An Attempt at Machine Composition by Machine Experience

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In the present attempt, we make a computing machine compose music through its experience of listening to music, without teaching it any "grammar" of music composition. The situations seem to be analogous to those when a child begins to speak his language through his experience without knowing any grammar.

The attempt consists of three stages: stage of listening, stage of composition and stage of learning. Some of the composed music sheets are shown.

1. *The First Stage (Stage of Listening)*

Through this stage, the computer listens to music and accumulates its experience under the procedure described below.

Setting criteria for classification into patterns

In listening to music man can make a distinction among many patterns of music from various points of view even if he has never heard it before: for example, a distinction between a jazz and a chanson, a children's song and a lied, a major scale melody and a minor scale one, or a music of Beethoven and of Chaikovskii. In most cases, such distinction comes from certain criteria which have been constructed unconsciously by catching characteristics of the patterns through a large stook of experience to hear music in his life.

The criteria in this sense are set by the computer. At first we prepare many music sheets in the form of imput data according to the notations shown in Fig. 1 and Table 1. The prepared music sheets are classified into several patterns among which we intend to make the computer distinguish in the present attempt.

In listening to the music, the computer calculates the maximum and minimum values, the mean and the standard deviation of quantities X_A, X_B, $\cdots$, X_I of the following *classifying items* for every pattern.

A. Ratio of appearance of every letter name.

B. Ratio of appearance of any combination of two or three letter

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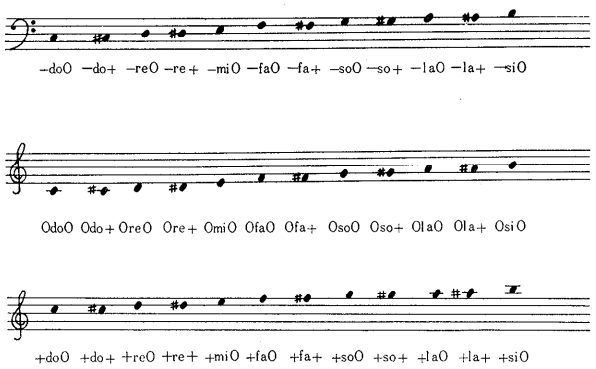


Fig. 1

Table 1

a whole note	01	a double dotted quaver	28
a minum	02	a semiquaver	06
a dotted minum	12	a dotted semiquaver	16
a double dotted minum	22	a demisemiquaver	03
a cretchet	04	a whole rest	10
a dotted cretchet	14	a half rest	20
a double dotted cretchet	24	a quarter rest	40
a quaver	08	an eighth rest	80
a dotted quaver	18	a sixteenth rest	60

names in sequence.

C. Number of any identical letter names that appear in sequence.

D. Number of letter names for which the melody goes monotonously up or down.

E. Length of one measure in the unit of quaver.*

F. Number of measures in one music sheet.

G. Number of passages in one music sheet.*

* The computer is artificially informed with the end points of measure, passage and music, respectively. Here passage means the part of a music that can not be divided any more from melodic point of view. For example, see Fig. 2.

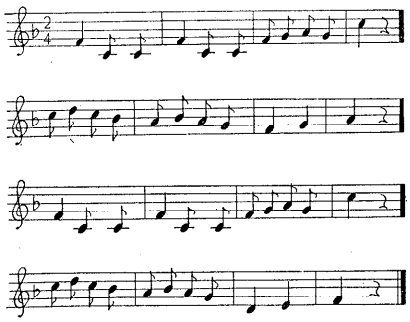


Fig. 2. Illustration of passage. Each line corresponds to one passage.

H. Ratio of appearance of every note or rest.
I. Ratio of appearance of any combination of chords.

Let, e.g., $M_{\alpha A}$, $M_{\beta A}$ and $S_{\alpha A}$, $S_{\beta A}$ be the means and the standard deviations of X_A with respect to the item A for two patterns α and β respectively. Then the computer regards the item A as a good criterion to distinguish between α and β only if the following condition is satisfied:

$$|M_{\alpha A}-M_{\beta A}|>\mathrm{Max}\,(S_{\alpha A}, S_{\beta A}),$$

where $\mathrm{Max}\,(p, q)$ means the larger of p and q. In this way, the computer sets some of the classifying items $A, B, \cdots, I$ as the good criteria for classifying music into patterns.

Accumulation of Experience

Making use of the good criteria the computer classifies into patterns any music it has newly listened to. At the same time it remembers some characteristic features of the patterns in the following way.

Every time the computer listens to a new music it calculates the quantities $X_A, X_B, \cdots, X_I$ of the music with respect to the classifying items $A, B, \cdots, I$ and defines $B_{\alpha A}$ etc. in the following manner:

$$B_{\alpha A}=\begin{cases}1 & \text{if} \quad |X_A-M_{\alpha A}|\leqq S_{\alpha A},\\ 0 & \text{if} \quad |X_A-M_{\alpha A}|>S_{\alpha A}.\end{cases}$$

Then it calculates the following sums T_α:

$$T_\alpha=\sum_{j=A}^{I} B_{\alpha j} \ (\alpha \text{ varies over all patterns}),$$

and decides that the new music belongs to the pattern for which the value of T_α is the largest of all patterns.

