The aesthetic implications of 3D technologies on the spatial conceptualizations, configurations, and articulations of my compositional process

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For all new conceptions there must be new means.[1]
Varese E.

Each art practice is inscribed in its own time, materializing a true 'media ecology', a set of mediations and mediators of various kinds, explicit (technical, institutional) and non-explicit (cognitive, cultural, symbolic).[2]
Di Scipio A.

The rapid development and widespread adoption of immersive audio technologies, such as Dolby Atmos, Ambisonics and Wave Field Synthesis, has given rise to several sonic practices in which spatial experience plays a crucial role. The use of these technologies present a notion of space as a quantifiable and predetermined object designed to replicate a 360-degree sound field that closely mimics human auditory perception. However, this stance does not sufficiently contemplate the complexities[3] of their reciprocal influence from an aesthetic and perceptual perspective. Intrinsically, sound has the ability to provide us with immediate spatial awareness and, the implementation of 3D audio technology, emphasizes this interconnection. Because 3D recorded sound holds spatial coordinates, the link between these two elements appears to be more clearer when the attributes are already entangled within the spatialization algorithms. Independently of visual cues, the ability to seamlessly incorporate spatial and auditory

[1] E. Varese, Varèse, *La mécanisation de la musique*, 1930, quoted in *Varèse*, 1983, pp. 58–63 and in *Composing Electronic Music, A New Aesthetic*, *Composing Electronic Music: A New Aesthetic,* Oxford University Press, 2015, XXIV.

[2] "Ogni prassi d'arte s'inscrive nel proprio tempo materializzando una vera e propria 'ecologia dei media', un insieme di mediazioni e mediatori di vario tipo, espliciti (tecnici, istituzionali) e non (cognitivi, culturali, simbolici). " in A. Di Scipio, *Circuiti del Tempo. Un percorso storico-critico nella creatività musicale elettroacustica e informatica*, Libreria Musicale Italiana, 2021, XVII

[3] Where "complexity" for Edgar Morin is a *complexus*, that is, what is woven together, made up of inseparably associated heterogeneous constituents and poses the paradox of the one and the multiple. E. Morin, *Introduzione al pensiero complesso. Gli strumenti per affrontare la sfida della complessità*, Sperling & Kupfer, 1993, p. 20

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attributes immediately establishes a connection between the concept of space and the experience domain. Hence, composers and sound artists can intentionally mold the perception of auditory spatial awareness by attuning themselves to the medium they are employing. The process of expanding spatial perception necessitates specific compositional considerations and unique listening approaches that directly involve the 3D sound system environment as essential elements within different setups.

Natasha Barrett, discussing her approach to spatial audio, describes her interest in realistic movement behavior and how the coupling of spatial tangibility and sound identity can influence our perception of spatial characteristics.

Whereas:

> *Although some answers can be found in mathematical models, these models are not designed to capture our perceptual experiences, nor can they address the context of musical materials. The complexity of the problem is such, however, that solutions can also be revealed through compositional investigation.*[4]

The integration of 3D spatialization technologies into my practice gave me the opportunity to contemplate a multifaceted perspective on how sound can reshape and expand our perception of space. The article investigates the implications of diverse methods, techniques, and 3D spatialization tools on my compositional approach. It provides a glimpse into my creative process, encompassing conceptualizations, configurations, and articulations illustrated through the presentation of two projects and future endeavors.

Correspondence and Transposition

As my comprehension of space evolved beyond acousmatic music, I began to envision different relationships between the elements involved in the construction of space and construct a transdisciplinary conceptual framework. I draw on the concepts of *correspondence*[5], as proposed by Tim Ingold to refer to how separate components interact with one another in various spatialization configurations and how, occasionally, these interactions inform a particular conception of space. And *transposition*[6], as dis-

[4] Carpentier T., Barrett N., Gottfried R., Noisternig M.. *Holophonic Sound in IRCAM's Concert Hall: Technological and Aesthetic Practices.* Computer Music Journal, Massachusetts, Institute of Technology Press (MIT Press), 2017, 40 (4), pp.14-34.

[5] Ingold T., *Correspondences, Knowing from the inside,* University of Aberdeen, 2017

[6] Braidotti R., *Transpositions On Nomadic Ethics,* Cambridge and Malden, MA: Polity, 2006, p.6. figurations.p.28 In the introduction to *Transpositions, Aesthetico-epistemic operators in Artistic research*, M. Schwab describes the concept: "*The logic of representation is singular, remaining the same in different instances, while the logic of transposition is multiple, because it requires attention to the differential aspects of the relations between the positions, having to be transposed from instance to instance. Such transpositional operations require a particular emphasis on the differential aspects of the relationships enacted between positions. The positional specificity that is part of transposition – be it in space, time or otherwise determined – explains why it has been so difficult to deal philosophically with transpositional operations and why artistic research, which is sensitive*

cussed by Rosi Braidotti, creating an interexchange between diverse disciplines dealing with the notion of space. This exploration leads to extra-musical ideas, approaches and perceptual categories provided by other fields. The notion of correspondence encapsulates the dynamic nature of the interconnections and interactions between various elements, such as 3D audio technologies, the composer's spatial intention, the sound source's attributes, and the listener's experience. To investigate this complexity, I developed a network that is based on the concept of *correspondence-thought*, which reflects the ever-changing nature of configurations and relationships. A network based on the dynamic process, known as *ontogenesis* where the principle of openness is central because it recognises the fluidity and malleability of interconnections and enables possibilities to evolve. This perspective highlights that space undergoes constant transformation through interactions between its components. Consequently, the transient configurations represent an ongoing series of processes in which human and nonhuman elements organize, assemble, and gather the space formation.

