Examination on Pseudo-Spectral Color Reproduction of Facial Image Using Spectral Skin Color Palette

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Abstract

This paper introduces a simple idea of RGB to spectral image conversion without any expensive multi-spectral devices. A spectral reflectance with the closest colorimetric value to that of RGB pixel is picked up from the spectral palette and embedded in each pixel of RGB image. SVD (Singular Value Decomposition) compresses the high-resolution spectral image to a compact data. A conventional RGB camera image is transformed into a pseudo-spectral image and facial skin color appearance is estimated under different illuminants. The paper reports a facial color reproduction experiments using skin color palette extracted from JIS spectral data base SOCS and discusses the color accuracy after SVD compression with low dimensional parameters.

Introduction

Recently, the spectral imaging technology has been widely applied to simulate the color appearances under various illuminants in the field of medical diagnostics, cosmetic development, digital archive of fine arts, facial image recognition, etc. Since the multi-spectral system is expensive and hard to cope with both high spatial and high spectral resolutions, we proposed a simple method for RGB to multi-spectral image conversion without any expensive devices but with spectral palette [1],[2].

In this paper, we apply our basic idea to a facial color rendition using a spectral palette constructed from a typical set of skin color chips. An RGB facial image taken by a conventional digital camera is converted into the pseudo-spectral image and its skin color appearance is simulated under different illuminants. Although the estimated color appearance depends on the specified skin color palette, if suitable conditions are set up, it offers a cheap and simple multi-spectral simulator. This paper introduces an example of facial color appearance under typical fluorescent lamps and reports an evaluation result in the spectral reproduction accuracy after SVD (Singular Value Decomposition) to compress the amount of data. Fig.1 shows the outline of the propose system.

Pseudo-Spectral Skin Color Image

The pseudo-spectral facial image is created from the measured spectral skin color chips as follows.

Skin Color Spectral Palette

We constructed a spectral palette with a real skin color spectral reflectance data. At first, to verify the principle model, we used the spectral reflectance data picked from the specified facial areas (7999 colors) provided by JIS (Japan Industrial Standard) spectral database SOCS.

Each color samples consists of 31-dimensional spectral reflectance data measured in the 400-700 nm visible wavelength range at intervals of 10 nm as shown in Fig.2.

Conversion to a pseudo-spectral image

Prior to the conversion to a spectral image, spectral reflectance in spectral palette is saved as L*a*b* value of CIELAB color space as shown in Fig.3.

First, an sRGB tri-color image is transformed into L*a*b* image. Next, each sRGB pixel is replaced by the spectral chip with L*a*b* value closest to that of pixel in the palette as shown in Fig.4. Through this process, we obtain a pseudo-spectral image with 31-dimensional spectral reflectance embedded in each pixel position.

