Morphological notation for interactive electroacoustic music

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Interactive electroacoustic music that alters or extends instrumental timbre, samples it, or generates sound based upon data generated in real time by the performer presents a new set of challenges for the performing musician. Unlike tape music, interactive music can continuously vary its response and, frequently, performers are unable are to predict how the computer will react. Many, if not most, scores include no visual representation of how the computer may affect the sound of the instrument.

Providing performers with a readily accessible visual representation of the sonic possibilities of interactive computer music will provide a conceptual framework within which performers can understand a piece of music. Interpretation of this type of notation by the performer will provide a perspective on how his or her acoustic instrument relates to the digital instrument. This can be especially useful when improvised or aleatoric methods are called for.

This paper outlines a system of interactive computer-music descriptive notation that links pictographic representations to the system of spectromorphologies suggested by Dennis Smalley. The morphological notation (MN) uses these morphologies and adds a *z*-plane to the well-established time-vs-pitch schema. Ideally, MN will not only represent the sound data of the moment, but also will be an intuitive picture of the musical possibilities of a composition's electronic component.

1. SPECTROMORPHOLOGY

One analysis of the perceptual categories that describe the way in which electroacoustic music changes in time is articulated by Dennis Smalley in his influential articles on spectromorphology (Smalley 1986, 1997). Spectromorphology here is a broad concept, but it can be described as the perceptual analysis of time-varying aural spectra. Smalley considers the development of these new musical materials as an extension of the modernist Western musical tradition.

Developments such as atonality, total serialism, the expansion of percussion instruments and the advent of electroacoustic media, all contribute to the recognition of the inherent musicality in all sounds. But it is sound recording, electronic technology and most recently the computer, which has opened up a musical exploration not previously possible. Spectromorphology is a way of perceiving and conceiving these new values resulting from a chain of influences which has accelerated since the turn of the century (Smalley 1986).

The system of spectromorphology Smalley proposes reflects a composer's perspective. That is to say, this approach is not necessarily concerned with quantifying or articulating a numerical, statistical model. Rather, spectromorphology is a typological, linguistic expression of musical issues related to the perception of elements of electroacoustic composition. This breakdown and categorisation of the way spectra change in time provides needed analytical tools towards the development of an electroacoustic notation system.

2. TOWARDS THE QUALIA OF A SOUND OBJECT

While spectromorphology is concerned with the way in which sounds move in time, it begs the question, 'What is moving?' A sound object is a fundamental, distinguishable, perceivable sound unit. There are certain qualities of a sound object this system attempts to visually express. Those qualities can be described by the term *qualia*. For the argument here, there is no need to enter into a discussion of the existence or make-up of qualia in the philosophical sense. However, the term *qualia* provides an intellectual mechanism by which we can talk about the character or constitution of a sound object outside of its motion behaviour. A definition of qualia freely adapted from Daniel Dennett is that of an ineffable, intrinsic, and private recognition in the conscious mind of the characteristics or qualitative essence of any object (Dennett 1988). Although Dennett is, in many ways, refuting qualia itself, his definition can be useful. Qualia form a subjective, epistemological link between perception and cognition, between experience and knowing. In this paper, qualia are repurposed to describe complex, abstract qualities of sound objects. So, a sound object's qualia describe those characteristics that help define that sound object at rest.

Although the term *qualia* is repurposed for the development of the MN system, embedded in its philosophical usage is a coupling of perception and cognition. This is useful, for in many respects the success of a spectromorphological approach rests on the ability

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to adequately link perceptual phenomena, which are linked to cognition, to those aspects of electroacoustic music that are the subject of spectromorphology.

There are three aspects we can consider to form the qualia of any sound object. They are duration (time), register (pitch), and spectra (timbre). These aspects are the basis of the three axes of representation used in this system of notation. Of course, sound objects may merge, morph, and change right before our ears. But a sound object is a fundamental unit perceived as homogenous, then the qualia of any sound object are its description.

