Real Time Visualization of Skin Pigment Distribution

Masahiro Nishibori[a], Ken Watanabe[b], Naofumi Tanaka[c], Shinichi Arakawa[d],

Yumi Chiba[e], Ayako Ninomiya[f], Norihide Sugano[g], Masaru Doi[h], Hiroshi Tanaka[i],

Mayu Komori[j], Kenji Kamimura[j], Toshiya Nakaguchi[j], Norimichi Tsumura[j], Yoichi Miyake[k],

Shin-ichiroh Kitoh[l], Po-Chieh Hung[l], Noriyuki Hashimoto[m]

[a] Department of Health Service Management, International University of Health and Welfare, JAPAN
[b] Dermatology, Yokosuka Municipal Hospital
[c] Operating Center, Tokyo Medical and Dental University Hospital
[d] Section of Periodontology, Tokyo Medical and Dental University Hospital
[e] Gerontological Nursing and Health Care System, Tokyo Medical and Dental University
[f] Fundamental Nursing and Life Support, Tokyo Medical and Dental University
[g] Vascular Surgery, Tokyo Medical and Dental University Hospital
[h] Department of Clinical and Molecular Endocrinology, Tokyo Medical and Dental University
[i] University Center for Information Medicine, Tokyo Medical and Dental University
[j] Department of Information and Image Sciences, Chiba University
[k] Research Center for Frontier Medical Engineering, Chiba University
[l] System Solution Technology R&D Laboratories, Konica Minolta Technology Center, Inc.
[m] R&D Visual Products, EIZO NANAO CORPORATION

Abstract

In morphological diagnosis, trained physicians compare medical findings with the typical case developed in their memory through experience of a sufficient number of similar cases with visual information coming into physicians' eyes that is always changing with time.

Based on this fact, with visualizing spectral information unrecognizable by naked human eyes, our system translates skin color captured by an ordinary three-band camera to distribution of melanin, hemoglobin and oxyhemoglobin in real time. The captured RGB raw image is converted into a spectral reflectance image by employing the Wiener estimation technique. Then the estimated reflectance spectra are used to calculate the distribution of those pigments of the skin.

In a preliminary experiment, professionals from a wide range of clinical fields pointed out various innovative uses of our system. Although numerical diagnostic methods using spectral information and equipment proper to multispectral imaging are still challenging targets for medical application, the impact of our approach will be no way inferior to them also.

Introduction

The spectral reflectance of skin and mucosa provides a lot of biological and medical information about the live human body. However, most current imaging systems record only a small part of this reflectance, and do so inaccurately. Therefore, a variety of new morphological diagnostic methods based on information not detectable by human sensation may be developed if the spectral reflectance of skin or mucosa can be recorded as a picture.

As one of promising applications, Tsumura et al. visualized the distribution of the three major skin pigments, melanin, hemoglobin and oxyhemoglobin by using the spectral reflectance of each pixel of a skin picture [1].

