Spatial Organization in Musical Form

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ABSTRACT

Classical Western music theory concerned itself primarily with tonal relationships between notes, while serialism focused instead on the relationship of elements in a series, typically, the temporal order of the 12 notes of the equal tempered scale. This work considers the nature of spatially organized music and how a theoretical basis might be formed for understanding the underlying concepts and expectations inherent in spatial composition. Previous examples of spatial organization are considered, and theoretical concepts such as dissonance, consonance, position, inertia, gravitation, and context are applied to spatial music. Practical considerations in achieving such motives are also discussed for real-world rooms and audio formats.

1. INTRODUCTION

In 2001, *Computer Music Journal* published a series of responses by well known composers to comments by York Höller in which he claimed, among other things, that spatialization in current electroacoustic music was inherently superficial. In the same issue, Jean-Claude Risset replied that

> It is wrong to view the spatial aspects of music as merely cosmetic. Stream segregation of sound events is the base for perceptual organization, which influences the perceived melodies and rhythms, as well as the consonance-dissonance or timbral aspects: it can be made to occur on the basis of purely spatial cues, thus spatial aspects can play a structural role. [1]

Another respondent from the same article, Jonty Harrison, claimed that most composers were working simultaneously with many different aspects of sound, including space as an integral part of this process. While it is doubtless true that all music exists in multiple dimensions – such as time, frequency, language, or space – in many cases music's basic organization structure, or *form*, privileges a single dimension, using others to serve the expression in the primary dimension.

To illustrate this, imagine the effect of collapsing the frequency/pitch space into a single point of middle C, while leaving the other domains untouched. Such a reduction would clearly diminish certain works more than others: a Bach fugue would be completely unlistenable after such a collapse, while a hip-hop single might emerge more intact because the essence of the work was constructed along primarily rhythmic and lyrical dimensions. Even in the case of truly multimodal pieces which draw equally from different dimensions, considering each dimension on its own can be helpful to understand its use in conjunction with others.

With this distinction in mind, is there such a thing as 'spatial' music in the same sense as 'tonal' music (organized primarily along tonal relationships) or 'serialist' music (organized primarily along the serial relationships of events, often with respect to time), and if so, is there a theoretical framework for the use of space in music? To reduce confusion with the common usage of 'spatial music' (referring to music that makes use of space in any form), throughout this work we will instead use the term 'spatially organized music' to refer to music using space as its primary organizational component. [1] We will first examine the development of spatial gestures in the past, then outline some thoughts on the structure of a spatial theory based on both composers' usage and the nature of spatial hearing, and finally we will address some practical considerations based on the constraints of current technology.

2. BACKGROUND

The dimensional framework outlined above should not be construed as a narrow view of a single compositional domain at the exclusion of all others – for instance, tonal theory is based on ideas of conflict and resolution, which work themselves out over the dimension of time but are not as rigorously bound to temporal sequence as in serialism. For most of the history of Western music, frequency/pitch has been the primary component, time has been secondary, and space has been mostly neglected. [2] While composers through history have made use of spatial gestures, the spatial palette available to them was rather coarse and thus very little acoustic music made use of space as its primary organizational component. [3]

[1] For instance, Karlheinz Stockhausen [1] refers to his masterwork Gesang Der Jünglinge as spatial, which despite its groundbreaking use of space, could still be rendered recognizably in mono.

[2] Interestingly, many non- Western music prized temporal aspects far before any Western composers, producing music that is far more interesting rhythmically than many canonical Western works. Space, in the sense of interior/reverberant environments versus exterior/acoustically dry environments, may have played a role in these dimensional emphases. [2, 3]

[3] Notable exceptions are *Terretektorh* by Iannis Xenakis [4], and the *DO Quintet* by Theodore Antoniou, both of which limit themselves to a single pitch to explore spatial relationships in the ensemble.

