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Sculpture in the Digitally Expanded Field

Abstract

The title of this text is an allusion to Rosalind Krauss's essay "Sculpture in the Expanded Field." She locates sculpture on a structural map between (not-)architecture and (not-)landscape and is able to classify the very different "sculptural" phenomena of the 1970s. I want to propose a kind of systematics to relate the sculptural to the virtual, as defined in the field of digital technologies. The central argument will be that digital technologies allow, among other things, the construction of virtual models of entities, meaning mathematical descriptions without materiality. Computers can, in this sense, construct virtual models of sculpture, which are mathematical descriptions of spatial objects. In that sense, there is a fundamental sculptural dimension to (certain types of) computer graphics. I will further discuss the notion of digital modernism. My thesis is that the worn-out paradigm of describing art as a reflection of medium specificity can have a comeback with digital technologies, since these are able to construct virtual models of media. With this malleable virtual media, questions regarding medium specificity can be posed anew. Finally, I will come back to Krauss's systematics of sculpture in the expanded field and try to develop a sketch of a similar systematic—of sculpture in the digitally expanded field.

Key Words

Computer graphics, object space, virtual camera, 3D-printing, Rosalind Krauss

I. Introduction

The title of this text is an allusion to Rosalind Krauss's paradigmatic essay "Sculpture in the Expanded Field."[1] In this essay, she locates sculpture on a structural map between (not-) architecture and (not-)landscape and classifies the very different "sculptural" phenomena of the 1970s. The idea in my paper is somewhat similar. I want to propose a kind of systematics

1 Rosalind Krauss, "Sculpture in the Expanded Field," *October*, no. 8 (1979): 30–44.

to relate the "sculptural" to the virtual, as defined in the field of digital technologies. A new expanded field of sculptural possibilities thereby becomes visible.[2]

In section 2 I will explain my use of the notion of virtuality. The central argument will be that digital technologies allow, among other things, the construction of virtual models of entities, meaning mathematical descriptions without materiality.[3] Computers can, in this sense, construct virtual models of sculpture, that is mathematical accounts of spatial objects. Actually, several types of computer graphics operate by constructing virtual objects in "object space," which are then "photographed" by a "virtual camera."[4] In that sense, there is a fundamental sculptural dimension to (certain types of) computer graphics.

In section 3 I will discuss the perhaps surprising notion of *digital* or *virtual modernism*. While in the second section I only discuss the formal spatiality of certain virtual objects, here the question is one of aesthetics. My thesis is that the worn-out paradigm of describing art as a reflection of medium-specificity can have a comeback with digital technologies, since these are able to construct virtual models of media. With this malleable virtual media, questions regarding medium-specificity can be posed anew—and this is also the case for sculpture.

In section 4, building on the discussion in sections 2 and 3, I will come back to Krauss' systematics of sculpture in the expanded field and try to develop a sketch of a similar systematic—of sculpture in the digitally expanded field. I want to do this by discussing some artworks and artistic practices.

II. The Virtual, Simulation, Object Space, and the Sculptural

Why do I speak of the "virtual"? First of all, because the notion of "digital" is somewhat confusing. Language is also a digital code, insofar as it is based on a discrete and disjunct repertoire of basic elements, namely the letters of the alphabet.[5] "Digital" is not a very specific criterion to describe the contemporary situation, characterized by the diffusion of

2 Martina Dobbe, "Lesarten einer generischen Bestimmung: Skulptur," in *Die Kunst und die Künste: Ein Kompendium zur Kunsttheorie der Gegenwar*t, ed. Georg W. Bertram, Stefan Deines, and Daniel Martin Feige (Berlin: Suhrkamp, 2021), pp. 297–316 for a discussion of the "sculptural" in analogy to the definition of "the photographic" also given by Krauss in other texts. See also Martina Dobbe and Ursula Ströbele, "Gegenstand: Skulptur," in *Gegenstand Skulptur*, ed. Martina Dobbe and Ursula Ströbele (Paderborn: Fink, 2020), pp. 1–16.

3 That does not mean that digital information processing is a process not bound to materiality and energy consumption (see Rudolf Landauer, "Irreversibility and Heat Generation in the Computing Process," *IBM Journal of Research and Development* 5, no. 3 [July 1961]: 83–90). Moreover, the production of computing machines and the data infrastructures needs lot of materials that have to be (often violently) extracted. But that does not mean that the mathematical descriptions of a material object are themselves material.

4 See John F. Hughes et al., *Computer Graphics: Principles and Practice*, Third Edition (Upper Saddle River, NJ: Addison Wesley, 2014), pp. 21–23.

5 Nelson Goodman, *Languages of Art: An Approach to a Theory of Symbols* (Indianapolis, IN: Bobbs-Merrill, 1968), pp. 130–41.

computing machines (of a certain type). I suggest that at least for the cases I discuss here, the notion of "virtual" is more helpful, although it has a complicated history, composed of several very different strands.[6] As far as the relation of sculpture and the sculptural to (the imagistic possibilities of) modern computing technologies is concerned, I focus on the notion of virtual as it emerged in the history of computing.

In the discourse of computer science, "virtual" is first used in the context of research on virtual memory. To cut a longer story short: around 1962, virtual memory took on the meaning it has today. At that time, the high price of memory with short access time was the main problem of electronic computers. As a result, information not needed at the moment had to be moved from main memory to auxiliary memory. Memory allocation refers to the process of deciding which data is currently required in main memory and which can be swapped out to auxiliary memory. There were a number of proposed solutions, of which the concept of virtual memory ultimately prevailed. It is an automatic memory allocation method that was first used in the Atlas computer developed in 1961.[7]

The programmer can operate with the "address" or "name space" on computers (with "virtual memory"), as if it were a continuous memory. The computer system maps (as a black box invisible to the programmer) these addresses in the name space by means of an "address-translation function" to the real addresses in memory space (that can be composed of quite different types of memories). The computer system only loads the program parts or data that are currently required by the program into the actual main memory. Virtual memories operate on the basis of the *separation of the logical address space from the actual material memory space*.

