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An Analysis of Denis Smalley's Wind Chimes: Some Preliminary Results

Abstract

This paper presents some preliminary results from a detailed analysis of Denis Smalley's Wind Chimes. *The segregation-integration, assimilation-meaning (SIAM) framework previously developed by the author is applied to several sections of the work. Conclusions are drawn regarding the possible syntactical forces operating within the piece.*

Introduction

Previous papers have reported on the development of a procedure for the analysis of acousmatic music which was derived from the synthesis of top-down (knowledge driven) and bottom-up (data-driven) views. (Hirst, 2003, 2004)

The procedure can be summarized as consisting of a number of points for consideration, which are not necessarily applied in sequence. They are:

Segregation of sonic objects

1. Identify the sonic objects.
2. Establish the factors responsible for identification (acoustic, semantic, syntactic, and ecological).

Horizontal integration and/or segregation

3. Identify horizontal streams consisting of sonic objects linked together and functioning as a "pattern" unit. "Trajectories" and "gestures" should also be considered.
4. Determine the causal linkages between the sonic objects within the pattern units.
5. Determine the relationships between "pattern units" – if this level of syntax exists.
6. Consider local organization in time – pulse, beat, accent, rhythm, meter.
7. Consider the horizontal integration of pitch, including emergent properties relating to timbre (vertical overlap).

Vertical integration and/or segregation

8. Consider vertical integration as a cause of timbre creation and variance:
    a. Timbre as a cause of integration and/or segregation.
    b. The dimensional approach to timbre, including emergent properties relating to pitch (horizontal overlap).
    c. Texture resulting from contrasting timbres.
9. Also consider vertical integration or segregation in terms of the potential for psychoacoustic and musical dissonance and consonance.

Assimilation and meaning

10. Consider the nature and type of discourse on the source-cause dominant to typological-relational dominant continuum, and the way it varies over time.
11. Consider implication-realization, and arousal and meaning on a moment-to-moment basis throughout the work.
12. Consider global organization in time – identify formal structures, like sectional or continuous organization, and the nature of the relationships between sections, i.e. hierarchical relationships.

This paper reports on the first application of this framework and provides some preliminary results on the analysis of Denis Smalley's *Wind Chimes*. (Smalley, 2004)

Aim

The work *Wind Chimes* was chosen for analysis as it is a classic example of the genre described as acousmatic music, and while a recent article by Young (2004) considered some aspects of the work, the aim of the present study is to apply the Segregation, Integration, Assimilation and Meaning framework (SIAM) in an analysis of the work in order to: Discover insights into the work itself; Discover the syntactic forces that may operate between events ("entities" and "relationships"); Test the appropriateness and usability of the SIAM framework.

Method

The CD recording was digitally transferred to computer disk at 44.1 kHz sampling rate. The original stereo version of the work is used for listening purposes and for examination of each channel's spectrum individually. This study does not include an analysis of the spatialisation aspects of the work.

In addition, a mono version of the work was created by combining the two channels to create a single spectral representation of all components of the work for further examination.

