Of Particle Systems and Picturesque Ontologies: Landscape, Nature and Realism in Video Games

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First released in late 1982, Microsoft's *Flight Simulator 1.0* was revolutionary for its time. Advertisements made the bold claim that "if flying your IBM PC got any more realistic, you'd need a license."[1] It wasn't just *FS1*'s accurate instrumentation that earned it this praise, but its innovative 3D color display graphics. From the cockpit, the would-be pilot enjoyed spectacular views over the surrounding landscape: "[the] ground is green, water blue, sky light blue, and clouds white and gray."[2] [insert Figure 1 here] Although *Flight Simulator 1.0* wouldn't be described as realistic by today's standards, realism in video games is still closely linked to the naturalistic representation of landscape.

Realism can be understood in different ways. Shapiro et. al. distinguish between "sensory" realism – high-resolution, photorealistic graphics and real-time physics phenomena that look, sound, and behave like the world we experience outside the game – and non-sensory cues, such as believable storylines and empathetic characters.[3] According to some, the latter qualities have a greater bearing on perceived realism than sensory qualities. Writing in 2004, Alexander Galloway set realistic representation – what he called "realistic-ness" – apart from social realism – the relationship between the game and the context in which it is played. The former, as Galloway writes, "is a yardstick held up to representation. … important, to be sure, but the more realistic-ness takes hold in gaming the more removed from gaming it actually becomes, relegated instead to simulation or modelling."[4] Realism, as Galloway and others understand it, has to do with the way that the game's narrative bleeds into the world beyond. In fact, as I will argue, realistic graphics and physics phenomena are equally important, and no more confined within the boundaries of a game than its ostensible social effects.

Landscape is much more difficult to model than architecture or interiors, and it almost always provides the benchmark for graphic realism in video games. Rudimentary as it is, the landscape in

FS1 – ground, water and sky, arrayed in a convincing three-dimensional space – shares the same basic elements as more recent games – such as *Metro Exodus, Alan Wake*, and *Assassin's Creed* – that have been praised for their realism. Computer graphics have evolved significantly in the years since *FS1* appeared, but many of the qualities that define graphic realism today – visual detail, dynamic lighting and weather effects, particle effects such as fire, smoke and mist – are still associated with the appearance and behaviour of "natural" assets.

"Nature" and "natural" are key terms in the following discussion, and they require some unpacking. Nature, for the Modern imagination, is not an external entity with an independent existence, but a construct that can only be understood in context. Here, the context is that of Western landscape representation. The overlaying of a systematic three-dimensional space with apparently random natural forms is the basis of the Western landscape idiom, not just in videogames, but in other historical forms such as landscape painting. The following essay, however, examines a category of landscape representation that has been largely overlooked by video game scholars: the eighteenth century Picturesque landscape garden.[5] Nature, in the Picturesque garden, was assumed and constructed as an entity and/or a set of processes beyond human control, but not necessarily exterior to representation itself. The garden – and Picturesque discourse more generally – granted a specific ontological status to nature as simultaneously inside and outside representation. As I will argue below, graphic realism in video games assumes and constructs nature in an analogous way.

The Picturesque landscape garden set the inherent disorder of nature and natural forms against the order imposed by human artifice. Though it was intended to emulate the work of nature, the garden was carefully constructed to resemble a picture, giving a legible structure to a space whose exact boundaries were otherwise unclear. The porous boundary between nature and representation, control and chaos, inside and outside, is also a concern for the creators of digital landscapes. Here, it is embodied in the relationship between front-end modelling – what the player sees – and back-end

modelling – the code that creates it. The modelling of natural assets often involves the deliberate introduction of visual and behavioural randomness into a highly ordered space. Weather effects, the behaviour of water and other liquids, the appearance and movement of vegetation, and other such phenomena are all simulated through a range of techniques that also govern the form and behaviour of phenomena in the world beyond the simulation, and that produce results independently of the designers' control.

