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A feature exaggeration system for basic piano performance with extracted performance parameters

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1. Introduction

The piano is one of the most popular musical instruments. In recent years, low-price keyboard instruments, such as MIDI pianos, have become available, making it easy for people to practice the piano. However, it is not always easy to obtain instruction by experts, resulting in many people giving up practicing the piano. To improve this situation, as well as several studies for piano training systems [1–3], we have proposed a method of automatically evaluating the skill level and appropriateness of scale performances of one octave [4].

In our previous study, an evaluation method based on onset time, velocity, and duration for the MIDI representation was proposed for the performance of scales on the piano, in which several parameters to evaluate the given performance were introduced. The proposed parameters were those expressing the tendencies of a given performance in terms of the above three basic features. The parameter set consisted of 15 parameters, among which 12 were three sets of four parameters. In our previous study, actual performance was modeled as the sum of a global curve and the deviation from it, where the spline interpolation was employed using locally averaged points, or representative points to be passed. Automatic evaluation of the skill level and evaluation of individual scale performance on the piano were investigated in this study using these 15 parameters. The musical score shown in Fig. 1 represents a task of scale performance and the number below each note represents a finger on the right hand.

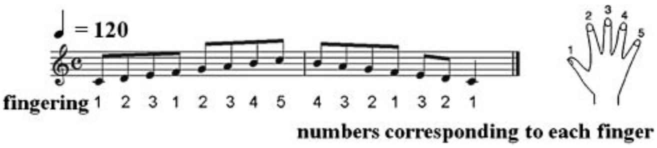

Fig. 1 An example of a musical score used to evaluate scale performance within one octave (key: C Major).

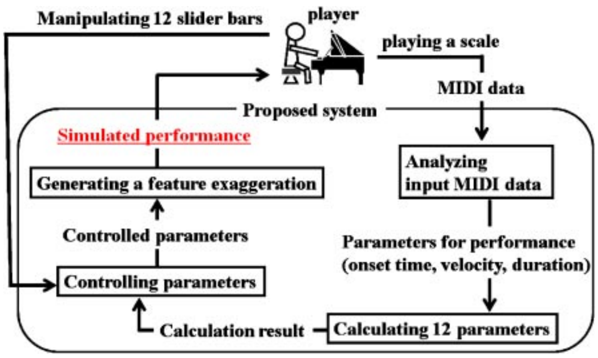

Fig. 2 An overview of the proposed system.

2. Outline of this paper

In this paper we aim to develop a feature exaggeration system for scale performance on the piano by modifying the performance parameters of the original performance. The features of performance can be exaggerated by controlling the feature parameters proposed in the previous paper. Concretely speaking, the difference between the global curve and the performance is controlled by modifying the performance parameters. The expression of performance can be exaggerated by a method similar to morphing techniques. We propose a system that synthesizes a performance that can be varied from "suppressed" to "exaggerated" by manipulating a slider bar on a screen. The proposed system is expected to support practice on the piano for a beginner or even for experts, because players are able to easily recognize their own style of playing and weak points. An overview of the proposed system is shown in Fig. 2.

3. Proposed method

3.1. Details of each parameter

A simulated performance is generated by controlling 12 parameters that distinguish three basic features: onset time, velocity, and duration. These parameters are denoted as p_{ij}, where the suffix i indicates onset time ($i = t$), velocity ($i = v$), or duration ($i = d$) and the suffix j indicates, the srss (square root sum of squares) of the deviations from the spline curve to

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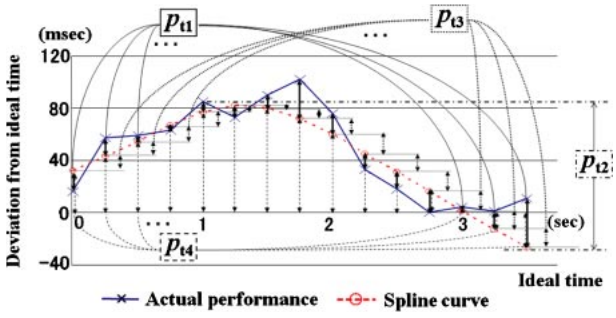

Fig. 3 The parameters used to describe onset time.

