# Representation of Decision Making Process in Music Composition Based on Hypernetwork Model

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**Abstract.** Music composition is treated as a repetitive decision making process, and represented using the hypernetwork model, the proposed model. The hypernetwork model allows more specific description of relationships among represented entities than conventional knowledge representation models such as semantic network. Music composition of a musical piece of 100 measures (performance duration of 6-8 minutes) by a professional composer is analyzed based on the description of decisions involved. Musical piece represented as musical scores are represented with hypernetwork model where the decisions are the representational units. Single or multiple decisions are related with other decisions, and quantitative similarity based on relationality among decision sequences provided by the hyperlink model enables the discrimination of various types and degrees of similarity.

**Keywords:** Knowledge representation, similarity relationship network, decision making, music composition.

## 1 Introduction

The present paper addresses the description model to represent decisions involved in composition of musical pieces. Music composition is an artistic creation process, but can also be understood as a complex sequence of decision processes that involves both formal theoretical basis of music theory that rules the decision freedom and artistic basis that expands idea creation employing mainly subjective artistic impressions and evaluations.

In the simplest view, music composition is a successive addition of single notes with specific pitch, duration and intensity. Therefore, a chord is a set of vertically aligned single notes, and a melody is a set of horizontally aligned single notes. At the finest detail level, the decision is to select a single note with determined pitch, duration and intensity. A higher level interpretation involves chord decisions on chord sequence, harmony, role distribution among different instruments, choice of measures and keys, tonality, and movements. Evidently the options and variety differ according to the type of musical piece to compose.

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The musical score represents the final product of composers. Intentions and thinking process of composers are hidden and not explicitly annotated, mainly because no description means exist. However, such information is crucial for musical instruments players to execute the musical piece, because better performance is possible by deeper understanding. For this reason, music courses provide analysis class which is dedicated exclusively to the analyses of musical pieces.

Even if written, composers' intentions are related solely to the final version of the music. On the other hand, more useful information is the creation history of the musical piece, described through the sequence of all decisions involved in the composition. Musical instrument players can understand deeper the "raison d'etre" of each passage, motive and aim of the composer. There is, consequently, a need for a comprehensive and powerful description model to annotate decisions.

The present model is a description model of decision processes. The following can be affirmed. (1) Descriptions of intermediate stages, progresses and background facts (reasons) of music composition processes are rare; and (2) All descriptions of the first item is written as text (natural language), thus "automatic" organization including classification and grouping is very difficult. Currently, no practical method exists to organize such information.

Conventional representation models of decision processes focalize on decision sequence and structures that arise from it. Although not explicitly stated or even noticed, these models are based on graph theory whose representation elements are nodes and links. A node represents a decision and two nodes are connected with arrow if direct temporal relation or some causal relation exists between the decisions. An arrow can be either uni- or bidirectional. More elaborated models provide multiple node types to visually differentiate decision types, such as single decision and conditional decisions, similar to computer program flow charts.

An advantage of conventional models is the easiness to grasp overall progress and structure because they offer overall view of the whole decision process, due to their simple and compact visualization.

This advantage is, however, also an disadvantage. Details of decisions can be described by adding nodes of lower hierarchy level to each node with proper annotation rules. On the other hand, details of decision transitions cannot be added, because decision transitions are simple links between nodes, and nodes cannot be connected directly to links. Furthermore, decision transitions among three or more decisions (nodes) cannot be represented since a link connects two nodes only. In reality, a decision may trigger multiple decisions, and a decision might be made subsequently to multiple decisions or integrate multiple decisions. These cases are *N*-to-*N* decisions, but impossible to be handled with conventional models that are based on graph theory.

## 2 Decisions in Music Compositions

A musical piece with 100 measures composed by a professional composer is analyzed to evaluate the proposed representation model of decision process. The composition process consists of four stages: (1) Creation of initial 21 measures; (2) Elaboration of the first 21 measures; (3) Creation of measures 22-49, adding to the result of the second stage; and (4) Creation of measures 50-100, the last part of this musical piece. At the end of each stage, all operations are described using composer's native language to ensure precision.

