Comparison of Spectral Colorimetric Measurements vs. Color Pictures in Dermatology

P. Blain[1], F. Michel[1], V. Moreau[1], O. Vanhooteghem[2], Y. Renotte[1], S. Habraken[1]
[1] HOLOLAB, Faculty of Sciences, Bat. B5a, University of Liège, B-4000 Liège, Belgium
[2] Department of Dermatology, CHU -ULg, B-4000 Liège, Belgium

ABSTRACT

We studied scars and wounds depths and surfaces thanks to our interferometric fringes projector 3D scanner[1, 2]. Color information of a wound indicates its deterioration level. That's why the visual color restitution, as realistic as possible, is a highly important parameter. Firstly our acquired 3D pictures were color mapped with an image recorded by a RGB camera. The results were not efficient enough. In order to improve our technique and provide more precise information, we add a spectral characterization to the set-up. Before adding the spectral information and a realistic color mapping to the 3D measurements, we evaluate the performances of colorimetric measurements. The tests have been made on mice with scars on their back.

Keywords: Dermatology, multi spectral pictures, color image reproduction

1. INTRODUCTION

1.1 A colorful world viewed by different sensors

The light emitted by the sun seems to be white to our eyes. The light receptors (the rods) in our eyes are sensitive to the red, green and blue (RGB). The white aspect of the light results from the combination of the three different responses to the light. In spite of the fact that most of the optoelectronic sensors (i.e. CCD or CMOS sensors) counterfeit this trichromatic perception, their spectral sensitivity is not the same, as shown in Figure 1.

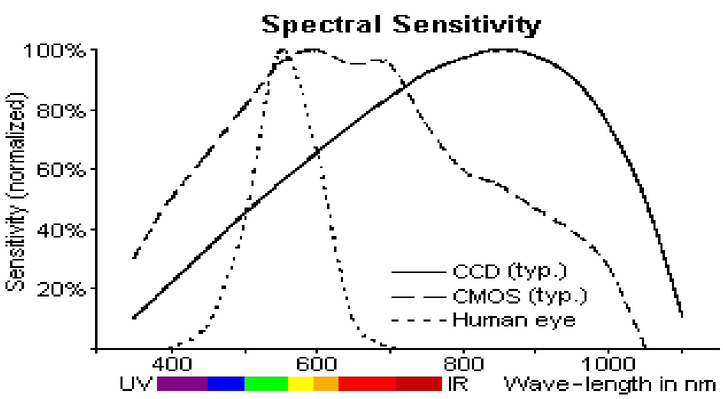

Figure 1. Comparison between the Human eye spectral sensitivity and .CMOS and CCD sensors spectral sensitivity[3].

This difference mostly explains the impression that the rendering color of a recorded picture is not as realistic as possible.

On top of that, artificial lightings are frequently used. The spectrum of a fluorescent linear tube, shown in Figure 2, is not spread like the sun's one, but with two major peak in the green and red area. It explains why most of picture recorded under this kind of lighting have a yellowish aspect (indeed the combination of Red and Green is Yellow).

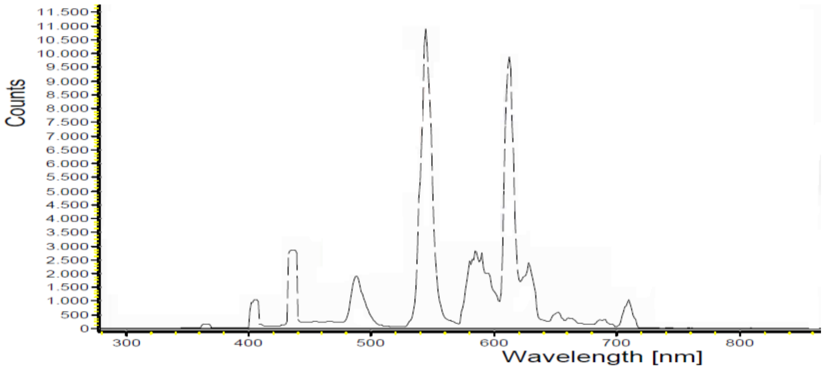

Figure 2. Typical fluorescent lamp spectrum (measured at the laboratory).