All acoustic music has some inherent spatial texture through the spacing of instruments and performers, but this spacing was usually the extent of such music's spatial domain. In Renaissance Venice, Adrian Willaert made famous the *coro spezzato* (split-choir) style, which prescribed two or more spatial positions to be used for the performance of complex polyphonic music [5, 6, 7]. Scholars are divided as to the regularity and exact position of this practice, but in any case it may be seen as an early spatial ornamentation on a basically tonal compositional structure. Hector Berlioz would use similar techniques in his *Requiem* (1837), in which he not only used spatial separation for four brass choirs [8], but he also saw these sources as parts of a larger instrument: the performance hall itself. Berlioz wrote in 1835 that

> Many fail to recognize that the very building in which music is made is itself a musical instrument, that it is to the performers what the sound board is to the strings of the violin, viola, cello, bass, harp, and piano stretched above. [9]

Many composers who made use of space in the 20th century made explicit reference to that which earlier composers only alluded: spatial separation, among other factors, improves the auditory stream segregation ability of the human auditory system, allowing it to better make sense of highly complex sound fields (the "cocktail party effect") [10]. This phenomenon was used to differentiate highly contrasted material by the American Experimental tradition, including Charles Ives and later Henry Brant, both of whom saw space primarily as a means to the end of increasing the scope of music that was still firmly rooted in a frequency/pitch paradigm [11].[4] Because the traditional tonal rules of counterpoint had been constructed in response to the frequency precision of the human auditory system due to the width of auditory critical bands, Brant saw that better usage of spatial separation could allow two tones to be heard as separate gestures rather than single dissonance. If we see the 'traditional paradigm as a three-stage hierarchy (fig. 1(a)), then Brant's approach might be said to raise up space as another secondary component on equal footing with time in the service of the frequency domain (fig. 1(b)).

In electroacoustic music, Karlheinz Stockhausen was able to make use of multi-loudspeaker setups to achieve far greater spatial control than any acoustic composer. Stockhausen believed that space held great promise as a new musical parameter, [13] and that the use of space could

> [move] the focus away from the pointillistic note relationships of early serialism and onto what Stockhausen referred to as "group composition", which emphasized the overall character of large groups of proportionally related material, rather than on the relationship between individual pitches. [14]

[4] Brant, did make use of explicitly spatial gestures such as 'traveling' motives via an ensemble surrounding the audience along both lateral walls [12]. However, his written works indicate a primarily utilitarian philosophy towards the use of space because of the greater freedom it allowed in the frequency domain.

Stockhausen's early-career philosophy thus elevates space as well, but keeps it as a secondary parameter to supplement temporal sequence (fig. 1(c)).

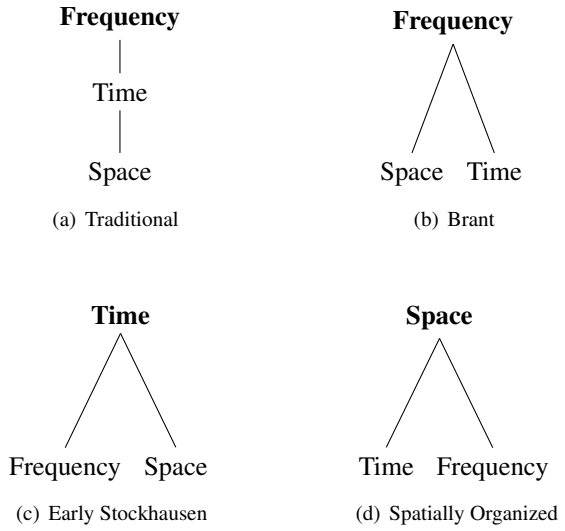

Figure 1. Organizational hierarchies in different compositional approaches, including a spatially organized framework.

A small subset of electroacoustic works do place space at the top of the hierarchy (fig. 1(d)), though not many composers go this far. One notable case is the famous Phillips Pavilion at the 1958 World's Fair, designed by Le Corbusier and Iannis Xenakis, which was the site of Edgard Varèse's *Poeme Electronique* [15]. Xenakis, whose experience as an architect informed his use of space in music, designed the structure to allow complex spatial trajectories for the sounds in Varèse's *Poeme*, but based on the layout and the presence of auditory and visual distracting elements these may have been difficult for the audience to perceive [14]. It was perhaps because of his experience with the Phillips Pavilion that Xenakis used visual cues to reinforce rather than distract from the spatial trajectories in the 1970s and his work with *Polytopes* [16].

