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# The creation and projection of ambiophonic and geometrical sonic spaces with reference to Denis Smalley's *Base Metals*

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Space is not the place (real or logical) within which things are disposed, but rather the means through which the position of things becomes possible. Instead of imagining space as a kind of ether that encompasses everything, or conceiving it as an abstract characteristic common to everything, we should think of it as the universal power that connects everything. (Merleau-Ponty 1945: 281)

**This article suggests a framework for the articulation of ambiophonic and geometrical spaces in electroacoustic composition and performance. *Space-ambiophony* explores the global perception of space, which is derived from the archetypal perception of surrounding environments. The term applies to usually large-scale observation but it can also include shifts in the listener's attention from gestalt perception to micro-structural observation. A spatial analysis of Smalley's *Base Metals* demonstrates the methods by which space-ambiophony is integrated into the composition. In *space-geometry*, relations and analogies are established between composed sonic events and principles of geometry and stereometry. Three primordial geometrical elements, drawn from Wassily Kandinsky's theoretical work on painting, serve as metaphorical cells for the construction and projection of this type of space: the point, the line and the plane.**

The interaction between the acoustic qualities of listening spaces, the configuration of loudspeakers, the composed space (sonic trajectories, background, foreground) and its projection by the interpreter in a concert, are all issues that occupy parts of the article.

## 1. HISTORICAL CONTEXT

The invention of recording and the development of computing and playback technology has, for the first time in music history, allowed a full exploration of musical space and motion. Although space is explored, if somewhat primitively, in instrumental music of the past,<sup>1</sup> the electronic means liberated the act of creating music from the constraints of real-time performing. Denis Smalley highlights the importance of this development by underlining that, 'Electro-acoustic composers working in the invisible domain of a music which can exist only in a recorded format can now create unique affective, spatial experience.

<sup>1</sup>Details and specific events covering the last century can be found in Vande Gorne (1998: 8–15).

Human experience of space – how we feel *in* it and how we feel *about* it – has therefore become a new dimension of musical experience' (Smalley 1991: 121). Musical space and motion are no longer ornamentations or by-products of the compositional process but rather unique aspects of it, and fundamental elements of thought and musical language. The notion of space has been traditionally associated with the pitch frame, where changes in instrumental and orchestral spectra were the elements that defined the two-dimensional spatial order in music.<sup>2</sup> Nowadays, however, spatial composition conceives of space not as a side effect of instrumental and tonal combinations, but as an essential element that can be assembled and created (Mamalis 1994: 179–80). The experience of musical space that questions and restructures our sense of hearing, '... is essentially a dynamic information process, unfolding in real time and requiring the listener to constantly update his or her mental representation of the composition'<sup>3</sup> (Karpinska). This process involves an interactive relation with the music that allows the listener to identify and interpret the temporal unfolding of spatial articulation. The psychology of time and the human perceptual faculty have been the areas of research for spatial composition in recent years.<sup>4</sup>

## 2. AMBIOPHONIC SPACES

One cannot examine ambiophony, real or imaginary, without considering archetypal types of spaces that surround everyday human activities, and which define, to a great extent, human presence in the earthly environment, simply because ambiophony *is* the voice of a place that encompasses all its sonic qualities. It is a sonic footprint of the outdoors and indoors, the mesmerising or intruding voice of the immediate environs of human activity. Its etymological roots from the Latin word 'ambire',<sup>5</sup> 'go round', confirm its

<sup>2</sup>However, there are exceptions to this argument, including Russolo's *Spirales de bruits* (1914) and Bartok's *Music for strings, percussion and celesta* (1936–1937), as well as composers such as Debussy, Berlioz, Ligeti, Xenakis and Stockhausen.

<sup>3</sup>In <<http://www.techneka.com/aya/cogSci/paper.html>>.

<sup>4</sup>Psychological considerations of music and the role of cognitive psychology are discussed extensively in McAdams (1987: 1–61).

<sup>5</sup>Latin *ambire* (go round) and Greek *ὄϊβ* (voice).

very meaning: the perception of the surrounding environment, the utterance of the global planet in which we all live.

Ambiophony is the most archetypal type of spatial articulation. It defines the global perception of the surrounding sonic environment. Furthermore, Bregman suggests that, from an ecological viewpoint, humans try to associate events with sounds in order to understand the environment (1990).<sup>6</sup> In music, ambiophony can be structured in meticulous detail, prepared by the composer in order to emphasise archetypal and global environmental perception. It offers a space in which attention is not guided by isolated or detached sounds, but focuses on larger-scale observation. Hence, the auditor does not localise the sources of sounds but becomes immersed in a diffused ambience. It is the nature of the diffused ambience that defines its archetypal character. It is easier to understand this by contemplating the way natural light is diffused. In an unobstructed environment, natural light is omnidiffused, distributing equally all its characteristics.

The relatively equal distribution of characteristics and the insignificance of the sources are the two main aspects of space-ambiophony. In an interview with Jean-Jacques Nattiez, Pierre Boulez, although not referring directly to ambiophonic spaces, indicates the importance of these aspects in his piece *Figures, Doubles, Prismes*: 'I had to think of the orchestra as a whole, and of the temporal dimension as homogeneous and unified. What interested me was to blend the sonorities' (Boulez and Nattiez 1991: 115). The perception of orchestral sonority as a whole often demands the sacrifice of individual instruments. Each of them has to contribute spectrally to the creation and projection of a diffused sonic world in which no specific timbre takes the lead. Eventually, each of the orchestral instruments carries a part of the musical message without being the message itself. In Berio's *Coro*, a similar preoccupation is explored. As Boulez explains later in the interview, Berio '... placed the singers very close to the instrumentalists in order to avoid their isolation' (*ibid.*: 116). This choice has two obvious reasons: the blending of the vocal and instrumental sonorities, and, occasionally, the avoidance of source identification.

