase in rhythm and intervallic relations (two intervals may vary), 'redundant' destination notes can be ignored. Also, if ellision occurs (that is, if the last note of segment X is also the first note of segment Y), the two segments do not exhibit the red_dest property. This property is considered to be a negative property.

3.6.4 Melodic-Graph Properties

The following melodic properties are useful for describing the topology of Mozart's main themes. It was found, in the course of doing analysis for the ISAS system, that Mozart's main themes tend to have a characteristic topology, which tends to make them distinct from, for example, Haydn's main themes. Graphs were then designed so that the topology of Mozart's sonatas could be visually inspected and compared with that of sonatas of his contemporaries (particularly, Haydn). A Cartesian graph was created in which the x-axis represents quarter-note beats, and the y-axis represents the scale notes of the particular key of the melody. (See Figures 1-1 through 1-10.) (The only exception is that a melody with a time signature of 6/8 is graphed with an x-axis representing dotted quarter notes.) Only the initial and final (written) notes of a trill are included in the graph.

It was found helpful to describe the topology of Mozart graphed themes in terms of mountainous shapes, peaks, and valleys. Analysis of Mozart's main melodies, done while developing the ISAS system, revealed a characteristic breadth of shape in the form of sweeping mountains and dynamically changing peaks and valleys. The Mozart graphs show a regular occurrence of smooth-sloped, relatively broader-based mountains which are not crowded together. This gives his melodies a soaring, expansive sound, and dynamic momentum as the melodies gradually rise and fall from changing peaks and valleys (Appendix B). Haydn's graphs of the beginning of his main themes show a quite large occurrence of irregular shapes, with narrow spires rather than broad-based mountains. The slopes are often not smooth, and the rises and falls are frequently crowded together, causing peaks and valleys to occur too closely spaced. The melodic graph properties listed below were designed to help interpret those graphs.

Property 26 below, mt_reg(X,Y,Z,W), is a style-dependent melodic-graph property. Properties 26a through 26e are 'internal properties' used in its definition. (Internal properties are properties that aid in defining style-dependent properties, but appear only within formulae. Properties 27 through 29 are additional melodic-graph properties.

26) mt_reg(X,Y,Z,W)

This melodic-graph property describes the existence of at least two 'regular, broad mountain' shapes formed by four adjacent segments in the uppermost voice (regb_mt, property 26a, defined below). This property was used predominantly to distinguish Mozart keyboard sonatas from Haydn keyboard sonatas. Almost 75 percent of Mozart's sonatas have more than one regular, broad mountain segment in the graphs of the first four measures of their exposition's main theme. In contrast, only 23 percent of Haydn's main-theme segments display this characteristic. Mozart shapes his main melodies with more sharply defined peaks and valleys, with new peaks often expanding what was formerly the highest note, and new valleys often expanding what was previously the lowest note. This contributes to the feeling of expansiveness that can frequently be heard when listening to Mozart's melodies. This property is considered to be a positive property.

26a) regb_mt(X,Y)

This internal property is used to define property 26 above (mt_reg(X,Y,Z,W). It describes the topology of the broad, open, mountainous shape found frequently in the graphs of the main themes of Mozart's sonatas (particularly the opening main theme). A 'regular broad mountain' is formed from two basically smooth slopes (adjacent segments X and Y), at least one of which is a 'long direct span' (property 26b, L_dspan). The other slope is similar to a long direct span except that it need not have a total span of a perfect fifth. It should have a peak that is at least a sixteenth note in duration (as defined in property 26c, m_peak).

However, a regular broad mountain can have one nonsmooth slope if the mountain has a base width of over four beats, and the nonsmooth slope is a scalar-type sequence in which alternate notes form ascending scales a second apart. For example, in the graph of the opening of Mozart's Sonata in C Major, K. 279, there is a visible mountainous shape between beat 1 of measure 1 and the first half of beat 3 of measure 2. The leftmost slope, though not smooth, is an upward, running scalar pattern. This regular pattern can be heard as a smooth rise to a peak, and the rise and fall are heard to take place gradually during a period of almost three beats. Also, a regular broad mountain can consist of only one descending slope, instead of one ascending and one descending slope, if it occurs at the opening of the sonata exposition (for example, Mozart's Sonata in B-Flat Major, K. 533, Appendix B, Figure 1-5).

The width of the base of the mountain should be at least two quarter-note beats, within one thirty-second note. (Width is measured in terms of the number of beats from the beginning of the segment to the 'struck beat' of the last note of the segment.) Thus, in the melodic graph of the first four measures of Mozart's Sonata in F Major, K. 332, there are two regular mountain subsegments: the subsegment from measure 1 through measure 2, and the subsegment from the end of measures 2 through 4. (Appendix B, Figure. 1-1).

Moreover, the upper part of the mountain shape in the melodic graph should be of sufficient width and not be a thin spire (property 26d, spire). This means that there should not be an ascent and descent of a third or more within approximately a half beat before and after the peak. Otherwise, the peak is reached or left too suddenly. Thus, in Mozart's Sonata in B-Flat Major, K. 333, segment starting on the "and" of beat 3 of measure 1 through end of measure 1, there is an ascent and descent of a fourth a half beat before and after the peak (appearing as a thin spire). Also, in the opening of Haydn's Sonata No. 8, Hob. XVI/5, end of measure 1 through beginning of measure 2, there is an ascent and descent of a third a half beat before and after the peak

(Appendix B, Figure 1-6). Also, the slopes should not contain a plateau. Specifically, they should not contain the same pitch repeated for at least 2-1/2 half beats (property 26e, plateau).

26b) L_dspan(X)

This internal property is used to define property 26, mt_reg. It describes the existence of an ascending or descending melodic line (segment X) that moves smoothly towards its peak (highest point) or valley (lowest point). (It can include steps, skips or repeated pitches.) There should be no more than a quarter-note's worth of rests within a 'long direct span', and at least twice as many beats of notes as rests. This keeps the melodic flow within a direct span from being substantially interrupted. For example, in the melodic graph of the opening four measures of Haydn's Sonata No. 60, Hob XVI/50, beats 1 through 3-1/2, many of the slopes do not have at least twice as many notes as rests. Therefore, the majority of the slopes are not 'long direct spans'.

Moreover, a segment with the L_dspan characteristic should rise or fall at least an interval of a perfect fifth, since these segments will be used to form the slopes of mountainous shapes. For example, in the melodic graph of the first four measures of Mozart's Sonata in C Major, K. 545 (Appendix B, Figure 1-4), four of the slopes are 'long direct spans'. In contrast, in the melodic graph of the opening of Haydn's Sonata No. 20, Hob XVI/18, there are no 'long direct spans' in the first four measures of the exposition's initial main theme.

26c) m_peak(a_i(x))

This internal property is used to define property 26, mt_reg. A note is a melodic peak if it is the highest note of a rising motion in the uppermost voice (segment X) or the high ridge of a descending melodic motion. The peak, or the sum of the durations of the peak and one of the other end points of the peak, should be greater than a dotted eighth-note's worth. If the peak note is repeated immediately afterward, the sum of the two durations (that is, its composite duration cdur(X), Section 3.4) is used. Otherwise, the move toward or away from the peak, and/or the peak itself, may feel rushed, and ungrounded. The peak note (or its composite duration) should be at least a sixteenth note. For example, in the melodic graph of the first four measures of Mozart's Sonata in B-Flat Major, K. 333, at the end of measure 2 through the middle of measure 3, there is a long direct span which extends an interval of a seventh, from a peak of "g" down to "a". The "g" on the "and" of beat 3 is a valid peak because it is the highest note of a descending direct span, and the duration of one of the other end points of the span added to the peak's duration results in a total duration greater than a dotted eighth-note's worth.

In contrast, in the melodic graph of the initial four measures of the main theme of the exposition of Haydn's Sonata No. 1, Hob. XVI/8, there is only one span within this segment with a peak of sufficient duration in measure 2, since the high-point notes and the end points of the other spans are all of too short duration. (However, as indicated in the next paragraph, there is a note higher than this peak within one beat.)

New melodic peaks should be at least 1-1/2 beats apart. The peaks in Mozart's main-theme graphs for the exposition generally are quite a bit wider apart than this minimum. For example, in the opening of Haydn's Sonata No. 34, Hob. XVI/33, the high point "a" at the end of the direct-span upbeat segment and the high point "d" on beat 2 of measure 1 are too close to each other to have the m_peak characteristic. The stately grace and dramatic expansiveness evident when listening to Mozart's main themes is created in part by the occurrence of frequent though cleanly spaced gradual peaks. In this way, one can clearly hear, with each peak, the soaring toward fresh melodic territory. Also, there should be no note higher than the peak note for at least one beat. In this way, the peak note is heard clearly in a well-defined fashion as the highest note. For example, in Haydn's Sonata No. 8, Hob. XV/5, the "a" which is the peak of an ascent in measure 2 is followed within less than a beat by a higher note ("b"). This can be seen on the melodic graph (Appendix B,

Figure 1-6) as a mountain with an additional rising slope close enough to make the mountain seem more like a narrow pass.

26d) spire(X,Y)

This internal property is used to describe the fact that a mountainous shape in the melodic graph formed from two adjacent segments X and Y in the graph is topped with a thin spire shape. A spire is formed when there is a an ascent and a descent of at least an interval of a third within a half beat before and after the peak of a slope is reached. For example, Haydn's Sonata No. 8, Hob XVI/5, measure 1 through the first half of measure 2 is a segment that has a peak and a large enough base width (greater than or equal to 2 beats). However, it is topped with a narrow spire, and thus cannot be a regular broad mountain (Appendix B, Figure 1-6). Mozart's sonata expositions have very few opening main themes with segments that are broad but have narrow spires. In contrast, the melodic graphs of the main themes of Haydn's expositions have more segments with this characteristic.

26e) plateau(X)

This internal property is used to describe the use of the same pitch repeated for 2-1/2 beats or more within a slope (segment X). Such a plateau slows down the sweeping momentum of a melody. For example, in Haydn's Sonata

No. 47, Hob. XVI/32, second half of measure 2 through the first half of measure 3, there are four "f sharps" which form a plateau, clearly discernible visually in its melodic graph.

27) pkpt>2(X)

This characteristic describes the fact that a melodic segment (segment X) has more than two peak-point notes (particularly in the opening four measures of the sonata exposition). A peak-point note is defined as a note that forms the highest point of an ascent. If there is an adjacent ascent to the same note, it is not considered a new peak point. (This property does not include notes that are part of the initial upbeat of the exposition or ornamentation.) The first note of the sonata exposition can be considered a peak-point note if it is not the opening upbeat and is the highest point of a descending line. (For example, the initial "c" in Mozart's Sonata in F Major, K. 533 would not be a peak-point note.) The segment should contain the 'full corner' of the peak. That is, it should contain at least one note of the peak's ascent and descent. Also, if the segment contains a pitch or pitch and rhythmic sequence of all sixteenth notes or less (same-duration sequence), only one of those notes can be considered a peak point.

This property reflects the presence of multiple changing peaks in the initial main melody of Mozart's expositions. For example, in Mozart's Sonata in C

Major, K. 545, there are four peak-point notes: "g", "d", "a", and "c" (Appendix B, Figure 1-4). Likewise, in Mozart's Sonata in B-Flat Major, K. 333, there are five peak-point notes. In contrast, the opening four measures of Haydn's Sonata No. 14, Hob. XVI/3 (also in C Major) do not exhibit the pkpt>2 property. Likewise, Haydn's Sonata No. 10, Hob XVI/1 (in C Major), lacks this characteristic, since it has only one peak-point note. In addition, Clementi's Sonata Op. 36, No. 3, opening four measures, also have only one peak-point note. Melodies with this characteristic, in conjunction with some of the melodic properties listed below, tend to sound more 'straight line' and one-dimensional, with less darting motion and corners. This property is considered to be a positive property in the contexts indicated.

28) y-pks(X)

This characteristic describes the fact that there is a noticeable rising (or at least, a balance of expansion and contraction) of successive 'peak-point notes' within a segment X in the uppermost voice (particularly in the opening four measures of the sonata exposition). (Peak-point notes are defined as in pkpt>2, property 27 above.) More specifically, the total number of times a peak-point note is higher than the one preceding it, is greater than or equal to the number of times it is lower than the one preceding it. One of these values must be greater than zero. Segment X can include initial upbeat notes (that is, the upbeat at the opening of the exposition). Ornamentation (for example, grace notes) are not included. The segment should contain the 'full corner' of the peak. That is, at least one note of its ascent and descent must be present in the segment. If the segment contains a pitch or pitch and rhythmic sequence of sixteenth notes or less (same-duration sequence), only one of these can be considered a peak point. The term 'yearning peaks' (which the abbreviated property name y-pks represents) is used to describe this expansion of peak points. It attempts to make tangible, in property form, the feeling of 'yearning' and reaching toward ever-expanding boundaries that can be evoked in both the listener and performer of Mozart's music. For example, in the initial four measures of Mozart's Sonata in C Major, K. 545, there are two adjacent rising peak points and one descending peak point (Appendix B, Figure 1-4). This contributes to a sense of expansiveness evoked by the melody. Likewise, in the initial four measures of Mozart's Sonata in F Major, K. 533, there are three risings of peak points and three descents of peak points (Appendix B, Figure 1-5). This balance of rising and falling peak points gives the melody a sense of balance, and expansion outward and downward.

Only approximately 10 percent of the opening main themes of Mozart's 19 sonatas lack this characteristic (Appendix A, Tables 1-1A, 1-1B). In contrast, approximately 40 percent of the opening four measures of Haydn's sonata expositions lack this characteristic (Appendix A, Tables 1-3A through 1-3F).

Likewise, over half of Clementi's sonatas lack this characteristic in this location. Thus, y-pks is considered to be a positive property.

29) mv_valley(X)

This characteristic represents the presence of at least three 'valleys' within the uppermost voice (particularly in the opening four measures of the sonata exposition). A valley is considered to be the lowest note of a descending line and its adjacent ascending line. Notes in the initial upbeat of the exposition are not included. (If there is an adjacent descent to the same note, it is not considered a new valley.) Segment X must contain the complete descent toward and ascent from those valleys. This enables the depth of each valley to be heard within the segment. The first note of an ascent at the very beginning of the exposition would not be considered to be a valley. If the segment contains a pitch or pitch and rhythmic sequence of sixteenth notes or less (same-duration sequence), only one of those notes can be considered to be a valley.

For example, in the opening four measures of Mozart's Sonata in B-Flat Major, K. 333, there are five different valleys. In contrast, in Haydn's Sonata No. 42, Hob. XVI/27, the opening four measures of the exposition constitute an essentially 'straight-line' melody with only one peak point and no valleys. It therefore lacks the mv_valley characteristic. Also, in Haydn's Sonata No.

10, Hob. XVI/1, there is only one valley, which recurs one measure later. Thus, this property is considered to be a positive property.

3.6.5 Harmonic Properties

30) est_tp(X)

This characteristic captures Mozart's predilection for strongly and clearly establishing the tonic pitch in the opening melody of the exposition (segment X) on beat 1 (or occasionally on the "and" of beat 1), with a duration greater than or equal to a dotted eighth by measure 2 (with the tonic harmony in the bass clef). If the tonic is repeated immediately afterward in the same or another octave on beat 1 or 2 (for example, Mozart's Sonata in B-Flat Major, K. 333), the duration of the tonic is considered to be the sum of these repeated notes (their 'composite duration', cdur(X), Section 3.4). Mozart strongly establishes the tonic pitch in over 70 percent of his sonatas (Appendix A, Tables 1-1A, 1-1B), whereas Haydn demonstrates this property in less than half of his sonatas (Appendix A, Tables 1-3A through 1-3F). Mozart clearly begins to establish a groundedness and sense of tonal center from the very start. Clementi, likewise, exhibits this property in less than half of his sonatas (Appendix A, Tables 1-4A through 1-4C). Thus, this property is considered to be a positive property.

31) est-I(X)

This characteristic refers to the strong establishment of all three notes of the root-position tonic chord by the first half of the opening measure of the sonata exposition (segment X). At least one of those notes should have a duration greater than or equal to a quarter note. If the chord note is repeated immediately afterward, the sum of those two durations may be used (composite duration, Section 3.4). The harmony should last at least 1-1/2 beats. The chord notes need not be struck simultaneously. They can also be formed from an Alberti bass or series of broken thirds which, in combination with notes in the upper voice, establish the root-position tonic chord (for example, Mozart's Sonata in C Major, K. 545, and Mozart's Sonata in C Major, K. 330). It can also be a horizontally "spelled-out" chord in the uppermost voice with adjacent notes or using every other note (as in Mozart's Sonata in F Major, K. 533). It will be considered root position if an ascending horizontal spelling starts with the tonic on beat 1, or if the lowest note of a descending chord spelling is the tonic. A full spelling of the root-position tonic chord using some initial grace notes is permissible (as in Mozart's Sonata in C Major, K. 309). One of the three notes can be an initial upbeat note if its duration is one beat or less.

The est-I characteristic occurs in over almost 75 percent) of the expositions of Mozart's sonatas (Appendix A, Tables 1-1A, 1-1B). In contrast, Haydn strongly establishes a full tonic chord in less than one third of his sonata expositions, giving many of them an initial less substantial texture (Appendix A, Tables 1-3A through 1-3F). Likewise, only approximately 35 percent of Clementi's sonatas exhibit this characteristic (Appendix A, Tables 1-4A through 1-4C). Almost half of Dussek's sonatas also lack this property. Moreover, over 80 percent of Hummel's sonatas have a similar lack. Thus, this property is considered to be a positive property.

32) h_yleap(X)

This characteristic describes the fact that a segment contains what is designated in the ISAS system as a 'harmonic y-leap' (harmonic yearning leap). A segment X contains a harmonic y-leap if the initial harmony of the segment moves (leaps) at least five chord steps to the next harmony (leap chord), and then moves to a chord closer to the initial chord (for example, a progression from I to V to I). This leap should occur by the first half of measures 2 of the sonata exposition. Otherwise, the leap chord is too far from the initial chord to retain a sense of striving away from it. The notes of the leap chord (which need not be simultaneous) should include the root, third, and fifth of a chord, or at least three out of four notes of a seventh chord. This enables the leap chord and its relative relation to the first chord to be heard clearly by the listener. The leap chord's harmony should last at least half a measure. However, it can be a quarter of a measure if it occurs on the last beat of the measure (for example, Mozart's Sonata in C Major, K. 330, measure 1). In this way, it is substantial and yet not too long to detract from its evoking a sense of yearning for the listener. Also, it should occur on a strong beat, unless it occurs during the last beat of the measure.

This property attempts to make tangible a harmonic 'yearning' to make an initial move that is a fairly substantial number of chord steps from the first chord of the segment, from which there is then a retreat. This is a harmonic version of the y-leap characteristic (property 23) described earlier. For example, the opening of Mozart's Sonata in B-Flat Major, K. 333, with its progression from the I chord to the VI chord, exhibits this property. However, the opening of Haydn's Sonata No. 42, Hob. XVI/27 does not display this property. This is due to the fact that the V chord is reached after the first half of measure 2, which removes a certain yearning momentum. The opening of Haydn's Sonata No. 51, Hob. XVI/38 also lacks this property.

Almost half of Mozart's sonatas begin with a harmonic y-leap (Appendix A, Tables 1-1A, 1-1B). However, only approximately 29 percent of Haydn's sonatas exhibit this characteristic (Appendix A, Tables 1-3A through 1-3F). Only approximately 30 percent of Clementi's sonatas display this characteristic. Thus, this property is considered to be a positive property.

33) static_harm(X,Y)

This relation represents the fact that a chord progression consisting of two harmonies (segment X) occurs again at least two times with the same chord position and spacing between chords in adjacent segment Y in the transition to the secondary theme of the exposition, but prior to any 'end' section at the end of the transition (end(X), property 42). The duration of segment X's chord progression should be at least one measure. In Mozart's expositions, the transition to the secondary theme generally does not exhibit such harmonic repetition and lack of harmonic motion. Thus, this is considered to be a negative property.

34) ev1,2(X)

This relation represents the fact that a segment X contains a progression to the tonic-chord harmony (or occurrence of the tonic-chord harmony) in at least three different measures (particularly, after the initial statement -- 6 - 8 measures -- of the exposition's main theme). These instances should last at least two beats. Also, there should be no more than two measures between each instance. For example, in Mozart's Sonata in G Major, K. 283, starting after measure 10, there is another V - I progression two measures later in measure 12, followed by another progression to the tonic two measures later in measure 14, followed by another such progression in measure 16. This series of four resolutions to the tonic, spaced closely together, repeatedly emphasizes the tonic firmly in a balanced fashion (prior to moving to the secondary theme's dominant key).

Likewise, in Mozart's Sonata in C Major, K. 330, starting after measure 8, there is a progression to the tonic two measures later in measure 10, followed by another progression to the tonic in measures 12, 14, and 16. Mozart (unlike Haydn, for example) often uses these evenly spaced repeated resolutions to the I chord as regular structural ballasts that maintain a strong harmonic center around the tonic. As shown in the examples mentioned above, Mozart sonatas have segments with this characteristic quite often after the initial statement of the exposition's main theme. This helps to strongly emphasize the tonic before there is a turn harmonically toward the dominant just prior to the secondary theme. Thus, ev1,2 is considered to be a positive property.

3.6.6 Cadential Properties

The following group of properties is concerned with the various cadences found in Mozart's sonatas. It was found, in the course of doing analysis for the ISAS system, that Mozart's cadences provide a distinct and consistent system of punctuation for his sonatas. Cadences are considered as resting points (which can be temporary or more final) that occur at the ends of phrases. Specific cadence types were found to occur only in certain locations, providing a particular form of punctuation. Thus, they are all considered to be positive properties when used in certain specified contexts. They are also 'segment-defining properties'. Haydn uses less regular cadential punctuation than Mozart. The punctuation he does use does not follow such a well-defined pattern.

35) I,IV,V-a(X)

This characteristic represents the fact that segment X's main phrase ends with a progression to the I, IV, or V chord (particularly at the end of the first phrase of the sonata exposition). This chord is either in root position or second inversion. (Seventh chords are only in inverted position.) The root should not be the first or last note in the uppermost voice over the root-position cadence harmony. (If the treble and bass clef of that cadence ending consist only of the root note, or the cadence ends on beat 1 of the measure adjacent to segment X, it is exempt from the above condition for root position.) Almost 80 percent of Mozart's sonatas exhibit this property in the opening four measures of the exposition (Appendix A, Tables 1-1A, 1-1B). This is in contrast to a finding of only approximately 50 percent for Haydn's sonatas (Appendix A, Tables 1-3A through 1-3F). Likewise, only less than half of Dussek's sonatas exhibited this property (Appendix A, Tables 1-5A, 1-5B). Mozart's expositions generally avoid perfect authentic cadences or other cadences with the root on top of the chord at this location. Such cadences might sound too strong or final to occur in the middle of the melody. Thus, this property is considered to be a positive property in this context..

All cadences referred to in properties 36 through 49 can end on beat one of the measure following segment X.

36) ret-I(X)

This segment characteristic represents the fact that segment X's main phrase ends with a progression to the I chord. Specifically, this property is satisfied if any exposition longer than 19 measures has a main theme ending with such a progression. (If the main theme is immediately repeated, it is exempt from the above requirement.) This can be an authentic or perfect authentic cadence, or a temporary motion to the tonic. This characteristic is useful for describing the return to the tonic at the end of the opening main melody of the exposition (between measures 6 and 8). For example, Mozart's Sonata in C major, K. 330 resolves to the tonic in measures 2, 4, and 6, again in measure 8, and more strongly in measure 12. Haydn's Sonata No. 41, Hob XVI/26 resolves to the V chord in measure 8, but does not return to the tonic.

Approximately 95 percent of the main themes of Mozart's sonata expositions return to the tonic chord after the initial six to eight measures (usually eight measures) (Appendix A, Tables 3-1A, 3-1B). In contrast, only 80 percent of Haydn's sonatas exhibit this characteristic (Appendix A, Tables 3-3A through 3-3F). Likewise, 67 percent of Dussek's sonatas display this property. Over 80 percent of the Hummel sonatas lack this property. Also, all but one of the C.P.E. Bach's sonatas do not exhibit this property. The return to the tonic after the initial eight bars in Mozart's main themes itself constitutes harmonic symmetry. Thus, this property is considered to be a positive property in the context indicated.

37) 3-based(X)

This property is a 'uni-group' (Section 3.5) property consisting of several properties involving triple repetition of the cadence's final chord (or chord notes) at the end of segment X. Cadences within this category generally are used in Mozart's sonatas as stronger cadences (for example, at the end of the exposition). For example, almost 90 percent of Mozart's sonata expositions end with a cadence within this category (Appendix A, Table 4-1). In contrast, only approximately 75 percent of Haydn's sonatas lack this cadence ending in this location (Appendix A, Tables 4-3A, 4-3B) Approximately 70 percent of Clementi's sonatas do not exhibit this cadence usage (Appendix A, Table 4-4). Also, over 40 percent of Dussek's sonatas and 100 percent of Hummel's and 80 percent of C.P.E. Bach's sonatas lack this ending. The use of triple repetition creates a greater sense of finality than, for example, a two-chord or single-chord ending. Also, the use of triple repetition contributes to a rounded, gracious sound. Thus, this property is considered to be a positive property in the context indicated.

The 3-based property consists of the following eight subproperties described below (properties 37a - 37h)

37a) 3n-ow(X)

This characteristic represents the fact that a segment X ends with a one-measure 'three-note octave walk' cadence. An octave walk cadence consists of a three-note descent of an interval of an octave in the lowest voice, that is softened by stepping through the dominant tone along the way. This three-note descent of quarter notes in the bass, which spells out the single harmony of the cadence ending, moves from the tonic note of the chord to the tonic note an octave below it. The walk is followed by a quarter-note rest. (The rest is omitted if the cadence occurs at the end of an exposition that begins with an upbeat.) This walk contains the final harmony of a perfect authentic cadence or semi-cadence. (If the sonata is in a minor key, the cadence is in the relative major.) For example, the exposition of Mozart's Sonata in B-Flat Major, K. 333 ends with this type of cadence (measure 63). Likewise, the end of the exposition of Mozart's Sonata in D Major, K. 311 has this characteristic cadence.

The ‘three-note octave walk’ cadence is one of the stronger cadences used in Mozart’s sonatas to punctuate important section endings such as the end of the exposition. However, it is not used for cadences at less final section endings, such as the end of the transition occurring before the secondary theme in the exposition. It has a function analogous to that of the period (‘.’) in language syntax. The use of three notes to outline the basic structure of the chord resolution contributes to the stronger sound of this cadence. This property is considered to be a positive property when it occurs at the end of the exposition or movement.

37b) 3n-owv(X)

This characteristic describes the fact that a segment X ends with a one-measure variant of the ‘three-note octave walk’ cadence described in subproperty 37a, above. However, in this variant form of the walk, beat 1 contains the dominant tone of the chord rather than the tonic. All chords are in root position. For example, in Mozart’s Sonata in D Major, K. 284, the exposition ends with a 3n-owv cadence. The variant form of the ‘three-note octave walk’ is a weaker version of the original strong cadence. It has a weaker, less final sound. This is due to its having two dominant chords in the closing measure. Thus, it is used only occasionally at the end of the exposition of most of Mozart’s sonatas. This property is considered to be a positive property when it occurs at the end of the exposition or movement.

37c) 3c-ob(X)

This characteristic describes the fact that a segment X ends with a one-measure '3-chord with octave bounce' cadence. This cadence contains three occurrences of the cadence's final harmony in at least the bass clef. There is an octave leap ('bounce') from the cadence chord's tonic note between two adjacent notes of either the lowest voice or the two lowest voices. All three chords are quarter notes (or, occasionally, all eighth notes) in duration. The cadence ends with a rest of the same duration. (The rest is omitted if the cadence occurs at the end of an exposition beginning with an upbeat.) It contains the final harmony of a perfect authentic cadence or semi-cadence (or relative minor, if the exposition is in a minor key). For example, in Mozart's Sonata in C Major, K. 545, at the end of the exposition (measure 28), there is a 3c-ob cadence. Also, in Mozart's Sonata in C Major, K. 309, Sonata in A Minor, K. 310, and Sonata in C Major, K. 330, this cadence is used to end the exposition. This cadence is one of Mozart's stronger cadences, used, for example, at the end of a sonata exposition. This property is considered to be a positive property when it occurs in this location.

