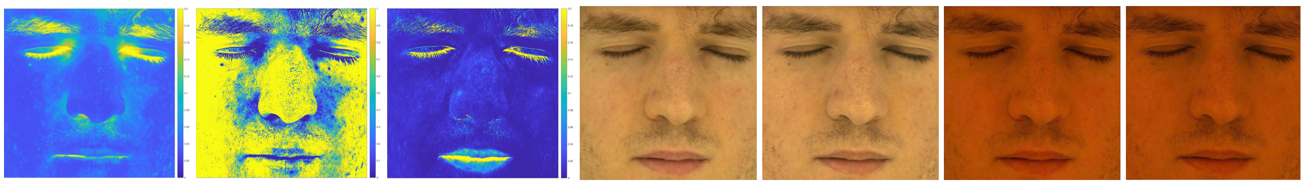
Practical Measurement and Modeling of Spectral Skin Reflectance

Yuliya Gitlina
Imperial College London

Daljit Singh Dhillon
Clemson University

Giuseppe Claudio Guarnera
NTNU

Abhijeet Ghosh
Imperial College London



(a) C_m (b) β_m (c) C_h (d) D57: photograph (e) D57: rendering (f) D27: photograph (g) D27: rendering

Figure 1: Estimated spectral parameters for a face $(a - c)$ and the predicted skin reflectance under various illumination spectra. (a) Melanin concetration C_m. (b) Melanin blend type β_m. (c) Hemoglobin concentration C_h. (d, e) Photograph-rendering comparison under D57 illumination. (f, g) Photograph-rendering comparison under D27 illumination.

CCS CONCEPTS

• **Computing methodologies → Reflectance modeling**;

KEYWORDS

Human skin, spectral imaging, computational photography

ACM Reference format:
Yuliya Gitlina, Daljit Singh Dhillon, Giuseppe Claudio Guarnera, and Abhijeet Ghosh. 2019. Practical Measurement and Modeling of Spectral Skin Reflectance. In *Proceedings of SIGGRAPH '19 Posters, Los Angeles, CA, USA, July 28 - August 01, 2019,* 2 pages.
https://doi.org/10.1145/3306214.3338607

1 INTRODUCTION

Accurate modeling and rendering of human skin appearance has been a long standing goal in computer graphics. Of particular importance has been the realistic modeling and rendering of layered subsurface scattering in skin for which various bio-physical models have been proposed based on the spectral distribution of chromophores in the epidermal and dermal layers of skin [Donner and Jensen 2006; Donner et al. 2008; Jimenez et al. 2010]. However, measurement of the spectral parameters of absorption and scattering of light for such bio-phyisical models has been a challenge in computer graphics. Previous works have either borrowed parameters for skin-type from tissue-optics literature [Donner and Jensen 2006], or employed extensive multispectral imaging for inverse rendering detailed spatially varying parameters for a patch of skin [Donner et al. 2008]. Closest to our approach, Jimenez et al. [2010] employed observations under uniform broadband illumination to estimate two dominant parameters (melanin and hemoglobin concentrations) for driving a qualitative appearance model for facial animation.

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the owner/author(s).
SIGGRAPH '19 Posters, July 28 - August 01, 2019, Los Angeles, CA, USA
© 2019 Copyright held by the owner/author(s).
ACM ISBN 978-1-4503-6314-3/19/07.
https://doi.org/10.1145/3306214.3338607

(a) Photograph (b) Jimenez et al. (c) Proposed

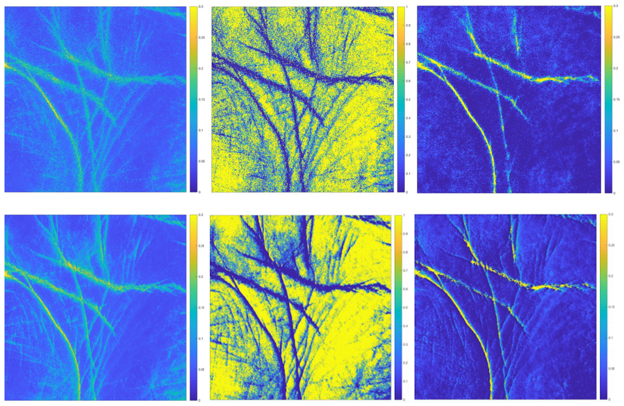
Figure 2: Comparison of a facial photograph under D57 illumination (a) to reconstruction using the spectral model of Jimenez et al. [2010] (b), and reconstruction using our proposed model (c).

In this work, we propose a practical simplification of the complex spectral model of Donner et al. [2008] that we demonstrate to have sufficient complexity to match photographs of skin under various illumination spectra (see Figure 1), as well as a practical measurement approach for driving the model that is suitable for facial appearance capture of live subjects (Section 2). We demonstrate that the our proposed model complexity is required to match subject photographs, which may not be possible using just a two parameter model such as [Jimenez et al. 2010], and our proposed measurement protocol combining two different and complementary spectral illumination conditions (broad band D57 + narrow band blue $480nm$ peak response) provides higher quality estimates of spectral parameters than those obtained with just broadband illumination. Thus, our work proposes an optimal measurement/modeling complexity trade-off for reproducing spatially varying spectral appearance of skin.

