SKIN MODELING AND RENDERING BASED ON VISUAL PERCEPTION

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Abstract: Human skin modelling and rendering are affected with a variety of cues. These are including human visual perception of skin texture and lighting. An attempt to mimic such attributes by computer is an aspiring goal and challenging task. This paper proposes a novel algorithm with two techniques as a key solution capturing such a variety of cues to skin appearance. The idea is to capture these two characteristics for skin rendering. The first is the texture generation that developed in visual perception. The second is skin texture rendering. These techniques discuss the skin noise simulation based on human perception theory and simulate skin noise texture. Then, the skin is rendered with what we call the Bidirectional Reflectance Distribution Function Texture Magnitude technique. The original contribution and advantages of this paper compared with other proposed methods are simple to implement, reliable and their computations are fast enough for an interactive environment. Experimental results demonstrate our approach for skin texture generation.

1 INTRODUCTION

Creating realistic rendering of human skin has an endeavour in computer graphics for nearly three decades (Nahas et al., 1990). Application of human skin modelling and rendering are founded in sophisticated computer interface, VR applications, computer games, multimedia and in a broad variety of production animation. Human visual system can easily recognize skin with other materials. Reproducing visual perception by computer is a difficult task because of the complex and individual texture of the skin and spatially varying reflectance properties of skin.

Rendering human skin based on human visual perception requires a handle on how to capture the image space created by the source of variation. In principle two main elements have to be considered in skin texture rendering based on human vision and skin reflectance. This paper shows how to simulate skin accounting for these elements. Our approach is motivated by a research on two studies.

The first is human visual perception and noise importance and texture generation for simulating skin texture. The second is the rendering skin texture based on a new BRDF technique.

The underlying idea to know the noise importance and its limit is useful to calculate ideal performance as a benchmark for simulation and rendering. Visual sensitivity is a product of two factors that isolate visual process more easily (Malik et al., 1990). These two factors contain observer efficiency and equivalent noise. On the other hand the ability to delineate characters skin in visual world depends partly upon the perception of noise consistency.

Perlin has determined a function, which uses an interpolation to combine noise-generating functions (Perlin, 1985). It has also been used to produce natural textures. Finally we render skin texture based on BRDF technique. In rendering phase generated texture is applied to render skin that will be discussed in section 4.2.

This paper organized as the followings. Section 2 reviews some of the prior researches in skin texture modelling and rendering with some discussions on its problem. Section 3 provides a brief summary of human vision and skin texture perception. Section 4, introduces our proposed techniques for skin texture generation and its reflectance. Some experimental results and discussion are given in section 5. Finally, conclusion and direction for future work are discussed in section 6.

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2 PRIOR WORKS AND PROBLEMS

Human skin modelling and rendering are extremely important in enhancing the realism of human appearance. Varied models are used to investigation on human skin and researchers discussed it from different point of view (Freefberg, 1999)(Hiraoka,1993). For example there are geometric models, physically based models and biomechanical models using either particle system or continues system. Ishii et al. (Ishii, 1993) also generated human skin texture, based on optical scattering in the skin layer with a 3D mesh structure of the skin surface. They reproduced the change in texture appearance for various scattering coefficients in the skin.

Debevec et al. (Debevec, 2000) proposed a technique to obtain the reflectance field of a face at each point by rotating the light source around the face. Hanrahan and Krueger (Hanrahan, 1993) have modelled skin subsurface structure and photon migration in the skin, and have simulated the shading of skin colour. Jensen et al.(Jensen, 2001) reproduced realistic facial images based on photon mapping or the diffusion equation technique for subsurface scattering.

Bastanfard et al (Bastanfard, 2004) proposed a technique for skin cosmetics based on wrinkle removal using inpainting.

Cula et al. (Cula, 2005) developed a texture representation technique that counts for changes of skin as imaging condition are varied. An E-cosmetic function for digital images based on physics and physiologically-based image processing was proposed by Tsuruma et al. (Tsuruma, 2004). Other extension and improvement have been reported in (Marschner, 1997)(Ramamoorthi, 2001)(Sato, 1994).

A Dynamic wrinkle model and skin aging was proposed by Wu and Thalmann (Wu, 1995). Another approach has been proposed by Boissieux et al. (Boissieux, 2000) to simulate skin aging and wrinkles with cosmetics insight. In this method texture mapping offers a good simulation of static wrinkles, but constructing visually interesting bump maps requires practice and artistic skills.

Although much work has been done in skin rendering, perception based model on description of skin does not exist because of the complexity. On the other hand there are no methods in which the texture image generates, then modified as a function for skin rendering. In this paper, a texture analysis/synthesis technique is used to change the amount of texture spatially then a Bidirectional reflectance distribution function texture magnitude is proposed to rendering effect. The results demonstrate realistic modelling and rendering of skin texture.