37d) 3ch_cad(X)

This characteristic represents the fact that a segment X ends with a 1- to 2-measure '3-chord cadence'. This cadence ending contains three evenly spaced occurrences of one of the following chord harmonies: three I chords, V chords (or, occasionally, I - V - I chords). These chords are at least one beat apart.

They can be adjacent or have one harmony between them. The first and last chords should be in root position. The root note should be in the uppermost voice in at least the first chord harmony. At least two out of three chords have at least one note in the uppermost or lowest voice with a duration of at least an eighth note. The cadence ends with at least an eighth-note rest in the uppermost or lowest voice. For example, the exposition of Mozart's Sonata in D Major, K. 576 ends with this type of cadence. Thus, this property is considered to be a positive property when it occurs at the end of the exposition.

37e) 3n-v(X)

This characteristic describes the fact that a segment X ends with a one-measure 'three-note variant' cadence. This cadence ending consists of three quarter notes followed by a quarter-note rest in the uppermost voice. All three notes are notes of the final root-position cadence harmony. (It can also be a seventh- or ninth- chord harmony.) For example, in Mozart's Sonata in C Minor, K. 457, at the end of the exposition (measure 74), there is a segment with this 'three-note variant' cadence. It is interesting to note that the first interval of this segment is almost an octave. This is reminiscent of the 'octave bounce' (leap) found in several of Mozart's cadences described in some of the above properties. The 3n-v cadence is termed a variant form (three-note variant) because it does not have the characteristic repetition of the tonic note throughout the cadence ending (as, for example, in the 4nc-cadence described in property 38c). Thus, this property is considered to be a positive property when it occurs at the end of the sonata exposition.

37f) wide_sp_3c(X)

This characteristic represents the fact that a segment X ends with a three-measure 'wide-spaced three-chord' cadence. Beat 1 of each of these three measures is the final root-position cadence chord, with the root on top. The first two of these occurrences has a duration of at least an eighth note in the uppermost or lowest voice. Beat 1 of the third measure is a quarter note. The segment ends with a quarter-note rest. Also, the second measure contains the same basic rhythmic and melodic pattern as the first measure (with no more than two intervallic mismatches). This cadence is either a semi-cadence or a perfect authentic cadence. This cadence is, in effect, a more widely spaced and more standardized version of the 'three-note variant' cadence (3n-v, property 37e). These three measures form a small closing section. For example, the exposition of Mozart's Sonata in C Major, K. 545 ends with this type of cadence (measures 26 through 28). The wide_sp_3c cadence, with its tonic notes on beat 1, underlines the similarly repetitive 'three-chord with octave bounce' (3c-ob cadence, property 37c) ending in measure 28 (thus creating a cadence within a cadence). The wide-sp-3c cadence and its usage in this fashion are found often in Mozart's sonatas. Thus, this property is considered to be a positive property when it occurs at the end of the exposition.

37g) wide_sp_3cv(X)

This characteristic ('wide-spaced three-chord variant' cadence) is a variant version of the wide_sp_3c characteristic (property 37f) described above. It differs from this property in the following aspects: At least the first measure of the cadence has the root on top of the chord. Beat 1 of its first and second measures has a duration of at least an eighth note in the uppermost or lowest voice. If the pitch is repeated, its composite duration can be used (Section 3.4). In measure 3 of the cadence, a cadence-chord note should appear in the uppermost voice by the second half of the measure. The segment ends with at least an eighth-note rest. For example, the exposition of Mozart's Sonata in B-Flat Major, K. 281 ends with this type of cadence. Despite the variances from the requirements of the wide_sp_3c property (property 37f), the three-chord ending can still be quite evident to the listener. These three measures form a small closing section. Thus, this property is considered to be a positive property when it occurs at the end of the exposition.

37h) dbl_wsp_3cv(X)

This characteristic represents the fact that a segment X ends with a five- or six-measure 'double wide-spaced three-chord' cadence. This is similar to the wide_sp_3c (wide-spaced three-chord) characteristic (property 37f). The final harmony of the cadence occurs on beat 1 of every other measure for the first five measures of the cadence, and the next measure as well (if it is a six-measure cadence). Thus, it occurs either in measures 1, 3, and 5 (for a five-measure cadence), or measures 1, 3, 5, and 6 (for a six-measure cadence). Measures 1, 5, and 6 are root-position chords. The root is on top in at least the first, fifth (and sixth) measures. If segment X is a six-measure cadence, the root appears on top in measure 6 by the beginning of the second half of the measure.

The uppermost or lowest voice of the chords in measures 1, 5, and 6 of the cadence should be at least an eighth note's worth in duration. The segment ends with at least an eighth-note rest. (If this occurs at the end of an exposition beginning with an initial upbeat, the rest is omitted.) No measure has all rests on beat 1 in either clef. Measures 1 and 3 of the cadence should have the same general rhythmic and/or melodic patterns. (Measure 3 can have additional notes.) This cadence contains the ending of a perfect authentic or semi-cadence. (If the sonata is in a minor key, the cadence is in the relative major.)

For example, the second movement of Mozart's Sonata in A Minor, K. 310 ends with this type of five-measure closing segment, and thus exhibits the above property. In this example, there is a sense of a wider-spaced triple repetition (consisting of 3 quarter notes), ending with the start of another, more compact triple repetition (of 3 quarter notes). Thus, the last measure is, in effect, a "diminution" of the spacing between the notes of the first triple repetition. This type of carefully crafted inner architectural structure is characteristic of Mozart's sonatas. Likewise, the exposition of Mozart's Sonata in D Major, K. 576 ends with a similar six-measure end segment, and thus exhibits the dble_wsp_3cv characteristic. These five or six measures form a small closing segment. Thus, dble_wsp_3cv is considered to be a positive property in the context indicated.

38) 2,4-based(X)

This characteristic represents the fact that a segment X ends with a '2,4-based cadence'. This property consists of cadences with double or quadruple repetition of the final cadence harmony. This is a stronger cadence category than the '1-based cadence' (property 41). It is, however, not as strong as the 3-based cadences (property 37). Generally, 2,4-based cadences are found right before the entrance of the secondary theme of the exposition of Mozart's sonatas. This cadence point, though stronger than the cadential points that precede it, lacks the finality of, for example, the end of the sonata's exposition. This 'uni-group property' consists of the following three subproperties (properties 38a through 38c).

38a) 2n-ob(X)

This segment characteristic represents the fact that a segment X ends with a one-measure 'two-note with octave bounce' cadence. It contains an octave leap from the tonic note of the cadence's ending harmony in the lowest or uppermost voice. Both chords are in root position. The octave leap notes are quarter notes, ending with a quarter-note rest. This is followed by a quarter-note rest. (The first note can also be followed by a rest.) This segment contains the final harmony of a semi-cadence. For example, in Mozart's Sonata in G Major, K. 283, there is a cadence of this type right before the entrance of the secondary theme (measure 22). Likewise, in his Sonata in F Major, K. 332, there is another cadence of this type just prior to the secondary theme (measure 40). As mentioned previously, cadences ending with two (or four) repetitions of the tonic note (root) of the cadence's harmony generally are used as weaker cadences in Mozart's sonatas. Thus, they would generally not be used at the ending of sections requiring a greater sound of finality (for example, at the end of the exposition). This property is considered to be a positive property when it occurs just before the secondary theme.

38b) 4n-ow(X)

This characteristic represents the fact that a segment X ends with a one-measure 'four-note octave walk' cadence. It consists of a four-note walk that spells out the single harmony of the measure by ascending an interval of an octave, stepping through the third and fifth in between. It can occur in the uppermost and/or lowest voice. The duration of the tonic notes should be at least an eighth note. All notes are not of the same duration. The cadence ends with a quarter-note rest. Only the root notes of the chord are on the beat. It contains the resolution chord of a semi-cadence. For example, Mozart's Sonata in C Major, K. 309, measure 32 has a cadence of this type right before the entrance of the exposition's secondary theme. This cadence, which is longer and more elaborate than the 'three-note octave walk' cadence (property 37a) is a weaker cadence used by Mozart, and is not found, for example, at the end of Mozart's sonata expositions, which require a strong concluding cadence. This property is considered to be a positive property when it occurs just before the secondary theme of the exposition.

38c) 4nc(X)

This characteristic describes the fact that a segment X ends with a one-measure 'four-note' or 'four-chord' cadence. It consists of a series of four occurrences of the tonic note of the cadence's final harmony in the uppermost and/or lowest voice. The notes are at least eighth notes. It ends with a rest of at least an eighth note in at least the uppermost or lowest voice. This segment contains the final harmony of a semi-cadence. For example, Mozart's Sonata in D Major, K. 576, exhibits this type of cadence at the end of the transition to the secondary theme (measure 41). Likewise, there is an occurrence of this type of cadence right before the exposition's secondary theme in Mozart's Sonata in C Minor, K. 457, measure 34.

In Mozart's sonatas, cadences with an even number of repetitions of the resolution note or chord generally are weaker cadences, and not found, for example, at strong endings such as the end of an exposition. Instead, they can be found (as in the examples above) at the end of sections not requiring a strong sound of finality. Also, even in one of the above examples (K. 576), Mozart's four-note cadence also has an octave bounce that is quite characteristic of many of the cadences described thus far. This property is considered to be a positive property when it occurs just before the entrance of the secondary theme of the exposition.

39) OF(X)

This characteristic describes the fact that a one-measure or greater segment (segment X) is a I^{6}_{4} - V_7 - I resolution. (It can be a I^{6}_{4} - V cadence in the tonic key only if it occurs right before the entrance of the second theme of the exposition.) The final tonic chord should occur on beat 1 of the last measure of the segment. At least two of the three chord harmonies should have a note with a duration of at least an eighth note in the uppermost or lowest voice. At least two of the three chord harmonies should be 'full chords' (that is, contain all notes of a chord, or three out of four notes of a seventh chord). The first two chord harmonies (I^{6}_{4} - V) should have a total duration of at least half a measure. OF resolutions occurring prior to the second theme of the exposition are in the tonic key. Those occurring in the secondary theme are in the dominant key (or relative major, if the exposition is in a minor key).

For example, in Mozart's Sonata in C Major, K. 330, there are segments containing OF cadences before closing segments in measures 33 - 34, 41 - 42, and 47 - 48, as well as in measures 53 - 54 (before the 'end section' of the exposition). Also, in Mozart's Sonata In G Major, K. 283, there are similar segments in measures 37 - 38, 42 - 43, and 50 - 51 (likewise before closing themes and an end section). Likewise, in Mozart's Sonata in B-Flat Major, K. 333, measures 45 - 46, 49 - 50, 53 - 54, and 57 - 59, are cadences with similar OF punctuation before the closing themes and end section.

The OF cadence is a weaker cadence that is used consistently in certain locations of Mozart's sonatas. For example, over 60 percent of Mozart's sonatas have at least three OF cadences occurring before closing themes and end sections (Appendix A, Table 4-1). In contrast, only two Haydn sonatas contain at least three OF cadences in this location. Also, almost 95 percent of Mozart's sonatas with expositions greater than 16 measures have an OF cadence before the final end section. In contrast, only approximately 35 percent of Haydn's expositions of this length have an OF cadence in that final location. Haydn's sonatas do not exhibit this degree of consistent use of this cadence in these locations. A large percentage of his sonatas lack repeated use of this punctuating cadence (Appendix A, Tables 4-3A, 4-3B). Likewise, the Clementi and Dussek sonatas also display a similar lack of such repeated OF cadences (Appendix A, Tables 4-4,4-5). This property is considered to be a positive property when it occurs just before the secondary theme or before the closing themes or final end section of the exposition.

40) ;_cad(X)

This 'uni-group property' (Section 3.5) represents the fact that a segment X ends with a 'semicolon' cadence. This category of cadence includes the following: 2,4-based cadences (property 38); and OF cadences (property 39). Cadences in this category are those that function similar to a semicolon in written text. They provide a pause that does not have a firm sense of finality. Mozart uses cadence punctuation often and consistently to delineate the various sections of his sonatas. Almost 75 percent of Mozart's expositions have segments with a semicolon cadence right before the entrance of the secondary theme (Appendix A, Table 4-1). This is in contrast to a finding of approximately 15 percent for Haydn's sonata expositions (Appendix A, Tables 4-3A, 4-3B). Likewise, only approximately 10 percent of Clementi's sonatas have semicolon cadences in that location. None of Dussek's sonatas exhibit this punctuation in that location. Similarly, only one of Hummel's and none of C.P.E. Bach's sonatas have this punctuation before the exposition's secondary theme. Thus, there is consistent use of this type of cadence in Mozart's expositions right before the secondary theme. This property is considered to be a positive property in the context indicated..

41) 1-based(X)

This characteristic describes the fact that segment X's main phrase has a half-measure or greater 'single-chord type' ending or momentary harmonic resting point. This is a simple ending that delineates phrases in an organized fashion. It refers to the last harmony of the phrase. It should be at least a half-measure in duration. The bass clef can be an Alberti-like bass (for example, measure 4 of Mozart's Sonata in C Major, K.545 and Sonata in G Major, K. 283). It can also be broken thirds, fifths, or an arpeggio. In addition, the bass clef can consist entirely of a measure of repeated chords (for example, Mozart's Sonata in A Minor, K. 310, measure 4). The repeated chords can be preceded and/or followed by a rest. It can also be a single simultaneity, note, or rest. If it occurs by measure 4 or the beginning of measure 5 of the exposition, there should be a pause in the melodic motion at the end of the segment, with no new pitch in the uppermost voice until at least the upbeat (with at least one beat separating them -- for example, Mozart's Sonata in D Major, K. 576, measure 4). If it occurs in measures 6 through 8, there should be at least one note with a duration of at least an eighth note, and no other new simultaneity with that harmony until at least the upbeat (unless it is repeated throughout the measure). If a phrase ending in measure 8 has no bass-clef notes, the simultaneity as defined above should be in measure 7. If there is ellision (that is, if the phrase ends on beat 1 of the measure following segment X, the start of the next phrase), the duration of the upmost voice plus any rests on that beat should be at least an eighth note.

However, the cadence should not include any 'octave bounces' (leaps of an octave) in the lowest voice or between the two lowest voices before or during the ending, with at least one note of duration greater or equal to an eighth note (for example, the murky bass in Clementi's Sonata in C Major, Op. 2, No.1). Likewise, the cadence in measure 4 of Haydn's Sonata No. 11, Hob. XVI/2, and Clementi's Sonata in G Minor, Op. 7 No. 3 also lack the 1-based property. The ending should also not have an 'octave walk' (a descent or ascent of an octave or more with the dominant tone in between) in the bass clef, with at least one note of duration greater than an eighth note (for example, octave walk cadences, properties 37a and 38b). This is the weakest cadence type used in Mozart's sonatas. It is used in the exposition, primarily in the section extending from the opening measure up to, but not including, the cadence before the secondary theme. It occurs consistently in all of Mozart's sonatas.

For example, approximately 90 percent of Mozart's sonatas have 1-based resolutions after the initial phrase of the first theme (Appendix A, Table 4-1, 'mm1' column). This is in contrast with a finding of only approximately 36 percent for Haydn's sonatas (Appendix A, Table 4-3A, 4-3B). Likewise, less than half of Clementi's sonatas, 36 percent of Dussek's sonatas, only one of Hummel's, and none of the C.P.E. Bach sonatas exhibit this property in the same location (Appendix A, Tables 4-4, 4-5, 4-6, 4-7). At the end of the initial statement of the first theme (usually eight measures), 100 percent of Mozart's sonatas exhibit this type of cadence. In contrast, only approximately 45 percent of Haydn's sonatas, approximately 57 percent of Clementi's sonatas, and 50 percent of Dussek's sonatas display this cadence in that location (Appendix A, Tables 4-3 through 4-5). This property is considered to be a positive property in the context indicated.

42) end(X)

This 'uni-group property' (Section 3.5) describes the fact that a segment X is a final small-ending section found, for example, at the very end of a sonata exposition or movement. This ending is two to six measures long. It contains the same final harmony on beat 1 of every measure or every other measure (except the last measure, which always contains this chord on beat 1). If the section occurs at the end of the exposition, the 'end' property consists of four subproperties: wide_sp_3c ('wide-spaced three-chord' cadence, property 37f); wide_sp_3cv ('wide-spaced three-chord variant' cadence, property 37g);

dble_wsp_3cv ('double wide-spaced three-chord variant' cadence, property 37h); 3ch_cad ('3-chord cadence', property 37d, if the cadence is longer than a measure in duration; or wide_sp_2,4 ('wide-spaced 2,4 chord' cadence, property 42a, defined below). These cadences define the end section.

42a) wide_sp_2,4(X)

This characteristic represents the fact that a segment X ends with a two- or four-measure 'wide-spaced 2,4 chord' cadence. Specifically, if the segment is two measures long, it has a root-position ending harmony both on beat 1 of the first measure, and by the beginning of the second half of the second measure. The duration in the uppermost voice or lowest voice of each of these chords is at least an eighth note. If the segment is four measures long, it has a root-position ending harmony in at least three of the four measures, (including measures 1 and 2). The root is on top in measures 1 and 2. The duration in the uppermost voice or lowest voice on beat 1 of these measures is at least an eighth note. This cadence ends with a quarter-note rest. For example, Mozart's Sonata in D Major, K. 311 has a cadence of this type at the end of the exposition. Alternatively, a four-measure ending can also have a root position ending harmony on beat 1 of its first and last measure, with a rhythmic sequence between measures 1 and 2. This property is considered to be a positive property if it occurs as an 'ending section' at the end of the transition to the secondary theme, or end of the exposition.

With respect to the end section (property 42), if it occurs at a location other than the end of the exposition, segment X's main phrase could have a 3 - 6 measure ending with the same harmony on beat 1 of every measure, except perhaps the last measure. The chord on beat 1 of the last measure is in root position.

With respect to Mozart's sonatas, 100 percent of expositions which are longer than 16 measures have an ending segment that satisfies the 'end' property at the conclusion of the exposition (Appendix A, Table 4-1). This is in contrast with a 36-percent finding for Haydn's sonata expositions (Appendix A, Table 4-3A and 4-3B). Likewise, only approximately 29 percent of Clementi's sonatas have end sections in this location (Appendix A, Table 4-4). Moreover, over 50 percent of Mozart's expositions also have ending sections just before the entrance of the second theme of the exposition. This property is considered to be a positive property.

43) trip_cad(X)

This characteristic represents the fact that segment X's main phrase ends with a 'triplet cadence'. This cadence contains at least one triplet note in the preparation or resolution chord, in the uppermost or lowest voice. For example, Haydn's Sonata No. 6, Hob. XVI/10, measure 8 has a cadence exhibiting this characteristic. Likewise, Haydn's Sonata No. 15, Hob. XVI/13, measures 4 and 12 has a similar cadence. Also, in Clementi's Sonata Op. 25, No. 1, measure 6, there is another 'triplet cadence'. The sixteenth-note triplet of this cadence in this sonata moves too quickly to create a substantial sense of arriving at a cadential point of rest. Thus, it weakens the cadence. Moreover, the sudden triplet rhythm that occurs without any preceding triple-based rhythm could contribute to an abrupt and unbalanced sound (2,4mwt, property 4).

Mozart sonatas generally do not have segments exhibiting this property (except, rarely, at the end of the exposition. None of Mozart's sonatas exhibit this property at the end of the first four measures of the exposition (Appendix A, Table 1-1A, 1-1B). In contrast, over 20 percent of Haydn's sonatas exhibit this property in this location (Appendix A, Tables 1-3A through 1-3F). Likewise, over 25 percent of Clementi's sonatas exhibit this property in the same location (Appendix A, Table 1-4A through 1-4C). Thus, this property is considered to be a negative property.

44) rest_cad(X)

This characteristic describes the fact that segment X's main phrase ends with a 'rest cadence'. That is, it has a considerable number of rests (in the bass or treble clef) just before, during, or right after the resolution chord. Specifically, a segment exhibiting this characteristic would have either: a) a rest greater than an eighth-note rest on beat 1 of the lowest voice; b) a rest greater than a quarter-note rest in the uppermost or lowest voice; or c) a rest in the lowest voice followed, no more than one beat later, by a rest in the treble clef, or vice versa.

For example, in Dussek's Sonata XII, Op. 35, No. 2, measure 4, there is a cadence ending that exhibits this property (according to definition b above). Likewise, in Clementi's Sonata Op. 40, No. 1, measure 4, there is a segment with this property. It has a rest on beat 1 of the bass clef (illustrating definition a). Also, in Haydn's Sonata No. 35, Hob. XVI/43, measure 6, there is a 'rest cadence'. The rest on beat 1 of the bass clef is followed on the next beat by a rest in the upper voice (illustrating definition c). The existence of a rest on the initial beat of a cadence weakens its cadential sound substantially. Thus, this property is considered to be a negative property.

45) midm_cad(X)

This characteristic describes the fact that segment X's main phrase ends with a 'mid-measure cadence'. Specifically, in segments with this characteristic either: a) the preparation chord occurs on beat 2 (a weak beat) in meters other than 2/4; or b) the ending harmony does not first occur on a strong beat (with the exception of an exposition with a meter of 2/4, or a I_{4}^{6} - V cadence in a 3/4 meter. These elements contribute to cadences that can sound less grounded and less substantial. For example, Haydn's Sonata No. 46, Hob. XVI/31, measure 4, beat 3 exhibits this property. Also, a cadence with a 4-3 appoggiatura starting on beat 3 out of 4 in a 4/4 time signature would be an example. Mozart's sonatas generally do not have cadences with this property. For example, only 5 percent of Mozart's sonatas exhibit this property at the end of the first three to four measures of the sonata exposition (Appendix A, Table 1-1A, 1-1B). In contrast, over 25 percent of Haydn's sonatas exhibit this characteristic in the same location. (Appendix A, Tables 1-3A through 1-3F). Thus, this is considered to be a negative property.

46) run_on(X,Y)

This relation represents the fact that a segment X ends with a cadence that provides little or no separation (using rests) between the segment it concludes and the adjacent segment that follows (segment Y). Specifically, it refers to the lack of at least an eighth-note rest in at least the lowest voice separating segment X from the beginning of segment Y (for example, at the end of the cadence before the secondary theme). It also includes the occurrence of ellision, in which there is an 'overlap of function' of the last chord. (That is, it functions as the end of the phrase and the beginning of the new phrase.) None of Mozart's sonatas exhibit this property in the cadence occurring before the entrance of the secondary theme (Appendix A, Table 5-1). In contrast, approximately 20 percent of Haydn's sonatas exhibit this property (Tables 5-3A through 5-3F). Mozart's sonata sections are carefully delineated, with rests acting as punctuating separators. This property is considered to be a negative property in the context indicated.

47) a_lpa(X,Y)

This characteristic describes the fact that segment Y begins right after the last perfect authentic cadence (or resolution) occurring at the end of segment X that immediately precedes it. (The root note in the uppermost voice would be the first or highest note of the ending harmony.) Specifically, it is useful in describing the fact that many of Mozart's expositions have a transition to the secondary theme or 'post main melody' section that begins right after the last of sometimes several perfect authentic resolutions. (The 'post main melody' section, pmm, extends from the last perfect authentic cadence after any initial statements of the opening theme, until the cadence just before the secondary theme. If there are no such perfect authentic cadences, the pmm starts after any initial statements of the opening theme.) For example, in Mozart's Sonata in G Major, K. 283, there is a perfect authentic-type resolution in measure 10.

This is followed by one more such resolution on beat 1 of measure 16. This is followed by a passage ending with a cadence on the dominant. Thus, the pmm starts in measure 16.

Also, in Mozart's Sonata in F Major, K. 332, the transition to the exposition's secondary theme exhibits a similar relation to the opening measures preceding it. Thus, the return to the tonic chord at the end of the main melody is firmly and often repeatedly emphasized in Mozart's sonatas prior to the motion in the transition toward the dominant. This occurs in approximately 95 percent of Mozart's sonatas with expositions longer than 16 measures (Appendix A, Table 5-1A through 5-1C). This is in contrast to a finding of only approximately 60 percent for Haydn's sonatas (Appendix A, Table 5-3A through 5-3F). Thus, this property is considered to be a positive property.

48) red_V(X)

This relation represents the fact that a segment X ending with a cadence on the dominant chord contains an earlier such cadence prior to it (This refers particularly to the occurrence of such redundant arrivals in the 'post main melody' section, defined in property 47 above). For example, in Mozart's Sonata in B-Flat Major, K. 281, the transition to the secondary theme has only one cadence in the dominant (measure 17). Also, in his Sonata in D Major, K. 311, there is a similar transition segment, with a final progression to the V in measure 16. In contrast, in the first movement of Haydn's Sonata No. 8, Hob. XVI/5, there are resolutions to the V or progressions that temporarily rest on the V (for example, in measures 15, 25, 30, and 37). Likewise, in the first movement of his Sonata No 20, Hob. XVI/18, there are two such harmonic motions to the V in both measures 12 and 20. Thus, this property is considered to be a negative property.

49) >=3/4cad(X)

This characteristic represents the fact that segment X's main phrase ends with a cadence (or resolution) that is at least three-quarters of a measure's worth in duration (including rests). If it extends to the measure following segment X, only the first half of that measure is included. Cadences occurring, for example, in the expositions of Mozart's sonatas generally have a duration of at least three quarters of a measure. This enables them to sound substantial and clearly punctuate his music. For example, in Haydn's Sonata No. 9, Hob. XVI/4, measure 7, the opening segment ending in measure 7 lacks this property. Likewise, in his Sonata No. 37, Hob XVI/22, the segments consisting of the first four and first eight measures also lack this property. This property is considered to be a negative property.

3.6.7 Textural Properties

50) sing_v(X)

This characteristic represents the fact that a segment in the treble clef of the sonata exposition (segment X) has a 'single-voice texture' in the initial four measures of the segment (particularly, in the opening four measures of the exposition). With respect to the opening four measures, the segment should contain no more than four simultaneities in the treble clef. None of Mozart's sonatas lacked this property in the opening four measures of the exposition. In contrast, over 20 percent of Haydn's sonatas lacked this property in the same location. Likewise, over 70 percent of Dussek's sonatas, and over 40 percent of Clementi's sonatas, and all but one of Hummel's sonatas lacked this property in that location. This property is considered to be a positive property.

51) fb_ch_tex(X)

This characteristic describes the fact that a segment X has a 'full block chord' texture (particularly in the opening four measures of the exposition). A segment X with this characteristic, when reduced to block chords, has at least one 'full block chord' harmony (that is, contains all three notes of a chord, or at least three out of four notes of a seventh chord) in each half of every measure of the segment. These notes need not occur simultaneously. Opening measures of the exposition consisting of all rests in the bass, or all unisons or octaves, are ignored. Thus, occurrences of a measure of all rests in any other location would be considered as two half-measures lacking two 'full chords'. Measures consisting of only one harmony need have only one 'full chord'. This segment characteristic is useful, for example, in describing the chordal texture of Mozart's expositions. This property is considered to be a positive property.

52) par_int(X)

This characteristic describes the fact that a segment X contains parallel motion in the treble clef or between the treble and bass clefs (particularly in the opening eight measures of the sonata exposition). A segment exhibiting this property in the opening four measures of the exposition would have at least 1-1/2 beats of parallel motion between the two uppermost voices, the uppermost and lowest voice (if there are no voices in between), or between any three voices. There can be intervening notes in an inner voice between the parallel notes if the total duration of parallel motion is at least 1-1/2 measures. A segment in measures 5 through 8 of the exposition's initial melody would have over one measure between at least two voices. Parallel motion between treble and bass clefs for this property does not include parallel octaves that start at the beginning of the exposition. Only approximately 10 percent of the Mozart sonatas exhibit this property in the opening four measures. This is in contrast with a finding of almost 40 percent for Haydn's sonatas. Likewise, over 65 percent of Dussek's sonatas display this property. Thus, this property is considered to be a negative property.

