A System Description Model Without Hierarchical Structure

Tetsuya Maeshiro[1,2(✉)] and Midori Maeshiro[3]

[1] Faculty of Library, Information and Media Studies, University of Tsukuba, Tsukuba 305-8550, Japan
maeshiro@slis.tsukuba.ac.jp
[2] Research Center for Knowledge Communities, University of Tsukuba, Tsukuba 305-8550, Japan
[3] School of Music, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

Abstract. In order to simulate and analyze the properties of a phenomena from systems point of view, a proper description is necessary, otherwise these objectives cannot be accomplished. We are currently describing two superficially distinctive phenomena, the feeding process of living organisms and music composition process by composers, but they share some fundamental properties from the system description point of view. Here we discuss these common characteristics and the requirements for the system description model.

1 Introduction

This paper focuses on the description of two different phenomena to elucidate properties that system description model should possess. Descriptions of two phenomena serve to analyze their properties and elucidate the functional relationships among elements. The basic assumption, fundamentally different from conventional system description and theories related to emergence, is the absence of hierarchical relationships among phenomena resulting from elements of different hierarchical levels.

For instance, a bee colony is as set of many bees with diverse roles inside the colony, such as queen and workers. The bee colony as a whole can be treated as a single honey collecting machine, where the number of outgoing worker bees that collect honey and of internal worker bees that receive collected honey are under decentralized control [1]. Bees are elements constituting the bee colony, and the bee colony and bees are in hierarchical relationships (Fig. 1(A)). Conventional studies assume that the phenomena of an entity and its elements also consitute the hierarchical relationship, which corresponds to the mechanism to control the number of collecting and receiving bees, and the behavior of individual bees (Fig. 1(B-1) and (B-2)).

We agree on the existence of hierarchical relationship among structural elements, such as individual bees and the bee colony. However, no hierarchical relationship exists among phenomena (Fig. 1(B-1) and (B-2)), differing from

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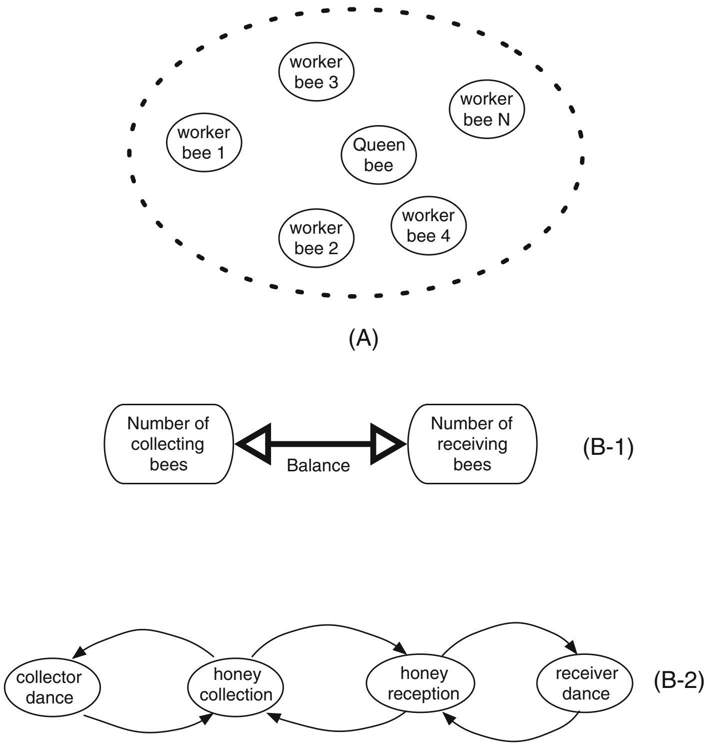


Fig. 1. (A) Bee colony and individual bees. (B-1) Balancing the number of honey collecting bees and honey receiving bees. (B-2) Honey collection and reception.

conventional studies. We assume that the phenomena (B-1) and (B-2) are two different viewpoints to describe the bee colony. The mechanism to control the number of collecting and receiving bees is generated by the interactions among bees and their behaviors, but the number controlling phenomena is independent from the description of individual bees' behaviors.