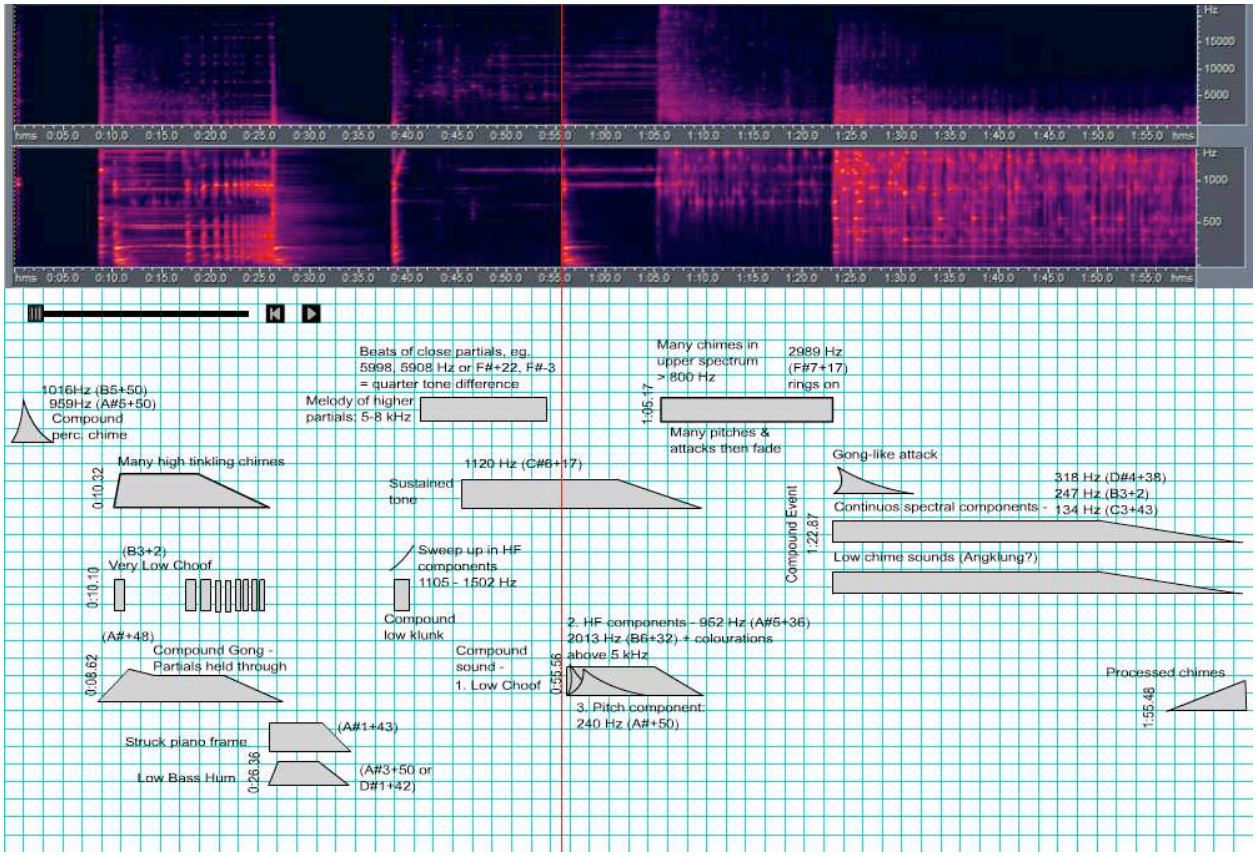

Figure 1. *Screen shot from the first two minutes of the Wind Chimes "interactive study score".*

The program Adobe Audition version 1.0 was used to both play the sound files and to create various spectral displays of frequency versus time. A "patch" was created in the graphical programming language PD (Puckette, 1996). The patch consisted of three sinewave oscillators that could be tuned to any desired frequencies and amplitudes. This allowed the researcher to tune in to certain frequency components in order to identify them precisely. During the course of the analysis, Adobe Audition version 1.5 was released and it included the capability to select a rectangular region of the spectrum, copy it to a new file, and play back the extracted region. This enhanced the researcher's ability to isolate various components within the polyphonic soundscape, and to ascribe specific frequency values to the components. Thus the analytical method was a combination of critical listening and signal analysis.

The work was segmented in time by applying a combination of the following factors in a flexible manner:

- Begin working with 30 second blocks as periods longer than this involve long-term memory considerations. This length of time also provides a convenient screen display to work with.
- Work with 4 to 5 second windows within the 30 second blocks. This approximates to our working memory and has resonances with Bigand's "sliding window" notion (Bigand, 1993).
- Having considered the first two factors, segment at obvious sonic boundaries such as those places where there may be silence or where there is a longer event.

Nine sections were identified within the 15 minute work. Some of the section boundaries are somewhat arbitrary. It should not be inferred that the sections are structural or functional in nature, rather they are just segments created for the sake of analytical convenience.

