DOCUMENT RESUME

ED 380 076 IR 016 997

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TITLE The Pedagogy of Photorealistic Rendering.
PUB DATE [95]
NOTE 8p.; In: Imagery and Visual Literacy: Selected Readings from the Annual Conference of the International Visual Literacy Association (26th, Tempe, Arizona, October 12-16, 1994); see IR 016 977.
PUB TYPE Guides - Classroom Use - Teaching Guides (For Teacher) (052) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Art Education; Art Expression; *Computer Graphics; *Graphic Arts; Imagery; *Teaching Methods; *Visual Arts; Visual Learning; Visual Literacy
IDENTIFIERS *Digital Imagery

ABSTRACT

This paper discusses current changes in the teaching and learning of artistic rendering in light of technological advances that may cause teachers to rethink both what is taught, and the manner in which the results of the artistic process are valued and evaluated. The two methods of generating a photorealistic computer image are described, followed by definitions of the following terms: rendering, photorealistic rendering, and digital (computer) photorealistic rendering. A distinction is made between internal aesthetic and external aesthetic, and an analogy is provided for illustration. A strategy for teaching photorealistic rendering, in such a way that the subject can be divided into tool creation and tool use, is outlined in the following steps: creation of valid geometry; creation of original material, environment, and bump maps; placement of geometry into context; effective choice of lights and viewing position; choice of appropriate maps and filters; and choice of appropriate output medium. Finally, students can be evaluated on their growth in understanding complex relationships of form, material, and presentation unique to this medium. This provides a bridge between traditional rendering and digital rendering. (Contains six references.) (MAS)

The Pedagogy of Photorealistic Rendering

Jon M. Duff

Introduction

This paper discusses current changes in the teaching and learning of artistic rendering in light of technological advances that may cause teachers and curriculum planners to rethink both what is taught and the manner in which the results of the artistic process are valued and subsequently evaluated.

Many of you have seen the currently popular computer images on television, in the print media, and in film and marveled, "that looks just like..." In a short five years this technique has migrated downward from the domain of computer science Ph.D.'s to the desktop computers used every day. Those who produce these images must have a unique form of literacy—a hybrid right brain–left brain approach to visual images. The dilemma is understanding how this technology changes our long-held perceptions concerning how much visual ability a person needs to intelligently create, use, and evaluate such sophisticated images. *

You may wonder why this paper isn't full of photorealistic images. To be able to distinguish their subtle nuances, you need to view either digital output on a display, video tape, or a high quality digital print such as that produced by dye sublimation. Reproduction in a publication would require a 133 lines per inch halftone just to discern differences in materials, lighting, and rendering methods. Consult the references listed at the end of this paper for more examples.

As a classically trained illustrator, I have worked commercially for 25 years. During that time I have taught both part and full-time in the areas of graphics, illustration, and industrial design. Traditionally, it was important for illustrators to be able to draw geometries accurately and then to render various materials realistically in a variety of media. A skilled illustrator had to be able to represent chrome, wood, fabric, glass, earth, skin, and a host of other materials. In fact, a teacher could evaluate accomplishment in an illustrator by how well objects were modeled visually and how effective materials were represented.

> "Photorealistic rendering causes visual literacy and technological literacy to be inexorably linked. One simply can't separate the two."

* If it has been years since you have read *The Saber-tooth Curriculum* by J. Abner Peddiwell, this might be a good time to revisit the land of wooly bear clubbing and fish grabbing.

Current computer graphics technologies question the efficacy of this traditional approach because with photorealistic software and the appropriate hardware, effective renderings are within reach of almost anyone. Prove this by running a two-hour workshop where elementary students have chrome spheres bouncing around an electronic room by following a list of simple commands. What used to be a perceptual-intellectual-manipulatory function is now handled in software. One student can produce more effective renderings not as the result of superior knowledge and skill, but simply as the result of more computing power, more sophisticated modeling and rendering software, and higher quality output.

If you evaluate only the output, a student willing to spend $50.00 for a 1250x1250 dots per inch 16.7 million digital color print from a service bureau will be at a distinct advantage over a student stuck with 256 colors and a color ink jet printer. Photorealistic rendering causes visual literacy and technological literacy to be inexorably linked. One simply can't separate the two.

One way to look at the problem is from a historical context, one that views the computer as simply another tool, another medium for visual expression. There has been a historical succession of material and media developments, each allowing visual artists greater power in creating and distributing their images, each allowing the artist to be removed a greater distance from making the tools of their art. This position firmly accepts computer images as fundamentally different expressions. Just as it would be inappropriate to directly compare a pencil sketch with a watercolor wash, it would be inappropriate to compare a computer rendering with a manual rendering. The two are entirely different media. As teachers, we must juggle time and resources, making value judgements as to what should be kept in the curriculum and what is no longer appropriate.