The issues of spatial authenticity and perceptibility are continual themes in the history of musical spatialization, as the human auditory system defines the spatial resolution with which events may be depicted, as well as the listener's expectations about what constitutes a natural use of space. The growing use of sound installations, such as LaMonte Young's *Dream House* (1969) [17] or David Tudor's *Rainforest I–IV* (1968-73) [18] opened up the exploration of space through the freedom of listeners to explore their aural environment. A more recent series of installations, Peter Batchelor's *GRIDs*, which explicitly uses multichannel loudspeaker grids to depict spatial images through sound [19]. The fundamentally spatial nature of installation work has led to some of the earliest calls to expand musical form to account for first-person perception in space [20].

Another example is John Chowning, who developed an extensive music spatialization system [21] for exactly this purpose. A rudimentary version of this was used in his piece *Sabelithe*, which varied trajectories in what he termed a 'spatial canon.' The more developed system was used for Chowning's *Turenas*, which uses more complex Lissajous patterns to create natural acceleration and decel-

eration for the synthesized sound objects [22]. Chowning's system also included a Doppler shift, which reversed Brant's paradigm by employing frequency-domain effects in the service of space, rather than vice-versa. Obviously time is a necessary component of any spatial trajectory, but for the works described above, time is the vehicle used to explore a fundamentally spatial composition.

Finally, in Stockhausen's later work, there is a move towards the use of space as a primary compositional element. This is evident in his *Kontakte*, as discussed by the composer. At the same time, he was also exploring the concept of a fundamental unity between pitch/frequency and time, indicating that he began to treat all three dimensions equally rather than privileging any single dimension [23].

3. THEORY

Modern tonal music theory evolved gradually over several centuries from the organic observations of composers and scholars and their own experience with realizing different combinations of tones in sequence. The ability to realize complex spatial effects over time has occurred relatively recently. Although these techniques have resulted in the beginnings of systems for the analysis of spatial aspects of music, [24, 25, 26] there has not been sufficient time to codify any hard-and-fast spatial 'rules' in the same sense as the rules that govern voice-leading or harmonic progression. However, there may be fundamentally analogous processes underlying both spatial and tonal gestures, such that some principles may be reinterpreted from tonal space into physical space. Similarly, many components of the auditory system's response to spatialized music may be useful for framing listeners' perceptual capacity and expectations regarding spatial organization. Indeed, one of the primary criteria for a music theory is its coherence with other better-established areas of study [27], and in this area observations from both aesthetics and psychoacoustics will be useful for constructing a spatial theory.

Just as tonal theory consists of tonal events (e.g. notes, phrases, and melodies) within a given background setting (e.g. time and key signatures), so too in considering how spatial theory might function we can distinguish between spatial events/gestures, and the larger 'space' or spatial context within which the gestures are situated [28].

3.1 Spatial Events

3.1.1 Spatial Dissonance and Consonance

A key theoretical idea underlying classical tonal theory is the juxtaposition of conflict and resolution within a piece of music. Though non-semantic tones, chords, and harmonies cannot convey conflict in the same sense that a narrative might, human listeners perceived similar themes owing to the 'beating' dissonance of certain tone combinations and the 'purer' consonance of others [29]. In a similar vein, it is possible to use these same fundamental themes in spatial gestures stemming from spatial rather than spectral auditory perception. Composer Natasha Barrett writes

> By presenting impossible juxtapositions of sound identities, or in other words conflicts in object identities, the composer can begin to work with a surreal landscape, accepted by the listener as unreal. [30]

Barrett suggests that these 'impossible' sound events create a sort of spatial dissonance [5] that discomfits the listener because of its inherent unreality, analogous to the beating of a tri-tone in the frequency domain. This can be resolved by a transition into spatial consonance, which requires highly realistic sound objects whose spatial identities do not conflict with their spatial positions. Note that the implied direction from conflict to resolution does not mean that all spatial dissonance must resolve: it is merely a statement about the listener's expectations that should be considered by the composer regardless of specific intentions about the composition. One could imagine the same principle motivating a Mozart-like approach, with spatial cadences occurring frequently, while the same framework could also inspire a Wagnerian approach that relishes spatial dissonance and holds onto it for as long as possible, either to achieve a more satisfying resolution or merely to play with the audience's expectations.