As accurately presented by Rosi Braidotti:

> *Transposition is a scientific theory that stresses the experience of creative insight in engendering other, alternative ways of knowing*[7]

M. Schwab[8], describe transposition as the fluid movement and cross-referencing between different disciplines and levels of discourse within artistic research. Through deconstruction, it gives rise to new methods of knowledge exchange that encompass aesthetic qualities. Transposable concepts, often described as *nomadic notions*, form a network that bridges philosophy with societal realities, theoretical pondering with practical strategies, and abstract concepts with creative potentials. In developing my conceptual framework I relied on interdisciplinary interactions that integrated insights and concepts from various fields including architecture, psychology, anthropology, media philosophy, sound and digital studies. The mutual exchange of concepts and practices from several disciplines deepened my understanding of space and its implications towards sound.

Ultimately, this mapping helped me to envision a multidimensional and complex outlook on space, one that could assume various forms contingent upon the interactions between sound, technology, spatial conceptualization, and the listeners.

3D Spatialization

There are two main sound spatialization systems: the acousmonium, which is a loudspeaker orchestra where the signal level is routed to several loudspeakers, and the

to the specificities of what is at hand, can present new options not only for a bottom-up rather than a top-down approach, but also for an approach for which there is no 'up', but only positions that result from movement."

[7] Braidotti, R., *Transpositions: On Nomadic Ethics,* Polity Press, 2006. p.6

[8] Schwab, M., *Transpositions: Aesthetico-Epistemic Operators in Artistic Research,* Leuven University Press, pp. 7-19.

soundfield, which employs an abstract arrangement that allows working with virtual sources. Although both systems aim to replicate a sense of spatial dimension, they provide distinct affordances and agencies. Drawing from my personal experience, composers can actively shape the perception, conceptualization, and overall sound experience within the spatial domain by understanding and harnessing these affordances and their agency. This gives them the ability to emphasise specific emotions related to spatial relationships, and even challenge conventional notions of space and spatiality.

In the case of the acousmonium, the composer has the ability to manipulate and control the movement of sound within the physical space. This system offers a more direct and tangible means of working with spatialization, allowing the composer to position sounds in specific locations and orchestrate their movement between speakers. On the other hand, the sound field approach takes a more abstract perspective, employing algorithms to simulate virtual sources within a virtual space. This method offers a different set of tools and possibilities for shaping the perception of space. Ambisonics is a technique used to encode and reproduce sound fields by capturing and representing their directional attributes. Unlike traditional multi-channel audio systems that assign specific channels to individual speakers, it uses channels that contain information about various physical properties of the sound field, such as pressure or acoustic speed. In doing so, it allows the creation of a more immersive and realistic sound field, offering a faithful representation of the spatial attributes of the original sound source. Employing a spherical coordinate system to capture the spatial characteristics of sound, Ambisonics allows the creation of a three-dimensional audio experience that can be enjoyed through an appropriate arrangement of speakers or headphones. It provides flexibility in sound reproduction, facilitating accurate location/ positioning and movement of sound sources within a virtual or physical space.

During the passage from a multi-channel system to virtual sources, my compositional methodology encountered a significant transformation. This shift has initiated a reconsideration of space, as the absence of physical speakers resulted in a fragmented understanding focused on the movement of sound among speakers. Instead, I embraced a more abstract notion where space is perceived as a unified and continuous flow, accompanied by a contingent sense of time.

Moreover, the process of encoding and decoding played a crucial role in this transformation. By integrating spatial information directly into sound, the intrinsic spatial quality of sound itself was revealed, highlighting that sound inherently possesses spatial characteristics. As a result, the interaction between space and sound, including their respective properties, occurred even before the compositional phase. These distinct characteristics of the ambisonic method led me to reconsider various aspects such as sound material selection, space pre-compositional conceptualization, and the resulting spatial experience perception. The composer's agency here is manifested through the manipulation of parameters and algorithms that determine the spatial characteristics of the sound field. The choice between these systems can significantly impact the conceptualization and creative process related to spatialization (in music composition).

At first I thought of sound as a vital source with a generative potential for materializing the spatial dimension. Then, with the addition of 3D technologies, I began to superimpose ideas and concepts of physical, virtual and imaginary spaces to my practice.

Sonorous substance

> *The philosophy of organized sound places great emphasis on the initial stage of composition—the construction and selection of the sound materials. Just as the molecular properties of mud, thatch, wood, stone, steel, glass, and concrete determine the architectural structures that one can construct with them, sonic morphology inevitably shapes the higher layers of musical structure. These interrelationships confirm what musicians have known all along: Material, transformation, and organization work together to construct a musical code. It is through this context that a given sound accrues meaning.*[9]
> Curtis Roads

Through my experimentation with 3D spatialization, I've realized more and more the potential of sound as a means to shape the morphology and morphogenesis of the spatial configuration. Identifying sound as a material entity for the construction of a space prompted inquiries into the notion of materiality and the distinctive qualities of sound. Initially attempting to associate sound with the notion of materiality defined by the qualities of physical substances, I conceived of sound objects as fragments extracted from a specific spatiotemporal environment, subsequently inheriting and preserving those environment-specific characteristics. Although extrapolated from their original context when diffused in a multichannel setup, they evoke expectations regarding their location. This leads to a dynamic interaction between the listener's preconceived spatial expectations and the compositional intention.

