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Feature extraction of bass guitar using principal component analysis

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ABSTRACT

Drums and bass guitars create rhythm in popular music. A drum pattern database including thousands of music excerpts was previously developed for investigating the tendency of constitution of drum in musical score. For the investigation of bass guitar, several studies have been done, such as estimating the fundamental frequencies (F0) of the melody or bass lines using monaural audio signals containing sounds from various instruments and focusing on the bass guitar to classify genres. However, the tendency for bass guitar in popular music using many patterns has not been investigated; therefore, the development of a database for bass guitar profiles, such as the rhythm and pitch, has not been reported. We propose an identification method for the MIDI tracks of the bass guitar from MIDI excerpts comprised of several instrumental tracks. The proposed method identifies the bass guitar part using a heuristic approach from several bass guitar players, so that an accumulation of patterns of bass guitar is obtained. Then, each one-bar length is identified as either a bass guitar part, called a "bass guitar pattern" or not. The onset, interval, and dynamics profiles are extracted from the bass guitar patterns. The onset profile represents the onset time sequence, the interval profile represents the interval for each note from the root note of the excerpt, and the dynamics profile represents the rank in value of the MIDI velocity for each note. We constructed a bass guitar pattern database comprised of these three types of profiles. We introduce several parameters for automatic arrangement, such as those from the proposed database, using principal component analysis (PCA). We call these parameters the "Eigenphrase of bass guitar". Using PCA, we extract the principal components for the "Onset profile for eigenphrase of bass guitar", "Interval profile for eigenphrase of bass guitar", and "Dynamics profile for eigenphrase of bass guitar" from the onset, interval, and dynamics profile databases, respectively. The eigenphrase for a bass guitar is a combination of the three profiles of eigenphrase of bass guitar in terms of the onset, interval, and dynamics of a bass guitar. We propose an arrangement method for the bass guitar part by multiplying each principal component vector from the eigenphrase of bass guitar with relative weights. The generated performances from automatic arrangement using the proposed method were confirmed as natural were judged by the authors as natural not artificial.

INTRODUCTION

In popular music, drums and the bass guitar have important roles in terms of rhythm. For investigating of drums, a drum pattern database using thousands of music excerpts has been developed [1]. For investigating that of the bass guitar, several studies have been reported, such as estimating fundamental frequencies (F0) of melody and bass lines using monaural audio signals containing sounds of various instruments [2] and focusing on bass guitar parts to classify music genres [3]. However, databases for analyzing the bass guitar profiles of onset and pitch have not been reported because methods have not been developed for identifying the MIDI track of the bass guitar from MIDI data.

We propose a method for identifying the track of bass guitar from MIDI excerpts comprised of several instrumental tracks because we need to automatically identify the track of bass guitar from approximately 5000 MIDI excerpts to create a database of the bass guitar part. However, the bass guitar track is possible to be one of the tracks in MIDI excerpts. So, it is required to automatically identify the track, in order to avoid manual labor of specifying. The proposed method for identify a bass guitar part employs a heuristic approach using "note-on message timing", "average value of note number", and "program change messages". Each track is then identified as either a bass guitar or not with this method, and each one-bar length contained in the track is extracted, which is called the bass guitar pattern (BGP). 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 for each note from the root note of the excerpt, and the dynamics profile represents the ranking of the MIDI velocity for each note. Therefore, the BGP database (BGP-DB) we constructed consists of these three types of profiles, and we were able to analyze the nature of BGPs by using this database. Moreover, we extracted several parameters using principal component analysis (PCA). We describe how to automatically arrange the bass guitar using these extracted parameters.

OUTLINE THIS STUDY

To identify a bass guitar in MIDI excerpts, we developeded a method for identifying the track of the bass guitar {R}. We used 3097 MIDI excerpts categorized as J-Pop (Japanese

Pop). These MIDI 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, so the proposed BGP-DB is comprised of these three types of profiles. We assume that the characteristics of a BGP can be analyzed using this BGP-DB. We also developed several parameters for automatic arrangement, such as those included in the proposed database using PCA (Principal Component Analysis). Then we will obtain eigenvecters of BGP-DB, representing the major frature of BGPs. Finally, we name the eigenvectors as “Eigenphrase of bass guitar”, which is a novel term and is expected to be able to analyze bass guitar patterns. Moreover, we propose an arrangement method for the bass guitar part using this eigenphrase. The aim of this method is the natural arrangement. Figure 1 is an outline of this study.