A nagging voice says that the reason computer tools make sense is that they spring from traditional tools. Without a firm foundation in traditional rendering, computer rendering is an empty expression. Yet another voice says that is "oldthink." Traditional rendering tools and techniques only limit the ways that this new medium can be used. Is one, the other, or both true?

The availability of these rendering tools causes a fundamental change in the pedagogy of teaching rendering and in evaluating a student's development as an illustrator. Hopefully, as the result of reading this paper, the following two questions might be answered:

- If anyone can make chrome look like chrome, what is the value in evaluating the "chromeness" of the rendering? And,
- If rendering quality is not an appropriate developmental criteria, what is?

Brief Optional Technobabble

If you are well versed in computer photorealistic techniques you will want to skip this section. If you could care less how the images are made you'll also want to skip it.

A photorealistic computer image can be generated in one of two ways. First, three-dimensional computer geometry can be assigned properties such as material, finish, environment, light, haze, or movement. The computer then laboriously calculates the value (color and brightness) of every addressable picture element (pixel) in the scene. Although the scene is 3D the rendering is a 2D raster image (3D Studio, StrataVision, Ray Dream Designer, Alias, Topas). The second way is to apply filters to two-dimensional drawings. This method is less automated and requires more traditional artistic skills and sensibilities and usually results in a less photorealistic image

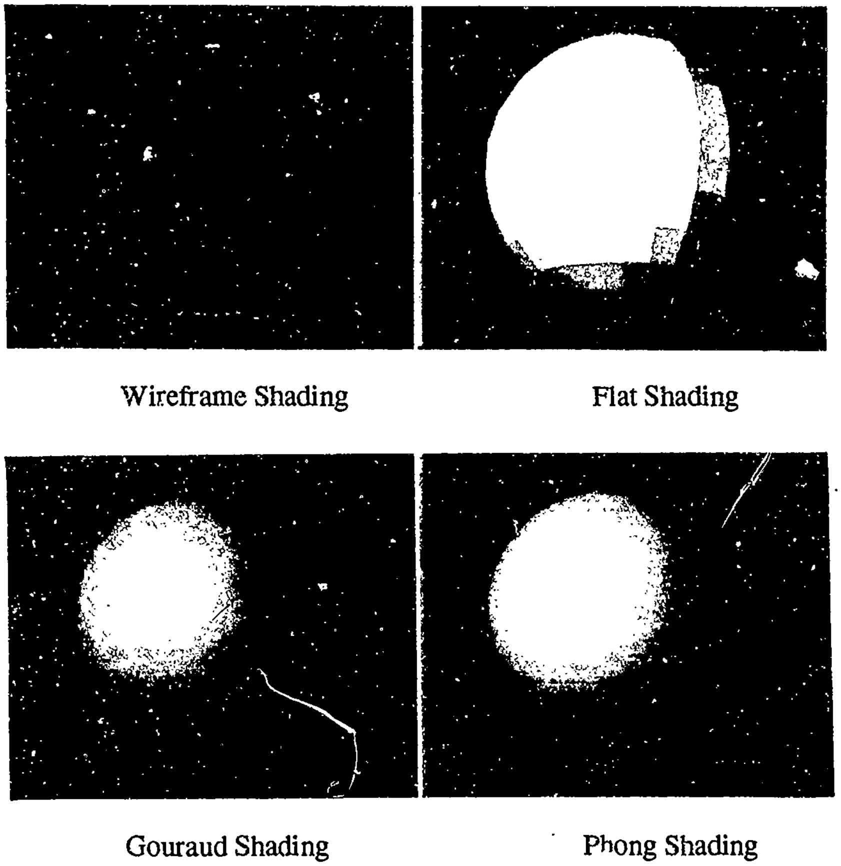

Figure 1. Rendering algorithms available for photorealistic renderings.

(PhotoShop, PhotoStyler, Fractal Painter). For the purpose if this discussion, photorealistic rendering refers to the former.

Four major rendering algorithms determine the *depth* of information at each pixel. See Figure 1. The greater the depth, the more realistic the image. *Wire frame rendering* represents intersections as lines. Planes are either transparent or visibility is determined. *Flat shading* assigns the same value to every pixel of a plane. This results in sharp faceted edges rather than smooth transitions. *Gouraud shading* calculates the value of pixels at each vertex of the plane and averages the values in between. This results in smoother transitions between planes but with no specular highlights or surface irregularities. *Phong shading* calculates a unique value for every pixel on a plane, allowing specular highlights and surface irregularities. See Figure 2. *Ray tracing* takes this one step farther by tracing the ray from every pixel back to its light source, noting how it changes color, brightness, and direction when it hits other objects. See Figure 3. This results in everything you get from Phong shading plus the influence of surrounding objects and light sources.

