Decomposition of Skin Color Image

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Outline

- Objective
- Overview
- Optics of human skin
- Different decomposition methods of skin color image
- Experimental results and evaluation
- Conclusion and perspective

Objective

In-vivo studies in dermatology and cosmetic science need to quantify skin color, erythema or pigmentation objectively and can be relevant for melanoma diagnostic.

Overview

Imaging based methods include:

- RGB imaging (digital color image)
  - Absorbance spectra based method [H. Takiwaki, 2008]
  - HSV color model based method [D. H. Kim, 2006]
  - PCA and ICA based method [N. Tsumura, 1999]
- Multi-spectral imaging

Optics of human skin

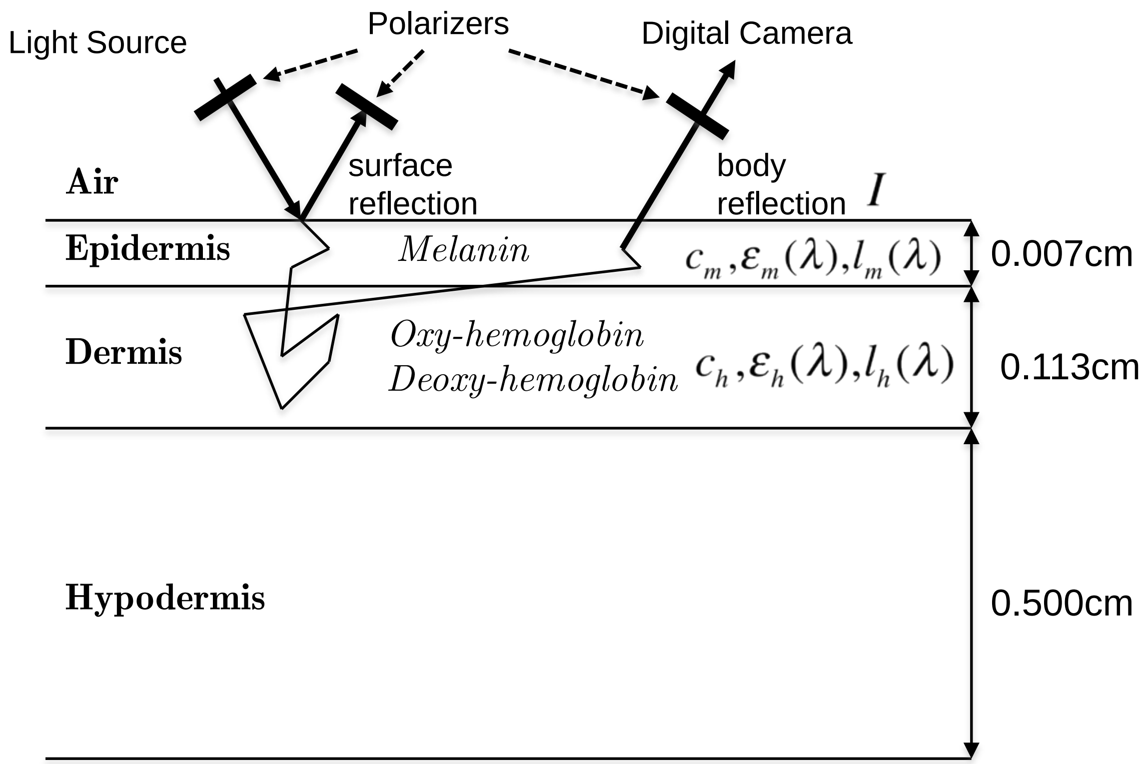


Fig.1. Schematic model of imaging process of three layered model of skin

Optics of human skin

Based on *Beer-Lambert law*, the absorbance A_λ of this skin model at a wavelength λ is expressed as

$$A_\lambda = \log(1/R_\lambda) = M_\lambda C_m + H_\lambda C_h + D \qquad (1)$$

where R_λ is the reflectance of the skin

M_λ and H_λ are coefficients depend on absorbance spectra of melanin and hemoglobin

