Spacetime-Craft: An Archaeology of Visions and Explorations of Spatial Experience

Constantinos Miltiadis

Introduction

The reappearance of virtual reality (VR) as a viable technology in the 2010s reignited interest into applications and research investigations in the fields of art, design and architecture. However, addressing VR from a contemporary standpoint, assuming current technological capacities and imaginaries, presents a crucial deficit. With *spacetime-craft*, the present contribution intends to integrate VR within a continuum concerned with the interrogation of space itself as a malleable entity and the experimental exploration, production and experience of spatiotemporal alterities. Observed in a diverse set of instances, this approach is distinct from what we can refer to as 'traditional design' concerned with design as production of objects for and within a 'given' understanding of space. *Spacetime-craft*, instead, refers to the practical investigation of notions of space and time themselves, through the experimentation and speculation with technical, conceptual, perceptual, epistemological and aesthetic boundaries, for the production of novel experienceable spatiotemporal scenarios.

Such efforts can be observed to closely follow advances in modern sciences and mathematics, and amplify with the advent of digital technologies and VR in the late twentieth century. However, contrary to science proper, concerned with the intelligible and the abstract, these investigations suggest an altogether different kind of engagement with space focused primarily on the sensible and pursued through modes of practice that entail craftmanship. *Spacetime-craft*, thus, concerns efforts to investigate spatial concepts experientially and affectively, foregrounding the capacity of craft and artistry to explore and reveal latent aesthetic qualities at the cognitive and perceptual limits of the human body.

The following does not aim to provide a complete or coherent history, but rather to trace a particular fascination with space and experience in the wider context of the arts, and to follow its evolution through time, across domains and bodies of knowledge. On the one hand, the construct of *spacetime-craft* intends to provide a resource to inform similar contemporary investigations by assembling precedents as a form of heritage. On the other, it underlines a

mode of investigation complementary to that of science and inherent in artistic practices, which involves making and relies on the "revelatory"[1] potential of the arts to bring forth concepts through affective aesthetic experience.

Space as a Malleable Entity

The question of space has been central in Western culture, and to its scientific revolutions.[2] New theories of space, such as that of Newton in the seventeenth century, came to modernise ways of doing science as well as ways of thinking. However, updating from previously held truths to modern ones was a much more complex task than the mere renewal of tools, since their repercussions were not just scientific or epistemological, but also ontological and existential. New concepts of space, as Margaret Wertheim argued, "[impact] our sense of not merely where we are but of what we are".[3] Investigations of the 'substance' of space were met with friction not only because of existing practiced conventions or their inherent complexity, but primarily because they aimed to reconfigure the world and the human at large.

Such an event took place during the nineteenth century, when Euclidean geometry was dethroned as the one and only mode of space. The invention of Hyperbolic geometry by János Bolyai and Nikolai Lobachevsky (in 1832 and 1829, respectively) initially, and the formalisation and generalisation of non-Euclidean geometry by Bernhard Riemann[4] soon after, showed alternative and consistent notions of space bypassing Euclid's 'parallel postulate' – which troubled mathematicians for two millennia. Here too, the repercussions of such advancements were not just mathematical, since Euclidean geometry was furthermore associated with Newtonian cosmology as well as Cartesian and Kantian philosophies. What these showed was that Euclid's was just but one instance of a greater universe of viable geometries and modes of spatial thinking.

Riemann's model in particular proposed something more of a toolbox where space itself was a synthetic object instead of an a priori definition. Riemannian manifolds are constructed on demand by adding dimensions, of any number, either quantitative (metric) or even qualitative. More importantly, unlike Euclidean/Cartesian/Absolute models, such spaces are not defined externally

1 Xenakis, *Arts-Sciences, Alloys*, p. 4.
2 Miltiadis, "The Architectural Continuum."
3 Wertheim, "Lost in Space," pp. 61–62.
4 Riemann, "On the Hypotheses Which Lie at the Bases of Geometry."

and globally, by an origin point that serves as an objective reference, but rather intrinsically and locally, through the differential comparison of equally subjective positions that reside on their own frames of reference. Thus, Riemannian space is relative, instead of absolute, and generalisable to n-dimensions.

Unconstrained by the two dimensions of paper or the three dimensions of visual space, manifolds paved the way for the generalisation of spatial thinking and modelling, allowing notions such as 'colour-space' but also the constitution of more complex, curved, and non-uniform spaces. Case in point, the later application of a four-dimensional manifold to account for *spacetime* in the theory of relativity (ToR; 1905, 1915), on the one hand nullified space and time as distinct categories of the physical world, while on the other exemplified – through paradoxes – the properties of such a model. By rendering space as a generalised tool-concept, these advancements were nothing short of revolutionary, impacting philosophy and epistemology as well as the arts. As Henderson writes:

> The philosophical impact of non-Euclidean geometry in the nineteenth century was far greater than simply its initial challenge to Kant. It substantially shook the foundations of mathematics and science, branches of learning that for two thousand years had depended on the truth of Euclid's axioms. As a result, optimistic belief in man's ability to acquire absolute truth gradually gave way during the later nineteenth century to a recognition of the relativity of knowledge. [It contributed substantially] to the demise of traditional positivism. For certain artists in the early twentieth century, non-Euclidean geometry was to be synonymous with the rejection of tradition and even with revolution.[5]

