Constructing a Validity Investigation System for Answers to Given Exercises in the Theory of Harmony

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Abstract

The theory of harmony is the basic subject in music education for western traditional music established in 17-18 centuries. The theory is a system of "inhibition rules" that collectively characterize European classical music. Students majoring in music are required to memorize the rules and then to solve given exercises concerning the rules so as to completely master the rules. Students, however, usually feel difficulties in judging correctness of their answers to the exercises, so they are forced to ask teacher's judgments. Proposed here is a system, named "VISAGE (Validity Investigation System for Answers to Given Exercises for the theory of harmony)", that can judge validity of students' answers and point out their errors if any. It is expected that VISAGE would help students understand the theory of harmony by providing comments on their answers to given exercises.

1. Introduction

To learn the theory of harmony by oneself is said to be difficult, because students cannot judge the correctness and/or appropriateness of their answers by themselves to given exercises. So, students are forced to rely on teacher's judgment. Proposed here is a "VISAGE", that can check correctness of a student's answer and point out errors if any. Using VISAGE, students can judge correctness of their answers by themselves, not relying on teacher's judgment. Self-learning of the theory of harmony will be realized using VISAGE. Outline and facilities of VISAGE are described, introducing a new scheme of a rule-base system "Rule Unit Model"[1].

2. Current State for Learning the Theory of Harmony

At the first stage of learning the theory of harmony, students are required to memorize and/or understand the inhibition rules in the theory of harmony. Though inhibition rules verbally means rules inhibiting something, there are some inhibition rules that recommend something. In this paper, we would like to interpret the inhibition rules include recommendation rules. Inhibition rules had been systematized collectively many rules realizing aesthetic features in the western classical music in 17-18 centuries. It can be said that acquiring the inhibition rules means assorting them to aesthetic features of western classical music. To learn and get knowledge of the inhibition rules is said to be difficult, because inhibition rules have mutual dependencies among them and priority weights among inhibition rules are not clear.

To certify the theory of harmony, students are required to solve several given bass and/or soprano tasks. In the beginning stage of training, any answers not violating the inhibition rules are regarded to be correct or allowable, without respect to beauty and/or aesthetic features, but depending only rules. It means that in the beginning stage of learning the theory of harmony students should concentrate themselves on memorizing and/or understanding the inhibition rules. In the next step, students are required to generate beautiful and/or aesthetic answers at solving given tasks. What students are required is to express their aesthetic sense if they can. If students cannot do that or have nothing to express, they have to accept teacher's sense of aesthetics. This step is very important for students majoring in music composition in particular, for practice in composing excerpts, even if they compose atonal music.

In the current state of the music education in the theory of harmony, most students cannot go to the step of generating aesthetic answers to given exercises if they do not have ability to yield answers. Though to generate beautiful and/or aesthetic answers is different thing from to memorize and/or master the inhibition rules, it is necessary to master the rules. It takes too much time and efforts to memorize and/or master the rules, because of mutual dependencies among rules and difficulties in self-checking validity of their answers. To improve current state of learning the inhibition rules, following points are desirable;

- Mutual dependencies among rules should be clear and students can confirm detail of each inhibition rule that students want to know.
- Students can check validity of their answers without relying on teachers.

3. A Validity Investigation System "VISAGE" for Answers to Given Exercises in the Theory of Harmony

3.1. Summary

To improve current state in learning the theory of harmony, developed here is a VISAGE, that can judge validity for answers to given exercises in the theory of harmony. Inhibition rules contained in the standard textbook[2] in Japan are implemented as a rule base system. VISAGE can deal with triads, 7th and 9th chords.

3.2. Difficulties in Implementing Inhibition Rules

It is difficult to add and/or modify inhibition rules if inhibition rules are implemented in algorithmic form. A Rule-base system "Rule Unit Model" is employed here.

3.3. Rule Unit Model[1]

3.3.1. Outline of Rule Unit Model

A "Rule Unit Model" is a network model consisting of rule units having common structure independent of rule types and links connecting them.

Either a rule or an inhibition rule is commonly expressed as a rule unit consisting of a control part and a rule description part as depicted in Fig. 1. Each rule unit has connection channels to other rule units. As shown in Fig.1, a rule unit has two input channels (I and Inv) and five output channels (I', I'', I''', Kil and J). Structured data are transmitted through connection channels I, I', I''' or I''', where "I" signifies information. "Kil" denotes an invalidation cue to invalidate or kill other units. "J" means a resultant judge or the output of the rule unit. "H" denotes temporary halt of the rule unit.