C_m and C_h represent respective amounts of melanin and hemoglobin

D is apparent absorbance of the dermis

Optics of human skin

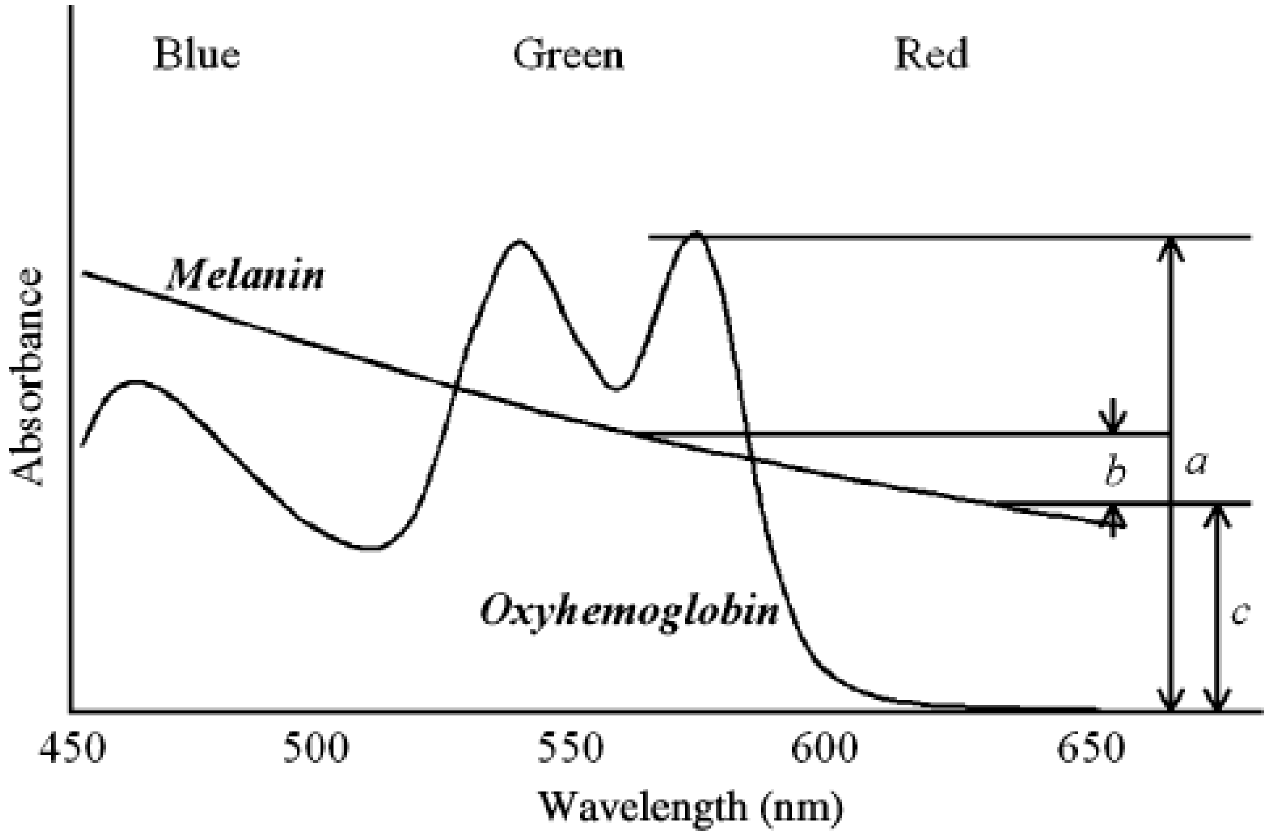


Fig. 2. Absorption spectra of melanin and hemoglobin and schematic conception of the erythema index (EI) and melanin index (MI) derived from images of the skin.

