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Performance Rules for Computer-Controlled Contemporary Keyboard Music

A computer program for synthesis of music performance, originally developed for traditional tonal music by means of an analysis-by-synthesis strategy, is applied to contemporary piano music as well as to various computer-generated random music. The program consists of rules that manipulate the durations and sound levels of the tones in a context-dependent way. When applying the rules to this music, the concept *harmonic charge*, which has been found useful for generating crescendi and diminuendi in performance of traditional tonal music for example, is replaced by *chromatic charge*. The music is performed on a Casio sampler controlled by a Macintosh II microcomputer. A listening panel of five experts on contemporary piano music or electroacoustic music clearly preferred performances processed by the performance program to "dead-pan" performances mechanically replicating the durations and sound levels nominally written in the music score.

Background

Music composed by algorithms and performed by computers sometimes sounds dull and lifeless, presumably depending on the absence of the many long- and short-term expressive variations normally produced by a human performer. While long-term events can be introduced into the performance in many ways, for example, by means of hand movements recorded by various devices, well-controlled short-term events are more difficult to introduce. In this article, we will show that both long- and short-

term rules developed for the performance of traditional, tonal music can also be used, with slight modifications, for improving the performance of contemporary, atonal music.

The starting point is a rule system that automatically converts a music score to the equivalent sound sequences (Sundberg and Frydén 1984; Sundberg 1988; Sundberg, Friberg, and Frydén 1989a, b). It contains a number of performance rules, which, alone or in combination, have been found to improve the musical quality of the performance (Thompson et al. 1989; Frydén, Sundberg, and Askenfelt 1989). Originally developed for one-voice melodies, the rules have recently been modified so that polyphonic music can also be automatically performed (Sundberg, Friberg, and Frydén 1988).

The purpose of the present investigation is to explore the possibilities of using these performance rules in the framework of nontonal music either written to be performed by musicians or generated and performed by computer.

The presence of an underlying tonal harmony constituted a requirement for two of the rules in the original system. Since harmony in the traditional sense is missing in much contemporary music, these rules have to be modified.

The rules were developed for music intended for performance by human musicians on traditional instruments. A straightforward assumption therefore is that they apply only to this special kind of music. This would mean that the rules reflect conventions that are applicable only to conventional music instrument playing. On the other hand, it is also conceivable that the rules have a more general applicability, reflecting more basic aspects of musical communication related to more universal factors such as the human perceptive and cognitive system.

Table 1. List of the rules of possible relevance for contemporary atonal music

<i>Target Parameters</i>		
Differentiation of Duration Categories		
DDC 1A	Short short*	Duration
1B	Short soft*	Sound level
2A	Accents	Sound level envelope
2B	Double duration*	Duration
Differentiation of Pitch Categories		
DPC 1A	High sharp	Fundamental frequency
1B	High loud	Sound level
Grouping of Micro Structures		
GMI 1A	Leap articulation*	Sound level envelope
1B	Leap tone duration	Duration
1C	Faster uphill*	Duration
2.	Amplitude smoothing	Sound level envelope
Grouping of Macro Structures		
GMA 1.	Phrase	Duration, sound level envelope
2B	Chromatic charge*	Sound level, duration
Ensemble		
ENS2	Ensemble synchronization*	
Technicalities		
TEC1	Social duration care*	Duration
TEC2	Amplitude normalization*	Sound level
TEC2	Duration normalization*	Duration

* These rules were used in the test described in this article. For a detailed description of the entire rule system, the reader is referred to (Friberg 1989).

For these reasons, it seemed interesting to find out whether the rules work better for traditional instrumental music than for computer music, which is mostly intended not to be performed in this way.

Performance Rules

There are about 20 context-dependent rules in our rule system. They can be divided into two main groups, according to their apparent musical function: differentiation rules and grouping rules. Table 1 presents the total set of rules formulated to date.

The differentiation rules seem to serve the pur-

pose of helping listeners to identify the structural elements by enhancing the differences between duration and pitch categories. For instance, the pitch differentiation rules distribute additional attributes to the various pitch classes, and the differences between duration categories are enhanced by adding sound level differences as well.