3.6.8 Sectional Properties

53) notrans_V(X)

This segment relation represents the fact that either: a) the exposition progresses to a dominant-key secondary theme without a transition; or b) a transition exists, but its final destination is not a cadence on the dominant, V of V, or V of the relative major for minor-key expositions). None of Mozart's sonata expositions exhibit this property. His sonatas do not exhibit sudden tonal shifts without preparation. This property is therefore considered to be a negative property.

54) late-pmm(X,Y)

This relation represents the fact that a segment X, occurring within segment Y, begins at least 37 percent of the way through segment Y. Specifically, this refers to the occurrence of the 'post main melody' section (pmm) at least 37 percent of the way through the exposition. The 'post main melody' section extends from the last perfect authentic cadence after any initial statements of the opening theme, until the cadence just before the secondary theme. If there is no such cadence, the pmm starts after any initial statements of the opening theme. This property is considered to be a negative property.

55) long-pmm(X,Y)

This relation describes the fact that the length of a segment X is at least 28 percent that of segment Y. Specifically, it refers to the fact that the 'post main melody' (pmm) section of the sonata exposition is at least 28 percent of the length of the exposition. Mozart's sonatas generally do not exhibit this property. His transition sections generally are compact, and move fairly directly to their harmonic destination. This property is considered to be a negative property.

Chapter 4

Statistical Data

4.1 Statistical Considerations

The properties listed in the 'style-dependent' predicate library are those that, in a general sense, seem to have musical significance from the point of view of a performer and an educated listener. They were, for the most part, formed intuitively from prior detailed listening and performing of the music. They constitute hypotheses to be tested, rather than features derived solely from a search for an exhaustive list of those properties that distinguish composers. Although the individual properties do not completely distinguish, for example, Mozart sonatas from Haydn sonatas, combinations of only a few of them will do so. It is important to emphasize the remark at the end of Section 3.5 that although the total number of such properties in the style-specific predicate library is fairly large, specific combinations of relatively few properties were used as "models" for distinguishing authors of the various compositions.

The sample size for examining Mozart's keyboard sonata style (that is, the historical data) was constrained by the number of sonatas available - - that is, 20 Mozart sonatas (one of which is of disputed authorship). The historical data used for the sample group of Mozart's contemporaries included the following - - 54 keyboard sonatas of Franz Joseph Haydn (Volumes I, II and III); 24 keyboard sonatas of Muzio Clementi (4 volumes); 15 keyboard sonatas of Jan Ladislav Dussek (2 volumes); the complete keyboard sonatas of Johann Nepomuk Hummel; 6 keyboard sonatas of Carl Philipp Emanuel (C.P.E.) Bach; Sonata in C für Klavier zu vier handen (for Piano Four Hands), K.V. 19d (which has been attributed to Mozart but is of questionable origin); Die sechs Romantischen Sonaten (for Violin and Piano), K. V. 55 - 60 (Anh. 20^{c-h}, $K.V.^{6}$ Anh. C23.01-23.06); and Sonata in D for Violin and Piano, $K.V.^{6}$ deest (both of which are also of doubtful origin). Although the last two cited works are for violin and piano, they were included in order to investigate whether their authenticity could be determined using the same properties and property patterns as those for keyboard sonatas alone. This sample group also includes an EMI-composed "Mozart work" by the twentieth-century composer David Cope.[1]

It seemed advisable that the works included should form a homogenous group. Thus, sonatas that were not generally in standard overall sonata (sonata-allegro) form were often omitted from the sample group. For example, Mozart's Sonata in A Major, K. 331 is in theme-with-variations form, and was therefore not homogenous with the other sonatas in the group. This was the only Mozart sonata to be excluded from the group studied. Likewise, there were a few Haydn sonatas omitted from the nonMozart sample group, also due to their being in overall nonstandard sonata form. However, when, for example, only the first four

[1] (Cope, 1991,158-159)

measures or first eight measures of the exposition were being studied, those nonstandard sonatas were sometimes included. This was done in an attempt to observe whether the absence of Mozart's distinctive crafting of melody would be recognizable even in these nonhomogenous sonatas. No clarification of data was necessary (as, for example, in the EMI program of David Cope). This clarification process can cause essential stylistic information to be altered or lost.

In order to increase the sample size for the expositions of the Mozart sonatas studied, the respective expositions of these sonatas were initially subdivided into six subsamples that were studied separately. These six subsamples are, specifically:

a) the first four measures

b) the first eight measures

c) the 'post main melody'

d) the cadential pattern of the entire exposition

e) the entire exposition as a whole

f) the secondary theme

(The 'post main melody' section, pmm, extends from the last perfect authentic cadence after any initial statements of the opening theme until the cadence just before the secondary theme. If there is no such cadence, the pmm starts after any initial statements of the opening theme.) The first four subsamples (a through d) were subsequently found to be sufficient for style authentication of Mozart's sonata expositions, and are therefore the ones included here (although subsamples e and f provided similar results). Vectors of properties (containing truth values of properties) have been devised for each of these subsamples to facilitate recognition of Mozartean traits specific to such sample types.

Vectors include both positive and negative properties. (Negative properties are properties that help identify Mozart by their noticeable absence in Mozart's sonatas, and frequent presence in sonatas of his contemporaries.) An ideal binary "Mozartean value" is given for each property of the vectors. This can be found in column 2 of vector Tables 1 through 3, and 5, and in the fourth row of vector Table 4. These values represent the ideal properties of a Mozartean sonata. Positive properties will have an ideal value of 1. Negative properties will have an ideal value of 0. In the columns that follow, an X is placed in the row for any value that deviates from these ideal values. A maximum number of deviations is listed at the bottom lower left of the table for this series of properties which, when surpassed, filters out sonatas considered to be presenting nonMozartean traits. The actual number of deviations for each sonata would be listed in the 'difference row' ('Dif') at the bottom of the table, under the respective column for each sonata. (In Table 4, this is listed in the final column.)

4.2 Vector Tables

A quite accurate estimate can be made as to whether the composer is indeed Mozart from just the first four measures of a keyboard sonata. It has been found, in the course of developing this system, that Mozart's style-specific properties are immediately imprinted in his music. The opening theme of a Mozart keyboard sonata is the main theme of the sonata's entire first movement. Mozart was a melodic craftsman, and it is his melodies that, more than any other element, stamp his music uniquely as Mozart. This seems to be in accordance with the perception of the educated listener who, after the opening four bars of the melody, has little need to wait for the transition, secondary theme, or mode of development, to strongly suspect that it was composed by Mozart. Thus, a vector of properties was created for the subsample consisting of the first four measures.

Negative properties of vector tables are superscripted with an asterisk. A few vector-table properties are composites of properties. That is, they consist of several properties joined by the logical connector "or" (as in the vector Table 5). If one of those properties is true, an entry of 1 is made. (Full definitions of properties are given in the library of predicates in Sections 3.6.1 through 3.6.8). The brief name in parentheses in column 3 after each property of the sample vector tables on the following pages of this section are merely more descriptive names than the property names themselves, and do not fully represent every aspect of their respective definitions. The first vector table (Table 1), which is for the first four measures of the sonata exposition, has a value for each of the following properties:

Table 1 - Vector 1 - First four measures

Property	Ideal	Abbreviated Name
1) dtyp5	1	'3 - 5 duration types'
2) dclss4	1	'3 - 4 duration classes'
3) fd_bt*	0	'fine division of a beat'
4) 2,4mwt*	0	'2,4-based measure with tuplet'
5) b1_Lrest*	0	'substantial rest on opening beat'
6) rep_dur*	0	'repeated single duration'
7) <=hmrseq*	0	'<=half-measure rhythmic sequence'
8) 2mrseq*	0	'two-measure rhythmic sequence'
9) <=hmrseqL>2*	0	'>2 occurrences of <=half-meas rhyth pattern'
10) 1mrseqL-e*	0	'1-meas rhythmic sequence, even # of occrrnces'
11) rseqL_odd*	0	'rhythmic sequence, odd # of occurrences
12) prseqL_mx*	0	'real or tonal pitch and rhythmic sequence'
13) ident_pr*	0	'repeat of pattern with ident pitches, rhythms'
14) lh_mel*	0	'lower range melodic line'
15) nonscal,>3	1	'nonscalar, broad span, with intervals>3rd'
16) r-ptch*	0	'repeated pitch'
17) diss_span*	0	'dissonant span'
18) pkpt>2	1	'>2 peak points'
19) y-pks	1	'yearning peaks'
20) mv_valley	1	'moving valley'
21) mt_reg	1	'mountainous melodic segment'
22) red_dest*	0	'redundant destination note'
23) sym_div	1	'symmetrically divided into 2 halves'
24) est_tp	1	'firmly established tonic pitch'
25) est-I	1	'firmly established I chord'
26) h_ylp	1	'harmonic yearning leap'
27) I,IV,V-a	1	'I,IV,V resolution, root not on top'
28) trip_cad*	0	'triplet/tuplet-type cadence'
29) rest_cad*	0	'rest cadence'
30) midm_cad*	0	'mid-measure cadence'
31)1-based	1	'1-based cadence'
32) >=3/4cad	1	'>=3/4 measure cadence'
33) sing_v	1	'single-voiced melody'
34) fb_ch_tex	1	'full-block-chord texture'
35) par_int*	0	'parallel intervals'

Max=6

This vector table provides a broader view of the occurrences of the various durational, rhythmic, melodic, melodic graphic, harmonic, cadential, and textural properties in the opening four measures of the exposition. The "ideal values" for this vector are listed in the second column. The maximum number of deviations (X's) for this vector is 6. Thus, works, for example, with eight X's would be considered as appearing nonMozartean. (Works with seven X's (just above the borderline) are not significant unless the results for any of Tables 3 through 5 are out of range.)

Only one of Mozart's 19 keyboard sonatas (K. 498a, listed as M20 in Table 1 due to its being the 20th sonata in the Bartok-edited edition used) surpassed this maximum value by a substantial margin (Appendix A, Table 1-1B). This is the one sonata whose authenticity has been in question. This suspicion is likewise underlined by the fact that many portions of this particular sonata could sound fairly nonMozartean to the educated listener. All of Haydn's 52 sonatas surpass the maximum number of deviations from the ideal Mozartean value, most by a substantial amount (Appendix A, Tables 1-3A through 1-3F). Likewise, all but one of Clementi's sonatas, all of Hummel's sonatas, and all of C.P.E. Bach's sonatas included surpass the maximum substantially.

The 35 properties of vector 1, which provide a more detailed view, were then reduced to a shorter version consisting of 16 properties. It includes durational, rhythmic, melodic, melodic graphic, harmonic, cadential, and textural properties. The second vector (Table 2, Vector 2) below consists of the following properties listed as follows:

Table 2 - Vector 2 - First four measures
(shortened version)

Property	Ideal	Abbreviated Name
1) fd_bt*	0	'fine division of a beat'
2) b1_Lrest*	0	'substantial rest on opening beat'
3) rep_dur*	0	'repeated single duration'
4) <=hmrseq*	0	'<=half-measure rhythmic sequence'
5) <=hmrseqL>2*	0	'>2 occurrences of <=half-meas rhyth pattern'
6) nonscal,>3	1	'nonscalar, broad span, with intervals>3rd'
7) y-pks	1	'yearning peaks'
8) sym_div	1	'symmetrically divided into 2 halves'
9) est_tp	1	'firmly established tonic pitch'
10) est-I	1	'firmly established I-chord'
11) h_ylp	1	'harmonic yearning leap'
12) I,IV,V-a	1	'I, IV or V resolution, root not on top'
13) trip_cad*	0	'triplet/tuplet-type cadence'
14) midm_cad*	0	'mid-measure cadence'
15) 1-based	1	'1-based cadence'
16) sing_v	1	'single-voiced melody'

Max=3

The ideal binary Mozartean values for vector 2 are listed in column 2 of Table 2. The maximum number of deviations for this vector is 3. Thus, four or more deviations from the ideal vector would constitute a nonMozartean result. Only one of Mozart's 19 sonatas surpasses this maximum (Appendix A, Tables 2-1A, 2-1B). This is the Sonata in B-Flat Major, K.498a, the keyboard sonata whose authenticity is in question. Likewise, all but one of Haydn's sonatas surpass the maximum, usually by a considerable amount (Appendix A, Tables 2-3A through 2-3F). All of

Hummel's sonatas also surpass the threshold, again by a considerable amount (Appendix A, Table 2-6). All of Clementi's sonatas exceed this maximum value by a substantial amount, thus exhibiting nonMozartean properties (Appendix A, Tables 2-4A through 2-4C). All but one of Dussek's sonatas also surpass this maximum (Appendix A, Tables 2-5A, 2-5B). All of C.P.E. Bach's sonatas similarly exceed the maximum number of deviations by an appreciable amount. Cope's EMI-composed work in imitation of Mozart's style also exceeds this maximum (Appendix A, Table 2-2). It exhibits five deviations from the ideal Mozartean vector.

The third vector (Table 3, vector 3) pertains to the first eight measures of the sonata's exposition. Although the essence of Mozart's melodic style is encapsulated within the sonata's first four measures, the first eight measures allow certain properties to be observed in a wider melodic context. This vector consists of 16 properties.

Table 3 - Vector 3 - First eight measures

Property	Ideal	Abbreviated Name
1) dtyp5	1	'3 - 5 durations'
2) rep_dur*	0	'repeated single duration'
3) <=hmrseqL>2*	0	'>2 occurrences of <=hlf-meas rhyth pattern'
4) ident_pr*	0	'repeat of pttrn with ident pitches, rhyth'
5) lh_mel*	0	'lower range melodic line'
6) r-ptch*	0	'repeated pitch'
7) red_dest*	0	'redundant destination note'
8) sym_div	1	'symmetrically divided into 2 halves'

9) y-leap	1	'yearning leap'
10) g-gest	1	'graceful gesture'
11) ret-I	1	'return to I-chord'
12) >=3/4cad	1	'>=3/4 cadence duration'
13)sing_v	1	'single-voiced melody'
14) par_int*	0	'parallel intervals'
15) 1-based	1	'1-based cadence'
16) trip_cad*	0	'triplet/tuplet-type cadence'

Max=3

Table 3 includes durational, rhythmic, melodic, cadential, and textural properties. It establishes the fact that many of the properties exhibited in the first four measures of the initial main melody also are evident in the entire main melody. For example, measures 5 through 8 of the opening theme, like the first four measures, has a set of durations neither too small nor too varied (dtyp5). It has a similar avoidance of both single-duration repetition (rep_dur), small-scale rhythmic sequence, and exact pitch and rhythmic sequence (Table 3, properties 1 through 4). With respect to melody (Table 3, properties 5 through 10), there is an analogous lack of melodic repetitiveness, with the second phrase of the melody frequently starting on a note other than the destination note of the first phrase (red_dest, Table 3, property 7). Also, like its first phrase, the entire main melody often can also be divided symmetrically into two halves (sym_div, Table 3, property 8). (A more detailed description of these properties can be found in Subsections 3.6.1 through 3.6.8 of Section 3.6, which contain the style-dependent predicate library.)

Moreover, the melody may contain 'yearning leaps' and 'graceful gestures' (Section 3.6.3). Y-leaps have more weight than the other properties in Table 3. The presence of both a 'y-leap' and 'g-gesture' early in the sonata exposition is a strong Mozartean indication. (This does not imply that the absence of either one in this location is necessarily a strong nonMozartean indication.) Properties 11, 12, and 15 in Table 3 are cadential properties that describe: a) the return to the tonic that often occurs at the end of the main melody (contributing a sense of harmonic symmetry); b) the substantial length of this cadence (>=3/4cad); and c) the simple type of cadence used (1-based). Properties 13 and 14 are textural properties. Property 14 implies continuation of the lack of parallel motion evident in the initial four measures. The ideal binary values for this vector are listed in column 2 of the table.

The maximum number of deviations for this table is 3. Thus, a result of four or more X's (deviating truth values) would indicate a nonMozartean result. Only one Mozart sonata (K. 498a), whose authenticity has been questioned, surpasses this maximum. In contrast, all of Haydn's sonatas surpass this maximum (Appendix A, Tables 3-3A through 3-3F). They would therefore be considered as having a nonMozartean result. Moreover, all of Hummel's sonatas examined also exceed this maximum (Appendix A, Table 3-6). Similarly, all of Clementi's sonatas examined also have a total number of deviations greater than the maximum

(Appendix A, Tables 3-5A through 3-5C). In addition, all of C.P.E. Bach's sonatas also exhibit a substantial nonMozartean result. Moreover, Cope's EMI-composed sonata exhibits 6 deviations from the ideal Mozartean vector (Appendix A, Table 3-2).

The fourth vector (Table 4, vector 4) is a vector that describes the cadence pattern of the sonata exposition. It consists of the following eight entries listed in the table below (not including the ideal and difference columns):

Table 4 - Vector 4 - Cadential pattern

	Mm1	Mm2	Pre-2nd	OF	OF	Pre-end OF	end	3-bsd	Dif
	1-bsd	1-bsd	;-cad						
Ideal	1	1	1	1	1	1	1	1	

Max=2 if exposition ≥ 28 measures
else max=1
'end'=nr if exposit. ≤ 16 meas

Thus, it comprises: a) column 1 -- the cadence after the first phrase of the main theme occurring by measure 4 or the beginning of measure 5 ('Mm1'); b)column 2 - the cadence after the second phrase of the main theme occurring between measure 6 and the beginning of measure 9 ('Mm2'); c) column 3 -- the cadence just before the secondary theme; d) columns 4 and 5 -- 2 OF resolutions (specifically, $I_{6 \atop 4}$ - V_7 - 1 resolutions) occurring after the first eight measures of the secondary theme and before the 'end section' (Section 3.6.6) of the exposition (for example, before the first and second closing themes); e) column 6 -- an OF resolution occurring 1 - 6 measures before the last measure of the exposition;

f) column 7 -- the existence of an end section at the end of the exposition; and g) column 8 -- the final cadence of the exposition. Columns 1 and 2 have an entry of 1 if their respective cadences are 1-based. Column 3 has an entry of 1 if it is a ';_cad' (property 40, Section 3.6.6); Entries for columns 4, 5, and 6 should all be 1 if the exposition is at least 39 measures long. Otherwise, there should be at least one OF resolution in one of these locations. (An entry of 'nr' (not required) would be placed in those entries not required to be filled.) Also, there should be an entry of 1 for the existence of an end section (column 7) if the exposition is at least 17 measures long. (Otherwise an entry of 'nr' is made.) An entry of 1 is made in column 8 if there is a final 3-based cadence (property 37). The maximum number of deviations for vector 4 is 2 if the exposition is at least 28 measures long. Otherwise, it is 1.

During the course of the development of the IMCS system, it was discovered that the series of cadences in Mozart's expositions generally followed a consistent syntax. This clear, consistent syntax helped to delineate his works in logical fashion. Mozart uses his cadences as punctuation with great care and regularity. He uses his strongest cadence punctuation at important junctures. His 2,4-based cadences (property 38), which sound more clipped, and less rounded (less gracious) than his 3-based cadences (property 37) are therefore used in less final locations. 1-based cadences (property 41) are even weaker cadences, used, for example, after the first and second phrases of the first theme of the sonata exposition. Almost 90 percent of his sonatas have 1-based endings ('single-chord cadences') at the end of the first phrase of the exposition's initial theme (Appendix A, Table 4-1). 100 percent of his sonatas have 1-based cadences at the end of the second phrase. 3-based cadences (stronger cadences) are used regularly at the end of the exposition. Approximately 90 percent of Mozart's sonatas have this type of cadence at the end of their respective expositions (Appendix A, Table 4-1). Moreover, OF cadences ($\underset{\hat{4}}{I_6}$ - V or $\underset{\hat{4}}{I_6}$ - V - I cadences) are used before the closing themes and end sections of a majority of Mozart's sonatas (Appendix A, Table 4-1).

None of Mozart's sonatas exceed the maximum number of deviations for Table 4, vector 4. In contrast, all but three of Haydn's sonatas and all of Clementi's sonatas exceed this maximum. Mozart's choice of cadence is closely related to its location within the work. Thus, the cadence punctuation of a typical Mozart sonata (for example, Mozart's Sonata in G Major, K. 283) could be represented as follows:

Mm1, mm2, extension, transition; 2nd th phr1, 2nd th phr2, extension; closng th1; closng th2; end.

where "," represents 1-based cadences; ";" represents 'semicolon cadences (2,4-based cadences and OF cadences); and "." represents 3-based cadences, as defined in Section 3.6.6).

In contrast, Haydn's sonatas often lack such frequent, well-defined punctuation. Almost 75 percent of Mozart's sonatas have a semicolon cadence right before the entrance of the second theme (Appendix A, Table 4-1). This is in contrast to an occurrence of only approximately 15 percent for Haydn's sonatas, 14 percent for Dussek's sonatas, and only approximately 10 percent for Clementi's sonatas. None of C.P.E. Bach's, and only one of Hummel's sonatas exhibit this cadence in that location.

Almost 70 percent of Mozart' expositions that are at least 39 measures long have three OF resolutions in the locations indicated. (Appendix A, Table 4-1). In contrast, only 36 percent of Haydn's sonatas of similar length have such punctuation (Appendix A, Tables 4-3A through 4-3F).

The fifth vector (Table 5, vector 5) is concerned primarily with the 'post main melody'. (The post main melody (pmm) extends from the last perfect authentic cadence occurring after any initial statements of the first theme. If there is no such cadence, the pmm starts after any initial statements of the first theme.)

The pmm includes, and frequently is equivalent to, the transition to the second theme. It consists of the following properties (or logical disjunction of properties):

Table 5 - Vector 5 - Post Main Melody, Transition

Property	Ideal	
1)>=1mrpseqL v 2mrseqLv1i (if pmm>5 meas)	1	'1-meas rhyth or ptch/rhyth seq or 2-meas variant rhyth seq'
2) <=hmrseqL>2*	0	'>2 occrrnces of <=hlf-meas rhyth pttrn'
3) rpseqL3 v dim_grp (if pmm>5 meas)	1	'3 occrnces of rhyth or ptch/rhyth pattrn' or occrnce of diminution-type'
4) ev1,2 (if exposit. >28 meas)	1	'regular, closely-spaced progressions to I' '
5) static_harm*	0	'repeat of >1 meas harmonic
6) notrans_V*	0	'no transition to V'
7) late-pmm*	0	'late pmm'
8) long-pmm* (if exposit. >16 meas)	0	'long pmm'
9) a_lpa (if exposit. > 16 meas)	1	'pmm after perf auth cadence'
10) red_V*	0	'redundant arrival on V'
11) end	1	'existence of end section'
12) ;_cad	1	'semicolon cadence'
13) midm_cad*	0	'mid-measure cadence'
14) run_on*	0	'run-on cadence'
15) trip_cad*	0	'triplet cadence'

Max=3
If exposit >28 meas,
else max=1

Properties 1 and 3 of this table consist of the disjunction of two properties. An entry of 1 indicates that at least one of these two properties is true.

With respect to rhythm (properties 1 through 3), this vector describes the frequent occurrence of larger-scale (one measure or greater) exact rhythmic sequence (if the pmm is longer than five measures), and the avoidance of multiple adjacent repetitions of smaller-scale rhythmic patterns (property 2). It also describes the use of triple repetition of rhythmic or pitch and rhythmic patterns (again, if the pmm is longer than 5 measures). It also detects the presence of "diminution" of spacing, duration, or harmony (dim_grp, Section 3.6.2) - - a dramatic gesture used by Mozart at the end of major sections.

Properties 4 and 5 of vector 5 are harmonic properties. Property 4 describes the frequent occurrence of the tonic every one or two measures within the pmm (if it is longer than five measures), thus firmly reaffirming the tonic before there is a harmonic motion toward the dominant. (All properties are described in greater detail in the style-dependent predicate library of Chapter 3.) Property 5 describes the avoidance of repetitiveness in harmonic progressions one measure or greater. Properties 6 through 8 are structural properties. They refer to the existence of a transition ending with a cadence on the dominant, and the avoidance of a 'late' or 'long' pmm (Section 3.6.8). Properties 9 through 15 are cadential properties. Property 9 refers to the fact that most pmm's occur after the last perfect authentic cadence prior to a move toward the dominant (a_lpa). Property 10 describes the avoidance of arrivals on the dominant before the end of the pmm (that is, harmonic redundancy). Property 11 refers to the occurrence of an 'end section' which helps delineate the end of a section. Properties 12 through 14 describe the frequent use of a ";_cadence" at the end of the transition, which is generally not a 'midm_cad' or 'trip_cad.' Likewise, the end of the transition and the beginning of the secondary theme are clearly delineated. (Properties 13 and 14 detect the absence of this). The maximum number of deviations for vector 5 is 3 if the exposition is longer than 28 measures. Otherwise it is 1. Works with four or more deviations from the ideal values are considered as exhibiting nonMozartean traits. Only one of the 19 Mozart sonatas significantly surpass this value. This is the sonata whose authenticity is in dispute (K.498a). This is in accordance with the fact that many portions of this sonata can be perceived by the educated listener as sounding 'less Mozartean'. Also, approximately 90 percent of Haydn's sonatas exceed the maximum number of deviations. Moreover, the few Haydn sonatas with a value below the maximum exhibit nonMozartean results in the other tables.

4.3 Comparative Study of Vector Tables

ISAS is designed to distinguish the following four situations:

a) distinguish a composer's work from works of his contemporaries (for example, Haydn, Clementi, Dussek, Hummel, and C.P.E Bach)

b) distinguish a composer's works from imitations of that composer's style

c) distinguish a composer's works from those with portions borrowed from that composer, but put together by another composer

d) distinguish those works in which portions of the work are borrowed from other works of the same composer

In evaluating the results of vector tables, both individual tables and a composite of two or more vector tables can both be of value. As mentioned in Section 4.1, an examination of the vector table for the first four measures of the opening theme of the sonata exposition can enable a quite accurate estimate to be made as to whether or not the composer is Mozart. Mozart's melodies in many ways embody many aspects of his style. An educated listener usually can establish mental recognition of Mozart by the first four measures. Vector 1, which contains style-specific properties for the first four measures, shows that approximately 80 percent of Mozart's sonatas have values under the allowable maximum number of 6 X's (deviating truth values), and approximately 95 percent with no more than 7 deviations. A borderline value of 7 is not significant unless other tables show definite out-of-range values. The only sonata significantly exceeding the maximum value is 'M20' (K. 498a). This is the only sonata of disputed authorship that has sometimes been printed with the name of Auguste Eberhard Müller as its composer.

Vector 1 tables for Haydn's sonatas exhibit very consistently values above the maximum (Appendix A, Tables 1-3A through 1-3F). Moreover, many of these values surpass the maximum by a considerable margin. Likewise, the vector 1 tables for Clementi's sonatas consistently surpass the maximum by a substantial amount (Appendix A, Tables 1-4A through 1-4C).

The vector 1 tables for Dussek's sonatas again show the same pattern of values that are consistently over the maximum allowable number of deviations, many by a substantial amount. Only one of Dussek's sonatas does not exceed the maximum (Appendix A, Tables 1-5A and 1-5B). (Op. 31, No. 2, with a value of 7, which is just above the maximum, could be said to have a slightly Mozartean sound. However, the continuation of this brief melodic segment does not maintain a Mozartean element, as evidenced in Appendix A, Table 3-5A). Likewise, Hummel's sonatas also display nonMozartean results in their vector 1 table (Appendix A, Table 1-6). The values are all above the maximum by a considerable amount.

Vector Table 2, which is a shorter subset of the properties of vector Table 1, shows similar results for all the composers under consideration. All but one of the Mozart sonatas are within the maximum of three deviations. The one exception is 'M20', Mozart's Sonata in B-Flat Major, K. 498a (Appendix A, Table 2-1B), which is of disputed authorship. Thus, the nonMozartean results of this sonata in vector Tables 1 and 2 for the first four measures are again underlined by still more nonMozartean results in vector Table 3 for the first eight measures. The entire statement of the initial themes of Haydn's expositions continues to consistently show nonMozartean results, with values above the maximum of three. Only one of the Haydn sonatas has a value not exceeding the maximum allowable value (Appendix A, Tables 2-3A through 2-3F). Likewise, all the Clementi sonatas show a continuation of the return of values above the maximum (Appendix A, Tables 2-4A through 2-4C). Dussek's sonatas also have consistent values above the maximum (Appendix A, Tables 2-5A, 2-5B). Only one Dussek sonata does not surpass this maximum value. (However, this sonata shows nonMozartean results in Table 3-5A). All of Hummel's sonatas (Appendix A, Table 2-6) show nonMozartean results that substantially surpass the maximum.

