AUTOMATIC ARRANGING MUSICAL SCORE FOR PIANO USING IMPORTANT MUSICAL ELEMENTS

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ABSTRACT

There is a demand for arranging music composed using multiple instruments for a solo piano because there are several pianists who wish to practice playing their favorite songs or music. Generally, the method used for piano arrangement entails reducing original notes to fit on a two-line staff. However, a fundamental solution that improves originality and playability in conjunction with score quality continues to elude approaches proposed by extant studies. Hence, the present study proposes a new approach to arranging a musical score for the piano by using four musical components, namely melody, chords, rhythm, and the number of notes that can be extracted from an original score. The proposed method involves inputting an original score and subsequently generating both right- and left-hand playing parts of piano scores. With respect to the right part, optional notes from a chord were added to the melody. With respect to the left part, appropriate accompaniments were selected from a database comprising pop musical piano scores. The selected accompaniments are considered to correspond to the impression of an original score. High-quality solo piano scores reflecting original characteristics were generated and considered as part of playability.

1. INTRODUCTION

Players often enjoy music while performing an instrument. However, it is typically difficult to play music that is composed using multiple instruments and vocal parts, and this is applicable to orchestral, chamber, and pop music. The main reason is that it is necessary to coordinate several individuals who can play an instrument and to adjust their schedules accordingly. Therefore, several studies have focused on support for solo playing by arranging an original score. Additionally, solo arrangements aid in playing comfortably and determining new aspects of the music. They also increase a player's motivation by playing their favorite music. Conversely, creating of an arranged score involves considerable labor and expertise. Hence, the present study investigates a problem involving an automated arrangement for a solo instrument based on music composed of multiple playing parts. Instruments that can simultaneously play the plurality of notes, such as the piano, guitar, and organ, involves various problems such as expressing impressions of original songs and considering playability. This is because an instrument that can play a plurality of notes has an extended range of expression compared with an instrument that only plays monotonic notes. This is followed by focusing on pop music as it involves music composed using multiple instruments. The study also focuses on a piano arrangement since the piano is one of the most famous instruments that generate a wide range of expressions. Therefore, the present study examines the automatic arrangement of pop music for a solo piano.

Generally, extant studies have discussed automating an arrangement for a piano from music composed of multiple parts. Fujita et al. [1] arranged an ensemble score for a piano by using a melody part and a base part that were extracted from an original score. They output piano scores corresponding to different levels of difficulty based on a user's skill level by considering a maximum musical interval and a minimum key stroke duration. Chiu et al. [2] analyzed the role of each part in an original score. The analysis resulted in generating a solo piano score by considering the preservation of original composition, maximum number of simultaneous key strokes, and maximum musical interval of each hand. Onuma et al. [3] analyzed a process of a piano arrangement used by arrangers, constructed a piano arrangement system based on specific problems that occur in the piano arrangement process, and proposed solutions for the same. When all the parts of an original score are summarized into a two-line staff, the notes leading to a problem in an arrangement are automatically detected and conveyed to a user. The choice of a solution depends on the user. Onuma et al. constructed a solo piano arrangement system corresponding to a user's performance skill. Nakamura et al. [4] considered playability based on a piano fingering model by using merged-output Hidden Markov Model. A continuous flow of notes was considered by the fingering model, and two indices were optimized, namely preservation of an original impression and playability. The problem was solved by considering simultaneous playability as well as a continuous of notes in both hands.

A common vein in previous studies involved reducing and selecting notes from an original score in a solo piano arrangement. Extant studies either used original notes directly or used octave shifts. This method prevents a piano-arranged score from dissonance and preserves an original score's impression. Additionally, they can generate a playable score by considering simultaneous playability and a time sequence of notes when notes are re-

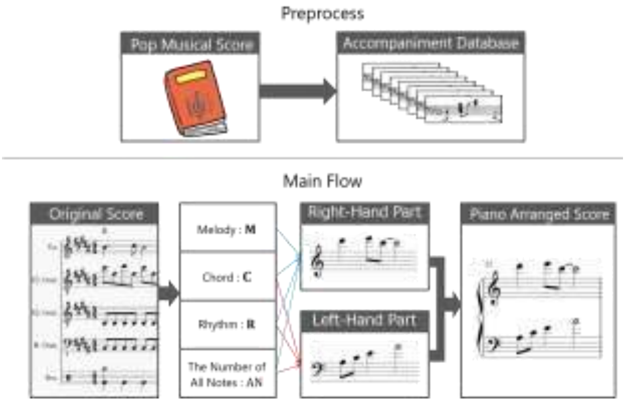

Figure 1. An overview of the proposed method. The preprocess involves constructing an accompaniment database. In the main flow, four musical components are extracted from the original musical score. Subsequently, a piano-arranged score for each hand is separately generated by using musical components. Finally, a correction is performed with respect to overlapped notes.