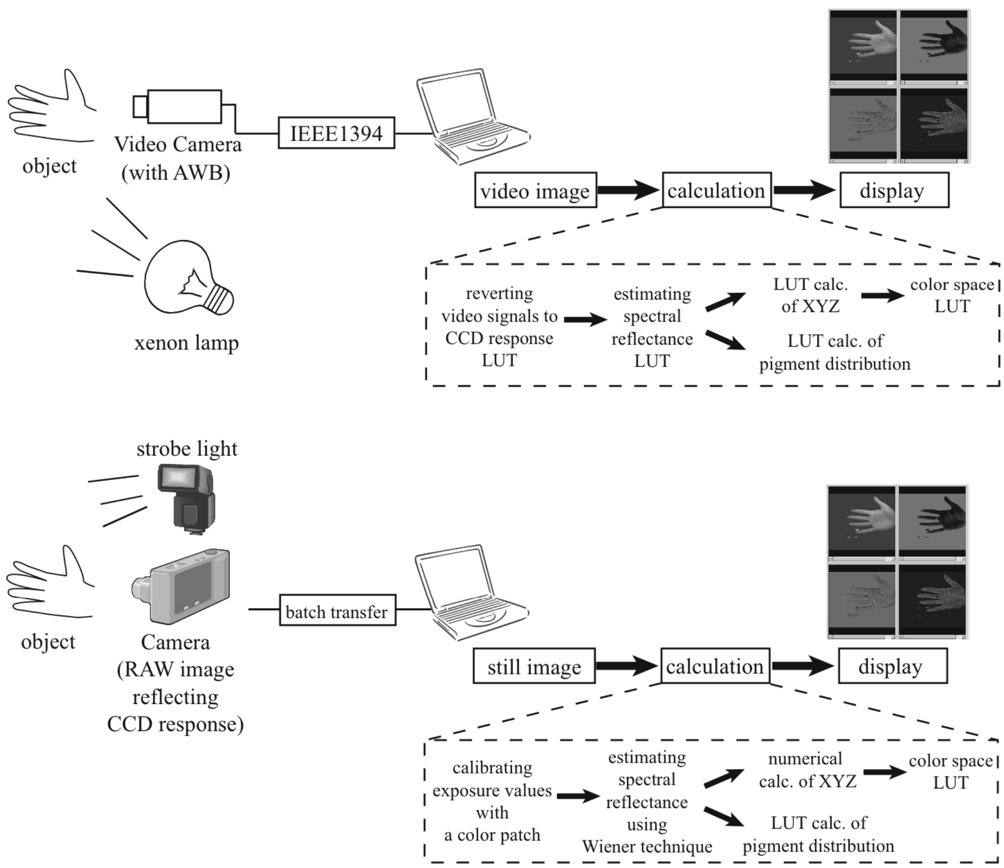
We developed an illuminant-independent color reproduction system for still image by using a multispectral imaging technique [2]. In this system, a RGB raw image captured an ordinary three-band still camera is converted into a spectral reflectance image by employing the Wiener estimation technique. The estimated reflectance spectra are converted into tristimulus values by using the spectral radiant distribution of the target illuminant.

With combining abovementioned two techniques, we developed a prototype system that translates skin color captured by an ordinary three-band still camera to distribution of melanin, hemoglobin and oxyhemoglobin. Once we inquired of healthcare professionals about clinical uses of the system, but the response was disappointing.

In morphological diagnosis, trained physicians compare medical findings not with the examples in the literature but with the typical case developed in their memory through experience of a sufficient number of similar cases with visual information coming into physicians' eyes, which is always changing with time like a video image and has much more amount of contents than a still image of the same resolution. This fact may be easily understood if you imagine how you identify a close friend among crowded people in an instant.

Therefore, in visualizing spectral information unrecognizable by naked human eyes, real time processing at the sacrifice of some accuracy would be much more effective for finding any morphological patterns common to a specific disease than providing elaborate still images.

Considering that, we evaluated clinical use of a modified version of the prototype system that translates skin color obtained by an ordinary three-band video camera to distribution of melanin, hemoglobin and oxyhemoglobin in real time.



The lower diagram is the prototype and the upper diagram is the modified one.

Figure 1. Overview of the systems.

Materials and Methods

System description

The prototype system was developed based on previously published methods (Fig. 1) [1][2].

In the prototype system, the skin image captured by a digital camera with flashes can be saved as RGB RAW images reflecting CCD response and the data is then transferred to a personal computer using USB interface or a flash memory card. The obtained RAW image is converted into a spectral reflectance image by employing the Wiener estimation technique [2]. Samples of skin reflectance spectra are used to prepare for the Wiener estimation. The relative concentration of each three major skin pigments, melanin, hemoglobin and oxyhemoglobin is calculated by using the estimated spectral reflectance of each pixel and is gathered to make up three kinds of still images of the same size for three pigments each [1].