This meaning of virtual can be supported by history: in an official letter to Christian Gottlob Voigt from November 24/25, 1795, Goethe wrote: "Libraries now also attract our attention. We have four of them: the local one, the Jenaisch Akademische; the Buderische and Büttnerische, which will probably always remain separate in terms of institution and place, but whose virtual unification is desired and thought possible." In a letter to Schiller from December 9, 1797, he wrote: "Perhaps I will have some influence in library matters in the future, tell me what you think of an idea with which I held for long, namely to unite the local, the Büttnische and Academic Library, virtually [virtualiter], into one corpus."[8] Goethe is not proposing a physical union of libraries, but a common catalogue that functions as a uniform "address space," although the physical location of the books (the "memory space") remains heterogeneous.

6 Jens Schröter, "What is a Virtual Image?," in *Virtual Images: Trilogy of Synthetic Realities I*, ed. Lars C. Grabbe, Patrick Rupert-Kruse, and Norbert M. Schmitz (Marburg: Büchner, 2021), pp. 91–104.

7 Peter J. Denning, "Virtual Memory," *ACM Computing Surveys* 2 (1970): 153–89, here 156.

8 Johann Wolfgang von Goethe, *Sämtliche Werke nach Epochen seines Schaffens: Münchner Ausgabe*, ed. Karl Richter et. al., vol. 4.2: 880 and vol. 8.1: 462 (Munich: Hanser, 1985 and following). All quotes from German are translated by the author.

This difference of structure and materiality is crucial.[9] To give a more recent and highly important example: the *computer simulation* of a real object or process used in science or the military consists of "detaching" mathematically describable structures from the materiality of the object. We can adopt Helmut Neunzert's definition: in simulations, an operationally defined "real process … is represented as mathematics … so as to be simulated in the computer using algorithms."[10] This means that, based on different kinds of gathered or sampled data, the rules governing the behavior of an object or process, that is, a theory, can be derived. This basic model is translated into a formalized model able to be carried out by a computer. To the extent that—to use Deleuze's formulation—the structure is the reality of the virtual, simulation models of objects are virtual objects.[11] Take the example of a rubber ball: the bouncing behavior of a ball is abstracted from the material ball made of rubber by observing and measuring it and then putting its data into mathematical equations, in order to then serve as the basis for a model. In other words, a "virtual ball" is created. This model can then be represented on a display showing a point that bounces "like a ball."[12] These virtual objects can now be used for virtual experiments in different ways: we could allow the model to develop more or less independently (guided by theoretical extrapolations), which permits time to be compressed considerably, so as to see what the modelled phenomenon presumably will be like; or we could modify certain parameters, so as to see how the object would behave under different conditions (for example, our virtual ball under different gravity, etc.). We could also change the parameters just to achieve surprising or aesthetically interesting effects.

After 1945, simulations were used to develop the hydrogen bomb, and today are omnipresent in urban planning, architecture, medicine, most natural and even social and economic sciences, as well as in the so-called interactive simulations used to train pilots, high-speed train drivers, and the staff of nuclear power stations.[13] They are also present in many forms of computer games, e. g., in the form of "physics engines" that control the behavior of certain objects in the game.

But for the discussion here, it is much more relevant that computer simulation techniques can also simulate other technological media.[14] There are many examples of this—one

9 See also Kathrin Koslicki, *The Structure of Objects* (Oxford: Oxford University Press, 2008). She delivers a convincing argument for structure as a constituent property of objects as apart from their matter.

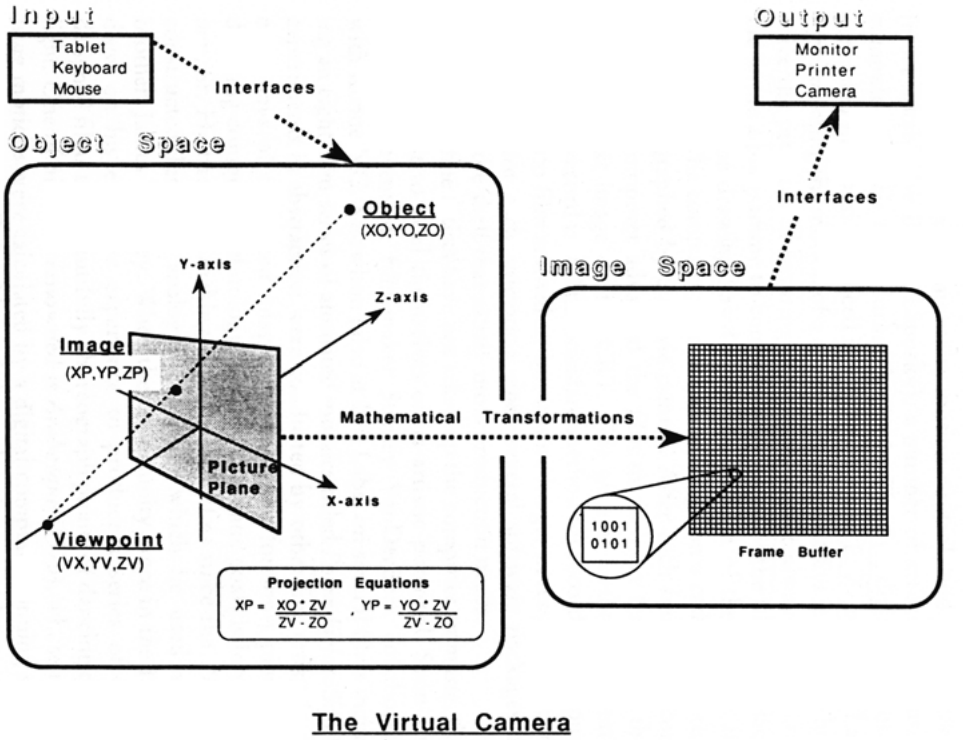
10 Helmut Neunzert, "Mathematik und Computersimulation: Modelle, Algorithmen, Bilder," in *Simulation. Computer zwischen Experiment und Theorie*, ed. Valentin Braitenberg and Inga Hosp (Reinbek bei Hamburg: Rowohlt, 1995), pp. 44–55, here p. 44.

11 Gilles Deleuze, *Difference and Repetition* (New York: Columbia University Press, 1994), p. 209: "The reality of the virtual is structure."

12 Other kinds of display are possible, for example an auditive representation. Often such simulations are not done to produce images, but deliver data that can be used for analytical purposes or to train machine learning systems, etc.

13 See Peter Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago: Chicago University Press, 1997), see chapter 8 for the early development of computer simulation.