Later, influenced by Tim Ingold's perspective on materiality, which suggests that a deeper understanding of materiality requires moving away from a narrow focus on physical materials[10]. I shifted my interest to how interactions among materials shape the overall experience, highlighting the importance of experiential aspects over the physical properties of the materials themselves. Sound is inherently intertwined with space and thus possesses its own spatial attributes, while remaining connected to an intangible idea of it. Considering the transition from matter as a potential for expression to materiality as a catalyst for effects and experiences, we can assert that the materiality of sound has the ability to activate spatial experiences. In this sense, sound has the capacity to materialize or bring life to a space, making it tangible through our perceptual experience. This quality makes sound a powerful tool for embodying and exploring various possibilities of inhabiting space through listening.

[9] Roads, C., *Composing Electronic Music: A New Aesthetic,* Oxford University Press, 2015, p.17

[10] Ingold, T. *Materials against materiality,* in Archaeological Dialogues 14 (1) 1–16, Cambridge University Press, 2007, p. 2 '*To understand materiality, it seems, we have to get as far away from materials as possible*'.

The utilization of 3D technology is akin to a means of questioning and rearticulating the connection between space and sound and investigating their materiality.

Ubiquitous feeling

Sound localization is a complex phenomenon involving the processing of multisensory information, synaptic plasticity dependent on previous auditory information, spatial experience, and movement. Our brain has learnt to associate specific characteristics of sound with certain spatial positions or movements.[11] To improve sound localization accuracy, the brain can integrate sensory observations with sensorimotor information based on previous experiences. By leveraging this information, the brain can make inferences about where sounds are more likely to occur. For example, the increase in volume and change in spectral content when sounds approach from a distance is a well-known perceptual cue derived from our real-world experiences. By manipulating these cues and challenging the expected spectral changes, composers can generate a sense of surprise, disorientation or work with spatial associations and tap into the listeners' preconceived expectations, creating a sense of familiarity. Kendall examines the behavior of perceptual activity of the spatial dimension during spatialization in a multichannel system of electroacoustic music, emphasizing how a fully embodied understanding of space and spatial movement is the basis of the listener's feelings and thoughts as they experience listening to sound in space[12]:

> *Listeners experience electroacoustic music as full of significance and meaning, and experience spatiality as one of the factors contributing to its significance. Perceived sound is always spatial, and spatiality is an integral part of any auditory experience. Sometimes spatiality is in the foreground of attention and is a primary carrier of meaning. Other times, it slips into the background. If we want to understand spatiality in electroacoustic music, we need to understand how the listener's mental processes give rise to the experience of meaning. The feelings and thoughts that the listener associates with the experience of sound in space seem to spring from a deeply embodied knowledge of space and movement spatial. This space knowledge is acquired through sensory experience that presumably begins at the beginning of life and continues through interactions with the everyday world. Notions of space, acquired and understood through bodily experience, at the heart of much of our everyday thinking. Spatial analogies and spatial metaphors traverse our language and reasoning. It is no wonder that space can be a powerful component of meaning in electroacoustic music.*

[11] Francl, A., McDermott, J.H. Deep neural network models of sound localization reveal how perception is adapted to real-world environments. *Nat Hum Behav* 6, 111–133 (2022).

[12] Kendall G., Spatial Perception and Cognition in Multichannel Audio for Electroacoustic Music in Organized sound, Cambridge Press 2010, p.228.238, p-228, Kendall G., *The feeling blend: feeling and emotions in electroacoustic music*, Organised Sound 19(2): 192–202 & Cambridge University Press, 2014.

In my current approach to composition, I am actively exploring the use of sound sources that gradually lose their recognizable qualities, becoming forms that traverse space, occupy it and evoke it. In this passage I experimented with the concept of the quantum of sound that holds significance from a psychoacoustic standpoint as an indivisible unit of information. In the time domain, it exhibits reversibility without altering the quality of perception.

By manipulating micro temporal relationships and micro intervals, the distribution of the sound spectrum in space is affected, consequently influencing its articulation within that space. The notion of grains arises from the process of discretization, where matter is atomized and divided into particles. From the concept of sound object to the adoption of particles has radically altered the framework of spatio-temporal references in my compositional approach. Completely detached from the sound sources, I can focus on shaping a material that contains an understanding of space that I define pre-morphological. This approach allows me to emphasize the inherent immanence of sound[13], its characteristics and behavior within spatial contexts. The utilization of 3D sound as a case study provides an opportunity to examine its impact on various aspects of human experience within immersive environments, such as perception and cognition. Through this investigation, we can delve into how 3D sound spatialization shapes our understanding of space, time, presence, and narrative. Additionally, it prompts us to consider how sound influences our sense of reality, identity, and agency.

Coefficient of space generator

Continuing to reflect on the specific materiality of sound, I employed my body as a means of vibration and imagination, serving as the vehicle for the materialization of the spaces invoked by it. This brings with it the idea of a body that is not merely a passive entity in space but an active agent that participates in the production and experience of it. The relationship between the body and space becomes a fundamental aspect in understanding how space is constructed, perceived, and inhabited, and how individuals shape their sense of self within spatial and temporal contexts. Gødoy'[14]s research on motor mimetic musical cognition suggests that listeners engage in a range of responses to music, including the generation of images or imitations of sounds. These responses can involve gestures that accompany sonic or emotional expressions, or trace the movement of a sound. Since movements give rise to sounds and sound is fundamentally the movement of air, he considers gesture as an integral element of

[13] Wanke R. Santarcangelo V., *Memory as the Aspatial Domain for the Perception of Certain Genres of Contemporary Art Music*, Music & Science, Volume 4: 1–18, 2021, p. 6.

[14] Gødoy R. I., *Gestural-Sonorous Objects: embodied extensions of Schaeffer's conceptual apparatus,* in *Organised Sound* 11, Cambridge University, 2007, p. 149–157.