Since this substitution is performed to all pixels, we can

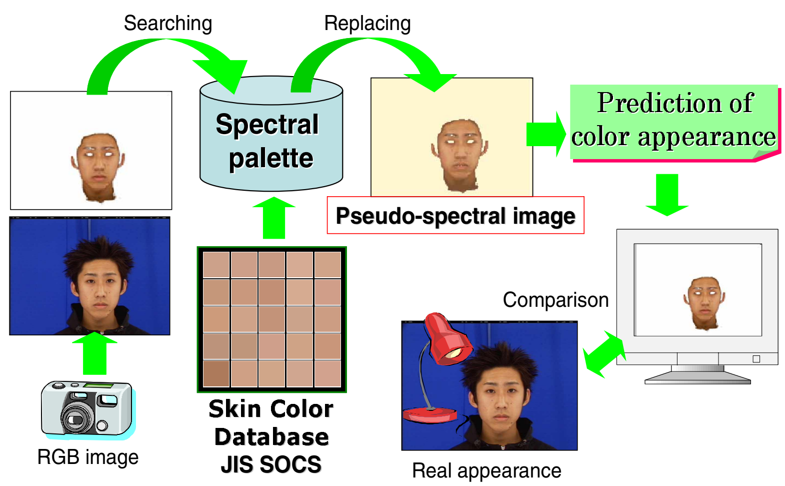


Figure 1. The outline of our system

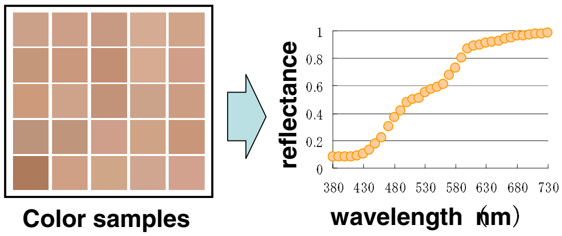


Figure 2. Color samples and 31-dimensional spectral reflectance

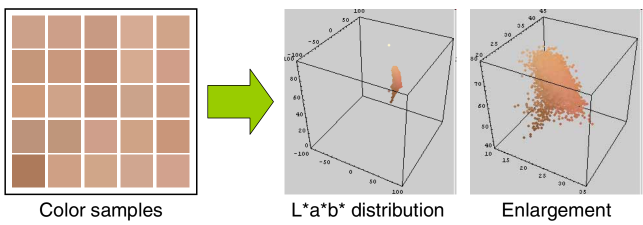


*Figure 3. Conversation to L*a*b* values*

obtain a pseudo-spectral image with the same spatial resolution as the original sRGB image keeping high spectral resolution.

Prediction of the color appearance under the different illuminants

In order to display the obtained pseudo-spectral image on a monitor, the XYZ tri-stimulus values of each pixel are calculated from the spectral reflectance with 1931 CIE color matching function by taking the spectral distribution of each illuminant into consideration as shown in Fig. 5.

Preparation of individual palette for test illuminant

Although the RGB camera image is taken under a different illuminant from the standard illuminant (normally D65) used for the spectral palette, the L*a*b* values between a pixel and the corresponding spectral chip should the matched under the same illuminant as shown in Fig. 6.

In order to search the matched spectral chip quickly, we created the plural sets of spectral palettes beforehand corresponding to the individual test illuminant as follows. Figure 7 shows the CIELAB color distributions of the 12 kinds of palette generated for the typical illuminants.

Palette Search Algorithm

As the number of color chips in a spectral palette increases, we can generate a pseudo-spectral image with high accuracy. On the other hand, the searching time for matched chip from a palette becomes longer inevitably.

To shorten the palette search time, we can omit the chips with larger color differences than a permissible range. Here the search area for a candidate is limited within the inside of a cube 2Δ on a side in the palette space corresponding to the near pixel location in attention. As a result, the color difference calculation could be limited for only about internal color chips inside the cube as shown in Fig. 8.

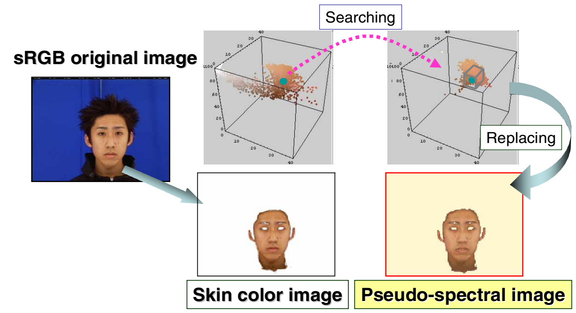


Figure 4. Conversion to pseudo-spectral image

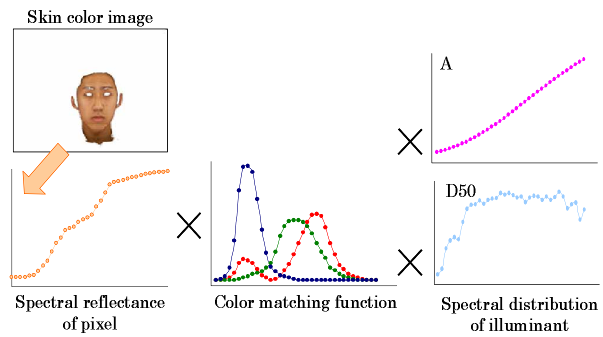


Figure 5. Conversation to 3 stimulus values with illuminant characteristic

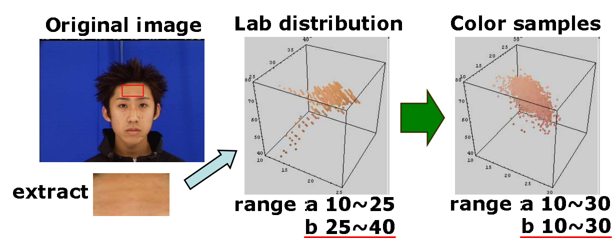


*Figure 6. Difference of L*a*b* gamut of an original picture image and that of color sample*

Spectral Image Compression by SVD

Since the pseudo-spectral image consists of the 31-dimensional spectral reflectance, the amount of data increases by about 10 times in comparison with the original sRGB image. To reduce the memory size, we introduced the data compression by SVD [3].