Takiwaki's method based on absorbance spectra of multi-layered skin model

Assume two wavelength, λ_1 and λ_2, equation (1) can be written as

$$A_1 - A_2 = (M_1 - M_2)C_m + (H_1 - H_2)C_h \qquad (2)$$

In RGB color image,

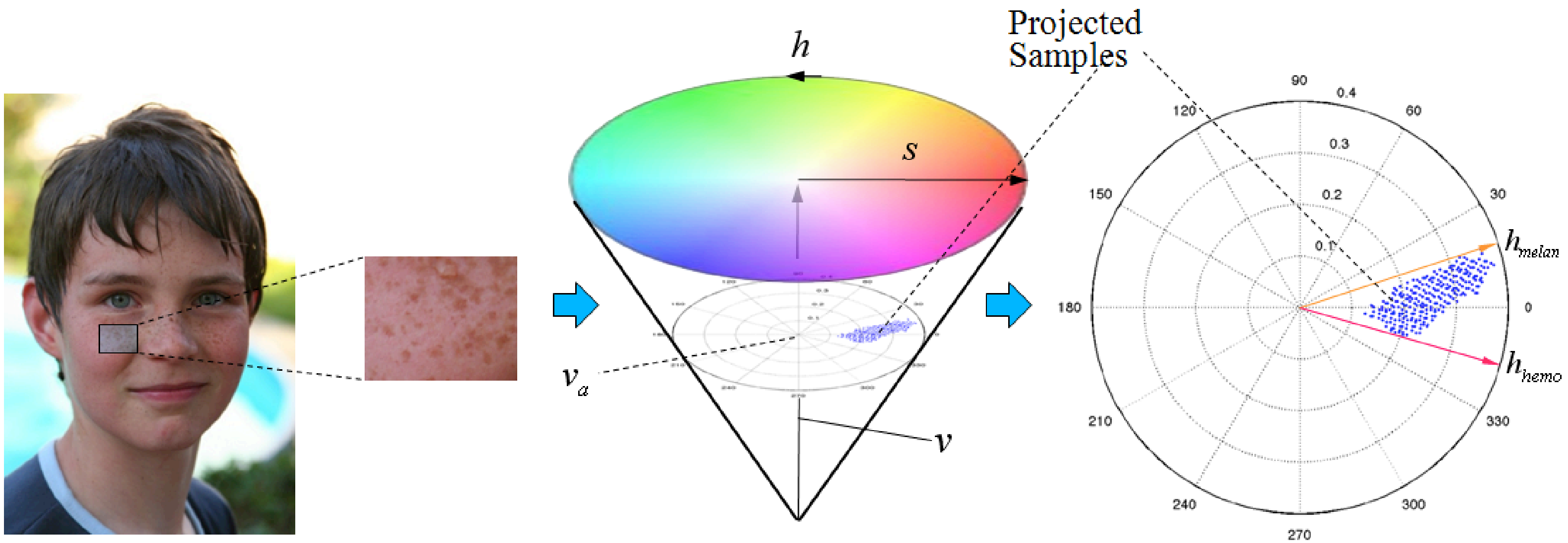
for EI, 'green band' for λ_1 , 'red band' for λ_2 then,

$$A_1 - A_2 = \log(1/R_{green}) - \log(1/R_{red}) \qquad (3)$$

for MI, 'red band' for both λ_1 and λ_2 then,

$$A = \log(1/R_{red}) \qquad (4)$$

Kim's method based on HSV color space



(a) Sampling Region (b) HSV Color Space (c) Circular Cross Section

Fig. 3. (a) User-selected sampling region. (b) Circular cross section, (h, s, v_a), computed by averaging brightness values of the sample. (c) Sample colors projected along the direction, (h_i, s_i, v_i) onto the circular cross section. Vector h_{melan}, h_{hemo} represent '*melanin*' and '*hemoglobin*' respectively.