The original contribution of this paper compared with the previous mentioned work is given in terms of following advantages. First the proposed techniques are efficient in time complexity and simple to implement. Second they are local. By local we mean that we can generate different skin based on local noise. Third they provide a simple way to capture the skin surface details. Finally, the computations are fast enough for an interactive environment.

3 VISUAL PERCEPTION OF TEXTURE

Modelling of human skin has been known as an essential step of different problems. Based on this need many attempts have been done in this regard. On the other hand, the ability to delicate skin texture in computer graphics and virtual worlds depends partly upon the perception of textural consistency. The theory of texture perception attribute pre-attentive texture discrimination to differences in first-order statistics of stimulus features such as orientation, size and brightness of constituent elements.

The reason to describe particular aspect of visual perception like contrast is human vision sensitivity factor due to achieve realism in computer graphics. For instance a local contrast calculation produces contrast image that describe the response of ensemble of neuron to a particular spatial frequency and orientation. Contrast energy E is the square of the contrast function summed over the dimensions along which the stimulus varies (Pelli, 1999). For static two-dimensional stimuli, signal energy is generated over space:

$$E = \iint c^2(x,y)\,dx\,dy \qquad (1)$$

The contrast function is normalized derivation of the luminance function from the background level,

$$c(x,y) = \left[L(x,y) - L_b\right] / L_b \qquad (2)$$

We call them the channel images as they represent different channel of visual system.

Therefore visual sensitivity can be proportioned into observer efficiency and visual noise (Pelli, 1999). In this paper we generate noise texture and new technique on texture luminance to gain geometry of skin texture.

4 OUR PROPOSED ALGORITHM

The quest for improving realism is always an important goal of computer graphic and virtual world. Therefore current models of skin appearance are not sufficient to support the demands for fast algorithms. One major difficulty in skin perceptual appearance is the extreme complexity of real skin that exhibit many subtle variations over its entire surface. This section explores a new algorithm with two techniques for modelling and rendering of skin based on human perception. In this approach Perlin method is used to generate a 2D skin texture. Then we extract noise from texture by proposing BRDF texture magnitude. Finally skin texture will be generated. Figure 1 illustrates the steps of our proposed algorithm.

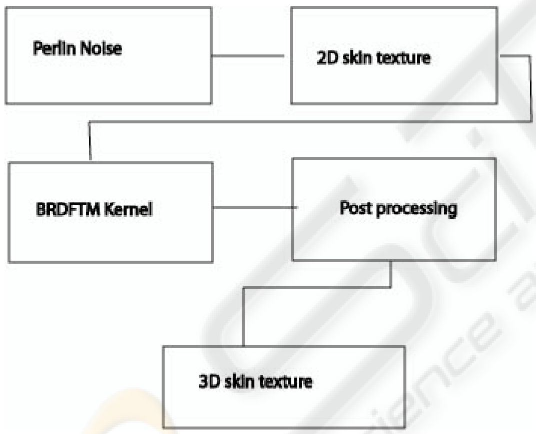

Figure 1: General structure algorithm outline.

4.1 Skin Rendering

Over the last few years, many construction of BRDF have been introduced in optics and in computer graphics literature (Kautz, 2004)(Kobbelt, 1997)(Marschner, 1999). This section focuses on rendering of skin texture. Our idea is derived from the geometry of bidirectional reflectance diffusion function BRDF and the concept of texture analysis/ synthesis in term of textures magnitude. In the followings we will summarize the fundamental definition and basic notation of BRDF, texture magnitude function and finally introduce our proposed technique.

4.2 Bidirectional Reflection Distribution Function

The bidirectional reflectance distribution function (BRDF) of a surface describes how light is scattered at its surface. Its value measures the ratio of the radiance L exiting the surface in a given direction to the incident irradiance I a particular wavelength λ from an incident solid angle $d\omega_i$ about a given illumination direction. The BRDF denoted by f_r is according to figure 2, as the following;

$$f_r(\theta_i,\phi_i;\theta_e,\phi_e,\lambda)=\frac{L_r(\theta_e,\phi_e)}{L_i(\theta_i,\phi_i)\cos\theta_i d\omega_i} \quad (3)$$

Where,

$$L_r = L_{r,s}(\theta_e,\phi_e)+L_{r,v}(\theta_e,\phi_e) \quad (4)$$

Is the reflected radiance which has two components, one is the reflected radiance due to the surface scattering $L_{r,s}$, and the other component $L_{r,v}$ is due to subsurface volume scattering. Therefore it has five variables but its domain is reduced somewhat by a symmetry called reciprocity. Reciprocity stated that reversing the light path doesn't change the reflectance, that is

$$f_r(\theta_1,\phi_1;\theta_2,\phi_2,\lambda)=f_r(\theta_2,\phi_2,\theta_1,\phi_1,\lambda) \quad (5)$$

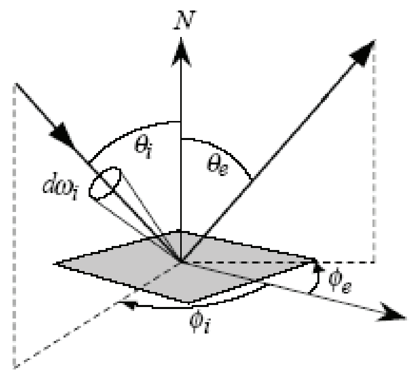

Figure 2: Geometry of surface reflection.

