Low-level topology of spatial texture

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ABSTRACT

Low-level topology of spatial texture is here introduced as the basis of an aesthetic principle of sonic texture and spatial structure in electroacoustic music. The term *spatial texture* is used to describe aggregate sound structures which have a perceived three-dimensional spatial presence, specifically meaning that they occupy several areas or a stretch of horizontal *perspectival space*[1] whilst also having a dynamic behaviour in *spectral space*[2]. The word *topology* refers to properties, qualities and structural features which remain distinct to a texture despite continuous change or recurrent incarnations in different specific shapes throughout a work.[3] Ultimately, *topology of spatial texture* may be thought of as the core principle behind an attitude to music which considers all elements of structure to be part of an elastic spatiotemporal sound fabric. Rather than conceiving a work as built from time-finite morphological 'objects', this view emphasises processes of deformation, where any singular shapes may be seen as instances of textural topologies. The terminology presented here is intended as a contribution to discourse on spatiality in music, with special relevance to multichannel compositions.[4] This article focuses on the low-level, internal, structure of a spatial texture.

1. DIMENSIONS OF SPATIAL TEXTURE

The terms introduced here pertain to perceived spatiality and offers vocabulary necessary for discussing textural distributions.[5] Terms originating in Smalley's writing on space-form are also applied and built upon [2].

1.1. Perspectival Field

The *perspectival field* extends from the listener's vantage point and encompasses all subcategories of perspectival space, of which the most important are *panoramic space* and *prospective space*, *circumspace*, and *circumspectral space*.[6] In circumspatial, multichannel compositions, listeners find themselves physically within the perspectival field, where regions have difference in presence and position in relation to vantage point. The degree to which such perspectival modularity is pronounced is an aesthetic decision in composition. Even if listeners are unable to change positions in most listening situations, their attention is free to project across the field in any direction. And because perspectival orientation is fundamental to human reality, listeners are able to construct a global view of the field, or imagine how it could appear from other vantage points.[7] If the composed relationships of stereophonic perspectives are analogous to pictorial representation, those of circumspace are more similar to architectural structures and designed landscapes: the relationships of the perspectival field are more radically affected by vantage point, yet – as in a building or a garden – the structure guides the attention of its inhabitants/visitors through balance, emphasis, and points of attraction.

1.2. Spectral Verticality

Relations in the audible frequency range create the upright dimension which is here termed the *spectral verticality* – specifically referring to the dimensional aspect of spectral space. As with perspectival orientation, our understanding of verticality is embodied – verticality is not only a scale which textures populate; as listeners, we also find ourselves within a vertical context.

[1] Smalley defines perspectival space as 'the relations of spatial position, movement and scale among spectromorphologies, viewed from the listener's vantage point' [5].
[2] Smalley defines spectral space as 'the impression of space and spaciousness produced by the occupancy of, and motion within, the range of audible frequencies' [4].
[3] Topology, here, is thus not referring to mathematics, the discipline in which the concept originated [3]. Rather, this is an interpretation and application of topology to suit stated musical purposes.
[4] The approach presented here emerged as part of an artistic research, and is primarily a result from composition [1]. Amongst the author's works, the four eight-channel pieces *Cataract* (2010), *Latitudes* (2011), *Catabolisms* (2012), and *Lucent Voids* (2012), may be considered demonstrative of the aesthetic thinking behind the topic of this paper. They have been published in stereo versions on CD [21].

[5] All important terms are written in italics first time mentioned. Those not referenced in footnotes are novel to this paper.
[6] *Panoramic space* is defined as 'the breadth of prospective space extending to the limits of the listener's peripheral view' [5]. *Prospective space* is 'the frontal image, which extends laterally to create panoramic space' [4]. *Circumspace* is 'the extension of prospective and panoramic space so that sound can move around the listener and through or across egocentric space' [5]. *Circumspectral space* is 'the spatial distribution or splitting up of the spectral space of what is perceived as a coherent or unified spectromorphology' [5].
[7] Alva Noë discusses how humans deal with perspectival orientation in *Action in Perception* (2004). One of his key points is that sensorimotor skills are essential to perception, and that these enable us to understand how perspectival deformations relate to actual shapes of objects. We have accumulated an intuition for spatial relationships through our ability to move our own bodies in relation to what we are perceiving [6].

