Anatomically Accurate Modeling and Rendering of the Human Eye

Guillaume François
IRISA - France Telecom R&D
gfranco@irisa.fr

Pascal Gautron
France Telecom R&D
pascal.gautron@orange-ftgroup.com

Gaspard Breton
France Telecom R&D
gaspard.breton@orange-ftgroup.com

Kadi Bouatouch
IRISA
kadi@irisa.fr

Figure 1: Human Eye Cloning: (a) Eye picture captured with polarizing filters to avoid corneal reflections, (b) Result using our rendering technique, (c) Closeup rendering of the iris showing the relieves of the stromal layer.

Introduction

Recovering anatomical features of organic materials is a challenging issue. The human eye, as an important part of the non-verbal communication, needs to be accurately modeled and rendered to increase the realism of virtual characters. The recent improvements of the graphics hardware offer the opportunity of rendering complex organic materials, following correct anatomical properties. We propose a novel method that allows to recover the iris structure and scattering features from a single eye photograph. In this aim, we developed a method to unrefract iris photographs. We model the iris using the Subsurface Texture Mapping representation [François et al. ] which allows to describe the relieves of the human iris. Finally, we introduce a refraction function for accurate real-time rendering of the eye, accounting for the refraction of the light at the corneal interface.

Human Eye Cloning

In [Lam and Baranoski 2006], an accurate method is proposed for computing subsurface scattering within a human iris using the anatomical and physical properties of its layers. However, this method does not take into account the irregularities of the iris relief, such as the crypts of Fuchs for instance. Our approach proposes to recover such relieves using iris photographs. Since the iris is overlaid and refracted by the cornea and aqueous humor, a photograph does not describe the real topography of the iris and needs to be preprocessed. More precisely, the iris image must be unrefracted by minimizing the optical path of the light starting at every point on the iris surface and arriving at the camera. Once the iris picture is unrefracted, we use its grey scale values to create a height field representation of the stromal layer. The thickness of the iris can be divided into two categories: its global and local thicknesses. The global thickness of the human iris varies along the radius of the iris. It can be easily measured using microscopical by ultrasounds. Since we do not want to use such a complex system of capture, we use the generic data presented in [Pavlin and Foster 1994] to model the global thickness of the iris. We make the assumption that the light scatters more in regions of the iris where the thickness is important, and scatters less in the regions where the thickness is small. Consequently, on an iris photograph, the lighter regions correspond to thicker parts of the iris stroma whereas the darker ones correspond to thin parts of the stroma. Furthermore, due to light scattering, the real relieves are “blurred” in the photograph and may appear larger than they are in reality. To compensate for this lack of information, we filter the height field, sharpening the iris details.

We recover the scattering parameters with a simple user interface focusing on the stromal and posterior epithelium layers. The user can also modify the thickness of these layers in real time. The computation of light refraction through the cornea up to a point \( P \) on the iris is computationally prohibitive. To overcome this problem, we define a refraction function, \( f_r(P, \omega) \), which, for a given point \( P \) on the iris and a given direction \( \omega \), gives the correct refraction direction \( \omega' \). The cornea being symmetrical around the z axis, the refraction function only needs to be estimated on a single radius of the iris. Therefore, we sample a radius of the iris and compute the refraction function for each sample point \( P \) and for \( N_{dir} \) incoming directions of its upper hemisphere. This allows a real-time and accurate estimation of the single scattering within the iris layers.

Results and Conclusion

Using a GPU implementation of our rendering method, a high frame rate of 60 fps has been obtained for a resolution of 1280 × 1024 with a dual Geforce 7900GTX graphics card. Optometrists often use a biomicroscope, or slit lamp, to see the different parts of the eye in extensive detail. We proposed a friendly and affordable human eye cloning method, using a simple digital camera and classical macro lens. We also take advantage of polarizing filters to avoid the light reflections on the cornea. Our refraction function significantly accelerates the rendering. We believe that this function can have multiple applications for other rendering issues. Future work will focus on integrating a more accurate estimation of the scattering parameters. We will work on an iterative method to recover the respective densities of the eumelanin and pheomelanin pigment in the stromal layer. This iterative search could be initialized with generic parameters given by [Lam and Baranoski 2006]. We would also like to extend our method to the rendering of non human eyes.

References
