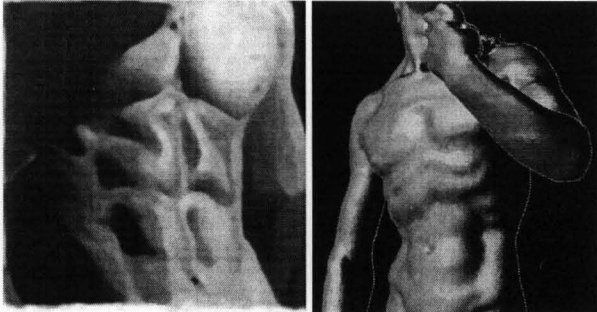


# A Painterly Approach to Human Skin

Category: short research paper



(a) Artist's painting.

(b) Computer-generated.

Figure 1: Comparison of a painting by Matt Kaplan and a computer-generated image produced using the approach presented this paper.

## Abstract

Rendering convincing human figures is one of the unsolved goals of computer graphics. Previous work has concentrated on modeling the physics of human skin. We have taken a different approach. We are exploring techniques used by artists, specifically artists who paint air-brushed portraits. Our goal is to give the impression of skin, without extraneous physical details such as pores, veins, and blemishes. In this paper, we provide rendering algorithms which are easy to incorporate into existing shaders, making rendering skin for medical illustration, computer animations, and other applications fast and simple. We accomplish this by using algorithms for real time drawing and shading of silhouette curves. We also build upon current non-photorealistic lighting methods using complementary colors to convey 3D shape information. Users select areas from a scanned art work and manipulate these areas to create shading models. The flexibility of this method of generating a shading model allows users to portray individuals with different skin tones or to capture the look and feel of a work of art.

**CR Categories:** I.3.0 [Computer Graphics]: General; I.3.6 [Computer Graphics]: Methodology and Techniques.

## 1 Introduction

Currently the process of shading and lighting human or human-like characters in animated features is experiencing a renaissance. New computer-based techniques are being integrated into systems that before were only concerned with duplicating existing lighting techniques. In addition, systems are being built which can create virtual photorealistic characters from previously acquired data [24, 18]. However, little work has gone into designing algorithms which can automatically render images in the style of portrait illustrations. This paper presents algorithms for rendering human skin based on the style of modern portrait illustrators such as Alberto Vargas, Hajime Sorayama, and Olivia DeBerardinis [9, 22, 1].

Photorealistic skin rendering has proven to be a difficult problem

partly because as humans, we are particularly attuned to the range of features which qualify as human [16]. Any rendering which fails to accurately capture these details will fail to achieve viewer acceptance. However, where art is concerned, an audience is often quite willing to accept some loss of detail in exchange for greater clarity of presentation.

This willing suspension of disbelief on the part of the viewer allowed us to create a paradigm for viewing human models which can communicate far better than traditional rendering algorithms allow. In Section 2 we review previous computer graphics work and conclude that little has been done to apply non-photorealistic techniques to human models. In Section 3 we analyze the conventions used by artists to portray human skin. Then in Section 4 we discuss the issues involved creating an interactive interface for rendering human characters. We conclude by discussing the results and future work in Section 5.

## 2 Related Work

Traditional approaches to rendering human skin have focused on simulating the underlying physical structures. As an example, Hanrahan et al. [14] model the skin with two basic epidermal layers, each containing distributions of scattering and absorbing elements. These elements are comprised of simulated pigment and tissue particles, which cause both wavelength independent and wavelength dependent attenuation resulting in variation of opacity and coloration respectively. Our paper takes a different approach, focusing on reproducing the shading algorithm used by an artist in their work. Reverse engineering BRDF's was applied to the domain of photorealism by Yu et al. [26]. In this paper, we attempt to solve a similar inverse problem to reproduce artistic shading by sampling art work.

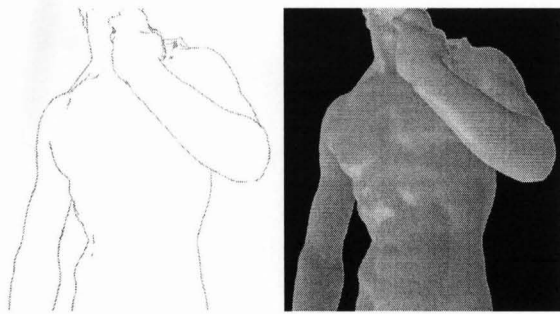
Our skin shading algorithms belong to a family of computer graphics techniques collectively referred to as non-photorealistic rendering (NPR). An underlying assumption in NPR is that artistic techniques developed by human artists have intrinsic merit based on the evolutionary nature of art. For this reason techniques are usually borrowed from artists rather than reinvented from first principles.

