

The Evolution of Pixel-Based Virtual Imaging: From the Digital Processing of Material Imagery to the Virtual Imagery of Digital Art

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Moving-image art underwent roughly three stages of development over the course of the twentieth century: avant-garde cinema in the period surrounding the Second World War; video art from the late 1960s to the early 1990s; and digital art, which emerged in the mid-to-late 1990s and continues to evolve today. Moving-image art shifted from the recording of material images¹ to virtual imaging by means of digital computer technology. This process involved not only the entry of computer technology into moving-image art but also a revolutionary transformation in the nature and definition of the image.

The computer technologies associated with this evolution include computer graphics processing, 3D modeling and animation, VR “six-dimensional imagery”², interactive game video, internet art, and AI-generated imagery based on algorithmic models. Avant-garde film and video art, using film stock and magnetic tape respectively, belong to the category of material imagery. After 2000, as high-definition video cameras entered the market, film stock was gradually displaced; film production and video-art production converged around high-definition digital cameras that stored images on chips. This signaled pixel-based digital capture and storage.

During the 1990s and the first decade after 2000, moving-image art occupied a transitional phase in which material imagery was being transformed into virtual imagery. The initial shift was from film and magnetic tape as capture and storage media to chip-based digital recording and storage; at the same time, computer image-processing technologies entered the postproduction and editing of material image footage. In the 1970s, when a stand-alone computer could still fill an entire room, the concept of the image changed fundamentally as programmed images were generated by computer and output as still frames through plotters: from generation to output, such images were composed entirely of pixels.

The pixel is the smallest element of a digital image; symbolic encoding replaces the logic of material production. The age of celluloid cinema has passed. In technical terms, television productions by American companies such as HBO and Netflix are scarcely different from Hollywood films, because both use digital cameras and computer-based postproduction on every frame. Fully 3D animation can dispense even with physical shooting, becoming a mode of digital image generation.

From post-First World War avant-garde cinema through the avant-garde film and early video art of the 1960s and 1970s, surrealist or formalist composite images depended chiefly on multiple exposure in film, image superimposition on video-editing equipment, or the construction of illusory physical sets through sound, lighting, and stage design, all in order to simulate material visual effects. In the 1980s, cinema formally began to move beyond the shooting of material images and the use of such images as raw material for surreal landscapes

1 实体影像 is rendered as “material imagery” or “materially recorded imagery.” In this essay, the term denotes images captured from physical scenes—especially through film or magnetic tape—and is opposed to computer-generated virtual imagery. This is the author’s conceptual usage rather than a standardized technical binary.

2 “Six-dimensional imagery” (六维影像) is not a standard term in VR studies. In context, the author describes visual extension in six directions—front, rear, left, right, above, and below—rather than six mathematical dimensions or the conventional technical meaning of six degrees of freedom.

produced through laboratory processing and editing. It introduced digitally produced films that simulated reality, with *TRON* (1982) as a pioneering example; in the 1990s came *Toy Story* (1995), Hollywood's first fully 3D-animated feature. The images in both films were produced entirely through digital 3D modeling, without on-location shooting by a film or video camera and without the construction of illusory sets through lighting and scenery.³

Because digital image production remained prohibitively expensive in the 1980s, it was available primarily to commercial films financed at great cost by major Hollywood studios and did not enter individual artists' moving-image experiments at the same pace. During the 1980s and 1990s, video art and experimental film shot on film stock relied mainly on computer image-processing software to create surrealist or formalist visual effects, as in the later works of Nam June Paik, Bill Viola, and Matthew Barney.

The large-scale digital processing of material imagery appeared in the final decade of the twentieth century. It depended on computer technologies such as computer graphics, video processing, programmable hardware, and nonlinear editing, and it integrated multiple forms of new-media imagery, including live-action footage, computer-composited imagery, three-dimensional virtual imagery, and hand-drawn animation. As moving-image art passed from film and magnetic tape to digital technology, its material aesthetics—grounded in the production of images from physical reality—gave way to a pixel aesthetics that reconstructed reality. Even surreal landscapes that had once simulated reality through physical set design could now be transformed into virtual landscapes through digital modeling.

In late-1990s video art, footage recorded by the camera from physical subjects was transformed through computer-based editing, compositing, and other effects into digital imagery constituted by pixels. It moved beyond the image-objecthood of traditional moving images, which simulated material forms shaped according to subjective conceptions, and beyond pictorial verisimilitude; pixel-based digital imagery entered a new visual mechanism. Digital technology affected the ontology of the moving image through principles of digital encoding and modularity: footage was converted into pixel data, completing another transformation of the medium.