Godøy, R. I., *Gestural Affordances of Musical Sound*, *in* Godøy R.I. & Leman M. (eds.), *Musical Gestures: Sound, Movement, and Meaning*, Routledge, New York, 2010, pp. 103-125.

sound itself. According to Gødoy, the construction of imagery and space in relation to auditory perception goes beyond the immediate perception of sound. It involves the memory and imagination of sound itself. In this context, the musicologist introduces the concept of the gestural sound object, expanding upon the traditional notion of a sound object. The gestural sound object is associated with embodied cognition, emphasizing the connection between sound and bodily movements. Sound opens up other perceptual dimensions, allowing us to explore the spatial realm from a unique perspective. It offers a rich and immersive medium through which we can engage with spatial environments, enabling us to perceive and navigate them in ways that transcend traditional visual perceptions.

> *The goal of spatial audio in electroacoustic music should be to evoke experiences in the listener with artistic meaning: in particular, meaning emerging from the spatiality of the perceived sound. Therefore, the goal of a multichannel audio system should be to deliver acoustic signals to the ears of the listener that provide the stimulus for such artistic spatial experiences and understandings. The more that we understand about the complex relationship between spatial sound systems and the listener's spatial thinking, the better we will be able to harness the capacities of such systems for artistic purposes.*[15]

In the process of constructing a space, while seeking correspondences and transpositions across various disciplines, the concept of space is envisioned as a dynamic and continuously evolving entity. It has the capacity to assume diverse forms or articulations according to the interactions among its constituent elements. In this perspective, space and sound are regarded as essential components of the overall experiential process, inseparable from the individuals engaged in the act of listening.[16] From the listener's perspective, which is inherently tied to the body's experience, engaging with a composition aimed at evoking a sense of spatiality involves a coefficient of spatial generation. When Di Scipio discusses the relational dimension of sound, he introduces the notion of the *coefficient of sound generation* in relation to the act of listening. This departs from the idea of sound as object and instead recognizes that sound takes shape not only within the creator but also within those who anticipate or receive it. Similarly, we can also discuss the concept of a space generation coefficient, highlighting how the experience of space is actively co-created by those who engage with it. This coefficient represents the listener's active participation in shaping and perceiving spatial cues within the auditory environment. It underscores the mutually dependent relationship between the listener and the spatial experience.

[15] G. Kendall, *Spatial Perception and Cognition in Multichannel Audio for Electroacoustic Music,* Organised Sound 15, Cambridge University Press, 2010, p. 228–238, p.229.

[16] A. Di Scipio, *Sulla dimensione relazionale del suono,* https://static1.squarespace.com/static/53161999e4b0ebfb9eceb115/t/534c50ede4b03c03e07b0c95/1397510381974/Di+Scipio+-+Sulla+dimensione+relazionale+del+suono.pdf, consulted on 10 June 2023.

Spatiotemporal heterogeneous components

The Lefebvre's[17] perspective on the production of space highlights how bodily practices contribute to the production of socially constructed spaces and times, and concurrently shape individuality that becomes internalized within the body. Lefebvre argues that space and time are intricately linked, and they both hold the same ontological significance. While they can be distinguished, they cannot be entirely separated, as they manifest themselves as distinct yet inseparable entities. His argument that space and time share ontological significance, intertwined and inseparable, echoes the dynamic relationship we've explored between the body and space. These discoveries highlight the delicate interaction of the body, space, and time, exposing a diverse range of perception, experience, and uniqueness within the constantly shifting landscape of human existence.

Through an immersive listening mode supported by 3D audio technologies, the listener has the opportunity to experience space-time coordinates from a perspective that is not only linear and geometric, but strongly interconnected with a phenomenological approach. At the same time from a composer perspective, with the support of these technological means the compositional approach can move beyond the articulation of spatial information in the space of projection and immediately interconnect to the *spatiotemporal* dimension.

Eleni Ikoniadou, in *The Rhythmic event*, *Art, Media and the Sonic*, investigates affective modes of perception, temporality, and experience enabled by experimental new media sonic art, with the aim of providing a new perspective to the speculative philosophy of media that focuses on the creative unpredictability of the event, refers to the perception of a sound event beyond what is actually heard.

> *Digital sound art introduces interesting mutations as new rules of form, time and space, treating them as complementary heterogeneous layers of the event rather than as dimensions subordinate to each other.*[18]

In an attempt to probe the presence of the artwork of sound as a set of sensations that transcend space, time and the bodies that compose and experience it, takes into account what remains, involuntary, non-nominal and unknowable forces along the periphery of sound. The final challenge proposed in the text is to think of rhythm as discrete continuity, as a center of uncertainty between real and virtual. Ikoniadou's exploration of rhythm and affective perception within the realm of digital sound art

[17] H. LeFebvre, *The production of space,* Blackwell, Oxford e Cambridge,1991, p. 407

[18] Ikonadiou E., *The Rhythmic event*, *Art, Media and the Sonic,* The MIT Press, Cambridge, 2014, p. 233. Eleni Ikoniadou with the aim of providing a new perspective to the speculative philosophy of media focuses on the creative unpredictability of the event, refers to the perception of a sound event beyond what is actually heard. In an attempt to probe the presence of the artwork of sound as a set of sensations that transcend space, time and the bodies that compose it and experience, takes into account what remains, involuntary, non-nominal and unknowable forces along the periphery of sound. The final challenge proposed in the text is to think of rhythm as discrete continuity, as a center of uncertainty between real and virtual.

aligns with Lefebvre's rhythmanalysis and his strong emphasis on the significance of the lived experiences of individuals engaging with a particular environment.