Tsumura's method based on PCA and ICA

Four assumptions as prerequisites:

- Lambert-Beer law holds is applicable in the skin layer for incident light
- spectral distribution of skin is not abrupt in sensitive spectral range of each channel in imaging system
- spatial variations of color in the skin are cause by two pigments: melanin and hemoglobin
- these quantities are mutually independent spatially

Tsumura's method based on PCA and ICA

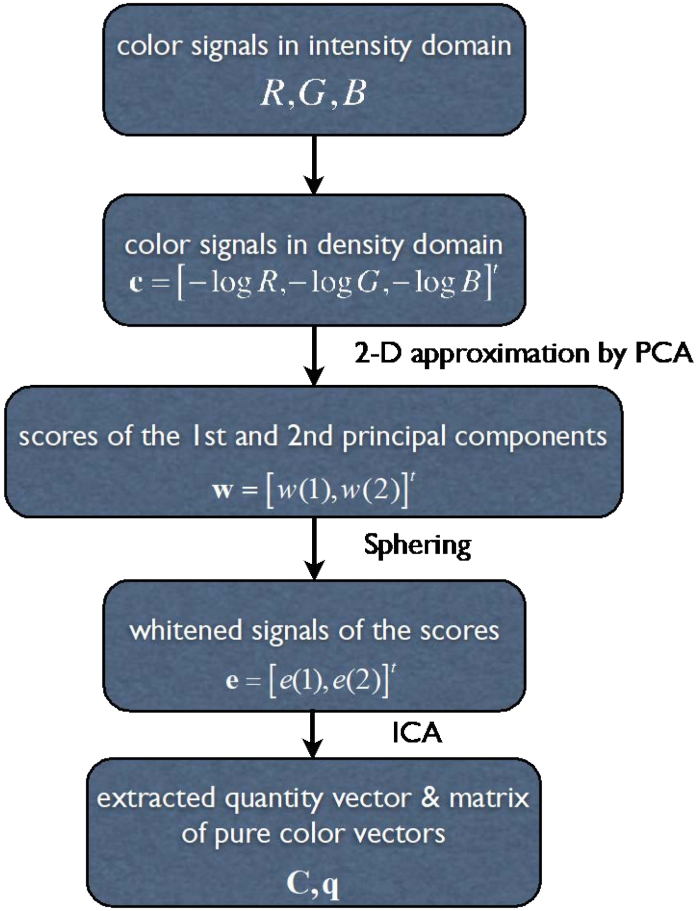


