Use of spline curve to evaluate performance proficiency of a Czerny piano piece

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Our previous study evaluated the level of proficiency in playing the piano for only a scale of one octave. We try to evaluate the proficiency for a piano etude by Czerny, by using some conventional parameters concerning the onset, velocity, and duration, as well as those concerning a new feature, which is the tempo, obtained from the intervals of time between adjacent notes. The deviations from the standards, such as the metronome for the onset time, the velocity average, the constant length (200 or 100 ms) of a duration, and the specified tempo (75 or 150 bpm) are obtained. Then, the tendencies of the current performance are obtained from a spline curve. The representative points of the curve are determined based on “crossing” and “turning.” We compared the obtained scores given by the proposed method with a simple or previous method, using the adjusted coefficients of determination between score of proficiency estimated by each method and that given by expert pianists. The scores obtained were 0.45, 0.67, and 0.69, for the simple, previous, and proposed, respectively, when playing under 75 (bpm), indicating that the proposed method can be used to evaluate the performance of piano etudes.

Keywords: piano; tendency curve; spline curve; performance evaluation; components calculating parameters

The development of electronic pianos has recently enabled more people to play the piano. Since it costs so much money and time to take piano lessons,
many people teach themselves. Several support systems for self-training have been invented. In previous studies on the support systems for self-training, evaluations on the proficiency of piano performances based on a spline curve representing the tendency of the current performance were studied (e.g. Miura et al. 2010). However, the task used in the proficiency evaluation in playing the piano was restricted to a scale of one octave. So, the flexibility of tasks is called into question. We tried to evaluate the proficiency for a piano etude by Czerny in this study by using the method proposed in the previous study as well as by introducing new parameters concerning tempo.

**METHOD**

**Participants**

Twenty three pianists with over 15 years of experience participated in this recording experiment. Moreover, four of them participated in the evaluation experiment for the piano proficiency.

**Materials**

*Performance task*

This study uses nine bars out of Czerny’s *Etude No. 40* as the performance task, as shown in Figure 1. Originally, the tempo of the task was specified as 208 bpm, but we changed it to 75 and 150 bpm.

*Evaluation model*

This study uses a spline curve as the evaluation model (Morita et al. 2009). The spline curve represents the tendency curve of current performance. In addition, in our previous study, the determination method for the representative points of the spline curve was based on the sequence of notes by dividing them into several clusters comprised of several notes, based on the “crossing” and “turning” of the finger when playing. Then, the center in each cluster is regarded as the representative points of each cluster. We used the conventional method here.

*Evaluation parameters*

Five ways of calculation were used, just as in the previous study, for four features such as the onset time, velocity, and duration covered in the previous study, and the tempo, in which the tempo parameters are newly introduced as representing the spontaneous deviations in tempo when playing. The tempo
curve is calculated from the interval of time between adjacent notes, shown in Equation 1 as the method for obtaining the tempo $b$ using the time interval for adjacent notes $j$ (ms) with a constant parameter $m$, which represent the kind of musical note (sixteenth note, in this case).

\[
b = \frac{4 \times 60000}{j \times m}
\]

The flow for obtaining the tempo parameter is shown in Figure 2.

**Procedure**

The effectiveness of the proposed condition is investigated to find a better condition for automatically evaluating the proficiency of a piano performance. The adjusted coefficients of determination between the evaluation scores given by each automatic evaluation and those given by expert pianists were calculated in order to confirm the effectiveness of the proposed method.

**Conditions to be compared**

Three conditions—“simple,” “previous,” and “proposed”—are listed in Table 1. The simple method uses six parameters comprised of three features (onset, velocity, and duration) and two statistic amounts (average and standard deviation), the previous method used 15 parameters comprised of three features and five ways of calculation, and the proposed method uses four features (onset, velocity, duration, and tempo) and five ways of calculation, as listed in Table 1. In the previous and proposed methods, the dimensions for the ob-
Figure 2. Flow for obtaining tempo curve. (See full color version at www.performancescience.org.)

Table 1. Comparison of conditions.

<table>
<thead>
<tr>
<th></th>
<th>Simple</th>
<th>Previous</th>
<th>Proposed</th>
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</thead>
<tbody>
<tr>
<td>Components for calculating parameters</td>
<td>Onset time</td>
<td>Onset time</td>
<td>Onset time</td>
</tr>
<tr>
<td></td>
<td>Velocity</td>
<td>Velocity</td>
<td>Velocity</td>
</tr>
<tr>
<td></td>
<td>Duration</td>
<td>Duration</td>
<td>Duration</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tempo</td>
</tr>
<tr>
<td>No. of parameters</td>
<td>6</td>
<td>15</td>
<td>20</td>
</tr>
</tbody>
</table>

tained parameters are compressed by using the Principle Component Analysis, and the evaluation score is then obtained using the $k$-NN algorithm. Here, originality employs the six principle components whose cumulative contribution ratio is 90%. Figure 3 shows an outline of proposed method.

RESULTS

We used 210 and 196 samples for 75 and 150 bpm, respectively. The results from the adjusted determination coefficients $R^2$ and correlation coefficients $r$
**Parameter Description**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
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<tbody>
<tr>
<td>$P_10$</td>
<td>standard deviation</td>
</tr>
<tr>
<td>$P_{k1}$</td>
<td>rms deviation from spline curve</td>
</tr>
<tr>
<td>$P_{k2}$</td>
<td>range of spline curve</td>
</tr>
<tr>
<td>$P_{k3}$</td>
<td>difference between adjacent notes</td>
</tr>
<tr>
<td>$P_{k4}$</td>
<td>sum of spline curve from standard</td>
</tr>
</tbody>
</table>

$x'$: subtracting standard from recorded  
$x''$: subtracting spline curve from $x$  
$ar{x}$: average of $x$  
$\bar{x'}$: spline curve

**Figure 3.** Flow of proposed method for obtaining evaluation score for piano proficiency. (See full color version at www.performancescience.org.)

are listed in Table 2, showing that the proposed method is the best among them in terms of evaluation accuracy.

**DISCUSSION**

Table 2 lists the adjusted coefficients of determination between the estimated score given by the spline curve or simple method and the evaluated score given by expert pianists in the 75 or 150 bpm performance. As a result, the adjusted determination coefficients of the previous and proposed methods are better than the simple method for the both performances. Therefore, the spline curve model is effective.
For the usage of the features, the tempo feature provides better results. Since the length of the etude is somewhat long at approximately 30 s at 75 bpm, a deviation in the player’s tempo is inevitable, so a tempo deviation is important when evaluating the proficiency of a performance.

Future works are to reconsider the determination method for representative points, to update the conventional way for calculating the parameters, and to consider the phrasing of the performance in order to acquire the player’s intention.

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References