This fundamental shift in the conception of space in mathematics was followed by a rather wide interest in the subject. Already by the late nineteenth century a series of theoretical works applied spatial thinking to questions concerning the underlying dimensionality and structure of physical space, while a higher-dimensional spatial intuition was seen as a means to challenge human intellect, imagination and eventually consciousness. Four-space was a major condenser for this period on both fronts: as a means to extend human intuition beyond the habitual three-space as well as speculation on a fourth elusive dimension of the actual world. Among notable contributors, Charles Howard Hinton, a mathematician and inventor of the tesseract (4D cube), discussed philosophical aspects of the fourth dimension advocating for a 4D mode of thinking as "a new era of thought" and the next step to spatial intuition.[6] In the same genre, the mathematically informed novel *Flatland* introduced such

5 Henderson, *The Fourth Dimension and Non-Euclidean Geometry in Modern Art*, p. 118.
6 Hinton, *A New Era of Thought*, p. 86.

matters to popular culture, demonstrating the limits of perception and cognition in regard to the dimensions of space through a playful narrative set in a flat space.[7]

By the end of the century works of "hyperspace philosophy" had elaborated on "philosophical, mystical, and pseudoscientific implications"[8] of the fourth dimension, making their way into the arts. The esoteric philosophy of P.D. Ouspensky[9] in the early twentieth century was particularly significant for the Russian avant-garde. Building on Hinton's work, he saw the fourth dimension linked to the psychic rather than the physical world, discussing higher dimensional spaces as key to the expansion of consciousness, which he deemed achievable through the affective power of art to reveal such ideas to the senses.[10] Given the additional 'revolutionary' connotation of new geometries, such concepts of space resonated deeply with modern art movements of the early twentieth century, such as Cubism, De Stijl, Russian Futurism, and Suprematism.[11]

A parallel event concurrent to revolutions regarding the concept of space was an epistemological shift concerned with experiential and embodied forms of knowing which emerged in German-speaking education reforms in the latter half of the nineteenth century. "Kinaesthetic knowing," as Zeynep Çelik Alexander termed the project,[12] explored an alternative non-discursive epistemology centred on the body and its movement in space, instead of the mind, that was distinct and superior from traditional scholarly forms of intelligence, knowledge and logic as well as analytical and verbal faculties. The embodied form of consciousness proposed by kinaesthetics championed a mode of knowing (*kennen*; knowhow) in the model of aesthetic inductive reasoning observed in the arts; accumulative by past experiences and akin to aesthetic cultivation.

---

7 Abbott, *Flatland*.

8 Henderson, *The Fourth Dimension and Non-Euclidean Geometry in Modern Art*, pp. 112, 142. For a spiritual interpretation of the fourth dimension see the work of Claude Fayette Bragdon (*A Primer of Higher Space*). For the context of mathematics see the elaboration of philosophical consequences of "metageometry" by Bertrand Russell (*An Essay on the Foundations of Geometry*), and Cassius J. Keyser's discussion of manifolds as "mathematical emancipation" and a concept "commensurate with […] being itself" ("Mathematical Emancipations. The Passing of the Point and the Number Three.").

9 Ouspensky, *Tertium Organum*.

10 Henderson, *The Fourth Dimension and Non-Euclidean Geometry in Modern Art*, pp. 380–383.

11 Henderson, "The Merging of Time and Space."

12 Çelik Alexander, *Kinaesthetic Knowing*, pp. 10–12.

Not only did this pedagogical model resonate with early twentieth century (German) design and architecture schools, but it was in such environments that it was exemplified and most celebrated as a means of uniting conceptual, experiential and practical means of investigation.[13] Notably, for the Bauhaus under Walter Gropius (1919–1928), kinaesthetics served as the cornerstone of its education qua cultivation, where teachers and students were preoccupied with the affective study of form implementing techniques and methods of psychophysics (the scientific basis of kinaesthetics) for their inquiries.[14] The question of space was at the core of this effort to create a 'science of design,' which, abstracted from its associations to building, served as the nexus of Bauhaus epistemology.[15] While the kinaesthetic project itself faded out soon after, through the lasting influence of schools like the Bauhaus on design education, its sediments are still present today in architecture and design epistemology.

The nineteenth-century paradigm shift in mathematical geometry brought about the liberation of space at large from its prior univocal nature and fixity on Euclidean principles. The period that followed saw a lively appropriation of spatial concepts and modes of thinking in a wide set of domains. Such early efforts exemplified space, in its new unencumbered form, as a much more potent entity and frame of reference capable to bridge the conceptual and experiential alike.