duced and selected. However, these still remain problems that the outputted piano-arranged score includes difficult notes to perform. A potential reason for this problem is that the definition of playability is not appropriate. Nakamura et al. [4] used a fingering model to consider playability. However, this entails considering several playability factors in addition to the simultaneous maximum number of the key strokes, simultaneous maximum musical interval, minimum duration of time between key strokes such as extension of the maximum musical interval by arpeggio, the cost of fingering, and variation in the difficulty that depends on a tempo. Therefore, it is difficult to define an appropriate restriction with respect to playability. The lack of defining an appropriate restriction of playability can generate a piano score that is not playable in specific places. Extant studies did not discuss the quality of a piano arrangement. However, a piano arrangement is not beautiful if it does not consider a continuous flow of musical sounds such as loudness of sound or change in volume. For example, two phrases, namely “A” and “B”, are involved in a music. The scores that are condensed into two-line staffs from “A” and “B” correspond to the same. Phrase “A” consists of a few instrument parts, and phrase “B” consists of several instrument parts. When piano reduction is considered, the output piano scores are not different between “A” and “B” because both condensed scores created by collecting all notes in the original score are almost the same. Therefore, it is difficult to express a continuous flow of musical sounds. Onuma et al. [3] considered this problem by analyzing a piano arrangement process that is actually performed by arrangers. However, the system is not automatic since the system requires manual corrections by a user.

The present study involves proposing a new approach to arrange a musical score for a piano. Fig. 1 shows an overview of the proposed method. When a piano-arranged score is generated, four important musical components are used, namely a melody, a chord, rhythm, and a number of notes that can be extracted from an original score as opposed to solving the problem of methods to select and delete a large number of notes in an original music score. With respect to the right part, optional notes are added from a chord to the melody. With respect to the left part, appropriate accompaniments are selected from a database that is constructed from pop musical piano scores. The generating process of each playing hand part involves preserving an original score’s impression and improving piano arrangement quality since it is based on an original rhythm and a number of notes for each measure. Rhythm is one of the most important elements of music, and a number of notes are necessary for considering transitions of a song. Additionally, the playability for the left-hand part is improved since it is based on the existing piano score.

2. CLASSIFICATION OF ARRANGING

The word “arranging” has several interpretations. Subsequently, “arranging” is classified into three classes as follows:

(1) Arranging a musical piece that cannot be played by a single instrument into one that can be played by a specific instrument.
(2) Transcribing an atmosphere of a musical piece into mainly a jazz version, a Chopin version and a rock version.
(3) Simplifying an original score which makes it easy to play.

Previous studies examined “arranging” with respect to (2) and (3) ([5-8] and [9-11]). However, there is a paucity of studies examining “arranging” with respect to (1).
The present study focuses on “Arranging” with respect to (1) and setting conditions required involving a high-quality piano arrangement in (1) as shown below:

(i) A melody line is the highest pitch in each measure.
(ii) A chord in a piano-arranged score corresponds to an original one.
(iii) An accompaniment suit for the rhythm part in an original musical piece.
(iv) A piano-arranged score reflects loudness in an original musical piece.
(v) A piano-arranged score is playable.

The reasons for setting the aforementioned five conditions are as follows. (i) The note that corresponds to the highest pitch can correspond to a melody that determines important characteristics of the music because it is more impressive when compared with other notes. Therefore, the impression of a piano-arranged score is significantly different from an original musical piece without condition (i). (ii) Dissonance occurs when a chord in the piano-arranged score does not match an original chord. Subsequently, a piano-arranged score corresponds to an uncomfortable piano-arranged score. Conditions (iii) and (iv)

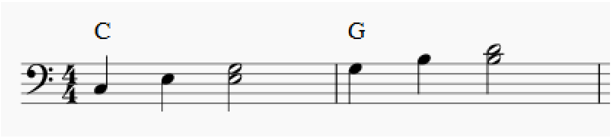

Figure 2. An example of an accompaniment.