The perceived realism of a video game also depends, in part, upon the player's conviction that they are a sovereign agent in this space. All 3D games are built on a Cartesian perspectival framework that emulates physiological vision, but that delimits and occupies the gaze "in a manner differing significantly from the perceived world."[6] Like the historical landscape representation on which it is based, 3D game space has a formal syntax that prompts the player to encounter it in a narrative way.[7] For the gamer to experience the environment as realistic, however, this coercion should not be explicit. Video games, as game journalist Keith Stuart writes, "are designed to specifically court and flatter our desire for autonomy."[8] Both real-world and digital landscapes are constructed spaces that camouflage their geometric framework with natural forms.

Video game studies is increasingly concerned with the histories and spatial politics of digital worlds. Recent scholarship has located video game landscape along a historical trajectory that spans Western painting, photography, and Hollywood film[9] – all of which posit the subject as *outside* the represented scene, looking in. Videogames, however, offer the unique experience of being "inside" the scene, and, as I will argue, this introduces complexities around questions of landscape, nature, and agency that can be more fully understood by examining similarly "interactive" historical forms of representation. Although some realistic game environments may resemble Picturesque compositions, the focus here is not simply on the way that an environment looks, but on the means by which this look is achieved, and the questions this raises about the ontological status of nature.

Like the Picturesque landscape garden, the video game is not a straightforward representation of "external nature". Nor, as I argue, is agency limited to the perception of autonomy and control *within* the game – it is distributed, as it was for the visitor to the Picturesque garden, across human subjects, spaces of representation, and the physical world.

I. Ordering Nature

Picturesque landscape gardens began to appear in early eighteenth-century England in response to the perceived formality of French and Dutch landscape gardens. Elaborate and labor-intensive methods were used to construct landscapes that looked as though they had arisen naturally. Obvious geometric organization was abandoned in favor of a guiding principle of mixture that contrasted the rough and the smooth, the old and the new, the artificial and the natural. As Picturesque theorist Uvedale Price wrote in 1842, "There is a wide difference between an avowed and characteristic formality, and a formality, not less real, but which assumes the airs of ease and playfulness."[10]

Creating a picturesque composition meant inviting disorder into a carefully ordered space. Organised around three key factors – viewing position, horizon line and vanishing point – the picturesque landscape was composed of layers of receding strata which drew the gaze inward from the foreground, through middle ground and background towards the horizon.[11] The underlying geometric structure of the landscape garden was carefully planned, but its outward appearance arose through uncontrolled processes of growth, decay, and time-based change – "an irregular, less apparent artifice derived from nature."[12] Controversy over the boundary between the natural and the artificial persisted throughout the century, with much of the debate focused, as Sidney K. Robinson has observed, on "the degree to which human artifice should be aligned with either nature's appearance

or its invisible laws."[13] The relationship between appearance and "invisible laws" or processes is key here, and we will return to it shortly.

Today, the perspectival schema on which the Picturesque landscape was based is built into most computer graphics software, and often into the hardware itself. It is embedded in both the game engine and the rendering API – the third-party software that is bolted onto the game engine to perform higher-level graphics functions. The modelling of gameworlds involves three sets of 3D co-ordinates: those defining individual objects, those defining the view volume (what the player sees) and those upon which the game world itself is built. The virtual camera that transforms the 3D virtual world into a 2D representation on the screen conforms to the same logic. Projection systems such as these are generated by means of geometrical techniques not much different from those developed in the Renaissance. First published in 1963, the algorithm for computer generation of perspective projection was derived from formulae developed in the eighteenth century.[14]

Realistic game landscapes are ordered in a way that would have been familiar to the eighteenth-century landscape designer: space is divided into foreground, middle ground, and background, with nearby features and landforms providing the structural basis of the scene, and distant ones furnishing its general context. The mountainous landscape in *Days Gone* and the Caspian Desert in *Metro Exodus* look very different, but they are organized around identical principles: foreground features are detailed and graphically precise, while surface texture gradient, brightness, detail, and contrast all diminish with distance – three-dimensional depth cues borrowed from landscape representation. [insert Figures 2 and 3 here] In Figure 3, strong cast shadows highlight the rich detail of objects closest to the player: tire tracks and footprints are clearly visible in the sand underfoot, rocks, trees and plant forms have distinct identities and characteristics. The landscape in Figure 2 follows more familiar conventions of Western landscape painting, with receding strata laid out in roughly triangular sections drawing the eye from the foreground into the distance. In both