Spatiotemporality in the Arts

For the history of space, the next milestone was the publication and popularisation of Einstein's ToR. Whereas the discovery of non-Euclidean geometry brought about a disruption to epistemological and philosophical traditions by virtue of their association to antiquated concepts of space, the ToR concretised, or better, naturalised such notions of 'space' as actual. In the arts as well, it curtailed speculations about a spatial fourth dimension and the structure of space at large, grounding the concept onto – the manifold of – spacetime.[16]

El Lissitzky was among the first artists to explore this modern science through his investigation of pictorial and architectural space in his Proun

13 Ibid., pp. 176, 185.
14 Ibid., p. 174.
15 Ibid., pp. 186, 192.
16 Henderson, "The Merging of Time and Space."

studies initiated in 1919.[17] Embracing relativistic spacetime that he viewed as insurmountable, he criticized his Suprematist colleagues as less scientifically rigorous, and pursued instead the integration of space and time through the use of technology (i.e. long-exposure photography of moving objects) that could afford an "immaterial materiality" for the production of an "imaginary space." Moreover, he declared the pursuit of higher-dimensional spaces categorically futile given the limitations of the human perceptive and cognitive faculties as well as the affordances of current technology:

> [...] multi-dimensional spaces existing mathematically cannot be conceived, cannot be represented, and indeed cannot be materialized. We can change only the form of our physical space, but not its structure, its three-dimensional property. We cannot really alter the measure of curvature in our space [...] Only the fata morgana can simulate this.[18]

Indeed, technology, not vision, was the main deficit for the arts of the twentieth century. The next paradigm shift of digital technologies that would allow the simulation of illusory worlds that Lissitzky foresaw was a few decades ahead. Nevertheless, the interim period that ensued was marked by efforts to produce new forms of architecture and music to apprehend the qualities of the spacetime continuum through the convergence of spatial and temporal aesthetics.

Among unique examples in architecture[19] is the Oblique Function, a theory put forth by Architecture Principe (Paul Virilio & Claude Parent, 1963–1968). It envisioned an architecture in space and time, liberated by the verticality and horizontality enforced by the force of gravity, and by Euclidean forms at large.[20] Using instead oblique planes and curved surfaces to "exploit the full potential of space,"[21] it sought to induce proprioceptive instability through unconventional spatial situations that encouraged a sensual relationship with architectural qualities and a "constant awareness of gravity".[22] Through embodied

17 Debelius, "El-Lissitzky, Irrational Space, and the *Proun* Studies"; Henderson, *The Fourth Dimension and Non-Euclidean Geometry in Modern Art*, p. 427.

18 Lissitzky, "A. And Pangeometry, El Lissitzky, 1925."

19 See also the work of Frederick Kiesler who, since 1939, developed a research programme for the investigation of embodiment and temporality and the design of spatial continua he termed "endless space" in Kiesler ("On Correalism and Biotechnique.") and Phillips ("Toward a Research Practice."). See also the built work of Madeline Gins and Shūsaku Arakawa, who explored unconventional proprioceptive conditions, and their discussion of the transformative potential of embodied architectural poetics (*Architectural Body*).

20 Redhead, "Toward a Theory of Critical Modernity."

21 Paul Virilio, "Architecture Principe 1, 3" (1966) in Johnston, *The Function of the Oblique*, p. 71.

22 Jacques Lacan in Johnston, *The Function of the Oblique*, p. 5.

spatial experience, its authors saw the Oblique Function as a method to establish a new way of thinking and even more so to induce states of mind and consciousness.[23]

Although Architecture Principe disbanded before materializing its visions, its theories became a primary influence much later to Lars Spuybroek, exemplified in the design of the HtwoOexpo pavilion (NOX Architects, 1997). As per the Oblique Function, the pavilion was conceived to be "more in time than in space,"[24] and designed with curved floors and walls to excite the human body through proprioceptive instability. Reminiscent of Riemannian geometry, the absence of horizontal and vertical elements or such references demanded of the body to find its own self-referential stability within the dynamic environment.[25] Similar to Architecture Principe that envisioned a transformative role for architectural experience, for Spuybroek, too, the implications of geometry were far greater than those of form, noting that "an anti-Cartesian view on geometry" followed "an anti-Cartesian view on the body".[26]

The field of music, on the other end, had a technological advantage – that allowed for artificial synthesis and reproduction of sound from the middle of the twentieth century – offering grounds for its fusion with the spatial domain. Already in 1936, Edgar Varèse envisioned the liberation of sound from its strict temporal framework through new intuitive instruments that would allow composing in space. These, he wrote, "will allow me to write music as I conceive it,"[27] using sound masses – instead of notes – orchestrated spatially via geometric and sculptural manipulations into an irreducible whole. Although the closest Varèse would come to his vision was with *Poème électronique* for the Philips Pavilion of 1958,[28] younger composers, such as Karlheinz Stockhausen and Iannis Xenakis, pursued spatiotemporal works further challenging both audiences and conventional aesthetic categorization.

---

23 Claude Parent, "Architecture Principe 1, 3" (1966) in Johnston, *The Function of the Oblique*, pp. 66–67.

24 Spuybroek, "SCI-Arc Lecture Series."

25 Cf. Spuybroek, *Lars Spuybroek, H2Oexpo*.

26 Spuybroek, "SCI-Arc Lecture Series."

27 Varèse and Wen-Chung, "The Liberation of Sound," p. 11.

28 The piece, which comprised of recorded and electronic sounds, was commissioned by Le Corbusier for the Philips Pavilion of the 1958 Brussels World Fair, and was spatialised by hundreds of loudspeakers embedded in the walls of the hyperbolic paraboloid structure designed by Iannis Xenakis. The pavilion, which was intended to demonstrate modern technology through a unification of the arts, consisted of music, lights, moving images and architectural space, amounting to a first work of spatiotemporal multimedia art (Lombardo et al., "A Virtual-Reality Reconstruction of *Poème Électronique* Based on Philological Research".)