As you might expect, the more realistic the image, the greater the penalty in processing time. Ray tracing a detailed scene on a 60 mhz Pentium might take days and result in a file requiring 30 standard diskettes (40 mb). To do studio quality photorealistic rendering in acceptable time requires, as Tim Allen the comedian says, "More Power!"

Figure 2. Phong shaded rendering with textures and bump maps (Stratavision).

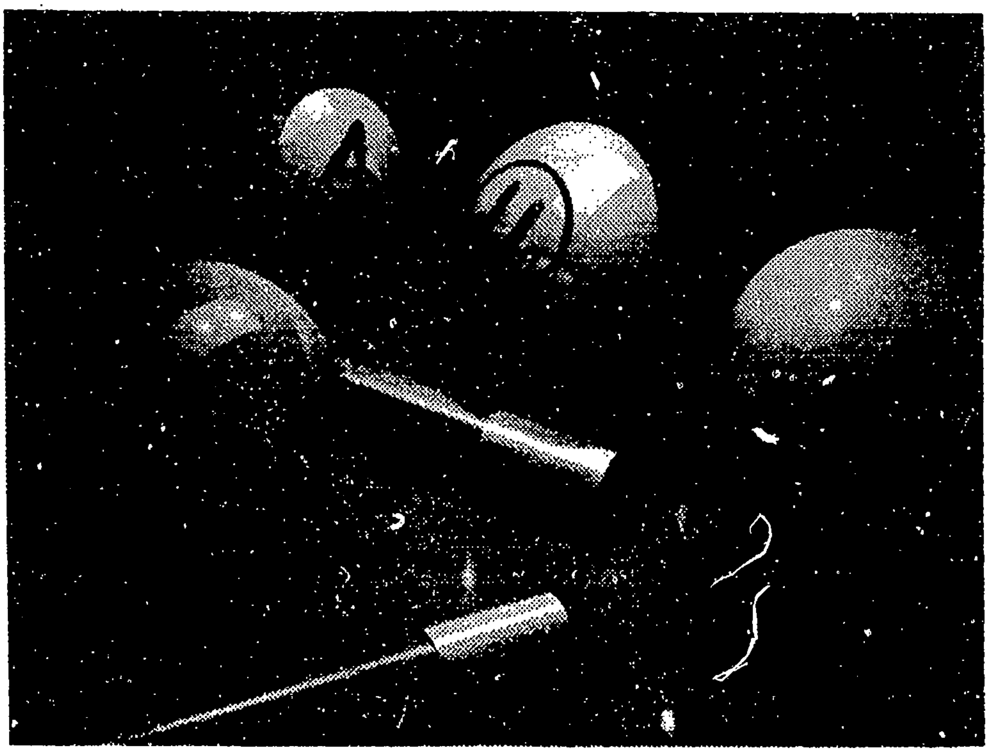

Figure 3. Ray traced photorealistic rendering (Stratavision).

Terms Defined

A *rendering* is a visual representation or depiction of a proposed or existing idea or physical situation. Renderings are done by illustrators, visual artists who combine artistic abilities with technical and commercial understanding. Such renderings are used to aid in decision making, document the visual nature of a finished or proposed design, or to persuade individuals to take action on the subject of the rendering. Renderings are used in product development, engineering, architecture, and marketing.

A *photorealistic rendering* is a depiction that appears so realistic that it appears to be a photograph. This type of rendering is of greatest value when the subject of the rendering does not exist. The closer a rendering depicts real-world situations, the greater confidence in decisions based on the rendering. Photorealism is independent of media—it can be done using manual or electronic tools.

Digital (computer) photorealistic rendering produces images that appear photographic by applying material, surface, and environment maps to valid two-dimensional, surface, or solid geometry. Ambient and directional lights are placed and a camera and view point chosen. A rendering algorithm is selected and the computer is allowed to render.

This word *rendering* describes the process of representing the natural world on a two-dimensional surface. There are levels of sophistication in this rendering process ranging from simple line drawings to illustrations that are photographic in nature. Renderings are usually ranked by how closely they approximate the generally held conception of natural appearance. Renderings differ from artistic impressions in that impressions are subject to the personal, political, social, and cultural biases and needs of the artist. The artist has the need for expression using art as the medium. We say that the artist works from an *internal aesthetic*. An illustrator, on the other hand. works from an *external aesthetic*, a controlling aesthetic that determines the nature of the image.

