Online Appendix to: Hyperspectral Modeling of Skin Appearance

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This online appendix contains values for certain model parameters (e.g., thickness, water content) associated with each skin layer, along with the concentration and absorption spectra of the absorbers employed in our simulations.
Please note that the reference list for this online appendix includes only those references that are not provided in the main article.

The absorption spectra of the light-absorbing materials employed in the simulations performed by the proposed hyperspectral skin appearance model (HyLIoS) are plotted in Figure 26. They are also provided in the supplementary video available in the ACM Digital Library.

As stated in the article, in order to evaluate the predictive capabilities of the proposed model, we have compared its results, provided as an independent unit of the rendering pipeline as proposed by Greenberg et al. [1997], with measured data and experimental observations reported in the literature. In the absence of measured skin characterization data for the specimens used in the actual experiments, the values assigned to the pigmentation parameters employed in the computation of the HyLIoS modeled curves (Tables III and IV) were selected based on the specimens' descriptions reported in the documents describing the actual experiments and the corresponding ranges for these parameters provided in the scientific literature. Accordingly, the datasets S1, S2, and S3 correspond to individual with relatively low levels of melanin pigmentation [Vrhel et al. 1994; Cooksey and Allen 2013] with average melanosome dimensions equal to $0.41\mu m \times 0.17\mu m$ [Olson et al. 1973], while dataset S4 corresponds to an individual with a high level of melanin pigmentation [Jacquez et al. 1955a, 1955b] with average melanosome dimensions equal to $0.69\mu m \times 0.28\mu m$ [Olson et al. 1973]. In the case of those comparisons involving BRDF data, the aspect ratio of the surface folds was set to 0.3 to approximate the description of the lightly pigmented individual whose measured skin BRDF [Marschner et al. 1999] was employed as a reference in the article.

The spectral refractive indices of the layers are computed using the Gladstone and Dale law [Tuchin 2007] considering their refractive indices (measured at 1300nm) specified in Table IV as well as the water content of each layer and the spectral refractive index of water provided by Palmer and Williams [1974]. We remark that the values assigned for most of the biophysical quantities (Table IV) employed in the formulation of the proposed model correspond to average values available in the literature that are not normally subject to change, and therefore can be kept fixed for the simulations.

As also noted in the article, we provide a prototype Web site [Natural Phenomena Simulation Group (NPSG) 2014] for HyLIoS. Through this Web site, researchers can specify simulation conditions (e.g., angle of incidence and spectral range), modify specimen characterization parameters, and obtain modeled skin spectral responses including those depicted in the quantitative spectral comparisons presented in the article. The standard version of this Web site depicts model parameters normally employed to characterize distinct skin specimens. Their default values were employed to generate the modeled reflectance curve associated with the dataset S3 indicated in the article. The values associated with datasets S1, S2, and S4 are presented in Table III. For consistency