Dust variations

Interstellar dust is thought to be produced by supernova explosions or by the nuclear fusion of stars. The different materials that make up the dust, the shapes and sizes of the particles, the evolution of the properties of the grains and their history all contribute to its variance. Space is not uniformly distributed among the particles, but they grow, occupy and move through it according to their unique properties.

Inspired by the interplanetary dust continuous cycle of life and death, *Dust Variations* is a three-part project. The aim of the project is to suggest to the listener a spatial experience and a reflection on the formation of space in a broad sense, but particularly the cosmic one. Each project variant explores different spatialization strategies, configurations, and approaches. Similarly, the data related to dust is gathered through varying methods on each occasion, serving as the foundational element for shaping the spatial, temporal, and spectral organization within the musical composition. These variations provide multiple cues, enabling the audience to immerse themselves in and experience the subject in various ways. The first variation originates from

Figure 1. Interstellar dust.

a speculative notion concerning the creation of cosmic space and the behavior of interstellar dust, following a conversation with astrophysicist Riccardo Gualtieri. The second variation involves the sonification of data related to the composition of the dust particles and their movement, achieved through the development of an agent-based model. The third one will be an interactive installation, enabling the audience to engage with sound spatialization through their movements where the sound material will be taken from the previous Dust Variations I and II.

Dust Variations I

Dust Variations I, a 5th order Ambisonic composition combined with other spatialization formats, such as 8 channels and stereo. The piece was created in 2020 during a residency as a Guest Artist, at ZKM, the Centre for Art and Media, Karlsruhe.

Sound material

Interstellar dust appears as a mixture of grains with a maximum diameter of 1 um micron. These grains are actually simple assemblies of molecules that become increasingly complex and, depending on their interactions, can form aggregates of various sizes. For the creation of the sound material, I focused on the properties of the dust, such as the mass and density of the different elements that form the compounds, and hypothesized their impact in the formation of the aggregates, finally arriving at a hypothesis on their spatial behavior. In fact, I created correspondences between these properties and the spatial attributes of the individual grains, working on the mass of the sounds at the frequency band level. I used granular synthesis and identified three basic types of dust grains, each grain has a specific sound mass, density and timbre that determine the specific speed of movement, distribution in space (Sound Example 1; Sound Example 2; Sound Example 3).[19]

These grains can grow by agglomerating with each other (Sound Example 4),[20] taking on different shapes from time to time, and can last over time or become extinct due to various factors, such as the magnetic force of attraction or repulsion between the elements. The composition incorporated two singers, Nadia Cunillera, a soprano, and Matthias Horn, a baritone. The vocal elements serve to symbolize the notion that we share the same fundamental components as interstellar dust. Their purpose is to accentuate a sense of unity and connection with the entirety of existence, emphasizing our interconnectedness rather than division from the surrounding world. The voices fulfill a role acting as triggers, initiating a change in the grain behavior linked to their

[19] Audio materials related to this article are available at the following DOI: https://doi.org/10.5281/zenodo.10646848

[20] Audio materials related to this article are available at the following DOI: https://doi.org/10.5281/zenodo.10646848

movement and evolution and in this way contributing to the formation of sound aggregates. The initial phase of the creative process involves exploring parallels and harmonies between various states of matter present in both cosmic dust and the human body, as expressed through vocalization. Consequently, qualities associated with liquid, gaseous, solid, and plasma states are translated into the vocal realm, manifesting as liquid-like timbres, breath-like articulations, sustained tones, glissandos, and punctiform sounds (Sound Example 5; Sound Exemple 6).[21] Depending on the state of matter these sounds interact in distinct ways with other sonic elements and the space image, giving rise to a specific form of intra-action.

Spatialization

The sound dome, which consists of a configuration of 43 Meyersound loudspeakers suspended three-dimensionally in space on an elliptical ring system and additional four speakers placed on the floor, was employed to create the piece. This configuration can be controlled by the free software Zirkonium, which the ZKM | IMA has been developing since 2004. For *Dust Variation I*, I used the Reaper software to create my own decoder from the speaker layout json file, using the IEM AIIRA plug-in and encoding stereo and multichannel files with IEM plug-ins.

The possibility of using this loudspeaker array and the ambisonic method favored the idea of a cosmic space in which to immerse the listener by exploiting the vertical plane in particular and working with the sense of upward expansion, which is usually not possible with non three-dimensional configurations. The sounds move, generating a space thought of as energy, and this is reinforced by the distribution in all directions x,y,z, and w, enabled by the ambisonics method. Indeed, I have taken great care to meticulously shape the composition's structure to convey the specific impressions I intend. However, recognizing that the foundational concept of space may not always be immediately apparent to the listener's ear, I have deliberately integrated elements that introduce a level of suggestion. This helps to bridge the gap between composer's intention and perception in the listener's experience. The emphasis on proximity, distance, and depth effects in the selection of sound materials is noteworthy. For instance, the choice of using three grains, as the foundational elements of the initial work, alludes to something organic, often falling within the medium to low-frequency range, which can evoke a sense of familiarity. Similarly, the nearly imperceptible vocal interventions follow a similar pattern. On the other hand, the agglomerations formed at times feature a somewhat ominous high-pitched quality, compelling the listener's perception to expand upwards and creating a desire to push these elements into the distance.