We are trying to build a system which can help dermatologist to evaluate the deterioration of a patient's wound. Therefore we use a 3D scanner based on interferometric fringe projection[1]. We can map the obtained 3D model with a color picture. Nevertheless, this color picture depends on both issues we just point out, the spectral response of the sensor and the spectrum of the light source.

1.2 Toward a skin realistic rendering

The correct description of the color is of increasing importance in application areas as diverse as dermatology, biometrics, computer vision and virtual imaging. In dermatology, many injuries result in a variation, even slight, of the color of the skin. The precise analysis of these variations allows to quantify the exact size of the lesion, and to determine whether it is benign or malignant. The multispectral imaging techniques are very promising for faithful color reproduction. Furthermore, the spectral information provided may be used for research or segmentation of images contained in databases. Several publications have reported very promising results in the diagnosis of melanoma[6], inflammatory or immunological diseases[7] and estimation of oxygen saturation in the blood[8]. However, to our knowledge, no publication refers to the combined use of 3D analysis and multispectral. These two methods seem yet complementary. According to the dermatologists, more than the relief of the wound, it is its color which indicates whether it is on the mend or not.

2. PRINCIPLE

2.1 The reflected spectrum measurement

We consider the simplest reflectance model, the Lambertian model. Thus we can reach the recorded spectrum of the reflected light by the studied object, which is given by the following equation:

$$I(\lambda) = E(\lambda)\,\rho(\lambda)\cos(\theta) \quad (1)$$

Where λ is the wavelength, $E(\lambda)$ is the incident light spectrum, $\rho(\lambda)$ is the albedo of the surface and θ is the angle of incidence The influence of each element in this measurement is shown Figure 3.

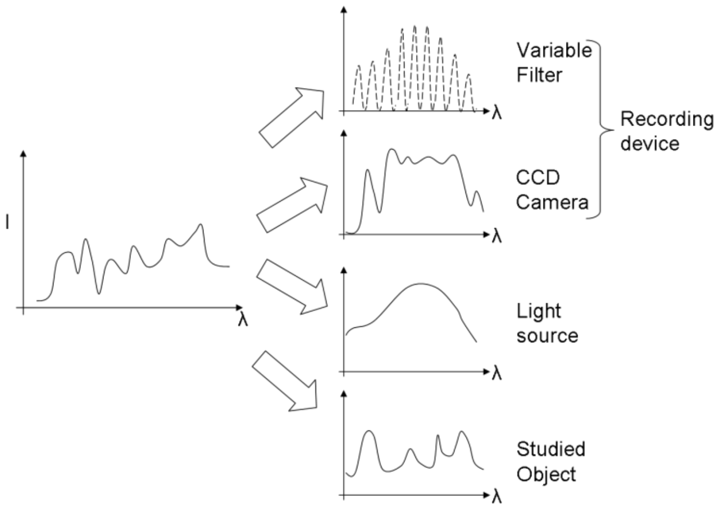

Figure 3. Pictorial representation of the multispectral device recorded spectrum. The recorded spectrum is the combination of the spectrum selected by the wavelength tunable filter and the CCD camera (which both form the recording device), the spectrum of the light source and the reflectance of the studied object.

In order to reach the reflectance of he studied object we have to take into account the sensitivity of the recording device and the influence of the lighting source.

2.2 The calibration of both the source and the recording device

To get rid of these parameters, the installation has to be calibrated. Under normal incidence illumination and by choosing an appropriate object which reflects equally every wavelength in the visible field, the obtained spectrum only depends on the recording instrumentation and the light source (Figure 4).