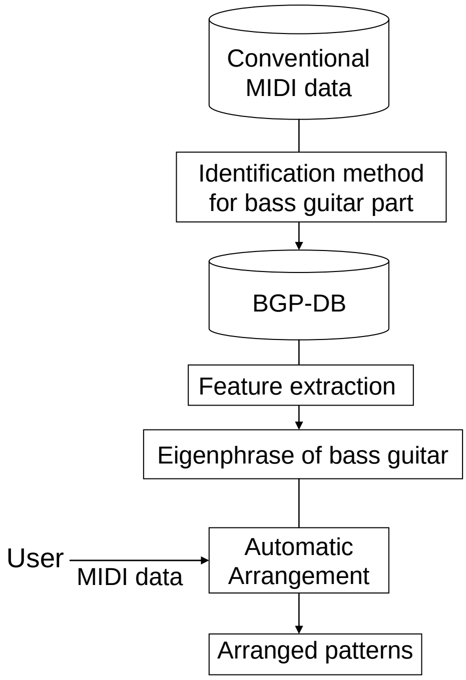


Figure 1. Outline of this study

IDENTIFICATION METHOD THE MIDI TRACK OF BASS GUITAR

Outline

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 note number of each track, such as high or low.

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

Each track has a candidate BGP score, called “bass score *S*”, calculated using the three rules for each bar. These bass scores are calculated by corresponding rules in {R}. The bass scores s_1, s_2, and s_3 correspond to each rule: R_1, R_2, and R_3. Figure 2 outlines the calculation for bass score *S*. We determined the bass guitar track from the highest average bass score *S* in the excerpt. Then, the track, in which the number of measures with sounding note is less than the average of all measures of the excerpt, is assumed as not playing the bass guitar role in this excerpt.

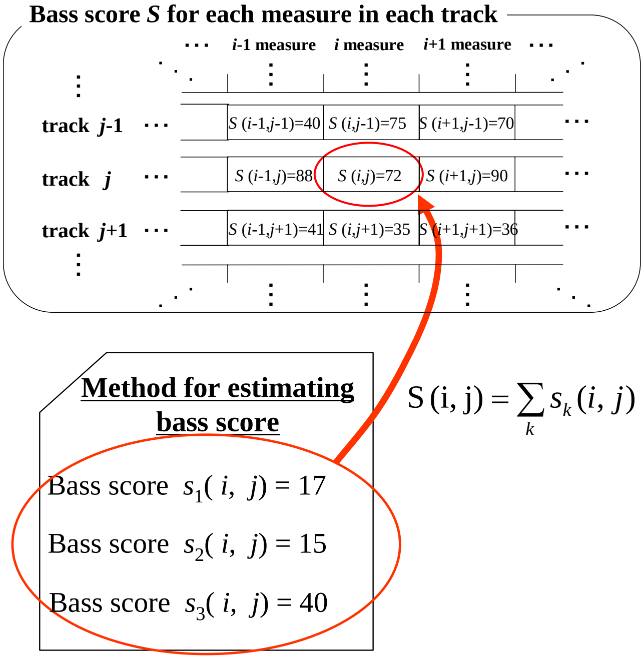


Figure 2. Calculation for bass score *S*

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, s_1 should be scored high when simultaneous notes are observed for each track in each bar, where simultaneous notes mean identical onsets of different note heights. Each track is evaluated to calculate the occurrence frequency of simultaneous notes using quantize note-on messages for each bar, where all MIDI events are quantized under a thirty-second note. The notation $c_{i,j}$ is defined as the occurrence frequency of played notes for *j*th track ($1 \leq j \leq 16$) in *i*th measure, $cmax_i$ is defined as the maximum value of $c_{i,j}$ for *i*th measure in all tracks, and max(s_1) is defined as the maximum value of all bass scores $s_1(i,j)$. Therefore, a bass score $s_1(i,j)$ is calculated as follows

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

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

R_2: criterion for average value of note number of each track, such as high or low

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

$$s_1(i, j) = \max(s_1) \times (1 - \frac{c_{i,j}}{cmax_i}) \qquad (3)$$

where $hmin_i$ is defined as the minimum value of $\overline{h}_{i,j}$ for jth track in ith measure, and $\max(s_2)$ is defined as the maximum of all bass scores $s_2(i,j)$. Therefore, a bass score $s_2(i,j)$ is calculated as

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

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

R$_3$: criterion for program change messages, presented or not, of specific timbres