examples, landforms and features in the middle ground and background are created by mapping two-dimensional images onto flat surfaces – billboards or "imposters" – that face the player. The distant factory, as well as the trees and ruined pylon in the marshlands next to the flooded Volga river in Figure 4 are designed along the lines of theatrical flats, cleverly layered to create the illusion of deep space[insert Figure 4 here].

With certain exceptions,[15] none of this subterfuge is evident to the player, nor is it desirable that it should be. In realistic video games, player agency and realism both depend upon the concealment of the perspectival framework on which the landscape is built. In the Picturesque garden, on the other hand, the boundary between the natural and the artificial was a focus of attention in its own right. A Picturesque composition worked, as Robinson argues, "when the artifice successfully posed a question about its status. To make its presence unmistakable or completely concealed is to leave out the primary experience of actively probing and questioning what one sees."[16] Agency, for the eighteenth-century subject, lay in the ability to spot the difference between nature and artifice – those who mistook the garden for a natural landscape were missing the point. This is not the case in the realistic video game.

II. Nature as Process

Visual realism is still the driving force behind the development of game hardware and software, with graphics first in line for processor resources. Euclidean geometry, however, is not very good at modelling natural forms. While the designer of the Picturesque garden relied on biological processes of growth and decay to conceal the framework on which it was built, game designers do not have this luxury.

The English landscape painter Alexander Cozens (1717-1786) structured many of his compositions around stage-managed "accidents" of representation, spreading ink on paper to produce "blots" – indistinct masses which suggested the natural contours of water, foliage, or topography. This process, he declared, was "conformable to nature; for in nature, forms are not distinguished by lines, but by shade and color."[17] As well as the study of nature, Cozens suggested borrowing her means, as it were, to "enlarge the powers of invention" in the viewer. Cozens' shortcut was an algorithm, the accidental forms of natured figured by means of nature's own logic.

What was significant about Cozens' tactic was not just the appearance of the forms he created, but the means he used to produce them. Procedural generation, a technique widely used in the computer generation of natural assets, uses algorithms based on biological and geological data to create forms that are 'conformable to nature'. Rather than modelling objects and features individually, procedural generation spawns trees, rocks, terrain and other assets in real time, using a limited set of variables. Algorithms used for generating vegetation, for instance, have long been based in Fibonacci sequences and other non-accidental numerical sequences that also determine the morphology and growth of real plants. The technique developed by de Reffye et. al. in 1988 produced plant models that were "faithful to their botanical nature … and [included] the known botanical laws which explain plants' growth and architecture."[18] Many of the algorithms used to generate graphically realistic natural forms are based on rules that play a functional role within the simulation, and in the real world.[19]

Procedural generation is used to simulate not just the look of natural features, but realistic behavior as well. A game's physics engine models object properties such as mass, velocity and friction by means of algorithms derived from physical laws. 'Fuzzy' objects, such as fire, fog, and water, have irregular, ill-defined surfaces that change their shape and appearance dynamically. Rather than geometric modelling, so-called 'particle systems' have long been a favored method for the

modelling of fuzzy objects. Particle systems hand over most of the work to processes that the designer initiates but does not control.

Objects and effects modelled by particle systems are represented not by hard boundaries, but by "clouds of primitive particles that define [a] volume."[20] Particles are introduced into a system via statistical processes that determine the number of new particles generated at a given time, as well as their position, velocity, size, color, transparency, shape, and lifespan. The shape and form of a particle system is not specified in advance, nor is it static – it changes over time as new particles are generated and older ones "die." The generation of particles can incorporate any computational model that describes the appearance or dynamics of an object – including models that have been developed empirically in other disciplines such as science or engineering. The dynamic weather effects in *Metro Exodus* – stormclouds that sweep in from the horizon, landscapes blanketed in fog, driving rain and blowing snow – are all created using particle systems.