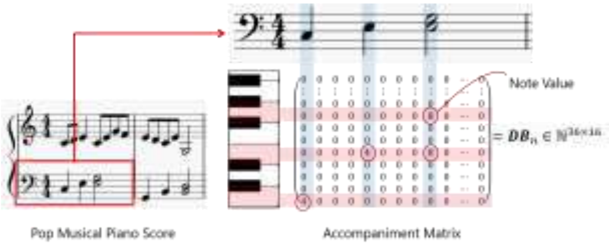

Figure 3. Construction of an accompaniment database.

correspond to the components of improving arrangement quality. (iii) A piano-arranged score becomes a closer impression of an original musical piece by reflecting the rhythm part as an accompaniment. (iv) If a piano-arranged score fulfills condition (iv), then it can express loudness including grand and delicate sounds that change based on the number of sounds of an original musical piece. (v) This condition should be satisfied since the piano-arranged score is finally played by users. In this paper, piano-arranged scores are generated with five conditions.

3. ACCOMPANIMENT DATABASE

Construction of an accompaniment database constitutes a preprocess in the proposed method. This involves considering the manner in which notes information should be treated. Fig. 2 shows an instance of an accompaniment. Each note involves information including sounding start time, pitch, and note value. At the first measure in Fig. 2, a quarter note “C” is put out at the first beat, a quarter note “E” is put out at the second beat, and half notes “E” and “G” are put out at the third beat. Similarly, at the second measure, a quarter note “G” is put out at the first beat, a quarter note “B” is put out at the second beat, and half notes “B” and “D” are put out at the third beat. Both measures completely correspond to the same sounding start times and notes value. The pitches are different in terms of a simple comparison. However, the two measures are the same at a flow of musical sounds, and the impressions generated by them are not different. This implies that the accompaniments that correspond to same sounding start time, notes value, and relative musical intervals between each note and each root note result in a similar impression. In order to reflect this fact, each accompaniment is expressed by a vector of three elements (sounding start time, a relative musical interval based on the root note, and a note value) when an accompaniment database is constructed. Sounding start time at the i-th beat is represented by $4(i-1)$. A half tone is represented by “1”. A whole note is represented by 16. With respect to the above rules of representations, both the measures in Fig. 2 are represented by (0, 0, 4), (4, 4, 4), (8, 4, 8), (8, 7, 8), and they correspond to the same meaning. Subsequently, this vector is rewritten as a matrix that represents relative information including row direction as time, column direction as pitch, and value as note value for each measure. In this study, this matrix is termed as an accompaniment matrix. A left part of a piano-arranged score is created from the accompaniment matrix by providing a root note as absolute information. The process is described in detail in section 5. 2.

Figure 4. Rhythm extraction from an original music.

Fig. 3 shows the process of constructing an accompaniment database. The left part in a pop musical piano score is divided into a measure. Each measure of an accompaniment is stored as an accompaniment matrix that corresponds to 36 rows and 16 columns. The size of rows corresponds to the number of keys in three octaves, and the size of columns corresponds to the maximum number of notes that can be set notes in a time direction. The creation of an accompaniment matrix involves setting a root note on the bottom row of the accompaniment matrix. For example, a root note at the accompaniment surrounded by a red rectangle line in Fig. 3 corresponds to “C”. The pitch of the first note also corresponds to “C”. The musical interval between the root note and the pitch of the first note corresponds to “0” at the first beat, and thus a note value “4” is set at the bottom left of the accompaniment matrix. The other notes are stored in a manner similar to the first note. In this study, the accompaniment database consists of pop musical piano scores which appear in the website [12]. The accompaniment database involves 285 different patterns in total.

4. EXTRACTION OF MUSICAL COMPONENTS

The proposed method uses four musical components, namely melody **M**, chord **C**, rhythm **R**, and the number of all notes AN. The variables $\mathbf{M}_i$, $\mathbf{C}_i$, $\mathbf{R}_i$, and AN_i represent each musical component with respect to the i-th measure. The melody $\mathbf{M}_i$ is obtained from a vocal score of the original music and is expressed as an 88×16 matrix. The study focuses on a phrase corresponding to a vocal part. A chord is represented by a root note that corresponds to a fundamental note and a chord type that indicates constituent notes of the chord. For example, “CM7” indicates that “C” represents a root note and “M7” represents a type of major 7th. The chord $\mathbf{C}_i$ is obtained from the original chord that is written in the original score. A chord is generally composed in the most popular music genres. This involves measures in which a chord is changing. In order to consider this case, the measure is divided into four blocks, and chords of the original music are assigned to each block of $\mathbf{C}_i$. If there is