In terms of spatial organization, I have focused both on the distribution of sound sources based on their intrinsic characteristics of frequency and therefore on their spatial attributes, e.g. mass, density, speed, both on listening in terms of expectations about

[21] Audio materials related to this article are available at the following DOI: https://doi.org/10.5281/zenodo.10646848

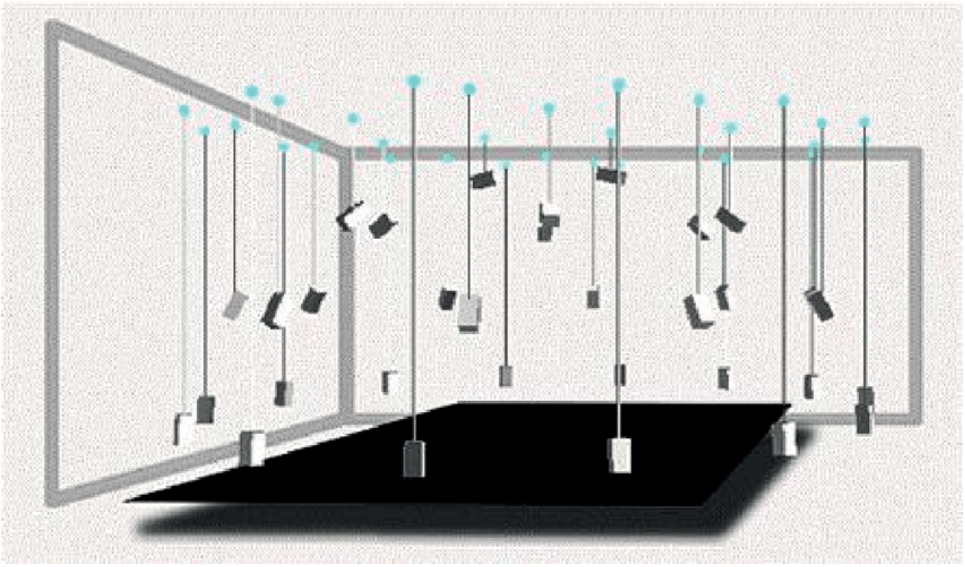

Figure 2. A graphic representation of speaker's position in the klangdom, Center for art and media, ZKM, Karlsruhe.

their position in space as mentioned in the previous paragraph. The spatial domain is strongly intertwined within the materiality of each sound source and the specificity of technology. The sound field aims to recreate the way in which dust particles move and change over time, e.g. from their rarefaction to a high density of dots covering all angles and distances in space, or from a saturated mass to an unbridgeable void.

To get a more complete spatial image, I used a hybrid approach that combines different techniques. This involved overlapping a full range spatial field created with a high-density speaker array, which aimed to blur the boundaries between sound and space using virtual speakers. Simultaneously, I incorporated a space built using localized and distributed points through 2D stereo panning. Using this combination, I tried to create a multi-dimensional sound environment.

Every spot is sweet

The Ambisonics method interprets an audio scene as a complete 360-degree sphere wherein sounds originating from diverse directions converge toward a central point. This central point represents the microphone's location during recording and/or the listener's designated sweet spot during playback. However, despite matching to the requirements defined by mathematical calculations, the notion of a singular point from which to listen does not accurately reflect the physical world. As a result, I have consistently viewed the concept of the sweet spot as a limitation. It not only perpetuates a hierarchical perception of our spatial orientation but also implies that our bodies must remain stationary in a fixed position to fully engage with sound. In

2018 during a Summer School hosted by the Technische Universität, Berlin, I had the opportunity to test a new speaker, IKO. This speaker, which can be defined as an instrument, employs via a 20-sided, 20-channel array of 20 speakers in the shape of a regular, convex icosahedron. The first prototype was created by Dr. Franz Zotter in 2006 at the Institute of Electronic Music and Acoustics (IEM) of the University of Music and Performing Arts in Graz, Austria, and was initially intended to holographically simulate the typical sound diffusion of musical instruments.

The IKO, as a compact array of acoustic loudspeakers with ambisonically regulated radiation patterns that project sound outwards, opposes the otherwise inwardly oriented ambisonic surround reproduction. Although the Ambisonics method is usually associated with speakers surrounding the audience, in this case it is used to control directional beams radiated outwards from the compact Iko spherical array. For example, within a room, the beam direction can be set to predominantly excite reflections

Figure 3. Iko speaker.

from selected walls or combinations of reflections, causing interesting effects in the perceived localization. This means that you can model the perception of directional sound sources in reverberant environments. We could imagine a centripetal force, in which many loudspeakers from predetermined points in space converge towards a fictitious ideal central listening point, available to a few and a centrifugal force, in which a single loudspeaker diffuse sound outwards from a center that varies from time to time, dismantling the sweet spot concept and rearticulating it towards an open multiple perspective. The possibility to create music with this instrument allowed me to develop a new perspective on the potential of 3D spatialization envisioning new sound trajectories and perceiving sound sources in unprecedented ways, thereby challenging the conventional sweet spot paradigm.

One distinctive characteristic of the compact speaker, in contrast to other 3D spatialization systems that demand a fixed arrangement of multiple speakers within the physical space, necessitating subsequent acoustic adjustments (e.g., domes, cubes), is that the IKO is a mobile and easily transportable device. It engages in a continuous dialogue with the surrounding architecture in which it is positioned. (the compositional process, and public perception.) In rooms and architecture with natural acoustic reflections, the iKO, dismantles the concept of the sweet spot and leaves the field open to a surprise effect that, with an unfixed dialogue and an unenclosed space, is able to bring out unforeseen resonances and shapes. In spaces and architectural environments characterized by natural acoustic reflections, the IKO dismantles the traditional notion of a sweet spot and engages in a dynamic interaction with the given space itself, revealing unforeseen resonances and forms. This allows the audience to select their preferred position within the spatial context. The capabilities of this compact speaker consequently introduce additional compositional possibilities that have yet to be fully explored.