Formulae used to explain the behavior of real-world phenomena – everything from the way that water moves to the way that snow falls or dust billows up in a sandstorm – can be translated into code and introduced into the playable environment. Simulating rainfall realistically, for instance, involves accounting for the way that raindrops appear under changing lighting conditions, the way they interact with objects and the ground, and the way they appear to the human optical system. The methods used to achieve this adhere closely to the physical, optical and statistical properties of actual raindrops.[21] In systems such as these, the designer can never be absolutely certain about the final appearance and behaviour of the assets that s/he models. The environment owes its nature to something more than human intention, and this frisson of 'something else' at work in/on the space of representation is the very essence of Picturesque ontology. Like the creator of the Picturesque garden, the modeler of natural assets does not "create" them as such, but instead initiates a process which follows the same imperatives that generate these objects and behaviours in the real world.

III. Inside/Outside

Picturesque gardens and video game landscapes are interactive 3D spaces built around hidden perspectival schemas. The first is a real space designed to be encountered as a picture, the second, a two-dimensional representation intended to be experienced as though it is real. Both incorporate processes that complicate their status as representations of "external" nature. For the garden designer, the engine driving these processes was biological; for the designer of digital landscapes, it takes the form of code.

Simulating natural processes with digital models can be understood as a postmodern reiteration of an essentially Cartesian notion of information (insubstantial essence) as privileged over materiality (presence).[22] But in realistic videogames, the line between "real" nature and simulated nature does not lend itself to such strict demarcation. In a Picturesque ontology, nature is understood as a *process* that incorporates both essence and presence; as such, it cannot easily be set apart from representation. The code used to model physical laws in a game exists on a continuum that also includes equations in domains such as mathematics and physics and physical laws that are enacted in real-world objects and events. Information of this kind is not abstract, in other words; it cannot be fully teased apart from its context, its enactment, or its meaning. Simulations of nature are instantiated as logical expressions in the gameworld *and* as complex embodiments in the real world, and they blur the boundary between the two in significant ways.

The correspondence between the observed world and the way it is formulated in/as code has been theorized in a number of different fields. Digital physics, for example, treats all observed physical phenomena as inherently computational. J.A. Wheeler's "it from bit" thesis claims that all objects in the material world have as their deep basis an immaterial source and explanation; physical phenomena such as electromagnetism, mechanics, and thermodynamics, "allow a digital interpretation and, therefore, can be conceived as computational processes".[23] This is not to claim that a real, biological

leaf is the same thing as a digital leaf. But it is equally reductive to claim that a Fibonacci sequence, for instance, is simply a human expression of a biological pattern; an interpretive strategy created by humans and used to model "external" nature. Such claims leave intact the distinction between the two realms as qualitatively different entities. Nor is it simply a matter of metaphorical correspondence between the functioning of media technologies and the "natural" world. As a geometric imperative governing the behavior of animate and inanimate structures, the ontological status of the Fibonacci sequence and other such forms embodies both concept and observable phenomenon, both real world and digital simulation.[24]

Recent research on augmented or 'hybrid' reality games (HRGs) such as *Pokémon Go* turns to the work of philosophers Gilles Deleuze and Félix Guattari in order to question the persistence of dualist paradigms within game studies – among them, the "misguided yet highly popularized demarcation between virtual game spaces and 'real world' physical spaces."[25] Deleuze and Guattari's materialist ontology treats thought, perception and ideas as intrinsic elements of material reality – components of "abstract machines" made up of multiple and dynamic processes that organize matter into "concrete assemblages," which are themselves in constant transformation.[26] In video games, these assemblages include (but aren't limited to) physical space, sensory information, code, digital information, and the gamer him or herself.

