Assembling Reality: Myths of Computer Graphics

Lev Manovich

(1992)

Giotto, the Inventor of 3D

This is how Frederick Hartt, the author of Art. History of Painting, Sculpture, Architecture, a widely used textbook, describes the importance of Giotto di Bondone, "the first giant in the long history of Italian painting": "In contemporary Italian eyes the step from Cimabue to Giotto was immense in that weight and mass, light and inward extension were suddenly introduced in a direct and convincing manner" (503). "Giotto's miracle lay in being able to produce for the first time on a flat surface three-dimensional forms, which the French could achieve only in sculpture." "For the first time since antiquity, a painter has truly conquered solid form" (504).

When the students in the introductory art history survey course at the University of Rochester which uses Hartt's textbook were asked to compare Giotto and Cimabue, they described Giotto's achievements in a somewhat different language: "Giotto first achieves strong 3D effect"; "Cimabue is still 2D, while Giotto has much more of 3D".

In his recent history of vision in the 19th century, Jonathan Crary suggests that the rapid development and diffusion of various computer graphics technologies in the last decade constitutes a "transformation in the nature of visuality probably more profound than the break that separates medieval imagery from Renaissance perspective" (Crary 1). What makes computer graphics so valuable to education and advertising, business and the military, science and entertainment industry is their ability to simulate three-dimensional images of both existent and imagined objects and environments. Usually, the viewer sees these simulated objects as images on a flat screen, however, new interfaces are being developed (virtual reality, computer holography) to enhance the illusion of their three-dimensional presence.

"Realism" is the concept that inevitably accompanies the development and assimilation of computer graphics technologies. In media, trade publications and research papers, the history of technological innovation and research are presented as a progression toward realism — the ability to simulate any object in such a way that its computer image is indistinguishable from a photograph. At the same time, it is constantly pointed out that this realism is qualitatively different from the realism of optically based image technologies (photography, film), for the simulated reality is not indexically related to the existing world.

Despite this difference, the ability to generate three-dimensional stills does not represent a radical break in the history of visual representation of the multitude comparable to the achievements of Giotto. A Renaissance painting and a computer image employ the same technique (a set of consistent depth cues) to create an illusion of space — existent or imaginary. The real break is the introduction of a moving synthetic image — interactive 3D computer graphics and computer animation. With

1

these technologies, a viewer has an experience of moving around the simulated 3D space — something one can't do with a painting.

In order to better understand the nature of "realism" of the synthetic moving image, it is relevant to consider a contiguous practice of the moving image — the cinema. I will approach the problem of "realism" in 3D computer animation starting from the arguments advanced in film theory in regard to cinematic realism. First, I review the key accounts which situate the realism of film in the histories of cinematic technology and style. The next section tests the models suggested in these accounts on the history of computer animation and computer graphics research. The third section shifts emphasis, considering realism in computer animation as an effect of subject matter.

Technology and Style in Cinema

The idea of cinematic realism is first of all associated with Andrĭ Bazin, for whom cinematic technology and style move toward a "total and complete representation of reality" (20). In "The Myth of Total Cinema" Bazin claims that the idea of cinema existed long before the medium had actually appeared and that the development of cinema technology "little by little made a reality out of original "myth" (21). In this account, the modern technology of cinema is a realization of an ancient myth of mimesis, just as the development of aviation is a realization of the myth of Icarus. In another influential essay, "The Evolution of the Language of Cinema," Bazin reads the history of film style in similar teleological terms: the introduction of the depth of field style at the end of the 1930s and the subsequent innovations of Italian neorealists in 1940s gradually bring a spectator "into a relation with the image closer to that which he enjoys with reality". The essays differ not only in that the first interprets film technology while the second concentrates on film style but also in their distinct approaches to the problem of realism. In the first essay, realism stands for the approximation of phenomenological qualities of reality, "the reconstruction of a perfect illusion of the outside world in sound, color and relief" (20). In the second essay, Bazin emphasizes that a realistic representation should also approximate the perceptual and cognitive dynamics of natural vision. For Bazin, this dynamics involves the active exploration of visual reality. Consequently, he interprets the introduction of the depth of field as a step toward realism, because now the viewer can freely explore the space of the film image (36-37).