Fig. 4. Flowchart of preprocessing and ICA for a skin color image

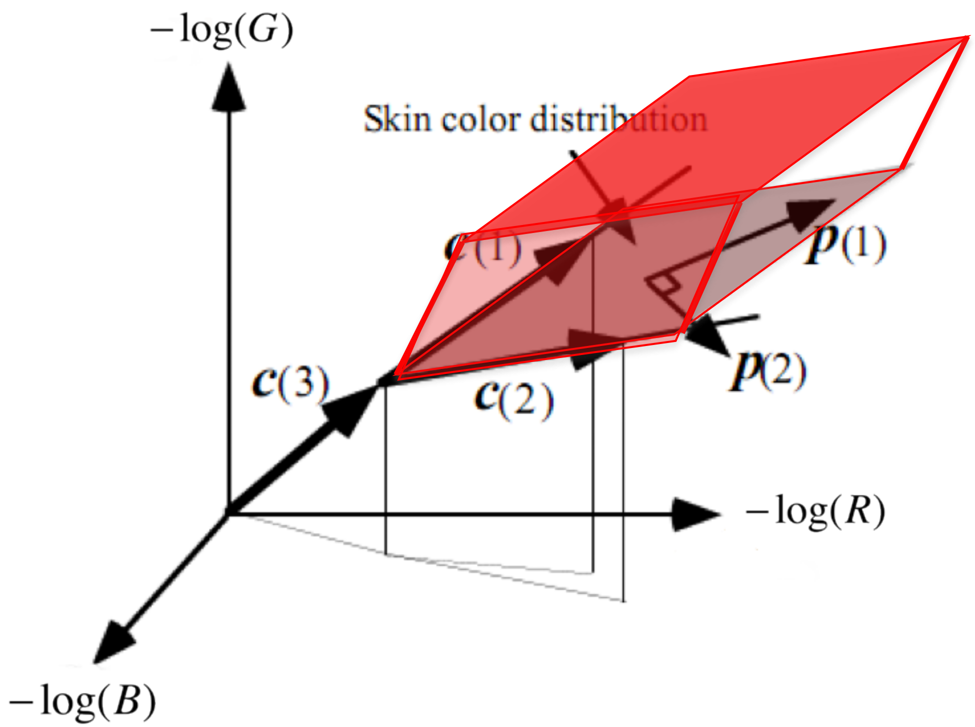


Fig. 5. Skin color model in the optical density domain

New method based on Tsumura's approach

- Normalized RGB color space

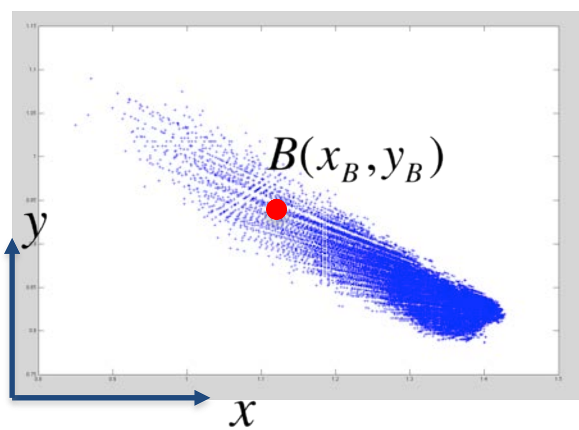
$$r = \frac{R}{R+B+G}, g = \frac{G}{R+B+G}, b = \frac{B}{R+G+B}$$

- Distribution in optical density domain

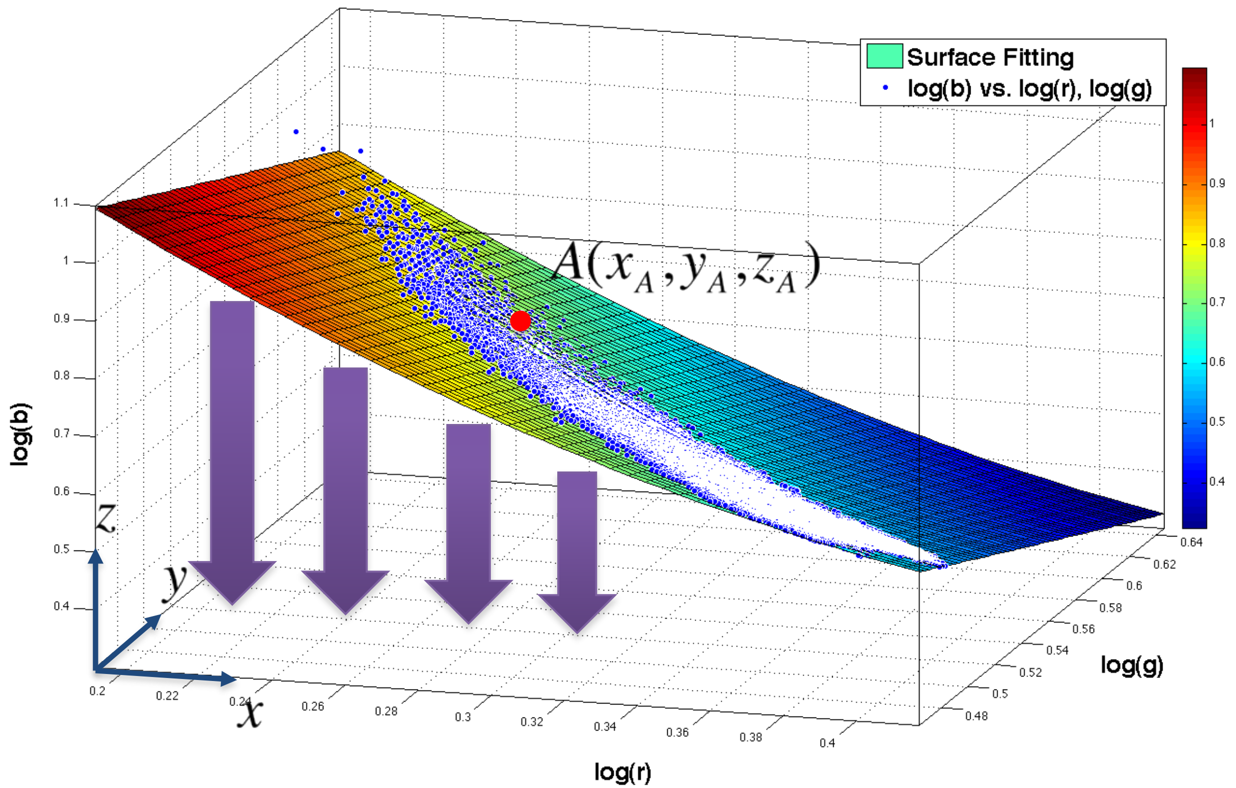
The distribution can be accurately described as
a second order polynomial functions:

$$\log b = c_1(\log r)^2 + c_2(\log g)^2 + c_3 \log r + c_4 \log g + c_5$$

New method based on Tsumura's approach



Flattened 2D plane



New method based on Tsumura's approach

$Point\ B(x_B, y_B)$ in the flatten 2D plane is a projection of $Point\ A(x_A, y_A, z_A)$ in the 3D optical density space.

The coordinate transformation between $A(x_A, y_A, z_A)$ and $B(x_B, y_B)$ can be expressed as:

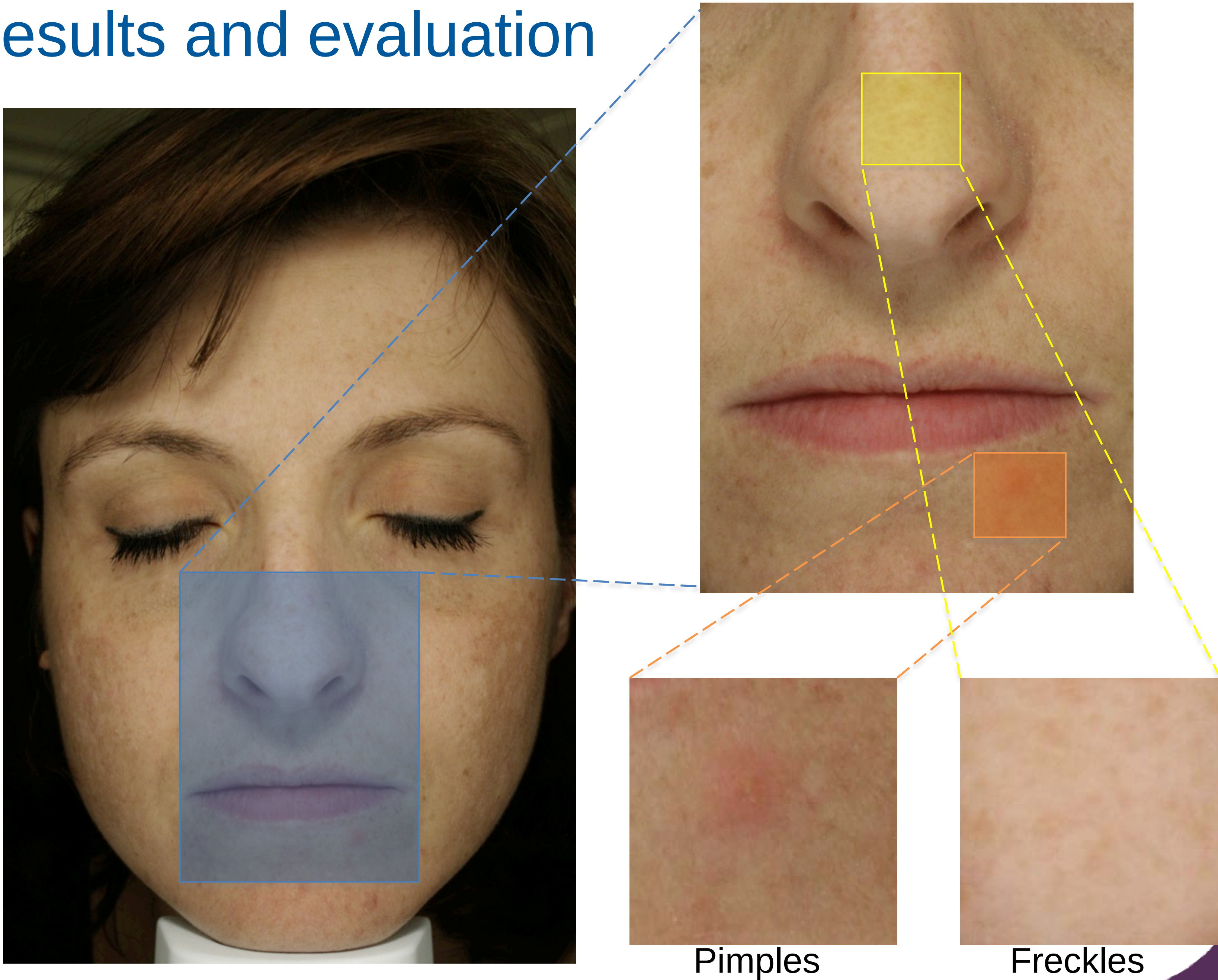
$$\begin{cases} x_B = dist_{geodesic}(A(x_A, y_A, z_A), P_1(0, y_A, c_2 y_A^2 + c_4 y_A + c_5)) \\ y_B = dist_{geodesic}(A(x_A, y_A, z_A), P_2(x_A, 0, c_1 x_A^2 + c_3 x_A + c_5)) \end{cases}$$