For the most part, however, game studies still approaches the realistic video game as a representation of nature. Galloway's insistence that realism in games involves a link or "congruence" between the social reality represented in the game and that lived by the gamer in the real world assumes the two domains as separate.[27] Similarly, arguments that understand games as first- or second-order representations of landscape suggest that they can do little more than offer "explicit moral messages and educational lessons" about the real world.[28] But confining such discussions to the messages and lessons embedded *in* the gameworld reveals little about the way that the game itself

also acts to constitute and delimit inside and outside, "real" nature and its digital simulation. Picturesque ontology, on the other hand, avoids categorical divisions between the digital and the natural in order to focus on the way that certain processes cross over and play functional roles in both domains.

The Picturesque landscape was not a representation with clear boundaries, but a deliberately equivocal assemblage which nature helped to create. And nature itself, for the eighteenth-century subject, was a similarly pliable category: at once a primal sphere or *alterum naturam*, separate from humanity, and an essential part of humanity itself. The Picturesque landscape garden was an expression of this simultaneity, setting an oblique vision of nature in its raw state alongside a picture of nature perfected by the hand of man. As debates throughout the century demonstrated, the distinction between the two was open to dispute, and agency was linked, in part, to the visitor's ability to interrogate this boundary and to situate themselves in relation to it. In a Picturesque ontology, the very act reflecting on the boundary between humanity and nature was – and still is – a political one.

Representing nature via the framework of landscape is an expression of power relations; a means of inscribing deeply-held cultural attitudes within an apparently neutral space of representation. The discourse of landscape – its definition, its conventions, its history – authorizes a specific cultural vision of nature, and its political potency is, in part, a function of its ability to naturalize this vision, to conceal deeply rooted cultural sensibilities behind a screen of benign realism. But the screen is never neutral. The suggestion that nature can be reduced to something qualitatively different from humanity and human endeavor marks a particular kind of mastery and control over the material world, and guides the way that humankind responds to its environment. The vision of a "wild nature," free from the dictates of politics and commercial capitalism, shapes environmental policy, individual rights, and national identity. As political theorist Jane Bennett writes, conceptualizing nature as other is a means of justifying an ecological management approach to the planet and to

individuals; a way of vindicating our destruction of ecosystems and our standardization of "irregular beliefs, practices, or populations."[29] More generally, nature is often invoked in support of dualistic ontologies (nature/culture, female/male, primitive/developed) which uphold repressive ideologies.

Examining realistic video games through the optic of Picturesque ontology encourages reflection on nature not simply as a quality that is inscribed *within* representation, but as a constellation of functional processes with the potential to disrupt the latter's limits. The object of study, then, is not just the contents of realistic video games (and the explicit messages and lessons they comprise), but the boundary between inside and outside, between nature and simulation – where and how it is located, and what is at stake in making that distinction.

This also has implications for the way that player agency is defined: reframed as a relational quality, not necessarily confined or reducible to individual subjects, but distributed across "complex and dynamic assemblages of matter, energy, affect and subjectivity articulated into particular organizations of space, place and mobility."[30] For the garden visitor and the gamer, agency can be understood in terms of a network or matrix of forces within which the subject is situated: a distributed system, parsed variously between codes, visual schemas, actions and processes which problematize the boundary between the simulation and the world "outside." Player agency, in other words, is more than something that exists within the game, it is also a function of the game's uncertain boundaries and the complex, transformative character of "nature" that they embody.

Since the Renaissance, Western philosophy has been steadily eroding the idea of nature as separate from human culture and human subjectivity. For the visitor to the Picturesque garden, the relative stability of a world regulated by the linked regimes of nature and God was undergoing a profound transformation into a more rational, secular society. Modernity reduced nature to something instrumental – a force to be harnessed by human ingenuity. Recently, we have reached a new critical

point in the history of this relationship. Nature may be tacitly acknowledged as a cultural myth, but recent events suggest that this myth has taken a disquieting turn to the primordial and unknowable in the form of mass extinctions, environmental changes, and extreme weather events that are generated by our actions, but which we lack the power to control.