Against Bazin's "idealist" and evolutionary account, Jean-Louis Comolli proposes a "materialist" and fundamentally non-linear reading of the history of cinematic technology and style. The cinema, Comolli tells us, "is born immediately as a social machine...from the anticipation and confirmation of its social profitability; economic, ideological and symbolic" (Comolli 122). Comolli thus proposes to read the history of cinema techniques as an intersection of technical, aesthetic, social and ideological determinations; however, his analyses clearly privilege an ideological function of the cinema. For Comolli, this function is an "objective" duplication of the "real" itself conceived as a "specular reflection" (133). Along with other representational cultural practices, cinema works to endlessly reduplicate the visible thus sustaining the illusion that it is the phenomenal forms (such as the commodity form) which constitute the social "real" — rather than "invisible" to the eye relations of productions. To fulfill its

function, cinema must maintain and constantly update its "realism". Comolli sketches this process using two alternative figures — addition and substitution.

In terms of technological developments, the history of realism in the cinema is one of additions. First, additions are necessary to maintain the process of disavowal, which for Comolli defines the nature of cinematic spectatorship (132). Each new technological development (sound, panchromatic stock, color) points to the viewers just how "unrealistic" the previous image was and also reminds them that the present image, even though more realistic, will be superseded in the future — thus constantly sustaining the state of disavowal. Secondly, since cinema functions in a structure with other visual media, it has to keep up with its changing level of realism. For instance, by the 1920s the spread of photography with its finely gradated image made cinematic image seem harsh by comparison, and film industry was forced to change to the panchromatic stock to keep up with the standard of photographic realism (131). This example is a good illustration of Comolli's reliance on Althusserian structuralist Marxism. Unprofitable economically for the film industry, this change is "profitable" in more abstract terms for the social structure as a whole, helping to sustain the ideology of the real/visible.

In terms of cinematic style, the history of realism in cinema is one of the substitutions of cinematic techniques. For instance, while the change to panchromatic stock adds to the image quality, it leads to other losses. If earlier cinematic realism was maintained through the effects of depth, now "depth(perspective) loses its importance in the production of "reality effects" in favor of shade, range, color" (131). So theorized, realistic effect in the cinema appears as a constant sum in an equation with a few variables which change historically and have equal weight: if more shading or color is "put in," perspective can be "taken out". Comolli follows the same logic of substitution/subtraction in sketching the development of cinematic style in its first two decades: the early cinematographic image announces its realism through an abundance of moving figures and the use of deep focus; later these devices fade away and others, such as fictional logic, psychological characters, coherent space-time of narration, take over (130).

While for Bazin realism functions as an Idea (in a Hegelian sense), for Comolli it plays an ideological role (in a Marxist sense); for David Bordwell and Janet Staiger, realism in film is first of all connected with the industrial organization of cinema. Put differently, Bazin draws the idea of realism from mythological utopian thinking. For him, realism is found in the space between reality and a transcendental spectator. Comolli sees it as an effect, produced between the image and the historical viewer and continuously sustained through the ideologically determined additions and substitutions of cinematic technologies and techniques. Bordwell and Staiger locate realism within the institutional discourses of film industries, implying that it is a rational and pragmatic tool in industrial competition.

Emphasizing that cinema is an industry like any other, Bordwell and Staiger attribute the changes in cinematic technology to the factors shared by all modern industries — efficiency, product differentiation, maintenance of a standard of quality (247). One of the advantages of adopting an industrial model is that it allows the authors to look at specific agents — manufacturing and supplying firms and professional associations (250). The latter is particularly important since it is in their discourses (conferences,

trade meetings and publications) that the standards and goals of stylistic and technical innovations are articulated.