The perceptual correlation between frequency and vertical height has been verified experimentally and it is believed that it goes beyond metaphorical links or cultural conditioning.[8] Moreover, research has suggested that frequency has a stronger influence on perceived vertical orientation than the physical position of a sound source[9]– so long as it is not visually or contextually obvious where and what the sound source is[10] – and that verticality can be simulated through the processing of audio signals.[11] Verticality often manifests convincingly in composed spectral relationships: high-frequency textures, for instance, can create an impression of canopy extending well above listeners although presented through a horizontal array of loudspeakers. In spatial texture, spectral verticality always has a perspectival distribution, and vice versa. Thus, a vertical relief can be apparent along the horizontal dimensions as a form of topography, especially in the layering of multiple spatial textures.

1.3. Latitudes, Longitudes, Altitudes

As illustrated in figure 1, the perspectival field comprises the dimensions of *latitude* and *longitude*. This is not a grid, as in geographic representations, but rather a percept of distances and orientations – an inferred structure of balance. In general terms, latitude is the sideways dimension, comprising the width of panoramic and/or *lateral space*[12]. Longitude represents the extension from frontal, distal space, to the rear of circumspace, along which several latitudes may appear as lateral or panoramic layers articulating degrees of distance in front, or presences on the sides, of the listener. The perceived centre of the perspectival field is dependent upon the listener's vantage point, but also influenced by what the listener deduces from knowledge of what the 'objective' centre of the listening context is. Peripheries may extend well beyond the loudspeaker arrangement, depending on the textural material, and represent the furthest edge of the spatial texture.

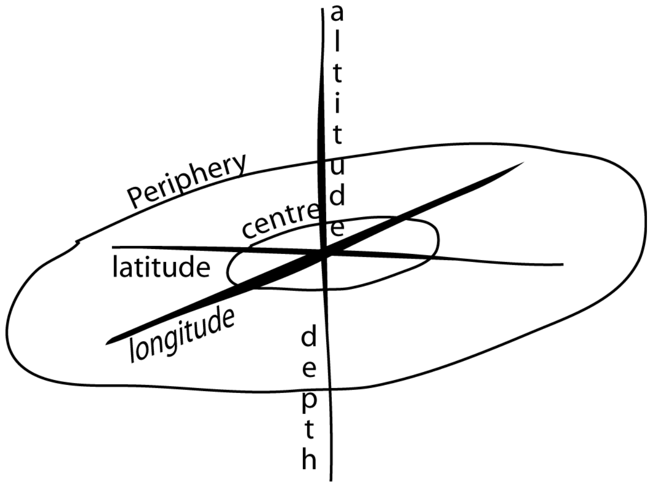

Figure 1: Dimensions of spatial texture.

The full extent of spectral verticality reaches from the lower extremities of *depth*, which is perceived as if existing below the listener, to higher *altitudes*, extending to areas perceived as above. It is in the nature of the perspectival field and spectral verticality that they both rely on the accumulation of experience throughout a work, and the structural loci and relationships that are established within this process. In the overall topology of a musical work, space is elastic: the presence of, and relationships among, dimensions are a matter of context-dependent, relational spatiality, and should therefore not be thought of as a fixed geometry. Perspectival field and spectral verticality are an emerging result from lower-level activity in spatial texture. However, simultaneously, it is also becomes the spatial context of this very same activity.

2. DISTRIBUTIONS

Distributions concern how the spectral and temporal micro-constituents of spatial texture are structured relatively to form the topology of a single spatial texture. In the textural interior, a distinction is made between *textons*[13] – temporal features which can result in, for example, textural surface complexion or pointillistic motion behaviour – and *filaments,* which are time-continuous and thus primarily spectrally segmented, as we may not perceive their beginnings and ends. The production of spatial texture over time is the result of propagating streams of textons or filaments. A spatial texture is often made up of several

[8] The verticality experienced in frequencies was studied as early as 1930 by C. C. Pratt, and has become known as 'Pratt's effect'. He had subjects estimate the height of an occluded source producing sine tones, and found a direct correspondence between verticality and frequency [8]. Roffler and Butler [9] affirmed the relationship in further experiments, and also found it occurring among congenitally blind persons – which suggests that it is not merely a visual influence – and young children who were unfamiliar with the conceptual and linguistic association between 'high' and 'low', and frequency. Pratt's effect has also been tested for un-pitched noise bands [10, 11] and complex harmonic sounds [12], with similar results. For a summary of research on the subject, see [13]. Khosravi's research on spectral spatiality offers convincing discussion and taxonomy on verticality in acousmatic music [16].