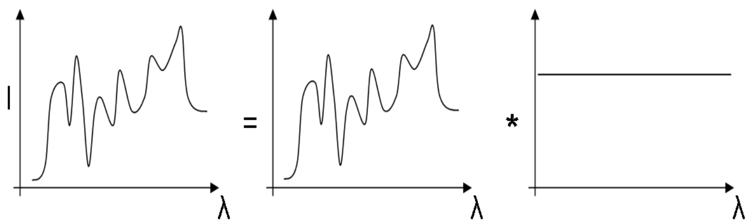

Figure 4. Pictorial representation of the calibration of the multispectral device. The recorded spectrum is the combination of both the spectrum selected from the light source by the whole camera and filter and the reflected spectrum by a standard object. The standard objet must reflect identically each wavelength.

To obtain such a spectrum, the integration time of the camera is switched until the mean level of gray reaches a threshold value which corresponds to the maximum of reflectance of the standard object for a given wavelength. This operation is repeated for each wavelength. By reusing those integration times and keep the same illumination conditions, the spectral response of the recording instrument is compensated. Each recorded picture corresponds to the reflectance of the object for a specific wavelength.

2.3 The multispectral device

Most of multispectral acquisition device operate by successively mechanically interposing different colored filters in front of a monochrome CCD sensor. We have chosen a different approach based on using a Liquid Crystal Tunable Filter device. Thus we can build a mutispectral device without any moving part. This type of device, which appeared recently, based on an old principle of filtering described by Bernard Lyot[10]: A wave plate (birefringent medium) placed between two crossed polarizers has a transitivity that varies sinusoidally with the wavelength. Several Lyot filter, showing birefringence different factor may be involved in successive stages to achieve a component with a relatively narrow bandwidth. The development of retardants tunable liquid crystal device (wave plate whose birefringence varies with an applied voltage) and their use in Loyd assemblies offers a new possibility: the controlled movement of the peak transmission over an extended spectral region. This property has spawned a new type of electro-optical component, compact and fast, capable of simulating hundreds of spectral filter.

3. EXPERIMENTAL SET UP

3.1 Acquisition

The system configuration is presented below (Figure 5). The multispectral imaging system used, is based on the performance from the Varispec^{TM} module from CRI[11], which is composed of a six Lyot filter stages, allowing a 10nm band pass around a chosen wavelength. The sensor used is a monochromatic CCD camera Vosskühler-1300 8-bit, 1280x1024 pixels, with a 35mm fixed focal lens.

The choice of the light source is also not trivial and can affect the quality of results. We choose a source whose spectrum is continuous and covers the whole region of interest (400 nm to 700 nm). We opted for four 35W halogen light bulbs, type Soluxa (Eiko ltd), whose spectral distribution is close to the sun.

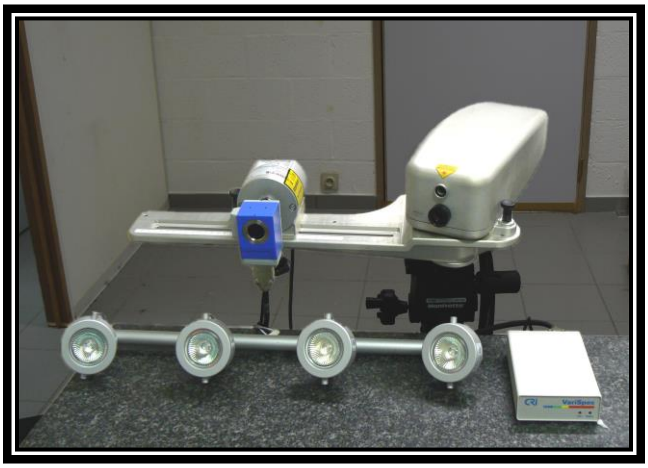

Figure 5. The complete installation with the interferometric fringe projector and the colorimetric installation.

