Blind source separation of skin chromophores on a hyperspectral cube

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Background/Purpose

The ASCLEPIOS system developed by the M2D+ team of the Le2i laboratory (Université de Bourgogne, France) allows determination of a skin reflectance spectrum over the visible wavelength range in each pixel of a 2D image, thereby generating a hyperspectral (3D) cube. Reflectance spectra mainly result from the reflectance of two skin chromophores, epidermal melanin and dermal haemoglobin. A source separation method was applied on the mixed reflectance spectra, resulting in two component spectra for melanin and haemoglobin, respectively. We also obtained through this process quantification of each chromophore in each pixel of a 2D skin image. The accuracy of the pure source spectra obtained was validated by comparison with the theoretical spectra of each chromophore [1]. In vivo assessment of the 2D quantification of chromophores was performed on an image of a café-au-lait macule where only melanin accounts for the difference in pigmentation from normal skin.

Method

Independent component analysis [2] was used as a source separation method. Melanin is mostly found in the epidermis and haemoglobin in the dermis. Thus, melanin and haemoglobin reflectance spectra are assumed to be completely independent from each other. As the known source spectra are non-Gaussian, this criterion was exploited in the separation process. In order to handle the noise in the obtained melanin spectrum, a polynomial fit method has been established to obtain a source spectrum close to the theoretical one. Consequently, melanin quantification was re-estimated using a linear mathematical model. As 'café-au-lait' macules result from increased melanin production from a normal number of melanocytes in the basal epidermal layer, the proposed method was tested on a skin image of a 'café-au-lait' spot on lightly pigmented skin

Results

Source spectra obtained for melanin and haemoglobin were similar to their calculated theoretical spectra. The amount of melanin calculated from the 2D quantification process was significantly increased in the pigmented area as compared with normal skin. In contrast, haemoglobin quantification was almost uniform, irrespective of visible pigmentation.

Conclusions

We have developed a quantification method for skin chromophores such as melanin and haemoglobin using an algorithm for blind source separation from hyperspectral data. A café-au-lait macule could be clearly differentiated from normal skin based on its melanin content. Likewise, erythema intensity could also be quantified from haemoglobin content. Therefore, ASCLEPIOS device combined with our blind source separation method could allow non-invasive monitoring of pigmentation and erythema in a number of skin diseases.

References

[1] Data by S. Prahl and S. Jacques from website http://omlc.ogi.edu/spectra/.
[2] A. Hyvärinen, J. Karhunen, E. Oja, Independent Component Analysis, John Wiley, New York, 2001.