[9] See [13] and [9]. Roffler and Butler [14] also found that frequencies above 7 kHz need to be present in a sound in order for any vertical localisation to take place. This is due to our dependence upon reflections of the pinna when binaural relationships are insufficient for determining source orientations.

[10] In acousmatic listening it is of course, technologically speaking, contextually obvious that the sound sources are the loudspeakers. However, when spectral space is efficiently articulated, the presence of loudspeakers is usually not a major aspect of the listening experience.

[11] Susnik et al. [11] found that up to 60 different elevations can be perceived in correspondence with spectral distributions and emphases. Bloom [15] simulated filtering introduced by the pinna through acoustic analysis and sound processing.

[12] Lateral space is 'the extension of panoramic space towards the rear of the listener' [5].

[13] Textons are discussed in depth in [17] – their microsonic properties have a critical influence on the texture as a whole. The word, *texton*, was invented by neuroscientist and experimental psychologist Bela Julesz, to describe the 'atoms' of visual texture perception. He developed the conjecture that the pre-conscious perception of textons is critical to the ability to see gradients and segregation in the visual field [18].

perceivable streams distributed horizontally and spectrally to create perspectival field and spectral verticality.[14]

The diagram in figure 2 shows the terminology of distribution, referring to the spatial composition of a texture in terms of relative positions of propagating streams.

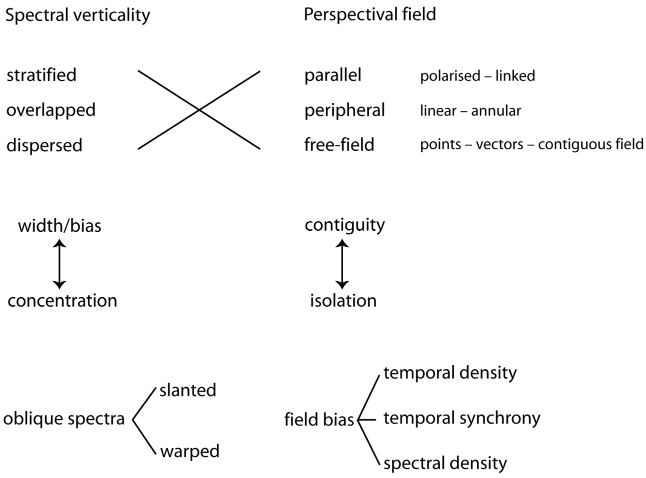

Figure 2: Distributions.

In spectral verticality, *stratified* distribution means that propagation streams are grouped into one or several spectral bands. *Overlapped* distributions can, for example, involve vertically intertwined processes. Textures may also be *dispersed,* as cloud-like gauzes of sound. The *width/bias–concentration* continuum concerns the vertical spread and balance of a texture.

Three distribution types are given for the manner in which propagation streams are arranged in the perspectival field: *parallel*, *peripheral*, and *free-field*. *Parallels* are lateral or panoramic pairs of propagation streams. The *polarised–linked* continuum depends on the degree of similarity between the propagations: they are polarised if distinct spectral and temporal differences set them apart, and linked if they are similar in spectrum, density and synchrony. Where several parallel distributions are present, they can be placed at different latitudinal positions (along the longitude), creating a spatial texture that extends over an area in the perspectival field. The parallels can be further separated as spectrally stratified latitudes.

Peripheral distributions are located along the edges of circumspace, and can be circumspectral. The *linear-annular* continuum concerns the extension of the periphery: a linear periphery may only stretch along a part of prospective space, whilst an annular periphery encircles the whole of circumspace. In *free-field* distributions, *points* are textons dispersed individually across the field, whilst *vectors* are propagations which move freely in beads. In the former case, zones or latitudes can be created in aggregations. *Contiguous field* represents a spread texture with no gaps. The *contiguity–isolation* continuum generally concerns whether the perspectival field is joined up or more segmented. *Oblique spectra* are formed when simultaneous propagation streams are differently distributed vertically in the same perspectival distribution so that a global contour emerges. A spectrum can be *slanted* as a regular line over multiple strata in the perspectival field, or *warped,* if the vertical contour is less regular. *Field bias* occurs when the relative density and synchronicity among different streams create an impression that a texture is attracted towards certain spatial areas.

