Polyhedron Network Model to Describe Creative Processes

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Abstract. This paper proposes a description of creative process as a combination of emotive thinking and explicit knowledge thinking. We analyze music composition process as a creative process. Specifically, we define five facets to describe the music composition process to capture different aspects of composition. A facet is a perspective to view the musical piece. The perspective is different for composers and performers. Two musical pieces composed by a professional composer are described using the proposed model and analyzed. Results indicate the existence of two types of decision makings.

1 Introduction

This paper proposes a model to describe creative process as a combination of emotive thinking and explicit knowledge thinking. We analyze music composition process as a creative process. Specifically, we define the facets to describe the music composition process to capture different aspects of composition. A facet is a perspective to view the musical piece.

Human being is skillful at creating new concepts and ideas, and imagining non-existing conditions. These abilities are mainly related with sensitivity and emotion. On the other hand, computer system is adept at storing large amount of data. Although executions of describable operations and numerical computations are also advantages of computers, they are not relevant to this paper's topic. It is the author's assumption that during the thinking process by human beings, 40 to 50 % is related to sensitivity, treating nonverbal information and imagination, and the rest, 50 to 60 %, treats verbal concepts and explicit knowledge. The model presented in this paper assumes that sole use of either sensitivity or explicit knowledge does not enable the generation of new ideas, but simultaneous employment of both abilities are essential [1]. Conventional research on knowledge representation focused on the explicit knowledge. The proposed model is an attempt to unify the two kinds of thinking process.

This paper analyses the composition process of two musical pieces composed by a professional composer, treating the composition process as a sequence of decision makings. Causal relationships among decisions is non-sequential, although it is linear in temporal base. Decisions are basically parallel, with ramifications and convergences.

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Music composition process is adequate since (i) it is a creative process, and because of its artistic nature, sensitivity and emotion is strongly involved; (ii) there is a solid foundation of music theory, differing from other Arts fields such as paitings, sculptures and dances. Harmony of tonal music, for instance, involves mathematics of sound frequencies. The liberty and amount of sensitivity that is involved in music composition is higher than engineering process, industrial design and product design, for example, whith have strong theoretical bases. These are the reason to treat music composition.

Musical score is the de facto representation of musical pieces. Musical score encompasses every aspect of the musical piece, and it describes what to be performed, how to be performed, and composer's intentions. Everything is in the score, as some say. John Cage once said that by looking at the music sheet, one can judge the composer's talent, but not by listening to the performance of a musical piece. Music composition process involves a wide range of fields, and the list of fields depends on the music style. Even limiting to fields directly related to music, a composer should be familiar with many disciplines of musical theory inclluding Harmony, acoustics of musical instruments, and genre-dependent articulations of each musical instrument.

We treat the representation model of knowledge included in musical pieces. Many works on music analysis have been published, including the description model of music structure. For instance, Generative Theory of Tonal Music (GTTM) [3] is a model to describe the structure of musical pieces based on linguistic theory. Conventional works try to represent this type of knowledge as the static entity, usually treating as a structure of notes, chords and groups of these elements [3]. Typical structure is hierarchical, where the whole musical piece is positioned at the top of the hierarchy.

The representation model presented here focus on the creation process or composition process, from a blank music sheet to the final work. This is a "creation history" of musical piece. Obviously if the data on intermediate process is absent, the representation will only be about the final status of the music. However, automatic recording of intermediate process should not be a problem in near future thanks to the recent spread of Digital Audio Workstations (DAWs), as the composition task is increasingly executed on computers and not with paper and pencil.

The disclosure of description of intermediate composition process is useful for both composers and players. For composers, it is valuable to overview and clarify his own composition process to improve the composed opus, besides the benefit to reorganize his ideas. For players, the acquisition of background and underlying phylosophy is invaluable, because deeper understanding of musical piece is fundamental and crucial for good execution. Before the execution, every music player analyzes the musical piece he/she will perform. During the analysis, players investigate every note and their context, their raison d'être, and instructions on execution indicated by the composer.

The proposed method differs from conventional works because the musical piece is represented by a temporal sequence of decisions. Such a creation history is more valuable than static structures generated by conventional methods due to reasons discussed before.

2 Model

Decisions executed during music compositions are described using the Hypernetwork model explained in this section. Relationships among decisions are also specified by the model.