The grouping rules seem to serve the purpose of facilitating the listener's grouping of structural elements. These are of "micro" magnitude (i.e., motive) or "macro" magnitude (i.e., subphrases and phrases). The grouping is made more obvious by moving grouped tones closer in time, and by avoiding discontinuities in tone parameters. Group

boundaries, on the other hand, are marked by micro-pauses, lengthening, and by introducing discontinuities in tone parameters. For a detailed account of the rules the reader is referred to (Friberg 1991), which follows this article.

A set of three differentiation rules, two grouping rules, and two technicality rules were selected from the performance rule system. In general, these rules were assumed to be the strongest candidates for this music. They operated on the amplitude and duration parameters and were therefore directly applicable to piano performance.

In our performance rule system for traditional tonal music the notion of *harmonic charge* was introduced as a quantitative estimate of the “remarkableness” of various chords. It generates crescendi and diminuendi depending on the harmonic progression. As a substitute for the macro grouping effect of this rule a new rule was formulated which worked on nontonal music.

A total of eight rules were used in the experiment. They are described below.

1. DDC 1A: *The shorter the shorter*—increasing the contrast between duration categories by making short notes relatively shorter.
2. DDC 1B: *The shorter the softer*—shortening the notes in proportion to their duration.
3. DDC 2B: *Double duration*—lengthening the shorter note and shortening the preceding longer note by the same amount of duration in a 2:1: <1 duration context.
4. GMI 1C: *Faster uphill*—increasing the tempo ascending melodic motion by shortening notes occurring in a sequence of rising pitch intervals. The effect of the rule is to make the shortened notes sound as if they aim at the “target” note terminating the ascending motion.
5. GMI 1B: *Leap articulation*—inserting micro-pauses in leaps in terms of very short silent intervals. The duration of these micro-pauses is proportional to the magnitude of the leap.
6. GMA 2B: *Chromatic charge*—is equivalent to the harmonic charge previously used for tonal music. The chromatic charge is the in-

verse of the mean interval in semitones over five adjacent notes. This chromatic charge is used for increasing the sound levels and durations of the notes; when the chromatic charge increases, sound level is increased proportionally and vice versa. In this way, the rule generates crescendi and diminuendi. In addition, the note durations are increased in proportion to the sound level increase.

7. T1: *Social duration*—care lengthening extremely short notes surrounded by longer notes by adding duration. The preceding note is shortened by the same amount.
8. T2: *Synchronization of voices*—applies in compositions containing more than one voice. The synchronization is achieved by devising a synchronization voice, constituted by the shortest note that occurs, at each instant, in the score. The synchronization voice is processed by all rules affecting tone duration, and then all voices synchronize with this synchronization voice.

In addition, a minimum duration of 50 msec was applied as an output constraint. This rule is similar to certain duration rules used in speech synthesis (Carlson et al. 1989).

Finally, an amplitude and duration normalization procedure was used, keeping the average sound level and the total duration of the piece constant.

These rules were tested by the authors on various contemporary music pieces. For reasons to be discussed below, the quantities by which the rules affected the performance were adjusted for each piece, taking into account, among other things, the character of the piece.

Listening Experiment

As mentioned above, we used two different kinds of music; music composed for piano and computer-generated random music. Seven examples were selected (see Table 2).