2.1. Time space

The *x*-axis represents time. Time space in this schema is unchanged from traditional notation. That is, the *x*-axis is a relative expression of duration. The bar/beat structure of conventional music notation operates in the same way.

2.2. Register or pitch space

There are two kinds of frequency information this system attempts to articulate. One is register or pitch space, the other spectral or timbral space. The register space of a sound object is a vertical assessment of its frequency – the perceived relationship to a fundamental pitch, like a note. This is the *y*-axis, as in conventional music notation. However, we can have the sense not only of a sound object's height in the register space (pitch continuum), but also of its width. A finely tuned viola note with no vibrato may be represented as a band of very thin width, whereas a piano cluster or even an out-of-tune trombone section may be perceived to be wider. Register space is represented on the *y*-axis as in traditional notation. But rather than representing a discrete set of frequencies (or notes), the *y*-axis then represents a continuum of pitch. Noise textures can challenge the idea of a pitch continuum. But granular noise like the crinkling of paper, or the grind of a cello bow, also have register, if not pitch. We certainly can perceive sound objects below and above these sounds.

2.3. Harmonicity and spectral space

Perhaps the most difficult aspect of spectromorphology to clearly articulate is spectral space or timbre. Smalley defines two generic timbres: granular noise, and inharmonicity. These both reflect his notion of the note–noise continuum (Smalley 1997). At the most extreme end of this continuum is a sine tone (with no spectra), while at the other end is noise. This noise can be further broken down into granularity. The *z*-axis is used to express this idea of the note–noise continuum. The *z*-plane represents a reduced timbral scale. Sound objects with a higher degree of harmonicity (tunedness) will be represented by moving further back on the *z*-scale, whereas those sound objects with strong noise (inharmonic spectra) will appear closer.

A secondary aspect of an object's representation will be the appearance of its width on the *z*-plane. An object's width is the range of the *variance* of its spectral activity, the amount that its spectral motion changes with respect to itself (this can be thought of as an auto-correlation function). A tuned note, while it may have high-frequency content, will not necessarily have much spectral motion (until vibrato is added). Thus, the viola note shown in Figure 1 would have a thin representation on the *z*-plane.

Figure 2 is the representation of a slightly pitch shifted sound of crinkling paper. The grey represents the spectral width whereas the black represents the registral space. At the attack of the sound, the initial crunch, there is a wide, inharmonic range of spectral activity. It is slightly pitch shifted over the course of the sound.

Pure noise would be represented as a large width on the *y*-axis, but a thin width on the *z*-axis – pure noise is very consistent. In fact, a fully random signal after enough time would correlate perfectly to itself. However, because of the note–noise continuum, a noise would appear closer than other sounds. Using transparency, large, dominant shapes do not obscure other simultaneous activity.

Another way to look at timbre is as a *Klangfarben*, or tone colour (Vaggione 1994). Timbres can have a consistent recognition, regardless of the listener's ability to attribute a source. Smalley recognises this through his idea of the source-cause texture, a complex multilayered experiential 'sonic physiognomy whose spectromorphological ensemble permits the attribution of an identity'

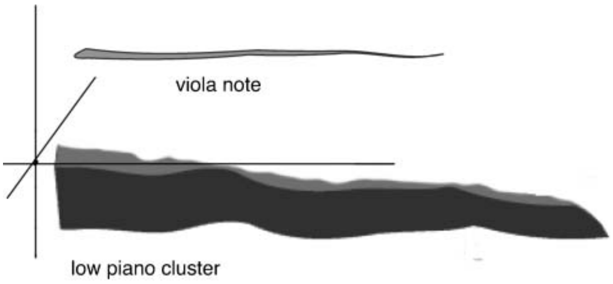

Figure 1. MN representations of a viola note and a piano cluster.