14 See Jens Schröter, "Medienästhetik, Simulation und 'Neue Medien,'" *Zeitschrift für Medienwissenschaft* 8 (2013): 88–100.



1 Schema of the virtual camera, in Timothy Binkley, "Refiguring Culture."[15]

example is "photorealism" in computer graphics, which made some of its early spectacular appearances in the early 1990s with movies such as *Terminator 2* or *Jurassic Park*. Photorealism is simulation, as the characteristics (of certain aspects) of photographic media are measured and the resulting data and their theoretical descriptions are used as the basis of computer models.[16] A simulated or virtual camera is a real (but not actual, material) camera,

15 Timothy Binkley, "Refiguring Culture," in *Future Visions: New Technologies of the Screen*, ed. Philip Hayward and Tana Wollen (London: BFI, 1993), pp. 92–122, here p. 104.

16 But it is important to add that computer graphics don't have to be photorealistic in the sense that they simulate the look of photographic images, although that might be the goal, especially if computer-generated graphics are to be integrated in an otherwise photographically recorded movie (as is often done in popular cinema). One could also construct cartoon-like objects in object space and then "photograph" them with a virtual camera that is modeled closely to photography, thereby producing images that are at the same time cartoonish and look like photography—as is done in Pixar's popular animated films, which playfully reflect their imagery's mixed status (see Jens Schröter, "Medienästhetik," 2013, Schröter, "Narration and Visuality in Monsters Inc.," in *The Cinema of Sensations*, ed. Agnes Pethö [Cambridge, UK: Cambridge Scholars Publishing, 2015], pp. 223–36). Since the computer-generated images are mathematical in nature, they can also follow completely different forms of representation: they can follow, e. g., nonoptical forms of projection like parallel perspective (see Benjamin Beil and Jens Schröter, "Die Parallelperspektive im digitalen Bild," *Zeitschrift für Medienwissenschaft* 4

which, depending on the data and theories available, can approximate its material model (actual, material cameras with their optical and material properties) as closely as desired (although a more detailed model needs more processing time and resources and that can be a hindrance).[17] The virtual camera, which ultimately is a mathematical construct, can also be changed in whichever way is desired, for example in order to be able to produce pictures which could not be produced by actual, material cameras.

On the left in fig. 1 we can see object space. The object is, for the sake of simplicity, only a point with the coordinates XO, YO, ZO (object position on the x-, y-, z-axis). The object is "photographed" from the viewpoint of the virtual camera, and the coordinates are XV (unfortunately given as VX in the image), YV, ZV. The point on the picture plane is computed through the projection equations (similar to perspectival projection). This image space is then rendered, for example, on a screen. The model presented in fig. 1 is highly simplified and does not include, for instance, a simulation of effects of the lenses or graininess, etc.

While in an earlier paper I put the emphasis on the construction and operations of the virtual camera, *simulating photography*,[18] I want to shift the emphasis here onto what the virtual camera "photographs." This is basically a mathematical process in which a mathematically defined "object space" is projected, using the mathematical rules of perspectival projection, onto an "image space" or the picture plane. This recalls Alberti and the notion of perspectival projection onto the *fenestra aperta*, but the scene in front of the "window" is mathematically constructed, as is the "window," meaning the camera and the process of projection. Instead of letting the light (and the system of lenses) do the projection automatically through physics (and chemistry in analog photography), it is done along the mathematics of perspective already developed in the Renaissance and performed by computers (but again: that is only one way to use computer graphics). Two points, relevant to this paper, follow from this:

On the one hand, there is a fundamental sculptural dimension to computer graphics (at least if they are based on a virtual camera model). The mathematical construction of objects

[2011]: 127–37). Computer graphics can be abstract or highly stylized (see Bruce Gooch and Amy Gooch, *Non-Photorealistic Rendering* [Natick, MA: A. K. Peters, 2001]). If the goal is to model objects without clear-cut boundaries (like fire, fog, or clouds) other procedures like particle systems are used (see William T. Reeves, "Particle Systems-A Technique for Modeling a Class of Fuzzy Objects," *Computer Graphics* 17, no. 3 [1983]: 359–75). And having said all this, we're still not talking about the many different methods for lighting the scene in object space, of texture mapping, and so on (see the comprehensive overview in Hughes, *Computer Graphics*, 2014. Computer graphics have many different roots and forms that cannot be reduced to one medial or pictorial "specificity." See Jens Schröter, "… especially the 'ambient term,' was a terrible thing. Ambient und Atmosphäre in der Computergraphik," in *Ambient: Ästhetik des Hintergrunds*, ed. Jens Schröter et al. (Berlin u.a.: Springer, 2018), pp. 167–84.

17 See Hughes, *Computer Graphics*, 2014, see chapter 13 on specifications for the virtual camera. The camera-model could include effects of the lens-system (like virtual lens flares) or effects of a simulated photo emulsion (graininess), etc.

18 See Jens Schröter, "Virtuelle Kamera: Zum Fortbestand fotografischer Medien in computergenerierten Bildern," *Fotogeschichte* 88 (2003): 3–16.

in object space is, insofar as their three-dimensional coordinates (and also their lighting and textures)[19] are concerned, similar in a way to the construction of sculptural objects in real space. Of course, one does not work with clay or marble or other real materials. But one does define a spatial structure, as does a sculptor with clay or marble or other real materials. It is, in that sense, possible to construct virtual sculptures in object space (and this does, actually, occur).[20] Perhaps this also means that an artistic approach, working with computer graphics and constructing virtual sculptures, should reflect on this basic medial dispositive of (certain types of) computer graphics (see section 3).

On the other hand: although I began above with the historical example of constructing virtual objects (in simulations) based on real data, it is—since it's all mathematical—possible to construct virtual objects that are completely fictitious.[21] One could construct structures in object space that are based on sampled or scanned but radically modified real data. One could also construct structures, so to speak, from scratch, that do not in any way resemble real objects, that could not even exist in the real world: sculptures of more than three dimensions with textures made of moving images.[22] Wouldn't this lead directly to the media-reflexive question of what "sculpture," the "sculptural" and their "expanded field" are? We always thought sculpture is necessary three-dimensional—but not necessarily so in object space.[23]

III. A Remark on Digital Modernism

This last remark brings up the question of what the a given medium's specificity is, so I want to address again the seemingly worn-out question of the specificity of media in art—simply because it may acquire new urgency with the onset of simulation and therefore the

19 See Hughes, *Computer Graphics*, 2014, chapter 20 on textures and chapter 26 on light.

20 See "The Rise of the Virtual Sculptor," *noupe.com*, July 5, 2011, https://www.noupe.com/inspiration/showcases/the-rise-of-the-virtual-sculptor.html (accessed December 22, 2021).