Stockhausen pursued the incorporation of space in music composition which he deemed crucial for producing new kinds of aesthetic experiences, and for transforming music at large. Spatial music, for him, could revive the neutralized function of space in Western music and introduce a property of perspective in musical listening, rendering musical space relativistic.[29] Additionally to early recorded works,[30] in a performance for the 1970 Osaka World Fair, he developed a spherical sonic environment that utilized a geodesic dome where sounds were rotated around the audience.[31] Investigations of space and time are multifaceted in the work of Xenakis,[32] and more prominent in his series of *Polytopes*: site-specific media installations initiated in 1967 which pursued the intersection of musical and architectural aesthetics. As in *Polytope de Cluny* (1972), they primarily implemented arrays of loudspeakers and coloured strobe lights inside a given empty space, orchestrated by mathematical distributions.[33] Building "in light and sound space,"[34] Xenakis was able to modulate the experience of space and time by superimposing artificial and abstract spatiotemporal scenarios onto given spaces. As hybrid conditions, these immersive dynamic atmospheres depended less on the physical boundaries and properties of space and more on the perceptual capacities of a virtual dimension.[35]

The cases of Xenakis and Stockhausen as well as of Architecture Principe and Spuybroek exemplify a shift in the conception of space from its implementation as a mere container of form, to the incorporation of a spatiotemporal framework as the substrate of experience itself. Following the model of relativistic spacetime, these works challenged the aesthetic and disciplinary boundaries of their respective practices, producing experiences neither about space nor time alone and with any possibility of an 'objective' perspective obliterated. What they materialize instead are sensory-rich environments accessible only as subjective experience to an active embodied agency which they require from their audience.

29 Stockhausen, "Four Criteria of Electronic Music", May 1972; Stockhausen, "Four Criteria of Electronic Music," 1989.

30 See the spatial audio works *Gesang der Jünglinge* (1958), and *Kontakte* (1960).

31 Emmerson, *Living Electronic Music*, p. 158.

32 Solomos, "The Complexity of Xenakis's Notion of Space"; Sterken, "Music as an Art of Space."

33 Matossian, *Xenakis*, pp. 259–277.

34 Sterken, "Towards a Space-Time Art," p. 270.

35 Oswalt, "Iannis Xenakis' Polytopes."

The 20th Century Appearance of VR

The emergence of VR in the late twentieth century offered new plateaus for spatiotemporal experimentation and the exploration of the human sensorium, bringing full circle matters of space and embodiment. Like Lissitzky anticipated, the new technology was envisioned as a substrate to conceive, materialize and render perceivable experiences beyond what was possible in the physical world. However, while computing afforded great capacities for imagination, these were essentially theoretical since the medium did not carry any inherent definition of space. Computer space, thus, had to be imagined. Given the lack of precedents and in the face of unparalleled capacities, speculation entangled both fact and fiction inasmuch as to generate a mythology that surrounded the technology. For VR in the twentieth century myth was an intimate counterpart, with an active role in its allusion to a "digital sublime,"[36] offering a glimpse of what was soon to come, while smoothening current technical shortcomings. Furthermore, from a contemporary point of view, and in the absence of systematic efforts to preserve work from this wave of VR that ended by the turn of the century, such discourses provide a sediment for understanding that period and its visions of technology.

Mythic visions of VR can be observed to precede and interweave with the actual technology. Already in 1965, three years before his invention of the first head-mounted display (the predecessor to VR technology), Ivan E. Sutherland described an "ultimate display" that was "a room within which the computer can control the existence of matter".[37] However, his vision was not after realism, but rather an affective technology that could serve as a tunnel to a fictional dimension. "With appropriate programming," he proclaimed, "such a display could literally be the Wonderland into which Alice walked".[38] Cyberpunk literature and videogames are two other domains of fiction that contributed in shaping VR. The dominant paradigm for VR came through William Gibson's 1984 novel *Neuromancer* popularizing the neology "cyberspace" which became the de-facto term for the technology – until it grew synonymous with the internet and was replaced by the later term "virtual reality". Similar to the function of "metaverse"[39] in current discussions, "cyberspace" served as a condenser of speculations pointing to Gibson's portrayal of a collective "consensual

36 Mosco, *The Digital Sublime*, pp. 21–29.
37 Sutherland, "The Ultimate Display," pp. 507–508.
38 Ibid.
39 Neology introduced by Stephenson (*Snow Crash*).

hallucination".[40] Part of the same continuum, the videogame phenomenon was already driving a similar vision capitalizing on early computer graphics and pre-internet networks.[41] As Sherry Turkle wrote the same year, videogames offered a glimpse into the specificity of computational aesthetics as well as "a new kind of intimacy with machines".[42] Furthermore, the financial crash of the videogame industry in the same period (1983–85) expediated the emergence of VR, as a number of videogame developers and researchers who left Atari then, became pioneers of VR soon after.[43]