3.2 Calibration

A Spectralon reflectance standard provides stable, diffuse reflectance. It is used to calibrate the installation in the 250-2500nm range. It is suppose to diffuse every wavelength in this range equally. The user puts a pellet of Spectralon in front of the camera. For each wavelength, a search of the exposure time of the camera that corresponds to a mean value of 250 (level of gray) on the surface of the pellet is made. The exposure times will be recorded and used when the corresponding wavelength is selected.

4. EXPERIMENTAL RESULTS

4.1 Preliminary test

We first tested the performance of the device by testing it on a RGB color reference test pattern (GretagMacbeth ColorChecker). We try to reconstruct a RGB image of this patrern by combining three images in gray level obtained through Varispec successively tuned to 465 nm (blue), 530 nm (green) and 610 nm (red). The Figure 6 shows the results.

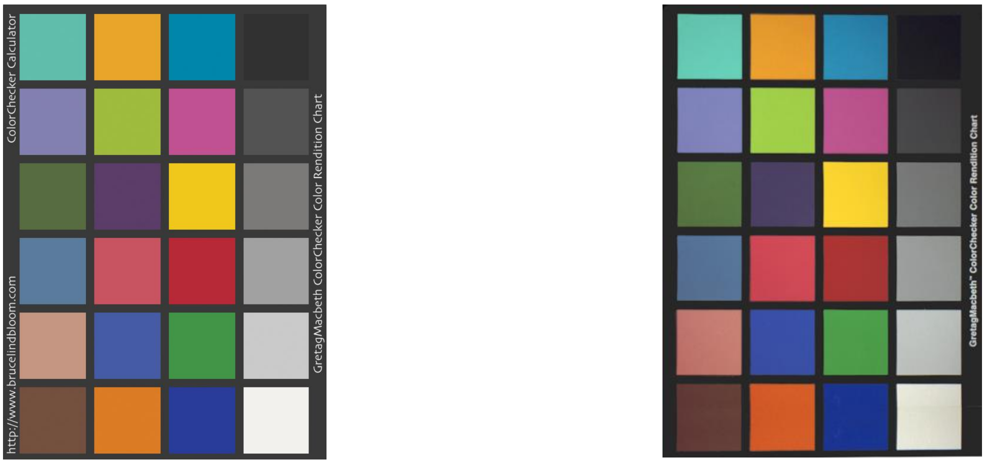

Figure 6. RGB color reconstruction test using the Varispec, comparing the image obtained by combination of acquisitions at 465, 530 and 610 nm (right) with the reference file of the reference pattern from GretagMacbeth (left).

The fidelity of the reconstruction of color was analyzed quantitatively for each color patch (Figure 7). This analysis provides a first validation of the calibration procedure implementation.

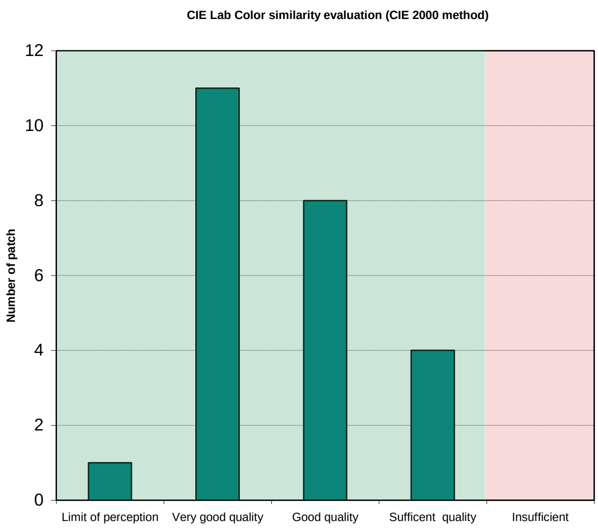

Figure 7. Evaluation of the colors similarity, depending on the comparison standard CIE (International Comission on Illumination). The distance between the reference color and the color measured and calculated in the Lab space and converted to a quality criterion. The criterions are: Limit of perception ($\Delta_{Lab} < 1$), Very good quality ($1 < \Delta_{Lab} < 3$), Good quality ($3 < \Delta_{Lab} < 6$), Sufficient quality ($6 < \Delta_{Lab} < 10$) et Insufficient (($\Delta_{Lab} > 10$).