21 On the relation of fiction and simulation, which are categorically different, see Jens Schröter, "Überlegungen zu Medientheorie und Fiktionalität," in *Fiktion im Vergleich der Medien und Künste*, ed. Anne Enderwitz and Irina Rajewsky (Berlin and Boston: De Gruyter, 2016), pp. 97–124.

22 Mathematically it's no problem to handle higher-dimensional geometries, although it would be necessary to project them somehow in three dimensions (for a 3D-printed model) or two dimensions (to have it on screen) to apprehend them visually. This often results in weird warped and distorted forms, unintelligible for the lay(wo)man's eye. See e. g., the visualizations of the six-dimensional spatial structure of the so-called "Calabi-Yau-Manifold," which is a mathematical structure important in superstring theory, https://analyticphysics.com/Higher%20Dimensions/Visualizing%20Calabi-Yau%20Manifolds.htm (accessed December 22, 2021). This particular visualization allows for n = 2 to 8, that is even more than six dimensions.

23 Virtual structures are of course not per se "sculptures"—to become so they should be designed and presented in an aesthetically convincing way to reflexively point to their mediality and their contexts of production and presentation (see 3). A more cynical version of this argument would be that any virtually spatial structure can be transformed into "sculpture" by the art market and its discourse industry at any time, as the hypes around so called "AI Art" or "NFT Art" have recently shown, namely that any new technology (and the forms produced with it) can be turned into "art" in principle.

construction of virtual media. The following short detour on the discussion of media specificity in abstract painting will help to illuminate this problem.

After World War II, various forms of abstraction established themselves as the dominant art movement in the United States and, from there, in other Western countries as well. Clement Greenberg developed a historical justification for these new forms of abstraction in painting. He emphasized that, in modernism, "the unique and proper area of competence of each art coincided with all that was unique in the nature of its medium."[24] Following on this, artists would have to analyze and explore their medium step by step to find out which conventions (e.g., narrative) are borrowed from other media and are therefore dispensable. One of his central examples was the work of Jackson Pollock, whose all-over drip paintings are said to focus on the role of the line, the flow of color, and a concentrated engagement with the plane surface of the canvas. In the late 1950s and early 1960s, the first artistic positions emerged that were difficult or impossible to reconcile with Greenberg's approach (e.g., Pop Art), but initially his position remained formative. This period also saw the first artistic experiments with computers.

I will briefly introduce one of the programmatic texts of this time period: A. Michael Noll's *The Digital Computer as a Creative Medium* from 1967.[25] The fact that the computer is already dubbed a medium here—some twenty-five years before the relevant media-theoretical discussion[26]—points to an important moment in two respects: *firstly*, the artistic practice that provided the model for the concept of media at that time was abstract painting—it is no coincidence that the title page of Noll's text (fig. 2) is already adorned by a graphic that is at least vaguely reminiscent of Bridget Riley's Op-Art.[27] For experiments with computers, especially in the 1960s, when the possibilities of computer graphics were limited, recourse to geometric-constructive variants of abstract painting are obvious, since they are relatively easy to formalize and display.[28]

In any case, *secondly*, given the dominant position of Greenbergian concepts, in order to identify a practice with computers as artistic, it was necessary to reflect on a medium.

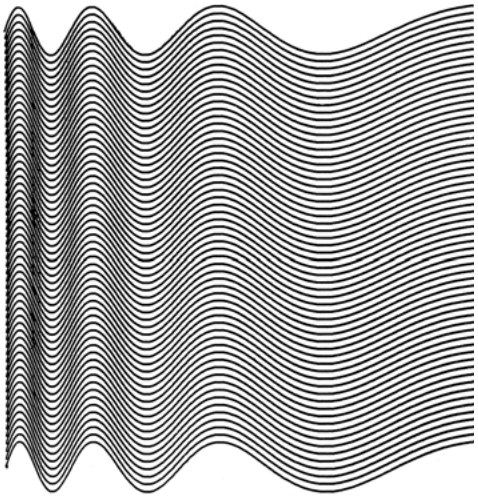
24 Clement Greenberg, "Modernist Painting," in *Clement Greenberg: The Collected Essays and Criticism*, vol. 4: *Modernism with a Vengeance, 1957–1969*, ed. John O'Brien (Chicago: University of Chicago Press, 1993), pp. 85–93, here p. 86.

25 See A. Michael Noll, "The Digital Computer as a Creative Medium," *IEEE Spectrum* 4, no. 10 (October 1967): 89–95. See also A. Michael Noll, "Computers and the Visual Arts," *Design Quarterly* 66f. (1967): 65–71.

26 See Norbert Bolz et al., *Computer als Medium* (Munich: Wilhelm Fink, 1994). However, McLuhan had already spoken of the "media of communication from speech to computer" in *Understanding Media* in 1964 (Marshall McLuhan, *Understanding Media: The Extensions of Man* [London and New York: McGraw Hill, 1964], p. 43), and moreover, according to Boris Groys, *Unter Verdacht: Eine Phänomenologie der Medien* (Munich and Vienna: Hanser, 2000), pp. 93–101. McLuhan was in turn inspired by Greenberg's modernism for his media theory.

27 Noll, "The Digital Computer as a Creative Medium," 1967, p. 91.

28 But see Clement Greenberg, "Recentness of Sculpture," in Greenberg, *Collected Essays*, 1993, pp. 250–56 who rejected Op-Art (252).



2 A. Michael Noll, *The Digital Computer as a Creative Medium*, 1967.

It was therefore necessary to understand the computer as just that.[29] Noll argues similarly to Greenberg: "The resistance of the canvas or its elastic give to the paint-loaded brush, the visual shock of real color and line, the smell of the paint, will all work on the artist's sensibilities… . So it is that an artist explores, discovers, and masters the possibilities of the medium."[30] The question of what possibilities and resistances the medium of the computer unfolds in artistic work is raised, because "computers are a *new* medium. They do not have the characteristics of paint, brushes, and canvas."[31] Noll notes that what is new about the computer is the *ability to mathematically model the specific processes that characterize other media in general*, and the processes of abstract painting, understood as a *paradigm* of artistic media, in particular. To the extent that the computer is used to simulate traditional media, it appears as a medium in itself.