There has been some prior work applying NPR methods to the depiction of the human form. Haeberli used image processing to produce some stunning images of a woman figure skating in Siggraph 90 [13]. More recently, Cassidy Curtis captured the dynamic quality of human figures using depth buffers to pull out "loose and sketchy" edge lines. Markosian et al. and Gooch et al. made use of silhouettes to provide cues of depth and shape. In addition Gooch used complementary colors to provide additional depth cues [20, 10, 11].

Finally, modeling is a critical aspect of depicting the human form. In the absence of a good model, any attempt at rendering skin will fail to satisfy. There has been some research in the area of modeling human figures [23, 5]. In our work, we have not considered modeling issues, relying instead on a Digibot scan of Michelangelo's David and a female model by Louise Bell.

## 3 Artistic Principles in Portraiture

In his book, *The Technique of Portrait Painting* [19], classical portrait painter Harrington Mann emphasizes that form and color are



(a) Form: edge lines.

(b) Color: shading.

Figure 2: Image comparing color information on a tessellated model of Michelangelo's David.

the essential components which need to be perceived in a portrait. More recently, computer vision systems were built which identify human figures using visual cues such as color, texture, and shape features, similar to the process which takes place in the human visual system [7, 8]. Our work attempts to aid in human character recognition by enhancing the way in which a model is displayed, catering to these perceptual skills in the user.

Portraits are stand-alone images from a single viewpoint presented on a non-stereo medium such as paint on canvas. In this section we discuss the components of portraits and illustrations which we use in a computer graphics context.

### 3.1 Form

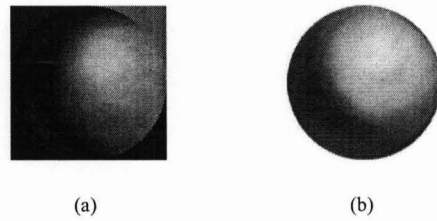
Previous research has established which lines should be drawn in a computer-generated image to maximize the amount of shape information conveyed while minimizing the number of lines drawn. Interrante et al. [17] chose to use only view independent ridge and valley lines. Elber et al. [6], Gooch et al. [10, 11], Markosian et al. [20], and Saito et al. [21] included ridge and valley lines, as well as edge lines, consisting of surface boundaries, silhouettes, and discontinuities, to separate individual parts and to emphasize important features in the shape of each object.

These edge lines lend definition to the image and give it form. However in the case of air-brushed portraits the edge lines only need to be distinct. As shown in Figure 1(b), the edge lines are darker than the rest of surface, but quickly blend into the colored and shaded interior region. The edge lines farthest from the light have a cooler, purple-ish tone, while the edge lines closest to the light have a warm, yellow-ish tone.

### 3.2 Color

Mann issues the poignant statement, "Color is more beautiful than form." Psychological research has also shown that color improves object recognition [25]. This can be seen in comparing the images in Figure 2.

*The Color Drawing Workshop* by Bet Borgeson [3] notes that most manufacturers of artists' paints offer a color called "flesh." Most artists scorn this color since it suggests that there is a single simple solution to portraying all skin colors. This simple solution is not possible due to the physical diversity of skin based on human genetics and because skin, like any object, will exhibit a number of local colors due to the environment. Artistic renderings may also



(a)

(b)

Figure 3: The second method creates an environment map from an artistically shaded sphere produced by an artist.

take into account factors such as color scheme and image composition which can affect the representation of skin.

For these reasons we avoid using a single object color to represent skin, but instead use a blending of colors from the silhouette of the character to the highlight. The color blend from the edges to the highlight used in a human portrait give a smooth texture to the skin. The shading from slightly cool to slightly warm as light varies over the subject gives depth to the image.

Recent research into shadows and illumination has shown that shadows caused by facial features hinder the recognition of a human face [4]. We therefore decided not to render self shadows.

## 4 Implementation

As outlined in the previous section, our system needs the ability to interactively display silhouettes, interior creases, and a custom shading model for complex geometric models. In this section we describe the techniques we used to achieve these goals.

### 4.1 Displaying Silhouettes and Creases

We build upon the algorithms explored by Gooch et al. [11] to draw silhouettes, boundaries, and creases for tessellated models. A silhouette is an edge that is connected to both a front facing and a back facing polygon. In our interface, the user is allowed to pick a color for the silhouettes which face towards the light called *warm silhouettes*, and a color for the silhouette which face away from the light, called *cool silhouettes*.