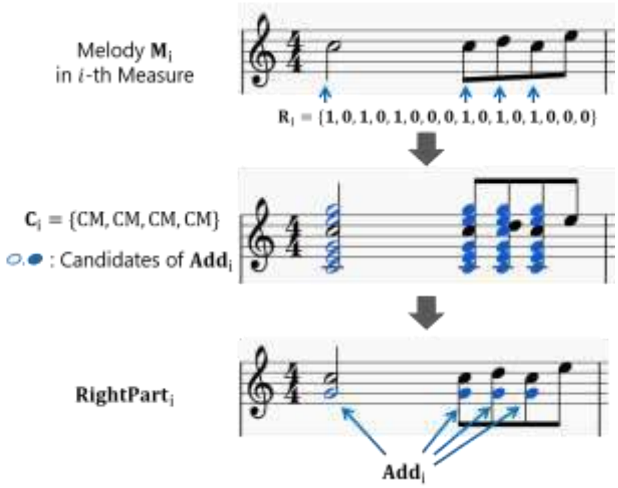

Figure 5. The process of generation in the right-hand part.

a music that is not written as chords, then the information in the chords can be extracted by using a web service "Songle" [14]. Rhythm $\mathbf{R}_i$ is extracted from the rhythm part that is designated by a user from an original musical score. Fig. 4 shows the process of rhythm extraction. In this case, the bass guitar is designated as the rhythm part. The rhythm $\mathbf{R}_i$ is represented as a 16-dimension vector. When the i-th measure of the rhythm part is divided into 16 blocks, the integer corresponding to "0" or "1" is stored in each element of $\mathbf{R}_i$. The "0" implies that there are no notes in the block, and "1" implies that there are one or a few notes in the block. The number of all notes AN_i corresponds to the sum of the number of all notes in the i-th measure. The maximum value of AN_i is set as "1" to normalize.

5. GENERATION OF PIANO -ARRANGED SCORE

5.1 Right-Hand Part

Fig. 5 shows the process of generation in the right-hand part. The process is performed with respect to a measure with a note number AN_i that exceeds a threshold $\phi\ (0 < \phi < 1)$ set by a user. This parameter is introduced to provide an impression of thick sound at a measure that involves several notes in the original score. A matrix $\mathbf{RightPart}_i$ is set as the right-hand part in the i-th measure. Thus, $\mathbf{RightPart}_i$ is given as follows:

$$\mathbf{RightPart}_i = \mathbf{M}_i + \mathbf{Add}_i(\mathbf{R}_i, \mathbf{C}_i, \mathrm{AN}_i) \qquad (1)$$

where $\mathbf{Add}_i$ denotes a function that selects an additional note. The algorithm of additional note selection involves three steps. The first step involves obtaining high accent blocks from $\mathbf{R}_i$. The second step involves determining candidates for an additional note to consider a chord $\mathbf{C}_i$ at high accent blocks. The final step involves selecting an additional note that is lower than the melody such that it does not disturb the melody. The operation satisfies conditions (ii) and (iv) that are related to a high-quality piano arrangement as discussed in section 2.

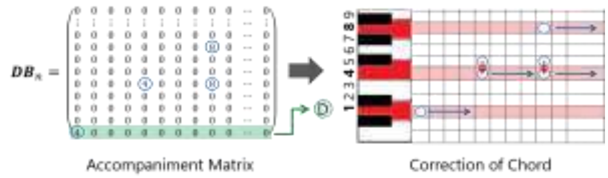

Figure 6. Harmonization process of the generation of the left-hand part from the accompaniment matrix.

5.2 Left-Hand Part

The left-hand part is generated by selection from the accompaniment database based on Dist_i that corresponds to the distance between an original song and arrangement. Following the selection, the selected accompaniment is harmonized based on $\mathbf{C}_i$. A matrix $\mathbf{LeftPart}_i$ is set as the left-hand part in the i-th measure. The left-hand part and distance function are as follows:

$$\mathbf{LeftPart}_i = \mathbf{Hrm}(\arg\min \mathrm{Dist}_i(\mathbf{DB}), \mathbf{C}_i) \qquad (2)$$

$$\mathrm{Dist}_i(\mathbf{DB}_n) = \omega_{AN} \times |\mathrm{DBAN}_n - \mathrm{AN}_i| + \omega_R \times \sum_{j=1}^{16} |\mathbf{DBR}_{n,j} - \mathbf{R}_{i,j}| \qquad (3)$$

