

PAPER

Automatic arrangement for the bass guitar in popular music using principle component analysis

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Abstract: In popular music, the drums and bass guitar create the rhythm. In 2008, we developed a drum pattern database including thousands of music excerpts to investigate the role of drums. However, no studies have been reported on using a large number of samples to investigate the role of the bass guitar in popular music. Moreover, it has been difficult to generate appropriate phrases on automatic-arrangement systems. We propose a method that we have developed for identifying the bass part using Musical Instrument Digital Interface (MIDI) excerpts. In the method, each one-bar length is identified as either a bass guitar part or not, and if it is, it is appropriately named a “bass guitar pattern.” The basic information of the bass guitar pattern, such as onset, interval, and dynamics profiles, was extracted from it and a database comprising these profiles was constructed in order to extract common features among patterns. We use principal component analysis (PCA) to introduce several automatic-arrangement parameters, including those in the proposed database, and call these parameters “eigenphrases of the bass guitar.” We propose a method of arranging the bass guitar part to generate an appropriate pattern as a musical phrase by multiplying each of the principal component vectors from the eigenphrase of the bass guitar with relative weights. The method is confirmed to be effective as a means of generating bass guitar parts in a natural rather than an artificial way.

Keywords: Bass guitar, Automatic arrangement, Eigenphrase, PCA, MIDI

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1. INTRODUCTION

In popular music, drums and the bass guitar play important roles in terms of rhythm. To investigate the role of drums, we previously developed a drum pattern database using thousands of music excerpts [1]. Several studies on the role of the bass guitar have been reported, such as one estimating fundamental frequencies (F_0) of melody and bass lines using monaural audio signals containing sounds of various instruments [2] and one focusing on bass guitar parts to classify music genres [3]. Another study revealed the common feature of drum rhythm patterns [4], and several studies on musical arrangement have been conducted [5–7]. Other studies have been reported on the handling of a large volume of musical data [8,9], and by using such data, an automatic performance system for

controlling musical emotion was developed [10]. However, no databases have been reported for analyzing “onset,” “interval,” or “dynamics” profiles for the bass guitar parts because no methods have been developed for identifying the Musical Instrument Digital Interface (MIDI) track of the bass guitar from MIDI excerpts. Moreover, a difficulty in generating appropriate phrases in terms of musical phrase in automatic arrangement has been revealed as a difficulty in maintaining the musical aspects on the generated patterns.

Here, we propose a method of identifying the bass guitar track from MIDI excerpts comprising several instrumental tracks, because we need to automatically identify the bass guitar track from approximately 3,000 MIDI excerpts to create a database of the bass guitar part and to automatically identify the bass track in order to avoid the labor of manually specifying it. Moreover, the database is required for the statistical analysis of many patterns, to apply the automatic arrangement. The data to be dealt with for the

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bass guitar is onset, interval, and dynamics, because each of them corresponds to MIDI information for a note, and all of them are required to represent the input pattern. The proposed method involves a heuristic approach using “note-on message timing,” “average value of note number,” and “program change messages.” “Note-on” means the time of sounding, “note number” means note height, and “program change” means the specification of timbre in MIDI format. With our method, each track is identified as either a bass guitar one or not. If it is, each one-bar length contained in the track, which is called the bass guitar pattern (BGP), is extracted. Extracts from the BGPs include “onset,” “interval,” and “dynamics” profiles. The onset profile represents the sequence of onset time, the interval profile represents the interval of each note from the first note of each measure, and the dynamics profile represents the fluctuation in dynamics. We constructed a BGP database (BGP-DB) that consists of these three profiles, and we were able to use it to analyze the nature of BGPs. We also extracted several parameters using principal component analysis (PCA). The purpose of using PCA is to extract typical patterns of the bass guitar, which are expected to be appropriate for automatic arrangement of a musical phrase. In this paper, we describe how we used the patterns to automatically arrange the bass guitar part.

To identify the bass guitar part in MIDI excerpts, we developed a method of identifying the bass guitar track {R}. We used 3,097 MIDI excerpts categorized as Japanese Pop (J.Pop) music. These excerpts were in the XF format, which contains several tags such as genre and chord name. We obtained BGPs under only four beat (i.e., only four beats in a measure), along with a consistent chord. The onset, interval, and dynamics profiles are extracted from the obtained BGPs, and the proposed BGP-DB comprises these three profiles. We assume that the characteristics of a BGP can be analyzed using this BGP-DB. We also use PCA to develop several automatic-arrangement parameters, including those in the proposed database. We then obtain BGP-DB eigenvectors, which represent the major feature of BGPs. We chose to name the eigenvectors for the bass guitar “eigenphrases of the bass guitar,” which is a novel term and one that we expect will enable bass guitar patterns to be analyzed. In this study, the length of one eigenphrase of the bass guitar is only the pattern of one-measure length. We also propose an arrangement method for the bass guitar part using these eigenphrases. The aim of this method is to achieve natural arrangements. Figure 1 is an outline of this study.

2. BASS GUITAR PATTERN DATABASE

Here, we employ popular music excerpts on MIDI format. Usually the bass guitar part is included so we need to extract it. Even though it is not so difficult for humans, automatic identification is desired because of the great

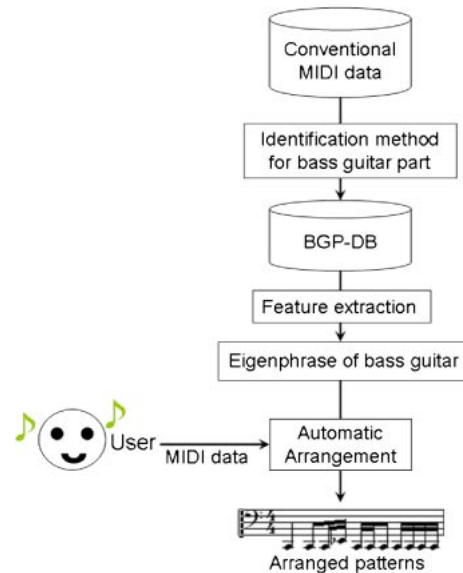


Fig. 1 Outline of this study.