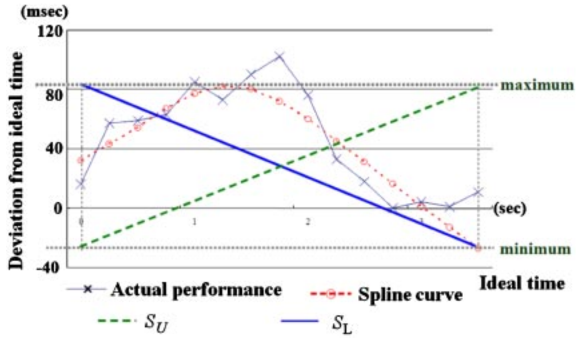

Fig. 4 The standard straight line.

the actual performance ($j = 1$), the range of the spline curve ($j = 2$), the srss of the differences in note height between successive notes on the spline curve ($j = 3$), or the sum of the deviations from the metronomic line to the spline curve ($j = 4$). A graph illustrating the onset time parameters used to generate the simulated performance is shown in Fig. 3 and a detailed formulation is given below, where t is the ideal onset time, t' is the actual onset time, $\hat{t'}$ is the interpolated time on the spline curve, t'' is the difference between actual onset time and the interpolated time on spline curve, and n is the total number of notes.

$$t'' = t' - \hat{t'} \tag{1}$$

(1) The parameter p_{t1} is defined as the srss of the deviations from the spline curve to the actual performance, and is expressed as

$$p_{t1} = \sqrt{\sum_{k=1}^{n} (t''_k)^2}. \tag{2}$$

(2) The parameter p_{t2} is defined as the range of the spline curve, and is expressed as

$$p_{t2} = \max(\hat{t'}) - \min(\hat{t'}). \tag{3}$$

(3) The parameter p_{t3} is defined as the srss of the differences between successive notes on the spline curve, and is expressed as

$$p_{t3} = \sqrt{\sum_{k=2}^{n} (\hat{t'_k} - \hat{t'_{k-1}})^2}. \tag{4}$$

(4) The parameter p_{t4} is defined as the sum of the deviations from the ideal, or metronomic time to the interpolated time on the spline curve, and is expressed as

$$p_{t4} = \sum_{k=1}^{n} \hat{t'_k}. \tag{5}$$

3.2. Controlling p_{t1}

The parameter p_{t1} is defined as the srss of the deviations from the spline curve to the actual performance. Thus, p_{t1} is controlled by manipulating the difference between the spline curve and the recorded performance of each note. Parameter C_{t1} represents the factor by which p_{t1} is changed ($0 \le C_{t1} \le 2$). $\tilde{t_1}$ denotes the exaggeration parameter for p_{t1}, where

$$\tilde{t_1} = \hat{t'} + C_{t1}(t' - \hat{t'}). \tag{6}$$

C_{ij} can be controlled by slider bars in the proposed system.

3.3. Controlling p_{t2}

The parameter p_{t2} is defined as the range of the spline curve. Thus, p_{t2} is controlled by manipulating the control value of the range calculated from the spline curve. M represents the control value of the range of the spline curve. The parameter C_{t2} represents the factor by which p_{t2} is changed ($0 \le C_{t2} \le 2$). $\tilde{t_2}$ denotes the exaggeration parameter for p_{t2}.

$$M = \frac{\max(\hat{t'}) + \min(\hat{t'})}{2} \tag{7}$$

$$\tilde{t_2} = \begin{cases} M + C_{t2}(\hat{t'} - M) & (\hat{t'} > M) \\ M - C_{t2}(M - \hat{t'}) & (\hat{t'} < M) \end{cases} \tag{8}$$