2 METHOD

2.1 Spectral Model

Starting from the detailed spectral model of Donner et al. [2008], which has been shown to accurately model spatially varying appearance of skin, we empirically simplify the model complexity such that the reduced model can still well reproduce the spatially



(a) C_m (b) β_m (c) C_h

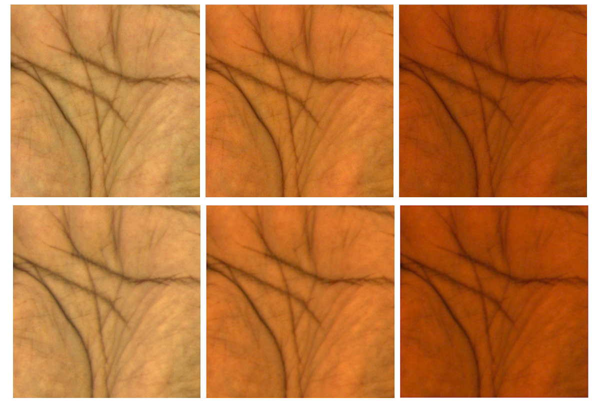
Figure 3: Estimated spectral parameters for a palm. Top-row: Using just broad band D57 illumination. Bottom-row: Joint-estimation using broad band D57 + narrow band blue LED illumination.

varying appearance of real skin. Our reduced model includes the two dominant parameters of melanin (C_m) and hemoglobin (C_h) concentrations, but we also found that the melanin blend type parameter β_m (blend between eumelanin and pheumelanin) needs to be varied over the skin surface in order to closely match the appearance of real skin. Our model also includes epidermal hemoglobin fraction C_{he} which we found to be necessary to match the very reddish areas of a face such as the lips. However, we empirically fixed C_{he} to be a constant fraction (0.6) of dermal hemoglobin C_h and hence do not need to independently estimate this parameter.

Figure 2 shows comparison of a facial photograph under uniform D57 illumination and its reconstruction using the simplified spectral model of Jimenez et al. [2010] with only two free parameters (C_m and C_h), and reconstruction using our proposed model with additional free parameter (β_m). As can be seen, our proposed model complexity allows a closer match to the spatially varying appearance of skin in the photograph.

2.2 Measurement Protocol

We now present our practical measurement protocol for robustly estimating the above three parameters with a minimal set of measurements suitable for live subjects. Note that Jimenez et al. [2010] employed a single observation with a color camera under uniform broadband illumination to estimate C_m and C_h. In our work, we employ a multispectral LED sphere equipped with a combination of narrow band Red, Green, and Blue LEDs, and three types of broad band LEDs (D27, D40, and D57) and a color camera for measurements. The LEDs on the sphere are all cross-polarized w.r.t. the camera allowing specular cancellation. With this setup, when we restricted ourselves to a single observation (as a baseline), we found the best illumination condition for estimating model parameters to be D57 illumination (which is closest to the flash illumination employed by Jimenez et al.). Here, the D57 illumination provided the highest color contrast in the skin reflectance for parameter estimation using CIELAB color matching (given a pre-computed 3D look-up table under D57 illumination). However, we found improved parameter estimation when using two different and complementary spectral illumination conditions: broad band D57 + narrow band blue LED illumination (480nm peak response). The premise here is that the blue illumination primarily only excites epidermal reflectance, while D57 illumination excites both epidermal and dermal reflectance. Note that we employ CIELAB measurements with the camera under D57 illumination, while restricting the measurements to the blue channel of camera under blue LED illumination (for further spectral isolation). With this measurement protocol, we do a joint look-up table search for best matching CIELAB values under simulated D57 illumination and best matching blue channel response under simulated blue LED illumination. Figure 3 shows comparisons of parameter maps for a palm of a hand obtained using both approaches (single vs two complementary measurements). As can be seen, our proposed approach of two complementary spectral measurements enable higher quality parameter estimation with less noise and clearer spatial structure of chromophore concentrations which can then enable rendering of the palm under various target illumination spectra (see Figure 4).



(a) *D57* (b) *D40* (c) *D27*

Figure 4: Photographs (top-row) vs renderings (bottom-row) of the palm under uniform illumination with three different spectra. The renderings use the estimated parameters in Figure 3 (bottom-row).

ACKNOWLEDGMENTS

The work is supported by an EPSRC Early Career Fellowship EP/N006259/1 and by the Spectraskin project N-288670, funded by the Research Council of Norway.

REFERENCES

Craig Donner and Henrik Wann Jensen. 2006. A Spectral BSSRDF for Shading Human Skin. In *Proceedings of the 17th Eurographics Conference on Rendering Techniques (EGSR '06)*. Eurographics Association, Aire-la-Ville, Switzerland, 409–417. https://doi.org/10.2312/EGWR/EGSR06/409-417

Craig Donner, Tim Weyrich, Eugene d'Eon, Ravi Ramamoorthi, and Szymon Rusinkiewicz. 2008. A Layered, Heterogeneous Reflectance Model for Acquiring and Rendering Human Skin. *ACM Transactions on Graphics (TOG)* 27, 5 (Dec. 2008), 140:1–140:12.

Jorge Jimenez, Timothy Scully, Nuno Barbosa, Craig Donner, Xenxo Alvarez, Teresa Vieira, Paul Matts, Verónica Orvalho, Diego Gutierrez, and Tim Weyrich. 2010. A Practical Appearance Model for Dynamic Facial Color. *ACM Transactions on Graphics (TOG)* 29, 6 (Dec. 2010), 141:1–141:10.