Prior to SVD, we divided the source image into a sub-block domain of M x M pixels and rearranged into the matrix R of M^2 pixels × 31 spectra which put the 31-dimensional spectrum reflectance of each pixel in order. Since the rearranged spectral sub-block is highly correlated spatially and spectrally, the effective compression is expected.

The spectral data in sub-block (m, n) is represented by SVD as

$$\boldsymbol{R}_{mn} = \left[r_{ij} \right]_{mn} = \boldsymbol{U}_{mn} \boldsymbol{\Lambda}_{mn} \boldsymbol{V}^{t}_{mn} \quad (1)$$

The columns of $\boldsymbol{U}_{mn}$ and $\boldsymbol{V}_{mn}$ are the eigenvectors of $\boldsymbol{R}_{mn}\boldsymbol{R}_{mn}{}^{t}$ and $\boldsymbol{R}_{mn}{}^{t}\boldsymbol{R}_{mn}$. $\boldsymbol{U}_{mn}$ and $\boldsymbol{V}_{mn}$, are $M^2 \times M^2$ and 31×31 square matrices, while $\boldsymbol{\Lambda}_{mn}$ is a $M^2 \times 31$ rectangular matrix with the singular values

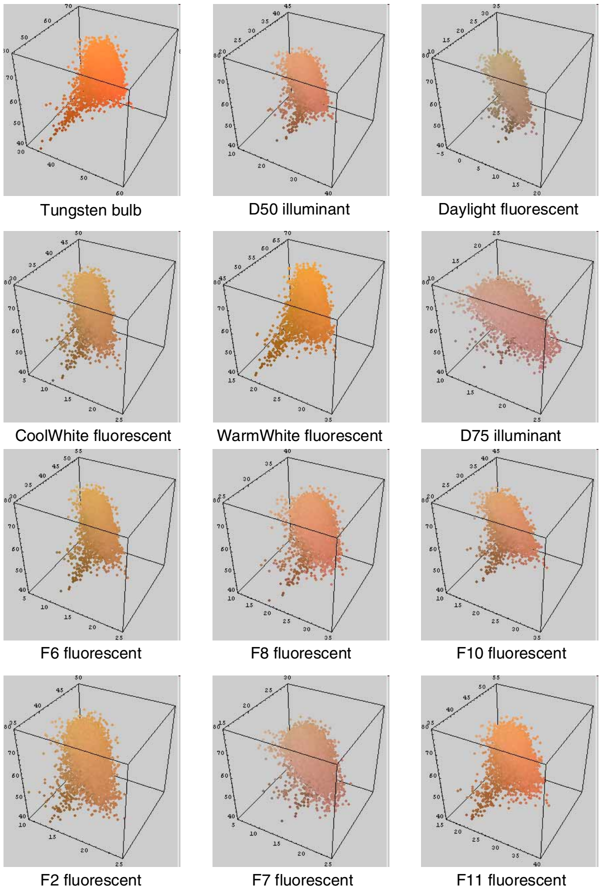


Figure 7. The spectrum palettes which correspond for every illuminants

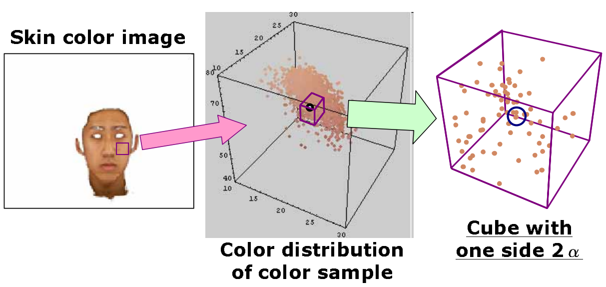


Figure 8. Algorithm of searching color sample

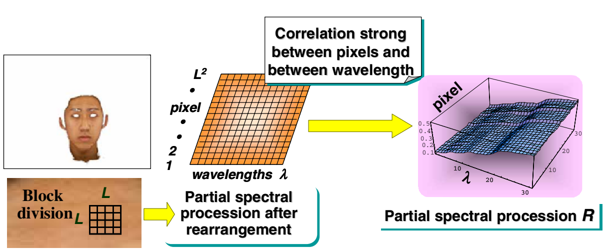


Figure 9. Construction of spectral reflectance procession

for $\mathbf{R}_{mn}$ along its diagonal. Since $\mathbf{U}_{mn}$ and $\mathbf{V}_{mn}$ are orthogonal, when $\mathbf{R}_{mn}$ has a maximum rank ($\mathbf{R}_{mn}$)=31 for $M^2 > 31$, a sub-block image $\mathbf{R}_{mn}$ is approximated by the reduced number of S (< 31) singular values $\hat{\boldsymbol{\Lambda}}_{mn}$ and the eigen vectors matrices of $M^2 \times S$ $\hat{\boldsymbol{U}}_{mn}$ and $S\times L^2$ $\hat{\boldsymbol{V}}_{mn}$ as