During the description, all involved decisions are classified into one of the categories based on the nature of decisions: (A) Theoretical, where the decision is derived from some music theory. Empirical (heuristics) foundations are excluded, because of the absence of theoretical basis. (B) Selective, where the composer makes an arbitrary choice from a set of candidate solutions based on chance or some theory. (C) Contingent, where the decision is arbitrary but uses composer's intuition.

It is important, however, that the decision maker (composer) is experienced, and even if the decisions are superficially apparent as random choice, the choices are based on experience accumulated by the composer. Therefore, selective choices are non-random and intuitive, which are most of the times correct or adequate [2], completely different from novices' shots in the dark.

The composition process is divided into four stages: Stage-1A, 1B, 2 and 3, following the composer's work procedure. The stages 1A and 1B refer to the first and second stages of composition of measures 1-21. The stages 2 and 3 refer respectively to compositions of measures 22-49 and 50-100, where both segments were composed in a single step. The time sequence of the composition is: Stage-1A, 1B, 2, 3. No overlap exists, i.e., no modifications in measures not belonging to the measures treated in each stage are observed.

The composed musical piece is post-tonal piece. The formal structure of such musical piece is clearly governed by the harmonic content, but not exclusively. Therefore, it is adequate to describe the decision process of musical composition, because the harmonic aspect of tonal music is completely regulated by harmonic theory, and theoretical aspect of tonal harmony is absent in atonal music.

Figure 1 is the frequencies of decision types in each composition stage. Theoretical decisions are most frequent in Stages 1A and 1B, and contingent decisions are the most frequent in 2 and 3. Small frequency of selective decisions (18.6% of all

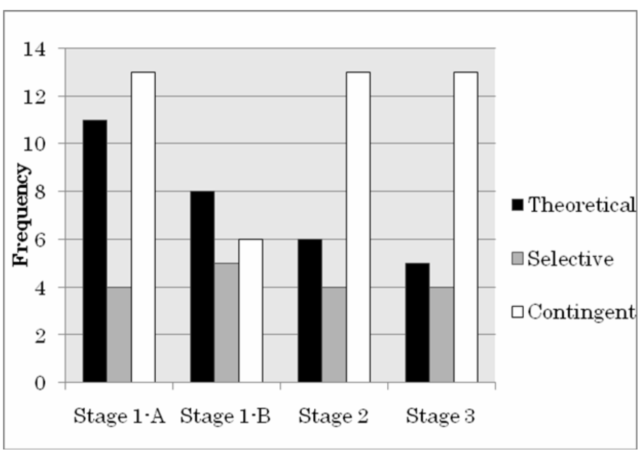


**Fig. 1.** Occurrences of decision types in each composition stage

decisions) suggests that professional composers create and improve musical pieces based either on theory for theoretically constrained factors or on intuition. In selective decisions, the composer has to explicitly imagine multiple solutions (options) and choose one. This is in accordance with result from decision making analysis, where an experienced professional employs the first option (solution) that comes to the mind if the solution has no apparent fault [2].

Decisions are classified into (i) framework and (ii) component decisions, based on the extent that the decisions affect. Framework decisions affect the entire musical piece, and component decisions the passsages or a part of the piece independent of the extent of influence. In other words, these are global and local decisions.

For a more detailed analysis, decisions involved until the concretization of the thematic material in the Stage S-1A are addressed in this section.

### 2.1 Framework Decisions

Framework decisions observed in analyzed musical piece are as follows.

1. D1A: Harmonic content is post-tonal.
2. D2A: Use pitch class set as the harmonic theme of the entire piece. The selected set is 6-Z25 in the Forte's table [1].
3. D2B: The harmonic content of the thematic material should follow strictly the selected harmonic theme.
4. D3A: Selected musical instruments are saxophone and piano.
5. D3B: Saxophone chosen as the instrument of main role to express the formal shape of the piece, at least of the part A.
6. D3C: Scheme of the piece is ternary, of the type A–B–A. The part B is dedicated to solo passages.
7. D3D: The total duration of the musical piece is between 6 and 8 minutes. This influences the tempo (bpm) and the number of measures.
8. D4C: The bpm (beats per minute) is 76.
9. D9A: Addition of the third musical instrument, the contrabass. At this point, it becomes clear that the procedure to fulfill characteristic intermittencies of main material is more effective with the existence of the third instrumental part. The new instrument not only reinforces the piano or the saxophone part, but also takes part of the metric contrast requested by the textural plane of the piece.