The aim of the present paper has not been necessarily to resolve questions about our relationship with nature, or to stake out its limits, but to posit the video game as a complex and pliable form through which such questions might be explored. Rethinking nature not as an outside, but as something that also exists and acts within the digital world, alongside technology and enmeshed with it, may help us to push past binary expressions of nature and artifice, digital and material, the virtual and the human. As we enter a new and uncertain phase of our relationship with the planetary ecosystem, so we should reconsider the video game not simply as an escape from reality, but as a site of deep involvement and investment in it.

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[1] Advertisement for Microsoft *Flight Simulator 1.0*, in *PC Magazine*, vol 1 no 9, January 1983, 2.

[2] See Will Fastie. "Flight of the 5150: The PC Takes Off." *PC Magazine* 1, no. 9 (1983): 303-307.

[3] Michael A. Shapiro, Jorge Peña-Herborn, and Jeffrey T. Hancock. "Realism, Imagination, and Narrative Video Games." *Playing Video Games: Motives, Responses and Consequences*. Peter Vorderer and Jennings Bryant, eds. (New Jersey & London: Lawrence Erlbaum Associates, 2006.), pp275-289.

[4] See Alexander R. Galloway. "Social Realism in Gaming." *Game Studies* 4, no. 1 (November 2004), http://www.gamestudies.org/0401/galloway/. Michael Longan makes a similar distinction in a recent article. The 'virtual' landscape of the video game, he argues, has the potential to 'represent

the often hidden social processes behind the production of real-world landscapes.' see Michael W. Longan. "Playing with Landscape: Social Process and Spatial Form in Video Games." *Aether* II (April 2008), 24.

[5] Picturesque aesthetics reached the peak of its popularity in mid- to late eighteenth-century England, where it found expression not just in painting, but in the three "sister arts" of landscape painting, landscape gardening, and poetry. In 1770, Horace Walpole referred to them as the "Three New Graces who Dress and adorn nature." See Stephanie Ross. "Ut Hortus Poesis: Gardening and Her Sister Arts in Eighteenth-Century England." *British Journal of Aesthetics* 25, no. 1 (Winter 1985), 17.

[6] Louis Marin. *To Destroy Painting.* (Chicago: University of Chicago Press, 1995), 35.

[7] The eighteenth-century landscape view shares its basic structure with the pictorial space of linear or Albertian perspective. Both are based around three key variables – viewing position, horizon line, and vanishing point – and instructions for composing landscapes were often included in early treatises on perspectival composition and stage design. Layers of receding strata lead the gaze inward from the foreground, through middle ground and background towards the horizon, while masses of light and shade, as well as atmospheric perspective, provide additional depth cues intended to provide "paths of reading" for the viewer, encouraging the gaze to advance "along the lines of a promenade offering successive partial glimpses of the surrounding landscape, or [taking their] place within a view from above, the pathway being inscribed into the encompassing geography." See Hubert Damisch. *The Origin of Perspective.* John Goodman, trans. (Boston: MIT Press, 1995), pp262-3. Along with the perspectival framework, game designers use a variety of spatial and depth cues to encourage players to head in a specific direction. The creation of positive and negative space – open space vs. obstruction – is a subtle but vital way of directing movement: "if subconsciously [players] feel that there is more space over there, they will tend to head in that direction. … It's like a path of least resistance … they're always going to be going forward, and it's up to you to lead them by the eyes, if you like." Interview with game designer Richard Franke, Guildford, Surrey, 23 October, 2006.

[8] Keith Stuart. “Video games aren’t about power – they’re about agency.” *The Guardian*, 16 October 2015. https://www.theguardian.com/technology/2015/oct/16/video-games-power-agency-control

[9] See Soraya Murray. *On Video Games: The Visual Politics of Race, Gender and Space* (London: I.B. Tauris, 2018).

[10] Uvedale Price. *On the Picturesque* (Edinburgh: Caldwell, Lloyd & Co., 1842), 309.

[11] This structure was evident not just in painting and landscape gardening, but in Picturesque Poetry as well:

Of Nature’s various scenes the painter culls
That for his favourite theme where the fair whole
Is broke into ample parts and bold;
Where to the eye three well-mark’d distances
Spread their peculiar colouring. Vivid green,
Warm brown and black opake the foreground bears
Conspicuous; sober olive coldly marks
The second distance; thence the third declines
In softer blue, or less’ning still, is lost
In faintest purple.
William Mason, *The English Garden*, 1772

[12] Sidney K Robinson. *Inquiry into the Picturesque* (Chicago: University of Chicago Press, 1991), 3.