$$\hat{\boldsymbol{R}}_{mn} \cong \hat{\boldsymbol{U}}_{mn}\hat{\boldsymbol{\Lambda}}_{mn}\hat{\boldsymbol{V}}_{mn}{}^{t} \tag{2}$$

$$\hat{\Lambda} = \boldsymbol{U}^{t}\boldsymbol{R}\boldsymbol{V} = \begin{pmatrix} \lambda_1 & & & 0 \\ & \lambda_2 & & \\ & & \ddots & \\ 0 & & & \lambda_S \end{pmatrix} \quad (S < 31) \tag{3}$$

Thereby, the high-dimensional spectral image is approximated by a low dimensional SVD code data using a reduced number of singular values out of 31. Figure 9 shows the construction of the spectral reflectance procession.

Experimental Results

In order to validate the performance of our method, we perform a series of experiments. A sample image used in our experiments is shown in Fig.10. The sample belongs to HOIP face image database. The graph of Fig.10(c) expresses the L*a*b* color distribution of the skin color image.

Result of Conversion of Pseudo-Spectral Image

The original facial image and pseudo-spectral image constructed by the proposed method are shown in Fig.11. In the original image, there are some patches such as local gradation in a local region by the lighting shadow or direct reflection of an illuminant. For this reason, lack of the number of color chips causes the problem that the local region with patches will be replaced to a single color unnaturally. Figure 12 shows that the shadow under a chin is replaced to a single color. In order to solve

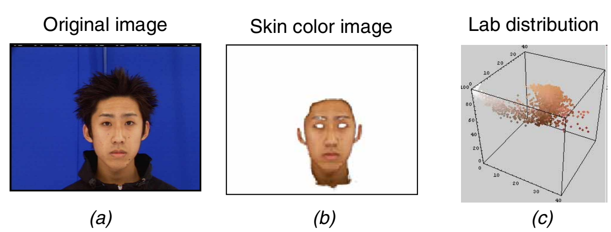


Figure 10. Sample face image of HOIP

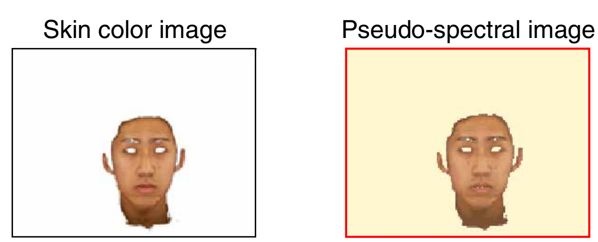


Figure 11. Creation of pseudo-spectral image

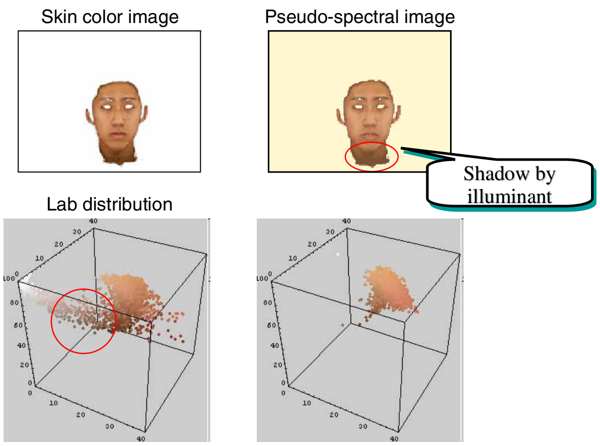


Figure 12. Effect of patches of shadow by the lighting at the time of photography hits