Analysis proceeded in a linear way from start to finish. For each section, a set of observations was recorded in text form, and a pictorial representation of separated sound events was drawn in pencil on paper along a timeline. Analytical data was also drawn on the pictorial representation. Over time the data that was collected began to include an event's: start time; duration; perceived pitch or significant frequency components or both; graphical indications of amplitude envelope; graphic symbols depicting special features, e.g. pitch glissando. A "Discussion" passage was also written for each section in order to interpret the observations that were made.

Once the observations, pencilled pictorial representation, and discussion passages had been completed, an "interactive study score" was created as a Flash interactive (See Figure 1). This attempted to establish a dynamic relationship between the analytical data, the spectral representations, and the audio sounds of the work itself.

Results

For the purposes of this paper, only the first three sections of the work will be discussed in detail.

In the discussion that follows, the conventions observed for the labelling of frequency, pitch and time are:

- Frequency - In Hertz (Hz).
- Pitch - Pitch class, octave, number of cents above (plus) or below (minus) the pitch class, e.g. (C4 + 23) is 23 cents above middle C.
- Time - Minutes, seconds, and hundredths of a second, e.g. 03:42.75

Section 1 [00:00.00-00:34.60]

Observations

Segregation of sonic objects is the first task along with specification of sonic properties and factors involved in identification.

The piece begins with a single sound event, or is it? We have ambiguity straight away. The work begins with a percussive chime-like sound that lasts for four seconds, but it would appear to be a combination of two sounds with an identical start time. The spectral plot reveals a spectrum with twin peaks dotted at regular intervals (on a logarithmic scale), e.g. 959 Hz and 1016 Hz. These frequencies correspond to the pitches (A#+50) and (B+50).

We would expect sounds a semi-tone apart would cause beating or roughness. There is some experience of this at the start of the sound event, but the (A#+50) component is the dominant component of the two.

So we can see that the piece begins with a combined sound event. I shall call this a "compound event" since it appears to have more that one source or cause. The initial sound event's pitch is centred around (A#+50) and it has a percussive chime-like spectrum, and that seems to be its source-cause.

Over eight seconds of silence precedes the second sound event which also seems to be a compound sound event consisting of several gong-like sounds. Although this event has a fast, percussive attack time, it has a number of its spectral components extended through time for nearly 18 seconds from time 00:08.62 to 00:26.40. Its pitch is estimated to be (A#+48). This sound is sustained as a backdrop to other sounds that are super-imposed.

The next event is a very low "choof" sound with spectral components as low as 30, 60, and 90 Hertz. It begins at 00:10.10 and lasts for 1.05 seconds. Its pitch is around (B3+2), although it is so spectrally dense that we should describe it as a shaped-noise sound with a pitch "centricity" of around (B3+2).

The low choof sound is closely followed by another event. This event is really a collection of contributing smaller events - many high tinkling chimes, and the collection acts as a texture that lasts nearly 16 seconds from 00:10.32 until 00:26.18. It is almost as if the choof sound has triggered this chime texture coming 0.2 seconds after it like a chain reaction.

Already we can see some of the binding forces coming into play in the relationships between events. Proximity in time in the form of simultaneous or near simultaneous attacks binds the events together.

The high tinkling chimes are sustained along with the sustained selected gong-like spectral components until another low choof sound is repeated at 00:17.40. Although repeated, it is a varied repetition in that a new element of frequency transformation is added - a subtle dip and rise in frequency within its dense spectral fabric.

The choof sound is repeated at 00:18.90, then again and again at decreasing inter-onset times creating an acceleration in time, and leading up to another loud percussive sound at 00:26.18.This sound appears to be a loudly struck piano frame. Superimposed over this sound, but at a slightly delayed onset, is a lower bass "hum". It has two peaks in its spectrum at 240 Hz (A#+50) and 39.8 Hz (D1#+42).