The bass score s_3 is calculated for rule R$_3$ in {R}. When calculating the bass score s_3, s_3 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. A $\max(s_3)$ 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 jth track in ith bar, the bass score $s_3(i,j)$ is scored as $\max(s_3)$; otherwise, the bass score $s_3(i,j)$ 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 used program numbers for jth track in ith bar. Therefore, a bass score $s_3(i,j)$ is calculated as

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

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

Table 1. Program numbers used as bass guitar parts

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

BASS GUITAR PATTERN DATABASE

Three types profile are extracted from the BGPs: onset profile T_B, interval profile I_B, and dynamics profile V_B. Each profile is used independently to construct each database: onset profile database, interval profile database, and dynamics profile database. These databases make up the BGP-DB. Figure 3 shows the procedure for constructing the BGP-DB. This database is used to estimate three types of the eigenphrases for bass guitar. These eigenphrases are the “Onset profile for eigenphrase of bass guitar”, “Interval profile for eigenphrase of bass guitar”, and “Dynamics profile for eigenphrase of bass guitar” using T_B, I_B, and V_B.

Onset profile database

T_B in the onset profile database means the rhythm profile for on extracted BGP. This profile consists of only note-on timing and no note-off messages. There were 8621 T_B samples in the 3097 MIDI excerpts.