Vector Table 3, which contains truth values for a set of properties for the first eight measures, also shows the same consistent results for Mozart's sonatas as opposed to those of his contemporaries. Vector Table 4, as a set of properties representing a Mozartean cadential pattern, has a maximum number of allowable deviations of 2 if the exposition is at least 28 measures long. Otherwise, the maximum is 1. All the Mozart sonatas have values within the maximum (Appendix A, Table 4-1). All but three of Haydn's sonatas have values that exceed the Mozartean limit (Appendix A, Tables 4-3A through 4-3B). All of Clementi's sonatas likewise have values over the maximum

(Appendix A, Table 4-4). All but two of Dussek's sonatas also have values above the maximum (Appendix A, Table 4-5). (However, the other tables for these sonatas show nonMozartean results.)

Vector Table 5 consists of a set of properties relating to the 'post main melody', which includes the transition. (The maximum number of allowable deviations of truth values is 3 if the sonata is longer than 28 measures long. Otherwise it is 1.) Table 5 for Mozart's sonatas exhibits a continuation of Mozartean values in the musical material following the initial theme. Only one of Mozart's sonatas, which is of disputed authorship, has a value over this maximum. In particular, only 'M20' (K.498a) continues to exhibit nonMozartean results noticeably above the maximum. All but five of Haydn's sonatas have nonMozartean results, with values above the maximum. Thus, the ISAS system's tables individually yield consistently nonMozartean results for the sonatas of Mozart's contemporaries.

ISAS is also designed to distinguish Mozart sonatas from works attempting to imitate his style. Cope's EMI-composed "Mozart sonata" (category b) exhibits values above the Mozartean maximum in every vector table (Appendix A, Tables 1-2, 2-2, 3-2, 4-2, and 5-2). Vector 4-2, for example, has

X's (deviations from the ideal value) in every column, excluding 'nr' (nonrequired) entries.

Composite scores for two or more tables (that is, the sum of the deviations occurring in those tables) can also be useful.. For example, the total number of allowable deviations for all five vector tables would be between 14 and 17 (occasionally 18). Cope's EMI-composed Mozart sonata exposition has a total of 30 deviations. All Mozart sonatas (except K. 498a, whose authenticity is in doubt) are within this maximum of 14 through 18, with a total of 2 - 16 deviations. The average total number of deviations is approximately 10. In contrast, K. 498a has a composite score of 27 deviations. For example, the opening four measures of its main theme exhibits 11 deviations. A substantial number of deviations in the main theme is a very strong indication of nonMozartean origin. ISAS would thus consider this exposition to be nonauthentic.

Also, the Sonata in D, K.V^{6} (for Violin and Piano), Sonata in C für Klavier zu vier handen (for Piano Four Hands) and the 6 Romantic Sonatas for Violin and Piano, K.V. 55 - 60 (Anh. 20^{c-h}, K.V.^{6}, Anh. C23.01 - 23.06), all Mozart sonatas of dubious origin, exhibit composite scores between 19 and 29, including just the first four tables. Almost all individual vector tables for these works exceed the maximum number of deviations allowed (Appendix A, Tables 1-8, 2-8, 3-8, and

4-8). ISAS would thus consider these expositions to be nonauthentic (nonMozartean).

K. 498a provides an example of category c (a work with portions borrowed from Mozart, but probably put together by another composer). The initial theme of the second movement of this sonata, used for a theme and variations, is borrowed from the slow movement of Mozart's Piano Concerto in B-Flat Major, K. 450. The initial 8 measures of the opening theme of this movement is virtually identical to the initial 8 measures of this concerto movement. Although the vector tables used focus on subsets of properties for the exposition, an initial examination of this movement would seem to imply a likelihood of nonMozartean results if tables were applied (perhaps with minor modification). The opening 8 measures of K. 498a's second movement already contains a 'y-leap' (in measures 1 through 3) and a 'p_apgr' (in measures 7 through 8). As mentioned in the discussion of Table 3, the occurrence of a y-leap and g-gest in this initial location is a strong Mozartean indicator (in conjunction with other evidence). The melody of measures 9 through 16 is also taken directly from the concerto movement (measures 17 through 24). The large jumps (including an augmented 5^{th} and major 7^{th}) and a seemingly nonMozartean cadence at the end of the movement, however, are some of the nonMozartean elements that might be initially apparent.

Mozart's Sonata in F Major, Anhang No. 135, is an example of category d (a sonata in which a portion of it is borrowed by Mozart from another of his works). For example, the first theme, and remainder of the exposition as well, are borrowed (in slightly modified form) from the second movement of his Sonata for Piano and Violin, K. 547. Every table for this sonata is well within the limits of the number of allowable deviations. Tables 4 and 5, for example, have 0 deviations. The composite score for all 5 tables is only 10, well below the maximum allowable composite score of 18. Thus, ISAS considers this exposition to be authentic Mozart.

4.4 Extension of the Library of Predicates

The ISAS system can be extended to other composers and other genres as well. Selective style-specific predicates must be designed which attempt to model only those audible aspects which seem to be involved in the educated listener's initial recognition of the work as being by that particular composer (in contrast with analysis per se). Libraries of style-independent atomic and nonatomic predicates must then be designed to aid in clear and intuitive building up of formula definitions. This usually should also include negative properties that enable the listener to initially exclude a work as being by that particular composer. These negative properties should, however, be present in the sample works collected from the other composers. The work (or portion of a work being studied) should be subdivided into sections. The number of sections depends in part on the amount of sample works available for detailed listening (and on the genre being studied). This is done to increase the number of samples. Vector tables containing subsets of properties would then be created. Maximum values for acceptable deviations for the particular composer must then be established. Moreover, properties with greater weight than others can be defined. Ideal truth values for each property should be established. A vector table entry can also include logical "oring" and "anding" (disjunction and conjunction) of properties.

The sample data ideally should include not only: a) composers contemporary with the composer to be authenticated; but also b) imitators of that style (human- or, if available, computer-composed); also, if available, c) works with portions borrowed from the composer but seamed together by another composer; and d) works with portions borrowed from other works of the same composer.

4.5 Conclusions

Based on the results of the study done for the ISAS system, it seems that the essentials of style can be captured by predicates representing properties. These predicates enable style to become a tangible entity that is formalized in IMCL precisely and intuitively. Its data structure, the segment, also facilitates the representation of musical structure in as hierarchical a fashion as desired. It is interesting to note that distinguishing Mozart's sonata expositions from Haydn's required a relatively smaller subset of the properties listed (although distinguishing his sonatas from contemporaries other than Haydn required additional properties within the vector table. (Clementi's and Dussek's sonatas required a few additional properties.) These sonatas had some of the outer-shell features (generic classical structure) of Mozart that Haydn's sonatas frequently did not exhibit, thus requiring the addition of a few more properties.

In observing the nature of the properties discovered for distinguishing Mozart, several interesting common threads could be observed. Mozart's properties exhibit evidence of a musical style typified, for example, by an attempt to establish a balance between variety and repetition. For example, duration properties dtyp5 and dclss4 (properties 1 and 2, respectively) refer to a set of durations that are neither very small (with a resulting repetitiveness) nor excessively varied. The fd_bt property (property 3) likewise reflects the avoidance of 'sudden 32nds' in a measure not usually so finely subdivided. This refers in essence to a measure with a lack of balance in its type of durations (where sudden 32nds are considered an "excess of variety"). With respect to variety, pkpt>2, y-pks, and mv_valley (properties 27, 28, and 29) refer to the existence of a balanced amount of melodic variety, with expanding peaks and valleys. The 2,4mwt property (property 4), where '3-based' rhythms appear in a measure at least half of which contains '2,4-based' rhythms, describes a similar lack of balance. Rep_dur (property 6), as a negative property, reflects a similar avoidance of rhythmic repetitiveness (as do many of the properties relating to rhythmic sequence. The property red_dest (property 25) reflects avoidance of melodic repetitiveness with respect to melodic destination notes. Likewise, r-ptch (property 20) also is concerned with melodic repetitiveness.

Avoidance of harmonic repetition is also evident. The static_harm property (property 33) is concerned with avoidance of repetitions of a harmonic progression, particularly within the section between the initial theme and the entrance of the secondary theme. Red_V (property 48) is a negative property that relates to avoidance of a 'redundant' harmonic destination of the dominant, particularly when it occurs in the transition prior to its end. Also, the property par_int (property 52) is concerned with textural repetitiveness in the form of parallel intervals.

The properties that deal with even and odd numbers of repetitions of rhythmic patterns (for example, rseqL_odd (property 11) and 1mrseqL-e (property 10)) are likewise concerned with a numerical balancing between duple- (or quadruple-) and triple-based (or other odd-numbered) occurrences. Trip_cad (property 43) is a negative property that reflects a lack of balance from a sudden cadence containing tuplets in an essentially 2,4-based environment. Sym_div (property 22) is concerned with balance created by the even division of a segment into two phrases. Midm_cad and run-on (properties 45 and 46, respectively) are negative cadential properties that reflect the avoidance of a lack of cadential balance. Notrans_V, late-pmm, and long-pmm (properties 53, 54, and 55, respectively) are negative properties involving a lack of structural balance (due to absence of a transition, or a relatively late or lengthy transition).

Tripartite divisions are evident in Mozart's sonatas. This is evident not only in the normal tripartite division of sonata-allegro form, but also in the sense of a stable starting point, with a departure leading to an eventual return. For example, properties est-I, h_yleap, and ret-I (properties 31, 32, and 36, respectively) refer to the firm establishment of the tonic, harmonic motion, and return to the harmonic point of origin, respectively. B1_Lrest (property 5), likewise, is a negative property that describes a lack of rhythmic groundedness at the beginning of the sonata exposition. Est_tp (property 30) refers to a lack of melodic groundedness from absence of the tonic at the beginning of the exposition. Also, the frequent and consistent use of cadential punctuation in Mozart's expositions (Section 3.6.6) contributes to structural balance.

The properties listed for the exposition of Mozart's sonatas can easily be adapted (with minor changes) for other sections and movements. They can also be easily adapted (with minor changes) to works in genres other than the sonata. Moreover, the vector tables could be adapted for use in distinguishing between different periods of a composer's style.

In summary, it appears to be clear that automated means for authenticating authorship for Mozart and his contemporaries and most probably for other composers as well, can be accomplished by methods such as ISAS.

APPENDIX A
Vector Tables

Table 1 -1A: Vector 1 - First four measures

Property	ideal	M1	M2	M3	M4	M5	M6	M7	M8	M10
1) dtyp5	1	1	1	1	1	X	1	1	1	1
2) dclss4	1	1	1	1	X	X	X	1	1	1
3) fd_bt*	0	0	0	X	0	0	0	0	X	0
4) 2,4mwt*	0	0	0	0	0	0	0	0	X	0
5) b1_Lrest*	0	0	0	0	0	0	0	0	0	0
6) rep_dur*	0	0	0	0	0	0	0	0	0	0
7) <=hmrseqL*	0	0	0	0	0	0	0	0	0	0
8) 2mrseqL*	0	0	X	0	0	X	0	0	0	0
9) <=hmrseqL>2*	0	0	0	0	0	0	0	0	0	0
10) 1mrseqL-e*	0	0	0	0	0	0	0	0	0	0
11) rseq_odd*	0	0	0	0	X	0	0	X	0	0
12) prseq_mx*	0	0	0	0	0	0	0	0	X	0
13) ident_pr*	0	0	0	0	0	X	0	0	0	0
14) lh_mel*	0	0	0	0	0	0	0	0	0	0
15) nonscal,>3	1	1	1	1	1	1	X	X	1	1
16) r-ptch*	0	0	0	0	0	0	0	0	0	0
17) diss_span*	0	0	0	0	0	0	0	0	0	0
18) pkpt>2	1	1	1	1	1	1	X	X	1	1
19) y-pks	1	1	1	X	1	1	1	1	1	1
20) mv_valley	1	1	1	1	1	1	X	X	1	1
21) mt_reg	1	1	1	1	X	1	1	1	X	1
22) red_dest*	0	0	0	0	0	0	0	0	X	0
23) sym_div	1	1	1	1	X	1	1	X	1	1
24) est_tp	1	1	X	1	1	1	X	1	1	1
25) est-I	1	1	1	1	1	1	1	1	X	1
26) h_ylp	1	1	1	1	X	X	X	1	1	1
27) I,IV,V-a	1	1	1	X	1	1	1	1	1	1
28) trip_cad*	0	0	0	0	0	0	0	0	0	0
29) rest_cad*	0	0	0	0	X	0	X	0	0	0
30) midm_cad*	0	0	0	0	0	0	0	0	X	0
31) 1-based	1	1	1	1	1	1	1	1	1	1
32) >=3/4cad	1	1	1	1	1	X	1	1	1	1
33) sing_v	1	1	1	1	1	1	1	1	1	1
34) fb_ch_tex	1	1	1	1	1	1	1	1	1	1
35) par_int*	0	0	0	0	0	0	0	0	0	X
Max=6										
Dif		0	2	3	6	6	7	5	7	1

(All sonatas are numbered according to the editions listed in the bibliography)

Table 1-1B: Vector 1 - First four measures

Property	Ideal	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20
1) dtyp5	1	1	1	1	1	1	1	1	1	1	1
2) dclss4	1	1	1	1	1	1	1	1	1	1	1
3) fd_bt*	0	0	0	0	0	0	0	0	0	0	0
4) 2,4mwt*	0	0	0	0	0	0	0	0	0	0	0
5) b1_Lrest*	0	0	0	0	0	0	0	0	0	0	0
6) rep_dur*	0	0	0	0	0	0	0	0	0	0	X
7) <=hmrseq*	0	0	0	0	0	0	X	0	0	X	0
8) 2mrseq*	0	0	0	0	0	0	0	0	0	0	0
9) <=hmrseqL>2*	0	0	0	0	0	0	0	0	0	0	0
10) 1mrseqL-e*	0	0	0	0	0	0	0	0	0	0	0
11) rseqL_odd*	0	0	X	0	0	0	0	0	0	0	0
12) prseqL_mx*	0	0	0	0	0	0	0	0	0	0	0
13) ident_pr*	0	0	0	0	0	X	0	0	0	0	0
14) lh_mel*	0	0	0	0	0	0	0	0	0	0	X
15) nonscal,>3	1	1	1	1	1	1	1	1	1	1	1
16) r-ptch*	0	0	0	0	0	0	0	0	0	0	0
17) diss_span*	0	0	0	0	0	0	0	0	0	0	X
18) pkpt>2	1	1	X	1	1	1	1	1	1	1	X
19) y-pks	1	1	1	1	1	1	X	1	1	1	1
20) mv_valley	1	1	X	1	1	1	1	1	X	1	X
21) mt_reg	1	1	1	X	X	1	1	1	1	1	X
22) red_dest*	0	X	0	0	0	0	0	0	0	0	0
23) sym_div	1	X	X	1	1	X	1	1	1	1	1
24) est_tp	1	1	1	1	X	1	X	1	1	X	1
25) est-I	1	1	X	1	X	1	1	1	X	1	X
26) h_ylp	1	X	X	1	X	X	1	1	X	X	X
27) I,IV,V-a	1	X	1	1	1	1	1	X	X	1	1
28) trip_cad*	0	0	0	0	0	0	0	0	0	0	0
29) rest_cad*	0	0	0	0	0	X	0	0	X	0	X
30) midm_cad*	0	0	0	0	0	0	0	0	0	0	0
31) 1-based	1	1	1	1	1	X	1	1	1	1	X
32) >=3/4cad	1	1	1	1	1	1	1	1	1	1	1
33) sing_v	1	1	1	1	1	1	1	1	1	1	1
34) fb_ch_tex	1	X	1	1	X	1	1	1	1	1	1
35) par_int*	0	0	0	0	0	0	0	0	0	0	X
Max=6											
Dif		5	6	1	5	5	3	1	5	3	11

Table 1-2: Vector 1 - First four measures

Property	Ideal	Cope
1) dtyp5	1	1
2) dclss4	1	1
3) fd_bt*	0	0
4) 2,4mwt*	0	0
5) b1_Lrest*	0	0
6) rep_dur*	0	0
7) <=hmrseq*	0	0
8) 2mrseq*	0	0
9) <=hmrseqL>2*	0	0
10) 1mrseqL-e*	0	0
11) rseqL_odd*	0	0
12) prseqL_mx*	0	0
13) ident_pr*	0	0
14) lh_mel*	0	0
15) nonscal,>3	1	1
16) r-ptch	0	X
17) diss_span	0	X
18) pkpt>2	1	X
19) y-pks	1	1
20) mv_valley*	1	X
21) mt_reg*	1	nr
22) red_dest*	0	0
23) sym_div*	1	X
24) est_tp	1	1
25) est-I	1	X
26) h_ylp	1	X
27) I,IV,V-a	1	X
28) trip_cad*	0	0
29) rest_cad*	0	0
30) midm_cad*	0	0
31) 1-based	1	X
32) >=3/4cad*	1	1
33) sing_v*	1	1
34) fb_ch_tex*	1	1
35) par_int	0	X
Max=6		
Dif		10

Table 1-3A: Vector 1 - First four measures

Property	Ideal	H1	H2	H3	H4	H6	H8	H9	H10	H11
1) dtyp5	1	1	1	1	1	1	1	1	X	1
2) dclss4	1	1	1	1	1	1	X	1	X	1
3) fd_bt*	0	X	X	X	X	0	0	0	0	0
4) 2,4mwt*	0	X	0	0	X	0	X	0	0	X
5) b1_Lrest*	0	0	0	0	0	0	0	0	0	0
6) rep_dur*	0	0	0	X	0	0	X	0	X	0
7) <=hmrseq*	0	X	0	X	0	X	0	X	0	0
8) 2mrseq*	0	0	0	0	0	0	0	0	0	0
9) <=hmrseqL>2*	0	X	0	0	0	0	0	X	0	0
10) 1mrseqL-e*	0	X	0	0	0	0	0	0	0	X
11) rseqL_odd*	0	X	0	0	0	0	0	X	0	0
12) prseqL_mx*	0	X	0	0	0	X	0	0	0	X
13) ident_pr*	0	0	0	0	0	0	0	0	0	X
14) lh_mel*	0	0	0	0	0	0	0	0	0	0
15) nonscal,>3	1	1	X	1	1	1	X	1	1	1
16) r-ptch*	0	0	0	0	0	0	0	0	0	0
17) diss_span*	0	0	0	0	0	0	0	0	0	0
18) pkpt>2	1	1	1	1	1	1	1	1	X	1
19) y-pks	1	X	1	X	1	1	1	1	X	1
20) mv_valley	1	1	X	X	X	1	1	1	X	1
21) mt_reg	1	X	X	X	1	X	X	1	1	X
22) red_dest*	0	0	X	X	0	X	0	0	X	X
23) sym_div	1	1	X	X	X	X	X	1	X	X
24) est_tp	1	1	1	1	1	X	X	X	1	X
25) est-I	1	1	X	1	X	X	X	X	1	X
26) h_ylp	1	X	1	X	X	X	X	X	X	X
27) I,IV,V-a	1	1	1	X	1	1	X	X	X	X
28) trip_cad*	0	X	0	0	X	0	X	0	0	X
29) rest_cad*	0	X	0	0	0	0	X	0	0	X
30) midm_cad*	0	0	0	X	0	0	0	0	0	0
31) 1-based	1	1	X	1	X	X	X	1	1	X
32) >=3/4cad	1	1	1	1	1	1	1	1	1	1
33) sing_v	1	1	1	1	X	1	1	1	1	X
34) fb_ch_tex	1	1	1	1	X	1	1	1	1	1
35) par_int*	0	0	0	X	X	X	0	0	0	X
Max=6										
Dif		12	8	12	11	10	13	7	10	16

Table 1-3B: Vector 1 - First four measures

Property	Ideal	H12	H13	H14	H15	H16	H17	H18	H19	H20
1) dtyp5	1	1	X	X	1	1	X	1	1	1
2) dclss4	1	1	1	X	1	1	1	1	1	1
3) fd_bt*	0	0	X	0	X	X	X	X	X	X
4) 2,4mwt*	0	X	X	X	X	0	X	X	0	0
5) b1_Lrest*	0	0	0	0	0	0	0	0	0	0
6) rep_dur*	0	0	0	X	X	0	0	0	0	0
7) <=hmrseq*	0	0	0	0	0	X	X	0	0	X
8) 2mrseq*	0	0	0	0	0	0	0	0	0	0
9) <=hmrseqL>2*	0	0	0	0	0	X	0	0	0	X
10) 1mrseqL-e*	0	0	0	0	0	0	0	0	0	0
11) rseqL_odd*	0	0	0	0	0	0	0	0	0	X
12) prseqL_mx*	0	0	0	0	X	0	0	0	0	X
13) ident_pr*	0	X	0	0	0	0	X	0	0	0
14) lh_mel*	0	0	X	0	0	0	0	0	X	0
15) nonscal,>3	1	X	1	1	1	1	1	1	X	1
16) r-ptch*	0	0	0	0	0	0	0	0	0	0
17) diss_span*	0	0	0	0	0	X	0	0	0	0
18) pkpt>2	1	1	1	X	1	1	1	1	1	1
19) y-pks	1	X	1	1	X	1	1	1	X	X
20) mv_valley	1	X	1	X	X	1	1	1	1	1
21) mt_reg	1	1	X	X	X	X	1	X	X	X
22) red_dest*	0	0	0	0	X	0	0	X	X	X
23) sym_div	1	X	1	1	1	X	X	1	X	X
24) est_tp	1	1	X	X	1	1	1	X	X	X
25) est-I	1	X	X	1	1	X	1	X	1	1
26) h_ylp	1	1	X	X	X	1	X	X	X	1
27) I,IV,V-a	1	X	1	1	X	1	1	1	X	X
28) trip_cad*	0	X	X	X	X	0	0	0	0	0
29) rest_cad*	0	0	0	0	0	0	X	0	X	X
30) midm_cad*	0	0	X	0	0	0	0	0	0	0
31) 1-based	1	X	1	1	X	X	X	X	X	X
32) >=3/4cad	1	1	X	1	1	1	X	1	1	1
33) sing_v	1	1	1	1	1	1	1	1	1	1
34) fb_ch_tex	1	1	1	1	X	1	1	X	X	1
35) par_int*	0	0	0	0	X	0	0	X	0	0
Max=6										
Dif		10	11	10	14	8	10	10	13	13

Table 1-3C: Vector 1 - First four measures

Property	Ideal	H29	H30	H31	H32	H33	H34	H35	H36	H37
1) dtyp5	1	X	X	X	X	1	X	X	1	1
2) dclss4	1	1	1	X	1	1	X	X	1	1
3) fd_bt*	0	X	X	X	X	0	X	X	X	0
4) 2,4mwt*	0	0	X	X	X	0	0	0	0	X
5) b1_Lrest*	0	0	0	0	0	0	0	0	0	0
6) rep_dur*	0	0	0	0	0	0	X	0	0	0
7) <=hmrseq*	0	X	X	X	0	X	0	X	X	0
8) 2mrseq*	0	0	0	0	0	0	X	0	0	0
9) <=hmrseqL>2*	0	X	X	0	0	0	0	0	0	0
10) 1mrseqL-e*	0	0	X	0	0	0	0	0	0	0
11) rseqL_odd*	0	X	X	0	0	0	0	X	X	0
12) prseqL_mx*	0	0	0	X	0	X	0	0	0	0
13) ident_pr*	0	X	X	0	0	0	0	0	0	0
14) lh_mel*	0	X	0	0	0	0	0	0	0	0
15) nonscal,>3	1	1	1	X	1	1	1	1	1	1
16) r-ptch*	0	0	0	0	0	0	0	0	0	0
17) diss_span*	0	0	0	0	0	X	0	0	X	0
18) pkpt>2	1	1	1	1	1	1	1	1	1	1
19) y-pks	1	1	1	X	X	1	X	1	X	X
20) mv_valley	1	1	X	1	1	1	1	1	1	1
21) mt_reg	1	X	1	X	1	X	X	1	X	X
22) red_dest*	0	0	X	0	0	0	0	X	0	0
23) sym_div	1	1	X	X	X	X	X	X	X	X
24) est_tp	1	X	X	1	X	X	X	1	X	1
25) est-I	1	X	X	X	X	X	X	X	X	1
26) h_ylp	1	X	X	1	X	X	X	1	X	X
27) I,IV,V-a	1	1	X	X	X	1	1	1	1	X
28) trip_cad*	0	0	X	0	0	0	0	0	0	0
29) rest_cad*	0	0	0	0	0	0	0	X	0	0
30) midm_cad*	0	X	0	0	X	X	X	0	0	X
31) 1-based	1	X	X	1	1	1	1	X	X	1
32) >=3/4cad	1	X	1	1	X	X	1	1	1	X
33) sing_v	1	1	1	1	X	X	1	1	1	X
34) fb_ch_tex	1	1	1	1	X	1	1	X	1	1
35) par_int*	0	X	0	0	X	X	X	0	0	0
Max=6										
Dif		15	17	13	14	12	13	11	11	9

Table 1-3D: Vector 1 - First four measures

Property	Ideal	H38	H39	H40	H41	H42	H43	H44	H45	H46
1) dtyp5	1	X	1	X	1	1	1	1	1	1
2) dclss4	1	1	1	1	1	X	1	1	1	1
3) fd_bt*	0	X	0	X	X	0	0	0	X	X
4) 2,4mwt*	0	X	0	0	0	0	0	0	0	0
5) b1_Lrest*	0	0	0	0	X	0	0	0	0	0
6) rep_dur*	0	0	X	0	0	X	0	X	0	0
7) <=hmrseq*	0	X	0	X	X	X	0	0	X	0
8) 2mrseq*	0	0	0	0	0	0	X	0	0	X
9) <=hmrseqL>2*	0	X	0	0	0	0	0	0	X	0
10) 1mrseqL-e*	0	0	0	0	0	0	0	0	0	0
11) rseqL_odd*	0	X	0	0	0	0	0	0	X	0
12) prseqL_mx*	0	0	X	X	0	X	0	0	X	0
13) ident_pr*	0	X	0	0	X	0	0	0	0	0
14) lh_mel*	0	0	0	X	0	0	X	X	0	0
15) nonscal,>3	1	1	1	1	1	X	1	1	1	1
16) r-ptch*	0	0	0	0	0	X	X	0	0	0
17) diss_span*	0	0	0	0	X	0	X	0	0	0
18) pkpt>2	1	1	1	1	1	X	1	1	1	1
19) y-pks	1	X	X	1	X	X	X	1	1	X
20) mv_valley	1	1	1	1	1	X	1	1	1	1
21) mt_reg	1	X	X	X	X	X	X	X	X	1
22) red_dest*	0	0	X	0	0	X	0	X	0	0
23) sym_div	1	1	1	X	1	X	1	X	X	X
24) est_tp	1	X	X	1	X	1	X	X	X	1
25) est-I	1	X	X	X	X	X	X	1	X	X
26) h_ylp	1	1	1	X	X	X	X	X	X	1
27) I,IV,V-a	1	1	1	X	X	1	X	X	1	1
28) trip_cad*	0	0	0	0	0	0	0	0	0	0
29) rest_cad*	0	0	X	0	X	0	X	X	X	0
30) midm_cad*	0	0	0	X	X	0	0	0	0	X
31) 1-based	1	X	X	1	X	X	X	X	1	1
32) >=3/4cad	1	1	1	X	1	1	1	X	1	X
33) sing_v	1	1	1	1	1	1	X	X	1	X
34) fb_ch_tex	1	1	1	X	1	1	1	1	1	1
35) par_int*	0	0	X	0	X	0	0	X	0	X
Max=6										
Dif		12	10	13	15	15	13	13	11	9