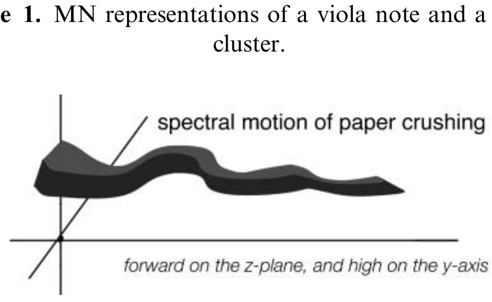

Figure 2. Spectral motion of pitch-shifted paper crushing.

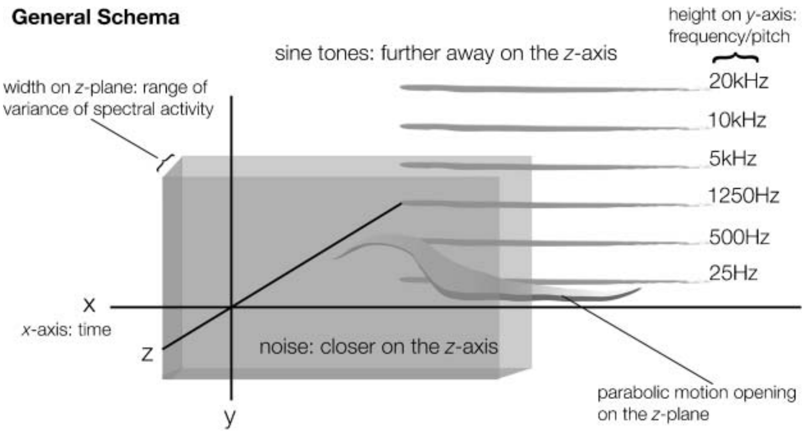

Figure 3. General schema of the MN system.

(Smalley 1994). For the MN system, within a single piece of music, when referring to a timbre that re-occurs, that timbre can be identified with colour, or fill pattern.

Of great importance for interactive music is the idea of source bonding. In his analysis Smalley offers a hierarchical typology of instrumental source-cause levels and gives evidence that in electroacoustic music does not lend itself to this hierarchical source-cause aspect of timbral identity. 'In electroacoustic music where source-cause links are severed, access to any deeper, primal, tensile level is not mediated by source-cause texture' (Smalley 1994).

With interactive music, however, the sounding body is returned to the listener. The self-referential aspect of instrumental performance combined with the presence of electroacoustic sound and processing present the problem that the source sound, while present as a source-cause referent, is often blurred and can be further obscured by the subsequent manipulations that may cause the source-cause referent to be severed. The connection between the physical action of the performer and the expectation of its sound can be very different from what is sounding. We can connect gesture on a physical level, the 'deeper, primal, tensile level', is returned and, indeed, this is one of the powerful aspects of interactive music. But the aural, timbral connection between that gesture and its ensuing sound can, and frequently does, remain clouded. In a sense you have the most difficult aspects of both instrumental timbre and electroacoustic timbre.

A large body of contemporary instrumental music, for decades now, has been extending instrumental technique to generate synthetic or noise-like textures. One can simply look to the work of Kaija Saariajo, Luigi Nono, Richard Barrett, Helmut Lachenmann, Albert Ayler, or Derek Bailey to find this (to name only a few). When extended instrumental techniques are combined with electroacoustic processing, source-bonding is again challenged. But for interactive electroacoustic music that is concerned with the integration of instrumentalists, the representation of electroacoustic timbre must include the acoustic source. Any composite timbre that includes a live source must reference the sounding body. The representation of electroacoustic processes must reflect the source, as well as the processing to the degree of presence of each.

Although the MN system proposed attempts to articulate electroacoustic processes in such a way as to be clear to an instrumentalist, the source sound will, in some way, always be present – even if simply sounding simultaneously with a triggered sample. This is not rooted in what Smalley described as the 'umbilical security of instrumental source-cause coherence', nor does this represent a 'hesitant reserve about cutting loose in order to pursue a freer exploration' (Smalley 1994).