The proposed model is extended from hypergraph [5], which has more representation power than conventional knowledge representation models that are based on graph [4]. The main difference is the capability to represent N-ary relationships and the property of duality. The proposed 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.

The model to represent the decision making process, the hypernetwork model [7], is extended from the bipartite representation of the hypergraph [5]. The hypergraph model, on the other hand, has more representation capability than conventional knowledge representation models that are based on graph [4], such as semantic network [6], frame, and ER-model [8]. 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

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

although the directionality of links depends on the context and what the network represents.

In order to represent decisions in music composition, we use the text description of decisions involved during the composition process. The text is written after each work stage defined by the composer himself, written by the composer himself. The number of stages depends on the composer's work style and musical piece being composed, as some pieces take years to be accomplished. Therefore, a stage is anything with varied work amount, number of created and edited notes, and working time durations. In other words, a stage corresponds to the amount of composition work between subsequent intermissions defined by the composer.

In each intermission and after the completion of composition, the composer reviews the modifications since the previous version of the music piece, enumerating every single alterations. Then the composer writes the Decision List Report, a text explaining each modification points, describing the decision type and the details. The decision type should be chosen from (a) Theoretical, (b) Selective, and (c) Intuitive. Theoretical decisions denote decisions based on Music theory. Empirical (heuristic) foundations are excluded because they are empirical and lack theoretical bases. The second type and the third type are used when multiple options exist. It is possible that a decision is theoretical and simultaneously either selective or intuitive, when multiple options exist. The selection of a theory is chosen from multiple possibilities or intuitively. Only one type is associated with decisions, however.

Moreover, it is important 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.

In order to homogenize the granularity of decision sizes, each decision description is analyzed to subdivide into smaller decisions or to join with other decisions depending on the explanation text. Two types of decisions exist, (1) Framework decisions and (2) Component decisions, differing on the extent affected by decisions. Framework decisions are global decisions, and affect the entire musical piece, such as tempo and instruments used. Component decisions are local decisions, modifying passages or a part of musical piece. Basically a component decision consists of a single modification on a single region of an instrument part. A region may contain any number of notes, between a single note, a single chord, or dozen of notes encompassing multiple measures. It may not involve any notes.

The next step is the generation of hypernetwork representation of extracted decisions. The hypernetwork model is explained in next section. The sizes of hypernetwork representation of all decisions are uniform, because the granularity of size of decisions are standardized in the previous step.

Then decisions are interconnected based on: Type-I: decision sequence, subdivided into Type-IA: Global order and Type-IB: Order within overlapped target region; Type-II: Overlap on target region (notes, measures, phrases, among others); Type-III: Identical element node (decision component); and Type-IV: Semantic relationship among element nodes (decision components). This connection process is semiautomatic using computer program. The Type-I connections generate sequence relationships among decisions. The second type of relationships, Type-II, connects decisions affecting at least one identical musical element. It connects multiple decisions that generate N-ary relationships, which are impossible to be generated using conventional representation models. The overlapped element is described in relationship entity, which also functions as a "concept" entity when a person reads the music score. Connections based on same musical element are used to connect multiple decisions if they contain identical elements. The hierarchical level of elements may differ in each decision. For instance, the composer refers to musical elements in other region to employ a variation of these elements. In this case, the hierarchical level of referred elements in decision structure will be different. In other cases, a same thematic element may be used multiple times, and the element description appearing in relevant decisions are linked.

The semantic connections, Type-IV, are based on semantic relationship among decision elements. The semantic relationship types used in our representation are: hierarchy of concept, hierarchy of target region, antonym (opposite concept), and synonym concept. Therefore, the identical connection is a special case of semantic connection.

The hierarchical relationship based on affected target region is generated automatically. Overlapped regions are excluded, as these are Type-II connections. Generation of antonym relationships is also automatic as it uses custom database which contains antonym concepts constructed manually from terms (words) present in decision descriptions.

A decision in a general form is a cause-result relationship. Multiple pre-status or precondition or facts and multiple post-status or postcondition are connected by a relationship that specifies the decision (Fig.1), thus a decision is an N-ary relationship, impossible to be represented by conventional knowledge representation models. A decision modifies the pre-status to generate the post-status. When adding new notes into a musical piece during composition, the pre-status is usually an empty set because it represents a blank sheet. Generally, the prestatus is varied because it depends on the recognition and interpretation of the composer.