In electroacoustic music the same principles apply. In order to compose a purely ambiophonic space, the composer should avoid any proliferation or accumulation of prominent sonic figures which firstly, draw the listener's attention to their own spectromorphology and structural role, and secondly reveal their source (Bregman 1990). This would result in a different spatial perception by the listener, and consequently, in the beginning of a chain reaction that would shift the

listener's attention away from a global perception. Léo Küpper, although discussing another topic, explains the occurrence of such a reaction: 'A space change in the acoustical field means a change in the attention paid to the perception of space which in turn imposes a change in intensity, in the spectrum colour, the form and the position in space' (Küpper 1998: 60).

Space-ambiophony, approached with these kinds of principles in mind, seems like an arabesque. There may be a vast amount of detail, each contributing to the perception of an overall pattern, and the composer may create a delicate sonic embroidery, but the role of the listener is equally important. According to Vande Gorne, 'It is the listener that carries out the *mix* of all the sonic events' (Vande Gorne 2003). After all, it is the listener's decision either to be immersed in the projected sonorities, or to be absorbed by the microscopic spectral alterations which unfold in the passage of time, although this has to be facilitated by the music and the listening context. The gestalt approach dominates the first case whilst in the second case, a more focused attention is needed. However, because attention is never fixed or static, it is inevitable that the listener will be oscillating between the two.

Ambiophony is very much related to the acoustic properties of the listening space. The quality and character of the composed space is eventually influenced by the types of places in which the performance of the piece might occur, and by the composer's experience of past performances. Although the composer cannot often predict the precise acoustic qualities that will dictate the articulation of the composed space during a concert, it is necessary to take them into account. Ignoring them simply means that the unfolding of the composed space will be either haphazard or, at worst, amorphous. The composed space, often produced in a studio with specific laboratory acoustic conditions, needs to be tuned into the acoustic properties of a listening space, in order to be perceptually balanced. The failure to do so may result to the situation described by Denis Smalley as *spatial dissonance* (Smalley 1991: 121).<sup>7</sup> Although not necessarily a negative result, spatial dissonance does not always match the compositional intentions of the composer. It is thus important to emphasise that the perception of ambiophonic space during a concert is the interaction between compositional intentions and the acoustical properties that put these intentions into practice. Quite often, the compositional intentions are scuttled into confusion

<sup>6</sup>Further discussion on an ecological theory of listening can be found in Windsor (1995).

<sup>7</sup>Smalley coined the terms *spatial consonance* and *spatial dissonance*. He argues that, 'Composed sound-spaces may be either *consonant* or *dissonant* with the listening space, changing the nature of the listening experience to an extent often not contemplated by the composer. For example, there is a very significant difference in presenting intimate, composed-space content within large listening spaces (dissonant spatial relationship) ...' (Smalley 1991: 121).

due to the inability to understand and use the interaction between composed and listening spaces. Although loudspeakers are often placed in relation to projection intentions and audience position, an ideal installation for the projection of space-ambiophony should be the placement of identical and equidistant loud speakers around the audience. Each speaker should contribute to the recreation and articulation of the projected space. An installation which fulfilled these criteria has been Karlheinz Stockhausen's sphere at the Universal Expo '70, in Osaka, Japan.<sup>8</sup>

### 2.1. *Base Metals* by Denis Smalley, or the articulation of space-ambiophony

The invisible spatial articulation in electroacoustic, and particularly in acousmatic, music generates an indirect and often ambiguous allusion to the real world, or more correctly, to the archetypal signification of the real world. The argument that electroacoustic music creates images through which the listener perceives the meaningful messages of the sounds is partly correct. What is most attractive, however, is the allusive reference to archetypal templates which are carried by those images, the continuous and ceaseless confrontation between what the image of a sound is and what it suggests. This is possibly the point where electroacoustic music becomes '... a meta-aural medium, a kind of metamusic' (Camilleri and Smalley 1998: 5). Perceiving and comprehending the archetypal templates that a piece of music has to offer, transcends the restraining character of a purely analytical approach and offers a schema through which the listener can develop an essential and interactive play with the sonic environments. This play is based not on the musical parameters themselves but on what they can offer, what kinds of possibilities they trigger in the listener's memory base. The question is not what the music we hear is, but what are the archetypes emerging from it and how they are stimulated. Thus, from an aural sonic-based medium we transfer to an after-image environment where the trace of a fingerprint is more important than the finger itself, and the analogies and relations between objects surpass their structural dimensions. As Camilleri and Smalley explain, 'The perceptual approach to electroacoustic music analysis has taught us that it is not viable practice to separate an account of sonic materials and musical structure from signification' (Camilleri and Smalley 1998: 7).