where $\mathbf{Hrm}$ denotes a function of giving original chords, $\mathbf{DB}$ denotes an accompaniment database, $\mathbf{DB}_n$ denotes the n-th accompaniment matrix, and DBAN_n denotes the number of values that are stored as "1" in $\mathbf{DB}_n$. Furthermore, ω_{AN} and ω_R represent the weights. The weights are introduced to adjust a balance between the degree of a number of notes and rhythm. Moreover, Dist_i denotes a function that evaluates the similarity between each accompaniment and an original musical score. The maximum value of DBAN_n is set as "1" to normalize. Additionally, $\mathbf{DBR}_n$ corresponds to a rhythm of $\mathbf{DB}_n$ and is represented as a 16-dimension vector in a manner similar to $\mathbf{R}_i$ in section 4. The j-th component of $\mathbf{DBR}_n$ is stored as "1" if there is a number of other than "0" in j-th column of $\mathbf{DB}_n$. It is stored as "0" if the all components in j-th column of $\mathbf{DB}_n$ are "0". The process selects an accompaniment matrix that minimizes $\mathrm{Dist}_i$and satisfies conditions (ii) and (iii) that relate to a high-quality piano arrangement as discussed in section 2.

The selected accompaniment matrices are represented as relative information. Subsequently, it is necessary to harmonize these accompaniments. Fig. 6 depicts the harmonization process. For example, an accompaniment matrix is output as a chord "Dm" as shown in Fig. 6. First, the bottom row of the matrix is set on root note "D", and the other components are translated based on the root note in a similar manner. The chord pattern "m" denotes "minor". When the root note first pitch is set, then "minor" includes the fourth and eighth pitch. However, there are a few notes that are not on the chord “Dm” when notes are simply translated based on the root note. In this case, the notes are relocated to the nearest constituent notes of the chord “Dm”.

It is considered that the generated left-hand part score is playable since it comprises an existing piano-arranged score. If the existing piano-arranged score is playable, then the selected accompaniment in the database is also playable. The process of left-hand part generation satisfies condition (v) that relates to a high-quality piano arrangement as discussed in section 2.

5.3 Correction

There is a possibility of overlapping with respect to the notes of the right- and left-hand parts if each part generated in sections 5. 1 and 5. 2 are simply combined. In this case, the problem is solved by reducing either the right-hand or left-hand part. However, the method of reduction results in a few problems. For example, the impression of a piano-arranged score departs from an original score because the accent becomes weaker due to the reduction of notes. Therefore, this problem is solved by relocating an overlapped note in the left-hand part to the nearest constituent note that is lower than the overlapped note. This operation enables the generation of a playable piano-arranged score by preserving an original impression. This process satisfies conditions (ii), (iv), and (v), which are related to a high-quality piano arrangement as discussed in section 2.

6. RESULT AND EVALUATION

Three pop music songs for a solo piano were arranged by using the proposed method, and the quality and playability of the arranged scores were evaluated. The correlation between the value of the distance function Dist_i and subjective evaluation was calculated. This ascertained as to whether the distance function Dist_i is appropriate for reflecting the quality of the piano arrangement. The study also involved investigating as to whether a generated piano score is playable with respect to a piano player’s evaluation. The songs used in the study included “*Zenzenzense*” by RADWIMPS, “*Senbonzakura*” by Kurousa-P and “*Sugar Song and Bitter Step*” by UNISON SQUARE GARDEN. Each score as an input was obtained from the website [15], and the base part was set as the rhythm part. Thresholds ϕ was set and corresponded to 0.86 for “*Zenzenzense*”, 0.83 for “*Senbonzakura*”, and 0.63 for “*Sugar Song and Bitter Step*”.

The correlation between the value of Dist_i and subjective evaluation was evaluated by calculating Spearman's rank correlation coefficient. The subjective evaluation was performed by eight evaluators including individuals who can play an instrument. Piano-arranged scores with values of Dist_i corresponding to minimum, median, and maximum were generated. Thus, there are three patterns of piano-arranged scores ranging from the worst arrangement to best arrangement. The evaluators randomly listened to the fore-mentioned three patterns of arrangement quality and evaluated the same by using the following indexes.

	Arithmetic mean of ρ	variance of ρ	Subjective evaluation	
			Our method	Arranger
Zenzenzense	0.59	0.19	5.4	5.8
Senbonzakura	0.44	0.39	5.7	—
Sugar Song and Bitter Step	0.34	0.43	5.6	—

Table 1. Spearman’s rank correlation coefficient ρ and subjective evaluation value.