The three piano pieces by Boulez, Webern, and Xenakis were composed for two hands. Random algorithms were used for composing two piano pieces

Table 2. Overview of the rule system listing all rules ordered according to their musical purpose

<i>Purpose</i>	<i>Name</i>	<i>Affected Sound Parameters</i>
A: Differentiation Rules		
Duration Categories		
DDC 1	Durational contrast	<i>DR, L</i>
DDC 2A	Accents	<i>L envelope</i>
DDC 2B	Double duration	<i>DR</i>
Pitch Categories		
DPC 1A	High sharp	<i>F</i>
DPC 1B	High loud	<i>L</i>
DPC 2A	Melodic charge	<i>DR, L, VA</i>
DPC 2B	Melodic intonation	<i>F</i>
B: Grouping Rules		
Microlevel		
GMI 1A	Leap articulation	<i>L envelope</i>
GMI 1A'	Leap articulation (alt)	<i>DRO</i>
GMI 1B	Leap tone duration	<i>DR</i>
GMI 1C	Faster uphill	<i>DR</i>
GMI 2	Amplitude smoothing	<i>L envelope</i>
GMI 3	Inegalles	<i>DR</i>
GMI 4	Repetition articulation	<i>L envelope</i>
GMI 4'	Repetition articulation	(alt) <i>DRO</i>
MAcrolevel		
GMA 1	Phrase	<i>DR, DRO</i>
GMA 2A	Harmonic charge	<i>DR, L, VF</i>
GMA 2B	Chromatic charge	<i>DR, L</i>
GMA 3	Final ritard	<i>DR</i>
C: Ensemble Rules		
ENS 1	Mixed intonation	<i>F envelope</i>
ENS 2	Melodic sync	<i>DR</i>
ENS 3	Bar sync	<i>DR</i>

and the four pieces listed last in Table 2, all of which had one voice. The two random pieces for piano and two of the other pieces (Random 3 and Random 4) had quantized note durations while other pieces had nonquantized note durations (Random 1 and Random 2). In the compositions with quantized durations, only three different durations were per-

mitted. In the compositions with nonquantized durations, a total of 27 different durations were permitted and sequences of more than two notes of the same duration were not allowed.

The random function used in one of the random pieces for piano and in the random pieces 1 and 3 was white noise. As a consequence the frequency of occurrence for the scale tones was the same throughout the range used for pitch. Also, the probability of a note was independent of the preceding note. The random functions used for the other random piece for piano and for the random pieces 2 and 4 was pink noise. In these pieces a note's interval to the following note was likely to be small. Models for the composing algorithms were taken from the survey by Dodge and Jerse (1985).

Three different setups of rule quantity were used, one for the Webern piece, one for the pieces by Boulez and Xenakis, and one for the computer-generated sequences. There were mostly only small differences between these sets. The largest difference between the setups occurred in rule DDC 1A (the shorter, the shorter) for the Webern music, where the quantity was increased eight times as compared to the other setups. The quantities, on the other hand, were much larger than was typically used for traditional music, about two or four times for some rules.

For the application of the rules, the piano music was divided into two voices, one for each hand, as specified in the score.

The music examples were arranged in pairs on a digital test tape. In each pair, the same excerpt was played with and without application of all the rules. The order of pairs and the order within pairs were randomly selected. The task of the listeners was to select which performance they preferred in each pair. The subjects were asked to pay attention to the performance as a whole and to disregard single "bad" notes.

For the piano music examples, it seemed essential to use a realistic sound that was easily associated with a human performer, while for the non-piano examples, it appeared more logical to use a purely synthetic sound that was not associated with any conventional instrument. Therefore, the sound used for the piano excerpts was that of a sampled

Fig. 1. The number of subjects preferring the versions played with and without application of the rules.

piano as produced by a Casio FZ1 sampler. For the remaining four examples, a purely synthetic sound on a Yamaha FBO1 synthesizer was used.

The pairwise comparison was preferred, as it was considered essential to limit the demands on the subjects.

The subjects were two professional pianists who specialized in the performance of contemporary music, and three composers of electroacoustic music. In most cases, they could hear a clear difference between the two performances, and they generally found the task reasonably simple.

As can be seen from Fig. 1, there is a clear preference for the rule-generated performances in all cases. The preference is slightly more evident for the random melodies. This is surprising in view of the fact that the rules were developed for music played on conventional instruments.

