Realistic Human Face Rendering for "The Matrix Reloaded"

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Introduction

The ultimate challenge in photorealistic computer graphics is rendering believable human faces. We are trained to study the human face since birth, so our brains are intimately familiar with every nuance and detail of what human skin is supposed look like. The challenge of rendering human skin is further complicated by some technical issues such as the fact that skin is a highly detailed surface with noticeable features in the order of ~100 microns and the fact that skin is translucent. On *The Matrix Reloaded* we had to create completely photorealistic renderings for most of the principal actors including Keanu Reeves, Lawrence Fishborne, and Hugo Weaving.

Facial Surface Detail

The geometry used for our rendering was based on a 100-micron resolution scan of a plaster cast mold of the actors' faces. Arius3d provided the scanning technology. These scans had extremely high polygonal counts (10 million triangles; see Fig. 1). To use these models in production and preserve the detail we deployed the following technique. A low-res ~5K quad model was constructed using Paraform software. The model was given a UV parameterization and then used as a subdivision surface. The high resolution detail was extracted using the lightmapping feature of the mental ray renderer combined with custom shaders that performed ray tracing from the low-res subdivision surface model to the high-detailed 10M triangle raw scan; the distance difference is stored in a displacement map. We applied the low frequency component of this map as displacement; the high frequency component was applied using bump mapping.

Image-based Derivation of Skin BRDF

Our skin BRDF was derived using an image-based approach. In Summer 2000 as part of the early stages of *Matrix Reloaded* R&D we had a setup, which consisted of 30 still cameras arranged around the actor's head. Actors were photographed illuminated with a series of light sources from different directions (see Fig. 2). The setup was carefully color calibrated and photogrammetry was used to precisely reconstruct the camera positions and head placement with respect to each camera for each image. The collected image data from each camera was brought into a common UV space through reprojection using a cyberscan model of the actor. This convenient space (see Fig. 3) allowed us to analyze the skin reflectance properties for many incident and outgoing light directions. We derived parameters for an approximate analytical BRDF that consisted of a Lambertian diffuse component and a modified Phong-like specular component with a Fresnel-like effect. (We would like to acknowledge Matthew Landauer for his contributions to this section).

Subsurface Scattering of Skin

As production progressed it became increasingly clear that realistic skin rendering couldn't be achieved without subsurface scattering simulation. There are a number of published methods for rendering translucent materials however they are all fairly complex, require large amounts of CPU power and produce somewhat disappointing results. To address this we developed a technique for producing the appearance of subsurface scattering in skin that is computationally inexpensive and fairly easy to implement. The result of the diffuse illumination reflecting off the face in the camera direction is stored in a 2-d light map (see Fig. 4). We then approximately simulate light diffusion in the image domain. To simulate the different mean free path for different light colors we vary the diffusion parameters for each color channel. For animations the lightmap needs to be computed at every frame, so our technique computes an appropriate lightmap resolution depending on the size of the head in frame. For objects like ears where light can pass directly through, we employed a more traditional ray tracing approach to achieve the desired translucency effect.

Results

The above components are combined with our Universal Capture, real world Lighting Reconstruction technologies, and a ray tracer such as mental ray to produce the synthetic images in Fig. 5 and 6. For comparison Fig. 7 shows a photograph of Keanu Reeves (Neo). The bottom image is a fully virtual frame from *The Matrix Reloaded*.