# Practical Measurement-Based Spectral Rendering of Human Skin

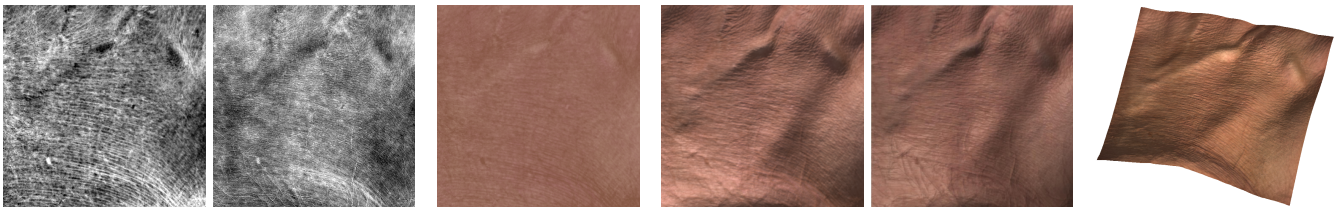
Yuliya Gitlina
Imperial College London

Daljit Singh J. Dhillon
Imperial College London

Jan Hansen
University of British Columbia

Dinesh K. Pai
University of British Columbia

Abhijeet Ghosh
Imperial College London



(a) Melanin (b) Hemoglobin (c) Diffuse albedo (d) Rendering (e) Photo (f) PBRT rendering

**Figure 1:** *(a, b) Normalized melanin and hemoglobin maps respectively for the back of a hand obtained using Antera 3D camera. The chromophore concentrations vary from low (dark) and high (lighter) values. (c) Planar surface rendered as a linear combination of four basis chromophore concentrations. The spatially varying diffuse texture results from bilinear interpolation of basis renderings with the measured chromophore concentrations acting as blending weights. (d, f) Interpolated rendering of skin patch using actual hand geometry. These renderings match subjectively well with the photo (e) captured using Antera 3D camera. (f) was rendered with a different pose and illumination in comparison to (e).*

## CCS CONCEPTS

• **Computing methodologies → Reflectance modeling**;

## KEYWORDS

Human skin, subsurface scattering, image-based realistic rendering

**ACM Reference Format:**
Yuliya Gitlina, Daljit Singh J. Dhillon, Jan Hansen, Dinesh K. Pai, and Abhijeet Ghosh. 2018. Practical Measurement-Based Spectral Rendering of Human Skin . In *Proceedings of SIGGRAPH '18 Posters.* Vancouver, Canada, *August 12 - August 16, 2018* , 2 pages. DOI: 10.1145/3230744.3230795

## 1 INTRODUCTION

Realistic appearance modeling of human skin is an important research topic with a variety of application in computer graphics. Various diffusion based BSSRDF models [Jensen et al. 2001, Donner and Jensen 2005, Donner and Jensen 2006] have been introduced in graphics to efficiently simulate subsurface scattering in skin including modeling its layered structure. These models however assume homogeneous subsurface scattering parameters and produce spatial color variation using an albedo map. In this work, we build upon the spectral scattering model of [Donner and Jensen 2006] and target a practical measurement-based rendering approach for such a spectral BSSRDF. The model assumes scattering in the two primary layers of skin (epidermis and dermis respectively) can be modeled with relative melanin and hemoglobin chromophore concentrations respectively. To drive this model for realistic rendering, we employ measurements of skin patches using an off-the-shelf Miravex Antera 3D camera which provides spatially varying maps of these chromophore concentrations as well as corresponding 3D surface geometry (see Figure 1) using a custom imaging setup.

We employ this data to implement a practical approximation of spatially varying subsurface scattering in PBRT using the [Donner and Jensen 2006] model. True heterogeneous subsurface scattering in skin has previously been proposed by [Donner et al. 2008] who employed a more complex spectral scattering model involving an additional absorption layer and additional chromophore parameters. Instead, we chose the simpler two layer model of [Donner and Jensen 2006] in this work because of ease of mapping available measurements of chromophore concentrations to model parameters, and achieve pseudo spatial variation in the final rendered result through spatially varying linear combinations of a few basis homogeneous subsurface scattering renderings.

## 2 OUR APPROACH

In order to render spatially varying subsurface scattering, we employ physically measured melanin ($\hat{C_m}$) and hemoglobin ($\hat{C_h}$) concentration maps acquired using a Miravex Antera 3D camera. Antera 3D is an off-the-shelf medical imaging device which can also measure the 3D surface geometry for real skin patches ($5 \times 5cm^2$) besides their chromophore concentrations. This is done by the device using a combination of cross polarized photometric stereo for surface shape estimation and multi-spectral illumination to extract the chromophore data.

The next step is to map the measured normalized chromophore concentrations to the parameters of the spectral BSSRDF model. We