In the 1990s, digital imagery entered the realm of what the author calls “six-dimensional” VR imagery. VR, or “virtual reality,” differs from the screen-based or single-channel simulation of digital works such as *TRON* and *Toy Story*: viewing VR requires a head-mounted display, through which the viewer encounters immersive virtual imagery extending in six directions. The term “virtual reality” was coined by Jaron Lanier, who founded a company devoted to virtual programming languages in 1983 and began the early commercial promotion of immersive VR

³ The source overstates the production method of *TRON*. The film combined live-action photography, backlit animation, and computer-generated imagery; it was not wholly modeled in 3D. *Toy Story* (1995), by contrast, is identified by Pixar as the world's first computer-animated feature. See American Society of Cinematographers, “The Making of ‘Tron,’” October 21, 2025, <https://theasc.com/article/making-of-tron-1982/>; Pixar Animation Studios, “Our Story,” accessed July 31, 2026, <https://www.pixar.com/our-story>.

products, including head-mounted displays (1987) and networked virtual-world systems.⁴ This suite of VR technologies moved digital imagery from virtual vision toward embodied and immersive virtuality. In a VR work, virtual scenes appear not only in front of, behind, to the left and right, and above the viewer, but also underfoot, producing a full-body virtual reality. Yet this virtual reality is not wholly realistic; it more closely resembles a void in which the entire body seems weightless.

The core of VR imagery is “cyberspace.” The term was introduced by Canadian writer William Gibson in his 1984 science-fiction novel *Neuromancer*.⁵ Formed from “cyber” (cybernetics) and “space,” it refers to the virtual world constituted by computer networks. The embodied, immersive, six-dimensional simulacrum of VR does more than enlarge the sense of reality into bodily immersion; some of it exceeds experience in the real world and enters virtual situations unique to cyberspace. The cyberworld built by virtual-reality technology blurs the boundary between the virtual and the real, constructing a second reality beyond ordinary reality: virtual reality.

Next-generation intelligent devices such as VR will serve as hardware portals into virtual worlds, providing digital visual experiences beyond an ocularcentrism governed by the naked eye. Because VR art unfolds through six-dimensional imagery, it foregrounds the spatial dimension of narrative. In 2017, American artist Laurie Anderson and Taiwanese artist Hsin-Chien Huang jointly created the VR work *La Camera Insabbiata* (Chalkroom), which won the Best VR Experience Award at the 74th Venice International Film Festival. The work consists of eight thematic rooms shaped like shipping containers: the Dust Room, Dog Room, Sound Room, Writing Room, Anagram Room, Water Room, Dance Room, and Tree Room.⁶ Viewers can use a navigation display’s “fast track” to reach each room or explore on their own in search of entrances. Wearing VR equipment, they fly through an infinite space composed of words, images, signs, sounds, and memories.

The central feature of VR imagery is interactivity between media. The body constitutes one pole of the interaction: the question is how to establish an interactive relation between the spectator-participant and digital media. As both performer and viewer, the spectator manipulates

4 Lanier’s official biography states that he “either coined or popularized” the term “virtual reality” and founded VPL Research in the early 1980s. His own 2001 account places VPL’s first experiments under that name in the mid-to-late 1980s and notes that VPL began selling virtual-world tools in the mid-1980s. The source’s exact date of 1983 cannot be confirmed from these materials. The Chinese phrase “网络虚拟世纪系统” (“networked virtual-century systems”) is evidently a textual corruption and has been rendered as “networked virtual-world systems.” See Jaron Lanier, “Jaron Lanier’s Bio,” accessed July 31, 2026, <https://www.jaronlanier.com/general.html>; Jaron Lanier, “Virtually There,” *Scientific American* 284, no. 4 (April 2001): 68–69, <https://www.jaronlanier.com/cocodexintro/lanier01sciam.pdf>.

5 Gibson first used “cyberspace” in the short story “Burning Chrome,” published in *Omni* in July 1982, and subsequently developed and popularized the concept in *Neuromancer* (1984). The source’s attribution solely to the novel is therefore incomplete. See William Gibson, “Burning Chrome,” *Omni* 4, no. 10 (July 1982): 72–77, 102–107; William Gibson, *Neuromancer* (New York: Ace, 1984).