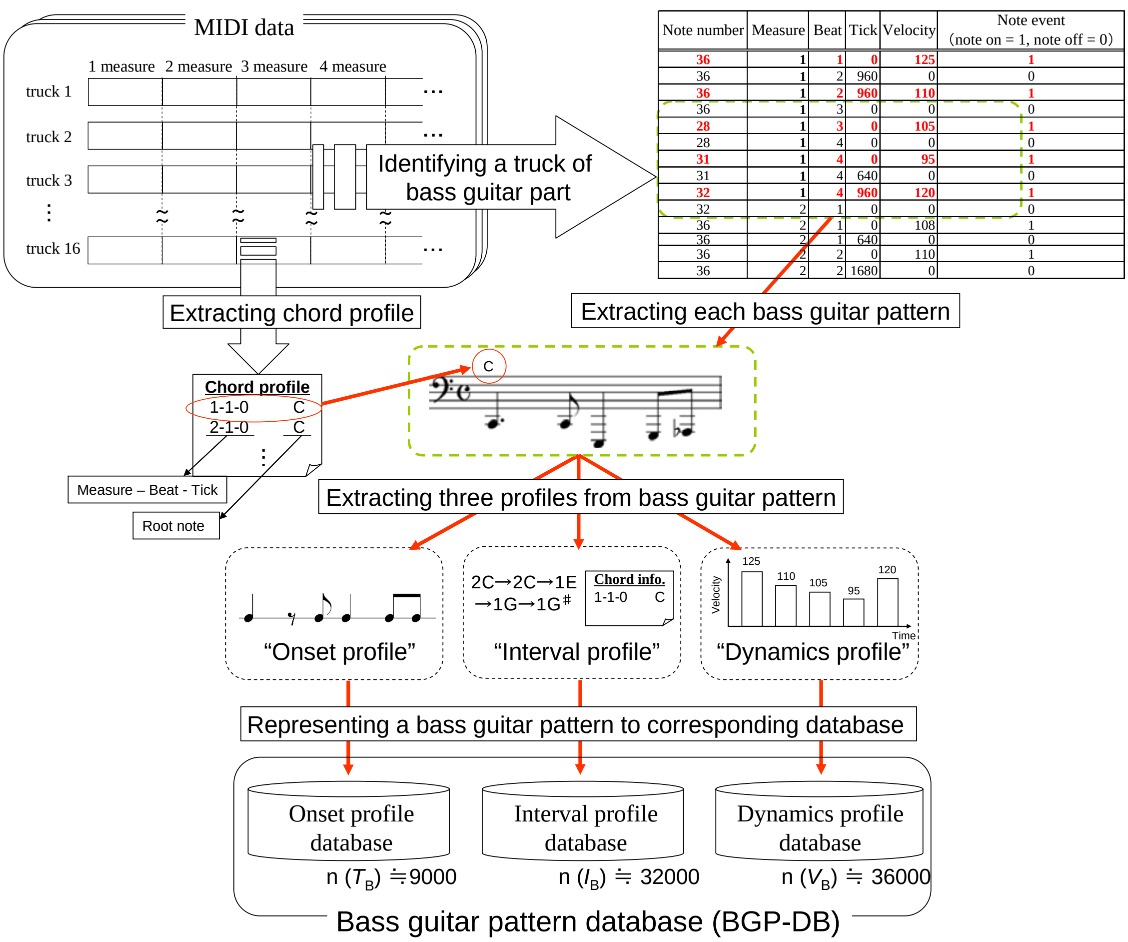


Figure 3. Procedure for constructing BGP-DB

Interval profile database

I_B in the interval profile database represents the profile of each difference between the root note and itself in note number because the pitch profile for the BGP without a chord profile is required. Therefore, the interval profile database is not constructed by the note number which means the pitch profile in the MIDI format, but the interval profile which means relative heights from the root note. I_B is represented as a value ranging from 0 to 11 for each note, so that it can represent all notes in an octave. The chord profile we used was extracted from the Sequence-Specific Meta Event of a MIDI excerpt in the XF format. Each note event in I_B was listed in the order to be performed in the interval profile database, although the time differences are not dealt with. There were 32171 I_B samples in the 3097 MIDI excerpts.

Dynamics profile database

V_B in the dynamics profile database represents an accent profile in a bar from the MIDI velocity. The V_B represents the ranking of the MIDI velocity on each bar. By using the rank score on observing a correlation between dynamics profile and the interval profiles in several BGPs, we can determine which note should be played with accent. There were 35929 V_B samples in the 3097 MIDI excerpts.

EIGENPHRASE OF BASS GUITAR

To create an automatic arrangement for the bass guitar part, we extracted the eigenphrase of bass guitar such as those given in the proposed database using PCA. We extracted three profiles for eigenphrases such as onset, interval, and dynamics of bass guitar by using T_B, I_B, and V_B, respectively. Therefore, the eigenphrase of bass guitar is a combination of these eigenphrase.

Onset profile for eigenphrase of bass guitar

The onset profile for eigenphrase of bass guitar is extracted from T_B on the BGP-DB by using PCA, where obtained onset profiles are denoted under a sixteenth note. Extracted BGPs are rarely triplet because BGPs are extracted under only the four-beat. Figure 4 shows the onset profile for eigenphrase of bass guitar for using all patterns of T_B in the BGP-DB. Notice that all the components of the second principal component of the onset profile for eigenphrase of bass guitar is positive at strong beats on eighth note for example locations of onset timings 3, 5, 7, 9, 11, 13, and 15, where each number means the ID of semiquavers of in Figure 4. 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 eighth note. Also, the third principal component of the onset profile for eigenphrase of bass guitar is both positive at anterior half and negative at posterior half in onset timing. Moreover, the principal component scores concerning the third principal component of all patterms are either positive or negative in all patterns of T_B, implying that a large number of onset timings for BGPs are located either anterior or posterior.

Figure 5 shows the cumulative contribution ratio of the onset profile for eigenphrase of bass guitar for all T_B. From the results, we can easily see that the cumulative contribution ratio forms almost a straight line because the results of T_B are mixed data of various characteristics. The characteristics of T_B are expected to be similar among several T_B when BGPs under a drum pattern are used because the correlation between the bass guitar and drums is expected to be high. We investigated another case for using the onset profile for eigenphrase of bass guitar for specified patterns, i.e., under specified bass drum patterns. The results of the cumulative contribution ratio of the eigenphrase under specified patterns for bass drum are also shown in Fig. 5. From these results, we found that the cumulative contribution ratios of the onset profile for eigenphrase of bass guitar for pecified patterns were more than 60% for from the first to the sixth principal components. When using all patterns, the cumulative contribution ratio of the onset profile for eigenphrase of bass guitar was more than 60% from the first to the seventh principal components.

We used the onset profile for eigenphrase of bass guitar with all patterns in the BGP-DB with our proposed arrangement method because of the difficulty in extarcting the onset profile for eigenphrase of bass guitar for specified patterns of each bass drum pattern for arrangement.