*SIGGRAPH '18 Posters, August 12-16, 2018, Vancouver, BC, Canada*

ACM ISBN 978-1-4503-5817-0/18/08.
DOI: 10.1145/3230744.3230795

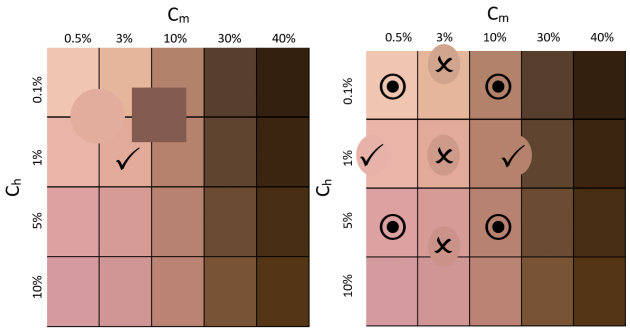
currently do this mapping empirically since we do not have access to the internal specifications of the device measurements. We first compute the average RGB color of the measured skin patch and subjectively find the closest mapping of this average RGB value in the 2D matrix of possible RGB skin colors given in [Donner and Jensen 2006] (see Figure 2). This indirectly provides us a mapping from the average measured chromophore concentrations for the skin patch to the corresponding model parameters in the 2D matrix. We first find the four nearest RGB values in the 2D matrix surrounding the given average RGB value of interest, and then scale the measured range of chromophore concentrations to the four bounding model parameter values corresponding to the four bounding RGB values. The final step of our method is to then approximate the individual RGB values of a specific pixel within the skin patch as a linear combination of the four bounding RGB values. For this, we employ the appropriately scaled measured chromophore maps as spatially varying weights for bilinear interpolation of the four basis chromophore values and convert from the interpolated parameter values to RGB using the spectral BSSRDF model. This is how we reconstruct the spatially varying RGB diffuse texture of the skin patch for rendering (Figure 1, c). We also tried our interpolation method for two more cases of open palm, as shown in Figure 3.

*Rendering Skin with PBRT.* Besides reconstruction of the diffuse albedo mapped on a flat surface, we employed the same bilinear interpolation mechanism to render a skin patch on a given 3D surface geometry with subsurface scattering according to the [Donner and Jensen 2006] model. We extended PBRT-v2 renderer, which natively supports subsurface scattering with dipole diffusion, and added multi-layered scattering functionality using the multipole diffusion approximation [Donner and Jensen 2005]. Instead of computing reflectance and transmittance profiles for epidermis and dermis separately on the fly, we precomputed the convolution of these profiles according to Kubleka-Munk theory [Kubelka 1954] and then passed that to PBRT for faster computation. The resulting RGB skin colors for chosen basis Cm and Ch values are computed using spectral sampling. We sample every 2nm from 400nm to 700nm and compute reflectance and transmittance profiles for each layer and selected wavelength. We then compute the convolution of the profiles in the frequency domain to generate final reflectance profiles for rendering. Final conversion from spectral to RGB space is done using CIE 1931 2-degree color matching functions.

We employ this rendering procedure in PBRT to separately render a given skin patch four times with the four different bounding basis parameter values of $C_m$ and $C_h$ and then finally interpolate the rendered images using the u-v mapping of the geometry to the measured chromophore concentration maps which act as weights of the interpolation. This approach was used for the rendering of the back of the hand in Figure 1.

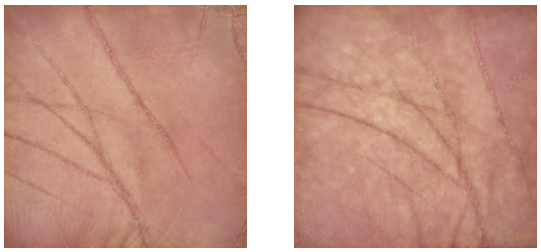
## 3 RESULTS AND FUTURE WORK

Our practical approximation approach for rendering skin with spatially varying subsurface scattering produce compelling results capturing fine skin features which qualitatively well match input photograph of the given skin patch. This includes spatial variation due to blood flow in a clenched palm seen in Figure 3. Our next goal is to formalize the parameter mapping and interpolation method




(a) Subjective tone matching (b) Interpolation

**Figure 2:** *Bilinear interpolation of the diffuse component for human skin coloration due to subsurface scattering.*



(a) Relaxed (b) Clenched

**Figure 3:** *Bilinear interpolation of the diffuse component for a palm patch. Sections of the clenched palm look paler/redder than the relaxed one due to blood rushing away from or into respectively from neighboring areas.*

for arbitrary geometry and chromophore maps with mathematical rigor and consistency and compare the quality of our approximation against ground truth simulations with path tracing. It would also be of an interest to test our approach not only for small patches of skin but for an entire face or hand for example. For this purpose, we plan to develop our own image-based acquisition method for estimating spatially varying melanin and hemoglobin concentration maps for larger skin sample areas and compare our estimates to those obtained using a biomedical device such as Antera 3D.

## ACKNOWLEDGMENTS

This work was funded by an EPSRC Early Career Fellowship (Grant No. EP/N006259/1 for A. Ghosh) and in part by NSERC Idea-to-Innovation grant, ICICS, Canada Foundation for Innovation, NSERC Discovery grants, and the Canada Research Chairs Program.

## REFERENCES

Jensen, H. W., Marschner, S. R., Levoy, M., and Hanrahan, P. 2001. A practical model for subsurface light transport. In Proceedings of ACM SIGGRAPH 2001, 511-518.

Donner, C., and Jensen, H. W. 2005. Light diffusion in multi-layered translucent materials. ACM Trans. Graphic. 24, 3, 1032-1039.

Paul Kubelka, "New Contributions to the Optics of Intensely Light-Scattering Materials. Part II: Nonhomogeneous Layers*," J. Opt. Soc. Am. 44, 330-335 (1954).

Donner, C., and Jensen, H. W. 2006. A spectral BSSRDF for shading human skin. In Rendering Techniques, 409-417.

Donner, C., Weyrich, T., Deon, E., Ramamoorthi, R., and Rusinkiewicz, S. 2008. A Layered, Heterogeneous Reflectance Model for Acquiring and Rendering Human Skin. In Trans. on Graphics (Proc. SIGGRAPH Asia), Vol. 27, 10:1 10:12.