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Interactive musical editing system to support human errors and offer personal preferences for an automatic piano
- A method for searching for similar phrases using DP matching and for inferring performance expression with the best alignment of DP matching –

Kenichi Koga *Eiji Hayashi*
Department of Mechanical Information Science and Technology
Faculty of Computer Science and Systems Engineering, Kyushu Institute of Technology
680-4, Kawazu, Iizuka-City, Fukuoka Prefecture, Japan

Abstract: We have developed a system that allows a piano to perform automatically. In order to play music in the manner of a live pianist, we must add expression to the piano's performance. In the case of piano music, there are often 1000 or more notes in the score of even a short piece of music, requiring that an editor spend a huge amount of time to accurately simulate the emotionally expressive performance of a highly skilled pianist. Therefore, we have developed an interactive musical editing system that utilizes a database to edit music more efficiently. We have analyzed MIDI data regarding the performances of highly skilled pianists in order to observe the stylistic tendencies of their performances. Our result showed that phrases having similar patterns in the same composition were performed in similar styles. Therefore, we developed a system that searches for similar phrases throughout a musical score and evaluates the style of the performance. The method of searching for similar phrases uses DP (Dynamic Programming) matching, and it evaluates performance expression based on the best alignment of DP matching.

Keywords: automatic piano, knowledge database, computer music, DP matching

I. INTRODUCTION

We have developed a performance system for an automatic piano. In this system, 90 actuators are installed on the 88 keys and the 2 pedals of a grand piano. These actuators operate key strokes and execute pedaling on the piano. (See Figure 1)

Reproducing music with the piano is similar in some ways to reproducing music on the computer. Essentially, variations in tempo, dynamics, and so on are needed to arrange the respective tones in the desired way. However, in the case of piano music, there are 1000 or more notes in a score of even a short piece of music, and for this reason an editor must spend an enormous amount of time working with an arrangement in order to simulate the expressions of an actual performance. Therefore, in this research, we have developed an interactive musical editing system to edit music more efficiently [1].

We have analyzed MIDI data from the performances of highly skilled pianists in order to observe the stylistic tendencies of their performances. Out results showed that phrases having similar patterns in the same composition were performed in similar styles. Moreover, we found that the pattern of notes in a score sometimes influences the expression of a piece of music..

In this research we developed a system that searches for similar phrases throughout a musical score and evaluates the style of a performance. We propose a method that uses DP matching as a way to search for similar phrases. This system converts notes into character strings. In addition, the system runs DP matching using character strings and calculates the degree of disagreement between these strings. We use these calculations as an index to determine whether the strings resemble each other. Moreover, we designed a method for evaluating the performance expression based on similar phrases as found by DP matching.

In this paper, we describe the results of searching for similar phrases using DP matching and evaluating performance expression.

Figure 1: View of the automatic piano

II. Musical Editing Support System

2.1 System Architecture

The structure of the system is shown in Figure 2.1. The user edits music via the user's interface on a computer display. The user can also access a database that has musical grammar, the user's preferences, and so on. As a result, editorial work is reduced and efficient editing becomes possible.

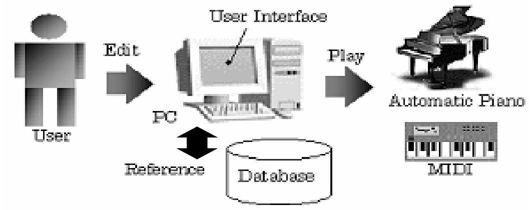


Figure 2.1 Structure of the editing system

2.2 Format of Performance Information

The parameters of performance information are shown in Tables 1 and 2. The automatic piano that we have developed uses a music data structure that is similar to MIDI. We defined performance information, dividing it into two categories: the notes and the pedals. The note information is comprised of the six parameters involved in producing a tone: "Key (note)", "Velo (velocity)", "Gate", "Step", "Bar", and "Time". "Velo" is the dynamics, given by the value of 1 ~ 127. "Gate" is the duration of the note in milliseconds. "Step" is the interval of time between notes, and it also exhibits tempo. "Bar" is the vertical line placed on the staff to divide the music into measures.

The pedal information is comprised of four parameters: "Key (indicating the kind of pedal: "Damper" or "Shifting")", "Velo (the pedaling quantity)", "Time (the duration for which the pedal is applied)", and "Bar".

2.3 Editing Support Process with Database

Our system can automatically apply a rough performance expression using a Musical Rules Database and Score Database. (See Figure 2.2)

In addition, the system has Preference Database, which stores the editing characteristic of the user.