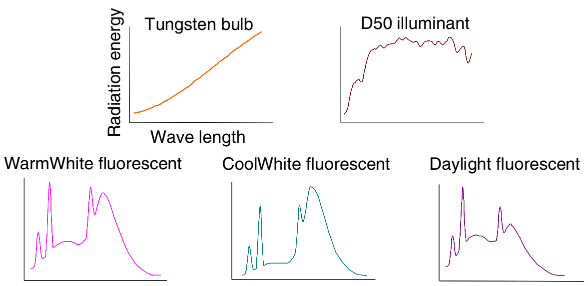


Figure 13. Spectral distribution of illuminants

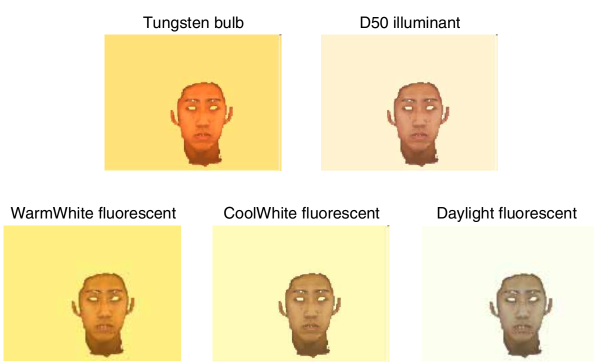
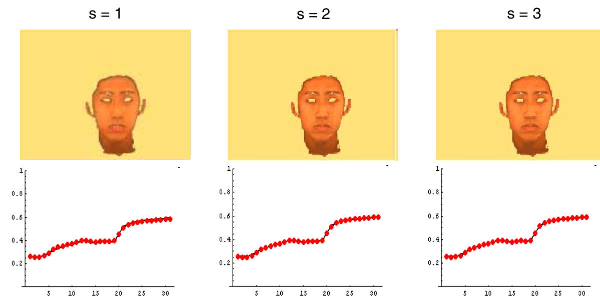


Figure 14. Simulation of illuminants

the problem, we have to extend the color domain of SOCS by increasing the number of color chips.

Simulation under Various illuminants

We performed the simulation by assuming the color appearance of a tungsten lamp, D50 illuminant and three kinds of fluorescent light with a spectral distribution of Fig.13. The results are shown in Fig.14. The single color problem described in the previous section also occurs under the chin. However, the color appearances reconstructed from pseudo-spectral image by SOCS palette look to be well matched to original facial color, although the delicate tonal changes in real camera are little bit lost due to the lack of chip number in palette.



Dotted line is reflectance after compression and solid line is that of no compression

Figure 15. Reappearance accuracy by SVD compression rate

Verification of Image Degradation by SVD Compression Rate

In this paper, we proposed the data compression technique by SVD. We verified the degradation of the image for the variable s in Eq.(3) which means the number of singular values used for restoration of data. Figure 15 shows the reconstructed facial skin spectrum from compressed SVD data for the reduced dimension s = 1,2,3. Since a human facial spectrum has a very slowly changing shape for the wavelength, it is well approximated by a few of low-dimensional principal components. A small error is observed in the case s = 1, but almost perfect reconstruction was possible for s = 2 or more.

Conclusion

In this paper, we proposed a facial color rendition technique by pseudo-spectral image using a spectral palette constructed from a typical set of skin color chips. Then skin color appearance was simulated under different illuminants. Moreover, we also reported an evaluation result in the spectral reproduction accuracy after SVD to compress the amount of data.

As future problems, we will verify the faithful generation of spectral image by improvement of color sample. A high speed algorithm will be also required to reduce calculation speed in searching procedure as increasing color sample.

References

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Author Biography

Sousuke Kagaya received his B.E. degree from Chiba University, Japan in 2005. Since 2005, he has been a graduate student in the Master's Program in Science and Technology of the same university. His research interest is pseudo-spectral imaging.