Results and evaluation

RGB imaging based method are useful in quantification on the perception of skin color, however, they provide relative index values rather than a standard (absolute measurements).

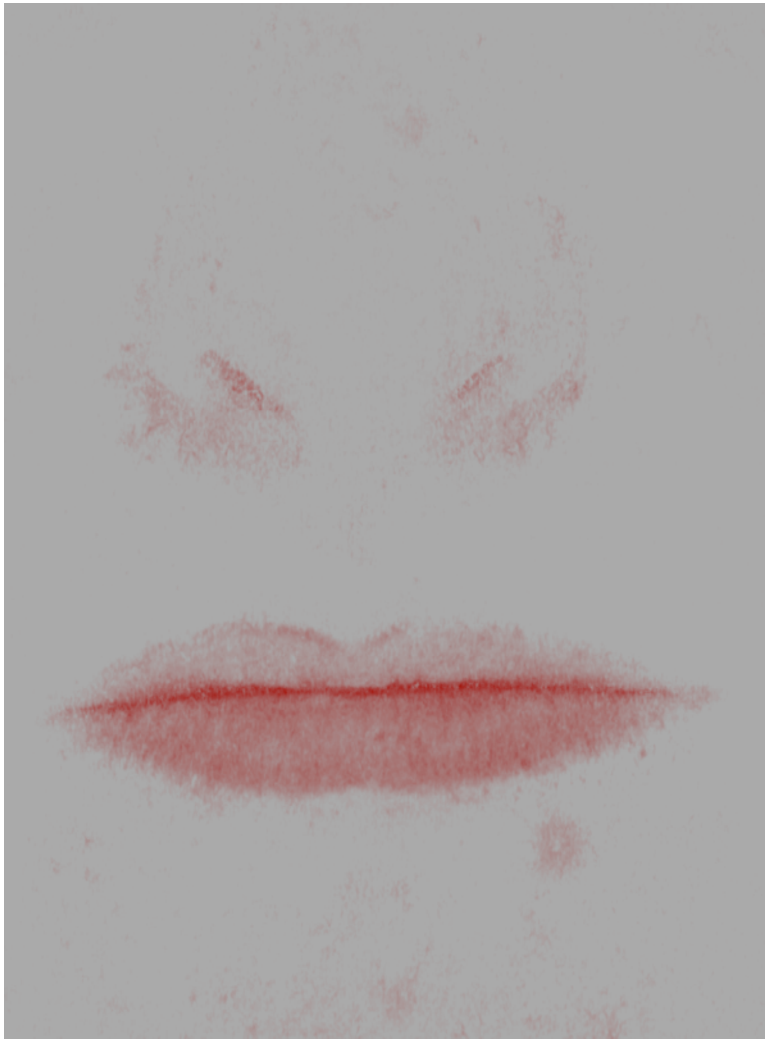
To evaluate the decomposition performs, we can refer to *pimple* and *freckle* as two physiological cues.