number of excerpts. To do so, we must identify the bass guitar part automatically from the MIDI data, so we require a method for such a purpose. A simple method which is merely to observe the timbre was employed. However, some backing patterns use it. Thus we must observe the note number, which should be low, and the number of played notes at the same time (usually chords are not played on the bass guitar). From here, we explain details of the process. To extract several BGP parameters for automatically arranging bass guitar parts, we constructed the BGP-DB by our proposed method of identifying the bass guitar track from MIDI excerpts comprising several instrumental tracks. The BGP-DB contains three profiles extracted from the BGPs, i.e., an “onset” profile T_B , an “interval” profile I_B , and a “dynamics” profile V_B . Each profile is used independently to construct a database, i.e., an onset profile database, an interval profile database, and a dynamics profile database. These databases combined make up the BGP-DB. Figure 2 shows the procedure for constructing the BGP-DB. This database is used to extract three profiles for eigenphrase of the bass guitar, i.e., “onset,” “interval,” and “dynamics” profiles, respectively denoted as T_B , I_B , and V_B . The three profiles are important for representing the nature of the bass guitar pattern.

2.1. Method for Identifying MIDI Bass Guitar Track

We explain {R} for automatically identifying the bass guitar part. {R} consists of three rules.

- R_1 : A criterion for note-on messages, presented or not, in terms of simultaneity
- R_2 : A criterion for the average value of the note number of each track, i.e., “high” or “low”
- R_3 : A criterion for program change messages, presented or not, of specific timbres

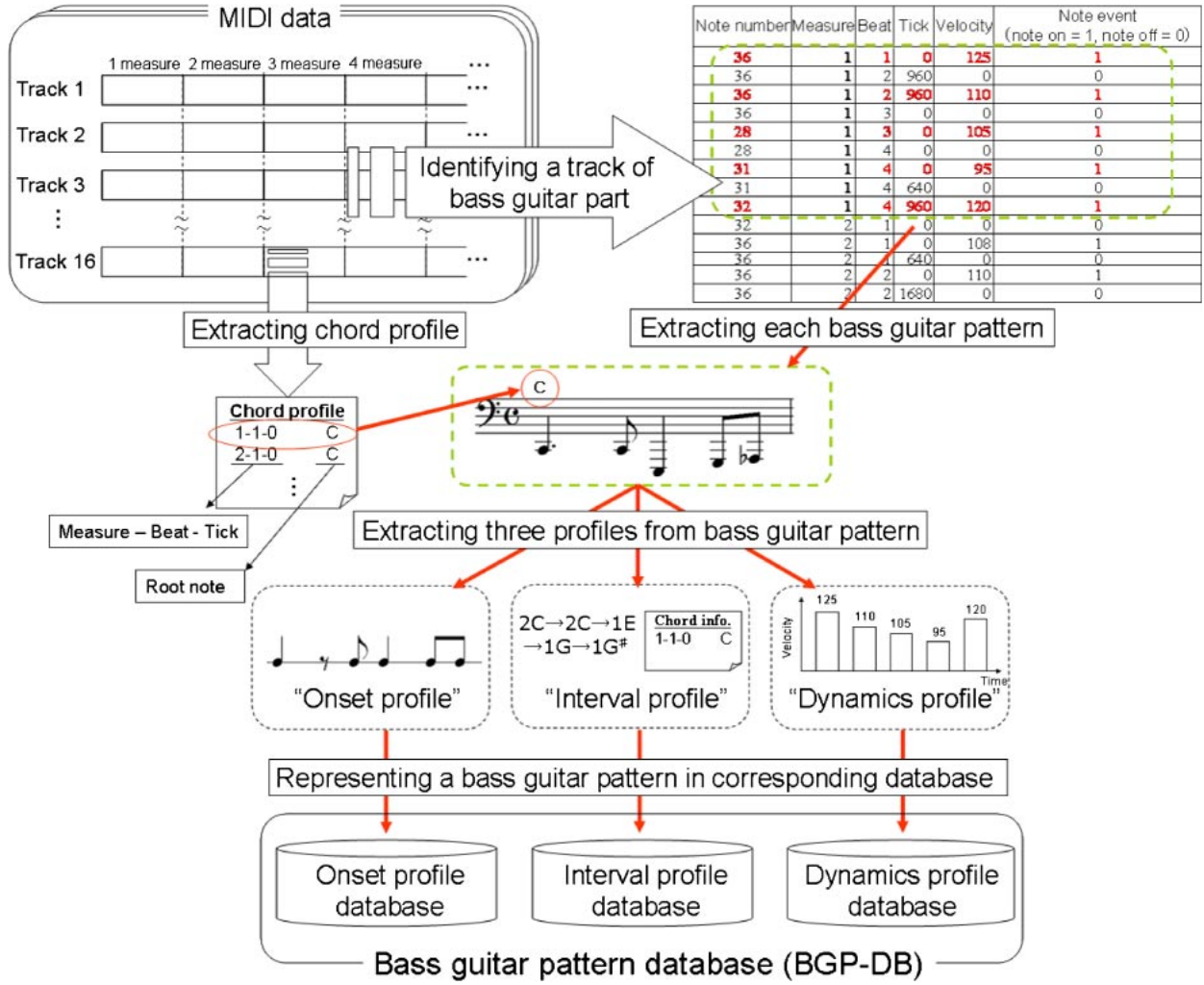
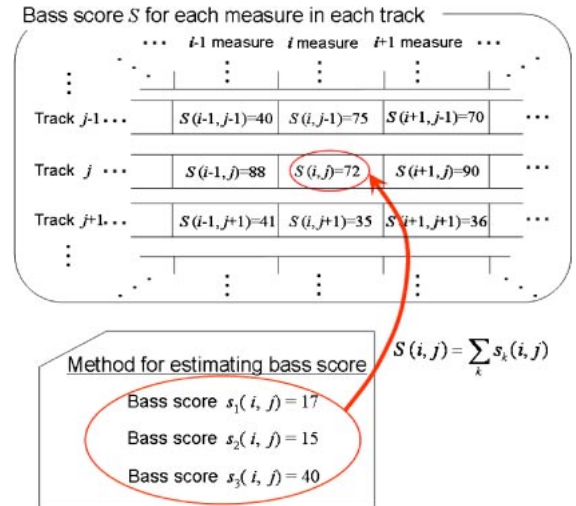


Fig. 2 Procedure for constructing BGP-DB.