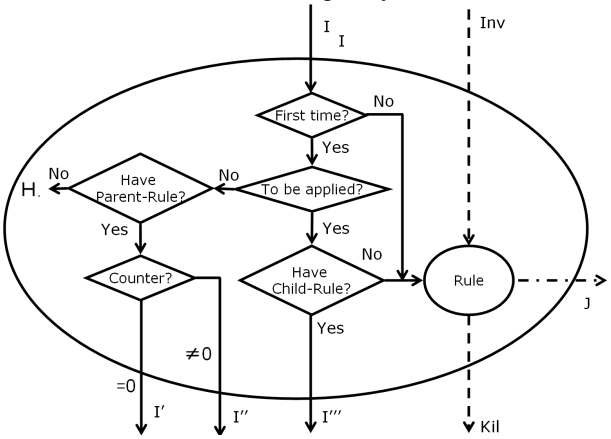

Figure 1: Details of a Rule Unit.

3.3.2. "Parent-Chile" Representation and "Killer-Invalidation" Relationship

There are two kinds in connections between two rule units; inclusion and invalidation. An example of the "inclusion" relation is depicted in Fig.2(a), where "Rp" denotes a parent unit (or a parent rule) and "Rc_1" through "Rc_m" are its child units (or child rules). For example, Rp is a rule concerning chord progression V-VI and Rc_1 is a rule for V-VI-II, Rc_2, for V-VI-IV, where Rc_1 and Rc_2 are detailed rules under Rp, which should not be adopted if either Rc_1 or Rc_2 is adopted. A parent rule is linked to a child rule via channel I''', child rules are linked to their parent rule via channel I, and their channels I' and I'' are connected to other child rules of the same parent rule.

"Invalidation" means that adoption of a rule kills other rule(s). We call a rule that invalidates other rule(s) a "Killer rule" as R_k, depicted in Fig.2(b), which kills R_i. The invalidation relation is represented by a dotted line. An example of a killer rule is one concerning chord progression V-VI that invalidates a rule concerning progression between root positions of any chord progression having no common notes. In case R_k is adopted, R_i becomes not necessarily observed, i.e. R_i should be invalidated.

When a set of data enters a rule unit for the first time, the rule unit checks if the rule is to be adopted to the input data on the "Evaluate?" step. In case the rule unit evaluates that it has to apply the rule to the input, the rule unit investigates whether the rule has any child rules or not on the "Have Child Rule?" step. In case the rule has no child rule, the rule is immediately applied to the data in the "Rule" step and outputs result via channel J represented by a broken line shown in Fig.1. In case the rule has some child rule(s), the unit stores the number of the child rules in a counter in the structured data and the data are sent to the top rule unit Rc_1 of the child rule group via channel I''' of the parent rule unit linked to channel I of Rc_1's. Rc1 investigates if it is the first time for the unit to receive the data. In case it is, the unit investigates if the data satisfy the conditions of Rc_1, and the main rule of Rc1 is applied to the data ignoring the parent rule Rp and all the rest of child rules Rc_2 through Rc_m.

As Rc_1 is a child rule of Rp, the counter is reduced by unity to memorize the number of unfinished child units. Then, the system checks the counter. In case the counter shows zero, it means that the rule unit just processed is the last child unit under a parent unit concerned, and the data are sent back to the parent unit via channel I'. In case the counter shows a non-zero value, the data are sent to the succeeding child unit until no child unit is left. In case no child unit matches the data, the counter value is reduced to be zero and the data are sent back to the parent unit. In this case the data enter the parent unit for the second time checked in the

"First time?" step, then the rule Rp is immediately applied to the data on the "Rule step and yields its result via channel J. On each "Rule" step in a rule unit, in case the rule unit is a killer rule, the rule unit sends an invalidation sign to the rule to be invalidated via channel Kil.

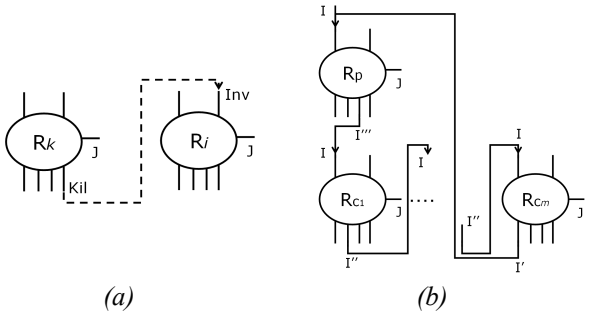

Figure 2: Dependency structures among rules. (a): root-rule or parent rule Rp and its descendant-rules or child rules Rc_1-Rc_m. (b): a killer rule R_k and rule R_i invalidated by R_k.

3.4. Outline of VISAGE

77 rules are implemented to VISAGE using rule unit model. Examples of inhibition rules are denoted in Table 1. Facilities of VISAGE are as follows;

- Accept user's input for exercise files,
- Accept user's input for four parts using MIDI-keyboard,
- Accept user's input of attributes on chord, such as degree, inversion type, 7th/9th chord, and omit/non-omit root note,
- Check validity of input answer and point out if any, indicating rule ID,
- Show details of each inhibition rules.

A display example of VISAGE is shown in Fig. 3.