By assimilating duration, spectral space or harmonicity, and pitch/register we have a two-dimensional assessment of the *qualia* of a sound object. A sound-object can have a perceived pitch or frequency band, and an independent sense of harmonicity or spectral space.

Another approach to the z-plane could use Smalley's categories that attempt to define the spectral space, but these are difficult to quantify. The four descriptive categories he lays out are: Emptiness–Plenitude; Diffuseness–Concentration; Streams–Interstices; Overlap–Crossover (Smalley 1997). Here, this description is that of a potential creative space more than any technical outline of what the spectral space of a sound object may be. 'In instrumental music and vocal music we have prior knowledge of the potential spectral space not only of the ensemble but of individual instruments and voices as well, and we have expectations of the use of spectral space relative to the musical style' (Smalley 1997). From a composer's perspective it is a space defined by the limits of sound sources, of bodies.

3. MOTION: GESTURE AND TEXTURE

Gesture and texture are at the crux of defining the motion of spectromorphology. In this system, careful attention was paid to the often nebulous borders that gesture and texture frequently transgress. Both gesture and texture motions frequently dissolve into each other. In this system, the distinction between gesture and texture can be thought of in terms of time scale. A gesture is a physical, human action – an exhale, a sweep of the arm. For gestures made of many sound objects, elements move in either the same direction or at the same rate in a time frame that corresponds to human motion. Many elements leave an impression of one sound event. There is also an implied directionality to the gesture shape that links what may be many sound objects into a single perceived event.

Texture, on the other hand, operates on a longer, more global, environmental level. Textures may have many elements with diffuse or very slow motion, or rapid oscillations. The scale of texture is slower and longer and may vary in its internal consistency. Texture conveys a sense of environment and multiplicity, and often there is a consistency to texture motion that belies its gestural tendency.

All motion on both the y-axis and z-axis are plotted with respect to time, thus using time scale and repetition, structural aspects of a process or larger sections of music will reveal themselves. While understanding the distinction between these two types of phenomena is important to thinking about their representation, there is no such distinction *per se* in the MN system.

4. MOTION AND GROWTH PROCESSES

Smalley identifies four families of motion or growth properties that are especially effective for pictographic representation: Linear, Parabolic, Circular, and Multidirectional. Linear sound objects move linearly, and as a single mass. Parabolic sound objects return to below and above a point of origin and generally operate on a single axis, or in one dimension only. Cyclic or circular sound objects move *around* a point of origin. This implies that there is a perceived coordination between the y-axis and z-axis. A cyclic motion creates activity in both the pitch and spectral space. Multidirectional sound objects evolve into or begin as a multi-agent system. While we still perceive a united object, it may split or merge, dilate or contract, dissipate or agglomerate (Smalley 1997).

These motions can be applied to either the registral space (y-axis) or the spectral space (z-axis), to gesture or texture alike. There are also group motions such as flocking, streaming and contortion. These are also important perceptual distinguishers of grouped sound objects. From four general shapes (Linear, Parabolic, Cyclic, and Multidirectional) any of these group motions can be represented. The direction of each growth is determined by the musical outcome desired.

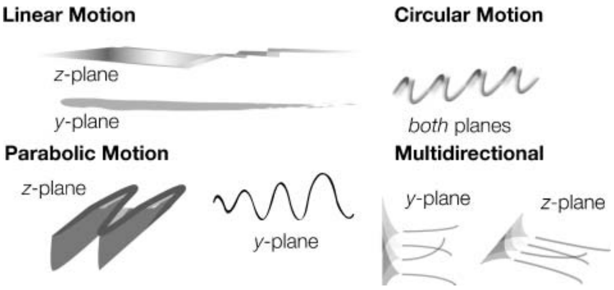

Figure 4. MN motion representations.

5. ATTACK AND DYNAMICS

Articulation, pitch, duration, dynamics and performance instructions are suitable for communicating the necessary musical information to a performer. Rather than providing performance instruction, the MN system is a descriptive notation intended to aid a performer. Many elements of traditional notation apply, including the measure system, subdivision of beats where appropriate, and dynamics.