Easily broken

Easily Broken is a composition designed for IKO and was featured in the Loudspeaker Orchestra series of concerts held in 2022. These concerts are organized by the Sound/Image research Group.[22] Easily Broken was performed during the concert on May 11th, as part of the Constructs event at St Alfege's Church in Greenwich.[23]

[22] https://www.gre.ac.uk/research/activity/las/loudspeaker-orchestra

[23] The body of the church – the first of eight in the fifty churches scheme in which Hawksmoore was involved – was built up against the medieval square tower, which survives inside the Portland casing which John James added, with the steeple above, in 1730. This view from across Greenwich High Road is practically the same today as far as the church and churchyard are concerned, with part of Church Street on the right. The church no longer has a flag mast and the roof and most of the interior dates from the 1950s, when it was sensitively rebuilt by Professor Sir Albert Richardson after being gutted by incendiary bombing during World War II. The victor of Quebec, 1759, Major-General James Wolfe, is buried in the vault as is John Julius Angerstein, founder of the National Gallery: both were local residents and have visible memorials in the church, as does Sir George Airy, 7th Astronomer Royal, though not buried there.

The composition takes inspiration from the concept of fragility, understood as the quality and condition of what is fragile, encompassing both its literal and metaphorical interpretations. It is composed in the 3rd-order Ambisonic format.

Sound material

The sound sources are sounds of organic and human materials and AI generated voices to create textures that blend, cross and create space. The voices are discussing the various meanings of human and nonhuman fragility throughout the composition. Fragility is defined as the quality of being easily damaged or broken. To give the voices a sense of movement and a specific role as if they were part of a choir I used mostly the elevation and in contrast to this instead the other sound sources moved mainly around the azimuth.

Attuning with the architectural space

One aspect of particular interest to me is the contrast between the compositional process that took place in the studio and the subsequent performance in a different venue, specifically St Alfege's Church. As the concert rehearsal commenced, I found

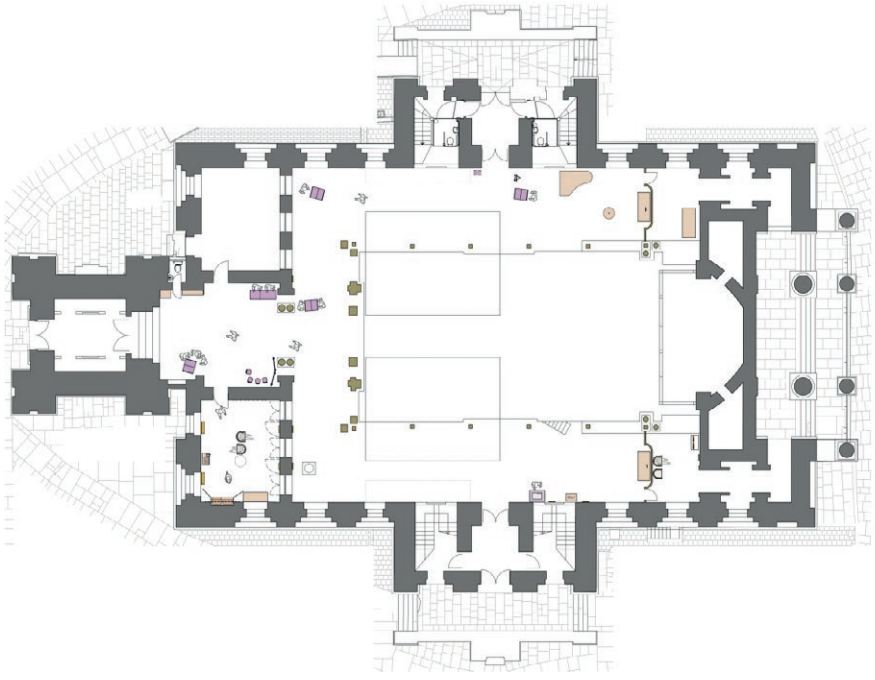

Figure 4. Plan of St. Alfege's Church.

Figure 5. IKO speaker at St. Alfege's Church.

myself concerned that the intended spatial concept of the piece would be completely transformed by the unique acoustics of the church.

Upon my arrival at the venue, I discovered that the Iko instrument had already been strategically positioned in the most suitable and logical location for the concert – at the far end of the entrance, just before the apse, after the seats. This placement was chosen to optimize the overall listening experience and create a comfortable sonic environment for the audience. Upon my arrival at the venue, I discovered that the Iko instrument had already been strategically positioned in the most suitable and logical location for the concert – at the far end of the entrance, just before the apse, after the seats. This placement was chosen to optimize the overall listening experience and create a comfortable sonic environment for the audience.

The studio's controlled environment and the church's unpredictable acoustics were in contrast. I wondered if the desired spatial qualities that I had meticulously achieved while in the studio would be faithfully transmitted in this new setting.

Could the unique reverberations and resonances of the church significantly alter the perception of the composition?

The surprise came when the speaker placed just before the apse entered into dialogue with the structure, making the voices flow exactly in the dome, creating an incredible choral effect. The term comes from the Latin chorus and the Greek χορός. This term is also used in architecture to indicate the apse area usually occupied by singers during liturgical functions in the church, or the place where the singers' places, known as stalls, or 'benches' were placed; the term chorus also indicates a musical composition written for such a chorus. the unexpected. Note how the apse is also called a chorus. However, as the performance unfolded and the sounds interacted with the architectural space, my initial concerns began to subside. The reverberations and

resonances of space added layers of depth and complexity, transforming the piece into a living, breathing entity within the church's unique sound environment.

The composition has taken on surprising meanings thinking about the fragility of the concept of sweet spot, the effect of surprise and dismay that technologies can still bring, the relationship between human voices and the fragility that becomes the power and expansion of architecture and voices generated by algorithms, IKO has become a multifaceted narrator.