Other framework decisions are possible, depending on the class of musical piece, although the general characteristics are common to all musical styles. For instance, the key should be determined for tonal musical pieces, but is unnecessary for atonal musical pieces. Key change and variations are also possible. These decisions refer to the entire musical piece, and are usually executed at the beginning of the compositions. Framework decisions are, however, also executed in the middle of composition process. In the analyzed music, for instance, a third musical instrument, the contrabass, is added in the middle of the process (Decision D9A), but this decision is still in the first stage (Stage 1-A).

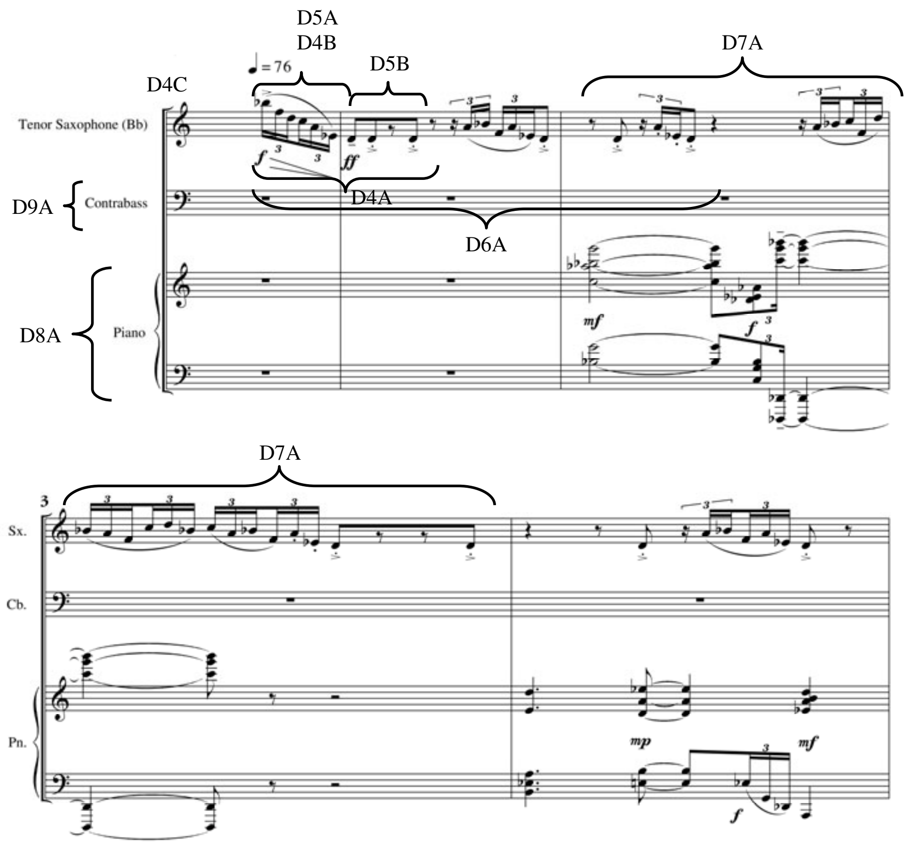


**Fig. 2.** The first version of the initial five measures. Target (affected) region of decisions are also indicated. IDs of decisions are the same used in the text, and the number indicates the sequence order of the decision.

## 2.2 Component Decisions

Component decisions are of varied type and account for 74% of decisions in Stage 1-A, and 92% of all decisions (Figure 1).