Bordwell and Staiger agree with Comolli that the development of cinematic technology is not linear, however, they claim that it is not random either, as the professional discourses articulate goals of the research and set the limits for permissible innovations (260). According to Bordwell and Staiger, realism is one of these goals. They believe that such definition of realism is specific to Hollywood:

"Showmanship", realism, invisibility: such cannons guided the SMPE members toward understanding the acceptable and unacceptable choices in technical innovations, and these too became teleological. In another industry, the engineer's goal might be un unbreakable glass or a lighter alloy. In the film industry, the goals were not only increased efficiency, economy, and flexibility but also spectacle, concealment of artifice, and what Goldsmith [1934 president of SMPE] called "the production of an acceptance semblance of reality". (258)

Bordwell and Staiger are satisfied with Goldsmith's definition of realism as "the production of an acceptance semblance of reality". However, such general and transhistorical definition does not seem to have any specificity for Hollywood and thus can't really account for the direction of technological innovation. Moreover, although they claim to have successfully reduced realism to a rational and a functional notion, in fact, they have not managed to eliminate Bazin's idealism. It reappears in the comparison between the goals of innovation in film and other industries. "Lighter alloy" is used in aviation industry which can be thought of as the realization of the myth of Icarus, and is there not something mythical and fairytale-like about "unbreakable glass"?

Technology and Style in Computer Animation

How can these three influential accounts of cinematic realism be used to approach the problem of realism in computer animation? Bazin, Comolli, and Bordwell and Staiger offer us three different strategies, three different starting points. Bazin builds his argument by comparing the changing quality of the cinematic image with the phenomenological impression of visual reality. Comolli's analysis suggests a different strategy: to think of the history of computer graphics technologies and the changing stylistic conventions as a chain of substitutions functioning to sustain the reality effect for audiences. Finally, to follow Bordwell and Staiger's approach is to analyze the relationship between the character of realism in computer animation and the particular industrial organization of the computer graphics industry. (For instance, we can ask how this character is affected by the cost difference between hardware and software development.) Further, we should pay attention to professional organizations in the field and their discourses which articulate the goals of research and where we may expect to find "admonitions about the range and nature of permissible innovations" (Bordwell and Staiger 260). I will try the three strategies in turn.

If we follow Bazin's approach and compare images drawn from the two decades of the history of computer graphics with the visual perception of natural reality, his evolutionary narrative appears to be confirmed. Images progress towards fuller and

fuller illusion of reality: from wireframe displays to smooth shadows, intricate textures, aerial perspective; from geometric shapes to moving animal and human figures; from Cimabue to Giotto to Leonardo and beyond. Bazin's idea that deep focus cinematography allowed the spectator a more active position in relation to film image, thus bringing cinematic perception closer to real-life perception, also finds a recent equivalent in interactive computer graphics, where the user can freely explore the virtual space of the display from different points of view. And with such extensions of computer graphics technology as virtual reality, the promise of Bazin's "total realism" appears to be closer than ever, literally within arms reach of virtual reality's user.

The history of the style and technology of computer animation can also be seen in a different way. Comolli reads the history of realistic media as a constant trade-off of codes, a chain of substitutions producing the reality effect for audiences, rather than as an asymptotic movement toward the axes labeled "reality". His interpretation of the history of film style is first of all supported by the shift he observes between the cinematic style of the 1900s and the 1920s, the example I have already mentioned. Early, film announces its realism by excessive representations of deep space achieved through every possible means: deep focus, moving figures, frame compositions which emphasize the effect of linear perspective. In the 1920s, with the adaptation of panchromatic film stock, "depth(perspective) loses its importance in the production of "reality effects" in favor of shade, range, color" (Comolli, 131). A similar trade-off of codes can be observed during the short history of commercial 3D computer animation.

Initially, the single frames of animations were schematic, cartoon-like because the objects could only be rendered in wireframe or facet-shaded form. Illusionism was limited to the indication of objects' volumes. To compensate for this limited illusionism of a single image, computer animations of the early 1980s ubiquitously showed deep space. This was done by emphasizing linear perspective (mostly, through the excessive use of grids) and by building animations around rapid movement in depth in the direction perpendicular to the screen. Toward the end of the 1980s, with commercial availability of such techniques as smooth shading, texture mapping and casted shadows, the individual frames of animations approached much closer the ideal of photorealism. At this time, the codes by which early animation signaled deep space started to disappear. In place of rapid in-depth movements and grids, animations began to feature lateral movements in shallow space.