Table 1-3E: Vector 1 - First four measures

Property	Ideal	H47	H48	H49	H50	H51	H52	H53	H54	H55
1) dtyp5	1	X	1	1	X	X	1	X	X	X
2) dclss4	1	X	1	1	X	1	1	X	X	X
3) fd_bt*	0	X	0	X	0	X	X	0	0	X
4) 2,4mwt*	0	0	0	0	0	0	0	X	X	0
5) b1_Lrest*	0	0	0	0	0	0	0	X	0	0
6) rep_dur*	0	0	0	X	X	0	0	0	X	0
7) <=hmrseq*	0	0	0	0	0	X	X	0	0	X
8) 2mrseq*	0	0	0	0	0	0	0	0	0	0
9) <=hmrseqL>2*	0	0	0	0	0	0	0	0	0	X
10) 1mrseqL-e*	0	0	0	X	0	0	0	X	0	0
11) rseqL_odd*	0	0	0	0	0	0	0	0	0	X
12) prseqL_mx*	0	0	0	0	X	0	X	0	0	X
13) ident_pr*	0	0	0	X	X	0	0	0	0	0
14) lh_mel*	0	0	0	X	0	0	0	X	0	0
15) nonscal,>3	1	1	1	1	1	1	1	1	X	X
16) r-ptch*	0	0	0	0	0	0	0	0	0	0
17) diss_span*	0	0	X	0	0	0	0	0	0	0
18) pkpt>2	1	1	X	X	1	1	1	1	1	1
19) y-pks	1	1	X	1	X	1	1	1	1	1
20) mv_valley	1	1	X	1	1	1	1	X	X	1
21) mt_reg	1	X	X	X	X	1	X	X	X	1
22) red_dest*	0	X	0	X	0	0	0	0	0	0
23) sym_div	1	X	1	X	1	1	X	X	X	X
24) est_tp	1	1	X	X	1	1	1	X	1	1
25) est-I	1	X	1	X	1	X	X	X	X	1
26) h_ylp	1	1	X	X	X	X	X	X	1	X
27) I,IV,V-a	1	X	1	1	X	X	X	1	1	X
28) trip_cad*	0	0	0	0	0	0	0	X	X	0
29) rest_cad*	0	0	X	X	X	X	0	X	0	X
30) midm_cad*	0	X	0	0	X	X	0	0	0	0
31) 1-based	1	1	1	X	X	X	X	X	X	X
32) >=3/4cad	1	X	1	1	1	1	1	1	1	1
33) sing_v	1	1	1	1	X	1	1	X	X	1
34) fb_ch_tex	1	X	1	1	1	1	X	1	X	1
35) par_int*	0	X	0	0	X	0	0	X	X	0
Max=6										
Dif		12	8	14	14	9	10	17	14	13

Table 1-3F: Vector 1 - First four measures

Property	Ideal	H56	H57	H58	H59	H60	H61	H62
1) dtyp5	1	X	1	X	1	X	1	1
2) dclss4	1	1	1	1	1	X	1	1
3) fd_bt*	0	X	0	X	0	0	0	X
4) 2,4mwt*	0	X	0	X	0	0	0	0
5) b1_Lrest*	0	0	0	0	X	X	X	0
6) rep_dur*	0	0	X	0	0	0	X	0
7) <=hmrseq*	0	X	0	0	0	X	X	X
8) 2mrseq*	0	0	0	0	0	0	0	0
9) <=hmrseqL>2*	0	X	0	0	0	X	X	0
10) 1mrseqL-e*	0	0	0	0	0	0	0	0
11) rseqL_odd*	0	X	0	0	0	X	0	0
12) prseqL_mx*	0	0	0	0	0	X	0	0
13) ident_pr*	0	0	0	0	0	0	0	X
14) lh_mel*	0	0	X	X	X	0	X	X
15) nonscal,>3	1	1	X	1	1	1	1	1
16) r-ptch*	0	0	0	0	0	0	0	0
17) diss_span*	0	0	X	0	0	X	0	0
18) pkpt>2	1	1	X	1	1	1	1	1
19) y-pks	1	1	1	1	1	X	1	1
20) mv_valley	1	1	X	1	1	1	1	1
21) mt_reg	1	X	X	X	X	X	X	1
22) red_dest*	0	0	0	0	0	X	0	X
23) sym_div	1	1	X	1	X	X	1	X
24) est_tp	1	1	X	X	X	X	1	1
25) est-I	1	X	1	1	X	X	X	X
26) h_ylp	1	X	1	1	X	X	1	X
27) I,IV,V-a	1	1	X	1	X	1	X	1
28) trip_cad*	0	0	0	0	0	0	0	0
29) rest_cad*	0	X	0	X	X	X	0	X
30) midm_cad*	0	0	X	0	0	0	0	0
31) 1-based	1	1	X	X	X	X	X	1
32) >=3/4cad	1	1	1	1	1	1	1	1
33) sing_v	1	1	1	1	1	1	1	X
34) fb_ch_tex	1	X	1	1	1	X	X	1
35) par_int*	0	0	0	0	X	0	0	X
Max=6								
Dif		11	12	8	11	18	10	11

Table 1-4A: Vector 1 - First four measures

Property	Ideal	C1	C2	C3	C4	C5	C6	C7	C8	C9
1) dtyp5	1	1	1	1	1	X	1	1	1	X
2) dclss4	1	1	1	1	1	X	1	1	1	1
3) fd_bt*	0	0	0	0	0	0	X	X	0	0
4) 2,4mwt*	0	0	X	0	X	0	X	0	0	X
5) b1_Lrest*	0	0	0	0	X	X	X	0	0	X
6) rep_dur*	0	0	0	0	X	X	0	0	X	0
7) <=hmrseq*	0	0	X	0	0	0	0	0	0	X
8) 2mrseq*	0	0	0	0	0	0	0	X	X	0
9) <=hmrseqL>2*	0	0	X	0	0	0	0	0	0	X
10) 1mrseqL-e*	0	0	0	0	X	0	0	0	0	0
11) rseqL_odd*	0	0	X	0	0	0	0	0	0	0
12) prseqL_mx*	0	0	0	0	X	X	0	0	0	0
13) ident_pr*	0	0	X	0	X	X	0	0	0	0
14) lh_mel*	0	0	0	0	0	0	0	0	0	0
15) nonscal,>3	1	1	1	1	1	X	1	1	1	1
16) r-ptch*	0	0	0	0	0	0	0	0	0	0
17) diss_span*	0	0	0	0	0	0	0	0	0	X
18) pkpt>2	1	1	1	1	1	1	1	1	X	1
19) y-pks	1	X	X	1	X	1	1	X	X	X
20) mv_valley	1	X	1	1	1	1	1	1	X	1
21) mt_reg	1	nr	nr	nr	nr	nr	nr	nr	nr	nr
22) red_dest*	0	0	0	X	0	0	0	0	0	0
23) sym_div	1	X	X	1	X	X	1	X	X	1
24) est_tp	1	1	1	X	X	X	X	X	1	X
25) est-I	1	1	X	X	X	X	X	X	1	X
26) h_ylp	1	X	X	X	X	X	1	X	X	X
27) I,IV,V-a	1	X	1	X	1	1	X	1	1	1
28) trip_cad*	0	0	X	0	X	0	X	0	0	0
29) rest_cad*	0	0	0	X	X	X	0	0	0	X
30) midm_cad*	0	0	0	0	0	X	0	0	0	0
31) 1-based	1	X	1	1	X	1	X	X	1	1
32) >=3/4cad	1	1	1	1	1	1	1	1	1	1
33) sing_v	1	X	1	1	1	1	1	X	X	X
34) fb_ch_tex	1	X	1	1	X	1	1	1	1	1
35) par_int*	0	X	0	0	0	0	0	X	X	X
Max=6										
Dif		9	10	6	15	13	8	10	9	13

Table 1-4B: Vector 1 - First four measures

Property	Ideal	C10	C11	C12	C13	C14	C15	C16	C17
1) dtyp5	1	1	X	1	1	1	1	1	1
2) dclss4	1	X	1	1	1	1	1	X	1
3) fd_bt*	0	0	X	0	0	0	0	0	0
4) 2,4mwt*	0	0	0	0	0	0	0	0	X
5) b1_Lrest*	0	0	0	X	0	0	0	X	0
6) rep_dur*	0	0	0	0	0	0	0	0	0
7) <=hmrseq*	0	X	X	0	X	X	X	0	0
8) 2mrseq*	0	0	0	0	0	0	0	X	0
9) <=hmrseqL>2*	0	X	X	0	0	0	X	0	0
10) 1mrseqL-e*	0	0	0	X	0	X	0	0	0
11) rseqL_odd*	0	0	0	X	0	X	X	0	0
12) prseqL_mx*	0	0	0	0	0	0	X	0	0
13) ident_pr*	0	0	0	0	0	0	0	X	0
14) lh_mel*	0	X	X	0	X	0	0	0	0
15) nonscal,>3	1	1	1	1	1	1	1	1	X
16) r-ptch*	0	0	0	X	0	0	X	0	0
17) diss_span*	0	0	X	0	0	0	X	X	X
18) pkpt>2	1	1	1	1	1	1	1	1	1
19) y-pks	1	X	1	1	1	X	X	1	1
20) mv_valley	1	1	1	1	X	1	1	1	1
21) mt_reg	1	nr	nr	nr	nr	nr	nr	nr	nr
22) red_dest*	0	0	0	X	X	X	0	0	X
23) sym_div	1	X	1	X	X	X	X	1	X
24) est_tp	1	X	1	1	X	1	1	X	1
25) est-I	1	X	1	X	1	1	1	X	1
26) h_ylp	1	1	X	1	1	X	X	X	X
27) I,IV,V-a	1	1	X	1	X	X	X	X	X
28) trip_cad*	0	0	0	0	0	0	0	0	X
29) rest_cad*	0	0	0	X	0	0	X	0	0
30) midm_cad*	0	0	0	X	0	0	0	0	0
31) 1-based	1	1	X	1	X	X	X	X	1
32) >=3/4cad	1	1	1	1	1	1	1	1	1
33) sing_v	1	X	X	1	X	1	1	X	1
34) fb_ch_tex	1	1	X	X	1	X	X	X	1
35) par_int*	0	0	X	0	X	0	0	X	0
Max=6									
Dif		9	12	10	10	10	13	13	8

Table 1-4C: Vector 1 - First four measures

Property	Ideal	C19	C20	C21	C22	C23	C24
1) dtyp5	1	1	X	1	1	X	1
2) dclss4	1	1	X	1	1	1	1
3) fd_bt*	0	0	0	0	0	X	0
4) 2,4mwt*	0	0	0	X	X	X	0
5) b1_Lrest*	0	0	0	X	0	0	0
6) rep_dur*	0	X	0	X	X	0	0
7) <=hmrseq*	0	0	0	0	0	0	0
8) 2mrseq*	0	0	0	0	0	0	X
9) <=hmrseqL>2*	0	0	0	0	0	0	0
10) 1mrseqL-e*	0	0	X	0	0	X	0
11) rseqL_odd*	0	0	0	0	0	0	0
12) prseqL_mx*	0	0	0	0	0	0	0
13) ident_pr*	0	0	0	X	0	0	0
14) lh_mel*	0	X	0	0	0	X	X
15) nonscal,>3	1	1	X	X	X	X	1
16) r-ptch*	0	0	0	0	0	0	0
17) diss_span*	0	X	0	X	0	0	0
18) pkpt>2	1	1	1	1	1	1	1
19) y-pks	1	X	X	X	1	X	1
20) mv_valley	1	X	X	1	1	1	1
21) mt_reg	1	nr	nr	nr	nr	nr	nr
22) red_dest*	0	X	0	0	X	0	0
23) sym_div	1	1	X	X	X	1	X
24) est_tp	1	X	X	X	X	1	1
25) est-I	1	X	X	X	1	X	X
26) h_ylp	1	1	1	X	1	X	X
27) I,IV,V-a	1	1	1	1	1	1	1
28) trip_cad*	0	0	0	X	X	0	0
29) rest_cad*	0	0	0	X	0	0	0
30) midm_cad*	0	0	0	0	0	0	0
31) 1-based	1	1	X	1	X	1	X
32) >=3/4cad	1	1	1	1	1	1	1
33) sing_v	1	1	X	1	1	1	X
34) fb_ch_tex	1	X	1	X	1	1	1
35) par_int*	0	0	0	0	0	0	X
Max=6							
Dif		9	11	14	8	9	8

Table 1-5A: Vector 1 - First four measures

Property	Ideal	D31	D35.1	D35.2	D35.3	D39.1	D39.2	D39.3
1) dtyp5	1	1	X	1	1	1	1	1
2) dclss4	1	1	1	1	1	1	1	1
3) fd_bt*	0	0	X	0	0	0	0	0
4) 2,4mwt*	0	0	0	0	X	0	0	0
5) b1_Lrest*	0	0	0	0	0	0	0	0
6) rep_dur*	0	X	0	0	0	0	0	0
7) <=hmrseq*	0	0	0	0	X	0	X	X
8) 2mrseq*	0	0	0	X	0	0	0	0
9) <=hmrseqL>2*	0	0	0	0	X	0	0	X
10) 1mrseqL-e*	0	X	X	0	0	0	0	0
11) rseqL_odd*	0	0	0	0	X	0	0	X
12) prseqL_mx*	0	0	0	0	0	0	0	0
13) ident_pr*	0	0	0	0	0	0	0	0
14) lh_mel*	0	0	X	0	0	0	X	0
15) nonscal,>3	1	X	1	1	1	X	X	1
16) r-ptch*	0	0	0	0	0	0	X	0
17) diss_span*	0	0	0	0	0	0	0	0
18) pkpt>2	1	1	X	1	1	X	X	1
19) y-pks	1	1	X	1	X	1	X	1
20) mv_valley	1	X	X	1	1	X	1	1
21) mt_reg	1	nr	nr	nr	nr	nr	nr	nr
22) red_dest*	0	0	0	0	X	X	0	0
23) sym_div	1	1	X	1	X	X	X	X
24) est_tp	1	1	1	1	1	1	X	1
25) est-I	1	X	X	1	1	X	1	1
26) h_ylp	1	X	1	X	X	X	X	X
27) I,IV,V-a	1	1	X	1	1	1	X	X
28) trip_cad*	0	0	0	0	0	0	0	0
29) rest_cad*	0	0	0	X	X	0	0	X
30) midm_cad*	0	0	0	0	X	0	0	0
31) 1-based	1	X	1	X	1	X	X	X
32) >=3/4cad	1	1	1	1	1	1	1	1
33) sing_v	1	1	X	X	X	X	X	X
34) fb_ch_tex	1	1	1	1	1	X	1	1
35) par_int*	0	0	X	X	X	X	X	X
Max=6								
Dif		7	12	6	12	11	13	10

Table 1-5B: Vector 1 - First four measures

Property	Ideal	D43	D45.1	D45.2	D45.3	D47.1	D47.2	D23	D25.2
1) dtyp5	1	1	X	1	1	X	1	1	1
2) dclss4	1	1	X	1	1	X	1	1	1
3) fd_bt*	0	0	0	X	X	0	0	0	X
4) 2,4mwt*	0	0	0	0	0	0	0	0	X
5) b1_Lrest*	0	X	0	0	0	0	0	0	0
6) rep_dur*	0	0	X	0	0	0	0	0	0
7) <=hmrseq*	0	0	0	0	X	0	0	0	0
8) 2mrseq*	0	0	0	0	X	X	0	0	0
9) <=hmrseqL>2*	0	0	0	0	0	0	0	0	0
10) 1mrseqL-e*	0	X	0	0	0	0	0	X	X
11) rseqL_odd*	0	0	0	0	0	0	0	0	0
12) prseqL_mx*	0	0	0	0	0	0	X	0	0
13) ident_pr*	0	0	0	0	0	0	0	0	0
14) lh_mel*	0	0	0	0	0	0	0	X	X
15) nonscal,>3	1	1	X	X	X	X	1	1	1
16) r-ptch*	0	0	0	0	0	0	0	0	X
17) diss_span*	0	0	0	0	0	0	0	X	0
18) pkpt>2	1	1	X	1	1	X	1	1	1
19) y-pks	1	1	X	1	1	X	X	X	X
20) mv_valley	1	1	X	1	1	X	X	1	1
21) mt_reg	1	nr	nr	nr	nr	nr	nr	nr	nr
22) red_dest*	0	0	0	0	0	0	0	0	0
23) sym_div	1	1	X	X	X	X	1	X	1
24) est_tp	1	X	X	X	X	X	1	1	1
25) est-I	1	X	1	X	1	1	X	1	X
26) h_ylp	1	1	1	X	1	X	X	1	1
27) I,IV,V-a	1	1	X	X	X	1	1	X	X
28) trip_cad*	0	0	0	0	0	0	0	0	0
29) rest_cad*	0	0	0	0	0	0	0	X	0
30) midm_cad*	0	0	X	0	0	0	0	X	0
31) 1-based	1	X	X	X	X	1	1	1	1
32) >=3/4cad	1	X	1	1	1	1	1	1	1
33) sing_v	1	X	X	1	1	1	X	X	X
34) fb_ch_tex	1	1	1	X	1	1	X	1	X
35) par_int*	0	0	X	X	0	0	X	0	X
Max=6									
Dif		7	14	10	8	10	8	9	11

Table 1-6: Vector 1 - First four measures

Property	Ideal	Hu1	Hu2	Hu3	Hu4	Hu5	Hu6
1) dtyp5	1	1	1	X	1	1	X
2) dclss4	1	1	X	X	1	1	1
3) fd_bt*	0	0	0	X	0	0	X
4) 2,4mwt*	0	0	0	X	0	0	0
5) b1_Lrest*	0	0	0	0	0	X	0
6) rep_dur*	0	X	0	0	X	0	0
7) <=hmrseq*	0	0	0	X	X	0	0
8) 2mrseq*	0	0	0	0	0	0	0
9) <=hmrseqL>2*	0	0	0	0	X	0	0
10) 1mrseqL-e*	0	0	X	0	0	0	0
11) rseqL_odd*	0	0	0	0	X	0	0
12) prseqL_mx*	0	0	0	0	0	0	0
13) ident_pr*	0	0	0	0	0	X	0
14) lh_mel*	0	X	0	0	X	0	0
15) nonscal,>3	1	1	X	1	1	1	1
16) r-ptch*	0	0	X	0	0	0	0
17) diss_span*	0	0	X	0	0	X	X
18) pkpt>2	1	1	1	X	1	1	1
19) y-pks	1	1	1	1	X	X	1
20) mv_valley	1	X	X	X	1	X	1
21) mt_reg	1	nr	nr	nr	nr	nr	nr
22) red_dest*	0	X	0	X	0	0	0
23) sym_div	1	X	X	X	X	X	X
24) est_tp	1	1	1	1	X	X	1
25) est-I	1	X	X	X	X	X	1
26) h_ylp	1	X	X	1	X	1	1
27) I,IV,V-a	1	X	1	X	X	1	X
28) trip_cad*	0	0	0	0	0	0	0
29) rest_cad*	0	0	X	X	0	0	X
30) midm_cad*	0	0	0	0	0	0	0
31) 1-based	1	X	X	X	1	X	X
32) >=3/4cad	1	1	1	1	1	1	1
33) sing_v	1	X	1	X	X	X	X
34) fb_ch_tex	1	X	1	1	X	1	1
35) par_int*	0	X	0	0	X	X	0
Max=6							
Dif		12	11	14	14	11	8

Table 1-7: Vector 1 - First four measures

Property	Ideal	B1	B2	B3	B4	B5	B6
1) dtyp5	1	1	X	X	X	1	1
2) dclss4	1	1	X	X	1	1	1
3) fd_bt*	0	0	X	0	X	X	X
4) 2,4mwt*	0	0	0	0	X	0	0
5) b1_Lrest*	0	X	X	0	0	0	X
6) rep_dur*	0	0	X	0	0	0	0
7) <=hmrseq*	0	X	0	X	0	X	0
8) 2mrseq*	0	0	0	X	0	0	0
9) <=hmrseqL>2*	0	X	0	X	0	X	0
10) 1mrseqL-e*	0	0	X	0	X	0	X
11) rseqL_odd*	0	X	0	0	0	0	0
12) prseqL_mx*	0	0	0	0	X	X	0
13) ident_pr*	0	0	0	0	0	0	0
14) lh_mel*	0	X	0	0	X	0	X
15) nonscal,>3	1	1	1	1	1	1	1
16) r-ptch*	0	0	0	0	0	0	0
17) diss_span*	0	X	0	X	0	0	0
18) pkpt>2	1	1	1	1	1	1	1
19) y-pks	1	X	X	1	1	X	1
20) mv_valley	1	1	1	X	1	1	1
21) mt_reg	1	nr	nr	nr	nr	nr	nr
22) red_dest*	0	0	0	0	0	0	0
23) sym_div	1	X	X	1	X	X	X
24) est_tp	1	X	X	1	X	1	X
25) est-I	1	X	X	1	X	X	1
26) h_ylp	1	1	X	1	X	X	X
27) I,IV,V-a	1	X	1	1	X	X	1
28) trip_cad*	0	0	0	0	0	0	0
29) rest_cad*	0	X	0	0	0	0	0
30) midm_cad*	0	0	X	0	X	X	X
31) 1-based	1	X	X	X	X	X	X
32) >=3/4cad	1	1	1	1	X	X	X
33) sing_v	1	1	1	X	X	1	X
34) fb_ch_tex	1	1	1	1	1	X	1
35) par_int*	0	0	0	X	X	X	X
Max=6							
Dif		13	13	10	16	14	12

Table 1-8: Vector 1 - First four measures

Property	Ideal	4-hand	Son in D	Rom1	Rom2	Rom3	Rom4	Rom5	Rom6
1) dtyp5	1	1	1	1	1	1	1	1	1
2) dclss4	1	1	1	1	1	1	1	1	1
3) fd_bt*	0	0	0	X	0	0	0	0	X
4) 2,4mwt	0	0	0	0	0	0	X	0	0
5) b1_Lrest*	0	0	0	X	0	0	0	0	0
6) rep_dur*	0	X	X	0	0	0	0	0	0
7) <=hmrseq*	0	0	0	0	0	0	0	X	X
8) 2mrseq*	0	0	0	0	0	0	0	X	0
9) <=hmrsL>2*	0	0	0	0	0	0	0	0	0
10) 1mrseqL-e*	0	X	0	0	0	X	X	0	0
11) rseqL_odd*	0	0	0	0	0	0	0	0	0
12) prseq_mx*	0	X	X	0	0	0	0	0	X
13) ident_pr*	0	0	X	X	0	X	0	0	0
14) lh_mel*	0	0	0	0	0	0	X	X	0
15) nonscal,>3	1	1	1	1	X	X	1	1	X
16) r-ptch*	0	0	0	0	0	0	0	0	0
17) diss_span*	0	0	0	0	0	0	0	0	0
18) pkpt>2	1	1	1	1	1	1	1	1	1
19) y-pks	1	X	1	X	1	1	X	1	1
20) mv_valley	1	X	1	1	X	1	1	1	1
21) mt_reg	1	nr	nr	nr	nr	nr	nr	nr	nr
22) red_dest*	0	0	0	0	0	0	0	X	0
23) sym_div	1	X	X	X	X	X	X	X	X
24) est_tp	1	1	X	X	X	X	X	1	X
25) est-I	1	1	X	1	1	X	1	X	X
26) h_ylp	1	X	X	1	X	X	X	1	X
27) I,IV,V-a	1	X	X	X	1	1	1	X	1
28) trip_cad*	0	0	0	0	0	0	X	0	0
29) rest_cad*	0	X	0	0	0	0	0	X	0
30) midm_cad*	0	0	0	0	0	0	0	0	0
31) 1-based	1	1	1	X	X	X	1	X	X
32) >=3/4cad	1	1	1	1	1	1	1	1	1
33) sing_v	1	1	1	1	1	1	1	X	1
34) fb_ch_tex	1	1	X	1	1	1	1	1	X
35) par_int*	0	0	0	0	0	0	0	X	0
Max=6									
Dif		9	9	8	6	8	8	11	10

Table 2-1A: Vector 2 - First four measures

Property	Ideal	M1	M2	M3	M4	M5	M6	M7	M8	M10
1) fd_bt*	0	0	0	X	0	0	0	0	X	0
2) b1_Lrest*	0	0	0	0	0	0	0	0	0	0
3) rep_dur*	0	0	0	0	0	0	0	0	0	0
4) <=hmrseq*	0	0	0	0	0	0	0	0	0	0
5) <=hmrseqL>2*	0	0	0	0	0	0	0	0	0	0
6) nonscal,>3	1	1	1	1	1	1	X	X	1	1
7) y-pks	1	1	1	X	1	1	1	1	1	1
8) sym_div	1	1	1	1	X	1	1	X	1	X
9) est_tp	1	1	X	1	1	1	X	1	1	1
10) est-I	1	1	1	1	1	1	1	1	X	1
11) h_ylp	1	1	1	1	X	X	X	1	1	1
12) I,IV,V-a	1	1	1	X	1	1	1	1	1	1
13) trip_cad*	0	0	0	0	0	0	0	0	0	0
14) midm_cad*	0	0	0	0	0	0	0	0	X	0
15) 1-based	1	1	1	1	1	1	1	1	1	1
16) sing_v	1	1	1	1	1	1	1	1	1	1
Max=3										
Dif		0	1	3	2	1	3	2	3	1

Table 2-1B: Vector 2 - First four measures

Property	Ideal	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20
1) fd_bt*	0	0	0	0	0	0	0	0	0	0	0
2) b1_Lrest*	0	0	0	0	0	0	0	0	0	0	0
3) rep_dur*	0	0	0	0	0	X	0	0	0	0	X
4) <=hmrseq*	0	0	0	0	0	0	X	0	0	X	0
5) <=hmrseqL>2*	0	0	0	0	0	0	0	0	0	0	0
6) nonscal,>3	1	1	1	1	1	1	1	1	1	1	1
7) y-pks	1	1	1	1	1	1	X	1	1	1	1
8) sym_div	1	X	X	1	1	1	1	1	1	1	X
9) est_tp	1	1	1	1	X	1	X	1	1	X	1
10) est-I	1	1	X	1	X	1	1	1	X	1	X
11) h_ylp	1	X	X	1	X	X	1	1	X	X	X
12) I,IV,V-a	1	1	1	1	1	1	1	X	X	1	1
13) trip_cad*	0	0	0	0	0	0	0	0	0	0	0
14) midm_cad*	0	0	0	0	0	0	0	0	0	0	0
15) 1-based	1	1	1	1	1	X	1	1	1	1	X
16) sing_v	1	1	1	1	1	1	1	1	1	1	1
Max=3											
Dif		2	3	0	3	3	3	1	3	3	5

Table 2-2: Vector 2 - First four measures

Property	Ideal	Cope
1) fd_bt*	0	0
2) b1_Lrest*	0	0
3) rep_dur*	0	0
4) <=hmrseq*	0	0
5) <=hmrseqL>2*	0	0
6) nonscal,>3	1	1
7) y-pks	1	1
8) sym_div	1	X
9) est_tp	1	1
10) est-I	1	X
11) h_ylp	1	X
12) I,IV,V-a	1	X
13) trip_cad*	0	0
14) midm_cad*	0	0
15) I-based	1	X
16) sing_v*	1	1
Max=3		
Dif		5

Table 2-3A: Vector 2 - First four measures

Property	Ideal	H1	H2	H3	H4	H6	H8	H9	H10	H11
1) fd_bt*	0	X	X	X	X	0	0	0	0	0
2) b1_Lrest*	0	0	0	0	0	0	0	0	0	0
3) rep_dur*	0	0	0	X	0	0	X	0	X	0
4) <=hmrseq*	0	X	0	X	0	X	0	X	0	0
5) <=hmrseqL>2*	0	X	0	0	0	0	0	X	0	0
6) nonscal,>3	1	1	X	1	1	1	X	1	1	1
7) y-pks	1	X	1	X	1	1	1	1	X	1
8) sym_div	1	1	X	X	X	X	X	1	X	X
9) est_tp	1	1	1	1	1	X	X	X	1	X
10) est-I	1	1	X	1	X	X	X	X	1	X
11) h_ylp	1	X	1	X	X	X	X	X	X	X
12) I,IV,V-a	1	1	1	X	1	1	X	X	X	X
13) trip_cad*	0	X	0	0	X	0	X	0	0	X
14) midm_cad*	0	0	0	X	0	0	0	0	0	0
15) 1-based	1	1	X	1	X	X	X	1	1	X
16) sing_v	1	1	1	1	X	1	1	1	1	X
Max=3										
Dif		6	5	8	7	6	9	6	5	8