3.4. Controlling p_{t3}

The parameter p_{t3} is defined as the srss of the differences between successive notes on the spline curve. To control p_{t3} independently from other parameters, we must introduce a standard straight line, representing the minimum value of p_{t3} on the spline curve for a given value of p_{t2}. Thus, p_{t3} is controlled by manipulating the difference between the spline curve and a standard straight line that connects the maximum and minimum points. A linearly increasing straight line is denoted as S_U and a linearly decreasing straight line is denoted as S_L, both of which are defined below. The straight line in which the sum of the differences between the interpolated time on the spline curve and corresponding time on itself is smaller than the other straight line is assumed to be the standard, which means 0% (see Eqs. (9), (10), and Fig. 4). In the case shown in Fig. 4, the standard straight line is assumed to be S_L. The parameter C_{t3} represents the factor by which p_{t3} is changed ($0 \le C_{t3} \le 2$). $\tilde{t_3}$ denotes te exaggeration parameter for p_{t3}.

$$S_U(x) = \frac{(\max(\hat{t'}) - \min(\hat{t'}))}{n-1} x + \min(\hat{t'}) \tag{9}$$

$$S_L(x) = \frac{(\min(\hat{t'}) - \max(\hat{t'}))}{n-1} x + \max(\hat{t'}) \tag{10}$$

Table 1 An example of exaggerating and suppressing the feature of onset time.

Value of Ctj	$\tilde{t_1}$	$\tilde{t_2}$	$\tilde{t_3}$	$\tilde{t_4}$
0	Exactly on the spline curve. $\tilde{t_1} = \hat{t'}$	Dynamic range of the exaggerated performance is suppressed to 0. $\tilde{t_2} = M$	Exactly on the standard straight line. $\tilde{t_3} = \begin{cases} S_U \\ S_L \end{cases}$	Exaggerated performance is made Exactly the same as the metronomic performance. $\tilde{t_4} = 0$
0.5	The midpoint between the spline curve and the actual performance. $\tilde{t_1} = (t' + \hat{t'})/2$	Dynamic range of the exaggerated performance is set to half that of the actual performance. $\tilde{t_2} = \begin{cases} M + (\hat{t'} - M)/2 & \hat{t'} > M \\ M - (M - \hat{t'})/2 & \hat{t'} < M \end{cases}$	The midpoint between the spline curve and the standard straight line. $\tilde{t_3} = \begin{cases} (\hat{t'} + S_U)/2 \\ (\hat{t'} + S_L)/2 \end{cases}$	Difference of the exaggerated performance from the metronomic curve is halved. $\tilde{t_4} = \frac{1}{2} \times \frac{1}{n} \sum \hat{t'}$
1	Exactly on the actual performance. $\tilde{t_1} = t'$	Dynamic range of the exaggerated performance is set to be exactly the same as the actual performance. $\tilde{t_2} = \hat{t'}$	Exactly on the spline curve. $\tilde{t_3} = \hat{t'}$	Difference of the exaggerated performance from the metronomic curve is made to be the same as the spline curve. $\tilde{t_4} = \frac{1}{n} \sum \hat{t'}$
2	Difference of the spline curve from the actual performance is doubled. $\tilde{t_1} = 2t' - \hat{t'}$	Dynamic range of the exaggerated performance is doubled. $\tilde{t_2} = \begin{cases} M + 2(\hat{t'} - M) & \hat{t'} > M \\ M - 2(M - \hat{t'}) & \hat{t'} < M \end{cases}$	Difference of the spline curve from the standard straight line is doubled. $\tilde{t_3} = \begin{cases} 2t' - S_U \\ 2t' - S_L \end{cases}$	Difference of the spline curve from the metronomic line is doubled. $\tilde{t_4} = \frac{2}{n} \sum \hat{t'}$

$$\tilde{t_3} = \begin{cases} S_L + C_{t3}(\hat{t'} - S_L) & \left(\sum |S_L - \hat{t'}| < \sum |S_U - \hat{t'}|\right) \\ S_U + C_{t3}(\hat{t'} - S_U) & \left(\sum |S_L - \hat{t'}| > \sum |S_U - \hat{t'}|\right) \end{cases} \tag{11}$$