The compositional strategy of *Base Metals* seems to be based mainly on this approach. The sound sources used by the composer are extremely limited and possess a very similar textural character. This is

perfectly justifiable because the intention is not the juxtaposition of contrasting and confronting sonic events but rather the creation of a mesmerising environment where the sounds, although rich in their content, play the least important role. Again, it is not what the sound is about, but what it can suggest. Of course the latter is very much dependent on the former in the sense that the sounds must possess certain attributes in order to fulfil the compositional intentions. Furthermore, Smalley clarifies that from the metal sounds that provided the central material for the piece he 'selected those with the internal resonant properties ...' that could provide him with '... variegated spectral families'.<sup>9</sup>

The principal idea behind *Base Metals* is simple and omni-present. The archetypal duality of attack-resonance, suggested from the nature of the sound sources, dominates the piece from the very beginning giving evidence of the two most important elements of a percussive sound. The first attack followed by a long resonance sets up the frame within which the piece will evolve, and makes known the composer's intentions (music example 1). However, although several types of attacks are repeated eight more times throughout the piece, their importance is of minor impact. It is the resonances, the sonic trails of the attacks that guide the listening faculty and grasp its attention. The attacks are presented as the remote causal origin of the unfolding sonic universe, the moment of the big bang, the starting point of what is going to follow. In that sense, although they mark and divide the structure, they are almost insignificant. They only serve as a reassurance of the memory, a snapshot of the moment that the mallet hit the surface of the instrument, a faithful servant that occasionally answers the listener's question: 'Where does all this come from?'. Moreover, none of the nine times that an attack is presented results in a completely different spatial environment. Resonances continue to unfold and shape the temporal dimension, oblivious of any distractions caused by instantaneous vertical events. This is the dominance of time unfolding over momentary action, the enforcement of the subtle but continuous presence of the resonances over the dynamic but occasional appearances of the attacks. A voice which mesmerises for a long period of time is stronger than a voice which utters a loud word. It is due to this omnipresent dominance of a resonant soundscape, and to the continuous unfolding of sustained and hovering frequencies that space-ambiophony comes into existence. The attacks themselves, as the tragic irony from an ancient chorus, remind us of what we do not know but we suspect: the fact that we are immersed in a vast diffused sonic space where isolated structural details are not as important

<sup>8</sup>Further information on this construction can be found in Maconie (1990).

<sup>9</sup>In the leaflet of the CD *Sources/Scènes, empreintes DIGITALes* (2000).

as the permanent evolution of ceaseless time. However, we do need to hear and be distracted by the attacks in order to become aware of this fact. Second irony: the attacks fulfil a role that they are not meant to. Instead of shifting the attention to their own qualities, they emphasise the role and the importance of the resonances. Although attack and resonance are the two poles of a seemingly opposed duality, or the two different phases of the same phenomenon, they form a homogeneous and coherent unity. It is very difficult, if not impossible, to imagine an attack with no resonance, or a metallic-type sonic tail without any kind of attack. The nine attacks presented in *Base Metals* remind us of this archetypal duality. Both poles are there, the one serving the other, the one existing due to the other. In gestalt perception, however, the sonic world created by the resonances triumphs over the instantaneous breaks of the attacks.

As a consequence, the temporal dimension acquires a homogeneous and unified presence supported by the continuous blending of the metallic sonorities. The listener becomes immersed in an ocean of sounds where no prominent figures exist and all the sources remain well hidden. From time to time an attack with an almost ritual and severe character will emerge, as a sonar giving indisputable evidence of how deep the ocean is.

Space-ambiophony is mainly shaped by amplitude arrangements. Volume faders move up and down sculpting the spectromorphologies in time and creating wave motion in delta forms ( $\Delta$ , fade-in/fade-out, or, appearance/disappearance) (music example 2). These forms create the internal pace that guides the listening ear. It is as if a piece of wood is undulating on the surface of the ocean with no apparent direction. The amplitude-shaped delta forms reinforce the perception of the ambiophonic space by offering a stable and recognisable vehicle that the listener can identify. Another aspect that reinforces the ambiophonic space is the lack of sound displacements. Except for minor transitions within the stereo field (L–R), all the textures and morphologies possess a wave-like motion without fixed boundaries.

The main compositional method for achieving the balanced spatial order in *Base Metals*, as revealed from the listening process, is the spectral and spatial orchestration of the partials of the resonances. The overall spatial articulation results from the spectromorphological transformations and developments within the spectra, rather than from an artificial application of reverberation.<sup>10</sup> Although the space is reverberant, it is so due to the spectromorphological shaping of an often large number of sustained frequencies which

results in different spatiomorphological developments.<sup>11</sup> That means that altering the spectral characteristics of a sound, possibly due to filtering, spectral transpositions or other processes, also alters the perception of its spatial positioning. But how is the perception of space-ambiophony in *Base Metals* influenced by changes occurring in the spectral domain?

### 2.1.1. Spectral appearance and frequency shaping

Spatiomorphology is very much dependent on how the partials of a sound or the individual frequencies that comprise a sound structure are shaped over time. For example, a spectrally low sound with a long duration will be easily diffused in the listening space, whilst a high frequency with a very short and percussive attack will be immediately located. The spatial articulation of *Base Metals* results from a thorough and detailed work on the spectromorphological shaping of the metallic resonances. This work can be examined at two different levels: *spectral appearance* and the *frequency shaping* of the sound morphologies (see table).