Figure 7. The original score of “RWC-MDB-P-2001 No. 5”.

Figure 8. The results of the piano arrangement.

1 : extremely low quality.
2 : moderately low quality.
3 : slightly low quality.
4 : neither low nor high quality.
5 : slightly high quality.
6 : moderately high quality.
7 : extremely high quality.

The subjective order was set, and it was sorted in the descending order of indexes set by evaluators. Additionally, the distance values corresponding to the ranking values of Dist_i were set in an ascending order. This is followed by calculating Spearman’s rank correlation coefficient ρ between subjective order and distance order. Additionally, the process also involved calculating the arithmetic mean and variance of ρ. Furthermore, “*Zenzenzense*” that corresponds to a piano-arranged score composed by a professional arranger [12] is also evaluated and compared with the best arrangement generated by the proposed method. The result of the evaluation is shown in Tab. 1. With respect to the playability, two individuals who could play the piano evaluated the same by playing the best piano-arranged score in the proposed method. The obtained results corresponded to views that suggested that there are a few difficult points although an unplayable point does not exist.

A part of "RWC-MDB-P-2001 No. 5" recorded in the RWC Music Database is shown as an example of the result [16]. The original score is shown in Fig. 7, and the results of piano arrangement are shown in Fig. 8. The bass part is set as the rhythm part, and the threshold ϕ is set as 0.5. Fig. 8 shows scores (a), (b), and (c) in ascending order of the values of Dist_i.

7. CONSIDERATIONS

The results confirmed that correlations existed between Dist_i and subjective evaluations based on the result of Spearman's rank correlation coefficient. Specifically, with respect to "*Zenzenzense*", the variance is lower than that of the others, and a strong positive correlation exists. It is assumed that rhythm is significantly involved in this result. The piano arrangement of "*Senbonzakura*" involves a rhythm that is a slightly different from that of the original without discomfort since the original rhythm is simple, and thus it is easier to fit any rhythms. Consequently, it is considered that a piano arrangement score that is slightly different from an original score also corresponds to a high-quality piano arrangement. With respect to "*Sugar Song and Bitter Step*", it is difficult to determine an optimum accompaniment from the accompaniment database since the rhythm of the original song is quite complicated. With respect to the rhythm perspective in "*Zenzenzense*", an optimum accompaniment could be selected because the original song of "*Zenzenzense*" involves a moderately complex rhythm. With respect to the calculation of the similarity of rhythm, a more appropriate selection of accompaniment is expected by applying different weights to each beat based on the importance of beats such as strong beats and weak beats. With respect to the quality of a piano arrangement, all songs are evaluated well generally. The piano-arranged score with the proposed method corresponded to approximately 93% of the performance relative to arrangements by a professional arranger. Two evaluators indicated that the piano-arranged score with the proposed method was better than the piano arrangement by a professional arranger. In conclusion, the results confirmed the usefulness of the proposed method.

With respect to the playability, unplayable parts were not revealed since published scores were used for the left-hand part. If the published scores are playable, then a generated left-hand score is also playable. However, the evaluators indicated that there were some parts that were not easy to play. Thus, it was assumed that the right-hand part that includes added notes to the melody is not considered with respect to playability in the proposed method. Therefore, this problem can be solved by considering the continuous of the notes.

8. CONCLUSIONS

In this paper, a piano-arranged score is generated by using four musical components extracted from an original score. Furthermore, the study involved defining five conditions necessary for a high-quality piano arrangement. Subsequently, the piano arrangement process is based on the five conditions. The proposed method involves constructing an accompaniment database in the form of accompaniment matrices. The right-hand part is generated by adding notes of a chord. The left-hand part is generated by selection from the accompaniment database and harmonizing the selected accompaniments. Finally, the right-hand part and the left-hand part are combined with the correction of overlapping notes.

The proposed method highlights a novelty of the piano arranging process. Previous studies used all the information in each part. The generated piano-arranged scores are directly affected by the original score. In contrast, the present study involved generating a piano-arranged score by using musical components that are abstracted from musical scores. Therefore, it is easy to generate a piano-arranged score from acoustic signals. A future study will involve generating a piano-arranged score from original acoustic signals. Additionally, future research will examine the construction of an accompaniment database divided into difficulty levels. It will also explore generating a piano-arranged score with respect to difficulty levels. Furthermore, future study aims also include increasing musical components of a database to select an appropriate accompaniment.

Acknowledgments

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