2 Music Composition Process

We are analysing the music composition process of professional composers, treating the composition process as a sequence of decision makings. We 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. 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, reasoning based on explicit knowledge is also necessary. 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. Our studies suggest that the sole use of either sensitivity or explicit knowledge does not enable the generation of new ideas, but simultaneous employment of both abilities are essential [2]. Conventional research on knowledge representation focused on the explicit knowledge. Our attempt is to unify the two kinds of thinking process.

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 including Harmony, acoustics of musical instruments, and genre-dependent articulations of each musical instrument. 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.

Music composition process presents following properties: (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 paintings, 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.

In the present work, a musical piece is represented by relationships among decisions. Such a creation history is more valuable than static structures generated by conventional methods. 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 musical instrument players, the acquisition of background and underlying phylosophy is invaluable, because deeper understanding of musical piece is fundamental and crucial for good execution. This kind of information is missing in all available music sheets, but is of fundamental importance for instrument players.

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.

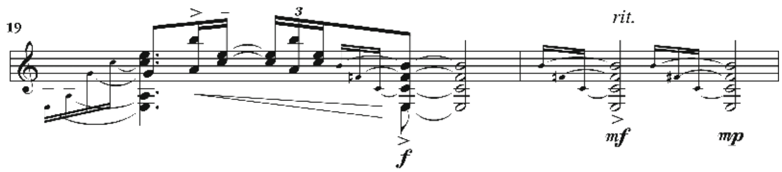
3. Structure. Related to music theory, which is explicit knowledge thinking.
4. Aesthetic. Mainly involving listeners, related to listening impression of executed music.
5. Playing technique. Mainly related to instrument players.

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. 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. 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). No facet is in hierarchical relationship with other facets, and no facet is totally independent from other facets.

Our analysis indicate that the number of decisions belonging to each facet is approximately similar. No decisions belonging to playing technique were detected, as contents related to techniques 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.

The frequency distribution of decision types indicates that all five facets are necessary to describe a musical piece. It also indicates that the composer devotes his attention to basic concept and musical structure with similar importance, i.e., emotional and explicit knowledge (verbal) thinking has approximately equal ratio. Specifically, the average value of emotional thinking is 40 %, and verbal thinking is 60 %. Therefore, two types of decision making exist in music composition processes, and the representation of both types of thinking process is necessary. 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.

It would be useful if the detection of similar passages, that is unable to be detected by other representation models, is possible. Conventional description models allow detection of only one type of similarity, which is insufficient for actual use, because they capture just a fraction of existing types. The connection of elements based on similarity among decisions elucidates implicit relationships among musical elements, difficult and time consuming to be clarified by



(A)

(B)

Fig. 2. Two passages created from same decision, although their musical aspects are dissimilar.

conventional music analysis methods. Figure 2 shows two passages from the same musical piece that were generated by identical decision. The decision making by the composer was to introduce release of tension to the movement that the target passage connects, which are measures until 19 and measures after 21 in Fig. 2-(A), and measures until 32 and after 34 in Fig. 2-(B).

Once the generated micro-decisions are connected by various relationships, a connected network of decisions of a musical piece is obtained. The plain network containing all extracted relationships is not primarily used to visualize and understand the structure of the described musical piece. Instead, the user chooses a viewpoint to filter unwanted relationships. The hierarchical structure is treated as one viewpoint. An important relationship in decision representation network is the causal relationship among micro-decisions, because causal relationships elucidate the sequence of decisions enables the analysis of indirect causes and results. By detecting indirect causes, which are obtained by following the decision sequence paths for more than one step, it is possible to clarify common ancestor decisions of diverse level of commoness. Identical operation applies to the detection of indirect results. Since the causal relationships among micro-decisions are independent of temporal sequence of decisions, which is linear, the structure is not a tree, and present ramifications and convergences. There are convergences in decisions, meaning that a decision has multiple decisions as causes. This structure can only be detected using the proposed method.