Discussion

Dominant discourse:

- Source bonding is weak.
- Sounds have vague sources which are related to percussion instruments.
- Dominant discourse is typological-relational (syntactic).

Relationships (syntax):

- Proximity in frequency. Many of the pitches are built around a pitch "centricity" of around (A#+50) - which is a binding force.
- Proximity in time binds separate sounds together into an experience of a single "compound" sound event by having the same attack point or nearly coincident attack point. For a nearly coincident attack point, the impression can be created that one portion of the sound is triggering the "consequent" portion of the sound event.
- Added colouration is provided by superimposing secondary events at approximately a tone apart in pitch/frequency. This creates the impression of a separate sound event but as an embellishment of the primary sound event due to the proximity in frequency and time, coupled with spectral similarity.

Contrast is also used for variation:

- Temporal: Short repeating choof sounds contrast with sustained gong sounds.
- Spectral: There are three layers of: spectrally dense (choof sounds); spectrally pure (gong sounds); rapid repeating chimes.

Section 2 [00:38.22 - 01:23.25]

Observations

This section is just over 45 seconds long and is marked by three significant events. Each one is quite complex and overlaps with its neighbour.

The first sound event at 00:38.47 is a compound event. It has a sharp attack that is a low klunk-like sound lasting about 1.33 seconds. At the same time

there is a rapid upward sweep in its high frequency components with a perceived pitch glide from 1105 Hz to 1502 Hz (C#6 to F#6).

After the explosive klunk-like sweep, the spectrum is sustained for around 17 seconds until the next major event at 00:55.56. During this "continuant" phase, there is a treatment of the high frequency components that we could describe as a "melody of higher partials" between 5 kHz and 8 kHz. For example there is a three "note" figure beginning at 00:41.24 with significant frequencies at 5447, 6092, and 5655 Hz or in terms of pitch: (F8-44), (F#8+49), and (F8+21). Thus we have auditory streaming of partials that are roughly a semitone apart. Inter-onset times are 1.46 secs and 0.46 secs respectively. The latter two "notes" of the three note figure repeat. Added to this scenario is the coloration of extra partials at 5998 and 5908 Hz. Their pitch equivalents are (F#+22) and (F#8-3) resulting in a certain beating effect.

On top of all this treatment there is evidence of an inverted U-shaped transformation to the frequency spectrum that results in a "smearing" of the perceived timbre. If that wasn't enough, a sustained harmonic spectrum is faded in - beginning at around 00:44.96. It has a defined pitch of 1102 Hertz (C#6+17) and is sustained right through the next two attacks until 01:09.00.

So this first compound event begins with a klunk-sweep from C# to F#, continues with spectral colourations centred around F#, then has a fairly pure spectrum added centring on C# that is sustained through the next event.

The second significant event begins at 00:55.56. It is another compound sound event with three components. We see a return of the low choof sound from section 1. A second entity enters at 00:55.78 and continues until 00:59.78. It is a pitch component with a frequency of 240 Hz (A#3+50). The third entity consists of sustained high frequency components with significant frequency components at 952 Hz (A#5+36) and 2013 Hz (B6+32). There are also intermittent colourations of frequencies above 5 kHz, e.g. 10,766 Hz at 01:01.00. The third entity's sustained components last until 01:09.00 and therefore overlap with the next major event. They also form a "spectral harmony" with the continuant from the first event forming an interval of about a minor third: (C#6+17) and (A#5+56). The "vertical integration" is further reinforced through similarity in the spectra of the next two events.

The third significant sound event in Section 2 begins at 01:05.17. It is the sound of many chimes in the higher register (> 800Hz). The chimes are excited repeatedly for around 18 seconds. The aggregate fades, but some frequency components ring on, e.g. 2989 Hz (F#7+17).

Discussion

In Section 2 we see the continuation and elaboration of the "compound sound event" technique where several different sound entities contribute to a complex attack, then we have the "continuant" phase where certain spectral components are drawn out, and a pitched element is added.