*Spectral appearance* refers to the overall disposition of spectra through time. Their shaping suggests motion and influences the gestalt perception of the listener. The metallic sculptures used as sound sources provide a basis for the *spectral typology* (Smalley 1986: 65) in *Base Metals*. Due to the nature of the metallic sounds, the spectral components are generally unrelated to the harmonic series. Although the spectral shaping is based on the inharmonic series provided either by the attacks or the mixing of resonances, there is a harmonic presence throughout the piece. Prominent or fundamental frequencies always emerge from the sound masses to indicate primary spectral regions (music example 3). As Smalley points out,

Table	
Spectral appearance (vertical disposition of spectra)	Frequency shaping (horizontal behaviour of frequencies)
– spectral typology	– high, medium or low frequencies
– opacity– transparency continuum	– dynamic energy of frequencies/ frequency spread
– mass profile	– motion typology of frequencies
– filtering	– gestural behaviour of frequencies
	– textural behaviour of frequencies
	– melodic profile
	– filtering

<sup>10</sup>The composer dislikes and seeks to avoid reverberations which imply a room-based acoustic by creating spaces less immediately attributable to confinement (personal communication).

<sup>11</sup>Smalley invented the term *spatiomorphology*. He describes: ‘It could be that a morphology is set in a sequence of spaces such that no significant morphological change occurs. We diagnose a change of spatial perspective through changes in the reflective properties and perceive a transformation of space rather than morphology’ (Smalley 1986: 91).

'Inharmonic spectra are not distributed in the predictable systematic order demonstrated by harmonic spectra . . . An inharmonic spectrum may contain intervals which evoke tonal references; simple inharmonic spectra may be interpreted as close relations of harmonic spectra' (Smalley 1986: 66). Although the shift between harmonic and inharmonic spectra is inherent to most of the metallic sounds, there has been an intentional decision by the composer to emphasise it. As a result, the ear constantly moves between harmonic and inharmonic sonic masses which are perceived ' . . . from a variety of angles provoking a fruitful ambiguity of focus' (*ibid.*: 66). The *opacity-transparency continuum* is also influenced by this ubiquitous ambiguity. When inharmonicity takes over, opaque spectra with blurred boundaries dominate perception. Very often they are mixed or superimposed with more transparent ones. In most cases, opaque and transparent spectra coexist offering both the possibility of pitch detection and the ambiguity of focus (music example 4). The *mass profile* refers to the contour of the sound typologies. It can be intentional, if for example the composer uses volume automations (music example 5) or filtering (music example 6) to sculpt the sounds in time, or drawn from the original recording of a source and used unchanged.

The delta shape ( $\Delta$ , appearance/disappearance) provides the main contour for the profiling of the sound masses in *Base Metals* and the resonances are shaped as waves with often an added accent on their peak (music example 7). The delta shape also creates the illusion of motion without direction. Its constant repetition results in a wave-like archetypal environment, familiar to most listeners. Sonic waves, either stretched in time or compressed and dynamic, disturb the surface of a sonic ocean beneath which the spectral components are shaped. The sonic waves are often morphed into varied sustained morphologies described by the composer as ' . . . varied pushes, surges, swirls and sweeps of spectral energy, balanced with calmer drifts, undulations and dips, all of which move in and out of more clearly pulsed moments' (music example 8).<sup>12</sup> The occasional attacks in the piece are welcomed as drops on the oceanic surface. Internal glissandi can also shape the mass profile of a sound or sound structure. When, for example, components of a sound move progressively within the spectral space, the profile of the sound follows this internal motion. An example of this is given after two and a half minutes into the piece (music example 9). Some of the partials are progressively transposed towards lower regions of the spectrum. The mass profile follows this transposition and the contour of the spectrum is consequently altered.

*Frequency shaping* refers to the horizontal behaviour of frequencies. *Base Metals* is mainly occupied by the low and medium primary regions of the audible

spectrum. High frequencies often emerge above opaque and blurred masses defining the spectral canopy. The *dynamic energy* of the frequencies is determined by continuous changes in amplitude, and the mixing models of appearance/disappearance and fade-in/fade-out also contribute to the distribution of their energy. The *motion typology* of frequencies is very much related to their mass profile. Individual frequencies that are mixed together in order to create sonic masses follow reciprocal types of motion, including undulations, surges, swirls, drifts and dips. Convolution is also applied in the sense that ' . . . implies a complex interweaving of reciprocal motion shapes' (Smalley 1986: 75). The overall motion style is characterised by continuity and periodicity. The *gestural* and *textural behaviours* of the frequencies are also interconnected with the way the sonic masses are shaped. Individual frequencies and partials of the metallic resonances, carrying their own internal behaviour patterning, are superimposed and shaped by wave-like gestures. Smalley argues that 'Gesture is concerned with action directed away from a previous goal or towards a new goal . . . it is synonymous with intervention, growth and progress, and is married to causality' (*ibid.*: 82). In *Base Metals* however, the gestural behaviour of the sounds does not appear to have such a powerful influence. It is used to create a constant pace rather than build up new expectations; to maintain a convenient and undulating environment rather than direct the ear from one goal to another. Gestural patterns may also have been applied to internal components of the resonances in order to dictate *melodic profiles*. It has to be emphasised here that melodic profiles refer to melodic patterns that occur within the spectrum of a sound and may be surrounded by other stable partials. Most of the time, these melodic profiles are masked by the density of the spectra and can only be perceived at a micro-structural level (music example 10). A gestalt listening approach will never bring to light the microscopic and subtle melodies of the partials developed within the spectra. At the end of the piece, however, a pure melody with harmonic references, hints of which appeared earlier in the piece, emerges, rewarding the attentive ear (music example 11). Although the source of the melody is a well-sealed secret kept by the composer, it seems to be the result of *filtering* of some resonances that already possessed intervallic properties.