3 Feeding Process

Similar to the description of music composition described in previous section, we are currently describing the feeding process of human beings. The feeding process refers to all functions, processes and control mechanisms regarding intake

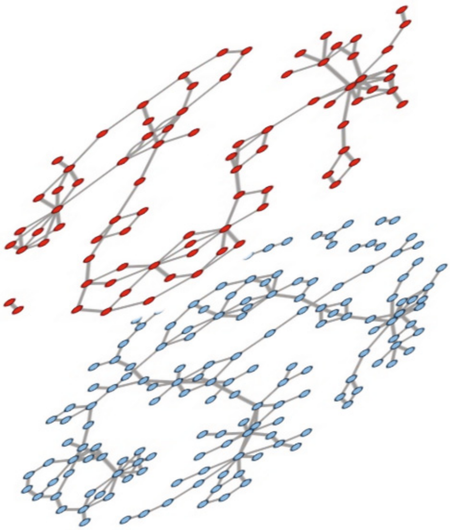


Fig. 3. The network with blue nodes (lower network) represents the genomics layer, and the network with red nodes (upper network) represents metabolomics layer. (Color figure online)

of food, energy absorption and feeding behavior [9–15]. The feeding process influences a wide range of other phenomena, mainly those related with energy. One of most important may be lifestyle diseases represented by diabetes meritus, in a sense that a huge number of people is affected. Other diseases are also related, for instance hyperorexia and anorexia, which are directly related with the control mechanism of feeding. Energy consumption is a fundamental function of organism behavior, thus the fact description of feeding behavior treats one of fundamental aspects of life.

We are compiling data from available papers and open databases, and generated integrated description of genes, RNA, proteins and metabolites. Genes, RNA and proteins were connected using primarily the central dogma. On the other hand, metabolites were integrated primarily to enzymes based on metabolic reactions. Since enzymes are proteins, metabolites are also integrated into the represented model. Figure 3 is a part of the generated network, visualizing the gene and metabolite networks. Figure 3 is the visualization example based on experiment, because genomics data and metabolomics data are the result of independent experiments. These networks can also be visualized as a single network.

Humans possess feeding mechanism partially similar to mouse and monkeys, whose mechanism is closely related to the instinct, so it is an automatic system. Figure 4 is the mechanism to generate appetite, involving three brain regions, which are hypothalamus, ventral tegmental area and nucleus

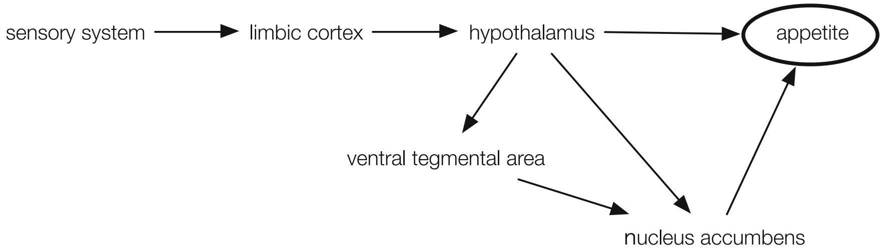


Fig. 4. General mechanism involving brain function area that generate appetite

accumbens. It seems that hypothalamus and nucleus accumbens directly generate the sense of appetite. The control flow to generate appetite by these mechanisms are straightforward because no considerable conflict exists. Humans, however, present a more complex mechanism, but details is still unknown. Anorexia nervosa, bulimia nervosa and the propagation of obesity [4] are three examples of complexity, which are phenomena unique to Humans. The first two are diseases, and the last one is an observed fact. But all three deregulate the basic feeding mechanism (Fig. 4) that is incorporated to the organism, the molecular mechanism that is shared with other mammals.

Transomics has objective similar to our research. There is, however, a fundamental difference, which is the data integration standpoint and basic concepts of the representation model. Transomics is biological experimental data driven. Currently, any high throughput data can measure only one kind of substance class, such as genes, RNA sequence, proteins and metabolites. Data generated from each substance class are treated as a single layer in the integrated representation. Then relationships among same substance class are inferred using some kind of algorithm, and a network of a given substance class is generated, which results in a network representation of one layer. The layer is sometimes referred as a hierarchical level. The use of the term "hierarchy" is misleading because there is no hierarchical relationship among substance classes in strict sense, neither structural nor functional. A layer in Transomics corresponds to a viewpoint in the proposed model. The problem of conventionally used methods in Transomics is that the concept of a layer is directly related to the kind of data that each high throughput experiment can generate, and not to the adequacy to describe biological phenomena. For instance, the description of a very simple gene regulation involves the gene encoding the transcription factor, mRNA transcripted from the gene, the protein synthesezed based on the mRNA sequence, the docking region in the granscription target gene, mRNA transcripted from the target gene, and the target protein. Ribosome and other substances involved in transcription and translation might be also included, but they are omitted for simplicity of explanation.