VR entered the public sphere in 1987, described as the new paradigm for immersive computer interaction and as a fascinating vehicle to create and embody "artificial realities".[44] However, at the time it was largely accessible to industrial and research applications only. Among the first to invest in the technology was the CAD software company Autodesk which spearheaded the effort of developing affordable VR systems for the masses. In a seminal 1988 memo that cited both science and fiction, its co-founder and president urged the company to take a leading role in the development of 'cyberspace' (i.e. VR), which he discussed as a step beyond user interfaces and into illusionistic 3D interactive experiences. The memo was titled "Through the Looking Glass" – alluding to Sutherland's reference to the world of Alice – and concluded with: "Cyberspace. Reality isn't enough any more".[45] The same year Autodesk established Project Cyberia to pursue that vision. Although most of its members left by the end of 1989, in this short period the team broke new ground producing a working prototype and applications that proved affordable VR was indeed possible.[46] Though, what they soon discovered was that however astonishing the capacities and freedoms of the virtual were, the practical limits of its

40 Gibson, *Neuromancer*, 51.

41 For an example of an online virtual world see the 1985 videogame *Habitat* by Lucas Arts discussed by Morningstar and Farmer ("The Lessons of Lucasfilm's Habitat".)

42 Turkle, "Video Games and Computer Holding Power," p. 501.

43 These include Thomas Zimmerman and Jaron Lanier (co-founders of VPL Research), Brenda Laurel (co-founder of Telepresence Research with Scott Fisher), William Bricken (Autodesk Cyberia), and (VR researchers) Michael Naimark and David Levitt.

44 Foley, "Interfaces for Advanced Computing."

45 For a reprint of the memo see Walker (*The Autodesk File*, pp. 439–452), and https://www.fourmilab.ch/autofile/e5/?chapter=chapter2_69. Although the memo was intended for internal use only, it soon circulated outside the company becoming an influential document for VR at the time. See Cohen, "Virtual Evolution," p. 18, Rheingold, *Virtual Reality*, pp. 181–185, and Pimentel and Teixeira, *Virtual Reality*, p. 56.

46 For a discussion of the Cyberia Project and its impact see Cohen, "Virtual Evolution," pp. 18–59. Additionally to hardware prototypes the team developed the exergame predecessors *HighCycle* and *Virtual Racquetball,* cycling and tennis VR simulations. See Pimentel and Teixeira, *Virtual Reality*, pp. 57–58, and Krueger, *Artificial Reality II*, 2, p. 242.

experience were set by the tolerances of the human perceptive apparatus. As Meredith Bricken discussed in a 1989 presentation, actual virtual reality lay at the intersection between technological and human capacities:

> [Cyberspace] takes [our] perceptual apparatus and gives it an entirely new frame of reference with an entirely new set of rules [...]. Movement is something we have to consider in terms of joining what we know how to perceive with this great freedom of cyberspace, and that means constraining things [...]. What we are doing now is taking these marvelous freedoms and learning how to merge those with what we are really physically capable of perceiving without total confusion to our system.[47]

The intersection between the technologically and perceptually possible that Bricken described was not a simple technicality to solve, but a question of interpretation key to the specificity of the medium and its metaphysical aspirations. The matter lay beyond balancing digital stimuli with habitual perception to achieve the illusion of realism. Rather, it was a question of tapping into a 'golden section' between the two for the exploration of the human sensorium through technology. In its most exaggerated version – for the Californian region that was the epicenter of VR development at the time – that intersection was nothing less than a transcendental gateway for the expansion of consciousness.[48] In the decade that followed, multiple investigations into the matter of technological embodiment offered scientific, theoretical and philosophical interpretations and aspirations, but no definitive answer as to the nature of that intersection. Even science-fiction speculations contributed to such discourses with a notable case being the *CyberTron* (fig. 10.1), a gyroscopic VR format directly inspired by the film *The Lawnmower Man* (1992), that afforded 3-axis rotations in virtual and physical space.[49]

Autodesk only released one VR product much later, the *Cyberspace Developer Kit* in 1993, that was met with limited success.

47 Meredith Bricken in Forbes ("Cyberspace", 36:10'–39:00').

48 Davis, who studied closely that culture, noted: "A psychedelic, do-it-yourself spirituality directly feeds the more utopian elements of this northern California subculture of VR designers, computer artists, and computer programmers, whose forums include The Whole Earth Review, Mondo 2000, and the WELL [...]. For many of these folks, computers are the latest and among the greatest tools available for the achievement of the Aquarian goal: the expansion of consciousness by whatever means necessary" ("Techgnosis, Magic, Memory, and the Angels of Information", p. 55).

49 *CyberTron* allowed 45-degree rotations about each axis – in physical space. Of about 25 units produced, two were installed at Disney World in Orlando between 1993 and 1995. Tony Asch (*StrayLight Corp.* founder), conversation with the author, October 11, 2021.

Fig. 10.1 *CyberTron* (1992), a VR format developed by StrayLight Corp., was directly inspired by the film *The Lawnmower Man* (1992).