A crease is an edge between two front facing polygons whose dihedral angle is above some user-controlled threshold. We assume an orientable surface and draw both ridge and valley creases. If the surface is oriented so face normals are pointing outwards and the region of the surface is locally concave, the crease edge is a ridge, otherwise it is a valley. First, valleys are rendered with the cool silhouette color, then ridges are drawn with the warm silhouette color.

We provide the user with the option to extract these view-dependent edges by a brute force software method or by using OpenGL hardware. The brute force method checks every edge of every triangle. This computation can be done in parallel with the shading of the surfaces. The OpenGL hardware methods take advantage of the Polygon Offset extension and the stencil buffer [11].

### 4.2 Shading

There are several ways to apply NPR shading models using hardware [10, 11, 2]. We chose to use environment maps because they provide the most flexibility in the shading model. This effectively allows us to evaluate a lighting model at every normal/reflection direction in the visible hemisphere in eye-space.

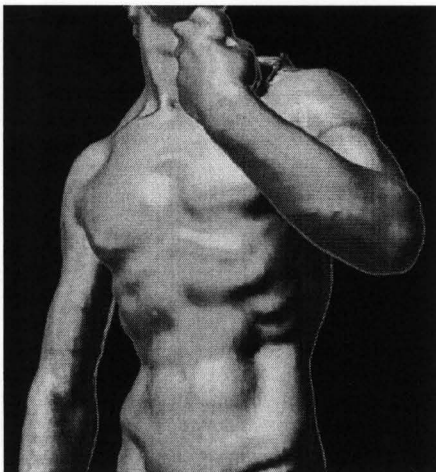
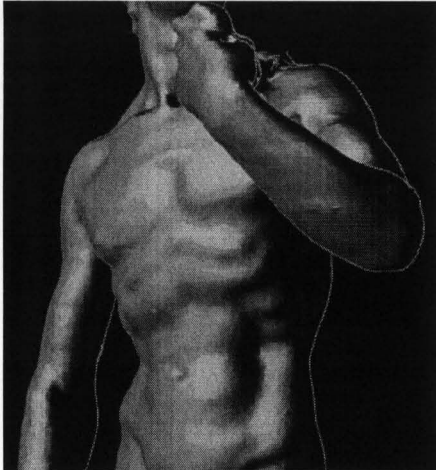


Figure 4: The result of using the environment maps from Figure 3 is a rendered model which resembles an artistic portrait.

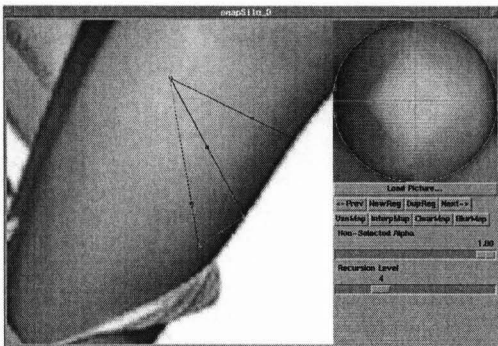


Figure 5: Our third method of generating an environment map allows the user to scan in a work of art and piece together a shading model. The figure shows the user interface for capturing a shading model from a work of art.

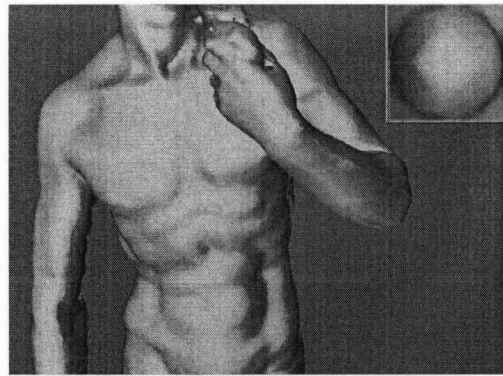


Figure 6: A model shaded with the resulting environment map from Figure 5.

In using an environment map, all normals in eye-space are mapped to a 2D texture. This shading only is valid in eye-space, but it is possible to extend these to view-independent environment maps [15]. We also implemented an alternative environment map parameterization which has better sampling near the silhouette, but poorer in the center. Heidrich et al. compute the shading model based on the reflection vector corresponding to each point on the surface so that it spans the entire visible hemisphere. Since everything is shaded with respect to the surface normal, we emit the normal as our texture coordinate, instead of reflection vectors.