The compact speaker, with its disposition of establishing a reciprocal dialogue with the physical space it occupies, brings forth relational dynamics that differ from the traditional configuration of speakers placed in a fixed position all around the listener. Instead of adhering to the conventional speakers arrangement, IKO activates a new set of relational dynamics by engaging with the specific characteristics and qualities of the physical space. By transcending the constraints of a fixed speaker setup, it opens up possibilities for a more dynamic and responsive spatial experience.

Another reflection on this specific experience with IKO is on the concept of authorship.

The dynamic nature of the spatial environment and the interaction between sound and space invite the listener to actively engage and shape their perceptual and emotional responses. As a result, the traditional notion of the composer as sole author and authority over the sound narrative becomes blurred. The boundaries between the composer's intentions and the listener's authority become porous, as the immersive and interactive nature of the experience allows for multiple interpretations and perspectives.

This confrontation with the illusion of authorship opens up new possibilities for collaboration and co-creation between composer and listener. It challenges us to rethink the hierarchical relationship between creator and audience and to embrace a more inclusive and participatory approach to artistic expression.

The discussion of the authorship of algorithms and artificial intelligences when they contribute to composition is also brought up by this contemplation, but it needs its own dedicated *space* in another context.

Unimaginable sound architectures

Moving into the virtual dimension allows for the exploration of sound and spatial synthesis in ways that are not yet possible in the physical world. In virtual environments, creators have the freedom to exaggerate, reinvent, and redefine spatial dimensions, leading to novel and expanded auditory experiences.

Archimusic

> *While I have used cyberspace as a thought-tool, I want to emphasize at this point that what is most important is not the technological expansion that cyberspace represents, but*

the conceptual space opened up to imaginative examination. Once we have a firm grasp on archimusic, we will be able to apply our findings to both virtual and actual worlds.[24]

The integration of technology has played a unifying role, bridging design practices and processes, particularly between architecture and sound. This convergence has opened up an additional (neutral) creative space where sound, space, and the body can intersect and establish different connections. Through this research, I have become increasingly intrigued by the potential for space to take on forms and configurations that are not yet fully comprehended or explored. By embracing technology and pushing the boundaries of traditional compositional approaches, I aim to uncover novel sonic and spatial possibilities.

Starting from the 90s the experiments belonging to Digital Architecture have often met those related to electronic music.[25] Markus Novak theorizes the concept of cyberspace, which defines as a new wild nature, a virtual world that becomes visible and within which music and Architecture can merge into a single discipline: *archimusic*.

When we look at music, architecture and calculus, we can ask ourselves what is shared and what is different in the inner and outer worlds they investigate, where are their boundaries, and in which direction lies the boundary of the known world, so that we can go in that direction, cross the line in the darkness and enlarge our universe.

The concept of archimusic informs the idea of a virtual space where to reshape the relationships between space and sound and where you can freely play with non existing and impossible forms.

Contagiousness

A transposition of particular relevance regarding the impact of 3D spatialization technologies can be associated with Luciana Parisi's reflection on digital architecture. According to Parisi, algorithms are responsible for constructing spatiotemporal actualities, implying that digital architecture is involved in the creation of instances of spatial thought. The crucial point here is not whether this construction process is physical or not, but rather the acknowledgment that digital architecture, and in this case, 3D sound spatialization, is already actively engaged in shaping our conceptions of space and time.

[24] Novak M., *The music of architecture Computation and composition,* Media Arts and Technology University of California, Santa Barbara, 2007, p.13.

[25] Cyberspace is a completely spatialized visualization of all information in global information processing systems, along pathways provided by present and future communication networks, enabling full co-presence and interaction of multiple users, allowing input and output from and to the full human sensorium, permitting simulations of real and virtual realities, remote data collection and control through telepresence, and total integration and intercommunication with the full range of intelligent products and environments in real space." In Marcos Novak, *Liquid Architectures in Cyberspace, in Cyberspace:First Steps,* Michael Benedikt, editor, MIT Press, 1991.

Algorithms allow the integration of space and sound and can no longer be considered abstract formalizations. Especially when generated through artistic experimentation and practice, they are intertwined in the mechanisms that create space and time.[26]

Temporary Sound architecture

At the MAxLab research group of the Royal Academy of Antwerp[27] and the Institute for Psychoacoustics and Electronic Music[28], Ipem, at the ASIL laboratory I am developing the project *Temporary Sonic Architecture*. The project lasts two years and is still in its early stages. I'm following two lines, a speculative approach that compares the acoustic characteristics of a physical space and its virtual reproduction. They are looking for a fracture between the acoustics of real space and its perception virtually rebuilt, also through the intervention of algorithms that approximate and generate acoustic models through auralization. And at the same time the development of a methodology to compose temporary sound architectures.

Conclusions

With this article I wanted to provide an initial, albeit not exhaustive, aesthetic-theoretical recognition of my personal path in the field of spatial composition, highlighting the basin and the areas of contact from which emerge the trajectories of research that I have explored and continue to explore and the main concept from where I develop a theoretical network. Unveiling the skein of insights I've gathered so far opens up new avenues and I hope it will inspire others interested in spatial composition. The changes that I am integrating into my practice concern the convergence of spatial information in the sound source and how this affects the perception of acoustic space and compositional modes.

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[26] Luciana Parisi & Steve Goodman, *Extensive Continuum Towards a rhythmic anarchitecture*, Journal INFLeXions No. 2 – Rhythmic Nexus: the Felt Togetherness of Movement and Thought (Jan. 2009).

[27] https://www.ap-arts.be/en/researchgroup/maxlab

[28] https://www.ugent.be/lw/kunstwetenschappen/ipem/en

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