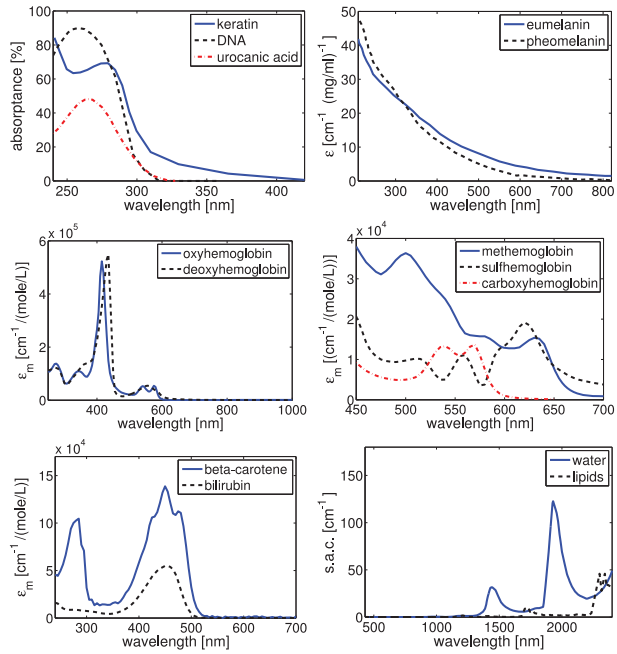

Fig. 26. Absorption spectra of the main absorbers acting within the skin tissues. Top left: absorptance curves for solid keratin over a distance of $4\mu m$ [Bendit and Ross 1961], $50\mu g/mL$ of DNA, and $15\mu mole/L$ of urocanic acid over a distance of 1cm [Sutherland and Griffin 1981; Young 1997; Clendening 2002; Oudhia 2012]. Top right: extinction coefficient (ε) curves for melanin [Jacques 2001]. Center left: molar extinction coefficient (ε_m) curves for functional hemoglobins [Prahl 1999]. Center right: molar extinction coefficient ε_m) curves for dysfunctional hemoglobins [Randeberg et al. 2004; Siggaard-Andersen et al. 1972; Yarynovska and Bilyi 2006]. Bottom left: molar extinction coefficient (ε_m) curves for beta-carotene and bilirubin [Prahl 2001]. Bottom right: specific absorption coefficient (s.a.c.) curves for water [Palmer and Williams 1974; Pope and Fry 1997] and lipids [Altshuler et al. 2003; Prahl 2004; van Veen et al. 2004].

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Table III. Four Sets of HyLIoS Parameters Employed to Characterize the Distinct Skin Specimens Considered in the Quantitative Comparisons Presented in this Work

Parameter	S1	S2	S3	S4	Source
Surface Fold Aspect Ratio	0.1	0.25	0.1	0.45	[Talreja et al. 2001; Magnenat-Thalmann et al. 2002]
Stratum Corneum Thickness (cm)	0.001	0.001	0.0004	0.0002	[Diffey 1980; Anderson and Parrish 1982]
Stratum Granulosum Thickness (cm)	0.0017	0.0033	0.0033	0.0007	[Robertson and Rees 2010]
Stratum Spinosum Thickness (cm)	0.0017	0.0033	0.0033	0.0007	[Robertson and Rees 2010]
Stratum Basale Thickness (cm)	0.0017	0.0033	0.0033	0.0007	[Shimizu 2007]
Papillary Dermis Thickness (cm)	0.02	0.01	0.02	0.023	[Anderson and Parrish 1981]
Reticular Dermis Thickness (cm)	0.1	0.1	0.125	0.2	[Anderson and Parrish 1981]
Stratum Granulosum Melanosome Content (%)	1.0	0.0	0.0	10.0	[Kollias et al. 1991; Lister 2013]
Stratum Spinosum Melanosome Content (%)	1.0	0.0	0.0	10.0	[Kollias et al. 1991; Lister 2013]
Stratum Basale Melanosome Content (%)	1.0	3.75	3.0	10.0	[Kollias et al. 1991; Lister 2013]
Stratum Granulosum Colloidal Melanin Content (%)	0.8	1.25	1.35	15.0	[Alaluf et al. 2002; Kollias et al. 1991; Pathak 1995]
Stratum Spinosum Colloidal Melanin Content (%)	0.8	1.25	1.35	15.0	[Alaluf et al. 2002; Kollias et al. 1991; Pathak 1995]
Stratum Basale Colloidal Melanin Content (%)	0.8	1.25	1.35	15.0	[Alaluf et al. 2002; Kollias et al. 1991; Pathak 1995]
Melanosome Eumelanin Concentration (mg/mL)	90.0	50.0	32.0	50.0	[Thody et al. 1991; Hennessy et al. 2005]
Melanosome Pheomelanin Concentration (mg/mL)	4.0	2.0	2.0	4.0	[Thody et al. 1991; Hennessy et al. 2005]
Melanosome Dimensions ($\mu m \times \mu m$)	0.41×0.17	0.41×0.17	0.41×0.17	0.69×0.28	[Olson et al. 1973]
Papillary Dermis Blood Content (%)	0.2	0.7	0.3	2.5	[Flewelling 2000; Jacques 1996]
Reticular Dermis Blood Content (%)	0.2	0.7	0.3	2.5	[Flewelling 2000; Jacques 1996]
Oxygenated Blood Fraction (%)	75.0	95.0	75.0	75.0	[Angelopoulou 2001]