3.5. Controlling p_{t4}

The parameter p_{t4} is defined as the sum of the deviations from the metronomic line of the spline curve. Thus, p_{t4} is controlled by manipulating the average difference between the spline curve and the metronomic line. The parameter C_{t4} represents the factor by which p_{t4} is changed ($0 \le C_{t4} \le 2$). $\tilde{t_4}$ denotes the exaggeration parameter for p_{t4}, where

$$\tilde{t_4} = \frac{C_{t4}}{n} \sum \hat{t'}. \tag{12}$$

An example of exaggerating and suppressing the feature of onset time is shown in Table 1.

4. Proposed system

The proposed system analyzes performances recorded as MIDI data, and gives the parameters for onset time, velocity, and duration: therefore, 12 parameters are calculated. Users can control their performance by changing the calculated parameters by manipulating the corresponding slider bars. The proposed system generates a simulated performance based on the parameters controlled by the user and presents it to the user. Therefore, the user can listen to the exaggerated performance, and can easily confirm his/her style of playing and/or weak points. A screenshot of the proposed system is shown in Fig. 5. The proposed system has three windows: a main window, a slider bar window, and a graph window. As shown in Fig. 5(a), the main window has several facilities such as a virtual metronome, the recording of MIDI data, the automatic evaluation of a performance, and the simulation of performance. As shown in Fig. 5(b), the slider bar window enables the control of the 12 parameters. As shown in Fig. 5(c), the graph window shows the results of exaggerating

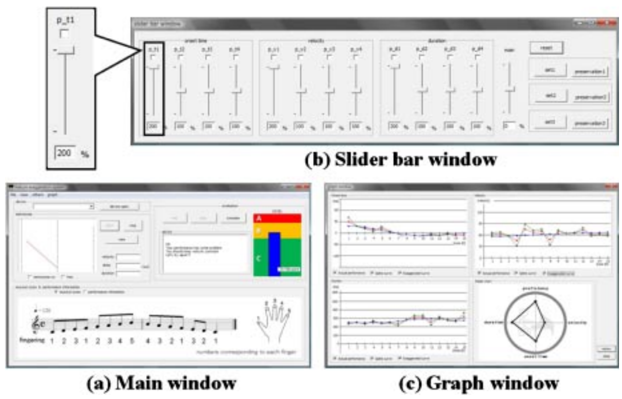

Fig. 5 A screenshot of the proposed system.

a feature of performance. Each slider bar can be operated in the range from 0 to 200%, where 100% represents the original performance. The use of the proposed system is as follows:

(1) The user clicks the "start" button in the main window, causing the visual metronome to start.
(2) The user plays the piano at the speed set by the metronome. When the user finishes playing, the system automatically analyzes the recorded performance and calculates the values of the parameters.
(3) The user can control the value of each parameter by manipulating the slider bars in the slider bar window.
(4) After manipulating the slider bars, the user clicks the "simulate" button in the main window. Then, the simulated performance is generated.
(5) The user can listen to the simulated performance by clicking the "play" button.

The proposed system can also visually present with the user the result of exaggerating the feature. Therefore, the player is able not only to listen to the simulated performance but also to visually confirm his/her weak points.

5. An example of feature exaggeration

5.1. Condition of exaggeration

To confirm the effect of exaggerating the onset time, exaggerated performances were generated for the parameter values of $C_{i1} = 2$, $C_{i2} = 1$, $C_{i3} = 1$, and $C_{i4} = 1$. The performances given by an unskilled player and a skilled player were exaggerated. The results of exaggerating the features using the proposed technique for the performances by an unskilled player and a skilled player are shown in Figs. 6 and 7, respectively. For example, by considering the fourth note in Fig. 6, the player is expected to easily recognize the degree of difference of the note from the timing the metronome using the proposed technique.