Depending on noise and resonance properties among textons and filaments, and on width or concentration of strata, distributions can acquire different roles in the overall image. For example, dispersed peripheries may extend into distal regions while textonal strata come forward in the image; filament textures often naturally end up in the background if stratified noisy or textonal material is also present.

3. CONNECTED LOW-LEVEL TOPOLOGY

Propagations, distributions, and properties of textons and filaments are flexibly connected in a continuum allowing for the shaping of texture in space and time, whilst also maintaining an essential topological structure which is temporally nonlinear.[15] The four main aspects – *texture warp*, *integration*, *surface texture–interior texture*, and *resolution* – are indicated in the diagram in figure 3, and represent the salient features of a textural topology in the temporal process of deformation. *Texture warp* occurs when distributions deform texture through contracting and dilating strata and parallels, oblique spectra, and field biases.

Integration concerns the degree to which the spatial distribution of streams form a whole as opposed to being segregated into individual areas of space. As all other topological aspects, this continuum is subject to temporal alteration, meaning that textures can integrate and segment recursively, as *local deviation* and *global coordination* work against each another. Differences in propagation or texton properties among streams will draw attention to local areas of the texture, whilst global motion affecting all streams, and similarities among textons, will serve to integrate the texture.

The continuum between surface and interior texture, at the bottom of the diagram, is related to the degree of articulation of textons and filaments in the texture. An interior needs a degree of local complexity to establish – homogeneous texton or filament textures often remain surface-oriented. *Resolution* concerns the spatial clarity of the texture, and is a matter of how clear the *definition* of its

[14] The role of spectral and temporal factors in the segregation of auditory information is an aspect of auditory scene analysis, as expounded by Bregman [19].

[15] Low-level topology can be related to what Jonathan Kramer considers to be nonlinear aspects of music. His typology refers to time, where nonlinearity is '*the determination of some characteristic(s) of music in accordance with implications that arise from principles or tendencies governing an entire piece or section.*'[20]: topology, as a temporally nonlinear structure, is understood from 'cumulative listening' (as Kramer puts it) to the behaviour of texture. In my view, however, this may also include directional – 'linear', in Kramer's terms – motion processes that reveal the malleability in texture.

activity is. Textons properties – especially temporal definition – affects this, as does the spectral gaps and relative propagation modes among filaments: spectral and temporal separation increases definition. *Diffusion* relates to spectral density and blurred or smeared features.

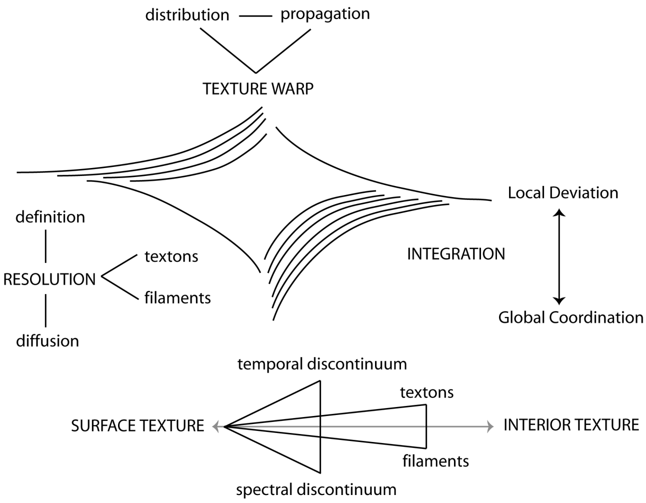

Figure 3: Low-level topology.

4. CONCLUSION

This paper has outlined the lower-level structures which give spatial textures identifiable qualities that may be sustained through temporal processes of deformation. This level of topology in spatial texture can be viewed as the primary source from which sonic forms are created in a work. What is presented here exists within a larger-scale theoretical framework where topology of spatial texture is also applied to higher level aspects of a work, thus also pertaining to relationships between multiple textures [1].

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