The feeding process at the molecular level can be viewed as a collection of reactions that correspond to causal relationships. Then feeding process can be described using description model analogous to that used to describe music composition process, described in previous section. Although the same should apply to the mechanism involving the brain, much more experimental data are still necessary. Although the mechanism is still unknown, it seems that brain functions of higher order than those functions directly involved in feeding mechanism of molecular level, mainly activated in hypothalamus. Therefore, it is possible that higher order brain function, present only in Human and denoted here as the "new" brain, overrides and modifies the control signals from hypothalamus and nucleus accumbens, present in other animals and denoted here as the "old" brain, to change the feeding behavior.

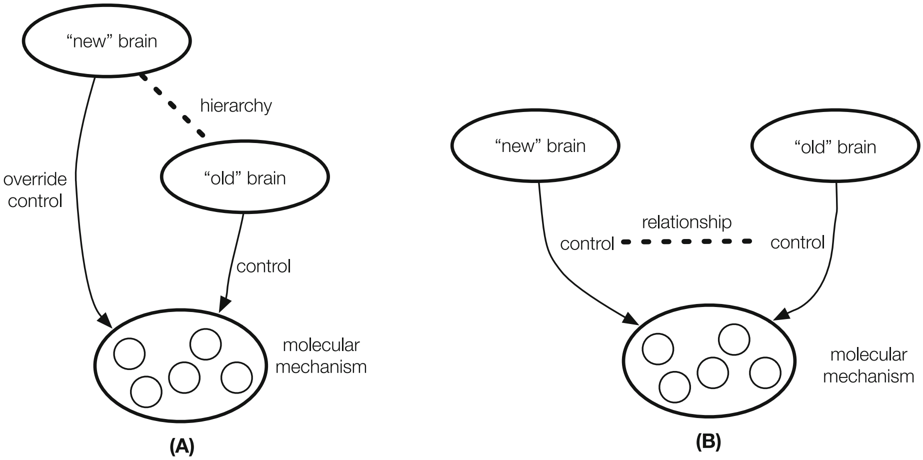


Fig. 5. (A) Conventional (hierarchical) viewpoint and (B) the viewpoint based on the proposed model

Figure 5 illustrates the difference of the viewpoint and representation of the control of feeding mechanism involving control by the two brains, the "new" and the "old" brains. The hierarchical relationship is absent among phenomena. Conventionally, the "new" brain is positioned in the higher level of the "old" brain (Fig. 5(A)), because the model supposes that the basic molecular level control is overridden by the "new" brain. Then the "new" brain is considered to be on the higher hierarchical level than the "old" brain. More precisely, not the two brains, but the involved control mechanism that are in hierarchical relationship, since the "new" brain's control overrides the "old" brain's control mechanism. In the proposed model, both "new" and "old" brains belong to the same level, the level of organs. The relationship between these two brains are basically of functional difference.

4 Common Properties of Analyzed Phenomena

An important aspect of both phenomena treated in this paper is the multi-viewpointness. No single viewpoint of description is sufficient to describe the phenomena, and in extreme cases, one viewpoint is required for each purpose, such as analysis and simulation, including different parameter settings. At least in the two phenomena treated in this paper, multiple hierarchical structures exist and should be described to understand these phenomena.

The hierarchy in system is a remarkable relationship among available viewpoints, and because the concept of hierarchy is natural and obvious, the hierarchy is often not considered as viewpoint, but is treated as an inherent property of system. However, in raw state of description using the proposed model, no hierarchy is present in the system. Because fundamental concepts of system such as emergence assume the existence of the hierarchical structure, where a set of interacting elements generates a phenomenon in higher hierarchical level, the hierarchy seems to be the necessity to a system. However, we treat the hierarchy as one of available viewpoints. Furthermore, multiple hierarchies can be defined, and the elements belonging to the same hierarchical level in a given viewpoint of hierarchy may belong to different hierarchical levels in another viewpoint of hierarchy. Conventional system theory allows only one definition of hierarchy, which strongly limits the phenomena that can be represented.

Another aspect of these phenomena are the dynamism of viewpoints. The most straightforward kind of dynamism is temporal. The dynamism of the system behavior is treated in conventional system theory, but not the dynamism of the viewpoint. As the relationships and interactions among elements constituting a system change, appropriate viewpoint to understand and analyze the target phenomena changes accordingly. Even if the hierarchical structure is maintained, the details of the hierarchical relationships change, including additions and deletions of a hierarchical level and move of elements to a different hierarchical level. Furthermore, emergences and disappearances of interactions among elements of a system change the hierarchical structure.