Envelope and object onset information will be expressed by the shape of the representation and will use standard notations for dynamics and articulation. The immediate onset of a sound object will be reflected both by the range of spectral activity, and with traditional articulation markings to indicate sharpness of attack.

Dynamic information will be expressed with standard notation, by piano and forte, and hairpins to indicate changes over the course of a sound object's envelope. These indications will go inside of an object, if it is large enough and just below if not. There are special indications for 'effect' processes like reverb.

Figures 5 and 6 show two implementations of the notation system at different stages of development (both compositions are mine, from 2006 and 2007).

6. CONCLUSION

Notation rarely attempts to give us a complete or total representation of musical activity. '[There is] … weakness in every single type of notation, because in the end, what is important is neither the symbols nor the auditive and motoric phenomena they signify, but what lies behind them, and what we must create by means of these symbols' (Karkoschka 1972).

A successful implementation of the MN system can have numerous positive returns. Performers will have a way to relate to the electroacoustic component of his or her sound without memorisation. Composers who wish to include interactive computer sound in their music, but are not technicians, will have a notation method. Students will have a record of a composer's conceptual

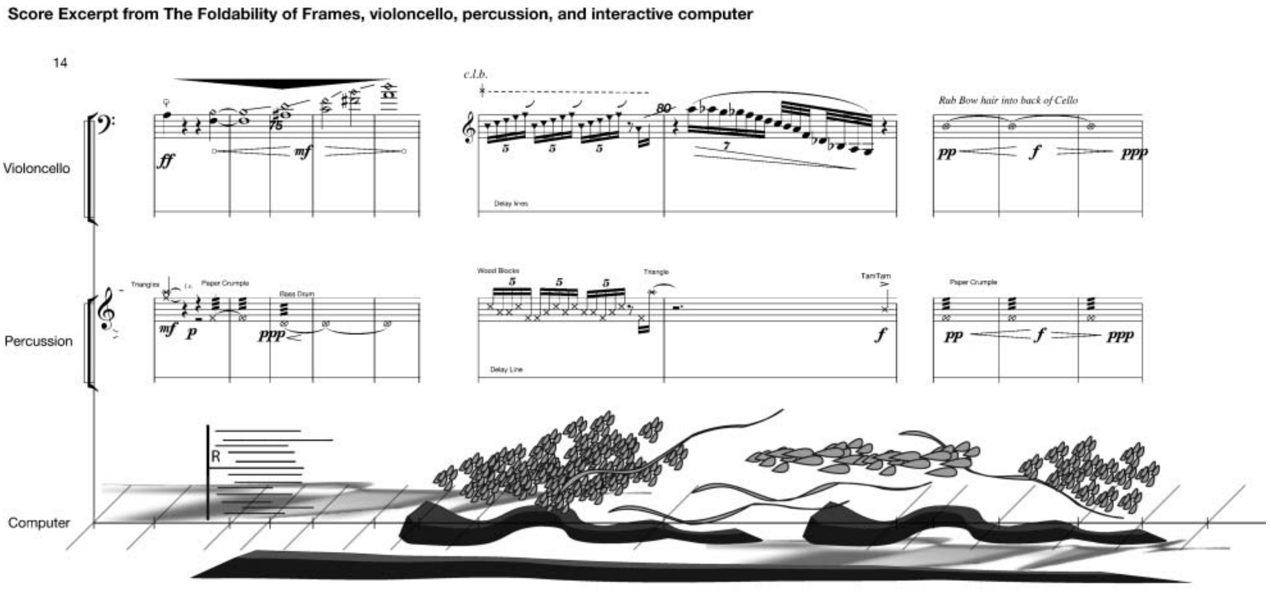

Figure 5. Score example from *The Foldability of Frames*, 2006. This shows representations of parabolic motion, linear motion, and granular clusters.