The continuant components are like a thread that links each sound event. Smalley is creating a spectral contrapuntal technique where attacks don't coincide, but at the same time, the sustain portion of each sound event continues past the attack of the next sound event.

A further binding element is the relationship between pitches. The first event combines (F# + 49) with (C# + 17). The C# overlaps with the pitch (A# + 50), with a final return to (F# + 17). These are consonant intervals of a fifth and a third forming some sort of triadic exploration.

There are links back to the first section with the return of the low "choof" sound and the use of the (A# + 50) pitch centricity.

Section 3 [01:22.84 - 03:33.69]

Observations

This section can be roughly divided into three phrases or episodes. Episodes 1 and 2 overlap and episodes 2 and 3 are separated by silence. Episode 3 is a varied repetition of episode 2.

The first episode begins with a compound sound event. Three sound events begin roughly simultaneously. The first component is a gong-like attack lasting from 01:22.37 to 01:26.66. The second component consists of a long continuous set of spectral components, sustained until 02:00.00 and then faded out (at 02:05.00). The most prominent frequencies in this sound are 133.9 Hz (C3+43), 247.36 Hz (B3+2), and 318.0 Hz (D#4+38). The sinewave generation patch was used to verify the "perceived pitch" associated with each of these frequencies. While the frequencies are not harmonically related, the intervals between them of roughly a seventh and a third do encourage a consonant interpretation.

The third component of this initial composite sound event is a series of low chime sounds that sound like a Javanese Anklung, but retaining a metallic timbre, not bamboo. These "shaken Anklung-like" sounds continue until 02:00.00 and fade out at 02:05.00.

Episode 2 begins by fading in from 01:55.40. It contains some complicated sound structures too. It begins with a cluster of sounds that appear to be processed Anklung sounds. The processing provides a "scratchy" effect. There are lots of high frequency components with peaks in the spectrum, such as the one around 2568 Hz, reinforced at short time intervals and giving the impression of "figures of two or three events" like little motives. Fading in at a slightly later time of 02:03.00 are some amplitude modulated Anklung sounds. This granulated and filtered texture is used as a background until the end of this episode. A distinctive figure of "triplet" patterns within the scratchy sound spectra enters at 02:28.62. The episode is terminated with the sudden entry of a muffled bass drum-like sound at 02:51.00.

After the drum has died away, episode 3 begins with the scratchy sounds using a motive we've just heard. The scratchy sounds continue until, at time

03:06.94, there begins an almost literal repeat of the "triplet patterns" within the upper partials of the scratchy sounds, accompanied by the granulated Anklung sounds in the background (as before). While this repeated section continues for over 20 seconds, a new element fades in at 03:12.00 and gradually gets louder. It is the sound of bells repeating. Their pitch becomes more distinctive with time and is centred around 806.45 Hz (G5+48). There is also a hint of some bells pitched at 664.54 Hz (E5+13), and the section actually ends with a grace note/final note combination on the (E5+13) pitch.

Discussion

So what are the operational forces within this section?

On the semantic-syntactic scale, the sounds events are skewed more to the syntactic end. While there is still some source bonding with the sound events sounding somewhat like chimes, gongs, angklungs, and bells, their spectra are stripped apart and given special treatment.

Compound sound events are created with a complex attack and then carefully crafted sustain portions extend certain preferred frequency elements that provide a function - a fusion mechanism or "glue". The circulating angklung sounds are used as background material throughout each episode and therefore create a unifying element, even though they are subjected to some variation treatments.

From the almost "real-space" source-causes in Episode 1, Smalley cross-fades into processed source-causes in Episode 2. The spectra are related, but they are transformed.

Distinctive timbrel figures are introduced in the upper portions of spectra, thereby creating a rhythm of partials - I shall describe these as "spectral motives".

A sudden percussive sound is used as punctuation (as we saw in Section 2), before a varied repetition of Episode 2 is heard in Episode 3.

Overall, Section 3 moves from "spectrally pitched" (around a B natural centricity) to a spectrally dense and rhythmic middle section to finally arrive on a definite pitch as its concluding event, articulating the minor third interval of G to E, in a pseudo cadence.