The observed substitution of realistic codes in the history of computer animation seems to confirm Comolli's argument. The introduction of new illusionistic techniques dislodges old ones. Comolli explains this process of sustaining reality effect from the point of view of audiences. Following Bordwell and Staiger's approach, we can consider the same phenomenon from the producers' point of view. For the production companies, the constant substitution of codes is necessary to stay competitive.

As in every industry, the producers of computer animation stay competitive by differentiating their products. To attract clients, a company has to be able to offer some novel effects and techniques. But why do the old techniques disappear? The specificity of industrial organization of the computer animation field is that it is driven by software innovation. (In this, the field is closer to the computer industry as a whole, rather than film industry or graphic design.) New algorithms to produce new effects are constantly developed. To stay competitive, a company has to quickly incorporate the new

software into its offerings. The animations are designed to show off the latest algorithm. Correspondingly, the effects possible with older algorithms are featured less often — available to everybody else in the field, they no longer signal "state of the art". Thus, the trade-off of codes in the history of computer animation can be related to the competitive pressure to quickly utilize the latest achievements of software research.

While commercial companies employ programmers capable of adopting published algorithms for the production environments, the theoretical work of developing these algorithms mainly takes place in academia. To further pursue the question of realism we need to ask about the direction of this work. Do computer graphics researchers share a common goal?

In analyzing the same question for film industry, Bordwell and Staiger claim that realism "was rationally adopted as an engineering aim" (258). They attempt to discover the specificity of Hollywood's conception of realism in the discourses of professional organizations such as SMPE.

For the computer graphics industry, the major professional organization is SIGGRAPH (Special Interest Group on Computer Graphics of the Association for Computing Machinery). Its annual conventions, attended by tenths of thousands, combine a trade show, a festival of computer animation and a scientific conference where the best new research work is presented. The conferences also serve as the meeting place for the researchers, engineers and commercial designers. If the research has a common direction, we can expect to find its articulations in SIGGRAPH proceedings.

Indeed, a typical research paper includes a reference to realism as the goal of investigations in computer graphics field. For example, a 1987 paper presented by three highly recognized scientists offers this definition of realism:

Reys is an image rendering system developed at Lucasfilm Ltd. and currently in use at Pixar. In designing Reys, our goal was an architecture optimized for fast high-quality rendering of complex animated scenes. By fast we mean being able to compute a feature-length film in about a year; high quality means virtually indistinguishable from live-action motion picture photography; and complex means as visually rich as real scenes. (Cook et al, 95. Emphasis mine — L.M.)

Achieving synthetic realism means attaining two goals: to simulate codes of traditional cinematography and to simulate the perceptual properties of real-life objects and environments.

The first goal, the simulation of cinematographic codes, was in principle solved early on as these codes are well-defined and few in number. Every current professional computer animation system incorporates variable length lens, depth of field effect, motion blur and controllable lights.

The second goal, the simulation of "real scenes," turned out to be more complex. Digital recreation of any object involves solving three separate problems: the representation of an object's shape, the effects of light, and the pattern of movement. To have a general solution for each problem requires the exact simulation of underlying physical properties and processes. This is impossible because of the extreme mathematical complexity. For instance, to fully simulate the shape of a tree would involve mathematically "growing" every leaf, every brunch, every piece of bark;

and to fully simulate the color of a tree's surface a programmer has to consider every other object in the scene, from grass to clouds to other trees. In practice, computer graphics researchers have resorted to solving particular local cases, developing a number of unrelated models for simulation of some kinds of shapes, materials and movements. Thus, the photorealistic simulation of "real scenes" is practically impossible as techniques available to commercial animators only cover the particular phenomena of visual reality. The animator can easily create a shape of a human face, but not the hair; the materials such as plastic or metal but not cloth or leather; the flight of a bird but not the jumps of a frog. The realism of computer animation is highly uneven, reflecting the range of problems which were addressed and solved.