In listening to music the computer arranges all its experience with respect to the following seven *remembering items.*

1) Number of music belonging to each pattern that the computer has listened to.
2) Combination of letter names of the first and the last note of a music.
3) Combination of any two letter names in sequence.
4) Number of measures constructing one passage.
5) i) Rythm of the first measure of a passage.
   ii) Rythm of the last measure of a passage.
   iii) Rythm of each measure of the remainder of a passage.
6) Variation of melody. The computer produces a series of melody numbers which is connected with the variation of melody in the following way. The first passage of a music is assigned the melody number 1. For any other, if a passage of the same melody has already appeared in

the music, the melody number to be assigned to the new passage is the same as that assigned to the former passage, and if not, the melody number larger by one than the largest that has already been assigned is assigned to the passage with the new melody. The numbers thus obtained make a series corresponding to the series of the passages.

7) Variation of rythm. The computer uses the same procedure as in the item 6, and produces a series of rythm numbers.

For each of the remembering items, a certain artificially limited amount of memories is allotted. The addresses of the memories are numbered in a series. It is to be noted that the features of composed music more or less depend on the amount of the memories, as will become clear.

On receiving new information, say Z, to be remembered, the computer first examines whether the same information has already been stored or not. In the case when the information is absent, the information Z is stored in the first memory that has the smallest address number and is accompanied with the frequency 1. At the same time each information other than Z that has already been stored is shifted to the neighbouring memory step by step. On the contrary, when the information Z is already present somewhere, the information Z is restored only in the first memory with the smallest address number and is accompanied with a new frequency larger by one than the old one. The other informations that have been stord in the memories from the first to the place before the old information Z are shifted step by step.

Because of the limited amount of the memories, it sometimes happens that the information stored in the last memory with the largest address number, which is relatively rare information, is shifted and consequently dropped.

2. *The Second Stage (Stage of Composition)*

In this stage, we make the computer compose music on the basis of its listening experience described above. The basic rule that the computer obeys is that *it generates a random number in proportion to the frequency of each of the remembering items and, by identifying the random number with the address of the memory, the computer decides what information it will adopt.* Therefore, for example, the so-called transition probability between two letter names in sequence of the melody that the computer will compose is the same as what the computer has listened to.

Detailed application of this rule is described below.

i) To decide the pattern of music to be composed by applying the rule to the frequency distribution of the remembering item 1.

ii) To decide the variation of rythm of series of passages by applying the rule to the frequency distribution of the series of rythm numbers

of the item 7.

iii) To decide the number of measures by applying the rule to the frequency distribution of the remembering item 4.

iv) To compose the rythm of music by repeatedly applying the rule to the frequency distribution of the remembering item 5.

v) To calculate the length of melody, the number of letter names, in reference to the length of rythm, the number of the notes, and so forth.

vi) To decide the variation of melody of series of passages by applying the rule to the frequency distribution of the series of melody number of the item 6.

vii) To decide the letter name of the first note by applying the rule to the frequency distribution of the item 2.

viii) To compose the melody of music, first by obtaining the letter name of the second note by applying the rule to the frequency distribution of the item 3 and then the third, the forth, etc., in a similar way.

ix) To print the whole music if the pair of the letter name of the first note decided in vii) and the last one obtained in viii) is found to have been stored in the memory of the remembering item 2. If not, the procedure vii)~ix) must again be repeated.

3. *The Third Stage* (*Stage of Learning*)

If we are not satisfied at all with the composed music in the second stage by some reason, be it redundant or desultory, we mark the unsatisfactory parts of the music sheet and again let the computer listen to it. The computer then calculates the quantities of the classifying items C and D with regard to the marked parts and further the quantities of the items A, B, H and I with regard to the whole music sheet. When the computer finds some of the quantities thus obtained to be outside of the range between the maximum and the minimum values that have been memorized in setting the criteria of the first stage, the computer is taught that it must hereafter always examine the items in question before printing, and is allowed to put out the music only if the examined quantities are within the limits set in the first stage and otherwise the computer abandons the music and tries a new one, returning to the starting point of the second stage.

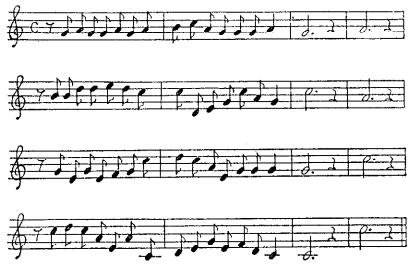
Through passing the third stage repeatedly the computer gradually removes its shortcomings by itself and will never repeat the same error. Therefore we can promote the efficiency of the composition saving trouble to read poor music sheets.

