Snapshot mapping of skin chromophores at triple-wavelength illumination

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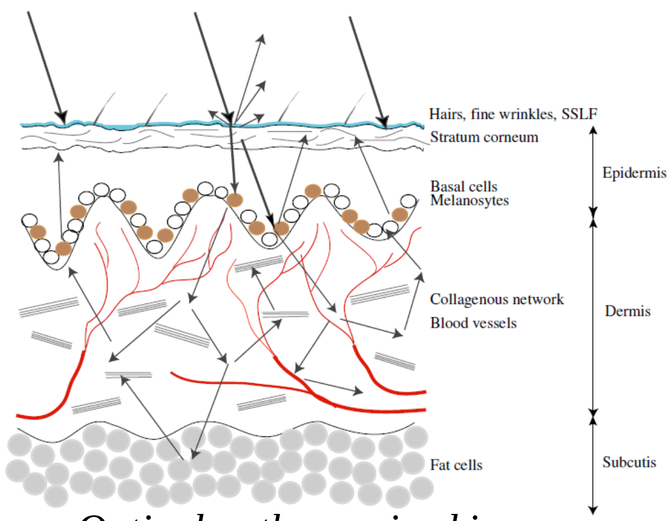
Introduction

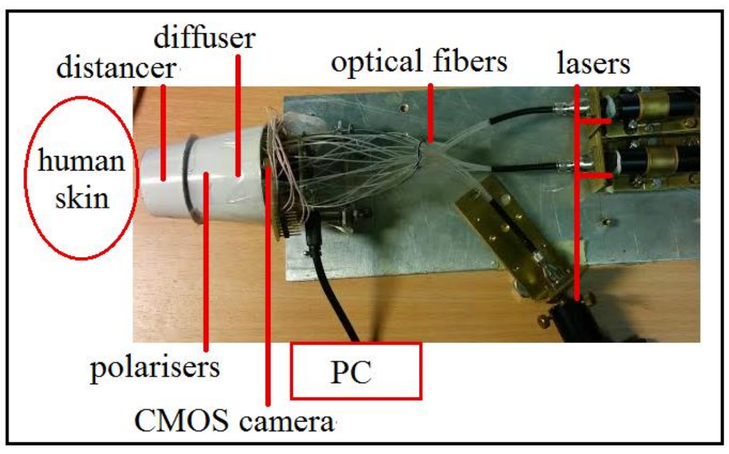
Skin chromophore distribution provides diagnostic information in cases of pigmented and vascular malformations, burns, bruises and other malformations. We propose a technique for immediate shapshot mapping of skin melanin, oxy-hemoglobin an deoxy-hemoglobin by means of RGB camera and illumination by three discrete spectral lines.

Methods



Optical pathways in skin.

When the light reaches skin, part of it is reflected at the surface. Another part of the light is absorbed by melanin in the epidermis or scattered by collagen fibers and absorbed by hemoglobin in the dermis.



The experimental setup

Monochromatic spectral images at the illumination wavelengths 473nm, 532nm and 659nm were extracted from single RGB image data set by separate registration of the R, G and B output values from each image pixel.

First we map spectral reflectance k_λ at three chosen wavelengths. Spectral reflectance is the ratio between the intensity of radiation reflected from the target at the specified wavelength I(λ) and the intensity of radiation, reflected at this wavelength from a non-absorbing white reference $I_0(\lambda)$.

Second we convert these three monochromatic images into distribution maps of skin oxy-hemoglobin, deoxy-hemoglobin and melanin. To do that we use system of 3 equations based on the Beer-Lambert law:

$$\begin{cases} c_a \cdot \varepsilon_a(\lambda_1) + c_b \cdot \varepsilon_b(\lambda_1) + c_c \cdot \varepsilon_c(\lambda_1) = -\dfrac{\ln k_1}{l_1} \\ c_a \cdot \varepsilon_a(\lambda_2) + c_b \cdot \varepsilon_b(\lambda_2) + c_c \cdot \varepsilon_c(\lambda_2) = -\dfrac{\ln k_2}{l_2} \\ c_a \cdot \varepsilon_a(\lambda_3) + c_b \cdot \varepsilon_b(\lambda_3) + c_c \cdot \varepsilon_c(\lambda_3) = -\dfrac{\ln k_3}{l_3} \end{cases}$$

c_i - relative concentration of the chromophore (a - oxy-hemoglobin, b - deoxy-hemoglobin, c - melanin),