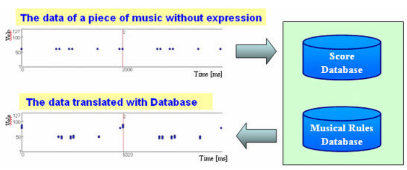


Figure 2.2: Automatic translation with database

2.3.1 Musical Rules Database

This database contains the architecture of musical grammar necessary to interpret symbols in musical notation. It is composed of five tables containing "Dynamics marks", "Articulation marks", "Symbol of Changing Dynamics or Changing Tempo (symbol that affects the speed of a note or the increase or decrease of the volume)", "Time signature", and "Tempo marks".

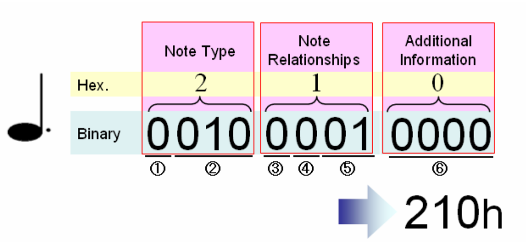
Analyzing a music symbol according to its usage allows efficient information processing by the system.

2.3.2 Score Database

This database has symbols including notes, time signature, rests and so on in standard musical notation. Symbols were pulled together in order of bars, and bar symbols are arranged in time series. Performance expression in itself is only information such as pitch, strength, and length and concerns only the enumeration of a sound. Because the identification of each sound is difficult, editing of the performance expression is difficult. By adding the Score Database's information to performance expression, we can connect each note. In doing so, it becomes easy to edit each phrase.

This database consists of three tables, the "Element table" (showing the position of the note and the composition of the chord), the "Symbol table" (showing the position of the music symbol) and the "Same table" (showing the position of the repetition of the phrase).

The Element table contains the field "Note Value". Data in this field indicates the type of note, e.g., a quarter note, a triplet, and so on. "Note Value" is expressed by three hexadecimal numbers, which are shown in Figure 2.3.



① Note or Rest (0: Note, 1: Rest)
② Note Value (000: A whole note, 001: A half note …etc)
③ Tie (If the note has a tie then this number is 1.)
④ Ornament
(If the note has an ornament then this number is 1.)
⑤ The number of dots
(Exceptionally, if it is "11" then the note is tuplet.)
⑥ Additional Information
The number of tuplets. (Triplets: 0011)
The type of an ornament. (Trill: 0101) etc…

Figure 2.3: Note Value

III. Searching for Similar Phrases

As a result of the analysis, it was found that phrases of the same pattern existing in the same tune are performed in a similar expression. This time, we used DP matching to search for similar phrases.

3.1 DP matching

a) DP matching

DP matching is a technique used well in the field of speech recognition, bioinformatics and so on. It has a feature that can calculate similarity between two words that are different in a number of characters from each other.

In Figure 3.1, the route of minimum cost in each point is taken, and the route with the lowest cost is assumed finally to be an optimal path. The cost at that time is defined as the distance between patterns. In this system, this distance is handled as a threshold to judge whether the phrases are similar to each other.

For example, if the cost moves up or to the right, the n it is increased by 1. If it moves to the upper right, then it does not increase. Also, if the characters do not corre spond in each point, then the cost is increased by 5.

$$g(i,j) = \min \begin{Bmatrix} g(i-1,j) \\ g(i,j) \\ g(i,j-1) \end{Bmatrix} + d(i,j)$$

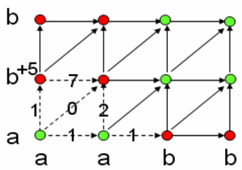


Figure 3.1 DP matching

b) Best alignment of DP matching

The best alignment of DP matching is what enables it to express the best correspondence between notes. Figure 3.2 shows the best alignment from Figure 3.1. This relation is not used because of the searching processing but instead is used because of the inference processing.

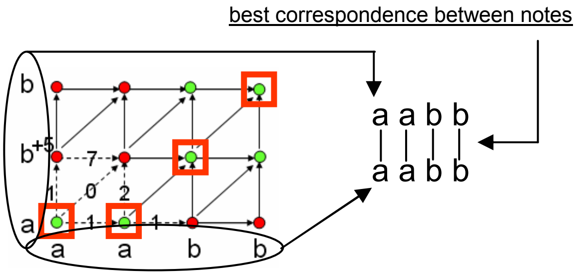


Figure 3.2 Best alignment of DP matching

3.2 Searching with DP matching

In this passage, we describe a method of searching with DP matching. We had to convert a musical score into character strings (a Note Pattern) before searching for similar phrases. This process is explained below.

3.2.1 Note Pattern

Our system converts a score into a Note Pattern using Note Values (See Passage 2.3) in order to perform DP matching. Of the three columns of Note Values, we used the two columns on the left. The system replaces numbers in the second column with letters of the alphabet (from G) because a letter, being a different notation than that used in the first column, allows the expression of one note with two columns. An example of a Note Pattern conversion is shown in Figure 3.3.

