Device- and Illumination-independent Color Reproduction in Medical Imaging

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A practical multispectral imaging system for medical use that includes spectral reflectance information for each pixel and provides partially device- and illumination-independent color reproduction of skin and mucosa was developed using common equipment.

Morphological diagnosis that requires reliable color reproduction plays an essential role in medicine. However, digital color imaging has been adopted in fields that do not require high accuracy of color reproduction at present. No current digital imaging device has sufficient quality of skin color reproduction to be applied in dermatology or nursing. The same situation is observed for oral mucosa and teeth in dentistry.

One of major reasons of these situations is that colorimetric color calibration, which is used to compensate for differences between the optical characteristics of cameras and displays, is not capable of compensating for differences in color appearance caused by differences in illumination. Because this is a theoretical limitation of colorimetric color reproduction using the three primary colors, only multispectral imaging, which provides pictures include spectral reflectance information for each pixel, is capable of managing this adjustment, but there is no practical equipment for its clinical application yet.

Usually, spectral reflectance of objects requires multi-band camera to be captured. But that of skin picture can be estimated by observation from a picture taken using a current digital camera because the three principal components are sufficient to approximate the reflectance spectra of normal skin and mucosa. In addition, multispectral imaging requires multi-band display to reproduce exact colors. However, thanks to the characteristics of three kinds of human cone cells, colorimetric color reproduction using the three primary colors will reproduce most colors of skin and mucosa under any illumination with good accuracy.

In addition, our recent study showed we have so various illuminant conditions in a hospital that a reliable imaging system capable of compensating for differences in color appearance caused by differences in illumination is indispensable.

An imaging system that the spectral reflectance of skin and mucosa is obtained using a current digital camera and its color appearance under any illumination is reproduced using a current three-band color display was developed.

Figure 1 and Figure 2 show examples of the results. Although these black and white figures do not represent any quality of color reproduction, significant influence of illuminant conditions is clearly shown. Most pictures reproduced by our methods had much closer colors to real objects than photographs that were taken with or without flash and adjusted by colorimetric color calibration. However, management of chromatic adaptation is left for future investigation.

References

A photograph of eczema on an arm taken without flash (the top left), a flash photograph (the middle left), and calculated color appearances under various illuminations (others) are shown separated by R, G and B color channels.

Figure 1 Reproduced colors of skin

A photograph of oral mucosa taken without flash (the upper left), a flash photograph (the lower left), and calculated color appearances under various illuminations (others) are shown separated by R, G and B color channels.

Figure 2 Reproduced colors of mucosa
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Introduction

NO imaging devices reproducing exactly the same color appearance in morphological diagnosis

Objective

To develop imaging system to exactly reproduce:

- real skin and mucosa
- under various viewing condition
Our Approach

A multi-spectral imaging technique is ideal for reproduction:

-> Could be costly and hard to use

Use of conventional three-band system with spectral estimation.

Our Three-band Capturing System

MACRO RING FLASH 1200
MACRO TWIN FLASH 2400
MACRO TWIN FLASH remodeling 4 flash lighting one by one
DIMAGE A1 KONICA MINOLTA
Remote capture by USB
LCD for Medical
Principal Component Analysis for Skin

177 samples of skin spectral reflectance

Three principal components may approximate the skin spectral reflectance.

System Outline

Raw image → Spectral image → Integration

Arbitrary light source → Colorimetric Color Reproduction
Color Processing: Overview

Image Capture

Light source \times CCD spectrum sensitivity

Sensor output

Raw image data

System function

Matrix

Multiple Regression Analysis

Spectral reflectance samples

+ System function

Estimated spectral reflectance

Color Processing: Detail

Input

Image Capture

Raw image (Bayer array)

Convert to RGB image

AE control by white patch

Spectral reflectance

Matrix

Output

Spectral reflectance

Spectrum radiance of illumination

Color matching functions

Colorimetric values (XYZ)

sRGB data

RGB data in monitor color space

Matrix

LUT
Graphic User Interface

Illuminations in a Hospital

Need to compensate
Color Reproduction Experiment 1

The two images colorimetrically reproduced

The real object under corresponding illuminations:
(1) normal white fluorescent (3965K)
(2) tri-chromatic fluorescent (6664K)

The images were approximately same to real objects.
Color Reproduction Experiment 2

Image under illuminant A (2779K)

Differences in color appearance between reproduced images and real objects were exist.

The color appearance model improved differences.

Colorimetric reproduction illuminant A(2779K)

With Color Appearance Model
Conclusion

>>We have developed an imaging system
   - Using 3-band camera
     *to solve cost issue*
   - Spectral estimation
     *to solve illuminant difference*
   - Incorporating color appearance model
     *to solve background color issue*

>>Preliminary evaluations were made by physicians who have various specialties
   - Well accepted

Future Work and Plan

Search a demand for this novel imaging system in the medical field.

Put this system into practical use in promising fields such as telemedicine, electronic medical records, etc.