$\varepsilon_i(\lambda_j)$ - extinction coefficient of the specified chromophore (i = a, b, c) at j-wavelength (1 = 473 nm, 2 = 532 nm, 3 = 659 nm),

k_j - spectral reflectance,

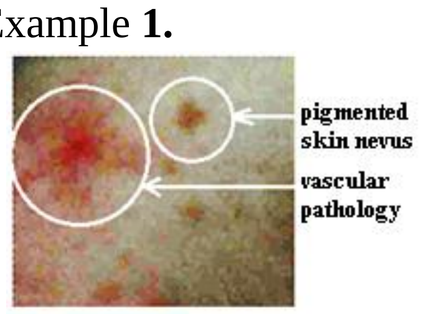
l_j - wavelength-dependent mean optical path length (j= 1, 2, 3).

Results

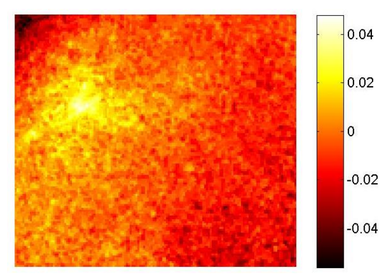
As a result, vascular pathologies showed notable changes in oxy- and deoxy-hemoglobin content, but practically unchanged melanin content. On the other hand, pigmented malformation area showed increased melanin content and unchanged oxy- and deoxy-hemoglobin content.

The color scales in images below represent chromophores concentrations measured 10^{-2}·mol/L .

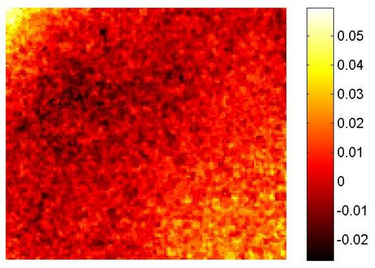
Example **1.**



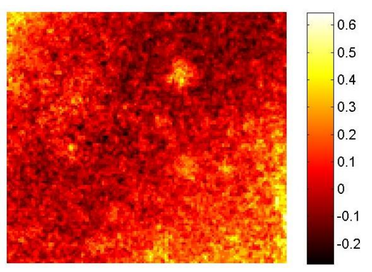
Skin nevus and vascular pathology image



Oxy-hemoglobin map

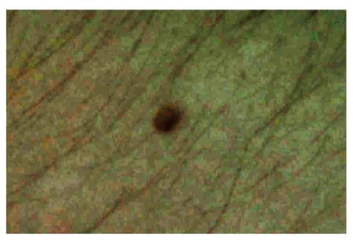


Deoxy-hemoglobin map

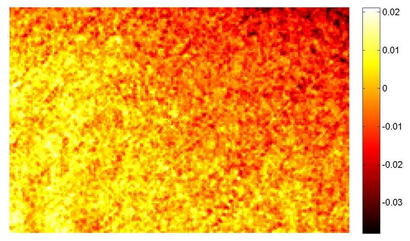


Melanin map

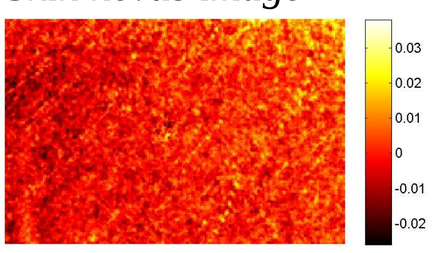
Example **2.**



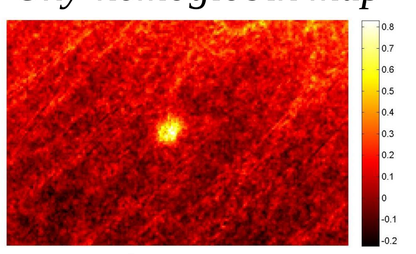
Skin nevus image



Oxy-hemoglobin map



Deoxy-hemoglobin map



Melanin map

Discussions

This method can be used in digital RGB cameras for fast and reliable express-diagnostics of skin by adding an adjusted poly-chromatic illumination source and appropriate software.

Acknowledgments

This work was supported by the European Regional Development Fund project "Innovative technologies for optical skin diagnostics" (#2014/0041/2DP/2.1.1.1.0/14/APIA /VIAA/015) and by the Latvian National research program SOPHIS under the grant agreement # 10-4/VPP-4/11.