It is possible to detection similar passages that is unable to be detected by other representation models. For instance, the passage shown in Fig.2 is the result of following decisions.

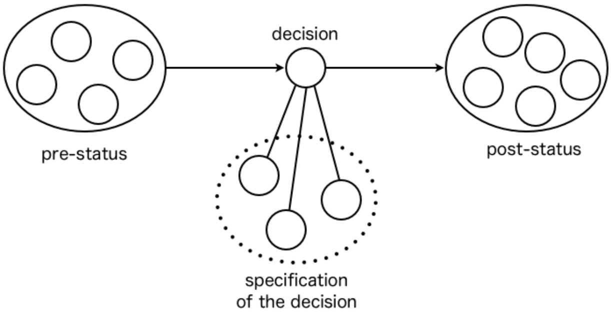

Fig. 1. Hypernetwork representation of a decision

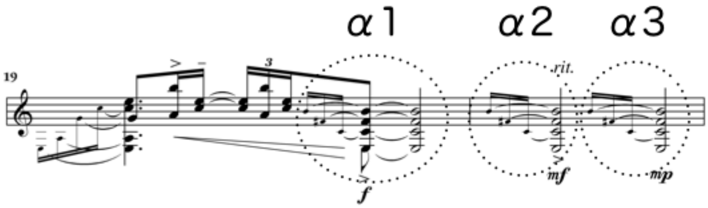

Fig. 2. Measures 19 – 20 of Music-Two

1. **D-1** After achieving the desired sharp boundary, the peak of the tension does not coincide with this boundary. Therefore, attach the tension peak to the bass boundary.
2. **D-2** Execute sudden shift to lower pitch to introduce unbalance.
3. **D-3** Introduce descending arpeggio with increasing sonority (***f***) to emphasize the unbalance that is deliberate.
4. **D-4** Repeat the descending gesture ($\alpha_1 \ldots \alpha_3$) that causes an immediate release of tension in measure 20 before the formal recover of equilibrium in measure 21.

Fig.3 is the simplified representation of these decisions in cause-result relationship following the representation format of Fig.1. Decisions D-1 to D-3 are in sequence, while the decision D-4 is independent. Specifications of decisions are further specified, generating multi level structure. For instance, "descending arpeggio" of the decision D-3 is further specified because pitch and duration selections are also the results of composer's decision.

Fig.5 is a direct representation of measures 19 and 20 extracted from decisions using hypernetwork representation. Multiple viewpoints exist, where the three nodes (α_1, α_2, α_3) surrounded by a larger circle also function as a node of "tension release" and "re-tension" relationships. These decisions are the subdecisions

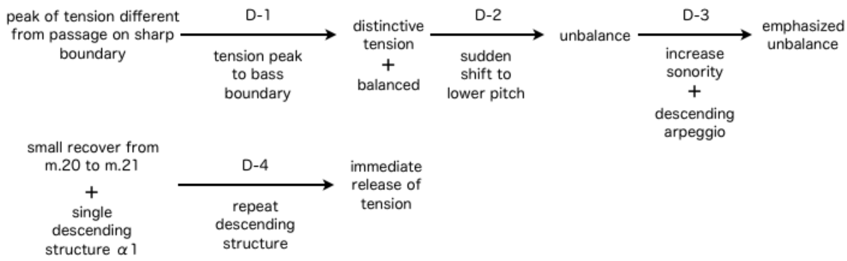

Fig. 3. Simplified representation of decisions D-1 to D-4

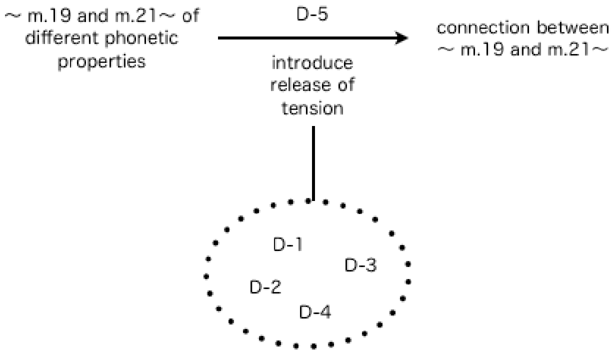

Fig. 4. Decision structure of decisions D1–D4

of a decision to release tension between until measure 19 and after measure 21 to achieve consistency of a single musical piece (Fig.4).