3.1.2 Spatial Position

Perhaps the one area of an emerging theory of spatial organization that has significant history is in the spatial position of sound events. In building from the practical ideas of dissonance and consonance, there is precedent for how positioning affects perception and focus. Events that are placed as point sources, front and center in relation to a listener are more likely to be perceived as 'important' material. Likewise, sound events that are diffuse and seem to inhabit a large portion of the ambient lateral plane are likely to be perceived as supporting, background, or secondary. These two scenarios feature heavily in the common mixing practice of commercial music. For example, the main vocal line is usually placed 'up front', panned to the center of the stereo field, with supporting material, such as drums or background singers spread along the stereo field in order to create a sense of 'space' [31].

Furthermore, this area of spatially organized music can be expanded through existing knowledge with regards to humans' ability to localize sound events. Although we do not localize sound events as well behind as in front of our heads, we still possess the ability to clearly identify events occurring outside the bounds of vision. This is an evolutionary adaptation for self-defense, to turn the visual system towards possible hazards [32].

This information suggests clear considerations that a composer could take with regard to spatial positioning of sound. Sounds behind a listener create a sort of spatial dissonance as long as the listener is unable to turn toward these sources. Moving the sound events in front of the listener (or simply allowing the listener to turn towards such sounds) can similarly resolve spatial dissonance. Likewise, the composer's use of point-source or diffuse positioning of sound events in accordance with the listener's expectations about the source material can be used to create tension or release. Caroline Shaw achieves this acoustically in orchestral performances of her work *Entr'acte*, in which extensive use

[5] This is similar to the analogy of "cognitive dissonance" in education theory, wherein the presentation of two apparently contradictory truths creates a mismatch in the student's mind that leads to a desire for consonance or resolution through learning.

of *pizzicato* makes an entire string section sound like a 40-foot wide classical guitar. As the piece ends, this sound field collapses into a plucked barre chord on a single cello, ending the spatial illusion.

3.1.3 Inertia and Gravitation

It must be noted that the term *gesture*, originally applied to motives in tonal music, is an inherently spatial metaphor [33]. Similarly many notions regarding *direction* or *motion* in tonal or even electroacoustic music can be safely applied to spatial gestures because we all have a pre-existing idea of what a gesture is and how it should unfold. As in Chowning's motion pieces, maintaining accurate spatial trajectories requires paying attention to physical ideas such as the inertia of an object in motion and the conservation of angular momentum when its trajectory is changing. Such details will make a composition tend toward spatial consonance, while their omission will tend toward spatial dissonance. [6]

Another physical parameter from everyday experience that must be considered in the motion and placement of spatial events is *gravitation*, the tendency of higher elevations to descend over time. Here especially the boundary between tonal space and physical space becomes very thin, as many theorists have noted that higher pitches inherently sound physically higher as well [12, 34]. The reason for this is the frequency-dependence of the head-related transfer function (HRTF), which is the auditory mechanism used for elevation perception [35]. Stockhausen describes a 6.5-octave drop in a tone, which causes "a strange feeling in the pit of [the audience's] stomach when they hear the sound falling down" [23]. This identification of sound elements with physical gravitation also induces a kind of spatial dissonance in the listener that must be resolved once the motion comes to rest.

The continual presence of gravitation requires greater effort to maintain higher positions, until an eventual resolution (indeed, the word 'cadence' derives from a Latin word meaning 'fall') [36]. This close relationship between tonal and physical space could lead to a Schenkerian treatment of physical space, considering the various ways in which a spatial *Urlinie* is prolonged prior to its inevitable descent [27].

3.2 Spatial Context

In his analysis of Xenakis's *Polytope de Cluny*, Adam Basanta has argued that there exist spatial analogs of transposition and modulation in the pitch domain [20]. These are formed by means of an auditory gestalt grouping of several spatial events into a larger structure, which constitutes a spatial motive. These motives in turn can begin to form a larger structure, the macroscopic sense in which 'space' is usually meant, similar to Berlioz's use above. A space of this kind could be a room, an environment, or a set of spatial rules about how sound events are prolonged or moved within that space. As in the case of a key signature in tonal composition, the larger background 'space' in which a piece is situated will shape listeners' experience of every sound event occurring inside it.