For Noll, the question of whether it is possible to mathematically generate works of art based on the formalization of existing works remains open. Noll exemplified this conundrum by juxtaposing a real and a mathematically simulated Mondrian and determining via a kind of aesthetic Turing-test that the majority of viewers thought the computer image was the real Mondrian—ergo, the simulation of the painterliness of painting seemed successful

29 See Rosalind Krauss, *"A Voyage on the North Sea": Art in the Age of the Post-Medium Condition* (New York: Thames & Hudson, 1999), p. 6: "[F]rom the 60s on, to utter the word 'medium' meant invoking 'Greenberg.' …." Whether Noll, as a computer scientist, was familiar with this discourse, however, must remain open.

30 Noll, "The Digital Computer as a Creative Medium," 1967, p. 90. Clement Greenberg, "Towards a Newer Laokoon," in *Clement Greenberg: The Collected Essays and Criticism,* vol. 1: *Perceptions and Judgments, 1939–1944*, ed. John O'Brien (Chicago: University of Chicago Press, 1986), pp. 23–37, here p. 34. Here he speaks in relation to "avant-garde painting" of "resistance of its medium." On the same page, he speaks in relation to sculpture of the "resistance of its material."

31 Noll, "The Digital Computer as a Creative Medium," 1967, p. 90, emphasis in original.

(although one can seriously doubt the validity these examples' "artiness").[32] Noll's ideas and similar ones (by Frieder Nake and many more) as a whole refer to a fundamental property of the medium computer, namely to be able to *approximate* all other media—either by measuring and simulating the properties of the technical *dispositive* or by sampling the resulting signals (sounds, images, etc.) and using them as material.[33]

However, Greenberg's paradigm of media reflection gradually died out from around the mid-1960s onwards, making way for a "postmodernism" oriented toward intermediality and quotation, or for entirely different art forms such as conceptual art (a), only to reappear, perhaps not coincidentally, in the more recent discussions about the artistic potential of digital media (b).

(a) Greenberg's program of a self-analytical reduction of painting and other art forms gradually became problematic in the early 1960s, for soon this program threatened to cross the boundary beyond which "a picture stops being a picture and turns into an arbitrary object," a boundary Greenberg had insisted was not to be crossed but rather "observed and indicated."[34] Ultimately, newly emergent developments such as Minimal Art shifted the emphasis away from media specificity.[35] Finally, new technologies appeared on the art scene—especially video—which, according to Rosalind Krauss, caused the concept of reflection on the medium as the basis of art to disappear, because media, like video, were involved in practices that were too disparate.[36] De Duve has described this shift in the 1960s as a shift from *specific* (i.e., directed at media-specificity) to *generic* (i.e., directed in Duchamp's wake at the status of art in general) questions.[37] Thus, in the 1970s and 1980s, forms of art flourished that broke with any media-reflexive purism and instead worked with multi- and intermedial strategies—often in the form of "installations."[38] "As is typical of what has come to be called postmodernism, this … work is not confined to any particular medium."[39] As a result, Greenberg's role as a critic declined; even his "disciple," Rosalind Krauss, proclaimed

32 The nature of the audience and its composition is explained in more detail in A. Michael Noll, "Human or Machine: A Subjective Comparison of Piet Mondrian's 'Composition with Lines' (1917) and a Computer-Generated Image," *The Psychological Record* 16 (January 1966): 1–10.

33 See Jens Schröter, "Das Ende der Welt: Analoge und digitale Bilder – mehr oder weniger Realität?," in *Analog/Digital – Opposition oder Kontinuum? Beiträge zur Theorie und Geschichte einer Unterscheidung*, ed. Jens Schröter and Alexander Böhnke (Bielefeld: transcript, 2004), pp. 335–54.

34 Greenberg, "Modernist Painting," 1993, p. 90.

35 See Donald Judd, "Specific Objects," *Arts Yearbook* 8 (1965), 74–82. The famous first sentence is: "Half or more of the best new work in the last few years has been neither painting nor sculpture."

36 Krauss, "*A Voyage on the North Sea*," 1999, pp. 30ff.

37 Thierry De Duve, *Kant after Duchamp* (Cambridge, MA: MIT Press, 1996), pp. 193–279.

38 For what Greenberg criticized, of course, see Clement Greenberg, "Intermedia," *Arts Magazine* 56, no. 2 (October 1981): 92–93.

39 Douglas Crimp, "Pictures," *October*, no. 8 (Spring 1979): 75–88, here 75.

a "post-medium condition."[40] Greenberg's insistence on the medium seems nowadays to be "hopelessly outdated."[41]

(b) After the seemingly complete collapse of the Greenberg paradigm, it is somewhat surprising that media reflection is once again playing an important role among newer artists. Juliane Rebentisch already notes "that in intermedial contemporary art … the knowledgeable reference to the various traditions of the arts and the possibilities of their media … plays an important role."[42] Interestingly, only one page earlier she points out that the "role of technologies and new media in this context should not be underestimated," especially with regard to the "thematization of older means of representation in newer ones (painting in film), for example." It seems that especially artists operating in the "medium of digitality"[43] are paying attention to these questions again. For example, as Thomas Ruff remarked already in 1999 with regard to his digitally processed porn photos from the net, the *Nudes*: "If I work with a certain medium, then I also want to reflect this medium in the picture."[44] In the preface to his book *net.art 2.0* from 2001, Tilman Baumgärtel explicitly refers to Greenberg to legitimize the artistic status of net art via its self-reflexive procedures.[45]

There is maybe a radicalization of the possibilities for reflection on "media-specificity": virtualized, simulated media are, so to speak, (selective and approximate) structures of media without their materiality.[46] There are possibilities to transform the virtualized, simulated media—as was said above: a virtual camera can be transformed beyond the limits that would be possible for an actual, physical, material camera. The same can be done with virtual sculpture. This option may be one reason why an almost neo-Greenbergian imperative for self-reflection again plays such a major role in works with digital media. Greenberg's

40 Krauss, "*A Voyage on the North Sea*," 1999.

41 Juliane Rebentisch, "Singularität, Gattung, Form," in Bertram, Deines, and Feige, *Die Kunst und die Künste: Ein Kompendium zur Kunsttheorie der Gegenwart*, 2021, pp. 123–37, here p. 124. Original: "hoffnungslos veraltet."