The description in Fig.5 is a conventional representation of musical structure and it focuses on the musical piece in its complete form, although it uses the hypernetwork model. On the other hand, the representation of decision structure (Fig.3) provides wider scope of background information, a new materials for performers to understand deeper the musical piece, resulting in better performance. These two structures are merged, and ability of viewpoint change allows better understanding of the musical piece.

The connection of elements based on similarity among decisions elucidates implicit relationships among musical elements, difficult and time consuming to be clarified by conventional music analysis methods. Fig.6 shows two regions, one of measures 19–20, and other of measures 32–34. These two regions were generated by identical decision, which is to introduce release of tension to the movement that the target passage connects, which are measures until 19 and measures after 21 in the first case, and measures until 32 and after 34 in the second case.

Detecting similar decisions is useful to analyze musical pieces and results in valuable information for the musical instrument players. Furthermore, similarity among decision sequences is more important than comparison of single decisions.

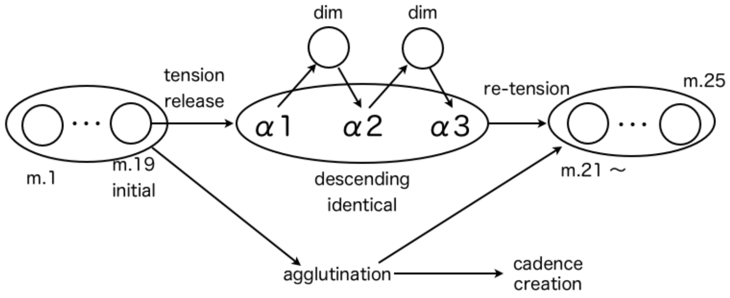

Fig. 5. Hypernetwork representation of relationships among elements involved in Fig.2

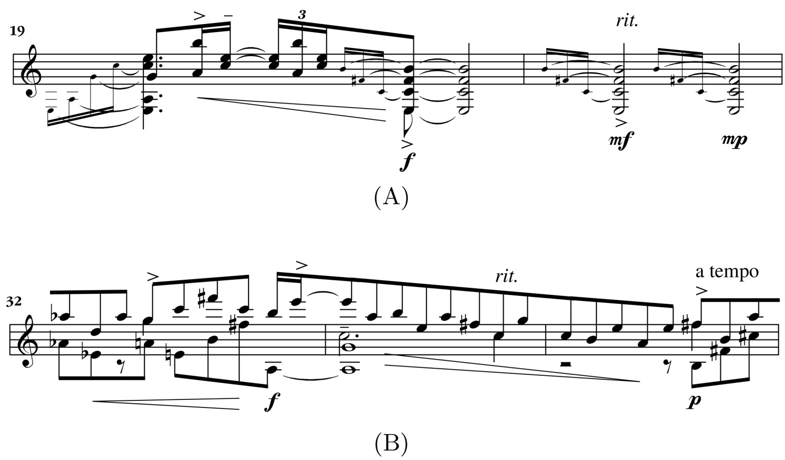

Fig. 6. Two passges that involve same decision, although their musical aspects are dissimilar

The computational cost of similarity detection among hypernetwork representations is nonpolynomial. However, we use a special purpose computer system, Starpack [9,10], customized to process hypernetwork representations. Starpack reduces the computational time to polynomial time by treating a set of decisions as a decision sequence.

3 Analysis and Discussions

We classify each decision element to the following five facets.

1. Decision type. Related to the process of decision making, and further classified to theoretical, selective and intuitive.
2. Concept. Composer's background idea, related to emotional aspect of decisions.
3. Structure. Related to music theory, which is explicit knowledge thinking.

Fig. 7. Simplified representation of a decision behind the measure 33

4. Aesthetic. Mainly involving listeners, related to listening impression of executed music.
5. Playing technique. MAinly related to instrument players.