Both R_1 and R_2 are required to correctly extract the BGP from MIDI excerpts when the program change messages of the bass guitar, such as Synth Bass 1 or Synth Bass 2 in GM format, are used in other parts such as that for the keyboard. Each track has a candidate BGP score, called "bass score S ," calculated using the three rules for each bar. These bass scores are calculated using the corresponding rules in $\{R\}$. The bass scores s_1 , s_2 , and s_3 correspond to rules R_1 , R_2 , and R_3 . The maximum values of each score were set as 30, 30, and 40 for s_1 , s_2 , and s_3 , respectively. They were manually set, then using the ratio, we found that BGPs are correctly obtained for 199 excerpts out of 200. Figure 3 outlines the calculation for bass score S . We determined the bass guitar track from the highest average bass score S in the excerpt. Any track in which the number of measures with any note-on message sounding note is less than the average of all measures of the excerpt is assumed to not include the bass guitar role.

2.1.1. R_1 : criterion for note-on messages, presented or not, in terms of simultaneity

The bass score s_1 is calculated for rule R_1 in $\{R\}$. When calculating bass score s_1 , it should be scored low when

Fig. 3 Calculation of bass score S .

simultaneous notes are observed for each track in each bar, where simultaneous notes mean identical onsets of different note heights. In other words, if the note-on messages are shown at a same time, $c_{i,j}$ becomes large so that s_1 should be low, where $c_{i,j}$ is defined as the occurrence

frequency of played notes for the j th track ($1 \leq j \leq 16$, except for percussion track) in the i th measure. Each track is evaluated to calculate the occurrence frequency of simultaneous notes using the quantize note-on messages function for each bar, where all MIDI events are quantized under a thirty-second note. The notation $cmax_i$ is defined as the maximum $c_{i,j}$ for the i th measure in all tracks, and $\max(s_1)$ is defined as the maximum among all bass scores $s_1(i, j)$. Therefore, bass score $s_1(i, j)$ is calculated as

$$cmax_i = \max_j(c_{i,j}) \quad (1)$$

$$s_1(i, j) = \max(s_1) \times \left(1 - \frac{c_{i,j}}{cmax_i}\right). \quad (2)$$

2.1.2. R_2 : criterion for average value of note number of each track, i.e., “high” or “low”

Bass score s_2 is calculated for rule R_2 in $\{R\}$. When calculating s_2 , it should be scored “high” when the average note number for each track in each bar is low. The notation $h_{i,j,k}$ is defined as the note number of the k th note-on message for the j th track in the i th measure, and $K_{i,j}$ is defined as the number of note-on messages for the j th track in the i th measure. Therefore, the average note number $\bar{h}_{i,j}$ is calculated as

$$\bar{h}_{i,j} = \frac{\sum_{k=1}^{K_{i,j}}(h_{i,j,k})}{K_{i,j}}, \quad (3)$$

where $hmin_i$ is defined as the minimum $\bar{h}_{i,j}$ for the j th track in the i th measure, and $\max(s_2)$ is defined as the maximum among all bass scores $s_2(i, j)$. Therefore, the bass score $s_2(i, j)$ is calculated as

$$hmin_i = \min_j(\bar{h}_{i,j}) \quad (4)$$

$$s_2(i, j) = \max(s_2) - (\bar{h}_{i,j} - hmin_i). \quad (5)$$

2.1.3. R_3 : criterion for program change messages, presented or not, of specific timbres

Bass score s_3 is calculated for rule R_3 in $\{R\}$. When calculating s_3 , it should be scored “high” when one of the timbres of the bass guitar is used for each track in each bar. The specific program numbers are listed in Table 1. $\max(s_3)$ is defined as the unit value of all bass scores $s_3(i, j)$ among all measures and tracks. If the specific timbres concerning a bass guitar are used for the j th track in the i th bar, $s_3(i, j)$ is scored as $\max(s_3)$; otherwise, it is scored as 0. $P\{\}$ is defined as the class of all program numbers, as shown in Table 1, and $p_{i,j}$ is defined as the program numbers used as bass guitar parts for the j th track in the i th bar. Therefore, the bass score $s_3(i, j)$ is calculated as

$$s_3(i, j) = \begin{cases} \max(s_3) & (p_{i,j} \in P) \\ 0 & (p_{i,j} \notin P) \end{cases} \quad (6)$$

$$P = \{33, 34, 35, 36, 37, 38, 39, 40, 44\}.$$

Table 1 Program numbers used as bass guitar parts.

Program number	Instrument
33	Acoustic Bass
34	Electric Bass (finger)
35	Electric Bass (pick)
36	Fretless Bass
37	Slap Bass1
38	Slap Bass2
39	Synth Bass1
40	Synth Bass2
44	Contrabass

2.2. Onset Profile Database

T_B in the onset profile database means the rhythm profile for an extracted BGP. This profile consists of only note-on and no note-off messages. There were 6,607 T_B samples in the 3,097 MIDI excerpts.

2.3. Interval Profile Database

I_B in the interval profile database represents the profile of each difference between the first note in each bar and itself in note number because a pitch profile for the BGP without a chord profile is required. By using these differences between the first and each note number on each bar, we can determine the fluctuation, i.e., the musical line in the pitch of a BGP. Therefore, the interval profile database comprises not the note number, which means the pitch profile in the MIDI format, but the interval profile, which means the relative height from the first note number of each bar. Each event in I_B is listed in the order to be performed in the interval profile database, although the time differences are not dealt with. There are 26,459 samples in the 3,097 MIDI excerpts in I_B .