42 Juliane Rebentisch, *Theorien der Gegenwartskunst zu Einführung* (Hamburg: Junius, 2013), p. 105. Original: "intermediale[n] Gegenwartskunst … der kenntnisreiche Bezug auf die verschiedenen Traditionen der Künste und die Möglichkeiten ihrer Medien … eine wichtige Rolle".

43 Ibid., p. 104. Original: "Rolle der Technologien und neuen Medien in diesem Zusammenhang nicht zu unterschätzen"; "Thematisierung älterer Darstellungsmittel in neueren (der Malerei im Film) beispielsweise"; "Medium der Digitalität."

44 Thomas Ruff, "Suchmaschinen: Ein Interview von Susanne Leeb," *Texte zur Kunst* 36 (December 1999), pp. 71–75, here p. 75. Original: "Wenn ich mit einem bestimmten Medium arbeite, dann will ich dieses Medium auch im Bild reflektieren."

45 See Tilman Baumgärtel, *[net.art 2.0] Neue Materialien zur Netzkunst* (Nuremberg: VFMK, 2001), pp. 16–17.

46 To avoid misunderstandings, see note 3. Digital technologies are of course very material and have very material infrastructures that are the topic of the work of several artists (Katja Novitzkova, Marguerite Humeau, Oliver Laric, etc.). But the virtual objects created with these very material technologies have themselves no materiality and can be changed at will (if necessary). That's why they are used, for instance, in scientific modeling.

idea of the medium also reappears in theoretical discourse.[47] In her recent work, Rosalind Krauss appraises it critically insofar as she emphasizes the necessity "to reclaim the specific from the deadening embrace of the general."[48] She sees in the work of James Coleman, William Kentridge, and others the effort to "reinvent" a specific medium by recourse to media-historically "antiquated" techniques (slide show in Coleman's case; drawn animation, 16-mm film in Kentridge's), but in a way that emphasizes the "differential" character of the medium.[49]

This is not to say that all art must now be related to the paradigm of media reflection as a figure of justification—after all, does "art" have to be related to a unified figure at all? Wouldn't it also be conceivable that, alongside—"contemporary"—artistic strategies that have detached themselves from this, there can also be, *indeed must be—today in the all-pervasive digitally expanded field*—artistic approaches that address the reconfigurations of the medial under the conditions of the computer and its differentiations into various constellations?[50] There have to be digital artistic strategies that follow the concept of a digital modernism—and some of these might reinvent sculpture.[51]

IV. Sculpture in the Digitally Expanded Field

If we take the results of sections 2 and 3 together, how can we theoretically assess sculpture in the digitally expanded field? Section 2 has shown us how (certain forms of) computer graphics are related to the sculptural in principle, and section 3 argues that the virtual forms of media can lead to new 'modernist' forms of media reflexivity. So, which new forms of sculpture in the digitally expanded field might be conceivable? Although I didn't succeed in developing an elegant structural scheme like Krauss in "Sculpture in the Expanded Field," I would argue that at least three options can be conceived.

47 There are currently further discussions on notions like "post-media" or "post-digitality." Although I cannot discuss these in detail here, they also point to a certain resurgence of questions of the medium (even if *ex negativo*).

48 Rosalind Krauss, "Reinventing the Medium," *Critical Inquiry* 25, no. 2 (Winter 1999): 289–305, here 305. The "deadly" character of the generic lies in the fact that anything can appear as art at will (see Duchamp), and thus with the disappearance of the specific in art, the specificity of art also threatens to collapse, see De Duve, *Kant after Duchamp*, 1996, p. 274. On this, see Rebentisch, *Theorien der Gegenwartskunst zu Einführung*, 2013, pp. 106–16.

49 See Krauss, "*A Voyage on the North Sea*," 1999, p. 53. On Kentridge, see Rosalind Krauss, "'The Rock': William Kentridge's Drawings for Protection," *October*, no. 92 (Spring 2000): 3–35.

50 On the concept of the differentiation of the computer see Jens Schröter, *Das Netz und die virtuelle Realität. Zur Selbstprogrammierung der Gesellschaft durch die universelle Maschine* (Bielefeld: transcript, 2004). Rebentisch, *Theorien der Gegenwartskunst zu Einführung*, 2013, p. 106 explicitly notes that despite all intermedial transgression, "the sometimes more, sometimes less stable fields of the traditional arts" still exist. Original: "die mal mehr, mal weniger stabilen Felder der traditionellen Künste."

51 See Ian Andrews, "Post-digital Aesthetics and the Return to Modernism," https://ian-andrews.org/texts/postdig.pdf, (accessed December 21, 2021) and Dominic McIver Lopes, "Digital Art," in *Philosophy of Computing and Information*, ed. Luciano Floridi (Malden, MA: Blackwell, 2004), pp. 106–16.

(a) Virtual Sculpture

This is the construction of virtual sculptures in object space, either based on acquired data and/or free construction, that then have to be displayed on screens. I would like to examine one example: Jeffrey Shaw's 1994 interactive installation *The Golden Calf* (fig. 3).[52] The installation consists of a conical column, square in cross-section and about one meter high, on which lies a color display connected to the column by a thick black cable. The color display shows an abstract, empty space in which a virtual column, on which a virtual golden calf stands, can be seen. The title is, of course, an allusion to the famous biblical passage Exodus 32: 1–4, where the Israelites make themselves a false idol, a golden calf, around which they dance, while Moses receives the tablets of testimony. The viewers of Shaw's installation move intensely. Like the Israelites, they dance around the calf.[53]