Component decisions are executed in steps, and each step consists of multiple decisions (microdecisions). The unit of decisions is determined by the composition task that the decision affects. A region can be the target of multiple decisions, each encompassing identical or different ranges. The affected notes or range is decision dependent, and no maximum boundary exists, possible up to a dozen of measures. The minimum boundary is obviously a single note.

Component decisions of the thematic material creation of Stage S-1A are as follows. The numbers denote the decision order, and the last alphabet indicates the order inside the decision group. For instance, D4B is the second decision of the fourth decision group.


**Fig. 3.** The final version of the initial five measures. For comparison purposes with the first version (Fig. 2).

1. D4A (Theoretical): For the creation of elements that constitute the thematic material, two cellular structures will be used: a fast descending movement element (element A) and pulsing element (element B), with no melodic contour.

2. D4B (Contingent): Element A contains the whole referential harmonic set, and should reach the lowest tone of the saxophone. The element B will be presented with this tone.

3. D4C (Contingent): From the movement characteristic of the element B and the rhythmic structure of elements A and B, tempo of 76 bpm is appropriate for the intended effect.

4. D5A (Contingent): The element A should sound starting with an explosive intensity, then followed by energy dissipation, represented with initial accent with diminuendo.

5. D5B (Contingent): The element B is characterized by higher intensity and articulations of counterpoint, indicated with accent and staccato, valuing the pause that is important to realize the theme.

6. D6A (Theoretical): The initial phrase is complete by joining to the principal motif (A+B) a complementary material by amplification derived from the element B.

7. D7A (Theoretical): A second phrase structure to establish a new symmetry is necessary to achieve the first formal closing point, on the level of complete phrase structure.

8. D7B (Contingent): The second phrase has the ornamentation type identical to the first phrase, keeping the economy and homogeneity of harmonic resources.

9. D7C (Contingent): The element A is modified with amplified ornamental movement, followed by a new element B without the central articulation.

10. D7D (Contingent): The second phrase is terminated with the complementary material of the initial phrase, but with reconfigured metric structure for fitting reason.

11. D8A (Selective): The imprint of the piano part of this section is the filling of intermittencies that exist in the main part's contour executed by the saxophone.

## 3 Hypernetwork Model

The model to represent the decision making process, the hypernetwork model [3], is extended from the bipartite representation of the hypergraph [4]. The hypergraph model, on the other hand, has more representation capability than conventional knowledge representation models that are based on graph [6], such as semantic network [5], frame, and ER-model [7]. Conventionally used decision sequence representation is also a graph. Basically, the hypernetwork model follows basic definitions of semantic networks, where a node is connected to other nodes (1) to specify the nodes or (2) when nodes are related by some relationship.

A uniqueness of the hypernetwork model is the existence of three types of description elements, equivalent to the types of nodes. Graph and hypergraph models consist of nodes and links connecting the nodes. In decision sequence representation, a node represents a decision, and a link connects two or more decisions in sequence relationship. A link of the graph model can connect only two decisions, and a link of the hypergraph (hyperlink) connects any number of decisions. The bipartite representation converts the links into nodes, denoted relation nodes, hence two types of node exist: the vertex node and the relation node. The vertex node serves to represent decisions (entities), and the relation node to describe relationships among decisions. An analysis of knowledge property, however, indicates that a third type of node is necessary, the attribute node, to specify the properties of vertex nodes and relation nodes. Therefore, conventional representation models present at least two flaws: (1) relationships among multiple entities cannot be represented, and (2) representation is incomplete since attributes are not provided. The hypernetwork model resolves both problems.

In the context of decision representation, details or properties of a concept represented by a vertex node can be specified in two ways: by attachment of attribute nodes, or by relating to other vertex nodes through relation nodes. Combination of the two descriptions is also possible. The attribute node exists to specify any of three node types. Table 1 indicates the connectivity constraints among three node types. Two connections are prohibited: between vertex node and vertex node, and between relation node and relation node, constraint imposed from their role in hypergraph. Table 1 is symmetrical on diagonal axis although the directionality of links depends on the context and what the network represents.