Since the exposure value is difficult to control in the prototype system, a small color patch is attached on the skin. The white and black patch is used to adjust the exposure value and the black level to show the image on the display appropriately.

To this system, we made the following modifications (Fig. 1).

- a video camera equipped with automatic white balance (AWB) adjustment and automatic gain control was adopted as an input device and connected directly to a notebook computer by an IEEE1394 interface.
- omitting a color patch used to determine the exposure value.
- a continuous lamp was used as a light source for obtaining RGB raw video images.
- making full use of look up tables (LUT) and lowering accuracy of calculation from 12 bits to eight bits speeded up time-consuming routines.

The prototype system converts estimated reflectance spectra into tristimulus values also by using the spectral radiant distribution of the target illuminant. This function was given the same modification so as to run side by side with other functions, but was not evaluated this time.

Evaluation of healthcare professionals

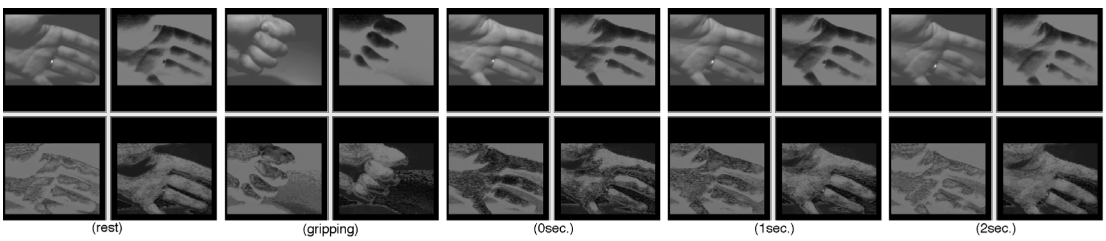
A group of healthcare professionals was shown demonstration of the modified system and was asked to evaluate possible uses of it in clinical practice. The specialties of the participants are laboratory medicine, dermatology, anesthesiology, periodontology, surgery, endocrinology and nursing.

Results

System performance

Each video image of pigment distribution was 640x480 pixels and displayed at about 18fps frequency with a delay of 0.4 second.

During demonstration, the change of distribution of each pigment by time after some event was almost compatible with known physiological phenomena. For example, when a person strongly clenched a fist for a while and unclenched it after that, decrease of oxyhemoglobin at his/her palm skin was recovered within one second, while recovery of hemoglobin took more than two seconds. The distribution of melanin was almost stable (Fig. 2).



Each frame consists of four windows; upper left: illuminant independent color reproduction, upper right: melanin, lower left: hemoglobin, lower right: oxyhemoglobin.

Figure 2. Changes in distribution of palm skin pigment by time after hand gripping.

Evaluation of healthcare professionals

They expected various innovative uses of our system such as:

- very early detection of latent decubital ulcers or latent diabetic gangrenes
- very early detection of latent hypoxia during anesthesia.
- detection of latent peripheral circulatory insufficiency
- monitoring circulation of transplanted skin grafts.

Most of them insist on the significance of the change of pigment distribution not only by regions but also by time after some event.

Discussion

Medical application of multispectral imaging includes various challenging targets such as numerical diagnostic methods using spectral information or equipment proper to multispectral imaging [3][4][5]. Compared to them, providing a video image is unique to our system and a preliminary needs study showed the impact of our approach will be no way inferior to them also. Now we are studying details on each use suggested by healthcare professionals aiming at some concrete applications.

Conclusion

Based on this consideration about the mechanism functioning inside morphological diagnosis, we adopted real time processing at the sacrifice of some accuracy rather than providing elaborate still images when we developed a system that translates skin color captured by an ordinary three-band camera to distribution of melanin, hemoglobin and oxyhemoglobin. Consequently, we succeeded in inspiring healthcare professionals to coming up with various innovative uses of our system.

References

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