[13] Robinson 1991, 3.

[14] Roberts had to refer to early c18th German textbooks on perspectival geometry from the early 1800s to work out his formulae. See Lev Manovich. “Automation of Sight: from Photography to

Computer Vision." (1997). http://manovich.net/content/04-projects/014-automation-of-sight-from-photography-to-computer-vision/11_article_1997.pdf

[15] In games like *Rez* (Tetsuya Mizuguchi, 2001) and *Cosmic Smash* (Sega, 2001), the geometric wireframe is part of the aesthetic.

[16] Robinson, 1991, 108.

[17] Bernard Denvir. *The Eighteenth Century: Art, Design, and Society 1689-1789.* (London and New York: Longman Group Ltd., 1983), p262

[18] Philippe de Reffye, Claude Edelin, Jean Françon, Marc Jaeger, and Claude Puech. "Plant Models Faithful to Botanical Structure and Development." *Computer Graphics* 22, no. 4 (August 1988), 151. Such algorithms incorporate parameters related to a plant's age, its speed of growth, and the growth patterns and layout of leaves and branches. Statistical probabilities measured experimentally on real-world species are assigned to individual parameters in order to generate accurate images of different types of plants.

[19] Similarly, fractal systems – sets of geometric shapes which are self-similar (or nearly so) at any scale – are used to generate features such as plant forms, clouds, water, massed vegetation and terrain. Models derived from geomorphology and other earth sciences create mountains, coastlines, deserts and waterways; hydraulic erosion and deposition models drawn from physics are used to give them a more realistic appearance. See Costin-Anton Boiangiu, Adrian Gabriel Morosan, and Marian Stan. "A Fractal World: Building Visually-Rich and Fully-Realistic Natural Environments". *International Journal of Mathematics and Computers in Simulation* 10 (2016). http://www.naun.org/main/NAUN/mcs/2016/a282001-428.pdf

[20] William T. Reeves. "Particle Systems: A Technique for Modeling a Class of Fuzzy Objects." *ACM Transactions on Graphics* 2, no. 2 (April 1983), 91.

[21] See Wang, Changbo et. al. "Real-time modelling and rendering of raining scenes." *The Visual Computer* vol. 24, issue 7-9 (July 2008), pp605-616. https://doi.org/10.1007/s00371-008-0241-0

[22] see N. Katherine Hayles. *How We Became Posthuman*, (Chicago and London: The University of Chicago Press, 1999), 73.

[23] Anderson Beraldo-de-Araújo and Lorenzo Baravalle. "The Ontology of Digital Physics." *Erkenntnis* 82, no. 6 (December 2017), 1214.

[24] For a more detailed discussion of symmetry as a concept, a method, and an observed phenomenon, see Gyorgy Darvas, *Symmetry: Cultural and Ontological Aspects of Science-Arts Relations; the Natural and Man-Made World in an Interdisciplinary Approach*. (Basel: Birkhauser Verlag, 2007).

[25] Justin Grandinetti and Charles Ecenbarger. "Imagine Pokémon in the "Real" world: a Deleuzian approach to Pokémon GO and augmented reality." *Critical Studies in Media Communication* 35, no. 5 (2018), 440. https://doi.org/10.1080/15295036.2018.1512751

[26] See Stephen B. Crofts Wiley, "Spatial Materialism." *Cultural Studies* 19, no. 1 (January 2005). 63-90.

[27] see Galloway, 2004

[28] Michael W. Longan. "Playing with Landscape: Social Process and Spatial Form in Video Games." *Aether* II (April 2008), 36.

[29] Jane Bennett. *Unthinking Faith and Enlightenment: Nature and the State in a Post-Hegelian Era*. (New York and London: New York University Press, 1987), 47.

[30] Wiley 2005, 79.