The viewers (or users?) have in their hands a *fenestra aperta* (Alberti) organized in central perspective. Viewers move the window; they are in the role of the virtual camera. The viewers decide by their movement which viewpoint is chosen in relation to the object space. One can try to correlate the view of the real column with that of the virtual column, but this will not succeed, if only because the virtual column is less conical than the real column. The spaces are separate and yet connected, as the thick black cable makes clear. Its length limits the possible distance of the viewers, whereby the real column marks the point in real space to which the entire set up remains related. The display, the cable, and the real column are objects whose places cannot be occupied by other objects, while the virtual calf stands more or less exactly where the display rests in real space in the initial and final state of the installation. This problematization of the relationship between the real surrounding space and object space is heightened by the fact that reflections of the installation's particular location can be seen on the virtual golden calf. Shaw takes digital photographs of the surrounding space that are mapped onto the virtual model depending on the viewer's perspective. The golden calf itself is part of the demo software of the Silicon Graphics Workstation on which the installation is based—and, in this respect, self-reflexively refers to the technical-institutional source of computer graphics. Although Shaw does not construct a physically impossible virtual sculpture, he presents a complex reflection on sculpture in space, the role and movements of the viewers around a three-dimensional object,[54] and the relation between real and virtual space. He thereby also problematizes a seemingly natural and inevitable property of sculpture. Mel Bochner wrote: "Before anything else, a sculpture

52 On Shaw see also the text by Ursula Ströbele in this volume.

53 See this helpful video showing the reception: *Jeffrey Shaw: The Golden Calf, Responsive Installation 1994*, YouTube Video, 2:07 min., uploaded by "MediaArtTube," June 1, 2008, https://www.youtube.com/watch?v=paaacEIF6wU, (accessed December 12, 2021).

54 The spatiality of sculpture and how it evokes bodily movement has been a much-discussed topic. See Alex Potts, *The Sculptural Imagination: Figurative, Modernist, Minimalist* (New Haven, CT: Yale University Press, 2001). See Nicola Glaubitz and Jens Schröter, "Quälende Kuben und beruhigende Tableaus. Fragmente einer Diskursgeschichte des Flächen- und des Raumbildes," *Sprache+Literatur* 35, no. 1 (Summer 2004): 33–63.

3 Jeffrey Shaw, *The Golden Calf*, Responsive Installation, Still taken during the exhibition *Interact!* (1997) at Wilhelm Lehmbruck Museum, Duisburg.

is an object-in-the-world, something in our shared space."[55] That is not directly the case for virtual sculpture, although its manifestation on a screen relates to our real space. Virtual sculpture is one way to reinvent sculpture and some of its parameters, such as spatiality and its relation to the moving body.

(b) 3D-Printed Sculpture

In this case, the sculptural object is in the same way as in (a) constructed in object space, either based on acquired data and/or free construction. But then it is not displayed two-dimensionally on a screen via a virtual camera, but printed with an additive printing system, a 3D printer. Now, Bochner's argument regarding the cospatiality of sculpture is valid again, since the sculptural objects inhabit the same space as the viewers' bodies. But firstly, these objects are normally quite small, since 3D printers for very big objects are very expensive. Secondly, the mentioned possibilities of "impossible" sculptural objects are reduced, since to be printable, objects need a certain materially possible form. Thirdly, since a 3D-printed sculpture is a print of a virtual template, it can— in principle—be printed on demand. In this way, a new form of reproducibility enters the sculptural field. Fourthly, the objects are often made of plastic, since this material can be handled easily with a 3D printer.

There are already a lot of artist experiments with 3D-printing in sculpture, for example Karin Sander's conceptual work *1:7,7 … Unlimited* (fig. 4). Visitors of an art fair are 3D-scanned and the resulting image is 3D-printed as a green-colored statuette. "Sander's

55 Bochner, quoted in Dobbe and Ströbele, *Gegenstand Skulptur*, 2020, p. 1.

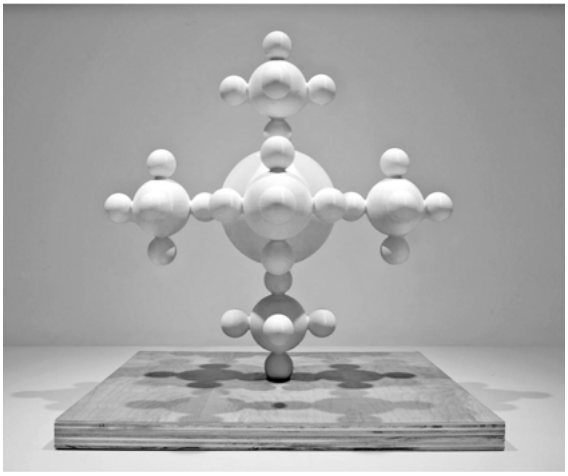
4 Karin Sander *1:7,7... Unlimited*, 2001, 3D body scan of the living person, 3D-printing, plaster material, pigment (chromium oxide hydrate green), Scale 1:7.7… Height: 20.6 cm. Exhibition view Galerie Ute Parduhn, Düsseldorf, Oct. 7–Nov. 14, 2005.

sculptures relinquish control over the forms and postures of the people reproduced here (on a scale of 1:7.7 …)—on the one hand to the subjects themselves and on the other to the disinterested, infinitely precise eye of the digital camera that scans them. Thus, *1:7,7 … Unlimited* is indeed a conceptual work, but it is one that both incorporates classical sculptural themes such as portraiture and self-portraiture and also constitutes a (three-dimensional) photograph—and thus a figurative sculpture."[56] Other artists like Gabriel Orozco also use the possibilities of 3D-printing, but more abstractly (fig. 5).[57]

While Sander uses scanned real-world data (the visitors) to produce a figurative 3D-printed sculptural object, Orozco constructs virtual objects mathematically and then prints these mathematical structures. These different positions oscillate between the poles of figurative and abstract and at the same time show the two principal sources for construction of virtual objects in object space: real-world data and mathematical construction, united in the necessity to use a certain scale of objects, since currently 3D printer can only produce relatively small objects. Orozco's abstract objects also emphasize mathematical structure and therefore reflect on the structurality of the virtual while simultaneously reducing the sculptural to basic structural and formal dimensions. At the same time, this reduced character might

56 See Karin Sander's website: https://www.karinsander.de/en/work/1-7-7-unlimited.

57 See also the exhibition *Out of Hand: Materializing the Postdigital* that took place from October 16, 2013 to June 1, 2014 in the Museum of Arts and Design, New York, https://madmuseum.org/exhibition/out-hand (accessed December 21, 2021). There is also a catalogue to that exhibition: Ronald T. Labaco, ed., *Out of Hand: Materializing the Postdigital*, exh. cat. Museum of Arts and Design New York (London: Black Dog, 2013).