Table 2-3B: Vector 2 - First four measures

Property	Ideal	H12	H13	H14	H15	H16	H17	H18	H19	H20
1) fd_bt*	0	0	X	0	X	X	X	X	X	X
2) b1_Lrest*	0	0	0	0	0	0	0	0	0	0
3) rep_dur*	0	0	0	X	X	0	0	0	0	0
4)<=hmrseq*	0	0	0	0	0	X	X	0	0	X
5) <=hmrseqL>2*	0	0	0	0	0	X	0	0	0	X
6) nonscal,>3	1	X	1	1	1	1	1	1	X	1
7) y-pks	1	X	1	1	X	1	1	1	X	X
8) sym_div	1	X	1	1	1	X	X	1	X	X
9) est_tp	1	1	X	X	1	1	1	X	X	X
10) est-I	1	X	X	1	1	X	1	X	1	1
11) h_ylp	1	1	X	X	X	1	X	X	X	1
12) I,IV,V-a	1	X	1	1	X	1	1	1	X	X
13) trip_cad*	0	X	X	X	X	0	0	0	0	0
14) midm_cad*	0	0	X	0	0	0	0	0	0	0
15) 1-based	1	X	1	1	X	X	X	X	X	X
16) sing_v	1	1	1	1	1	1	1	1	1	1
Max=3										
Dif		7	6	4	7	6	5	5	8	8

Table 2-3C: Vector 2 - First four measures

Property	Ideal	H29	H30	H31	H32	H33	H34	H35	H36	H37
1) fd_bt*	0	X	X	X	X	0	X	X	X	0
2) b1_Lrest*	0	0	0	0	0	0	0	0	0	0
3) rep_dur*	0	0	0	0	0	0	X	0	0	0
4) <=hmrseq*	0	X	X	X	0	X	0	X	X	0
5) <=hmrseqL>2*	0	X	X	0	0	0	0	0	0	0
6) nonscal,>3	1	1	1	X	1	1	1	1	1	1
7) y-pks	1	1	1	X	X	1	X	1	X	X
8) sym_div	1	1	X	X	X	X	X	X	X	X
9) est_tp	1	X	X	1	X	X	X	1	X	1
10) est-I	1	X	X	X	X	X	X	X	X	1
11) h_ylp	1	X	X	1	X	X	X	1	X	X
12) I,IV,V-a	1	1	X	X	X	1	1	1	1	X
13) trip_cad*	0	0	X	0	0	0	0	0	0	0
14) midm_cad*	0	X	0	0	X	X	X	0	0	X
15) 1-based	1	X	X	1	1	1	1	X	X	1
16) sing_v	1	1	1	1	X	X	1	1	1	X
Max=3										
Dif		8	10	7	9	7	8	5	8	6

Table 2-3D: Vector 2 - First four measures

Property	Ideal	H38	H39	H40	H41	H42	H43	H44	H45	H46
1) fd_bt*	0	X	0	X	X	0	0	0	X	X
2) b1_Lrest*	0	0	0	0	X	0	0	0	0	0
3) rep_dur*	0	0	X	0	0	X	0	X	0	0
4) <=hmrseq*	0	X	0	X	X	X	0	0	X	0
5) <=hmrseqL>2*	0	X	0	0	0	0	0	0	X	0
6) nonscal,>3	1	1	1	1	1	X	1	1	1	1
7) y-pks	1	X	X	1	X	X	X	1	1	X
8) sym_div	1	1	1	X	1	X	1	X	X	X
9) est_tp	1	X	X	1	X	1	X	X	X	1
10) est-I	1	X	X	X	X	X	X	1	X	X
11) h_ylp	1	1	1	X	X	X	X	X	X	1
12) I,IV,V-a	1	1	1	X	X	1	X	X	1	1
13) trip_cad*	0	0	0	0	0	0	0	0	0	0
14) midm_cad*	0	0	0	X	X	0	0	0	0	X
15) 1-based	1	X	X	1	X	X	X	X	1	1
16) sing_v	1	1	1	1	1	1	X	X	1	X
Max=3										
Dif		7	5	7	10	8	7	7	7	6

Table 2-3E: Vector 2 - First four measures

Property	Ideal	H47	H48	H49	H50	H51	H52	H53	H54	H55
1) fd_bt*	0	X	0	X	0	X	X	0	0	X
2) b1_Lrest*	0	0	0	0	0	0	0	X	0	0
3) rep_dur*	0	0	0	X	X	0	0	0	X	0
4) <=hmrseq*	0	0	0	0	0	X	X	0	0	X
5) <=hmrseqL>2*	0	0	0	0	0	0	0	0	0	X
6) nonscal,>3	1	1	1	1	1	1	1	1	X	X
7) y-pks	1	1	X	1	X	1	1	1	1	1
8) sym_div	1	X	1	X	1	1	X	X	X	X
9) est_tp	1	1	X	X	1	1	1	X	1	1
10) est-I	1	X	1	X	1	X	X	X	X	1
11) h_ylp	1	1	X	X	X	X	X	X	1	X
12) I,IV,V-a	1	X	1	1	X	X	X	1	1	X
13) trip_cad*	0	0	0	0	0	0	0	X	X	0
14) midm_cad*	0	X	0	0	X	X	0	0	0	0
15) 1-based	1	1	1	X	X	X	X	X	X	X
16) sing_v	1	1	1	1	X	1	1	X	X	1
Max=3										
Dif		5	3	7	7	7	7	8	7	8

Table 2-3F: Vector 2 - First four measures

Property	Ideal	H56	H57	H59	H60	H61	H62
1) fd_bt*	0	X	0	0	0	0	X
2) b1_Lrest*	0	0	0	X	X	X	0
3) rep_dur*	0	0	X	0	0	X	0
4) <=hmrseq*	0	X	0	0	X	X	X
5) <=hmrseqL>2*	0	X	0	0	X	X	0
6) nonscal,>3	1	1	X	1	1	1	1
7) y-pks	1	1	1	1	X	1	1
8) sym_div	1	1	X	X	X	1	X
9) est_tp	1	1	X	X	X	1	1
10) est-I	1	X	1	X	X	X	X
11) h_ylp	1	X	1	X	X	1	X
12) I,IV,V-a	1	1	X	X	1	X	1
13) trip_cad*	0	0	0	0	0	0	0
14) midm_cad*	0	0	X	0	0	0	0
15) 1-based	1	1	X	X	X	X	1
16) sing_v	1	1	1	1	1	1	X
Max=3							
Dif		5	7	7	9	7	6

Table 2-4A: Vector 2 - First four measures

Property	Ideal	C1	C2	C3	C4	C5	C6	C7	C8	C9
1) fd_bt*	0	0	0	0	0	0	X	X	0	0
2) b1_Lrest*	0	0	0	0	X	X	X	0	0	X
3) rep_dur*	0	0	0	0	X	X	0	0	X	0
4) <=hmrseq*	0	0	X	0	0	0	0	0	0	X
5) <=hmrseqL>2*	0	0	X	0	0	0	0	0	0	X
6) nonscal,>3	1	1	1	1	1	X	1	1	1	1
7) y-pks	1	X	X	1	X	1	1	X	X	X
8) sym_div	1	X	X	1	X	X	1	X	X	1
9) est_tp	1	1	1	X	X	X	X	X	1	X
10) est-I	1	1	X	X	X	X	X	X	1	X
11) h_ylp	1	X	X	X	X	X	1	X	X	X
12) I,IV,V-a	1	X	1	X	1	1	X	1	1	1
13) trip_cad*	0	0	X	0	X	0	X	0	0	0
14) midm_cad*	0	0	0	0	0	X	0	0	0	0
15) 1-based	1	X	1	1	X	1	X	X	1	1
16) sing_v	1	X	1	1	1	1	1	X	X	X
Max=3										
Dif		6	7	4	9	8	7	8	5	8

Table 2-4B: Vector 2 - First four measures

Property	Ideal	C10	C11	C12	C13	C14	C15	C16	C17
1) fd_bt*	0	0	X	0	0	0	0	0	0
2) b1_Lrest*	0	0	0	X	0	0	0	X	0
3) rep_dur*	0	0	0	0	0	0	0	0	0
4) <=hmrseq*	0	X	X	0	X	X	X	0	0
5) <=hmrseqL>2*	0	X	X	0	0	0	X	0	0
6) nonscal,>3	1	1	1	1	1	1	1	1	X
7) y-pks	1	X	1	1	1	X	X	1	1
8) sym_div	1	X	1	X	X	X	X	1	X
9) est_tp	1	X	1	1	X	1	1	X	1
10) est-I	1	X	1	X	1	1	1	X	1
11) h_ylp	1	1	X	1	1	X	X	X	X
12) I,IV,V-a	1	1	X	1	X	X	X	X	X
13) trip_cad*	0	0	0	0	0	0	0	0	X
14) midm_cad*	0	0	0	X	0	0	0	0	0
15) 1-based	1	1	X	1	X	X	X	X	1
16) sing_v	1	X	X	1	X	1	1	X	1
Max=3									
Dif		7	7	4	6	6	7	7	5

Table 2-4C: Vector 2 - First four measures

Property	Ideal	C19	C20	C21	C22	C23	C24
1) fd_bt*	0	0	0	0	0	X	0
2) b1_Lrest*	0	0	0	X	0	0	0
3) rep_dur*	0	X	0	X	X	0	0
4) <=hmrseq*	0	0	0	0	0	0	0
5) <=hmrseqL>2*	0	0	0	0	0	0	0
6) nonscal,>3	1	1	X	X	X	X	1
7) y-pks	1	X	X	X	1	X	1
8) sym_div	1	1	X	X	X	1	X
9) est_tp	1	X	X	X	X	1	1
10) est-I	1	X	X	X	1	X	X
11) h_ylp	1	1	1	X	1	X	X
12) I,IV,V-a	1	1	1	1	1	1	1
13) trip_cad*	0	0	0	X	X	0	0
14) midm_cad*	0	0	0	0	0	0	0
15) 1-based	1	1	X	1	X	1	X
16) sing_v	1	1	X	1	1	1	X
Max=3							
Dif		4	7	9	6	5	5

Table 2-5A: Vector 2 - First four measures

Property	Ideal	D31	D35.1	D35.2	D35.3	D39.1	D39.2	D39.3
1) fd_bt*	0	0	X	0	0	0	0	0
2) b1_Lrest*	0	0	0	0	0	0	0	0
3) rep_dur*	0	X	0	0	0	0	0	0
4) <=hmrseq*	0	0	0	0	X	0	X	X
5) <=hmrseqL>2*	0	0	0	0	X	0	0	X
6) nonscal,>3	1	X	1	1	1	X	X	1
7) y-pks	1	1	X	1	X	1	X	1
8) sym_div	1	1	X	1	X	X	X	X
9) est_tp	1	1	1	1	1	1	X	1
10) est-I	1	X	X	1	1	X	1	1
11) h_ylp	1	X	1	X	X	X	X	X
12) I,IV,V-a	1	1	X	1	1	1	X	X
13) trip_cad*	0	0	0	0	0	0	0	0
14) midm_cad*	0	0	0	0	X	0	0	0
15) 1-based	1	X	1	X	1	X	X	X
16) sing_v	1	1	X	X	X	X	X	X
Max=3								
Dif		5	6	3	7	6	9	7

Table 2-5B: Vector 2 - First four measures

Property	Ideal	D43	D45.1	D45.2	D45.3	D47.1	D47.2	D23	D25.2
1) fd_bt*	0	0	0	X	X	0	0	0	X
2) b1_Lrest*	0	X	0	0	0	0	0	0	0
3) rep_dur*	0	0	X	0	0	0	0	0	0
4) <=hmrseq*	0	0	0	0	X	0	0	0	0
5) <=hmrseqL>2*	0	0	0	0	0	0	0	0	0
6) nonscal,>3	1	1	X	X	X	X	1	1	1
7) y-pks	1	1	X	1	1	X	X	X	X
8) sym_div	1	1	X	X	X	X	1	X	1
9) est_tp	1	X	X	X	X	X	1	1	1
10)est-I	1	X	1	X	1	1	X	1	X
11) h_ylp	1	1	1	X	1	X	X	1	1
12) I,IV,V-a	1	1	X	X	X	1	1	X	X
13) trip_cad*	0	0	0	0	0	0	0	0	0
14) midm_cad*	0	0	X	0	0	0	0	X	0
15) I-based	1	X	X	X	X	1	1	1	1
16) sing_v	1	X	X	1	1	1	X	X	X
Max=3									
Dif		5	9	8	7	5	4	5	5

Table 2-6: Vector 2 - First four measures

Property	Ideal	Hu1	Hu2	Hu3	Hu4	Hu5	Hu6
1) fd_bt*	0	0	0	X	0	0	X
2) b1_Lrest*	0	0	0	0	0	X	0
3) rep_dur*	0	X	0	0	X	0	0
4) <=hmrseq*	0	0	0	X	X	0	0
5) <=hmrseqL>2*	0	0	0	0	X	0	0
6) nonscal,>3	1	1	X	1	1	1	1
7) y_pks	1	1	1	1	X	X	1
8) sym_div	1	X	X	X	X	X	X
9) est_tp	1	1	1	1	1	X	1
10) est-I	1	X	X	X	X	X	X
11) h_ylp	1	X	X	1	X	1	X
12) I,IV,V-a	1	X	1	X	X	1	X
13) trip_cad*	0	0	0	0	0	0	0
14) midm_cad*	0	0	0	0	0	0	0
15) 1-based	1	X	X	X	1	X	X
16) sing_v	1	X	1	X	X	X	X
Max=3							
Dif		7	5	7	9	7	7

Table 2-7: Vector 2 - First four measures

Property	Ideal	B1	B2	B3	B4	B5	B6
1) fd_bt*	0	0	X	0	X	X	X
2) b1_Lrest*	0	X	X	0	0	0	X
3) rep_dur*	0	0	X	0	0	0	0
4) <=hmrseq*	0	X	0	X	0	X	0
5) <=hmrseqL>2*	0	X	0	X	0	X	0
6) nonscal,>3	1	1	1	1	1	1	1
7) y-pks	1	X	X	1	1	X	1
8) sym_div	1	X	X	1	X	X	1
9) est_tp	1	X	X	1	X	1	X
10) est-I	1	X	X	1	X	X	1
11) h_ylp	1	1	X	1	X	X	X
12) I,IV,V-a	1	X	0	0	X	X	1
13) trip_cad*	0	0	0	0	0	0	0
14) midm_cad*	0	0	X	0	X	X	X
15) I-based	1	X	X	X	X	X	X
16) sing_v	1	1	1	X	X	1	X
Max=3							
Dif		9	10	4	9	10	7

Table 2-8: Vector 2 - First four measures

Property	Ideal	4-hand	Son in D	Rom1	Rom2	Rom3	Rom4	Rom5	Rom6
1) fd_bt*	0	0	0	X	0	0	0	0	X
2) b1_Lrest*	0	0	0	X	0	0	0	0	0
3) rep_dur*	0	X	X	0	0	0	0	0	0
4) <=hmrseq*	0	0	0	0	0	0	0	X	X
5)<=hmrseqL>2*	0	0	0	0	0	0	0	0	0
6) nonscal,>3	1	1	1	1	X	X	1	1	X
7) y-pks	1	X	1	X	1	1	X	1	1
8) sym_div	1	X	X	X	X	X	X	X	X
9) est_tp	1	1	X	X	X	X	X	1	X
10) est-I	1	1	X	1	1	X	1	X	X
11) h_ylp	1	X	X	1	X	X	X	1	X
12) I,IV,V-a	1	X	X	X	1	1	1	X	1
13) trip_cad*	0	0	0	0	0	0	X	0	0
14) midm_cad*	0	0	0	0	0	0	0	0	0
15) 1-based	1	1	1	X	X	X	1	X	X
16) sing_v	1	1	1	1	1	1	1	X	1
Max=3									
Dif		5	6	7	5	6	5	6	8

Table 3-1A: Vector 3 - First eight measures

Property	Ideal	M1	M2	M3	M4	M5	M6	M7	M8	M10
1) dtyp5	1	1	1	1	1	X	1	1	X	1
2) rep_dur*	0	0	0	0	0	0	0	0	0	0
3) <=hmrseqL>2*	0	0	0	0	0	0	0	0	0	0
4) ident_pr*	0	0	0	0	0	X	0	0	0	0
5) lh_mel*	0	0	0	0	0	0	0	X	0	0
6) r-ptch*	0	0	0	0	0	0	0	0	0	0
7) red_dest*	0	0	0	0	0	0	0	0	0	X
8) sym_div	1	1	1	1	X	1	1	1	1	1
9) y-leap	1	1	1	X	1	X	1	X	X	X
10) g-gest	1	1	1	1	1	1	1	1	X	1
11) ret-I	1	1	1	1	nr	1	1	1	1	1
12) >=3/4cad	1	1	1	1	1	1	1	1	1	1
13)sing_v	1	1	1	1	1	1	1	1	1	1
14) par_int*	0	0	0	0	0	0	0	0	0	X
15) 1-based	1	1	1	1	1	1	1	1	1	1
16) trip_cad*	0	0	0	0	0	0	0	0	0	0
Max=3										
Dif		0	0	1	2	3	0	2	3	3

Table 3-1B: Vector 3 - First eight measures

Property	Ideal	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20
1) dtyp5	1	1	1	1	1	1	1	1	1	X	1
2) rep_dur*	0	0	0	0	0	0	0	0	0	0	X
3) <=hmrseqL>2*	0	0	0	0	0	0	X	0	0	0	0
4) ident*	0	X	0	0	0	X	0	0	0	0	0
5) lh_mel*	0	0	0	0	0	0	0	0	X	0	X
6) r-ptch*	0	0	0	0	0	0	0	0	0	0	0
7) red_dest*	0	0	X	0	X	0	0	0	0	0	0
8) sym_div	1	X	1	1	1	X	1	1	1	1	1
9) y-leap	1	X	X	X	X	X	1	1	X	X	1
10) g-gest	1	1	1	1	1	1	1	1	X	1	X
11) ret-I	1	1	1	1	1	1	1	1	1	nr	1
12) >=3/4cad	1	1	1	1	1	1	1	1	1	X	1
13)sing_v	1	1	1	1	1	1	1	1	1	1	1
14) par_int*	0	0	0	0	0	0	X	0	0	0	X
15) 1-based	1	1	1	1	1	1	1	1	1	1	1
16) trip_cad*	0	0	0	0	0	0	0	0	0	0	0
Max=3											
Dif		3	2	1	2	3	2	0	3	3	4

Table 3-2: Vector 3 - First eight measures

Property	Ideal	Cope
1) dtyp5	1	1
2) rep_dur*	0	0
3) <=hmrseqL>2*	0	0
4) ident_pr*	0	0
5) lh_mel*	0	0
6) r-ptch*	0	X
7) red_dest*	0	0
8) sym_div	1	X
9) y-leap	1	X
10) g-gest	1	X
11) ret-I	1	1
12) >=3/4cad	1	X
13)sing_v	1	1
14) par_int*	0	X
15) 1-based	1	1
16) trip_cad*	0	0
Max=3		6

Table 3-3A: Vector 3 - First eight measures

Property	Ideal	H1	H2	H3	H4	H6	H8	H9	H10	H11
1) dtyp5	1	X	1	X	1	X	1	X	X	1
2) rep_dur*	0	0	X	X	0	0	X	0	X	0
3) <=hmrsL>2*	0	X	0	X	0	0	0	X	X	X
4) ident_pr*	0	0	0	0	0	0	X	0	X	X
5) lh_mel*	0	0	0	0	0	0	0	0	0	0
6) r-ptch*	0	0	0	0	0	0	0	0	0	0
7) red_dest*	0	0	X	0	0	0	0	0	0	0
8) sym_div	1	1	X	1	X	X	X	X	X	X
9) y-leap	1	X	X	X	X	X	X	X	1	X
10) g-gest	1	X	X	X	1	X	X	X	X	X
11) ret-I	1	nr	nr	nr	1	X	1	nr	nr	1
12) >=3/4cad	1	1	1	1	1	1	1	X	1	1
13)sing_v	1	1	1	1	X	1	1	1	1	X
14) par_int*	0	0	X	X	X	X	0	0	0	X
15) 1-based	1	X	1	X	X	1	X	1	X	X
16) trip_cad*	0	0	0	0	0	X	X	0	0	X
Max=3										
Dif		5	6	7	5	7	7	6	7	9

Table 3-3B: Vector 3 - First eight measures

Property	Ideal	H12	H13	H14	H15	H16	H17	H18	H19	H20
1) dtyp5	1	1	X	X	1	1	X	1	1	1
2) rep_dur*	0	X	0	X	0	0	0	0	0	0
3) <=hmrseqL>2*	0	0	X	0	0	X	0	X	0	X
4) ident_pr*	0	X	X	0	0	0	X	0	0	0
5) lh_mel*	0	0	X	0	0	0	0	0	X	0
6) r-ptch*	0	0	0	0	0	0	0	0	0	0
7) red_dest*	0	X	X	0	X	X	0	X	0	X
8) sym_div	1	X	1	1	X	X	X	1	X	1
9) y-leap	1	X	X	X	X	1	X	X	X	X
10) g-gest	1	X	X	X	X	X	X	1	X	X
11) ret-I	1	1	nr	1	1	X	1	1	nr	1
12) >=3/4cad	1	1	1	1	1	1	1	1	1	1
13)sing_v	1	1	1	1	1	1	1	1	1	1
14) par_int*	0	0	0	0	X	0	0	X	0	0
15) 1-based	1	X	X	1	X	X	1	X	X	X
16) trip_cad*	0	X	0	X	0	0	X	0	0	0
Max=3										
Dif		8	8	5	6	6	6	5	6	5

Table 3-3C: Vector 3 - First eight measures

Property	Ideal	H29	H30	H31	H32	H33	H34	H35	H36	H27
1) dtyp5	1	X	X	X	X	X	X	X	1	X
2) rep_dur*	0	0	0	X	0	0	X	0	0	0
3) <=hmrseqL>2*	0	X	X	X	X	X	0	0	X	0
4) ident_pr*	0	X	X	0	0	0	0	0	0	0
5) lh_mel*	0	X	X	X	0	0	0	0	0	X
6) r-ptch*	0	0	0	0	0	0	0	0	0	0
7) red_dest*	0	0	X	X	X	0	0	0	0	X
8) sym_div	1	X	X	X	X	1	1	X	X	1
9) y-leap	1	1	X	X	X	X	1	X	X	X
10) g-gest	1	X	X	1	X	1	1	X	1	1
11) ret-I	1	1	1	1	X	1	1	1	1	1
12) >=3/4cad	1	1	1	1	1	X	1	1	1	X
13)sing_v	1	1	1	1	X	X	1	1	1	X
14) par_int*	0	X	0	0	X	X	X	0	0	0
15) 1-based	1	X	X	X	X	1	X	X	X	1
16) trip_cad*	0	0	0	0	0	0	0	0	0	0
Max=3										
Dif		8	9	7	10	6	4	5	4	6

Table 3-3D: Vector 3 - First eight measures

Property	Ideal	H38	H39	H40	H41	H42	H43	H44	H45	H46
1) dtyp5	1	X	1	X	X	1	X	1	1	X
2) rep_dur*	0	0	X	X	0	X	0	X	0	X
3) <=hmrseqL>2*	0	X	0	0	0	X	X	0	X	0
4) ident_pr*	0	X	0	0	X	0	0	0	0	0
5) lh_mel*	0	0	0	X	X	0	X	X	X	X
6) r-ptch*	0	0	0	0	0	X	X	0	0	0
7) red_dest*	0	0	0	0	0	X	X	0	0	0
8) sym_div	1	X	1	X	X	X	1	1	X	X
9) y-leap	1	X	X	X	X	X	X	1	X	X
10) g-gest	1	X	X	1	1	X	X	X	1	X
11) ret-I	1	X	1	1	X	1	1	1	1	1
12) >=3/4cad	1	1	1	X	1	1	1	X	1	1
13)sing_v	1	1	1	1	1	1	X	X	1	X
14) par_int*	0	0	X	0	X	0	0	X	0	X
15) 1-based	1	1	1	1	X	1	X	1	1	X
16) trip_cad*	0	0	X	0	0	0	0	0	0	X
Max=3										
Dif		7	5	6	8	7	9	6	4	10

Table 3-3E: Vector 3 - First eight measures

Property	Ideal	H47	H48	H49	H50	H51	H52	H53	H54	H55
1) dtyp5	1	X	1	1	X	X	X	X	X	X
2) rep_dur*	0	0	0	X	X	0	0	0	X	0
3) <=hmrseqL>2*	0	0	X	X	0	0	0	0	0	X
4) ident_pr*	0	X	0	X	X	0	0	X	0	0
5) lh_mel*	0	0	0	X	0	0	0	0	0	0
6) r-ptch*	0	0	0	0	0	0	0	0	0	0
7) red_dest*	0	0	0	0	0	X	0	0	0	0
8) sym_div	1	X	1	1	1	1	X	X	X	X
9) y-leap	1	X	X	X	X	X	X	X	X	1
10) g-gest	1	1	X	1	X	1	X	X	1	X
11) ret-I	1	1	1	1	1	1	X	X	X	1
12) >=3/4cad	1	X	1	1	X	X	1	1	1	1
13)sing_v	1	1	1	1	X	1	1	X	X	1
14) par_int*	0	0	0	0	X	0	0	X	X	0
15) 1-based	1	1	1	1	1	X	X	1	X	1
16) trip_cad*	0	0	X	0	0	0	0	X	X	0
Max=3										
Dif		5	4	5	8	5	6	9	9	4

Table 3-3F: Vector 3 - First eight measures

Property	Ideal	H56	H57	H58	H59	H60	H61	H62
1) dtyp5	1	X	1	X	1	X	1	1
2) rep_dur*	0	0	X	0	0	0	X	0
3) <=hmrseqL>2*	0	X	0	0	0	X	X	X
4) ident_pr*	0	0	0	0	0	0	0	X
5) lh_mel*	0	0	X	X	X	X	X	X
6) r-ptch*	0	0	0	0	0	0	0	0
7) red_dest*	0	0	X	0	X	0	0	0
8) sym_div	1	X	X	X	X	X	1	X
9) y-leap	1	X	1	X	X	X	X	X
10) g-gest	1	1	X	X	1	X	X	X
11) ret-I	1	X	1	1	1	1	1	1
12) >=3/4cad	1	1	1	1	1	1	1	1
13)sing_v	1	1	1	1	1	1	1	X
14) par_int*	0	0	0	0	X	0	0	X
15) 1-based	1	X	X	1	1	X	1	1
16) trip_cad*	0	0	0	0	0	0	0	0
Max=3								
Dif		6	6	5	5	7	5	8

Table 3-4A: Vector 3 - First eight measures

Property	Ideal	C1	C2	C3	C4	C5	C6	C7	C8	C9
1) dtyp5	1	X	1	X	1	X	X	1	1	X
2) rep_dur*	0	0	0	X	X	X	0	0	X	0
3) <=hmrseqL>2*	0	0	X	0	0	X	0	0	0	X
4) ident_pr*	0	0	X	0	X	X	0	X	X	0
5) lh_mel*	0	X	0	0	0	0	0	0	X	0
6) r-ptch*	0	0	0	0	0	0	0	0	0	0
7) red_dest*	0	0	X	0	0	0	0	0	X	0
8) sym_div	1	X	X	X	X	X	X	X	X	1
9) y-leap	1	X	X	X	X	X	X	X	X	X
10) g-gest	1	X	X	X	X	X	X	X	X	1
11) ret-I	1	1	1	X	1	1	1	X	1	1
12) >=3/4cad	1	1	1	1	1	1	1	1	1	1
13)sing_v	1	X	1	1	1	1	1	X	X	X
14) par_int*	0	X	0	0	0	0	0	X	X	X
15) 1-based	1	X	1	1	1	1	1	X	1	1
16) trip_cad*	0	0	X	0	X	0	0	0	0	X
Max=3										
Dif		8	7	6	6	7	4	8	9	6