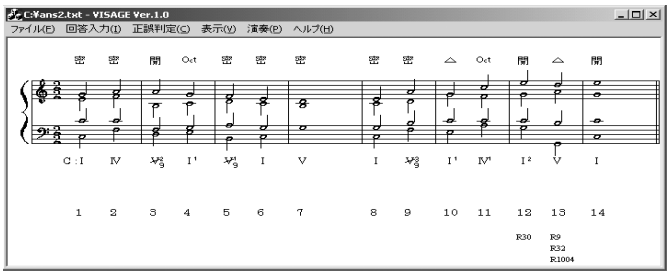

Figure 3: A display example of VISAGE (Japanese version).

3.5. Usability of VISAGE

Usability of VISAGE is evaluated using five students who have experiences in learning the theory of harmony as subjects. Firstly, subjects are asked to solve four given bass tasks (A, B, C, and D). Number of bass sequence on task A, B, C, and D is 14, 14, 27, and 28, respectively. Then, students are asked to input their answers into VISAGE using MIDI-keyboard and PC-keyboard. Required time for inputting each answer is measured. Subjects are divided into two groups, according to experiences of keyboard instruments, more or less than five years. Before inputting their answers to VISAGE, they were allowed to practice in using VISAGE within thirty minutes.

Experimental results are shown in Fig.4. Ordinate represents averages of required time for inputting student's answer and abscissa represents given bass tasks. Students are informed of the validation result, whether their answers are correct or not, within one second. As you can see, a couple of minutes are necessary to input an answer.

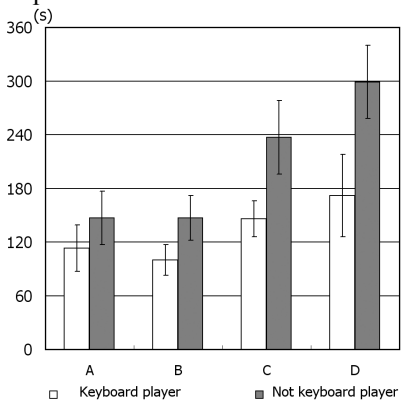

Figure 4: Average of required time for inputting student's answer.

4. Conclusions

Presented here is a system that can check validity of students' answers, so that teachers can take a load off from checking vast number of students' answers. VISAGE will be helpful not only for students learning the theory of harmony, but also for teachers. Improvements of user interface and usability of VISAGE will be discussed in the near future.

5. References

[1] Miura, M., Shimoishizaka T., Saiki, Y., and Yanagida, M.,: A study for reconstructing Basse Donnée system using a rule unit model, Acoustical Science and Technology, Vol.~22, No.~4, pp.299-301 (2001)

[2] T. Ikenouchi et al, *Harmony Theory-theory and practice*- (Ongaku no tomosha, 1964, in Japanese).

Table 1: Examples of inhibition rules implemented on VISAGE.

ID	Description
3	distance between each voice
6	Inhibit parallel 5th
7	Inhibit continuous 5th and 8th
9	General rule for distribution type of triads
10	General rule for X-X connection having common notes
11	General rule for X-X connection having no common note
12	Rule for II→V
13	Rule for II→V^1
14	Rule for V→VI
15	Rule for IV→II where the hightest note of IV is the 3rd note and that of II is the root note
16	Rule for V→VI→V
17	Rule for V→VI→II
18	Chord Progression
19	Allocation rule for X^1
20	General rule for X→X^1 and/or X^1→X connection having common notes
21	General rule for X→X^1 and/or X^1→X connection having no common notes
23	Rule for II^1→V^0
24	Rule for II^1→V^1
24	Rule for X→II^1
26	Rule for X→II^1 where distribution type of II is "close" and the highest note is the root note
27	Rule for V→I^1 where distribution type of V is "close" and the highest note is the root note
30	General rule for X^0→X^2 and/or X^2→X^0 connection
32	Maintain chord-distribution type on connecting root-position chords
34	Rule for II/II^1→I^2→V
35	Rule for II/II^1(whose inversion type is root and distribution type is Octave)→I^2→V
36	Rule for IV/IV^1→I^2→V
37	Exception rule for inter-voice distance between Bas. and Ten.
39	Rule for chord notes of V_7
41	Rule for V_7→I/I^1
42	Maintain common notes on common voices for V_7→I
43	Rule for $V^3{}_7$→I^1
46	Rule for II/IV→V_7
49	Rule for V_7→VI
50	Rule for X→V_7
55	Note progression of the 5th note on V_7(second inversion without root note)→I
57	General rule for distribution type on V_7 (second inversion without root note, and distribution type is (b))
59	General rule for X→V_7(second inversion without root note)
65	General rule of X←→V_9 connection
71	General rule on a Dominat chord having 4-degree distance between Bas. and root note
72	General rule for V_9(without root note) on Dur scale
73	General rule for V_9(without root note)* on Dur scale
1001-1004	Fundamental rules not written in the textbook[2]

*X : any chord degree. X^n : n-th inversion of chord X. *: distribution type is open and highest note is 9th, distribution type is close and highest note is 9th, or distribution type is open and highest note is 7th.*