An Analogy

A person goes out and purchases a player piano and a roll that plays Beethoven's Moonlight Sonata. Is the person "playing" Beethoven? Is the person a musician?

A person goes out and purchases a Silicon Graphics Indy workstation with Alias software and a dye sublimation printer, then loads, renders, and prints a sample scene. Did this person "render" the scene? Is this person an illustrator?

To be honest, many would answer "who cares?" to each of the questions. If the music accomplishes its intended purpose, who cares if it is live, recorded, or canned. If the image accomplishes its intended purpose who cares if it is done by hand, by camera, or by computer. As an evaluation of the end product this is only partially valid because a live musical performance functions differently than recorded music. Images that are identified as being done on a computer function differently than images done by hand and emote a different response.

This suggests a difference between someone who creates something that a tool operates on, and someone who uses a tool. For example, popping a compact disk into a player and listening to someone play a piano sonata is two tools (the CD player and the piano) removed from the fundamental creative act—writing the sonata. Choosing an output device and selecting RENDER SCENE from a menu to get a photorealistic print is two tools (the computer and the printer) removed from the creative act—designing the scene.

Designing the Scene

So it would appear that the value in photorealistic rendering lies in those activities that occur *before* the actual rendering takes place. True, the rendering (like the playing of the sonata) is a method of establishing the validity, and evaluating the impact of the creative process. However, it isn't a necessary requirement and may actually interfere, either positively or negatively, with its evaluation.

A Pedagogy of Photorealistic Rendering

The previous discussion sets the stage for developing a strategy for teaching photorealistic rendering in such a way that the subject can be divided into *tool creation* and *tool use*. Students can then be evaluated as to their growth in understanding complex relationships of form, material, and presentation unique to this medium. This provides a bridge between traditional rendering and digital rendering.

Tool Creation

1. Creation of valid geometry. To a much greater degree, photorealistic rendering depends on valid computer geometry than did traditional rendering on valid drawing. Because the rendering engine can't make subtle changes in how surfaces or materials are interpreted, invalid geometry (surfaces that aren't closed, solids that aren't contiguous, intersections that are not positioned correctly in space, etc.) simply will not render correctly. Digital illustrators must be geometricians. They must be able to define geometry correctly and efficiently.

2. Creation of original material, environmental, and bump maps. The truly creative activity is not the simple selection of textures and maps (see point 5 below). An illustrator must be able to *create* maps that are realistic depictions of materials, textures, and environments. This probably bears the closest parallel to traditional rendering techniques. Being able to create bump maps as an alternative to geometric modeling is the mark of an efficient photorealistic rendering.

Tool Use

3. Placement of geometry into context (create the scene). This compositional aspect is probably the least dependent on digital rendering technology. Placing elements in space might be best taught using visual-haptic methods where physical models are manipulated by hand. This has the advantage of reinforcing the relationship of the physical universe to its representation in electronic space

4. Effective choice of lights and viewing position. The study of lights and cameras is critical in photorealistic rendering. The relationship of focal length to the traditional topic of perspective and an understanding of color and light and how the two impact sunlight, shade, and shadow colors for material and texture maps can determine the effectiveness of the rendering.

5. Choice of appropriate maps and filters. This is the modern example of having "good taste," something that was always difficult or impossible to teach. Inexperienced illustrators, given access to hundreds of textures, materials, and maps will almost always make horrific visual decisions. The old adage "less is more" still applies.

6. Choice of appropriate output medium. Photorealistic renderings are used for some purpose. They are distributed in some medium. Knowing the capabilities and limitations of offset lithography, gravure, video tape and digital display are imperative. Understanding digital color printing technologies and how raster images are stored and separated keeps an illustrator from making decisions that might ruin an otherwise effective image.

Summary

To answer the questions posed earlier, there is very little value in giving an illustrator credit for making chrome look like chrome using photorealistic tools. In fact if the chrome doesn't look like chrome, it had better be for a good reason, out of conscious effort, and not from lack of software knowledge. The second question was also answered. What is of value is any activity *before* the actual rendering— planning, sketching, storyboarding; modeling, map creation, and light and camera positioning. This revives the old *product vs. process* argument. Even with the change in tools, or possibly exacerbated by it, we have the tendency to take the easy way out and evaluate the product.

Students and teachers alike must understand that if the geometry is correct, if material, environment, and bump maps are correctly designed and applied, if lights are effectively placed, and if cameras are selected and positioned so as to produce the desired view, that a great looking rendering is simply a matter of spending enough money on computer time and output.

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