2.4. Dynamics Profile Database

V_B in the dynamics profile database represents an accent profile in a bar from the MIDI velocity. V_B represents each difference between the first note event and itself in a note of MIDI velocity, which is quantized in multiples of five, i.e., MIDI velocity is quantized as 0, 5, 10, ..., 120, or 125. By using the differences between the first note and other notes of MIDI velocity on each bar, we can determine the fluctuation, i.e., the musical line in the dynamics of a BGP. As in I_B , each event in V_B is listed in the order to be performed in the dynamics profile database, although the time differences are not dealt with. There are 22,160 samples in the 3,097 MIDI excerpts in V_B .

2.5. Nature of BGP-DB

We extracted the BGPs from MIDI excerpts using our proposed method of automatically identifying the bass guitar tracks from current MIDI excerpts. The performance of the identification method described in section 2.1. produces a “correct” ratio of 99% by comparing the

estimated tracks and hand-labeled data for 200 MIDI excerpts randomly extracted from 3,097 J.Pop excerpts. Although the BGPs in this study have several restrictions, such as those under a consistent chord progression, those under exactly four beats, and those under the quantization for a thirty-second note without triplets, we were able to confirm that these features are not specific but universal. Specifically, 59% of the BGPs in the 3,097 MIDI excerpts are included in BGP-DB and 98% of them are four beats in length. In addition, if a triplet is used in a MIDI excerpt, the quantization of a thirty-second note will show a duple note each time. We found that 93% of the BGPs did not show any duple notes, meaning that triplets are infrequently used in the 3,097 MIDI excerpts. Therefore, we can say that the nature of this database is not specific but universal.

3. EIGENPHRASE OF BASS GUITAR

As described in chapter 1, although automatic arrangement systems have been available, they have difficulty in generating appropriate phrases from a musical viewpoint. In other words, naturalness in terms of music is hard to realize when generating excerpts automatically. Therefore, the generated patterns should have such features. Here we extract it from among the numerous patterns in MIDI excerpts by a statistical method. Hereon, we explain the details of the process.

To create an automatic arrangement for the bass guitar part, we used PCA to extract the eigenphrase of the bass guitar including those in the proposed database. We extracted three profiles for the eigenphrase of the bass guitar, i.e., “onset,” “interval,” and “dynamics” profiles, respectively denoted as T_B , I_B , and V_B . Therefore, the eigenphrase of the bass guitar has one of these profiles.

3.1. Onset Profile for Eigenphrase of Bass Guitar

We used PCA to extract the onset profile for the eigenphrase of the bass guitar from T_B in the BGP-DB, where the obtained onset profiles are denoted under a sixteenth note. Figure 4 shows the onset profile for the eigenphrase of the bass guitar using all patterns of T_B in the BGP-DB and Fig. 5 shows its cumulative contribution ratio. Note that all the components of the second principal component of the onset profile for the eigenphrase of the bass guitar are positive at strong beats on the eighth note, e.g., the locations of onset timings 3, 5, 7, 9, 11, 13, and 15, where each number means the ID of the sixteenth note in the figure. Moreover, all principal component scores concerning the second principal component are confirmed to be positive for all T_B , implying that a large number of onset timings are located on the BGPs of the eighth note. Also, the third principal component of the onset profile for the eigenphrase of the bass guitar is both negative at the anterior half and positive at the posterior half in onset

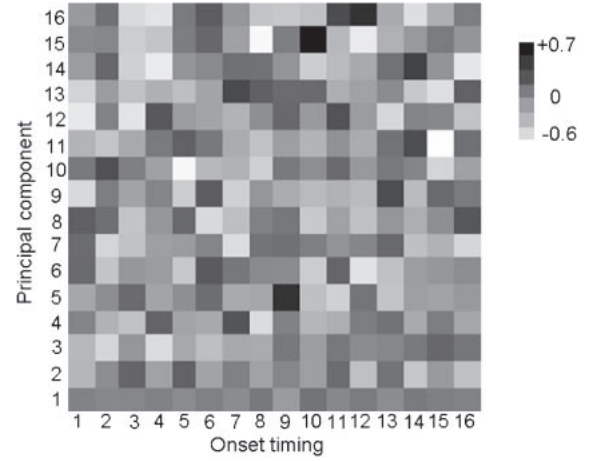


Fig. 4 Onset profile for eigenphrase of bass guitar.

timing. Moreover, the principal component scores concerning the third principal component of all patterns are either positive or negative in all patterns of T_B , implying that a large number of onset timings for BGPs are located either anteriorly or posteriorly.

3.2. Interval Profile for Eigenphrase of Bass Guitar

The interval profile for the eigenphrase of the bass guitar is extracted for each number of notes in a measure, because of the requirement that the size of the vector to compress the dimension by PCA should be consistent among patterns. Therefore, the extracted I_B from the BGP-DB is classified according to the number of notes. We investigated I_B ranging from $n = 3$ to 14 after it was quantized under a sixteenth note because the number of notes in BGPs was different. The probability of I_B being in the range from $n = 3$ to 14 was approximately 98% for all patterns of I_B . We extracted the interval profile for the eigenphrase of the bass guitar for each number of notes. Therefore, we could extract the fluctuation, i.e., the musical line in the pitch of a BGP.

Figure 6 shows the interval profile for the eigenphrase of the bass guitar for (a) $n = 6$ and (b) $n = 8$ and Fig. 7 shows their cumulative contribution ratios. The second principal component of the interval profile for the eigenphrase of the bass guitar for $n = 8$ in Fig. 6(b) is positive at the anterior half (NoteID: 1–4) and negative at the posterior half (NoteID: 4–7). Moreover, the principal component scores concerning the second principal component of all I_B are either positive or negative in all patterns of I_B , implying that a large number of BGPs are either rising or falling patterns with regard to degrees of pitch. Also, the third principal component of the interval profile for the eigenphrase of the bass guitar for $n = 8$ in Fig. 6(b) is negative at the middle (NoteID: 3–5). Moreover, the principal component scores concerning the third principal component of all I_B are either positive or negative in all

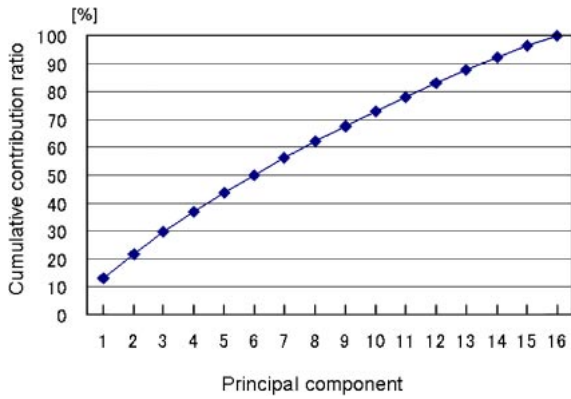


Fig. 5 Cumulative contribution ratio for onset profile.