Table 3-4B: Vector 1 - First eight measures

Property	Ideal	C10	C11	C12	C13	C14	C15	C16	C17
1) dtyp5	1	1	X	X	1	1	1	1	X
2) rep_dur*	0	0	0	0	0	X	X	0	0
3) <=hmrseqL>2*	0	X	X	0	0	0	X	0	0
4) ident_pr*	0	0	0	0	X	X	0	X	0
5) lh_mel*	0	X	X	0	X	0	0	0	0
6) r-ptch*	0	0	0	X	0	0	X	0	0
7) red_dest*	0	X	0	0	0	0	0	0	0
8) sym_div	1	X	1	X	X	1	X	1	X
9) y-leap	1	X	X	X	1	X	X	X	X
10) g-gest	1	1	X	X	X	X	1	X	X
11) ret-I	1	X	1	1	1	1	1	X	X
12) >=3/4cad	1	1	1	1	1	1	1	1	1
13)sing_v	1	X	X	1	X	1	1	X	1
14) par_int*	0	0	X	0	X	0	0	X	0
15) 1-based	1	X	1	X	X	X	X	X	1
16) trip_cad*	0	X	0	X	0	0	0	0	X
Max=3									
Dif		9	7	7	7	5	6	7	6

Table 3-4C: Vector 3 - First eight measures

Property	Ideal	C19	C20	C21	C22	C23	C24
1) dtyp5	1	1	X	1	1	X	1
2) rep_dur*	0	X	0	X	X	0	0
3) <=hmrseqL>2*	0	0	0	0	0	0	0
4) ident_pr*	0	0	0	X	X	0	0
5) lh_mel*	0	X	0	0	0	X	X
6) r-ptch*	0	0	0	0	0	0	0
7) red_dest*	0	0	0	X	X	X	0
8) sym_div	1	1	1	X	X	X	X
9) y-leap	1	X	1	X	X	X	1
10) g-gest	1	X	X	X	X	X	1
11) ret-I	1	X	X	1	1	1	X
12) >=3/4cad	1	1	1	1	1	1	1
13)sing_v	1	1	X	1	1	1	X
14) par_int*	0	0	0	0	0	0	X
15) 1-based	1	1	1	1	X	1	X
16) trip_cad*	0	0	0	X	X	X	0
Max=3							
Dif		5	4	7	8	7	6

Table 3-5A Vector 3 - First eight measures

Property	Ideal	D31	D35.1	D35.2	D35.3	D39.1	D39.2	D39.3
1) dtyp5	1	1	X	1	1	1	X	1
2) rep_dur*	0	X	0	0	0	X	0	0
3) <=hmrseqL>2*	0	0	X	X	X	0	0	X
4) ident_pr*	0	0	0	0	0	0	0	0
5) lh_mel*	0	0	X	0	0	0	X	0
6) r-ptch*	0	0	0	0	0	0	X	0
7) red_dest*	0	X	0	X	0	0	0	0
8) sym_div	1	1	1	X	X	X	X	X
9) y-leap	1	X	1	1	X	X	X	X
10) g-gest	1	X	X	1	X	X	1	X
11) ret-I	1	X	X	X	1	X	1	1
12) >=3/4cad	1	1	1	1	1	1	1	1
13)sing_v	1	1	X	X	X	X	X	X
14) par_int*	0	X	X	X	X	X	X	X
15) 1-based	1	1	X	X	1	X	X	X
16) trip_cad*	0	0	0	0	0	0	0	0
Max=3								
Dif		6	8	6	6	8	8	7

Table 3-5B: Vector 3 - First eight measures

Property	Ideal	D43	D45.1	D45.2	D45.3	D47.1	D47.2	D23	D25.2
1) dtyp5	1	X	X	X	X	X	1	1	1
2) rep_dur*	0	0	X	0	0	0	X	0	0
3) <=hmrseqL>2*	0	0	0	0	0	0	0	X	X
4) ident_pr*	0	0	0	0	0	0	0	0	0
5) lh_mel*	0	0	0	0	0	0	0	X	X
6) r-ptch*	0	0	0	0	0	0	0	0	X
7) red_dest*	0	0	0	X	0	0	0	0	0
8) sym_div	1	X	X	1	X	X	1	X	1
9) y-leap	1	X	X	X	X	X	1	1	X
10) g-gest	1	X	X	X	X	X	1	X	X
11) ret-I	1	1	X	1	1	1	1	1	1
12) >=3/4cad	1	1	1	1	X	1	1	1	1
13)sing_v	1	X	X	1	1	1	X	X	X
14) par_int*	0	0	X	X	0	0	X	X	X
15) 1-based	1	1	1	1	1	1	X	X	X
16) trip_cad*	0	0	0	0	X	0	0	0	0
Max=3									
Dif		5	8	5	6	4	4	7	8

Table 3-6: Vector 3 - First eight measures

Property	Ideal	Hu1	Hu2	Hu3	Hu4	Hu5	Hu6
1) dtyp5	1	1	X	X	X	1	X
2) rep_dur*	0	X	0	0	X	0	0
3) <=hmrseqL>2*	0	0	0	0	X	0	0
4) ident_pr*	0	0	0	0	X	X	0
5) lh_mel*	0	X	X	X	X	0	0
6) r-ptch*	0	0	X	0	0	0	0
7) red_dest*	0	X	X	0	0	0	0
8) sym_div	1	X	1	X	X	X	X
9) y-leap	1	X	1	1	1	X	X
10) g-gest	1	X	X	X	X	X	1
11) ret-I	1	1	X	X	X	X	X
12) >=3/4cad	1	1	1	1	1	1	X
13)sing_v	1	X	1	X	X	X	X
14) par_int*	0	X	0	0	X	X	0
15)1-based	1	1	X	X	1	1	X
16) trip_cad*	0	0	X	0	0	0	0
Max=3							
Dif		8	8	7	10	7	7

Table 3-7: Vector 3 - First eight measures

Property	Ideal	Bch1	Bch2	Bch3	Bch4	Bch5	Bch6
1) dtyp5	1	X	X	X	X	1	1
2) rep_dur*	0	0	X	0	0	0	0
3) <=hmrseqL>2*	0	X	0	X	0	X	0
4) ident_pr*	0	0	0	0	0	0	0
5) lh_mel*	0	X	X	0	X	0	0
6) r-ptch*	0	0	0	0	0	0	0
7) red_dest*	0	0	0	0	0	X	X
8) sym_div	1	X	1	X	X	X	X
9) y-leap	1	X	X	1	X	X	X
10) g-gest	1	X	X	1	X	1	1
11) ret-I	1	X	nr	X	X	X	X
12) >=3/4cad	1	1	1	1	X	X	X
13)sing_v	1	1	1	X	X	1	X
14) par_int*	0	0	0	X	X	X	X
15) 1-based	1	X	X	X	X	X	1
16) trip_cad*	0	X	0	0	0	0	0
Max=3							
Dif		9	6	7	10	8	7

Table 3-8: Vector 3 - First eight measures

Property	Ideal	4-hnd	Son. In D	Rom 1	Rom 2	Rom 3	Rom 4	Rom 5	Rom 6
1) dtyp5	1	1	1	1	1	1	1	X	1
2) rep_dur*	0	X	X	0	0	0	0	0	0
3) <=hmrseqL>2*	0	0	0	0	0	0	0	0	0
4) ident_pr*	0	0	X	X	0	X	0	0	0
5) lh_mel*	0	0	0	0	0	0	X	X	0
6) r-ptch*	0	0	0	0	0	0	0	0	0
7) red_dest*	0	0	0	0	X	0	0	0	0
8) sym_div	1	X	X	X	X	X	X	X	X
9) y-leap	1	1	X	X	X	X	X	1	X
10) g-gest	1	X	X	X	1	X	X	X	X
11) ret-I	1	1	1	nr	1	1	1	nr	X
12) >=3/4cad	1	1	1	1	1	1	1	1	1
13)sing_v	1	1	1	1	1	1	1	X	1
14) par_int*	0	0	0	0	0	0	0	X	0
15) I-based	1	X	1	X	X	X	1	X	X
16) trip_cad*	0	0	0	0	0	0	X	0	0
Max=3									
Dif		4	5	5	4	5	5	7	5

Table 4-1: Vector 4 - Cadential pattern

	Mm1 1-based	Mm2 1-based	Pre-2ndry ;-cad	OF	OF	Pre-end OF	End	3-based	Dif
Ideal	1	1	1	1	1	1	1	1	
M1	1	1	X	nr	nr	1	1	1	1
M2	1	1	1	1	1	1	1	1	0
M3	1	1	1	1	1	1	1	1	0
M4	1	1	1	1	1	1	1	1	0
M5	1	1	1	1	nr	nr	1	1	0
M6	1	1	1	1	1	1	1	1	0
M7	1	1	1	1	X	1	1	X	2
M8	1	1	X	1	X	1	1	1	2
M10	1	1	1	1	1	1	1	1	0
M11	1	1	1	X	X	1	1	1	2
M12	1	1	1	1	1	1	1	1	0
M13	1	1	1	1	1	1	1	1	0
M14	1	1	1	X	X	1	1	1	2
M15	X	1	X	1	1	1	1	1	2
M16	1	1	1	1	1	1	1	1	0
M17	1	1	X	1	1	1	1	X	2
M18	1	1	1	1	1	1	1	1	0
M19	1	1	X	nr	nr	1	nr	1	1
M20	X	1	1	1	X	1	1	1	2

Max =2 if exposition ≥ 28 measures,
else max=1

In Vector Table 4
(an entry of nr is made for the end(X) property
if the exposition is ≤ 16 measures;

if the exposition < 39 measures, only one OF
column need have an entry of 1)

Table 4-2: Vector 4 - Cadential pattern

	Mm1 1-based	Mm2 1-based	Pre-2ndry ;-cad	OF	OF	Pre-end OF	End	3-based	Dif
Ideal	1	1	1	1	1	1	1	1	
Cope	X	1	X	X	nr	nr	X	X	5

Max=2 if exposition ≥ 28 measures,
else max=1

Table 4-3a: Vector 4 - Cadential pattern

	Mm1 1-based	Mm2 1-based	Pre-2ndry ;-cad	OF	OF	Pre-end OF	End	3-based	Dif
Ideal	1	1	1	1	1	1	1	1	
H1	1	X	X	X	nr	nr	nr	X	4
H3	1	X	X	X	nr	nr	nr	X	4
H4	X	X	X	nr	nr	X	X	X	6
H6	X	1	X	nr	nr	X	X	X	5
H8	X	X	X	X	X	X	1	1	6
H9	1	1	X	nr	nr	X	X	X	4
H10	1	X	X	n/r	nr	1	X	1	3
H11	X	X	1	X	X	X	1	1	5
H12	X	X	X	X	n/r	n/r	1	1	4
H13	1	X	1	X	nr	nr	X	X	4
H14	1	1	1	X	nr	nr	1	1	1
H15	X	X	X	X	nr	nr	X	X	6
H16	X	X	X	1	nr	nr	X	X	5
H17	X	1	X	nr	nr	1	X	X	4
H18	X	X	X	X	X	X	1	1	6
H19	X	X	X	X	nr	nr	X	X	6
H20	X	X	X	X	X	X	X	X	8
H29	X	X	X	X	X	X	X	X	8
H30	X	X	X	X	X	X	1	1	6
H31	1	X	X	nr	nr	1	1	1	2
H32	1	X	X	X	nr	nr	X	X	5
H33	1	1	X	X	nr	nr	X	X	4
H34	1	X	1	X	1	X	X	X	5
H35	X	X	X	1	1	X	X	X	6
H36	X	X	1	X	X	X	X	X	7
H37	1	1	X	X	n/r	nr	X	1	3
H38	X	1	X	X	1	1	1	1	3
H39	X	1	1	1	X	1	X	X	4
H40	1	1	X	X	nr	nr	X	1	3
H41	X	X	X	nr	nr	1	X	X	5

Max=2 if exposition ≥ 28 measures,
else max=1

Table 4-3b: Vector 4 - Cadential pattern

	Mm1 1-based	Mm2 1-based	Pre-2ndry ;-cad	OF	OF	Pre-end OF	End	3-based	Dif
Ideal	1	1	1	1	1	1	1	1	
H42	X	1	X	X	X	X	1	1	5
H43	X	X	X	1	1	1	X	X	5
H44	X	1	X	X	nr	nr	1	1	3
H45	1	1	X	X	1	1	X	X	4
H46	1	X	X	X	nr	nr	X	1	4
H47	1	1	X	X	nr	nr	X	X	4
H48	1	1	X	1	X	1	1	1	2
H49	X	1	X	X	nr	nr	1	1	3
H50	X	1	X	X	X	1	X	1	5
H51	X	X	X	X	nr	nr	X	X	6
H53	X	1	X	1	1	1	X	X	4
H55	X	1	1	X	1	1	1	X	3
H57	X	X	X	nr	nr	1	X	X	5
H59	X	1	X	1	X	1	1	1	3
H60	X	X	X	X	X	1	1	1	5
H61	X	1	X	1	X	1	1	1	3
H62	1	1	X	X	X	1	X	X	5

Max=2 if exposition ≥ 28 measures,
else max=1

Table 4-4: Vector 4 - Cadential pattern

	Mm1 1-based	Mm2 1-based	Pre-2ndry ;-cad	OF	OF	Pre-end OF	End	3-based	Dif
Ideal	1	1	1	1	1	1	1	1	
C1	X	X	X	1	X	1	X	X	6
C2	1	1	X	X	1	X	1	1	3
C3	1	1	X	X	X	X	X	X	6
C4	X	1	X	X	X	1	1	1	4
C5	1	1	X	1	X	X	X	X	5
C6	X	1	X	X	1	X	1	1	4
C7	X	X	X	X	nr	nr	1	X	5
C8	1	1	X	1	1	X	X	X	4
C9	1	1	X	X	1	X	1	1	3
C12	1	X	X	1	X	1	X	1	4
C13	X	X	1	X	X	X	X	X	7
C14	X	X	X	1	1	X	X	X	6
C15	X	X	X	X	1	1	X	X	6
C16	X	X	X	X	X	X	X	X	8
C17	1	1	X	1	1	X	X	X	4
C19	1	1	X	X	X	X	X	X	6
C20	X	1	X	1	1	X	X	X	5
C21	1	1	X	X	X	1	X	X	5
C22	X	X	X	1	1	1	1	1	3
C23	1	1	X	X	X	X	X	X	6
C24	X	X	1	1	X	X	X	X	6

Max=2 if exposition ≥ 28 measures,
else max=1

Table 4-5: Vector 4 - Cadential pattern

	Mm1 1-based	Mm2 1-based	Pre-2ndry ;-cad	OF	OF	Pre-end OF	End	3-based	Dif
Ideal	1	1	1	1	1	1	1	1	
D23	1	X	X	1	X	X	1	1	4
D31.2	X	1	X	1	X	1	1	X	4
D35.1	1	X	X	X	X	X	X	1	6
D35.2	X	X	X	1	1	1	1	1	3
D35.3	1	1	X	1	1	X	1	1	2
D39.1	X	X	X	X	X	1	1	X	6
D39.2	X	X	X	1	X	1	X	1	5
D39.3	X	X	X	X	X	1	X	X	7
D43	X	1	X	1	1	X	1	1	3
D45.1	X	1	X	X	X	X	X	X	7
D45.2	X	1	X	X	X	X	X	X	7
D45.3	X	1	X	1	1	1	1	1	2
D47.1	1	1	X	1	X	1	1	X	3
D47.2	1	X	X	X	X	1	1	1	4

Maximum=2 if exposition $\geq$ 28 measures,
else max=1

Table 4-6: Vector 4 - Cadential pattern

	Mm1 1-based	Mm2 1-based	Pre-2ndry ;-cad	OF	OF	Pre-end OF	End	3-based	Dif
Ideal	1	1	1	1	1	1	1	1	
Hum1	X	1	X	1	1	1	X	X	4
Hum2	X	X	X	1	X	X	X	X	7
Hum4	1	1	X	1	X	X	X	X	5
Hum5	X	1	1	1	1	X	X	X	4

Max=2 if exposition ≥ 28 measures,
else max=1

Table 4-7: Vector 4 - Cadential pattern

	Mm1 1-based	Mm2 1-based	Pre-2ndry ;-cad	OF	OF	Pre-end OF	End	3-based	Dif
Ideal	1	1	1	1	1	1	1	1	
Bch1	X	X	X	X	nr	nr	X	X	6
Bch2	X	X	X	X	nr	nr	X	X	6
Bch3	X	X	X	X	X	X	X	X	8
Bch4	X	X	X	X	nr	nr	X	X	6
Bch5	X	X	X	nr	nr	1	1	1	3

Max=2 if exposition $\geq$ 28 measures,
else max=1

Table 4-8: Vector 4 - Cadential pattern

	Mm1 1-based	Mm2 1-based	Pre-2ndry ;-cad	OF	OF	Pre-end OF	End	3-based	Dif
Ideal	1	1	1	1	1	1	1	1	
4-hnd	1	X	X	X	X	X	1	1	5
Son. In D	1	1	X	X	X	1	1	1	3
Rom1	X	X	X	nr	nr	1	1	1	3
Rom2	X	X	X	X	nr	nr	1	1	4
Rom3	X	X	X	X	X	1	X	X	7
Rom4	1	1	X	X	nr	nr	X	X	4
Rom6	X	X	X	X	nr	nr	X	X	6

Max=2 if exposition $\geq$ 28 measures,
else max=1

Table 5-1a: Vector 5 - Post Main Melody, Transition

Property	Ideal	M1	M2	M3	M4	M5	M6	M7	M8
1) >=1mrpseqL v 2mrseqLv1i (if pmm>5 meas.)	1	nr	1	nr	1	nr	X	1	1
2) <=hmrseqL>2*	0	0	0	0	0	0	0	0	0
3) rpseqL3 v dim_grp (if pmm>5 meas.)	1	nr	1	nr	1	nr	X	1	1
4) ev1,2 (if exposit. >28 meas.)	1	nr	1	nr	1	nr	1	1	1
5) static_harm-*	0	0	0	0	0	0	0	0	0
6) notrans_V*	0	0	0	0	0	0	0	0	0
7) late-pmm*	0	0	0	0	0	0	0	0	0
8) long-pmm* (if exposit. > 16 meas)	0	0	0	0	0	0	0	0	0
9) a_lpa (if exposit. > 16 meas)	1	X	1	1	1	1	1	1	1
10) red_V*	0	0	0	0	0	0	0	0	0
11) end	1	1	X	1	1	X	1	1	1
12) ;-cad	1	X	1	1	1	1	1	1	X
13) mid_meas*	0	0	0	0	0	X	0	0	0
14) run_on*	0	0	0	0	0	0	0	0	0
15) trip_cad*	0	0	0	0	0	0	0	0	0
Dif		2	1	0	0	2	2	0	1

If exposit. > 28 meas,
max=3
(else max=1)

Table 5-1b: Vector 5 - Post Main Melody, Transition

Property	Ideal	M10	M11	M12	M13	M14	M15	M16	M17
1) >=1mrpseqL v 2mrseqLv1i (if pmm>5 meas)	1	1	1	1	1	1	1	1	1
2) <=hmrseqL>2*	0	0	X	0	0	X	0	0	X
3) rspeqL3 v dim_grp (if pmm>5 meas)	1	X	1	1	1	1	X	1	X
4) ev1,2 (if expos. > 28 meas.)	1	1	1	1	1	1	1	X	1
5) static_harm*	0	0	0	0	0	0	0	0	0
6) notrans_V*	0	0	0	0	0	0	0	0	0
7) late-pmm*	0	0	0	0	0	0	0	0	0
8) long-pmm* (if exposit. > 16 meas	0	0	0	0	0	X	0	0	0
9) a_lpa (if exposit. > 16 meas	1	1	1	1	1	1	1	X	1
10) red_V*	0	X	X	0	0	X	0	0	0
11) end	1	1	X	1	1	1	1	1	1
12) ;-cad	1	1	1	1	1	1	X	1	X
13) mid_meas*	0	0	0	0	0	0	0	0	0
14) run_on*	0	0	0	0	0	0	0	0	0
15) trip_cad*	0	0	0	0	0	0	0	0	0
Dif		2	3	0	0	3	2	2	3

If exposit > 28meas,
max=3
(else max=1)

Table 5-1c: Vector 5 - Post Main Melody, Transition

Property	Ideal	M18	M19	M20
1) >=1mrpseqL v 2mrseqLv1i (if pmm>5 meas)	1	1	nr	1
2) <=hmrseqL>2*	0	X	0	X
3) rpseqL 3 v dim_grp (if pmm>5 meas)	1	1	nr	X
4) ev1,2 (if exp.>28 meas)	1	1	nr	X
5) static_harm*	0	0	0	0
6) notrans_V*	0	0	0	0
7) late-pmm*	0	0	0	0
8) long -pmm* (if exposit. > 16 meas)	0	0	nr	X
9) a_lpa (if exposit. > 16 meas)	1	1	nr	1
10) red_V*	0	X	0	X
11) end	1	1	1	1
12) ;-cad	1	1	X	1
13) mid_meas*	0	0	X	0
14) run_on*	0	0	0	0
15) trip_cad*	0	0	0	0
Dif		2	2	5

If exposit > 28 meas,
max=3
(else max=1)

Table 5-2: Vector 5 - Post Main Melody, Transition

Property	Ideal	Cope
1)1mrpseqL v 2mrseqL v1i (if pmm>5 meas)	1	1
2) <=hmrseqL>2*	0	0
3) rseqL 3 v dim_grp (if pmm>5 meas)	1	1
4) ev1,2 (if exposit > 28 meas.)	1	1
5) static_harm*	0	0
6) notrans_V*	0	X
7) late-pmm*	0	0
8) long-pmm* (if exposit. > 16 meas)	0	X
9) a_lpa (if exposit. > 16 meas)	1	1
10) red_V*	0	0
11) end	1	X
12) ;-cad	1	X
13) mid_meas*	0	0
14) run_on*	0	0
15) trip_cad*	0	0
Dif		4

If exposit > 28 meas,
max=3
(else max=1)

Table 5-3a: Vector 5 - Post Main Melody, Transition

Property	Ideal	H1	H3	H4	H6	H8	H9	H10	H11
1) >=1mrpseqL v 2mrseqLv1i (if pmm>5 meas)	1	nr	nr	nr	nr	1	nr	nr	X
2) <=hmrseqL>2*	0	0	0	0	0	0	0	0	X
3) rpseqL3 v Dim_grp (if pmm>5 meas)	1	nr	nr	nr	nr	1	nr	nr	X
4) ev1,2 (if exposit > 28 meas.)	1	nr	nr	nr	nr	X	nr	nr	X
5) static_harm*	0	0	0	0	0	0	0	0	0
6) notrans_V*	0	X	X	X	X	0	0	X	0
7) late-pmm*	0	0	0	0	0	0	X	0	0
8) long-pmm* (if exposit. > 16 meas)	0	nr	nr	0	0	X	0	0	0
9) a_lpa (if exposit. > 16 meas)	1	nr	nr	1	X	X	1	X	X
10) red_V*	0	0	0	0	0	X	0	0	X
11) end	1	X	X	X	X	X	X	X	X
12) ;-cad	1	X	X	X	X	X	X	X	1
13) mid_meas*	0	0	0	X	0	0	0	0	0
14) run_on*	0	X	X	0	0	0	X	0	X
15) trip_cad*	0	0	0	0	X	0	0	0	0
Dif		4	4	4	5	6	4	4	8

If exposit > 28 meas,
max=3
(else max=1)

Table 5-3b: Vector 5 - Post Main Melody, Transition

Property	Ideal	H12	H13	H14	H15	H16	H17	H18	H19
1) >=1mprseqL v 2mrseqLv1I (if pmm>5 meas)	1	nr	nr	X	1	1	X	1	nr
2) <=hmrseqL>2*	0	0	0	0	0	0	X	X	0
3) rpseqL3 v dim_grp (if pmm>5 meas)	1	nr	nr	X	X	X	X	X	nr
4) ev1,2 (if exposit. > 28 meas)	1	nr	nr	1	X	X	nr	1	nr
5) static_harm*	0	0	0	0	0	0	0	0	0
6) notrans_V*	0	X	X	0	0	0	0	0	X
7) late-pmm*	0	0	0	X	X	0	0	0	0
8) long-pmm* (if exposit. > 16 meas)	0	0	0	0	X	X	0	0	0
9) a_lpa (if exposit. > 16 meas)	1	X	X	X	X	X	1	X	X
10) red_V*	0	0	0	0	X	X	0	0	0
11) end	1	X	X	X	X	X	1	1	X
12) ;-cad	1	X	1	1	X	X	X	X	X
13) mid_meas*	0	0	X	0	0	0	0	X	0
14) run_on*_	0	X	0	0	X	X	X	X	0
15) trip_cad	0	X	X	0	0	0	X	0	0
Dif		6	5	5	9	8	6	6	4

If exposit. > 28 meas,
max=3
else max=1

Table 5-3c: Vector 5 - Post Main Melody, Transition

Property	Ideal	H20	H29	H30	H31	H32	H33	H34	H35
1) >=1mrpeqL v 2mrseqLv1i (if pmm>5 meas)	1	1	X	nr	1	X	X	1	X
2) <=hmrseqL>2*	0	X	0	X	0	X	0	0	0
3) rpseqL3v dim_grp (if pmm> 5 meas)	1	1	X	nr	X	X	X	X	X
4) ev1,2 (if exposit. > 28 meas.)	1	X	1	1	X	X	X	X	1
5) static_harm*	0	X	0	0	0	0	0	0	0
6) notrans_V*	0	0	0	0	0	0	0	0	0
7) late-pmm*	0	0	0	0	0	0	0	0	0
8) long-pmm* (if exposit. > 16 meas)	0	X	0	0	0	0	0	0	0
9) a_lpa (if exposit. > 16 meas)	1	1	1	X	X	1	1	1	1
10) red_V*	0	X	0	0	0	0	0	0	0
11) end	1	X	X	X	1	X	X	X	1
12) ;-cad	1	X	X	X	X	X	X	1	X
13) mid_meas*	0	0	X	0	0	0	0	0	X
14) run_on*	0	X	0	0	0	0	0	0	0
15) trip_cad	0	0	0	0	X	0	0	0	0
Dif		8	5	4	5	6	5	3	4

If exposit. > 28 meas,
max=3
(else max=1)

Table 5-3d: Vector 5 - Post Main Melody, Transition

Property	Ideal	H36	H37	H38	H39	H40	H41	H42	H43
1) >=1mprseqL v 2mrseqLv1i v (if pmm>5 meas)	1	1	nr	X	1	X	nr	X	1
2) <=hmrseqL>2*	0	X	0	0	0	0	0	0	X
3) rpseqL3 v dim_grp v (if pmm>5 meas)	1	X	nr	X	X	X	nr	X	X
4) ev1,2 (if exposit. > 28 meas.)	1	X	nr	X	X	nr	X	1	1
5) static_harm*	0	0	0	0	X	0	0	0	0
6) notrans_V*	0	0	X	0	0	0	X	0	0
7) late-pmm*	0	0	0	0	0	0	0	0	0
8) long-pmm* (if exposit. > 16 meas)	0	0	0	0	0	0	0	0	0
9) a_lpa (if exposit. > 16 meas)	1	1	X	1	X	1	X	1	1
10) red_V*	0	0	0	0	0	0	0	0	X
11) end	1	X	X	X	X	X	X	X	X
12) ;-cad	1	1	X	X	1	X	X	X	X
13) mid_meas*	0	0	X	0	0	X	X	0	0
14) run_on*	0	0	0	X	0	0	0	0	0
15) trip_cad*	0	0	0	0	0	0	0	0	0
Dif		4	5	6	5	5	6	4	5

If exposit > 28 meas,
max=3
(else max=1)