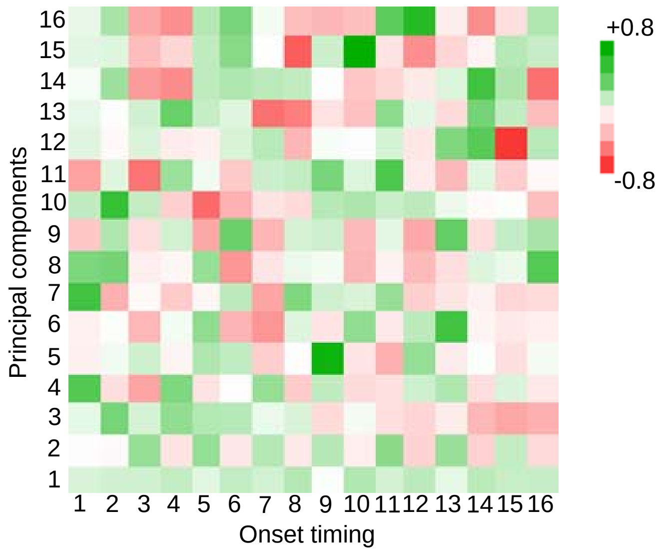


Figure 4. Onset profile for eigenphrase of bass guitar

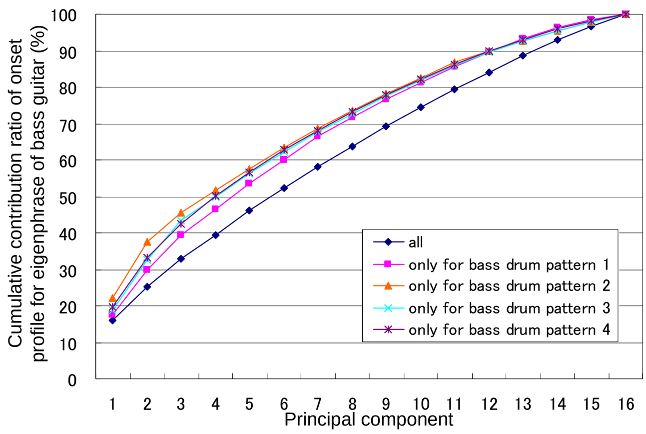
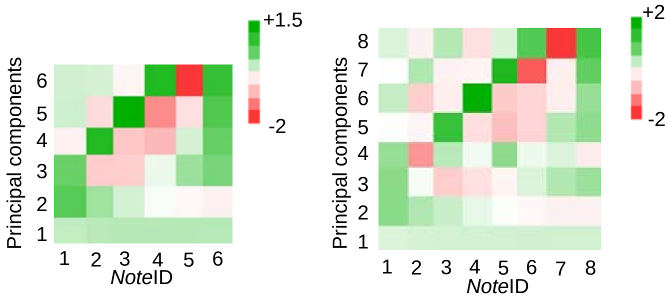


Figure 5. Cumulative contribution ratio of onset profile for eigenphrase of bass guitar

Interval profile for eigenphrase of bass guitar

The interval profile for eigenphrase of 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 being quantized under a sixteenth note because the number of notes in BGPs is different. The probability of I_B in the range from n=3 to 14 is approximately 87% for all patterns of I_B. We extracted the interval profile for eigenphrase of bass guitar for each number of notes. Therefore, we can extract the fluctuation, that is to say a musical line in pitch of a BGP. We can compare between each I_B directly, because each I_B was transposed to a consistent key among them by observing the root note for each BGP.

Figure 6 shows the interval profile for eigenphrase of bass guitar for *n*= 6 on (a) or *n*=8 on (b). The second principal component of the interval profile for eigenphrase of bass guitar for *n*=8 in Fig. 6(b) is positive at anterior (NoteID: 1~4) and negative at posterior (NoteID: 5~8). 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 in degrees of pitch. The third principal component of the interval profile for eigenphrase of bass guitar for *n*=8 in Fig. 6(b) is negative at the middle (NoteID: 3~6). Moreover, the principal component scores concerning the third 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 at anterior and falling or rising patterns at posterior in pitch.



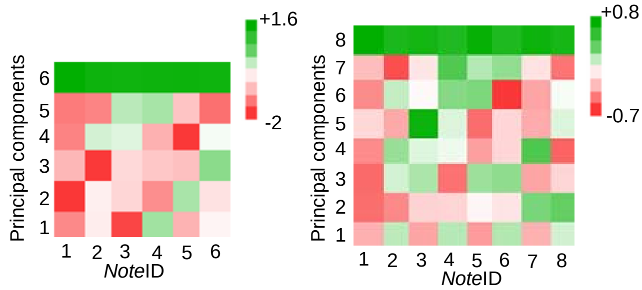
(a) Interval profile for eigenphrase of bass guitar for *n*=6. (b) Interval profile for eigenphrase of bass guitar for *n*=8.