Our system allows the user three ways of generating environment maps. In each of these methods, silhouettes can be added to the environment map as a separate process. The first method requires the user to provide cool, warm, and midrange colors, as shown in Figure 4.2. The system then generates an environment map by creating a shading model from these colors, mapping the model onto a sphere, and then projecting this lit sphere onto a planar texture map. We have extended the light splash-back model of Gooch et al. [11] by allowing multiple colors in the light model.

The second method involves having an artist produce an art work depicting a lit sphere using skin tone colors, as demonstrated in Figure 3. This art work is scanned and used as an environment map.

Our third method of generating environment maps allows the user to select triangular regions in a reference artwork, and then maps these regions to spherical triangles on a hemisphere. This hemisphere is next projected onto an environment map that is used to shade geometric models. The “splat-push-pull” method due to Gortler et al. [12] is used to interpolate gaps in the environment map. The user has the ability to change the size and placement of both the triangles on the source image and the spherical triangles on the hemisphere, as seen in Figure 5. The user also has the ability to easily change the parameterization of the plane triangles as they are mapped to the spherical triangles. The resulting shading models of these last two methods can help provide more surface detail because they are not restricted to a linear or symmetrical algorithm, as shown in Figure 4.2.

### 4.3 Color Blending

We implemented several methods of blurring the image in order to get the colors of the shading model to blend well with each other, and to get the colors of the silhouettes to blend with the shading model when projected onto a geometric model. This was accomplished by blurring the image with the OpenGL 2D convolution filter extension or by blurring the environment map directly.

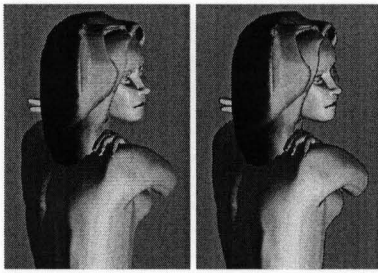


Figure 7: Applying different environment maps to different parts of a model. Model shown without and with edge lines.

We found that simply blurring the image in screen space then drawing the silhouettes caused a loss in fine detail of the image regardless of the size of the blur kernel. As an alternative we rendered the model into the frame buffer, blurred the image, and blend the blurred image with the unblurred image.

We also blurred the environment map directly, which we found was the best technique for the artist drawn environment maps, and the sampled artwork. This was done using a Gaussian blur with a user defined kernel. Additionally we implemented a modulated blur based on the intensity of the illumination of the environment map. The alpha planes in the environment map were set up to match the intensity of the map. The image is then computed as a linear blend between blurred image and the unblurred image based on the alpha or intensity. We found that this allowed us fine control of “artistic artifacts” in the environment maps, such as the grain of the paper and the strokes left in the medium as demonstrated in Figure 4 or 7.

## 5 Future Work and Conclusion

We have reported on an approach that allows convincing human skin to be rendered on geometric models of human characters. This work incorporates established principles from traditional art and perceptual psychology into the framework of a 3D viewer. The goal is to produce non-photorealistic images of human characters.

Although this system is based on artists’ work, a number of parameter settings are available to the user based on the user’s aesthetic preferences. Our approach incorporates parameters for cool and warm color choices, parameters for cool and warm silhouette color choices, line choices for internal features versus external outlines, and rendering methods exploiting texture maps.

This paper addresses the problem of generating attractive and artistic human characters. It represents an advance in the relatively under-developed area of computer graphics involving non-photorealistic rendering. We believe that in the future, this approach can also be used in domains such as medical illustration and the entertainment industry. We would like to further explore similar methods for rendering hair and cloth. We would also like to explore the use of these methods on non-human characters, such as dolphins or whales. We are also examining automatically solving an optimization problem for the shading model based on an image.

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# A Painterly Approach to Human Skin

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Rendering convincing human figures is one of the unsolved goals of computer graphics. Previous work has concentrated on modeling the physics of human skin. We have taken a different approach. We are exploring techniques used by artists, specifically artists who paint air-brushed portraits. Our goal is to give the impression of skin, without extraneous physical details such as pores, veins, and blemishes. In this paper, we provide rendering algorithms which are easy to incorporate into existing shaders, making rendering skin for medical illustration, computer animations, and other applications fast and simple. We accomplish this by using algorithms for real time drawing and shading of silhouette curves. We also build upon current non-photorealistic lighting methods using complementary colors to convey 3D shape information. Users select areas from a scanned art work and manipulate these areas to create shading models. The flexibility of this method of generating a shading model allows users to portray individuals with different skin tones or to capture the look and feel of a work of art.