### 2.1.2. Some thoughts concerning the spatial projection of Base Metals

The detailed work on spectromorphological shaping in *Base Metals* provides the foundations for its spatial articulation. Long sustained resonances and undulating textures can be projected in listening spaces with the form of 'approaches, emergences, dispersals and

<sup>12</sup>In the CD leaflet, *empreintes DIGITALes* (2000).

distant disappearances, sometimes leaving behind the residues of spectral trails'.<sup>13</sup> Two figures of space, drawn from the theoretical work of Annette Vande Gorne (2003), can be used for the projection: the *crossfade* and the *wave*. The crossfade occurs between different groups of loudspeakers and it should not create acoustic voids. This technique may be used to reinforce composed crossfades, such as the fade-in and fade-out between sonic textures, and to change perspectives. The wave figure is a reciprocal motion comprising successive crossfades from the front to the rear speakers or between the sides of the listening space, and can be used in order to emphasise the delta forms and all their possible variations.

The absence of sources and the equally distributed characteristics of the sonic textures throughout the piece, should be the criteria for a coherent and meaningful projection. Space-ambiophony is based on these criteria and on the temporal development that guides the listener's attention. The listening faculty oscillates between the gestalt perception of the sonic masses and the micro-structural developments within the spectra. However, it is not an easy task to fulfil and maintain these criteria during spatial projection. The sounds should exit the loudspeakers without 'banging the door' behind, which means that the speakers should never be localisable. The listening experience of space-ambiophony should resemble the view of a vast forest from above. One cannot see isolated trees but one can pick up the peaks and the wavy surface of the forest as a whole. As the composer states, 'Between and beyond the loudspeakers virtual, metaphorical worlds approach and encroach in sonic flow, and are revealed for imaginative contemplation. The listener-spectator is left to observe and experience the scenes and spaces, alone'.<sup>14</sup>

### 3. GEOMETRICAL SPACES

The science of geometry is concerned with the properties and relations of points, lines, surfaces, solids and higher-dimensional analogues, as well as the shapes and relative arrangements of their individual parts. It is very much connected to shapes, structures and analogies found in the earthly environment. Due to electroacoustic techniques, the exploration and recreation of geometrical spaces in music, and the conduct of abstract mathematical relations, is feasible without the intervention of vision and the use of specialised calculating machinery. The creation of space-geometry, both in music composition and during the projection of a piece, is based upon the

archetypal opposed duality of *immobility–mobility*. In basic geometry the primary element is considered to be the *point*, a type of nucleus that is characterised by one-dimensional immobility but has an inherent potential for motion. The addition of a second point renders a second dimension and defines the space by creating the possibility of a linear series of points which shape a *line*. Iannis Xenakis, since the early days of electroacoustic music, foresaw a musical future constructed on geometrical principles. He wrote, 'We can assume that a loudspeaker is a point-source in a three-dimensional space. The principles that govern the Euclidean space can be transferred and applied to acoustical space' (Xenakis and Solomos 2001: 66). He then tried to establish in sonic terms the relation between geometry and stereometry: 'Let us assume an acoustic line which is defined by points that project sound. The sound can emerge simultaneously from all the points of the line. We can further assume a rectangular network consisting of acoustic lines that define an acoustic plane. In that sense, we can also assume curves, curvilinear surfaces within the acoustic plane, etc.' (*ibid.*: 66). A little further on in his argument, Xenakis eventually included the temporal dimension for the creation of geometrical shapes: 'We could use motion in order to create an acoustic line that moves between a series of loudspeakers. Thus, we introduce the notions of acoustic speed and acceleration'. He concluded that, 'All geometric curvatures and surfaces can be kinetically transferred with the help of sonic points' (*ibid.*: 67).

Xenakis' early observations suspect the importance of linear time for the perception of space-geometry in music. Geometrical figures, often static in the visual world, are never so in the sonic world. The intervention of time not only supports their acoustical construction but also influences our perception of their shape and structure. Sounds formed in various geometrical shapes exist in a perpetual state of growth. Vande Gorne underlines that, '... time and space are interconnected: a slow rotation does not generate the same significance as a rapid one, and if it transfers to a progressively faster tempo, it changes its form and becomes a spiral' (Vande Gorne 1991: 125). Hence, motion becomes transition and geometrical figure and therefore part of the form. Temporal evolution indicates the changes in geometry and guides audition. Space-geometry, however ornamental or metaphorical it may be, offers an expressive spatial support to sounds and is very much related to motion behaviours and the temporal dimension.

#### 3.1. The sound dome and Wassily Kandinsky

Since the beginning of the 1970s, the composer and researcher Léo Küpper has been trying to complete

<sup>13</sup>Smalley, In the CD leaflet, *empreintes DIGITALes* (2000).

<sup>14</sup>Smalley, In the CD leaflet, *empreintes DIGITALes* (2000).

a well-tempered sound instrument for the diffusion of electroacoustic music through a sound dome. His installations in various places have led the way to a meaningful approach to spatialisation. His aim has been the completion of a space modulation system with which the interpreter will be able to articulate the spatial structure of a piece. This system should function according to a series of pre-determined laws and parameters on equal terms with the ones governing the pitch modulation system. Although I shall not be examining this system in great detail, suffice it to mention that Küpper argues that it is possible to ‘... measure the interval which, in space perception, corresponds to the semi-tone interval in pitch perception’ (Küpper 1998: 61). The results of his research define this spatial interval somewhere between  $13.2^\circ$  and  $15.8^\circ$ , and he therefore suggests that the *tempered space interval* should be  $15^\circ$ . That means that human auditory perception can distinguish sonic sources and spatial points, such as loudspeakers, that have a minimum distance of  $15^\circ$  between them. Due to their radiating nature, however, loudspeakers can be perceived as spatial points only close to their cones. One can assume that the construction of a sound dome with loudspeakers defining its periphery, can take advantage of Küpper’s observations for the projection of space-geometry. In theory, a new *spatial scale* can be created, based on the tempered space interval that will allow the projection of spatial ‘melodies’ and contrapuntal spaces constructed upon combinations of spatial intervals. A sound dome could thus be regarded as a gigantic well-tempered spatial instrument with equidistant loudspeakers on its periphery.