It is to be noticed that one can add new classfying items or replace old items by new ones when the nine items as described in the first stage are found not to be enough to composing non-unsatisfactory music.

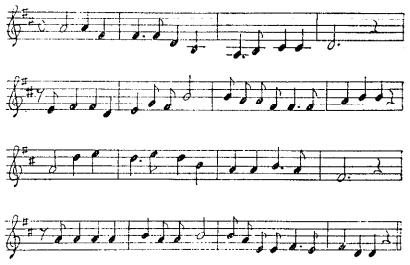
Furthermore man could make the computer learn his taste for music in this learning process. Of course one has the freedom to select music that the computer is made to listen to in the first stage, which would also serve to teach his taste.

4. *Results*

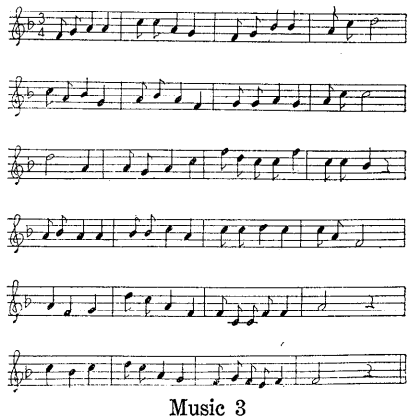
In the present section, we show some results of our attempt for two patterns. Music 1～7 are the composed music sheets on listening to forty-six Japanese children's songs of both the major and the minor scales*. Musics 8～11 show the composed results based on the experience



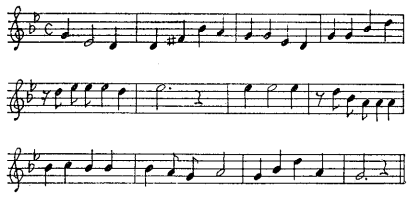
Music 1



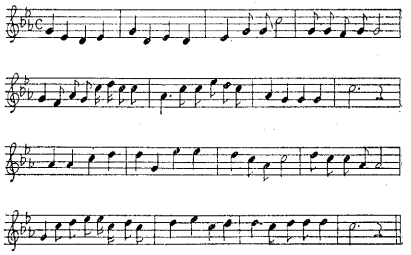
Music 2



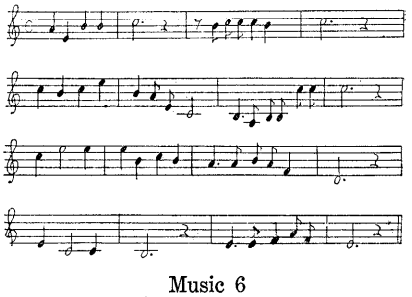
Music 3



Music 4



Music 5

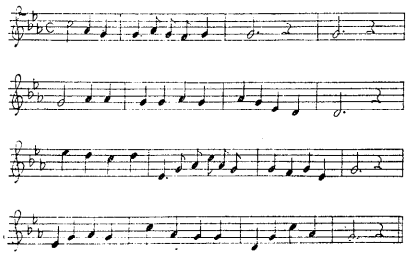


Music 6

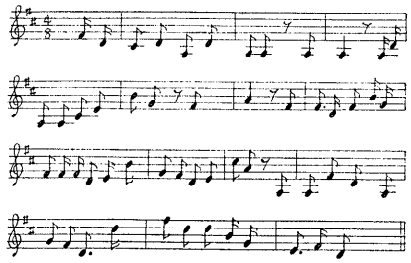
* "Nihon Doyo Hyakkyoku Shu, Vol. 1", edited by S. Kato, Shinko Music Pub. Co., Tokoyo.

of listening to Schubert's melodies in "Die schöne Müllerin".

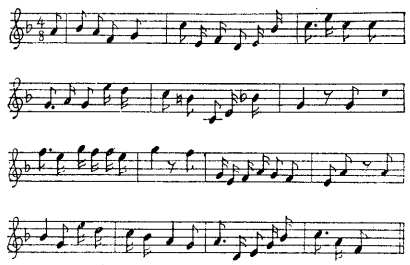
In the same way it is possible to supply the composed music by an accompaniment and chord, but such attempt has not been tried on account of the limited capacity of the computer.



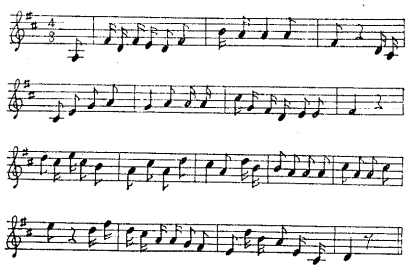
Music 7



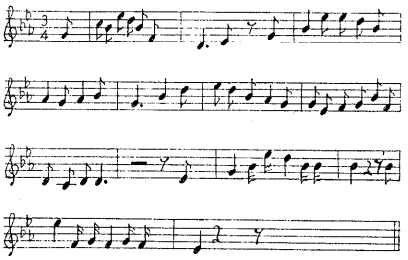
Music 8



Music 9



Music 10



Music 11