Discussion and Conclusions

The present investigation showed that performance rules developed for traditional tonal music improved the performance of contemporary, atonal music as well. Only a few rules could not be applied for various reasons, and a major revision was required in only one case (GMA 2B, chromatic charge instead of GMA 2A, harmonic charge). It is likely that some rules which were not included in the present test excerpts might be useful in this type of music. The possible candidates are listed in Table 1.

In atonal music, there are no chords in a traditional sense. As a consequence, the notion of harmonic charge becomes meaningless. In an early stage of this project, we tried performances in which the harmonic charge was simply omitted. These performances seemed to suffer from a lack of long-term

events so that the music gave the impression of aimless wandering. As soon as the chromatic charge was introduced, this improved. We find it interesting that music performance seems to need events embracing, and thus marking, the formation of greater blocks.

In music generated by random algorithms, wide leaps are very likely to occur, while long sequences of small melodic intervals are rare. In traditional music, on the other hand, melodic movements along the scale are frequent. The chromatic charge rule GMA 2B which increased the sound level in sequences of small intervals may serve the purpose of marking emphasis. Emphasis seems to be added when predictability is low, that is, when something remarkable occurs. In this sense it seems appropriate to add emphasis to the rare sequences of small intervals. In all types of communication it seems important to emphasize the unexpected elements (Carlson, et al. 1989).

Another modification required for this application of the rules was that the quantities needed adjustment. Most of the rules had to be exaggerated in order to produce the desired effect. Also, in some cases the amount of a rule had to be altered between different pieces. The reason for this is not known. However, the following explanations seem likely.

First, we used only six rules while the complete rule system now contains 14 main rules. When introducing a new rule in the system, we often observed that a reduction of the quantities of the existing rules is necessary in order to avoid exaggerated effects. A small number of rules would then entail the need of increasing the quantities of these rules.

Second, it is possible that contemporary music calls for a more overt marking of musical events than traditional music. Lacking the competence of the compositional information of musical structure in a novel musical style a listener may need more help in order to succeed in identifying the structure than when listening to the well-known style of traditional music. For example, it would be more difficult to predict the continuation of a series of tones in contemporary music. In any event, a "deadpan" performance of the human-composed pieces seemed more acceptable than when the same type of performance was applied to the randomly-composed

pieces. A planned structure may account for some or all of this difference.

The present listening experiment was carried out with highly experienced experts only, composers and pianists, as subjects. A possible question is to what extent the results also hold true for a typical audience at contemporary music concerts. Our assumption is that these two groups of listeners do not disagree to any great extent; for example, it seems impossible that a successful pianist could maintain ideals not shared by his or her audience. The advantage with experts as listeners was their consistency, thus reducing the number of subjects required.

In the experiment, we have shown that the rules improved the performance. On the other hand, our method does not allow us to conclude that our rules are the best possible; for instance, we cannot exclude the possibility that a random distribution of expressive variations would not produce a comparable improvement of the performance. On the other hand, at an early stage during the development of the rules for marking chromatic charge, we tried to make crescendi where the average chromatic charge reduced instead of increased. The musical effect of this was unsatisfactory, however, and the opposite formulation of the rule was clearly preferable. This speaks against the assumption that random distribution of crescendi is a musically possible alternative. One would expect that such a random distribution would sound good or possible in some cases and completely impossible in others.

Perhaps the most interesting finding is that the same rules were successful in contemporary music and in traditional music. This supports the assumption that these rules are not style dependent, but may even work for other types of music. This is not to say that no other rules are needed for improving the rule system, nor that there are no style-dependent rules. The fact that the rules worked also in contemporary music suggests that they introduce qualities to the performance that have a more general validity.

A general applicability may be related to the musical functions of the rules. The differentiation rules appear to serve the purpose of helping the listener in identifying the structural elements in terms of

duration and pitch categories. The grouping rules facilitate the grouping of notes into phrases. The results suggest that the listener appreciates help in these tasks when listening to contemporary atonal music.

It is also interesting to see that the performance of very different types of music does not require entirely different skills on the part of the performer. It is often argued that music is so subjective and variable that a scientific analysis is hardly worthwhile. The findings in this investigation do not support such a view.

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