In the descriptions of both the music composition process and feeding process, causal relationship is the intuitive relationship that is useful in these representations. Each causal relationship description has multiple pre-status or precondition or facts and multiple post-status or postcondition are connected by a relationship that specifies the process, which corresponds to a causal relationship. Thus a process is an N-ary relationship, impossible to be accurately represented by conventional representation models. A process modifies the pre-status to generate the post-status. Generally, the pre-status is varied because it depends on the type of relationship. External facts may also compose the pre-status set. Detecting similar causal relationships is useful to analyze the mechanisms of the feeding process and music composition process, and valuable information is obtained for the understanding and further research of the process. Furthermore, similarity among causal relationship sequences is more important than comparison of single causal relationship.

Currently, the proposed model uses known concepts and semantic relationships among concepts to describe the target phenomena [16,17]. Semantic relationships are specified using other concepts. The describability and understanding of the target phenomena are unrelated. Even if mathematical formula and computer program are able to reconstruct the target phenomena, it does not imply the target phenomena is understood, particularly when so called emergence is involved, where phenomena of different hierarchical levels are involved. This is because no description is provided for phenomena of the emerged hierarchical level, which is usually of upper hierarchical level than the level of described elements.

The proposed model provides direct description of each hierarchical level, treating each level as an independent viewpoint that represents a phenomenon or a process. Therefore, a description is also provided for the "emerged" phenomena, and concepts belonging to the lower hierarchical level may or may not be used in the description. Consequently, only a vague explanation is provided if the phenomena is poorly understood. However, there is a concrete link between the emerged phenomena and the elements that generate the phenomena by interactions. These properties of the proposed model results in the absence of hierarchy in the description. No phenomena belongs to the lower or higher hierarchical level, and descriptions of each phenomenon are interrelated based on the intersections of concepts used in each representation.

Conventional representations provide only the hierarchical relationship among phenomena. In the context of the proposed model, hierarchy is only one facet of the relationship among phenomena. On the other hand, our model enables the definition of varied types of relationships among phenomena, including the hierarchical relationship, which is a clear but simple type of relationship. The hierarchical viewpoint is not emphasized as in conventional models, enabling employment of diverse viewpoints that enables elucidation of new viewpoints to treat the phenomena. Therefore, the proposed model allows description of multiple relationships among different processes. Moreover, the details of a relationship can be further described, because the proposed model allows specification of the relationship entity.

The advantage of the proposed model is the ability to create any viewpoint for representation, analysis and visualization, due to the use of model extended from hypergraph, which presents more representation capability than the conventionally used models that are based on graph model. The hypernetwork model allows creation of links among multiple links, which is impossible with conventional models. Furthermore, the hypernetwork model allows addition of further links from the newly generated link, enabling more freedom in representation than conventional models.

With the representation based on the proposed model, the hypernetwork model, detection of similar subnetworks (cluster of nodes) with varied degree of granularity of description levels is possible. In the case of the music composition process, detection of similar subnetworks (node groups) corresponds to the detection of similar decisions. Granularity of represented decision corresponds to the granularity of concepts and connected concepts to the subnetwork. Similarly, in the case of feeding process, detection of similar subnetworks corresponds to the extraction of similar biochemical processes.

Furthermore, a causal relationship may consist of multiple causal relationships, functioning as elements of a larger causal relationship. Then it is possible to extract similar sequence of causal relationships. The sequence is particularly important in both music composition and feeding processes, because it represents the development of creative process in music composition and sequence of biochemical reactions in feeding process. The similarity among sequences of causal relationships is more valuable than the comparison of single causal relationships. Moreover, the sequences are nonlinear, with ramifications and convergences, and parallel sequences also exist.

The description of the feeding process provides an even more valuable functionality, which is the elucidation of missing relationships, such as biochemical reactions and interactions among elements that constitute the entire feeding process. Prediction of missing links in currently available facts is important to support the design of new biological experiments to fill the unknown facts. This approach is contrary to the traditional approach that is hypotheses-driven. We aim to realize the data-driven research, enabling the detection of missing part in gathered and integrated data. We are currently developing an algorithm to detect the "missing links" in the integrated data representation.

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