Two musical piecess, denoted Music-B1 and Music-B2, were analyzed. Music-B1 is for two violins, viola and violoncello, and consists of 39 measures. Music-B2, for clarinet Bb and fagotte, consists of 120 measures. composition of Music-B1 involved 41 main decisions. on the other hand, Music-B2 involved 16 main decisions. A main decision denotes a single decision that the composer makes as a unit. After the analysis of description of composition process by the composer, a main decision is subdivided into smaller decisions. Typically a main decision consists of 2 to 5 decisions.

Each decision is classified into one of five facets, besides the classification into theoretical and intuitive. Theoretical decisions use explicit knowledge, and intuitive decisions belong to sensitivity and emotional thinking process. Then the integration of all decisions offers a global view of a creation process that is a combination of emotional and explicit knowledge thinking processes.

Fig.8 shows the number of decisions extracted from Music B-1 and Music B-2. The number of decisions belonging to each facet is approximately similar. No decisions belonging to playing technique were detected, as technique related contents were not directly mentioned. However, playing techniques are indicated in musical score using conventional notations. It is interesting that playing technique is not involved in decisions to create musical piece, although this might be a particular case of analyzed musical pieces. since playing technique is annotated by the composer in music score, playing technique is important element in composed musical piece. However, it is not a factor to consider during the music creation process.

Another fact from Fig.8 is the weight on each facet that the composer devotes his attention. In this context, basic concept and musical structure have similar importance, i.e., emotional and explicit knowledge (verbal) thinking has approximately equal ratio. Specifically, the average value of emotional thinking is 50%, and verbal thinking is 60%, which are values very close to our initial assumption described in Introduction. This is a quantitative data that supports our basic assumption, and that both type of thinking process is involved in creative process of musical pieces.

Our previous analysis targeted stepwise composition process, where the composer wrote musical piece by small number of measures [7]. On the other hand, the composition process analyzed in this paper present different creation process,

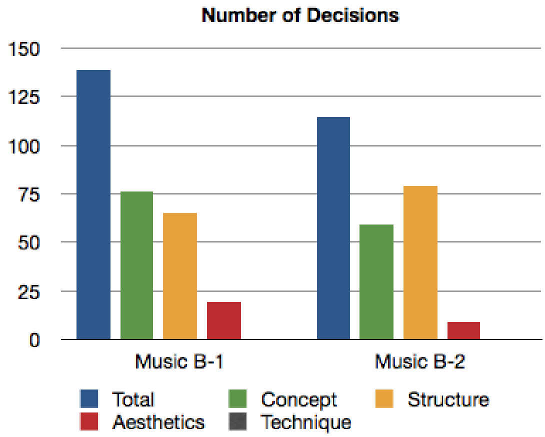

Fig. 8. Number of total decisions of Music B-1 and Music B-2. Number of decisions belonging to each of four facets except the decision type is also shown.

where the composer writes directly the best solution, with no significant modification of previously written parts. The composition involves very small after editing process, and passages written on the paper sheet is usually the definitive and final version with no further modifications. In this sense, it is more similar to the decision making process of experienced professional people [2].

Therefore, two types of decision making exist in musica composition process. The existence of a sequence of multiple decisions applied to the same passage is partially due to the lack of emergency in music composition task, which is fundamentally different from conditions encountered by firefighters, medical doctors and military commands. Such relaxation of constraints results in diversity of decision making process, and consequently of different creative process styles. Some composers do not postedit, while others executes a certain number of revisions.

This kind of information is missing in all available music sheets, but is of fundamental importance for instrument players. An interview survey to professional musical instrument players indicate that historic of every note and passage of musical piece is useful and helpful to understand the musical piece and generate images of musical piece to decide techniques and sonority to use when playing. In this context, an objective of the proposed description model is to provide representation of musical piece that musical instrument players are easy to understand. The five facets proposed in this paper are representations of a single set of facts and concepts. These facets are dependent to each other, and some elements of a facet are shared by other facet(s).

The proposed representation model is an attempt to represent two types of thinking, emotional and explicit knowledge, in order to analyze and understand the creative process. This paper focused on music composition process. The description was generated from a single person's creative process, but the explicit knowledge element can be implemented on computer systems, whose forte is a huge amount of storage. In the current stage, the interaction part should belong to human being. With this implementation, the proposed representation model can also be interpreted as the description of human computer interaction during creative processes.

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