Sustained spectra are used to connect frequencies through time, while loud percussive sounds are used to delineate and punctuate sections and phrases.

Conclusions

Reflecting on the process of analysis, one can observe that the application of the framework is not a systematic, stepwise, serial sequence of actions, but rather a checklist that is accessed according to what may be appropriate for a particular segment of the work.

In the segmentation process, the very first impulse was to ascribe a label to a sound event, either as an identification of the possible cause or as an onomatopoeic reference to the sound event. This reflects how strong the urge for us to identify a possible source-cause for a sound is, and it provides a convenient device to use when we are recording and communicating our observations and thoughts in text.

What is immediately obvious is that Smalley is playing with the internal spectral structures of what we think of as single sound events. The listener is drawn into a giant internal sound world within which Smalley performs his microsurgery. One minute Smalley is a surgeon and excising components from the spectrum, the next minute he is a sculptor extruding and elongating individual frequency components.

Smalley has taken some traditional tonal music concepts and pushed them higher in the frequency spectrum, or in some cases embedded more in the spectrum, but lower down. So we see harmony being expressed as a "spectral chorale", rhythm expressed in the "HF Triplet" figures, and melody in the form of filtering of low frequency material to create ascending and descending melodic lines, or "spectral counterpoint". He uses the notion of compound sound events extensively where several simple sounds add together to give a complex composite.

Wind Chimes also makes extensive use of attack-resonance, which may involve a combination of several of the above techniques. An attack that is an agglomeration of sounds is prolonged into a resonance phase by the extension or addition of some component frequencies. The overall form of the work is like an attack-resonance on a macro scale. Sound events tend to aggregate at certain time points then there is a relaxation of activity revealing long sustained sounds that have their own fascinating micro-colourations. The form is like a breathing animal: a sudden in-breath, followed by a momentary held-breath, then a long, lingering exhalation.

We have coined the term "pitch centricity" to try and convey an observation that, although Smalley doesn't use an extensive tonal music organisation of pitch materials, he does manipulate pitch to create certain points of attraction that pitch may gravitate to. Transpositions tend to be by thirds or sixths too, which is wider than the critical band. On the other hand, Smalley uses smaller intervals for simultaneous events, less than a major second, to create beats and to provide colourations.

The overall form of the work is that it moves from the more concrete to the abstract. It progresses along the scale from a Source-Cause Discourse that is "about chimes" to a Typological-Relational Discourse that explores frequency and time relationships. This is achieved through an increasing use of signal processing and manipulation as the work progresses. Processing slowly detaches the sound events from their real-world connotations and places them in the new musical sound space Smalley is creating. The sound space uses pitch centricity as points of attraction for sounds. Singular sound events are bound together with a glue that is primarily frequency. Where simultaneous sounds share a frequency component they tend to bind together. Where sequential sounds share a frequency component, or are very close together in frequency, they tend to bind together to form a stream. So frequency components are extruded from one sound, elongated, then overlapped with the same frequency within another sound to fuse the events together to create a new gesture. The other binding force is time. Simultaneous events fuse together to form compound

sounds and nearly simultaneous events tend to form an association where one sound seems to trigger the other implying some common cause.

The form of the work is sectional and episodic. Smalley makes use of a lot of repetition of sound events, but the repetition is varied. Either the sound events are a processed repeat of the originals, or a literal repetition is set within a new context of different sounds around them.

Smalley uses the whole spectrum, with sustained sounds in the lower register, pitched sounds in the middle register, and interesting noise colourations in the high frequency register.

While the interpretation of the analytical results is in its preliminary phase, certain syntactic traits are emerging: Compound sound events; tonal centres and harmonic fields; organisation in time.