6 The official award title was “Best VR Experience Award (for Interactive Content).” Official project materials list the Cloud Room—not the Dust Room—among the eight rooms; the other listed spaces correspond to the Dog, Sound, Writing, Anagram, Water, Dance, and Tree Rooms. See La Biennale di Venezia, “Official Awards of the 74th Venice Film Festival,” September 9, 2017, <https://www.labiennale.org/en/news/official-awards-74th-venice-film-festival>; Hsin-Chien Huang, “*La Camera Insabbiata*,” accessed July 31, 2026, https://www.hsinchienhuang.com/pix/_3artworks/i_laCameraInsabbiata/p0.php?lang=en.

a simulacrum, creates a virtual avatar to enter the scene, and interacts in real time through real-time 3D technology. The player enters the image from a first-person perspective and experiences a powerful identification with the role.

In its early phase, digital imagery still functioned as a simulation of material objects. Through computer-based 3D modeling, it reproduced visual scenes resembling physical objects or real-world settings, while also producing surrealist or formalist simulations of reality. Although this production method surpassed material imagery, the image itself remained a simulation of the real or an imitation of objects; it did not move beyond ocularcentric visual experience. As a means of image simulation, early digital technology did not produce an ontological image specific to digital imagery itself. Even in the six-dimensional imagery of VR, although some works convey the weightlessness of embodied virtuality, the medium as a whole still belongs to the simulation of reality.

With AI-generated imagery, however, this problem underwent a genuinely revolutionary breakthrough. Algorithm-based generative AI introduced procedural generation and data visualization into moving images. AI imagery became a virtual image wholly unrelated to materially recorded reality: moving from the simulation of reality to “becoming virtual,” it finally realized virtual imagery at the ontological level.

Early AI-generated imagery took primarily the form of computer-based procedural generation: an artist specified a program through computer code, after which the program automatically generated a virtual image. In *The Blind Watchmaker* (1986), Richard Dawkins set out the principle of what the author identifies as an interactive genetic algorithm (IGA). A computer program for generating “biomorphs” could produce 118 billion distinct images—two-dimensional vector images composed from nine digital “genes.” The maker needed only to select a preferred biomorph; the program would then evolve its chosen biological features into a descendant form.⁷ In the early 1990s, artist William Latham and mathematician Stephen Todd introduced the interactive genetic algorithm into 3D computer-image production in *FormGrow* (1992/93). The project unfolded in two stages. The first defined a form-generating system that allowed the computer to produce different virtual forms. In the second, the algorithmic program (IGA) selected graphic structures on its own and automatically generated virtual organisms in evolutionary forms. This practice of customizing form through an evaluation function may be called “Mutator-Generated Art.”⁸

7 Dawkins’s biomorph program used nine numerical “genes” to generate two-dimensional branching forms and relied on user selection among offspring. “Interactive genetic algorithm” is a later technical classification; Dawkins did not introduce the program under that term in *The Blind Watchmaker*. The primary materials consulted confirm the nine genes and interactive selection but not the exact figure of 118 billion possible images; that number is therefore retained as a claim made by the source. See Richard Dawkins, *The Blind Watchmaker*, 1st American ed. (New York: W. W. Norton, 1986), chap. 3; Richard Dawkins, “This Is My Vision of Life,” *Watchmaker Suite*, accessed July 31, 2026, <https://watchmakersuite.sourceforge.net/thisismyvisionoflife.html>.

8 Primary descriptions distinguish *FormGrow*, a rule-based 3D form-generating “virtual machine,” from Mutator’s interactive evolutionary process, in which artists or viewers select preferred forms for further breeding. The source’s claim that the algorithm itself performed the selection therefore conflates human-guided selection with automated fitness functions. See William Latham et al., “FormGrow Revisited—from DNA to 3D Organic Visualisation,” *Computational Creativity 2007*, 147, <https://computationalcreativity.net/ijwcc07/papers/latham-et-al.pdf>; Goldsmiths, University of London, “Evolutionary Art Moves to Edinburgh International Science Festival,” April 27, 2015, <https://www.gold.ac.uk/news/w-latham---mutator-1-and-2/>; Stephen Todd and William Latham, *Evolutionary Art and Computers* (London: Academic Press, 1992).