Results and evaluation



Results and evaluation

EI of Tsumura's method



EI of our method

Results and evaluation

EI of Kim's method

EI of Takiwaki's method

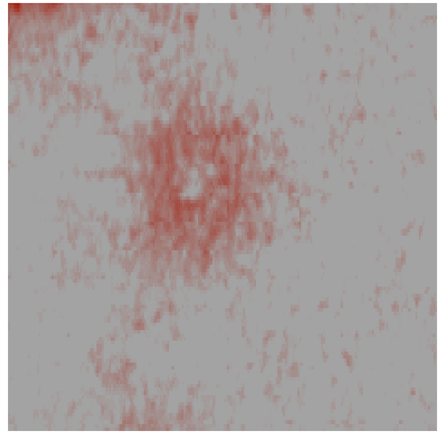
Results and evaluation

MI of Tsumura's method

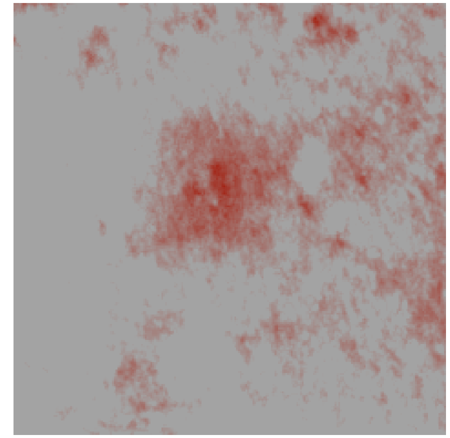
MI of our method

Results and evaluation

Pimples

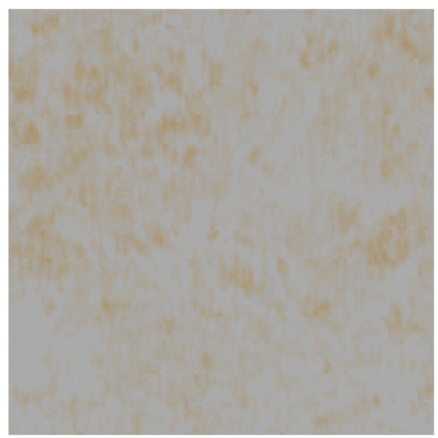


EI of our method



EI of Tsumura’s method

Freckles



MI of our method

MI of Tsumura’s method

Conclusion

Methods	Advantages	Disadvantages
Takiwaki's method	Ease of use; Objective assessment of intensity of pigmentation	Limited information; Possible artifacts
Kim's method	Relevant to color perception; Ease of use	Subjective results Possible artifacts
Tsumura's method	two-dimensional information	Small patches of ROIs only; Sensitive to shading effect
Our method	Invariant to illumination variation; Less sensitive to noise and shading effect	Limited information; Possible artifacts

Perspective

Although we can approximate pigment quantity by using methods that rely on skin reflectance measured at a few selected wavelength bands, more accurate quantification can be achieved when we collect detailed spectral data.

In the future, we will use multi-spectral imaging based method.

THANK YOU!