Figure 6. Examples of interval profile for eigenphrase of bass guitar for *n*=6 or *n*=8

Dynamics profile for eigenphrase of bass guitar

The dynamics profile for eigenphrase of bass guitar is extracted for each number of notes because of the same reason for interval profile of eigenphrase of bass guitar. Therefore, extracted V_B from the BGP-DB is classified according to the number of notes. As in the interval profile for eigenphrase of bass guitar, we investigated V_B ranging from *n*=3 to 14 after being quantized under a sixteenth note because the number of notes in the BGPs is different. The probability for V_B ranging from *n*=3 to 14 is approximately more than 97% for all V_B patterns. We extracted the dynamics profile for eigenphrase of bass guitar for each number of notes. Therefore, we can extract the fluctuations in the accent of a BGP.

Figure 7 shows the dynamics profile for eigenphrase of bass guitar for *n*= 6 on (a) or *n*=8 on (b). The first principal component of the dynamics profile for eigenphrase of bass guitar *n*=8 in Fig. 7(b) is alternately positive and negative. Moreover, the principal component scores concerning the first principal component of all V_B are either positive or negative in all V_B patterns, implying that a large number of BGPs are accented alternation in sequential notes. The second principal component of the dynamics profile for eigenphrase of bass guitar for *n*=8 in Fig. 7(b) is negative at anterior (NoteID: 1~4) and positive at posterior (NoteID: 5~8). Moreover, the principal component scores concerning the second 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 by degree of MIDI velocity.



(a) Dynamics profile for eigenphrase of bass guitar for *n*=6. (b) Dynamics profile for eigenphrase of bass guitar for *n*=8.

Figure 7. Examples of dynamics profile for eigenphrase of bass guitar for *n*=6 or 8

ARRANGEMENT METHOD FOR BASS GUITAR USING EIGENPHRASE FOR BASS GUITAR

We propose a method for automatically arranging the bass guitar using the eigenphrase of bass guitar. Automatic arrangement is expected to be suitable for user requirements, and to generate natural-sounding excerpts. Although autotomatically arranging excerpts to sound natural is difficult, we believe it can be done with the proposeed method because the essential characteristics of the bass guitar extracted from the BGP-DB with a large number of MIDI excerpts, i.e., the eigenphrase of bass guitar are used. In the next section we explain the automatic arrangement method for bass guitar using the eigenphrase of bass guitar.

Automatic arrangement for bass guitar

This method uses the eigenphrase of bass guitar and its relative weights for multiplying them with obtained eigenvecters. More specifically, after feeding a MIDI excerpt for arrangement, proposed system extracts the track of bass guitar from the MIDI excerpt and extracts the onset timing and the number of notes for each measure using the onset profile for eigenphrase of bass guitar. Then, we use the method to determine each number of each note whose onset has been already determined using the interval profile for eigenphrase of bass guitar. Finally, we use the method to determine the MIDI velocity for each note by using the dynamics profile for eigenphrase of bass guitar. Figure 8 shows the automatic arrangement for the bass guitar.

In this method, we extract a BGP for each measure (four beats length) from the inputted excerpt to be arranged. First for the arrangement, we first calculated a score of to be performed of all onset timings at the sixteenth note using the onset profile for eigenphrase of bass guitar. The score means the possibility of locations for each sixteenth note. We calculated the score using the onset profile for *M*th eigenphrase of bass guitar (1<*M*<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 inputted excerpt to be arranged, according to the score for each BGP. Figure 9 shows an example ex of determining onset timing for *n*=6 for arranging the BGP.

The note number for each note is then determined using the interval profile for eigenphrase of bass guitar. The note numbers are extracted from the current BGP for arrangement. More specifically, the first note number in the BGP is determined as standard. We introduce the thresholds, which determine the range of pitch to obtain note numbers, i.e., a quantization in the height of notes. The number of thresholds of the positive region on the pitch score is determined by the number of notes that are higher than the standard. On the other hand, the number of thresholds of the negative region is determined by the number of notes that are lower than the standard. Note numbers are determined after arrangement by using these threshold values. Figure 10 shows an example of determing the note number of several notes for the current BGP of *n*=6 for arrangment under the order of as, D1, E1, F1, C1, D1, and, B0. Figure 10 also shows a multiplication of each of the principal component vectors from the interval profile for *M*th eigenphrase of bass guitar of *n*=6 (1≤*M*≤6) using the relative weights. To explain an example of fluctuation in note numbers, In this case, the standard note is D1. The two thresholds ε_1 and ε_2 in the positive region are determined, as shown in Fig. 10. The number of thresholds is only two in this case because only E1 and F1 are higher than the standard note. Similarly, the two thresholds ε_{-1} and ε_{-2} in the negative region are determined, as also shown in Fig. 10.