What determines which particular problems received priority in research? To a large extent, this was determined by the needs of the early sponsors of this research — the Pentagon and Hollywood. I am not concerned here to fully trace the history of these sponsorships. What is important for my argument is that the requirements of military and entertainment applications determined the concentration of research to simulate the particular phenomena of visual reality, such as landscapes and moving figures.

One of the original motivations behind the development of photorealistic computer graphics was its application for flight simulators and other training technology (Goodman 22, 102). And since simulators require synthetic landscapes, a lot of research went into the techniques to render clouds, rugged terrains, trees, aerial perspective. Thus, the work which led to the development of the famous technique to represent natural shapes (such as mountains) using fractal mathematics was undertaken at Boeing (Carpenter et all). Other well-known algorithms to simulate natural scenes and clouds were developed by the researchers of Grumman Aerospace Corporation (Gardner). The latter technology was used for flight simulators and also was applied to pattern recognition research in target tracking by a missile (Gardner 1984: 19).

Another major sponsor was the entertainment industry, lured by the promise of lowering the costs of film and television production. In 1979 Lucasfilm, Ltd., George Lucas's company, organized a computer animation research division. It hired the best computer scientists in the field to produce animations for special effects. The research for the effects in such films as Star Trek II: The Wrath of Khan and Return of the Jedi have led to the development of important algorithms which became widely used (Reeves 1983). Along with special effects, a lot of research activity has been dedicated to the development of moving humanoid figures and synthetic actors, since commercial film and video productions center around characters. Significantly, the first time computer animation was used in a feature film (Looker, 1980) was to create a three-dimensional model of an actress. One of the early attempts to simulate human facial expressions featured synthetic replicas of Marilyn Monroe and Humphrey Bogart (Magnenat-Thalmann & Thalmann). In another acclaimed animation, produced by Kleiser-Walczak Construction Company in 1988, a synthetic human figure was humorously cast as Nestor Sextone, a candidate for the presidency in the Synthetic Actors Guild.

The icons of mimesis

While the privileging of certain areas in research can be attributed to the needs of the sponsors, other areas received consistent attention for a different reason. To support the idea of progress of computer graphics toward realism, researchers privilege particular subjects that culturally connote the mastery of mimetic representation.

Historically, the idea of mimesis has been connected with the success in illusionistic representation of certain subjects. The original episode in the history of Western painting is the story of the competition between Zeuxis and Parrhasiuss. The grapes painted by Zeuxis symbolize his skill to create living nature out of inanimate matter of paint. Further examples in the history of art include the celebration of the mimetic skill of those painters who were able to simulate another symbol of living nature — the human flesh.

While the painting tradition had its own iconography of subjects connoting mimesis, moving image media relied on different sets of subjects. Steven Neale describes how early film demonstrated its authenticity by representing moving nature: "What was lacking [in photographs] was the wind, the very index of real, natural movement. Hence the obsessive contemporary fascination, not just with movement, not just with scale, but also with waves and sea spray, with smoke and spray" (52). Computer graphics researchers resort to similar subjects to signify the realism of animation. "Moving nature" presented at SIGGRAPH conferences has included animations of smoke, fire, sea waves, and moving grass (Perlin; Max; Reeves and Blau). These privileged signs of realism overcompensate for the inability of computer graphics researchers to fully simulate "real scenes".

Conclusion

Bazin's Evolution of the Language of Cinema is a compilation of three articles written between 1952 and 1955.

In 1951 the viewers of the popular television show "See it Now" for the first time saw a computer graphics display, generated by M.I.T. computer Whirlwind, built in 1949. One animation was of a bouncing ball, another of a rocket's trajectory (Goodman 18-19).

Comolli's Machines of the Visible was given as a paper at the seminal conference on the cinematic apparatus in 1978.