However promising or controversial this instrument might be, its function is based on the geometrical principles mentioned in previous pages. Also, Wassily Kandinsky’s theory on the construction of forms in painting can provide useful templates for the projection of space-geometry through sound domes. In his treatise *Punkt und Linie zu Fläche* (Kandinsky 1926), we encounter a number of elements which, even

though they are originally related to painting, can be used for the projection of musical space. For Kandinsky, the primordial component of form is the *point*. He considers the point as the most laconic, ephemeral form, which is characterised by excessive immobility. Motion overwhelms the point’s immobility and creates the *line* by leaping from a static to a dynamic status. The line may have any direction, either horizontal, vertical or diagonal. The transfer from the point to the line underlines an important opposed duality found in geometry: the immobility of the point versus the mobility of the line, stasis versus kinesis. *Planes* are eventually constructed with combinations of bi-directional lines.

These three primordial geometrical components can be applied not only in painting but also to the composition and projection of musical forms. Point refers to any short percussive sound with a short resonance, or a loudspeaker that occupies a geographical location in the listening space. Line can be considered as the projection of any sound morphology between two speakers, and plane can be the multi-directional projection of soundscapes and images through a combination of concentric or non-concentric group of speakers, as shown in figure 1.

Sonic lines and trajectories emerging from one or more loudspeakers situated in different points of the dome, and also countless combinations of sonic planes and images, can all be directed towards the listener without any previous reflections. From the immobility of the point to the daedalian combinations of motion, the structure of the sound dome which hovers over the audience, projects the sound directly to the listener. The hemispherical form of the dome mirrors the geometrical perfection of a sphere. It symbolises at the same time infinitude and the point, that is, space and its primordial structural element. The dome itself, being half a sphere, is a point consisting of other points (loudspeakers) outlining its periphery, the expansion of which is boundless.

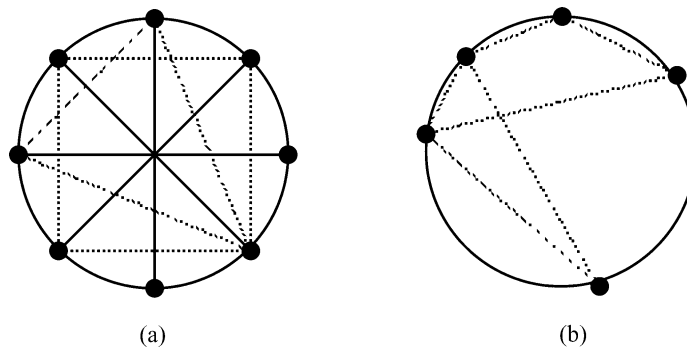


Figure 1. (a) Concentric projection, and (b) non-concentric projection.

### 3.2. Propositions for multi-channel projection of space-geometry

The experience of the eight loudspeakers is extraordinary. There is no room for anything but immediate listening. The air was so alive one was simply part of it. (Nattiez 1995: 142–3)<sup>15</sup>

The perception of space-geometry requires a critical listening and sonic clarity that is not always achievable through stereo recording and projection. The articulation of geometrical shapes and structures in a three-dimensional sonic environment cannot be accurately realised within the boundaries of a conventional stereo image projected by a pair of loudspeakers. The addition of more pairs can provide a compromise solution to this problem which, however, lacks clarity and efficiency. Discrete multi-channel reproduction is a convenient means for the transcription of geometrical similitude in listening spaces because it provides all the basic geometrical elements upon which replicas of geometrical spaces can be constructed and projected. A loudspeaker, assigned to a discrete channel, can be used as a point-source whilst combinations of two or more speakers can project two- and three-dimensional structures. When projecting geometrical structures, reality and fidelity are essential, and discrete channels can offer a 'sonic pencil' with which the projector can clearly and accurately draw outlines, peripheries and sonic trajectories. Furthermore, as Chris Rolfe underlines, 'Assigning individual channels to individual speakers for monitoring, improves fidelity, since speakers work most efficiently when not taxed by overly complex signals' (Rolfe 1999).<sup>16</sup>

Space-geometry refers to the abstract construction and projection of sonic spaces within definite bounds, and in that sense, the structure and development of a piece is related to specific shapes of geometry or stereometry. A sonic triangle, for example, projected via three loudspeakers becomes a rectangle with the addition of one speaker, and a three-dimensional parallelepiped with the superposition of four more speakers. In contrast to space-ambiophony, the pre-decision as to how the discrete channels will be assigned, and the layout of the speakers in the listening space are crucial. The composer should decide the types of geometrical shapes and the configuration of the loudspeakers in the very early stages of the composition process. Moreover, the composition process would certainly be based on and influenced by these strategic decisions, in the sense that the geometric

installation of the loudspeakers will eventually determine the structure of the composition. Composers and performers of electroacoustic music, however, should be aware that a very complex installation will possibly sacrifice the clarity of geometry and architectural transparency. During a personal communication, composer Annette Vande Gorne pointed out that the intersection of different superimposed lines and planes, and the simultaneous projection of oblique, vertical, transversal etc. trajectories, will probably result in a confused and amorphous sound mass with unclear boundaries and few, if no, geometrical references. A solution to this problem might be the addition of perspective. Remote or distant lines and planes could be differentiated from close ones and be perceived as geometrical shapes within different 'spatial galaxies'.