The units of BRDF are thus inverse steradians. It has been widely adopted where θ_i,ϕ_i are the incident zenith and azimuth angles and θ_e, ϕ_e are the corresponding reflection angles.

Intuitively the BRDF represents for each incoming angle, the amount of light that is scattered in each outgoing angle. For a Lambertian (perfectly diffuse) surface, for example, the BRDF is constant, and equal to $\frac{\rho}{\pi}$ where ρ is the diffuse reflection coefficient and the factor of π is necessary so that the BRDF is correctly normalized. From this point of view then for a diffused surface, skin texture can be rendered by texture magnitude that will explain in next section.

4.3 BRDF Texture Magnitude

Skin data collection is time consuming and tedious task. Therefore we generate texture using Perlin noise.

In this approach we do not need to have a lot of skin sample. The high spatial sampling of the generated texture used to determine the BRDF inherently enables extraction of the BRDFTM. Figure 3 illustrates 2D skin texture generated using Perlin noise. For example this 500 × 500 pixel textures has an average digital count for the R, G and B channels of 252, 215 and 190, this is proportional to the BRDF.

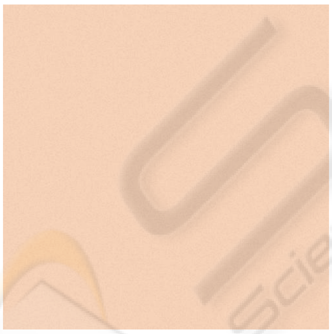

Figure 3: 2D skin generated texture.

We implement BRDF for texture magnitude be computed by convolution of the BRDF texture.

$$g[x,y] = \frac{1}{x^2} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} f[x,y]h[x-i, y-j] \quad (6)$$

Where f[x,y] is the texture and h[x,y] is a convolution kernel. The g[x,y] histograms use BRDFs texture data.

Therefore we made a new fast and empirical algorithm for skin texture rendering.

In this approach at first we make a texture using Perlin method. Since the texture colour ratio will be changed, we called it texture magnitude. Then we convert texture magnitude to BRDF average. We have colour dispersion when the RGB refraction indices are different. The difference in colour between the images correspond changes gives the texture magnitude, which can create complex shading.

The process of our algorithm yields skin images with fine appearance in a simple way. In this method we control the skin noise and skin surface, surface variation by adjust the noise range in texture. Therefore, by generating Perlin noise texture and proposing BRDFTM technique we generated skin surface based on visual perception. This modelling and rendering of human skin is fast and it is convenient for interactive environments.

5 EXPERIMENTAL RESULTS

In this section, we present some images from implementation of our proposed technique. Figure 4 demonstrates a virtual human with our skin texture generation algorithm.

We illustrate generated skin texture with near view in figure 5. The skin texture parameter contains 252,215,190 for R, G, and B. The period of Perlin noise in this image is 1.56 and limit of noise is 10. Figure 6. illustrates skin texture on more details.

In this approach at first we make a texture, change the colour ratio that we called it texture magnitude. Then we convert texture magnitude to BRDF average. Therefore by generating different skin noise texture, skin surface will be generated.

How ever our approach is not the exact rendering of human skin but it is fast and it is convenient for interactive environments. Figures show skin texture with more convincing appearance by proposed method.

Figure 4: Proposed skin rendering.

Figure 5: Skin texture.

Figure 6: Skin texture in more details.

6 CONCLUSION AND FUTURE WORK

Modelling and rendering of human skin texture are difficult task and challenging problem. Many different approaches have been proposed for human skin modelling and rendering. This paper presents a new and effective skin texture rendering. Two proposed techniques have been introduced one for empirical texture modelling and other for the rendering effects. The advantages of the proposed technique over previous method are given as follows. First, the proposed techniques are efficient in time complexity, simple to implement, and reliable in which they don't need to collect lot of data. Second they provide a simple way to capture the geometrical details founded in generated texture without any constraints and render them smoothly. Finally their computations are fast enough for an interactive environment. On the other hand the definition of skin texture appearance is a difficult task. It depends not only on the structure of skin but also so many aspects of one's life, including climatic, Psychology, and other parameters. Therefore for more realistic skin effect further research effort is needed. We would like to extend our algorithm based on spherical wavelets.

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