The same year saw the publication of a crucial paper on the history of computer graphics research. It presented a method to simulate bump textures which is still one of the most powerful techniques of synthetic photorealism (Blinn).

Bordwell and Staiger's chapter Technology, Style and Mode of Production forms a part of the comprehensive The Classical Hollywood Cinema: Film Style & Mode of Production to 1960, published in 1985. By this year, most of the fundamental photorealistic techniques were discovered and turnkey computer animation systems were already employed by media production companies.

By 1991, 3D computer animation becomes the yardstick by which realism of any visual representation is measured. A student in art history class writes: "Renaissance perspective is the first development of realistic 3D".

On the one hand, computer graphics is employed to mimic the existing optically based modes of representation — photography and film. The goal of the research is the achievement of photorealism.

On the other hand, synthetic realism is fundamentally different from the realism of the optical media, being partial and uneven, rather than analog. This difference presents a theoretical challenge to the existing accounts of realism developed on the analyses of optical media. During the 20th century, these media were the culturally dominant modes of visual representation and set the standards of mimetic imagination. Presently, the role of 3D synthetic imagery is rapidly becoming more important. If we want to understand the transformations of contemporary visual culture, the problem of realism has to be studied afresh.

References

[1] Bazin, Andre, trans. What is Cinema? 2 vols. Berkeley: University of California Press, 1967, Vol. 1.

[2] Blinn, J. F. "Simulation of Wrinkled Surfaces". Computer Graphics. (August 1978): 286-92.

[3] Bordwell, David and Janet Staiger. "Technology, Style and Mode of Production". The Classical Hollywood Cinema. David Bordwell, Janet Staiger and Kristin Thompson. New York: Columbia University Press, 1985. 243-261.Carpenter, L., A. Fournier and D. Fussell. "Fractal Surfaces". Communications of the ACM. 1981.

[4] Comolli, Jean-Louis. "Machines of the Visible". The Cinematic Apparatus. Ed. Teresa De Lauretis and Steven Health. New York: St.Martin Press, 1980. 121-142.Cook, R., L. Carpenter and E. Catull. "The Reys Image Rendering Architecture". Computer Graphics. 21.4 (1987): 91-102.

[5] Crary, Jonathan. Techniques of the Observer. Cambridge, MA and London: MIT Press, 1990.

[6] Gardner, Geoffrey Y. "Simulation of Natural Scenes Using Textured Quadric Surfaces". Computer Graphics. 18.3 (1984): 21-30.

[7] Gardner, Geoffrey Y. "Visual Simulation of Clouds". Computer Graphics. 19.3 (1985): 297-304.

[8] Goodman, Cynthia. Digital Visions. New York: Harry N. Abrams, Inc., 1987.

[9] Magnenat-Thalman and Thalman. "The Direction of Synthetic Actors in the Film "Rendezvous a Montreal"." IEEE Computer Graphics and Applications. December 1987.

[10] Manovich, Lev. "Real" Wars: Aesthetics and Professionalism in Computer Animation". Design Issues. 8.1. (Fall 1991): 18-25.

[11] Max, Nelson. "Vectorized procedure models for natural terrain: waves and islands in the sunset". Computer Graphics. 15.3. (1981).

[12] Neale, Steve. Cinema and Technology. Bloomington: Indiana University Press, 1985.

[13] Perlin, Ken. "An Image Synthesizer". Computer Graphics. 19.3 (1985): 287-296.

[14] Reeves, William T. "Particle Systems — A Technique for Modeling a Class of Fuzzy Objects". ACM Transactions on Graphics. 2.3 (1983): 91-108.

[15] Reeves, William T. and Ricki Blau. "Approximate and Probabilistic Algorithms for Shading and Rendering Structured Particle Systems". Computer Graphics. 19.3 (1985): 313-322.

[16] The difference between the earlier and the more recent computer animation images can also be observed in synchronic dimensions. It is the difference between the state of the art professional production and the amateur production which is forced to rely on the outmoded technology. See Manovich 1991.