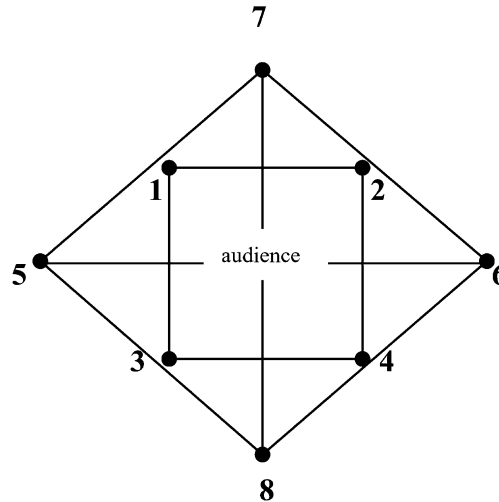
The configuration of the loudspeakers should follow and reinforce the geometrical schemes determined by the composer. It would be very difficult, for example, to project a circular motion around the audience if the loudspeakers are placed asymmetrically and haphazardly in the listening space. Very often different types of circular motion are projected via a loudspeaker installation which forms a circle around the audience. The angle between eight speakers arranged equidistantly in a circle is more or less 45°. Although their symmetry will guarantee regularity and periodicity, the circular positioning of a multi-channel installation has a notable disadvantage. As Chris Rolfe indicates, 'Because amplitude panning, which is still the core technique for most music diffusion, is sensitive to listener position, an audience member sitting even a few feet off-centre will not perceive a phantom image between a panned pair, but, rather, localise the sound on the nearer of the two speakers' (Rolfe 1999). A possible solution to this inconvenience is to break the symmetry of the installation by inserting some spatial points/loudspeakers in the listening room, which will indicate, during the projection, the spatial boundaries, and will play the role of spatial references. The configuration that I chose in order to deal partly with this psychoacoustic effect, known as *precedence* or *Haas effect* (Kendall 1995: 71–87),<sup>17</sup> is shown in figure 2. Loudspeakers 1–2 and 3–4 consist of a nearfield quadraphony which surrounds the audience and can project different types of circular motion, such as spirals, helixes, etc. A more distant quadraphony comprising the pairs 5–6 and 7–8 indicates the remote spatial boundaries and superimposes a shifted geometrical plane compared with that created in nearfield quadraphony. Pairs 5–6 and 7–8 also create a sonic 'cross' that provides the horizontal

<sup>15</sup>The quotation is from a letter sent by John Cage to Pierre Boulez in 1953. It can be found in *The Boulez–Cage correspondence* (Nattiez 1995).

<sup>16</sup>Rolfe's paper, *A Practical Guide to Diffusion*, can be found in electronic form in eContact! 2.4, <<http://cec.concordia.ca/econtact/Diffusion/diffindex.htm>>.

<sup>17</sup>See Kendall (1995), and Kaup, Khoury, Freed and Wessel in *Volumetric Modeling of Acoustic Fields in CNMATs Sound Spatialization Theatre* <http://cnmat.cnmat.berkeley.edu/ICMC99/papers/vizicmc/vizicmc.html>.





**Allocation of the tracks**

- |                           |                           |
|---------------------------|---------------------------|
| <b>Track 1:</b> speaker 1 | <b>Track 5:</b> speaker 5 |
| <b>Track 2:</b> speaker 2 | <b>Track 6:</b> speaker 6 |
| <b>Track 3:</b> speaker 3 | <b>Track 7:</b> speaker 7 |
| <b>Track 4:</b> speaker 4 | <b>Track 8:</b> speaker 8 |

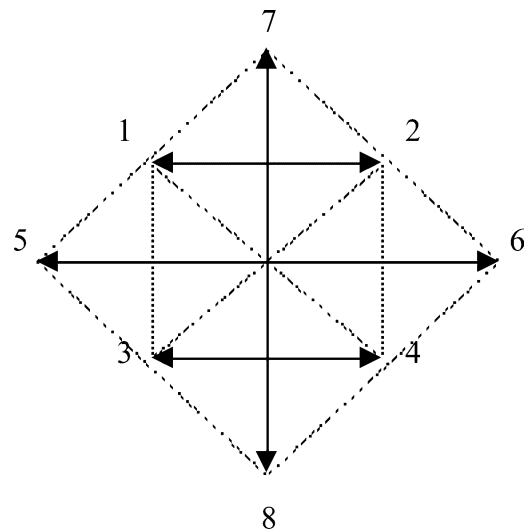
**Figure 2.** Two-dimensional configuration of the eight-channel installation.

(5–6) and vertical (7–8) axes of the spatial perimeter and indicate specific spatial points of reference, which help listeners to deal rather efficiently with the Haas effect. Hence, space is defined by nearfield (1–2 and 3–4) and distant (5–6 and 7–8) trajectories, as shown in figure 3. Secondary diagonal trajectories, such as 1–4, 2–3, 7–5, etc., are also used occasionally in order to diversify the articulation of space.

Ideally, a second configuration of the eight speakers should be suspended from the ceiling in order to provide a complete three-dimensional layout, as shown in figure 4. Thus, sonic trajectories and planes can be transformed into ‘objects’ of solid geometry.