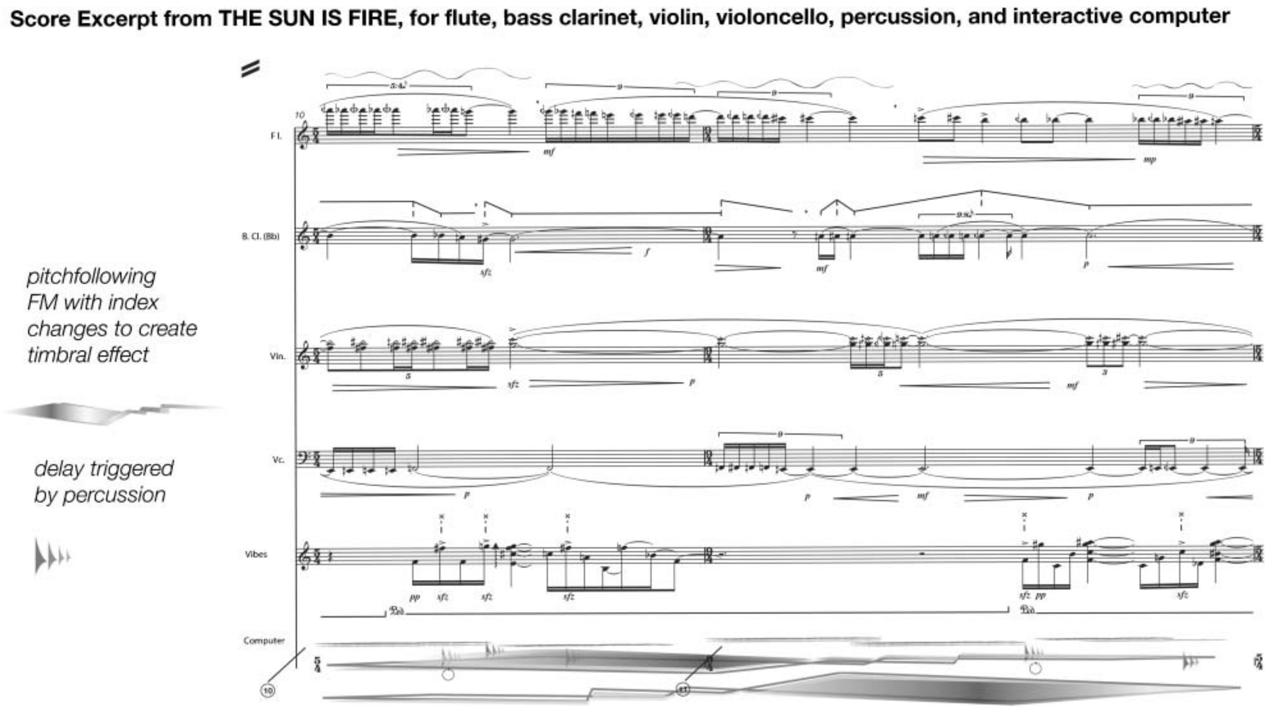

Figure 6. Score example from *THE SUN IS FIRE*, 2007. This shows the representation of a pitch-following FM synthesis module where inharmonic ratios are shown as growth in the z-plane.

and formal considerations of the electronic elements in the score.

In the future, I hope to distribute a library of representations ready for import into notation software. The proposed system will take full advantage of current technologies and allow for the specific mapping of real-time data to the graphic representation of sound. A specific data mapping of lower-level sound object descriptions can help to create higher-level interpretations of motion and growth in time. This, combined with data-driven estimations of spectro-morphological characteristics, can link larger structural morphologies in a machine listening context. Visualisation may even provide an intuitive entry point into what Dennis Smalley has called 'the bewildering sonic array'.

For updates and examples, please go to http://studios.brown.edu/~kpatton/MorphologicalNotation. Special thanks to Diego Gutierrez for his brilliant graphic design and assistance.

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