Spatial context can include the time-dispersal relationships determined by real spaces and environments, or synthetic relationships that could not exist in the real world. For instance, a virtual space could have a backwards time decay pattern where an initial sound's reflections grow in amplitude, up to a given limit, which contributes to spatial dissonance by the unreality inherent in such a system. Similarly, highly coordinated sound events at fast tempos in the context of a very long reverberation time can sound unreal, as such a situation is virtually impossible to achieve with real performers in a real space. In addition, the virtual room may be modified over time, another distinctly unreal spatial sensation. Soundscape composition can be seen as an extension of this idea, in which spatial events and context are fused into a single musical percept.

4. PRACTICAL CONSIDERATIONS

As the community works towards emergent theories of spatially organized music, there are practical considerations that will need to be considered by music theorists and artists that will influence both the development of these theories as well as compositional practice. Though the previous section considered spatial control in the abstract, real world considerations will sometimes specify the boundaries within which certain gestures can be achieved.

4.1 Hardware

Perhaps the most important of these issues at present is access to and knowledge of technologies for spatially organized music. With regards to tonal music, centers of academic music generally maintain large numbers of pianos, which give a composer easy access to the entire spectrum of tonal pitches. It is becoming more common to have 'decent' stereo speaker arrays in most community music spaces within these institutions (classrooms, concert halls, etc.), but in a tonal context, this would be akin to a piano that only contained two notes. As many academic institutions have limited financial resources, it might be infeasible to maintain multiple immersive loudspeaker arrays for the use of individual composers. However, a standardized individual binaural system using headphones might provide a suitable spatial composition resource for a much smaller price than large loudspeaker arrays. The composer would then need to make some on-site revisions for successful translation into a loudspeaker rendering for a large hall.

4.2 Format & Techniques

The vast majority of electroacoustic works of the past 60 years have been in stereo, which has led some to advocate composing multiple 'stems' in stereo, and later diffusing the stems during live performance [37, 38]. Other popular techniques include Vector Base Amplitude Panning [39] or Distance-Based Amplitude Panning [40] for composing directly for multichannel loudspeaker arrays. Soundfield techniques like Ambisonics and Wave Field Synthesis [41, 42] seek instead to encode an entire sound field, with

[6] Though in fairness, these basic physical laws were unknown in their present formulation for most of human history, so perfect numeric adherence to these laws may not always be necessary to maintain a perceptual sense of reality or consonance.

distinct decoding mechanisms for different playback systems. While sound-field techniques are often thought to be specific to a given sweet spot, it is possible to 'smear' the sweet spot during the decoding process, rendering a large listening area that maintains important spatial localization cues.

4.3 Environmental Control

For loudspeaker-based rendering in real spaces, the spatial context of the real room will be added to that of the composition itself. For that reason, the composite space presented to the listener will be constrained within certain practical boundaries determined by the physical performance space. For instance, if the virtual room has a longer reverberation time than the real room, the result will be a 'double-slope' decay that will be perceived as the reverberation time of the virtual room [43, 44]. However, the perceptual decay of the composite space can never fall below that of the physical space for the same reason, and thus any intended reduction in 'envelopment' or increase in 'clarity' will be limited by this consideration. On the other hand, perceived 'intimacy' could be increased by reducing the initial time-delay gap (ITDG) [45], which can be achieved by inserting a delay shorter than the first reflection delay in the physical room.

5. CONCLUSIONS

Though some individual theorists and composers have explicitly or implicitly explored the issues raised in this work, in general spatial form and theory are almost completely undeveloped in comparison to tonal or temporal theory. With that in mind, there are no doubt much more specific issues that could be addressed but which might be divisive within the community of spatial musicians. This work has intentionally been constructed to build a consensus around the broadest, most fundamental concepts underlying spatial theory with the hope that it will be useful to anyone interested in spatially organized music. It is hoped that these wider concepts can provide a foundation for more specific theories and richer compositional experimentation.

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