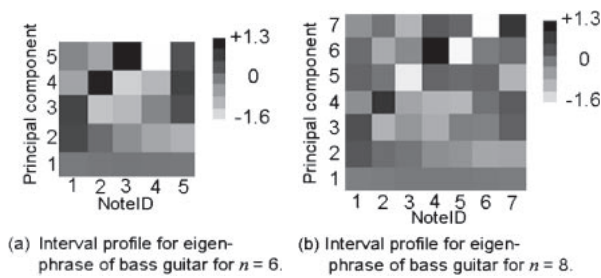


Fig. 6 Examples of interval profiles for eigenphrases of bass guitar for $n = 6$ and $n = 8$.

patterns of I_B , implying that a large number of BGPs are either rising and then falling pitch patterns or falling and then rising pitch patterns.

3.3. Dynamics Profile for Eigenphrase of Bass Guitar

The dynamics profile for the eigenphrase of the bass guitar is extracted for each number of notes for the same reason as given above for the interval profile for the eigenphrase of the bass guitar. Therefore, extracted V_B from the BGP-DB is classified according to the number of notes. As in the interval profile for the eigenphrase of the bass guitar, we investigated V_B ranging from $n = 3$ to 14 after it was quantized under a sixteenth note because the number of notes in the BGPs was different. The probability of V_B ranging from $n = 3$ to 14 was approximately 98% or higher for all V_B patterns. We extracted the dynamics profile for the eigenphrase of the bass guitar for each number of notes. Therefore, we could extract the fluctuations in the accent of a BGP.

Figure 8 shows the dynamics profile for the eigenphrase of the bass guitar for (a) $n = 6$ and (b) $n = 8$ and Fig. 9 shows their cumulative contribution ratios. The second principal component of the dynamics profile for eigenphrase of bass guitar for $n = 8$ in Fig. 8(b) is alternately positive and negative. Moreover, the principal component scores concerning the second principal component of all V_B are either positive or negative in all V_B patterns, implying that a large number of BGPs are

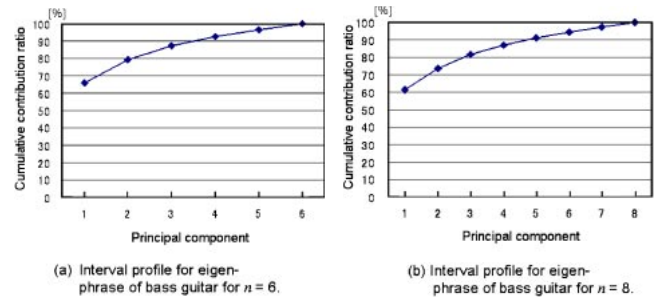


Fig. 7 Cumulative contribution ratios for interval profiles for $n = 6$ and $n = 8$.

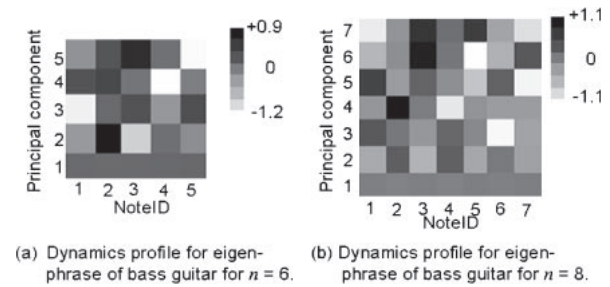


Fig. 8 Examples of dynamics profiles for eigenphrases of bass guitar for $n = 6$ and $n = 8$.

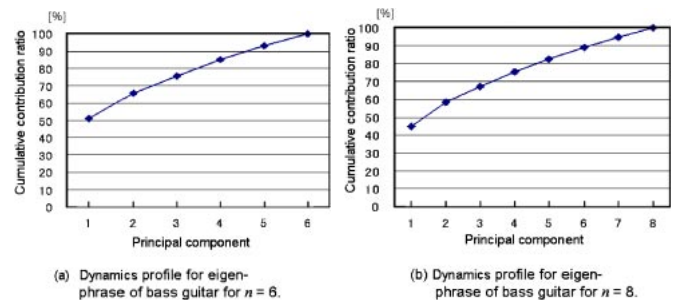


Fig. 9 Cumulative contribution ratios for dynamics profiles for $n = 6$ and $n = 8$.

alternately accented in sequential notes. Also, the third principal component of the dynamics profile for the eigenphrase of the bass guitar for $n = 8$ in Fig. 8(b) is positive at the anterior half (NoteID: 1–4) and negative at the posterior half (NoteID: 4–7). Moreover, the principal component scores concerning the third principal component of all V_B are either positive or negative in all V_B , implying that a large number of BGPs are either rising or falling patterns in terms of the MIDI velocity.