Generative AI art based on algorithmic models uses trained programmatic models to produce digital imagery, bringing visual art into a mode of human-machine co-creation. The artist first trains an algorithmic model, after which the programmed model automatically generates virtual digital images. These images no longer simulate natural or physical forms; they constitute ontological images native to the computer's digital mechanisms.

Another mode of human-machine co-created generative art based on algorithmic models is data-visualization imagery. Beginning in 2019, the Turkish American artist Refik Anadol experimented with deep-learning algorithms to process massive datasets, transforming vast stores of image data through algorithmic models into “data paintings” or “data-stream imagery.” In 2017, Anadol created the data-visualization work *Archive Dreaming*. The work drew on approximately 1.7 million archival documents as its data source, and viewers could use interactive devices to access and retrieve the images stored in digital space.⁹

A representative work in Anadol's *Machine Hallucinations* series, which began in 2019, is *Unsupervised* (2019). It processed the archival data of 138,000 digital images from the collection of the Museum of Modern Art (MoMA) in New York, generating continuously evolving, dynamic abstract imagery. Beginning in 2022, it was presented for one year on a large screen in MoMA's lobby.¹⁰

The *Machine Hallucinations* series uses AI-trained algorithmic models to process enormous visual datasets and stages the process by which data are processed and formed into image streams; this method is a form of “data visualization.” Works in the series include *Machine Hallucinations: NYC* (2019), which trained algorithms on more than 100 million publicly available photographs of New York City to generate a thirty-minute experimental film in 16K resolution, exploring an urban narrative from a “machine perspective”; *Nature Dreams* (2019), based on 300 million images of nature, which generated image streams marked by fluidity and structure and embodied the fusion of nature with machine perception; and *ISS Dreams* (2021), which used satellite images in combination with a GAN algorithm to generate dynamic image streams.¹¹

Generative moving-image art refers mainly to imagery produced directly by computer programs based on deep-learning models. Drawing on powerful machine-learning capacities and data supplied by the artist, algorithmic models generate the images. Constrained by algorithms, computing power, and insufficient high-quality training datasets, AI programs still cannot

9 The date and dataset size are confirmed by the artist's official project description: *Archive Dreaming* was presented in 2017 and used 1,700,000 documents from SALT Research. See Refik Anadol, “*Archive Dreaming*—AI Data Sculpture,” accessed July 31, 2026, <https://refikanadol.com/works/archive-dreaming/>.

10 Refik Anadol Studio identifies the corpus as 138,151 images or metadata records. MoMA dates *Unsupervised—Machine Hallucinations—MoMA* to 2022 and the exhibition to November 19, 2022–October 29, 2023; the source's date “2019” is not supported by the institutional record. See Refik Anadol, “*Unsupervised—Machine Hallucinations—MoMA*,” accessed July 31, 2026, <https://refikanadol.com/works/unsupervised/>; Museum of Modern Art, “Refik Anadol: *Unsupervised*,” November 19, 2022–October 29, 2023, <https://www.moma.org/calendar/exhibitions/5535>.

11 Official project pages confirm *Machine Hallucinations: NYC* (2019), its use of more than 100 million public photographs, 16K resolution, and thirty-minute duration. They date *Machine Hallucinations—Nature Dreams* to 2021, not 2019, and *Machine Hallucinations: ISS Dreams* to March 2018 onward, not 2021; the latter uses 1.2 million ISS images together with additional satellite images. See Refik Anadol, “*Machine Hallucination*,” <https://refikanadol.com/works/machine-hallucination/>; Refik Anadol, “*Machine Hallucinations—Nature Dreams*,” <https://refikanadol.com/works/machine-hallucinations-nature-dreams/>; Refik Anadol, “*Machine Hallucinations: ISS Dreams*,” <https://refikanadol.com/works/machinehallucinations-iss/>; all accessed July 31, 2026.

generate narrative films with a high degree of logical coherence.¹² From a technical standpoint, most computer-based graphic art contains stochastic parameters, and variations in those parameters produce unpredictable results. The randomness of AI generation can likewise yield unexpected visual effects and even images beyond the scope of human thought. AI thus represents a “machine perspective” on the world and enables a new visual perception of conceptual images that lie outside reality yet differ from the dreamlike or imaginary images of the past.

¹² This assessment is preserved as the author’s time-bound judgment, written in November 2025. The capabilities of generative video systems are rapidly changing, and the statement should not be read as a timeless technical limit.