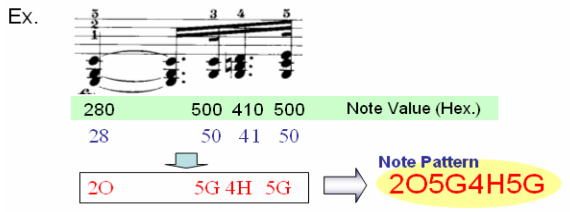


Figure 3.3 Example of Note Pattern

3.2.2 The Method of Searching

The flow of the similar phrase search is shown in Figure 3.4.

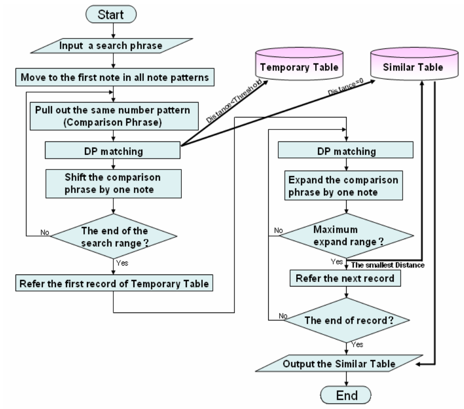


Figure 3.4 The flow of the similar phrase search
(Search range and expand range are set beforehand.)

Essentially, two rounds of search processing are performed. The first processing round narrows down the points to those having a resemblance in all search ranges. A pattern with the same number as the search phrase is pulled out, and the distance between two patterns is calculated using DP matching. If they are in complete accord (distance = 0), then the phrase is stored in the Similar Table. If the distance is lower than the threshold, then the phrase is stored in the Temporary Table. In the second round of processing, DP matching is performed again using the phrases in the Temporary Table while increasing the number of characters. In other words, the system looks for the most similar phrases in the surrounding phrases. The threshold of this system has been decided by trial and error.

VI. Phrase Expression System of Evaluations

The similar phrases derived by the search method described in Chapter 3 are evaluated with regard to the performance expressions of the search phrases.

3.3 Method of evaluating phrase expressions

The method of evaluating performance expression, which uses the best alignment in DP matching, enables it to express the best correspondence between notes. The best alignment in DP matching gives us points of agreement and disagreement.

Our evaluation method to determine the disagreement points is as follows. A correspondence between note patterns is revealed when the distance is minimized in DP matching. Next, the ratio of Velo to the previous sound is calculated for each sound in the searching phrases. The Velo of associated phrases is determined using a ratio R_i so that the ratio of the Velo is shown in the expression:

$$R_i = \frac{V_{i+1}}{V_i}$$

V is the Velo of each searching phrase, and W is the Velo of similar phrase as calculated in R.

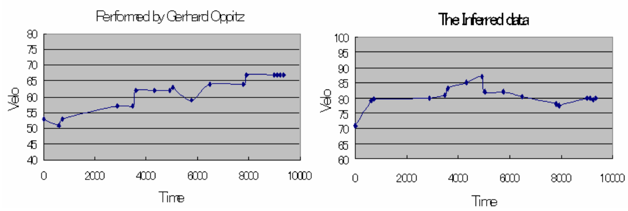
$$W_{i+1} = W_i \times R_i$$

Thus, the Velo of a similar phrase is determined. The value of Time uses the value determined by Automatic translation (see Passage 2.3).

3.4 Searching & Inference Result

The result of the searches and inferences using this system is shown in Figure 4. The phrase in the seventh bar of Beethoven's Sonata No. 23 in a performance by Gerhard Oppitz was inferred from the first bar . The figure shows that the basis for this result is that the distance = 33 between the two phrases. The inferred phrase was similar to the performance expression of the searched phrase.

In addition, even the phrase which distance leaves, we understand that the reasoning that resembled closely to some extent is made.



Distance 33

Figure 4 Searching and Inference Results

V. CONCLUSION

We designed methods of searching for similar phrases and evaluating performance expressions using DP matching and combined these functions into a single system.

In the similar phrase search, the system was able to find similar phrases using DP matching in a short time, and it was even possible to find phrases whose resemblance might not be immediately apparent.

In evaluating performance expressions, the system could make the best associations between phrases by DP matching of search results.

The performance expression of some similar phrases that exist in a tune can be inferred at the same time using this system. We believe that this system can increase work efficiency by its automatic editing without sacrificing quality, in contrast to editing a piece by hand from the beginning.

In this study, we were able to perform only similar phrase searches and evaluations of performance expressions in the same piece of music. In the future we will perform evaluations with different pieces of music and will evaluate the existing system. In addition, it will be necessary to consider the music sign in these evaluations

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