Some Applications of Time Theory to Computer Music Design

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Previous work by the author in time theory is extended to the internal structure of musical events, via the use of time control points. The theory is then interpreted compositionally and used to elaborate a number of time control possibilities for musical events that require or are made more practical with computer control. These include: temporal temperaments; conditional editing; temporal microstructure designed for timbral or articulatory effect; shifted polyrhythms; dissimilar quantization of nominally coordinated parts; application of arbitrary functions to tempo or internal time event control; projection of multiple temporal schemes from a single line.

Prolegomena

In a previous paper I outlined the relationships between musical and scientific time (Pressing 1992). To summarize, it was found that musical time differs from scientific time in several ways: it is composed rather than received; its subjective interpretation is not necessarily bound by physical experience; it can be regarded as multidimensional; it has intrinsic cyclic aspects; and it draws on a wider range of sources, such as culture, environment, the body, conceptual operations, and interpersonal interaction in performance. The similarities between musical and scientific time include: the property of ordering of events; measurability; divisibility; the existence of characteristic time scales; and relationships with number. These considerations made possible the development of a sketch of a formal theory of musical time, which was related in a preliminary way to the earlier models of Lewin (1987) and Bel (1990). Time is considered to form a one-dimensional metric space, with definable time points and time intervals. The metric space has a distance function and contains time point structures - ordered sequences of time points which may serve to localize events or act as a perceptual grid for the placement of events. Event sequences were defined, as consisting of time point structures that have associated events. Operations involving these concepts were also defined: time point structures or event sequences may be merged; event sequences may have a defined vector product; and weights may be assigned to time points. Time maps and temporal temperaments were also introduced (see below).

Here we note that these concepts may be applied to several kinds of time relevant to music. Most noticeably, when music is operating under a compositional protocol, events are interpreted according to a score - that is, assigned symbolic times (Bel 1990). When subsequently interpreted in performance or realized in studio production, these events are assigned physical time values. In contrast, when music
operates under an improvisational protocol, it is physical event time that is first accessible. No set of symbolic times is necessarily available. A symbolic score can only be resurrected imperfectly, by transcription, from the physical timings. Such a transcription may aim to be etic – exactly equivalent to the physical time, or more typically emic, attempting to discern the meaningfulness of the performer's intentions – generating what might be called intentional time. The correspondence between these various times is far from unique. An infinite number of interpretations is possible from a given score, just as an infinite number of transcriptions may be generated in correspondence to a given passage of sound.

**Temporal control of events and processes**

The idea of the event was used intuitively above, but a more critical look is essential. Musical events contain sound objects, and sometimes also control objects (either control points or control processes). Examples of sound objects are a note (in a score), a motive, and a sample. Examples of control objects are a crescendo, an articulation mark, and a set of MIDI controller messages.

As defined here, a musical event must contain at least one sound object, and if it is to be used compositionally it must have at least one control object – customarily onset time (a control point). This level of specification may be all that is required for many kinds of decaying sounds, but if the timbre is sustaining, onset time will also be significant. Events that contain exactly one sound object, exactly one onset time, and either zero or one offset time will be called simple. More complicated events are complex, and may contain any number of sound objects, and possibly many internal control objects (e.g. envelope parameters, vibrato onset point and speed, a ritardando function). Figure 1 shows a complex sound object made of a single sound, but with internal amplitude controllers. The plot is amplitude versus time.

![Figure 1: Control points in an event](image)

In general, events have their own characteristic in-built time structure, which may or may not be controllable in a given musical environment. One clear example of this is the contrast between the effects brought about by transposition on classically synthesized MIDI events and (unlooped) samples. In the first case the internal time scale of events will typically not change (although such effects can be programmed on many systems), while in the second case the internal tempo will scale according to the transposition interval. A second example is the difference between decaying and sustaining sounds. The former, in contrast to the latter, normally cannot be scaled by
a traditional performer under tempo change, except for damping, they have an
intrinsically inaccessible time structure. Decaying sounds in a computer music
environment, on the other hand, may typically be time stretched, shaped by
envelopes, etc., obviating this control distinction in many cases.