Finally, the MIDI velocity for each note is determined using the dynamics profile for eigenphrase of bass guitar. Several MIDI velocities for the current BGP are extracted. The arranging method uses the MIDI velocities. Figure 11 shows an example of determing the MIDI velocity for MIDI velocity ranging from 116 to 120 for a current BGP of *n*=6. Figure 11 shows the accent score in which a multiplication of each principal component vector from the dynamics profile for *M*th eigenphrase of bass guitar of *n*=6 (1≤*M*≤6) using the relative weights. The point of the calculated maximum value determines the maximum MIDI velocity from the current BGP. On the other hand, the point of the calculated minimum value determins the minimum MIDI velocity from the current BGP for arrangement. For the rest of the points, these calculated values determin the MIDI velocities for the calculated value between the maximum and minimum in the calculated value. Figure 12 shows the arrangement result, and Fig. 13 shows an example of an arrangement.

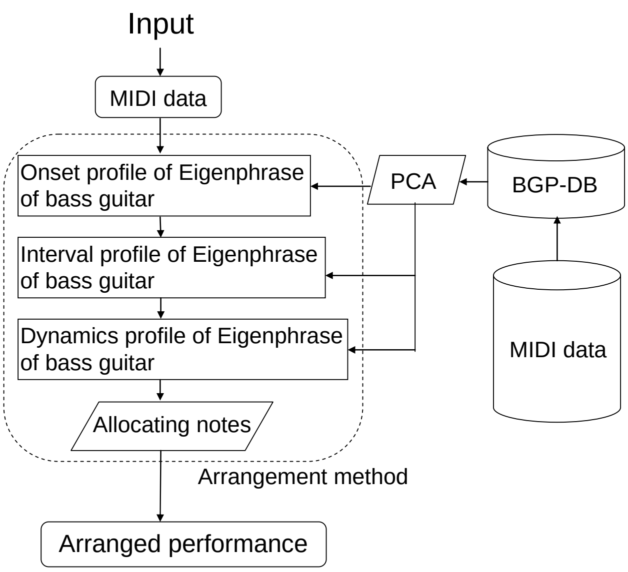


Figure 8. Automatic arrangement for bass guitar part

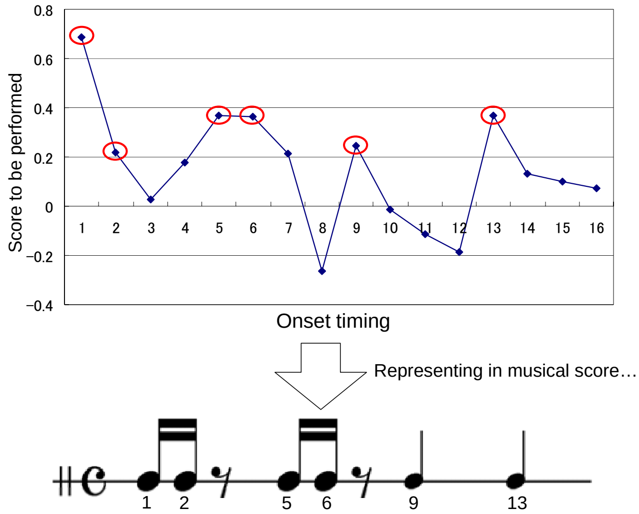


Figure 9. Example of determining onset timing for *n*=6

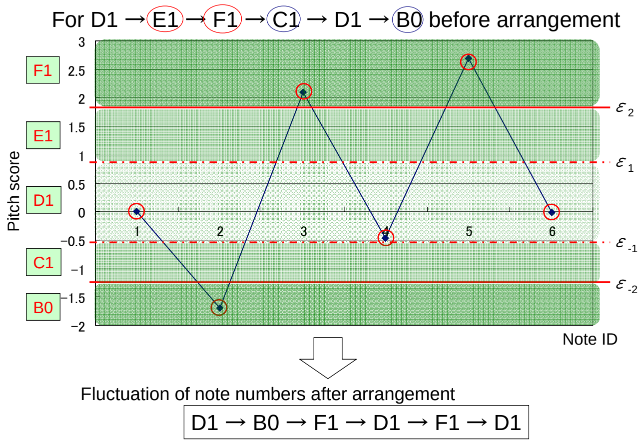


Figure 10. Example of determing note number in several note numbers for current BGP of *n*=6