**Table 1.** Connectivity among vertex node, relation node and attribute node

| | Vertex node | Relation node | Attribute node |
|---|---|---|---|
| Vertex node | – | Connect | *Connect* |
| Relation node | Connect | – | *Connect* |
| Attribute node | *Connect* | *Connect* | *Connect* |

## 4 Discussions

The proposed model focuses on the process of composition, and not on methods to represent the final outcome.

Uniqueness of the presented analysis is that decisions are of intermediate stages, related to the fact that composition process of musical pieces is a succession of intermediate versions. Surely some musical pieces were created in a single stage, but most are succession of intermittent generation and improvement. It is known that some large musical pieces such as symphony have taken several years to be completed.

The model is also useful for musical piece analysis by the performers, such as instrument players and conductors, to understand the "raison d'etre" of individual passages and of the whole piece. This is important, because better execution is possible by deeper understanding.

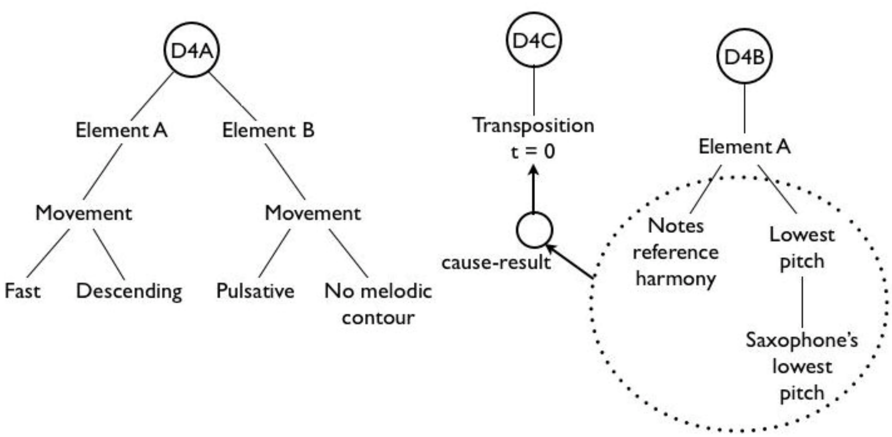


**Fig. 4.** Hypernetwork representation of the decisions D4A, D4B and D4C. "Element A" in D4A and D4B can also be related by identity relationship. In D4B, a higher order hierarchical level is created to related with D4C.

An application of the hypernetwork model is the evaluation of decision processes. Quantitative comparison of decision process based on the structure of represented hypernetwork allows the design of composition strategy. The quality of the whole decision process is measured by the quality of composed music. Obviously the quality of the generated music is affected by many factors unrelated with the decisions involved in the composition. However, the structural analysis can be a useful measure.

Attribute node linked to a vertex node specifies or defines the properties of the entity represented by the vertex node. Attribute node linked to another attribute node is homologous to the previous case, and it defines the properties of the quality or concept expressed by the other attribute node. On the other hand, attribute node connected to a link node is the element absent in conventional representation models. This connection enables a detailed specification of relationship among vertex nodes. Note that the relationship treated here is N-ary which covers the binary relationship, the only relationship that conventional models can represent.

The ability to assign attributes to relationship is essential to qualify and then quantify the similarity relationships that are simply labeled "similar" in semantic networks, for example. Furthermore, attribute nodes connected to link node are specified with more details by further connecting attribute nodes, generating a multi-level hierarchical structure of attributes. Any type of relationship is specified in same manner, but this paper focus on "similarity", a very broad conception, meaning anything between identical and different. Since vertex nodes and relation nodes can connect to attribute nodes, relation nodes are related to other relation nodes. Consequently, a decision network with higher density than conventional models emerges.

Knowledge description using representation models is difficult, and no definitive model exists. The proposed representation model is useful to embed into knowledge base system to search similar composition decisions/operations/techniques, mainly for professional composers. Once composition stages and types of musical piece are specified, it is useful for composers to widen their views and overview multiple composition solutions as their creative process can be enriched by choosing one of solutions, combining them, or improving them.

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