Whether a control object is discrete or continuous, it can be represented by an
ordered set of control points. These control points (onset, offset, or internal) define
significant time positions of either objects or processes. In the second case they will
have attached parameters that specify details of the control process. For example,
many commercial computer notation programs use this approach for the placement of
music symbols on the score. Each control point has the horizontal coordinate as its
time location and the vertical one as its pitch variable. In the audio realm of
synthesis, each fixed shape segment of a multitape envelope has two end control
points, and each control point can determine time and amplitude, for a total of 4
parameters. Of course, since the segments must join at their endpoints, only two of
these parameters are actually independent per segment.

Objects or processes may be subject to various operations through their control
points. Merging and the formation of vector products of sequences of events defined
in Pressing (1992) for events can also be readily extended to event components - viz.
the control points. Consider two events:

\[ E_A = \{ P_1(t_1), P_{1+1}(t_{1+y}), ..., P_n(t_{1+n}) \} \], with n control points, and
\[ E_B = \{ P_j(t_j), P_{j+1}(t_{j+1}), ..., P_{j+m}(t_{j+m}) \} , \] with m control points.

Define their vector product as follows:

\[ E_A \ast E_B = \{ P_1(t_1), P_{1+1}(t_{1+y}), P_{1+2}(t_{1+y}), ..., P_{1+n+r}(t_{1+n+r}) \} , \]

where \( r = \min(n,m) \), so that in general \( E_A \ast E_B \neq E_B \ast E_A \). In other words,
the control points from the first event \( E_A \) are allocated to the times of the control
points of the second event \( E_B \).

Also applicable is the earlier concept of the time map \( M(C, F) \) that operates on a
time structure \( S \), or event sequence \( E \), where \( C \) is the set of criteria of inclusion
defining the range of application of the map, and \( F \) is the function applied to the
selected time points (or events). A time map acts to selectively stretch the fabric of
time. Time maps can correspond to such familiar things as rubato interpretation of
notated rhythms, swing (in jazz), accellerando and retrogression, or much more
complex ideas (as below).

Maps may also be classified as bringing about either rearrangement change or
attribute change (or both). In the first case change occurs through the rearrangement
of entities that readily maintain a core of identity, while in the second case it is
parametric change of objects or processes that establishes time processes.

Some extended temporal design possibilities

The most common time map operations are shift, scale, and retrograde, but the
notion of the time map is a rich one, especially when computer time control is
considered. Some possibilities of temporal control or transformation made possible or easier by current software capacities include the following:

- **Conditional editing:** as found in commercial sequencer software, where criteria like proximity to a certain position in the measure, or dynamic range limitations are invoked before a musical transformation is applied;
- **Independent accelerandi and decelerandi in different parts:**
- **Multiple changes of tempo within the measure:**
- **Temporal temperaments:** this refers to the construction of unconventional deviations from normal additive and divisive metric schemes. Each level of subdivision in the hierarchy of rhythmic values may have its own independent temperament. For example, the second 16th note of each quarter note beat may be consistently delayed by 1/8 of a quarter note;
- **Shifted polyrhythms:** where polyrhythms do not begin at the same point in a cycle, or may not be in metric phase at all, as when one half of a 3:4 pattern is shifted by 1/5 of a beat;
- **Temporal microstructure designed for timbral or articulatory effect:** as when very quick grace note figures are heard as a timbral modification;
- **A single line projecting multiple temporal schemes:** as when a compound melody (a single line projecting multiple independent lines) uses a highly differentiated rhythmic vocabulary for each projected line;
- **Dissimilar quantization of nominally coordinated parts:** causing a consistent distortion of the sets of relationships built into the original parts, an effect most effective with percussive timbres;
- **Complex mensuration canons:**
- **Non-whole number division:**
- **Extension of the scales of perceptibility:** the very slow and the very fast;
- **Piecewise construction of events:** e.g. granular synthesis, wavesequencing;
- **Application of arbitrary functions to tempo or internal time event control:**

**Perceptibility of novel temporal structures (processes)**

Temporal structure of virtually limitless complexity can be set up mathematically. But I take it as axiomatic that for such ideas to act as ideas-in-music, the innovations must be both perceptible, and display an affinity with the predilections of musical possibility. This last phrase is problematic, but it refers to a very palpable phenomenon. In the sound examples constructed to illustrate the effects discussed, audibility has seemed to require that the time structures be mapped onto fairly marked changes in volume, spectrum or other prominent perceptual parameters of the sound, following the common experience that time structure can be most easily heard where sharp temporal boundaries are found.

**Bibliography**