Compound sound events

Smalley uses compound sound events where the technique may consist of:

1. The attack portion of a sound event (eg. 4:49.54) contains a number of components drawn from different sound sources. This attack is sudden and percussive. It provides a significant point of punctuation to announce a new phrase or section.
2. The sustain portion of a compound sound event draws out selected frequency components, from the attack, that contribute to a certain "tonal centricity" (see below). Other sound entities contribute to the "compound sustain" to add colour, variety and complexity.
3. A variation of the "compound attack" is the "point of attraction" (eg. around 4:58.80). Sound elements are accumulated around the one point in time, often creating a complex gesture that may have no counterpart in the real world. The "compound gesture" becomes a new creation in Smalley's musical world. A compound gesture (or "point of attraction") can use a large proportion of the frequency spectrum, so how does Smalley avoid a crowded, muddied sound? He does this through a skilful selection of contributing sounds where each one occupies its own segment of the spectrum in a way that doesn't overlap too much with others. For example: A middle-band "sh" sound may be combined with some enhanced upper frequencies (> 10,000 Hz) and added to a low "thud" which consists of lower frequencies only. Where frequency components do coincide, these become significant frequencies that can contribute to a tonal framework (see "tonal centricity" below).

Tonal centres and harmonic fields

Smalley has moved the manipulation of pitch upwards within the spectra of sounds used. Rather than creating melodies that consist of notes with definite pitches, Smalley emphasises certain frequencies within the spectra of the sounds he employs, or he transposes sounds so that they gravitate to certain tonal centres.

These tonal centres act like pedal points in tonal instrumental music. At around 05:22.00, one such tonal centre is a quarter tone above E natural. Smalley creates a "harmonic field" using the pitches associated with an E major/minor seventh chord.

A B natural tonal centre is alternated with the E natural tonal centre throughout the section. Smalley colours these with thirds, fifths, and sevenths to create his harmonic fields.

Smalley has also re-interpreted traditional harmony and voice-leading practices by taking the principle of "common tones" between two successive chords in tonal harmony and applying it as a principle of "common partials" between two successive sound events in acousmatic music. The common partials then become a binding agent between the sounds through a strong horizontal steaming tendency.

An extension of this principle is the principle of "stepwise motion" used in harmonic progression. Smalley creates a stepwise motion of sustained partials when some dominant partials are changed to values that are close in frequency.

A beautiful application of these principles is evident at the end of “Section 5” (at 06:23.04) where we have a "spectral chorale". The B natural tonality is embellished by a G harmony with motion to B's neighbour C# and back again.

Organisation in Time

Throughout Wind Chimes there is no strong pulse, no meter, and no elaborate rhythmic structuring present, however there is careful structuring in time. The re are a number of temporal elements that are apparent.

The attack-continuant paradigm is a strong structuring force.

Pseudo-rhythmic figures are used within the attack-continuant framework. Some examples are the high frequency couplets and triplets beginning at 4:58.80, or the low frequency figure at 5:05.39.

Sustained partials are overlapped with the next attack-continuant expansion, providing a "proximity in time" Gestalt glue throughout.

Simultaneous attacks create "compound sounds" by virtue of their "vertical integration".

Nearly-simultaneous attacks create "compound gestures" that are so unique they generate interest and variety.

Repetition is also used in a number of ways. Repeating a sound at short, and ever-increasing, time intervals produces a feeling of acceleration, propelling the listener towards a goal event.

A more subtle technique, used over a wider timeframe, is the creation of a "pre-echo" or anticipation of a sound. Smalley achieves this by taking its spectrum, transforming it in some way, then placing the processed sound before the unprocessed sound in time. For example the "ghost components" at 5:21.59 are from the high cymbal at 6:04.47. This is much more subtle and effective that using the reverse order, that is playing the original sound followed by its transformations.

Repetition of sound in a new context is also extensively used, for example the "whispering glass rim" sounds at 5:23.80 are repeated at 5:48.36.

Distinctive sounds make judicious return appearances throughout the piece. For example, the return of the original percussive chime from the start of the piece returns at time 6:07.17. This is disguised with a busy phrase, but it is like a preparation of a full, unaccompanied return in the next section.

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