An additional mode of research we can discuss as virtual *spacetime-craft* is when the centrefold between technology and experience is subjected to practical and artistic means of inquiry. This method puts into trial computational and perceptive affordances to reveal and explore an expanded area of both technical and aesthetic possibilities. Here, vision, technology, science, design and aesthetics all come together to inform practices of crafting technological spatiotemporal environments as well as means of embodiment, with one serving as the means to interrogate the other. Such modes of investigation are exemplified by Marcos Novak and Char Davies, who saw VR as a poetic instrument able to evoke latent aesthetic and even conceptual capacities through the embodied experience of novel spatiotemporal scenarios.[50]

Davies' piece *Osmose* (ca. 1996) was one of the first examples of VR art. It orchestrated a series of interconnected spatiotemporal scenarios, each with its own visual and sonic character as well as laws of physics, where users navigated by means of breathing.[51] In her written work, Davies discussed VR as

50 Cf. Nelson, "From Sfumato to Transarchitectures and 'Osmose'."

51 Immersence, "Osmose (1995) – Mini-documentary"; Davies and Harrison, "Osmose."

a philosophical medium; a spatiotemporal arena for exploring metaphors of being in the world while abstracting from habitual modes of perception,[52] and a means of perceptual expansion through the kinaesthetic exploration of ideas expressed spatially.[53] In parallel, the work of Novak throughout the decade marked a series of seminal contributions in the apprehension of VR, spanning non-Euclidean geometry, navigable music, and higher-dimensional forms. Although his artistic work is not preserved, his elaborations of "liquid architecture,"[54] "trans-architecture"[55] and "archimusic,"[56] positioned VR as a new epistemological paradigm for the arts:[57] a "reconvergence of art, science, and technology into techne, 'a single manifold revealing'".[58] Subsuming music and architecture, for Novak the medium signified a new form of poetics and an instrument concerned with the pursuit of an "edge of thought"[59] through the investigation of spatiality and embodiment.

Regardless of the growing interest in the exploration of virtual space and experience, these come to a definitive halt by the end of the decade. On the one hand, contrary to its initial aspirations, computational space was taken up by a colonial attitude towards the "new world" of cyberspace that ratified the spatially and philosophically obsolete Cartesian paradigm that it had set out to overthrow – which is inherited in contemporary design systems and videogame engines, too.[60] On the other, VR was put to rest as a technology for a later time, bringing to a close a brief and intense chapter of technological speculations.

Conclusion

As a brief syllabus and selective archaeology, this series of examples demonstrates a persistent fascination with spatiality in Western culture following the emancipation of mathematical space in the nineteenth century. Across domains and practices, it outlined subsequent episodes in the apprehension of

52 Davies, "Virtual Space."
53 Davies, "Changing Space."
54 Novak, "Liquid Architectures in Cyberspace."
55 Novak, "Trans-Architecture."
56 Novak, "Dancing with the Virtual Dervish."
57 Novak, "Automated Writing, Automatic Writing."
58 Novak, "TransArchitecture: Building the Edge of Thought."
59 Novak, "Trans-Architecture."
60 Cf. Chesher, "Colonizing Virtual Reality. Construction of the Discourse of Virtual Reality, 1984–1992"; Penny, "Virtual Reality as the Completion of the Enlightenment Project"; Gunkel and Gunkel, "Virtual Geographies."

space as an epistemological frame of thinking, and as a substrate of experience. This assembly of precedents frames *spacetime-craft* as a mode of investigation observed in artistic practices concerned with the poetic interpretation of spatial concepts and their exploration as aesthetic experience. Such approaches intensified in the late twentieth century, especially in discourses around VR in its first and brief appearance when the medium was envisioned as an arena for the exploration of spatiotemporal environments in tandem with embodied consciousness. From a contemporary viewpoint, this heritage forms a resource for reconsidering technology as an instrument that can unite the conceptual and the experiential into a poetic tool for intimate aesthetic explorations. Especially for contemporary VR, which is markedly different in vision, though much more capable as technology (albeit impoverished when it comes to its implementation of space), its twentieth-century antecedent serves to remind of modes of artistic engagement invested in revealing the rich universe of spatial possibilities latent in the medium.

Bibliography

Abbott, Edwin A. *Flatland: A Romance of Many Dimensions*. New edition. New York: Dover Publications Inc., 1992.

Bragdon, Claude Fayette. *A Primer of Higher Space.* (*The Fourth Dimension*) [1913]. New York: Cosimo Classics, 2005.

Çelik Alexander, Zeynep. *Kinaesthetic Knowing: Aesthetics, Epistemology, Modern Design*. Chicago: University of Chicago Press, 2017.

Chesher, Chris. "Colonizing Virtual Reality. Construction of the Discourse of Virtual Reality, 1984–1992." *Cultronix* 1, 1 (1994).

Cohen, James Nicholas. "Virtual Evolution: An Alternate History of Cyberspace, 1988–1997." Dissertation for Doctorate of Philosophy in Comparative Literature and Cultural Studies, Stony Brook University, 2019.