Note that, in the absence of measured skin characterization data for the specimens used in the actual experiments, the values assigned to the pigmentation parameters employed in the computation of the modeled curves were selected based on the specimens' descriptions reported in the documents describing the actual experiments and the corresponding ranges for these parameters provided in the scientific literature. Accordingly, the datasets S1, S2, and S3 correspond to individuals with relative low level of melanin pigmentation [Vrhel et al. 1994; Cooksey and Allen 2013], while dataset S4 corresponds to an individual with a high level of melanin pigmentation [Jacquez et al. 1955a, 1955b].

Table IV. Set of HyLIoS Parameters Kept Fixed for the Simulations that Resulted in the Modeled Curves Depicted in Quantitative Comparisons Presented in this Work

Parameter	Value	Source
Stratum Corneum Refractive Index	1.55	[Tearney et al. 1995; Diffey 1983]
Epidermis Refractive Index	1.4	[Tearney et al. 1995; Tuchin 2007]
Papillary Dermis Refractive Index	1.39	[Tearney et al. 1995; Jacques et al. 1987]
Reticular Dermis Refractive Index	1.41	[Tearney et al. 1995; Jacques et al. 1987]
Melanin Refractive Index	1.7	[Bashkatov et al. 2000]
Hemoglobin Concentration in Whole Blood (mg/mL)	147.0	[Lovell et al. 1999; Flewelling 2000]
Methemoglobin Concentration in Whole Blood (mg/mL)	1.5	[Haymond et al. 2005]
Carboxyhemoglobin Concentration in Whole Blood (mg/mL)	1.5	[Cunnington et al. 2004]
Sulfhemoglobin Concentration in Whole Blood (mg/mL)	0.0	[Yarynovska and Bilyi 2006]
Whole Blood Bilirubin Concentration (mg/mL)	0.003	[Zucker et al. 2004]
Stratum Corneum Beta-carotene Concentration (mg/mL)	2.1E-4	[Lee et al. 1975]
Epidermis Beta-carotene Concentration (mg/mL)	2.1E-4	[Lee et al. 1975]
Blood Beta-carotene Concentration (mg/mL)	7.0E-5	[Lee et al. 1975]
Stratum Corneum Water Content (%)	35.0	[Agache and Humbert 2004; Nakagawa et al. 2010]
Epidermis Water Content (%)	60.0	[Agache and Humbert 2004; Viator et al. 2004]
Papillary Dermis Water Content (%)	75.0	[Agache and Humbert 2004; Viator et al. 2004]
Reticular Dermis Water Content (%)	75.0	[Agache and Humbert 2004; Viator et al. 2004]
Stratum Corneum Lipid Content (%)	20.0	[Williams et al. 1988]
Epidermis Lipid Content (%)	15.1	[Squier et al. 1991; Cerussi et al. 2001; Agache and Humbert 2004]
Papillary Dermis Lipid Content (%)	17.33	[Squier et al. 1991; Cerussi et al. 2001; Agache and Humbert 2004]
Reticular Dermis Lipid Content (%)	17.33	[Squier et al. 1991; Cerussi et al. 2001; Agache and Humbert 2004]
Stratum Corneum Keratin Content (%)	65.0	[Fuchs 1995; Shimizu 2007; Gawkrodger 2002]
Stratum Corneum Urocanic Acid Density (mol/L)	0.01	[Young 1997]
Skin DNA Density (mg/mL)	0.185	[Varcoe 2001; Agache and Humbert 2004; Flindt 2006]

The refractive indices for the skin layers were measured at 1300nm as reported in the listed sources.

with the related scientific literature, the range of certain parameters has been restricted in this prototype. The full set of model parameters, including those normally not subject to change for the simulations (Table IV), can also be accessed and modified in the extended version (which is linked from the standard version) of this Web site.

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