Table 5-3e: Vector 5 - Post Main Melody, Transition

Property	Ideal	H44	H45	H46	H47	H48	H49	H50	H51
1)>=1mrpseqL v 2mrseqLv1i (if pmm>5 meas)	1	1	1	nr	nr	X	nr	X	nr
2) <=hmrseqL>2*	0	0	X	0	X	X	0	0	X
3) rpseqL3 v dim_grp (if pmm>5 meas)	1	X	X	nr	nr	X	nr	X	nr
4) ev1,2 (if exposit. > 28 meas.)	1	X	1	nr	nr	1	X	1	n/r
5) static_harm*	0	0	0	0	0	X	0	X	0
6) notrans_V*	0	0	0	0	0	0	0	0	0
7) late-pmm*	0	0	0	X	0	0	0	0	0
8) long-pmm* (if exposit. > 16 meas)	0	0	0	0	0	X	0	0	0
9) a_lpa (if exposit > 16 meas)	1	1	X	1	1	1	1	1	1
10) red_V*	0	X	X	0	0	X	0	0	0
11) end	1	X	X	X	X	1	X	1	X
12) ;-cad	1	X	X	X	X	X	X	1	X
13) mid_meas*	0	0	0	X	X	0	0	0	0
14) run_on*	0	0	0	X	0	0	0	0	0
15) trip_cad*	0	0	0	X	0	0	0	0	0
Dif		5	6	6	4	7	3	3	3

If exposit. > 28 meas,
max=3 else
max=1

Table 5-3f: Vector 5 - Post Main Melody, Transition

Property	Ideal	H53	H55	H57	H59	H60	H61	H62
1) >=1mrpseqL v 2mrseqLv1i (if pmm>5 meas)	1	n/r	1	1	1	1	1	X
2) <=hmrseqL>2*	0	0	X	0	0	X	0	0
3) rpseqL3 v dim_grp (if pmm>5 meas)	1	n/r	X	X	X	X	X	X
4) ev1,2 (if exposit. >28 meas.)	1	1	1	1	1	1	1	X
5) static_harm*	0	0	0	0	0	X	0	0
6) notrans_V*	0	0	0	0	0	0	0	0
7) late-pmm*	0	0	0	X	0	0	X	0
8) long-pmm* (if exposit. > 16 meas)	0	0	0	X	0	0	0	0
9) a_lpa (if exposit. > 16 meas)	1	X	1	1	1	1	1	1
10) red_V*	0	0	0	X	0	0	0	0
11) end	1	X	X	X	X	1	X	1
12) ;-cad	1	X	1	X	X	X	X	X
13) mid_meas*	0	0	0	0	0	0	0	0
14) run_on*	0	X	0	X	0	0	0	X
15) trip_cad*	0	0	0	0	0	0	X	X
Dif		4	3	7	3	4	5	6

If exposit > 28 meas,
max=3
(else max=1)

APPENDIX B
SAMPLE MELODIC GRAPHS

FIGURE 1-1

Mozart

M7

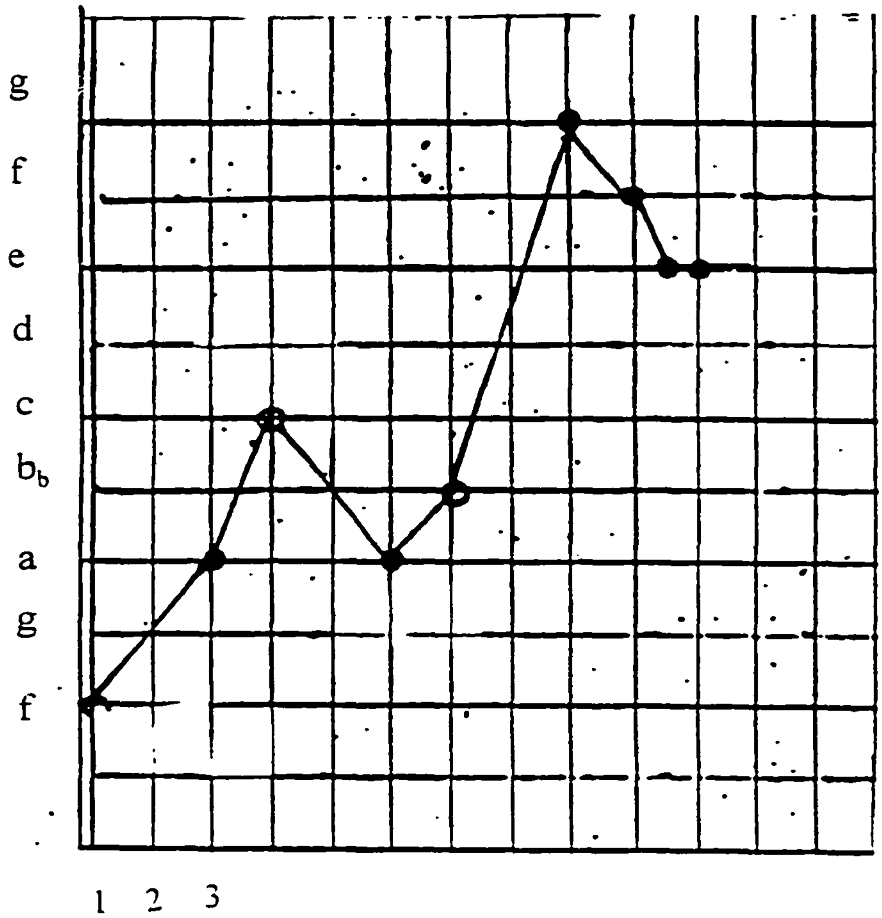


FIGURE 1-2
Mozart

M11

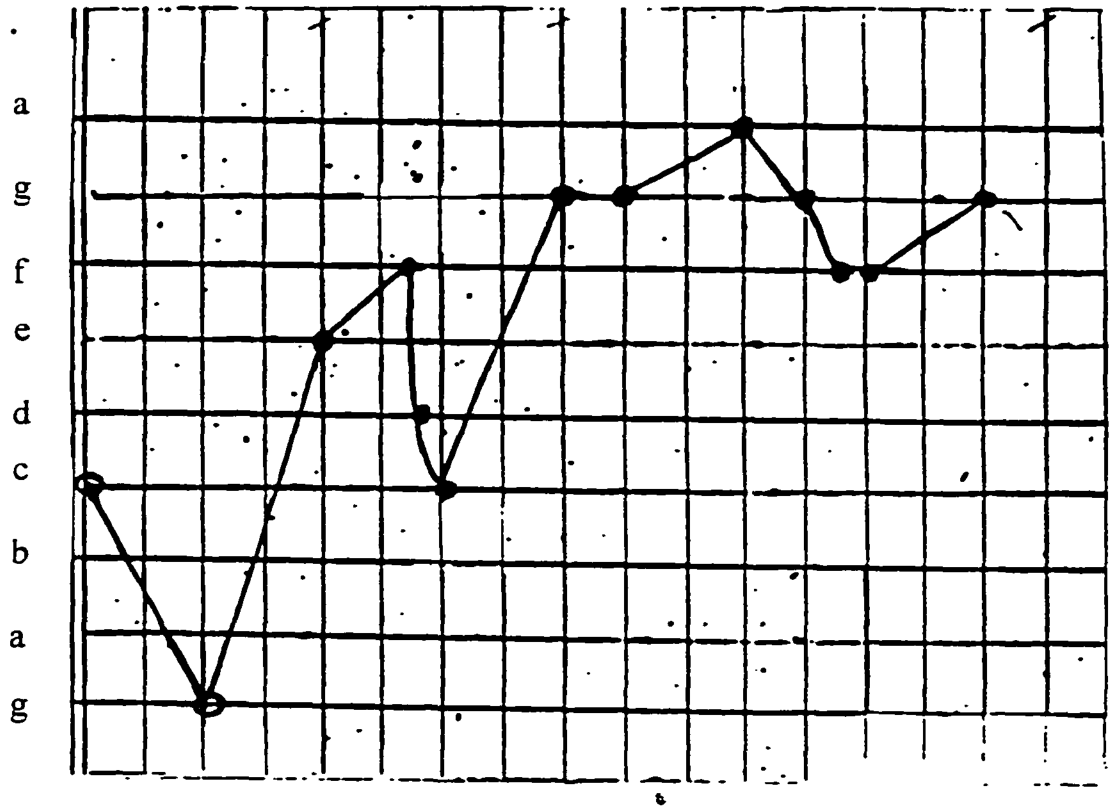


FIGURE 1-3
Mozart

M12

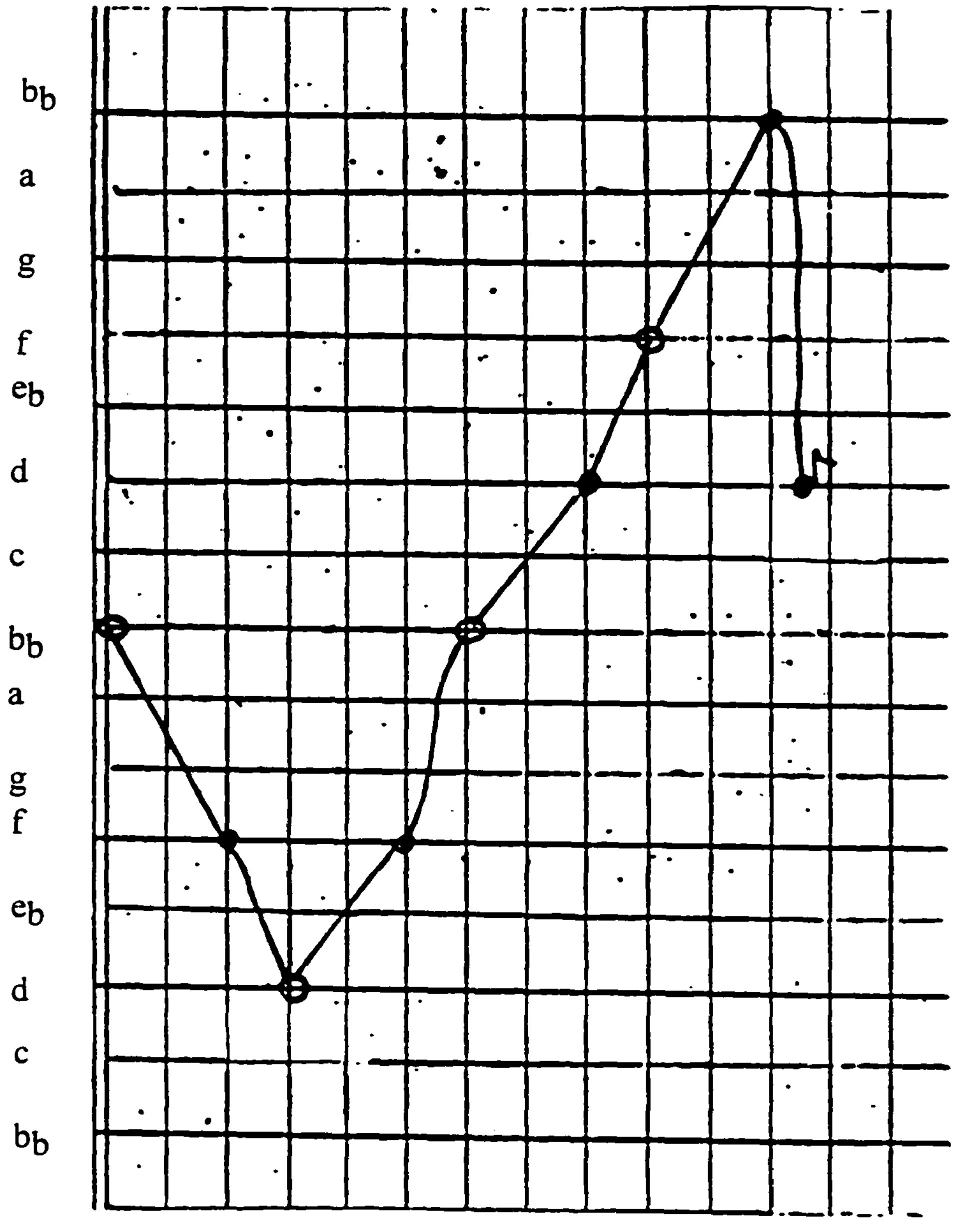


FIGURE 1-4
Mozart

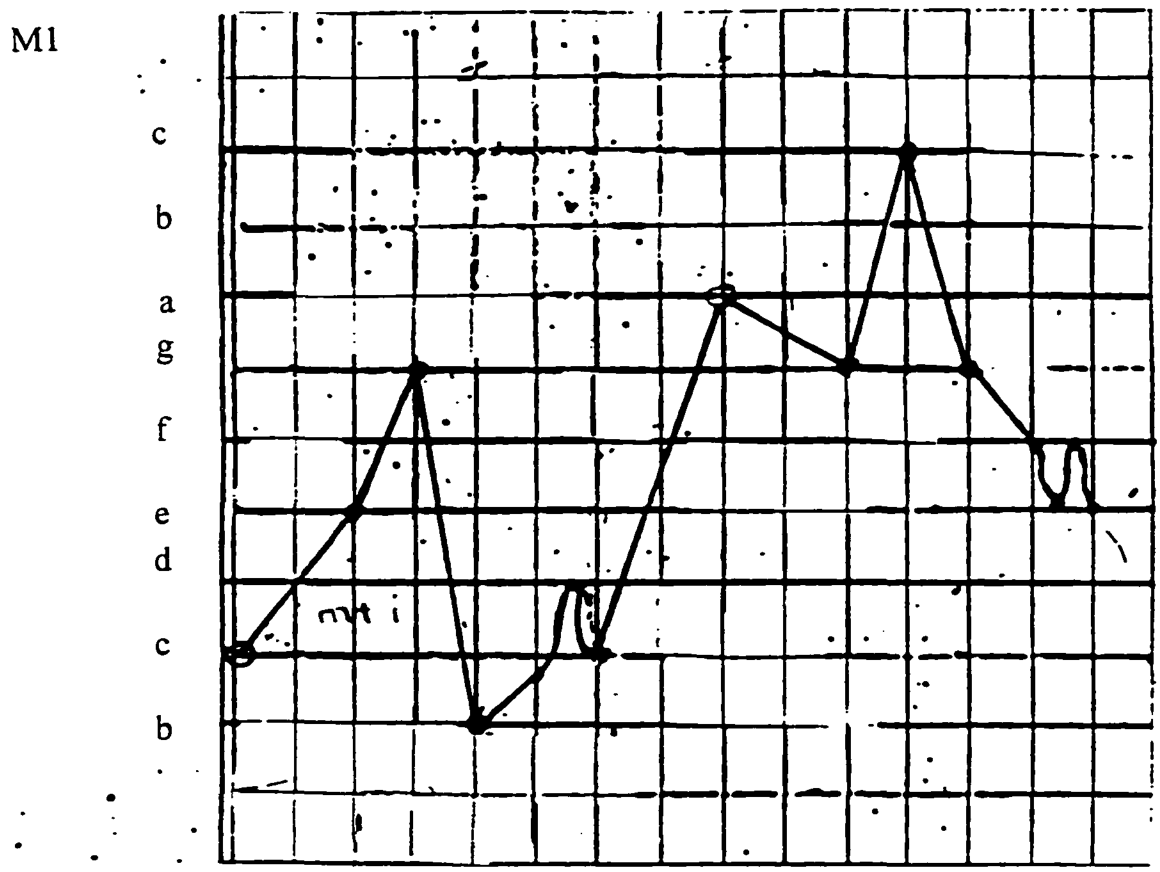


FIGURE 1-5
Mozart

M17

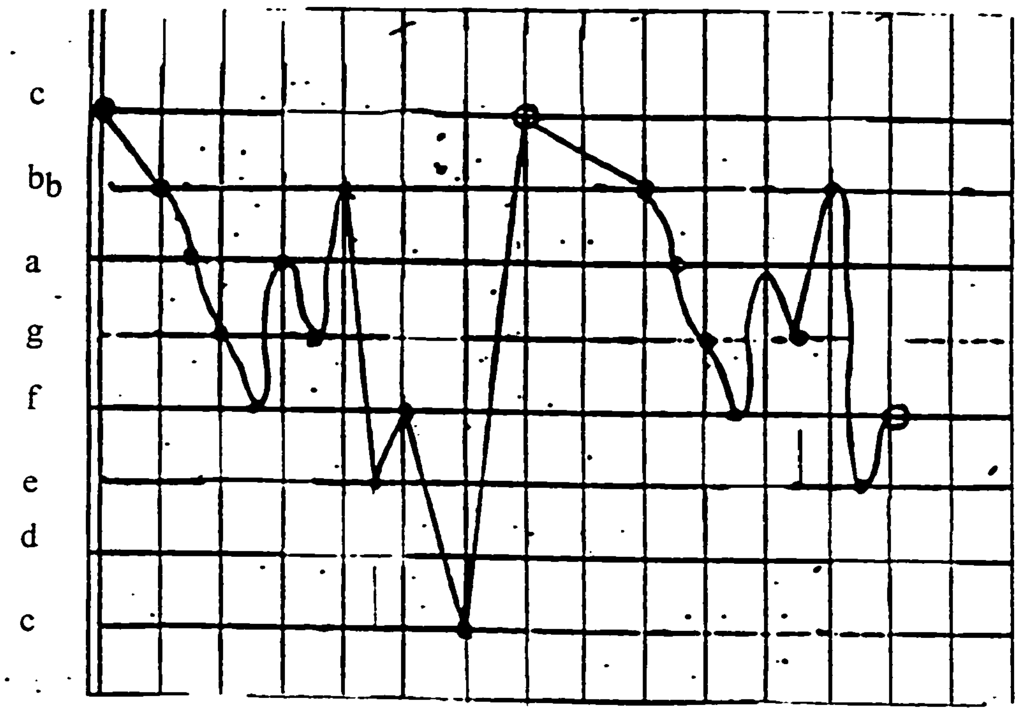


FIGURE 1-6
Haydn

H8

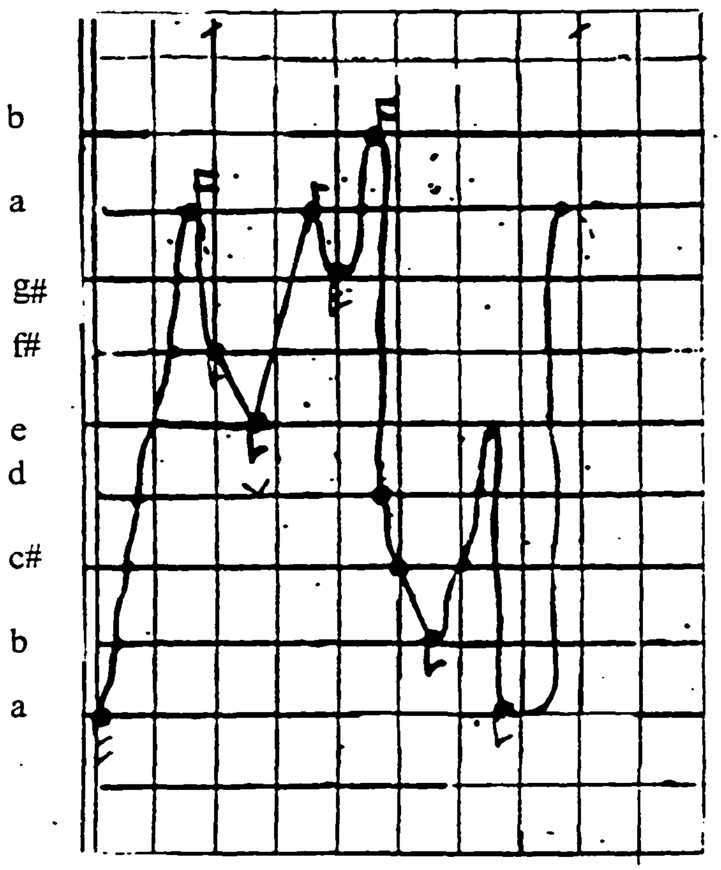


FIGURE 1-7
Haydn

H6

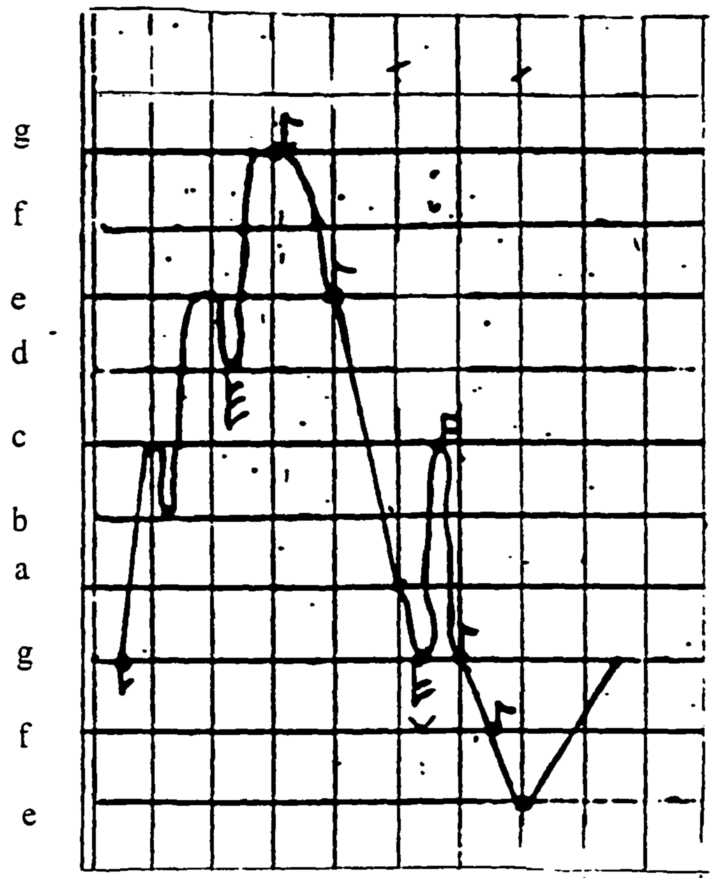


FIGURE 1-8
Haydn

H38

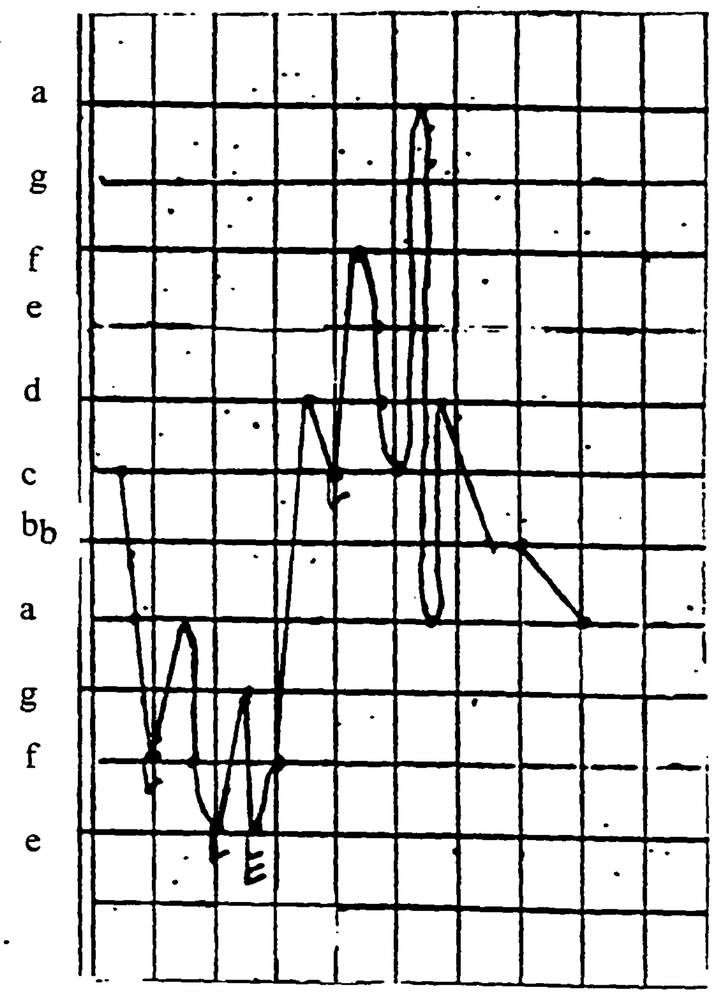


FIGURE 1-9

Dussek
XIX

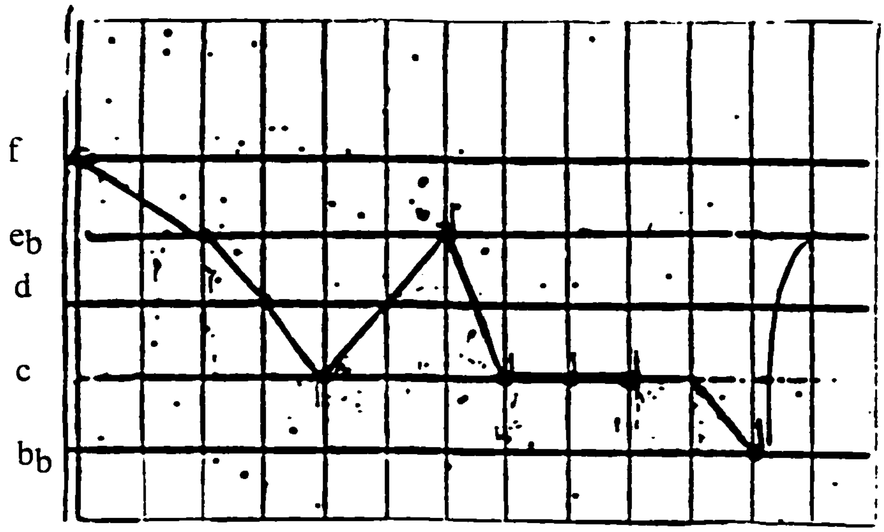
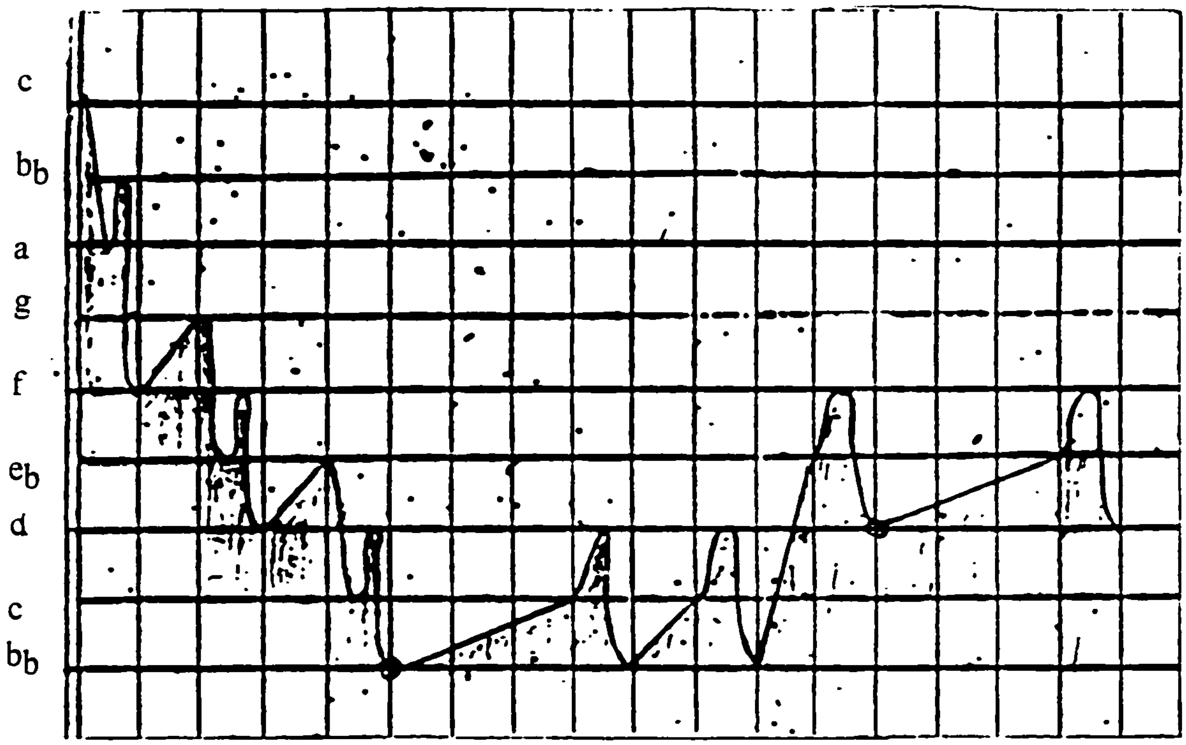


FIGURE 1-10
Clementi
2



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