5.2. Effects of exaggeration

In the case of a skilled player, it is difficult to confirm his/her errors in a performance without exaggerating them, which can be realized using our proposed system. In addition, the tendency of skilled players to use agogic and/or vary the duration for artistic effect can be confirmed. In contrast, by exaggerating the features of performances by unskilled players, they can easily confirm their weak points by listening to the exaggerated performance, even without expertise in the piano. Thus, by exaggerating features of performances by skilled and unskilled players, it is thought that their playing habits and weak points can be easily extracted.

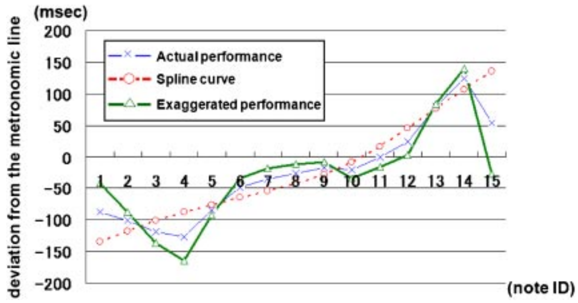

Fig. 6 The result of exaggerating the feature for an unskilled performance.

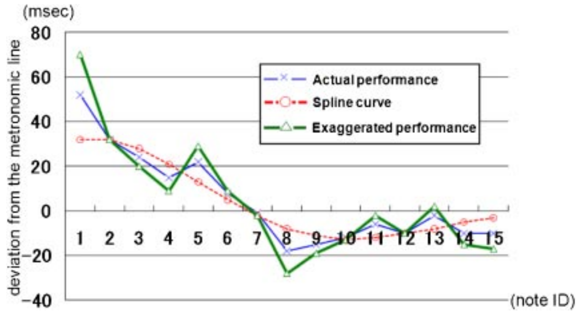

Fig. 7 The result of exaggerating the feature for a skilled performance.

6. Conclusion

In this paper we propose a feature exaggeration system to improve basic piano performance by extracting performance parameters. Parameters can be controlled by manipulating the slider bar corresponding to each parameter to values between 0 and 200%. As a result, the proposed system generates piano performances with arbitrary degrees of exaggeration of tendencies by modifying the original performance. Features of a performance can be exaggerated by setting the parameter values to above 100%, enabling the weak points of players to be discovered. The proposed system can support piano practice for players from beginners to experts, because players can analyze their performances using this system. Arbitrary combinations of parameter values are allowed because all 12 parameters can be controlled independently.

In the future, it will be necessary to compare the simulated performance in cases when two or more parameters are simultaneously manipulated. Moreover, it is expected that the proposed system can be applied to the analysis of the piano performance because players' individuality and tendencies can be emphasized by exaggerating the features of a given performance.

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References

[1] R. Dannenberg, M. Sanchez, A. Joseph, R. Joseph, R. Saul and P. Capell, "Results from the Piano Tutor Project," *Proc. 4th Bienn. Arts and Technology Symp.*, pp. 143–150 (1993).
[2] S. Smoliar, J. Waterworth and P. Kellock, "pianoFORTE: A system for piano education beyond notation literacy," *Proc. ACM Multimedia*, pp. 457–465 (1995).
[3] C. Lin and D. Liu, "An intelligent virtual piano tutor," *Proc. 2006 ACM Int. Conf. Virtual Reality Continuum and Its Applications*, pp. 171–178 (2006).
[4] S. Akinaga, M. Miura, N. Emura and M. Yanagida, "Toward realizing automatic evaluation of playing scales on the piano," *Proc. ICMPC9*, pp. 1843–1847 (2006).