3.4. Discussion on Number of MIDI Excerpts

Here we discuss the appropriateness of the number of MIDI excerpts used in this study. We extracted a number of eigenphrases of the bass guitar using 75%, 67%, 50%, 33%, and 25% of all MIDI excerpts categorized as J.Pop, i.e., the excerpts used in this study. Moreover, we calculated a score showing the similarity of each eigenphrase of the bass guitar to the original one. The similarity

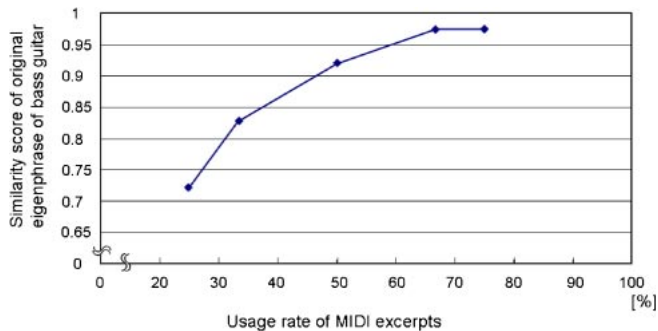


Fig. 10 Similarity score of onset profile for eigenphrase of bass guitar.

scores obtained are defined as the average of the absolute value of the correlation coefficient between the M th eigenphrase of the bass guitar obtained from all data and those obtained from each subset of all data.

Figure 10 shows the similarity score of the onset profile for the eigenphrase of the bass guitar. The results lead us to believe that no more than 3,097 MIDI excerpts are required to obtain the onset profile for the eigenphrase of the bass guitar, because the figure shows that a logarithmic curve is produced when the amount of bass guitar data is increased. Moreover, for the interval and dynamics profiles for the eigenphrase of the bass guitar for $n = 4-10$, the average similarity score is over 0.9 when using 50% of all MIDI excerpts. Thus we conclude that these 3,097 MIDI excerpts are enough to obtain our eigenphrases in this study.

4. AUTOMATIC ARRANGEMENT METHOD FOR BASS GUITAR PART

After obtaining the eigenphrase of the bass guitar, we need to develop a method of automatic arrangement. Although the natural feature should be retained on the generated pattern, there should be some variety among generated patterns. As such, we propose the use of eigenphrases with relative weights. We expect that such automatic arrangement will be suitable for meeting user requirements with respect to obtaining natural-sounding BGPs. Although it is difficult for automatically generated patterns to sound natural in general, it can be achieved with the proposed method since it makes use of the essential bass guitar characteristics extracted from the BGP-DB with a large number of MIDI excerpts, i.e., the eigenphrases of the bass guitar.

Our automatic arrangement method makes use of the eigenphrases of the bass guitar and relative weights for multiplying them with obtained eigenvectors. More specifically, after feeding a MIDI excerpt that contains BGPs for arrangement, the proposed method extracts the bass guitar track from the excerpt and extracts the onset timing and the number of notes for each measure using the onset profile for the eigenphrase of the bass guitar. Concretely, the number of notes, the list of note number, and the range of

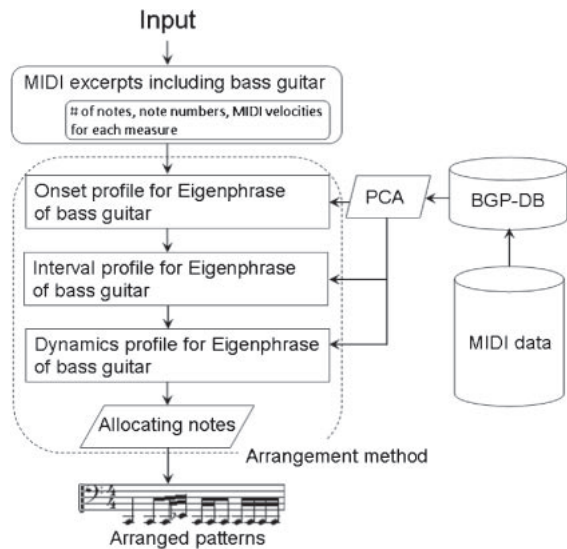


Fig. 11 Automatic arrangement method for bass guitar part.

MIDI velocity in a measure are consistent with those of the input BGP. In other words, the note number and the MIDI velocity of each note are not consistent in the arranged pattern. Thus, we use our method to determine each number of each note whose onset has already been determined using the interval profile for the eigenphrase of the bass guitar. We also employ it to determine the MIDI velocity for each note using the dynamics profile for the eigenphrase of the bass guitar. Figure 11 shows the automatic arrangement method for the bass guitar. In this method, we extract a BGP for each measure (four beats in length) from the input excerpt to be arranged.

4.1. Determining Onset Timing Using the Eigenphrase of Bass Guitar

In the arrangement procedure, we first calculated a score for all onset timings at the sixteenth note using the onset profile for the eigenphrase of the bass guitar. The score reflects the possible locations for each sixteenth note. We calculated the score using the onset profile for the M th eigenphrase of the bass guitar ($1 \leq M \leq 16$) with relative weights. In other words, the number of notes after arranging the BGP is determined by observing the number of notes on the BGP extracted from the input excerpt to be arranged, in accordance with the score for each BGP. Figure 12 shows an example of determining the onset timing for $n = 6$ for arranging the BGP. In other words, n is the number of notes in the input BGP and then the number of notes in the generated pattern is set as 6. The locations of onsets are determined on the basis of the score to be performed, on the vertical axis. The labels on the horizontal axis represent the location of onset in time. Here the numbers 1, 2, 5, 6, 9, and 13 are selected, and then the rhythmic score is automatically generated where the length of each note is automatically determined.

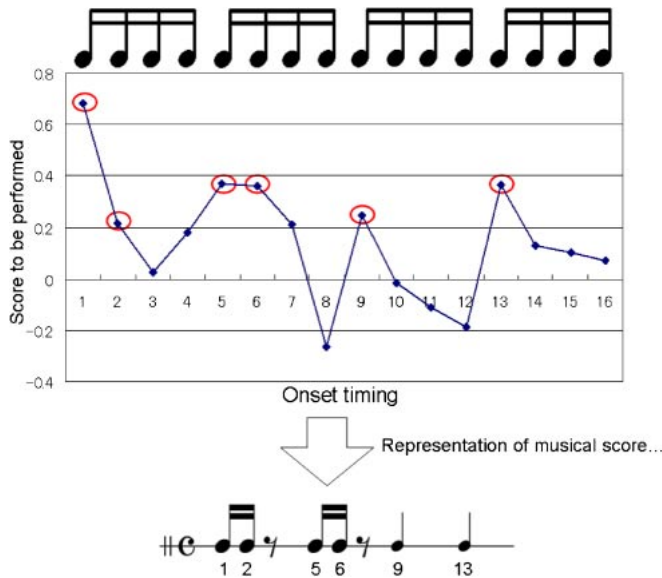


Fig. 12 Example of determining onset timing for $n = 6$.