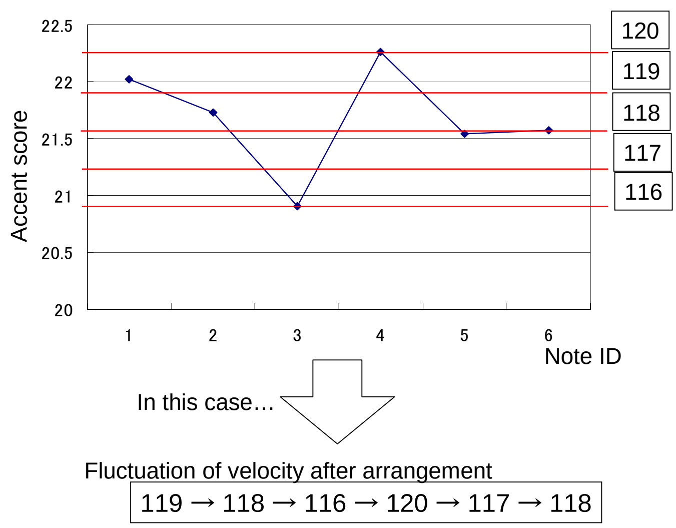


Figure 11. Example of MIDI velocity ranging from 116 to 120 for current BGP of *n*=6

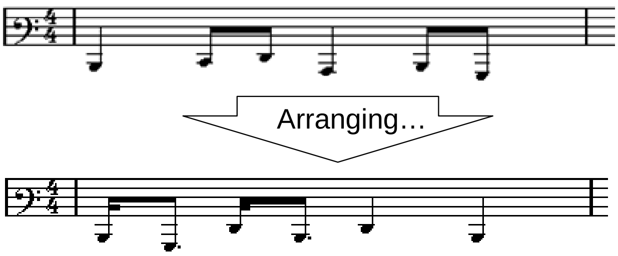


Figure 12. Result of arrangement

Figure 13. Example of arrangement in MIDI excerpt

Relative weights of several artists

The arrangement method using eigenphrase of bass guitar requires several relative weights to arrange BGPs. We calculated the principal components vector for artist features. More specifically, we extracted the BGPs for artists specified by a user, and we calculated several principal component scores from the *M*th eigenphrase of bass guitar for each of these BGPs. We will be able to use the averages of these principal component scores together with the relative weights of several artists. We are currently investigating a method for arranging the bass guitar part by multiplying each of the principal component vectors with the weights of several artists, making it possible to generate similar excerpts for specified artists. Figure 14 shows three principal component vectors for each artist feature in the interval profile for eigenphrase of bass guitar of n=8. As a result of the difference in principal component vectors for each artist feature, the relative weights of several artists would represent some implicit and/or explicit aspects of excerpts by specified artists.

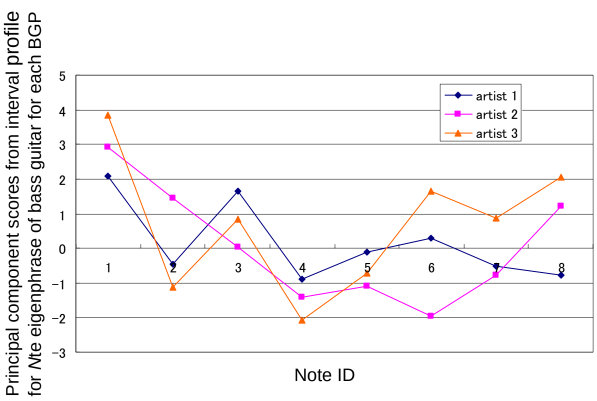


Figure 14. Three principal component vectors for feature of each artist in interval profile for eigenphrase of bass guitar of n=8

CONCLUSION

We constructed a BGP-DB using an identification method developed for the bass guitar part from MIDI excerpts comprised of several instrumental parts. We also described how to automatically arrange the bass guitar part using a feature of the bass guitar part using the eigenphrase of bass guitar.

Future work is considering methods for arranging the bass guitar part using a multiplication of each of the principal component vectors with user requirements, such as genre and artists, thus constructing a bass guitar arrangement that satisfyies these requirements.

ACKNOWLEDGMENT

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