Davies, Char. "Changing Space: Virtual Reality as an Arena of Embodied Being." In *Disappearing Architecture: From Real to Virtual to Quantum*, edited by Georg Flachbart and Peter Weibel. Basel: Birkhäuser Architecture, 2005.

———. "Virtual Space." In *Space: In Science, Art and Society*, edited by François Penz, Gregory Radick, and Robert Howell. Cambridge, U.K.; New York: Cambridge University Press, 2004.

Davies, Char, and John Harrison. "Osmose: Towards Broadening the Aesthetics of Virtual Reality." *SIGGRAPH* 30, 4 (1996), pp. 25–28.

Davis, Erik. "Techgnosis, Magic, Memory, and the Angels of Information." In *Flame Wars: The Discourse of Cyberculture*, edited by Mark Dery. Durham, NC: Duke University Press Books, 1994, pp. 29–60.

Debelius, C. A. "El-Lissitzky, Irrational Space, and the *Proun* Studies." In *ACSA Annual Meeting*. Louisville, Kentucky: University of Tennessee, 2003, pp. 330–41.

Emmerson, Simon. *Living Electronic Music*. Hampshire, England; Burlington, USA: Ashgate, 2007.

Foley, James D. "Interfaces for Advanced Computing." *Scientific American* 257, 4 (October 1987), pp. 126–35. https://doi.org/10.1038/scientificamerican1087-126.

Forbes, John. "Cyberspace: The New Explorers," 1989. https://archive.org/details/Timothy_Leary_Archives_005.dv [21.02.2022].

Gibson, William. *Neuromancer*. New York: Ace Books, 2003.

Gins, Madeline, and Shūsaku Arakawa. *Architectural Body*. Modern and Contemporary Poetics. Tuscaloosa: University of Alabama Press, 2002.

Gunkel, David J., and Ann Hetzel Gunkel. "Virtual Geographies: The New Worlds of Cyberspace." *Critical Studies in Media Communication* 14, 2 (1997), pp. 123–37.

Henderson, Linda Dalrymple. *The Fourth Dimension and Non-Euclidean Geometry in Modern Art*. Revised. London, England; Cambridge, Mass.: MIT Press, 2013.

———. "The Merging of Time and Space: the Fourth Dimension in Russia from Ouspensky to Malevich." *The Structurist*, 15 (1975), p. 97.

Hinton, Charles Howard. *A New Era of Thought*. S. Sonnenschein & Company, 1888.

Immersence. "Osmose (1995) – Mini-documentary," 1995. https://www.youtube.com/watch?v=bsT59fp8LpY [21.02.2022].

Johnston, Pamela, ed. *The Function of the Oblique: The Architecture of Claude Parent and Paul Virilio 1963–1969*. AA Documents 3. London: AA Publications, 1996.

Keyser, Cassius J. "Mathematical Emancipations. The Passing of the Point and the Number Three: Dimensionality and Hyperspace." *The Monist*, 1906, pp. 65–83.

Kiesler, Frederick. "On Correalism and Biotechnique: A Definition and Test of a New Approach to Building Design." Edited by Morgan Sutherland. *Architectural Record* 86, 3 (1939), pp. 60–75.

Krueger, Myron W. *Artificial Reality II*. Reading, Mass.: Addison-Wesley, 1991.

Lissitzky, El. "A. And Pangeometry, El Lissitzky, 1925." *THE DETACHED GAZE*, March 2014. https://thedetachedgaze.com/2014/03/15/105/ [21.02.2022].

Lombardo, Vincenzo, Andrea Valle, John Fitch, Kees Tazelaar, Stefan Weinzierl, and Wojciech Borczyk. "A Virtual-Reality Reconstruction of *Poème Électronique* Based on Philological Research." *Computer Music Journal* 33, 2 (June 2009), pp. 24–47. https://doi.org/10.1162/comj.2009.33.2.24.

Matossian, Nouritza. *Xenakis*. Lefkosia: Moufflon Publications, 2005.

Miltiadis, Constantinos. "The Architectural Continuum: Choropoietic Media and Post-Physical-World Environments." In *Architectonics of Game Spaces. The Spatial Logic of the Virtual and Its Meaning for the Real*, edited by Andri Gerber and Ulrich Götz. Bielefeld: transcript, 2019, pp. 183–99.

Morningstar, Chip, and F. Randall Farmer. "The Lessons of Lucasfilm's Habitat." *Journal For Virtual Worlds Research* 1, 1 (2008). https://doi.org/10.4101/jvwr.v1i1.287.

Mosco, Vincent. *The Digital Sublime: Myth, Power, and Cyberspace*. Cambridge, Mass.: MIT Press, 2004.

Nelson, Cami. "From Sfumato to Transarchitectures and 'Osmose': Leonardo Da Vinci's Virtual Reality". *Leonardo* 42, 3 (2009), pp. 204–205, 259–264.

Novak, Marcos. "Automated Writing, Automatic Writing: The Poetics of Cyberspace." *Design Book Review* Computers 'R' Us, 27 (1993), pp. 24–28.

———. "Dancing with the Virtual Dervish: Worlds in Progress." In *Immersed in Technology: Art and Virtual Environments*, edited by Mary Anne Moser and Douglas MacLeod. Cambridge, Mass.: MIT Press, 1996, pp. 303–307.