4.2. Determining Note Number Using the Eigenphrase of Bass Guitar

The note number for each note is determined using the interval profile for the eigenphrase of the bass guitar. The numbers are extracted from the current BGP for arrangement. More specifically, the first number in the BGP is determined as a standard. We introduce several thresholds, which determine the range of pitch, for obtaining note numbers. The number of thresholds in the positive region of the pitch score is determined by the number of notes that are higher than the standard. Conversely, the number of thresholds in the negative region is determined by the number of notes that are lower than the standard. Note numbers are determined using these threshold values. Figure 13 shows an example of determining the note number of several notes for the current BGP of $n = 6$ in the order D1, E1, F1, C1, D1, and B0. The figure also shows a multiplication of each of the principal component vectors from the interval profile for the M th eigenphrase of the bass guitar of $n = 6$ ($1 \leq M \leq 5$) using the relative weights, where the first note is set to 0 as the initial value. To explain an example of fluctuation in note numbers, we assume the standard note is D1. The two thresholds ε_1 and ε_2 in the positive region are determined, as shown in Fig. 13. The number of thresholds is only two in this case because only E1 and F1 are higher than the standard note. The two thresholds ε_1 and ε_2 are automatically determined using even values from 0 to the maximum. Similarly, the two thresholds ε_{-1} and ε_{-2} in the negative region are also determined, as shown in Fig. 13. The list of pitch to be played is consistent with the input pattern. Then the pitch score for each note is calculated by multiplication using the principal component and relative weights. The pitch is determined by the pitch score and value of the threshold.

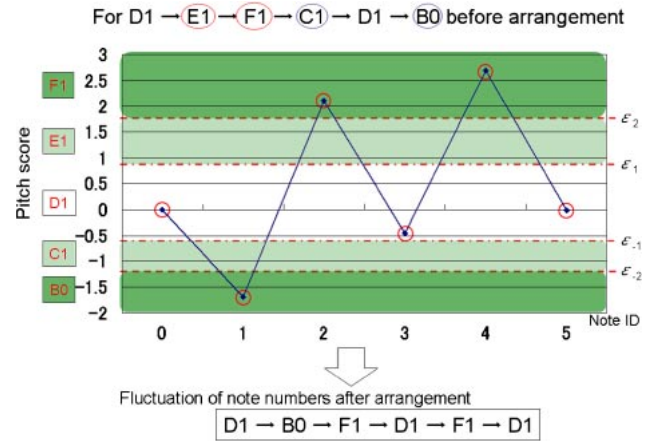


Fig. 13 Example of determining note numbers in current BGP of $n = 6$.

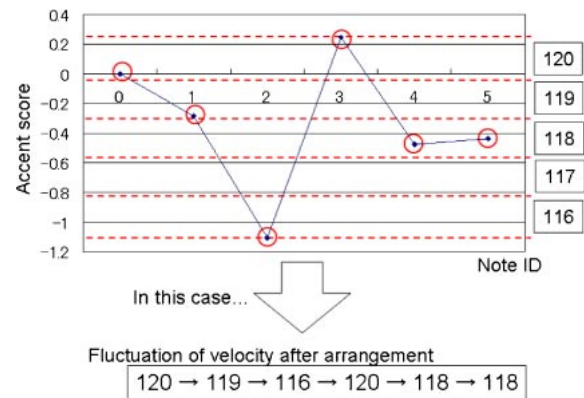


Fig. 14 Example of MIDI velocity ranging from 116 to 120 for current BGP of $n = 6$.

Variation of the generated pattern is realized by changing the relative weights.

4.3. Determining MIDI Velocity Using the Eigenphrase of Bass Guitar

The MIDI velocity for each note is determined using the dynamics profile for the eigenphrase of the bass guitar. Several MIDI velocities for the current BGP are extracted and used in the arranging method. Figure 14 shows an example of determining the MIDI velocity to be in the range from 116 to 120 for the current BGP of $n = 6$. It also shows the accent score reflecting the multiplication of each principal component vector from the dynamics profile for the M th eigenphrase of the bass guitar of $n = 6$ ($1 \leq M \leq 5$) using the relative weights, where the first note is set to 0 as the initial value. The point of the calculated maximum value determines the maximum MIDI velocity from the current BGP. Conversely, the point of the calculated minimum value determines the minimum MIDI velocity from the current BGP for arrangement. For the rest of the points, the calculated values determine the MIDI

velocities for the calculated values lying between the maximum and minimum ones.

4.4. Relative Weights

The arrangement method using the eigenphrase of the bass guitar requires several relative weights to arrange BGPs. We calculated the principal component vectors for the average phrase features of BGPs to obtain natural arrangements. More specifically, we calculated several principal component scores from the M th eigenphrase of the bass guitar for each BGP. In the future, we will be able to use the averages of these principal component scores together with the relative weights. We are currently investigating methods of arranging the bass guitar part by multiplying each of the principal component vectors by the average score weights, which would make it possible to generate similar excerpts for standard and natural BGPs. The method of using the average principal component score was named “AVE.” We used this score to calculate normally distributed random numbers; the method of using these numbers was named “NDR.” We also calculated the uniform random numbers in the range from the minimum to the maximum principal component scores; the method of using these numbers was named “RND.”