5 Gabriel Orozco, *Untitled*, 2013, 3D-printed ABS plastic, Gabriel Orozco, 23 9/16 × 23 9/16 × 23 9/16 in. (60 × 60 × 60 cm). Printed by Ribuoli Digital, New York.

point to the limitations of the available technology as the geometric forms in early computer art once did (see fig. 2). But, compared to more irregular forms of sculptural abstraction, e. g., by David Smith,[58] Orozco's approach might seem boring, a typical case of "stiff regularity (such as that which borders on mathematical regularity) [that] is inherently repugnant to taste, in that the contemplation of it affords us no lasting entertainment."[59] His printed objects could even be criticized as too decorative. But that is not a principal argument against 3D sculpture; perhaps these approaches are only early steps. Anyway, the reproducible character of these virtual objects reiterates an aspect that was discussed by Rosalind Krauss in relation to Rodin—the relation between sculptural reproducibility, uniqueness, and "originality of the artist."[60] Sculptural templates could be sent by the artist via email and the printed out by the "viewer" anywhere—the relation between the sculptural and its reproduction will be reconfigured by 3D-printing, as will be the difference between artist and viewer. 3D-printed sculptural objects also reinvent sculpture and could reflexively problematize questions of scale, regularity, mathematical structure of the sculptural in relation to the virtual, and the reproducibility of the sculptural object.

(c) Augmented Reality Sculpture

The last form I want to discuss is Augmented Reality Sculpture (= AR sculpture). Augmented Reality means that on a display, often the display of a smart phone, the real background

58 See Potts, *The Sculptural Imagination*, 2001, pp. 158–77.

59 Immanuel Kant, *Critique of Judgement*, trans. by James Creed Meredith, ed. Nicholas Walker (Oxford: Oxford University Press, 2007), p. 73.

60 See Rosalind Krauss, "The Originality of the Avantgarde," in *The Originality of the Avantgarde and Other Modernist Myths* (Cambridge, MA: MIT Press, 1985), pp. 151–70, especially pp. 151–57.

6, 7 Sander Veenhof and Mark Skwarek, *Augmented Reality Art Invasion MoMA*, New York, 2010.

is overlayed with virtual objects. Object space is mapped onto real space, with the viewers again steering the virtual camera.[61]

These images document a project that took place on October 9, 2010. Visitors with the appropriate smartphones and AR software, called "Layar Augmented Reality browser," could participate in a virtual and unofficial exhibition at MoMA: "The virtual exhibition will occupy the space inside the MoMA building using Augmented Reality technology. The show will not be visible to regular visitors of the MoMA, but those who are using a mobile phone application called 'Layar Augmented Reality browser' on their iPhone or Android smartphones, will see numerous additional works on each of the floors."[62] In other words, AR sculpture occupies the space of the MoMA, and the authoritative selection of works and the narrative of their arrangement are subverted and undermined. In fig. 6–7 we can see how an additional virtual sculptural object is introduced into the authoritative space of the museum. This can certainly be understood as a subversive attack on MoMA's hegemonic function (however, the AR exhibition can also be seen as a recognition of MoMA's hegemonic role). Here, critical potentials of an AR art practice are hinted at. This practice in turn could challenge the stabilized, hierarchical spatial structures of the MoMA. In this sense, working

61 See Ronald T. Azuma, "A Survey of Augmented Reality," *Presence: Teleoperators and Virtual Environments* 6, no. 4 (1997): 355–85 and Paul Milgram, Haruo Takemura, Akira Utsumi, and Fumio Kishino, "Augmented Reality: A Class of Displays on the Reality-Virtuality Continuum," *Proceedings of SPIE 2351.1* (1994): 282–92. See also Vladimir Geroimenko, *Augmented Reality Art: From an Emerging Technology to a Novel Creative Medium* (Cham: Springer, 2014). See https://www.jeffreyshawcompendium.com/portfolio/sculpture/ (accessed December 22, 2021), for an early experiment in AR sculpture by Jeffrey Shaw.

62 See http://www.sndrv.nl/moma/ (accessed December 12, 2021).

with AR sculpture might be a strategy to reinvent, in a digitally transformed way, questions of institutional critique and site-specificity that were connected to certain forms of (post-) modern sculptural interventions. Famously, Douglas Crimp discussed these in relation to Richard Serra, also in an exhibition at the MoMA.[63] But he emphasizes the controversial case of Serra's *Tilted Arc*, which was to be relocated, as its installation on the plaza of the Jacob K. Javits Federal Building in Lower Manhattan during the summer of 1981 resulted in fierce opposition: "But, for all its passion and eloquence, the testimony failed to convince the adversaries of *Tilted Arc*. To them the work was in conflict with its site, disrupted the normal views and social functions of the plaza, and, indeed, would be far more pleasant to contemplate in a landscape setting. Its size would presumably be less overwhelming to landscape surroundings, its rust-colored steel surface more harmonious with the colors of nature."[64] While a real sculptural intervention can disrupt a real place and thereby deconstruct the spatial normality of that place, AR sculpture is only individually located on a given smart phone and does not disrupt collective and public space. In this regard, AR sculpture could also be read as a taming of the critical function of site-specificity, but in certain contexts, perhaps where public space is controlled by authorities, it could have an important critical function. AR sculpture, again, problematizes Bochner's argument that sculpture is necessarily located in shared space and transforms problems of institutional critique and site-specificity.

V. Very Short Conclusion

By using a notion of virtuality derived from computer science, I tried to show that in particular forms of computer graphics, virtual objects can be constructed in an "object space" that then can be recorded by a virtual camera. In turn, these virtual objects, being described with spatial coordinate systems, have potentially a sculptural structure. Therefore, virtual sculptures that are freed from the material and even dimensional constraints of real sculpture can be constructed. That means that by using virtualization, the questions concerning the specificity of sculpture can be posed in a new way—which also means that the seemingly obsolete question of medium-specificity can be posed anew under virtual conditions. Some modernist questions can reappear with simulation, virtualization, and modeling. This necessitates a remark on virtual modernism as a contemporary aesthetic option. From this, finally, an attempt was made to list possible virtual-modernist expansions of the field of sculpture: virtual sculpture, 3D-printed sculpture, and AR sculpture.

63 Douglas Crimp, "Serra's Public Sculpture: Redefining Site Specificity," in *Richard Serra/Sculpture*, ed. Rosalind Krauss (New York: Museum of Modern Art, 1986), pp. 41–56.

64 Ibid., p. 42.