———. "Liquid Architectures in Cyberspace." In *Cyberspace: First Steps*, edited by Michael Benedikt. Cambridge, Mass.: MIT Press, 1991, pp. 225–254.

———. "Trans-Architecture." *Fen-Om.com/Theory*. http://www.fen-om.com/theory/theory12.pdf, 1994.

———. "Trans-Architecture: Buiding The Edge Of Thought." *Telepolis*, 9 December 1996. https://www.heise.de/tp/features/transArchitecture-2445869.html?seite=all.

Oswalt, Philipp. "Iannis Xenakis' Polytopes." *Contemporary Music Review* 21, 2/3 (June 2002), pp. 35–44. https://doi.org/10.1080/0749446021665 8.

Ouspensky, P. D. *Tertium Organum: The Third Canon of Thought – A Key to the Enigmas of the World*. Translated by Nicholas Bessaraboff and Claude Fayette Bragdon. Second American Edition. New York: Alfred A. Knopf, 1922.

Penny, Simon. "Virtual Reality as the Completion of the Enlightenment Project." In *Culture on the Brink: Ideologies of Technology*, edited by Gretchen Bender and Timothy Druckrey. Discussions in Contemporary Culture 9. Seattle: BayPress, 1994, pp. 231–248.

Phillips, Stephen. "Toward a Research Practice: Frederick Kiesler's Design-Correlation Laboratory." *Grey Room* 38 (January 2010), pp. 90–120. https://doi.org/10.1162/grey.2010.1.38.90.

Pimentel, Ken, and Kevin Teixeira. *Virtual Reality: Through the New Looking Glass*. New York: TAB Books Inc, 1993.

Redhead, Steve. "Toward a Theory of Critical Modernity: The Post-Architecture of Claude Parent and Paul Virilio." *TOPIA: Canadian Journal of Cultural Studies* 14 (September 2005), pp. 37–56. https://doi.org/10.3138/topia.14.37.

Rheingold, Howard. *Virtual Reality*. New York: Summit Books, 1991.

Riemann, Bernhard. "On the Hypotheses Which Lie at the Bases of Geometry." Habilitation thesis, University of Göttingen, 1854.

Russell, Bertrand. *An Essay on the Foundations of Geometry*. London; New York: Routledge, 1996.

Solomos, Makis. "The Complexity of Xenakis's Notion of Space." In *Kompositionen für hörbaren Raum*, edited by Martha Brech and Ralph Paland. Bielefeld: transcript, 2015, pp. 323–337.

Spuybroek, Lars. *Lars Spuybroek, H2Oexpo*. Edited by Greg Lynn. Archaeology of the Digital. Montreal, Quebec: Canadian Centre for Architecture, 2015.

———. "SCI-Arc Lecture Series." SCI-Arc, Los Angeles, March 1998. https://www.youtube.com/watch?v=Z4TfTErRRio [21.02.2022].

Stephenson, Neal. *Snow Crash*. New York, NY: Random House Publishing Group, 2000.

Sterken, Sven. "Music as an Art of Space: Interactions Between Music and Architecture in the Work of Iannis Xenakis." In *Resonance. Essays on the Intersection of Music and Architecture*, edited by Mikesh Muecke and Miriam Zach. Ames, Iowa: Culcidae Architectural Press, 2007, pp 31–61.

———. "Towards a Space-Time Art: Iannis Xenakis's Polytopes." *Perspectives of New Music* 39, 2 (2001), pp. 262–73.

Stockhausen, Karlheinz. "Four Criteria of Electronic Music." Lecture. Oxford Union, May 1972. https://www.youtube.com/watch?v=7xyGtI7KKIY [21.02.2022].

———. "Four Criteria of Electronic Music." In *Stockhausen on Music: Lectures and Interviews*. London: Marion Boyars, 1989, pp. 88–111.

Sutherland, Ivan E. "The Ultimate Display." In *Proceedings of the IFIP Congress*. New York, 1965, pp. 506–508.

Turkle, Sherry. "Video Games and Computer Holding Power." (1984) In *The New Media Reader*, edited by Noah Wardrip-Fruin and Nick Montfort. Cambridge, Mass.: MIT Press, 2003, pp. 499–513.

Varèse, Edgard, and Chou Wen-Chung. "The Liberation of Sound." *Perspectives of New Music* 5, 1 (1966), pp. 11–19.

Walker, John, ed. *The Autodesk File: Bits of History, Words of Experience*. Fifth edition. fourmilab.ch, 2017.

Wertheim, Margaret. "Lost in Space: The Spiritual Crisis of Newtonian Cosmology." In *Seeing Further: 350 Years of the Royal Society and Scientific Endeavour*, Harper Collins Publ. UK, 2010, pp. 42–59.

Xenakis, Iannis. *Arts-Sciences, Alloys: The Thesis Defense of Iannis Xenakis*. Translated by Sharon Kanach. Aesthetics in Music 2. New York: Pendragon Press, 2010.

Image Credit

Fig. 10.1: *CyberTron* (1992) by StrayLight Corp. Picture courtesy of StrayLight Corp.