5. PERFORMANCE OF PROPOSED METHOD

5.1. Evaluation Experiment

An experiment was conducted to confirm the validity of the proposed method of automatically arranging the bass guitar part. For the experiment, ten MIDI excerpts were randomly selected from 3,097 MIDI J.Pop excerpts, from which ten pieces of 8–16 bars were extracted. The arrangement of the MIDI velocity of the bass guitar part of these pieces was controlled so that it could be listened to comfortably. The bass guitar part was arranged using the three variations of the proposed method. The subjects were asked to listen to the ten pieces four times each, once for the original and once for each of the three variations (“AVE,” “NDR,” and “RND”), i.e., forty pieces in total. They then ranked each set hierarchically across five categories: “natural,” “favorable,” “eccentric,” “stable,” and “cheerful.” “Natural” and “stable” are used for investigating the naturalness of generated patterns, “eccentric” is used for investigating whether or not generated patterns have strange or unnatural features, and “favorable” and “cheerful” are used to investigate whether or not generated patterns are acceptable to the listener’s sensibilities. Evaluation scores were obtained by using scores of 3 to 0. For example, a score of “3” in the “natural” category meant that the sound was the most natural, whereas “0” indicated least natural. Eight listeners, four of them amateur bassists and the other four non-bassists, participated in the experiment. Figure 15 outlines the evaluation experiment.

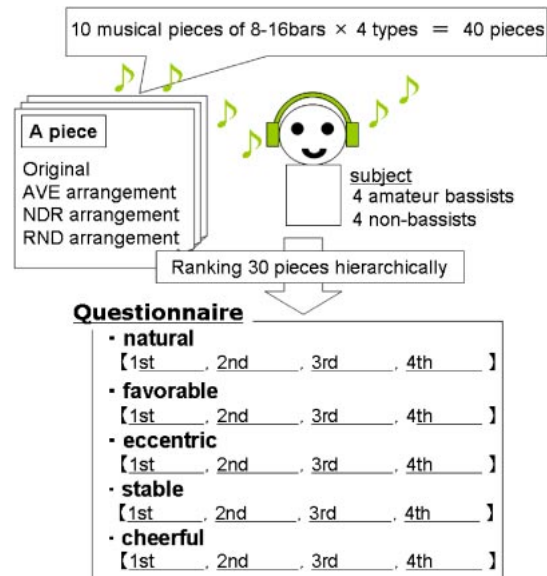


Fig. 15 Evaluation experiment outline.

5.2. Results and Discussion

Average evaluation scores were calculated for eight sets of pieces from all listeners. Figure 16 shows the average scores for “natural,” “favorable,” “eccentric,” “stable,” and “cheerful” for the three arrangement types and for the original. Using Steel-Dwass’ test, we found that in the “natural” category, the average scores for “original” and “AVE” were relatively high compared with those for the other two arrangement types. ($p < 0.05$). This indicates that one of the methods using the eigenphrase of the bass guitar exhibited good performance in terms of natural arrangement for the bass guitar part. Moreover, the same tendency was found for the categories “favorable,” “stable,” and “cheerful.” The average score for “favorable” showed a strong correlation with the case of “natural” ($r = 0.97(N = 4, p < 0.05)$), as did the average scores for “stable” ($r = 0.99(N = 4, p < 0.05)$) and “cheerful” ($r = 0.92(N = 4, p < 0.10)$). In addition, “NDR” results were higher than those of “AVE” in the average evaluation score for “eccentric.” This raises the possibility that an automatic arrangement method other than “AVE” can be used to obtain various kinds of excerpts.

6. CONCLUSION

We constructed a bass guitar pattern database (BGP-DB) by a method developed for identifying the bass guitar part from Musical Instrument Digital Interface (MIDI) excerpts comprising several instrumental parts. We also described how the eigenphrase of the bass guitar can be used to automatically arrange bass guitar parts by making use of the parts’ features.

Future work will include the consideration of methods of arranging the bass guitar part by multiplying each of the principal component vectors by user requirements (such as

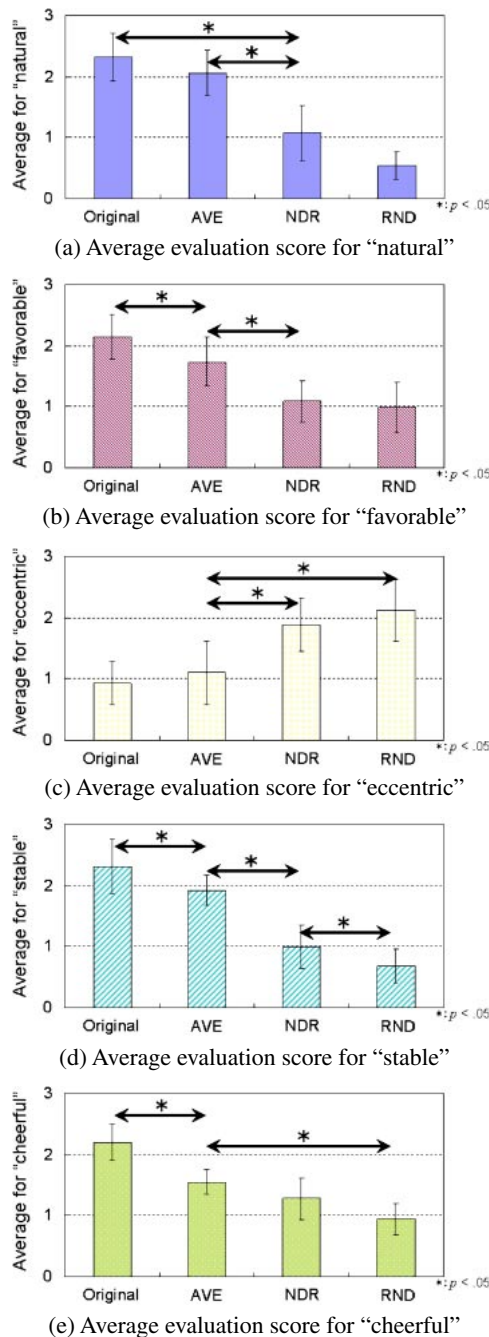


Fig. 16 Average evaluation scores.

genres and artists), thus creating a bass guitar arrangement system that satisfies those requirements. Another future work will be discussing the validity of the way of dealing with the three profiles: onset, interval and dynamics profiles. Usually the musical phrase has an interaction among the profiles, such as the onset and interval ones. Although we deal with them independently in this paper, we must confirm the validity of the proposed method.

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