**4. CONCLUSIONS**

Space-ambiophony and space-geometry have been examined not only for their musical applications but also in relation to perception. The ideas throughout the article, concerning the composition and projection of space in electroacoustic music are based on a theoretical approach combined with subjective judgement.



**Figure 3.** Nearfield and distant trajectories of the eight-channel installation.

One of the main issues considered is the importance of performance of electroacoustic music: the art of spatial projection and the development of a methodology for its practice. It is through this practice

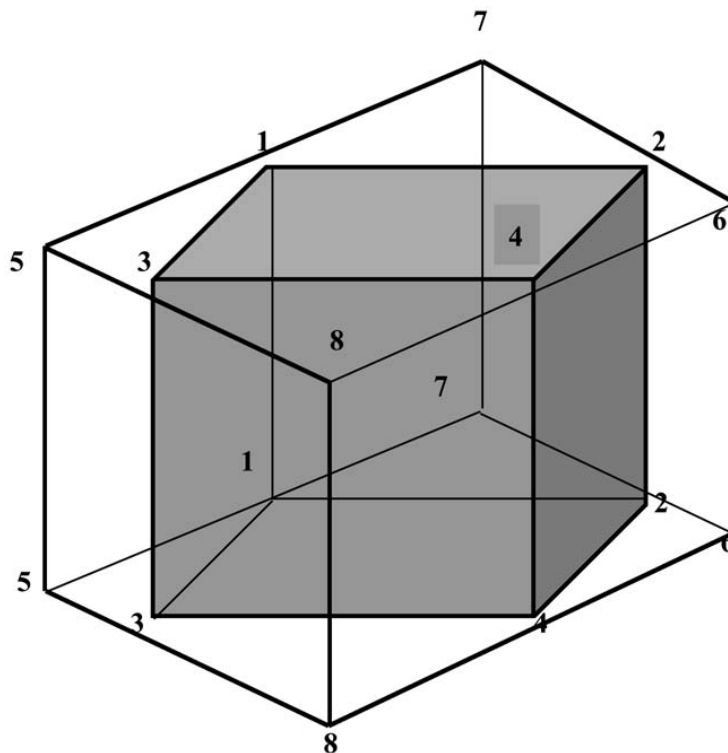


Figure 4. Three-dimensional configuration of the eight-channel installation.

that music is perceived and comprehended, a factor as important as the process of composition itself. Ignoring or underestimating the impact of the spatial element means that a blind eye is turned to many of the innumerable meaningful possibilities that electroacoustic music has to offer.

#### 4.1. Codetta

The art of projection plays a decisive role in the perception of electroacoustic music. The way we compose and hear this type of music is defined by a loudspeaker-based approach. Individual or pairs of loudspeakers project 'images' which are influenced by the acoustic properties of the listening space and the projection decisions made by the performer. However, new technological developments will shortly question the practice and experience of electroacoustic music, and will possibly offer new and promising practical potential. Such developments include the systems of *wave field synthesis* and *audio spotlight*.

One of the main inconveniences confronted by the performer of electroacoustic music is that there is virtually only one ideal listening position, usually in the centre of the loudspeaker installation, where the listener can perceive both the composed and the projected space. As a result, the spatial imaging and kinetic properties projected by the loudspeakers do not reach the listener in a homogenous and coherent way. According to Malham, 'A homogenous sound

reproduction system is . . . one in which no direction is preferentially treated and a coherent system . . . one in which the image remains stable, i.e. is subject to no significant discontinuities, if the listener changes positions within it, though the image may change as, indeed, a natural soundfield does' (Malham 1999). Therefore, a homogenous and coherent system would be one that not only includes the requirements of flat frequency response and low distortion, but also a system that remains faithful to the original compositional intentions without imposing its own spatial properties. Wave field synthesis, derived from the work of Berkhout (1988), which uses ' . . . a curtain of microphones hung in front of the sound source feeding a similar curtain of loudspeakers' (Malham 1999), could provide convenient solutions to the problem of coherence and homogeneity by reconstructing in the listening space a set of spatial articulations which matches those of the composed space. Malham concludes that such a system will ' . . . be both homogenous in its treatment of the 3-D audio space the listener is immersed in and capable of remaining coherent as the listener moves within that space'. Moreover, 'This would make it possible to leave all the original artistic decisions about how and where to place material . . . intact whilst allowing engineers and producers . . . full artistic freedom in their use of sound in space' (Malham 1999).

Audio spotlight, invented by Joseph Pompei in 1998, originates from the way light is projected and

promises to generate the opposite effect of wave field synthesis, that is, to direct audio via ultrasonic signals, which only listeners within its sonic beam can hear. Pompei explains that, '... as the ultrasonic beam travels through the air, the inherent properties of the air cause the ultrasound to distort (change shape) in a predictable way. This distortion gives rise to frequency components in the audible bandwidth, which can be accurately predicted, and therefore precisely controlled. By generating the correct ultrasonic signal, we can create, within the air itself, essentially any sound desired' (Pompei 1998). That means that loudspeakers would no longer project signals through retrogressive movements which result in sound diffusion, but ultrasounds that would permit the accurate directivity of sound within the listening space.

The benefits of the two systems and the inevitable changes they might cause, not only to the performance of electroacoustic music but also to the compositional process, are evident. Whether these changes will provoke a meaningful discussion of what the nature of electroacoustic music and the art of projection are, remains to be seen.

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