4.2 Multispectral acquisition on mice

We conducted a serie of multispectral acquisition on a mouse with a known scar on its back. Thirty successive images have been captured, while the 20nm one, covering a spectral range from 430nm to 720nm. The filter width is 10nm half-pitch.

Based on these acquisitions, an RGB image can be reconstructed (Figure 8) with the pictures at 465 nm (blue), 530 nm (green) and 610 nm (red). The spectra presented in Figure 9 were obtained through our software, targeting respectively three images area multispectral: a wounded area, a neutral area of the skin and fur.

Figure 8. Comparison of a color picture recorded with a trichomatic CCD camera under fluorescent tube lighting (which has a yellowish aspect as expected) and a reconstructed RGB picture recorded with the colorimetric installation under the illumination of the 4 halogen lamps.

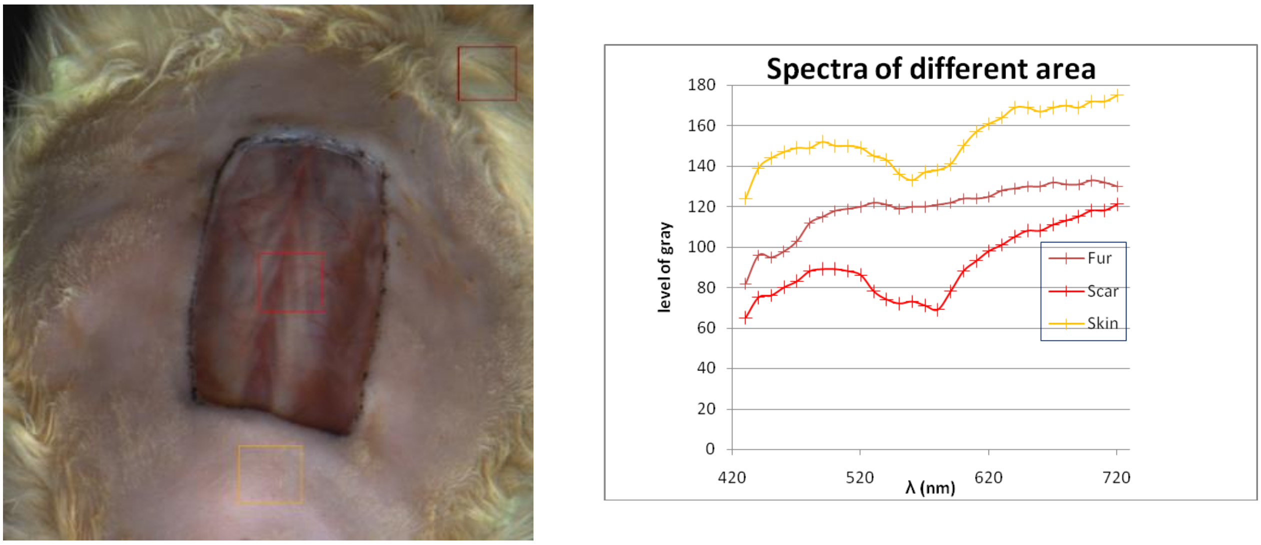

Figure 9. On the left: Reconstructed RGB picture of the mouse back. On the right: Spectra of the selected area on the reconstructed RGB picture.

4.3 Coupling 3D and multispectral images

We also conducted a multi-modal acquisition of the mouse back. Multimodal is the combination of both the 3D information and the colorimetric information. In order to show the difference between an only color mapped 3D model and the color reconstructed mapped 3D model, they are respectively shown in Figure 10 and Figure 11.

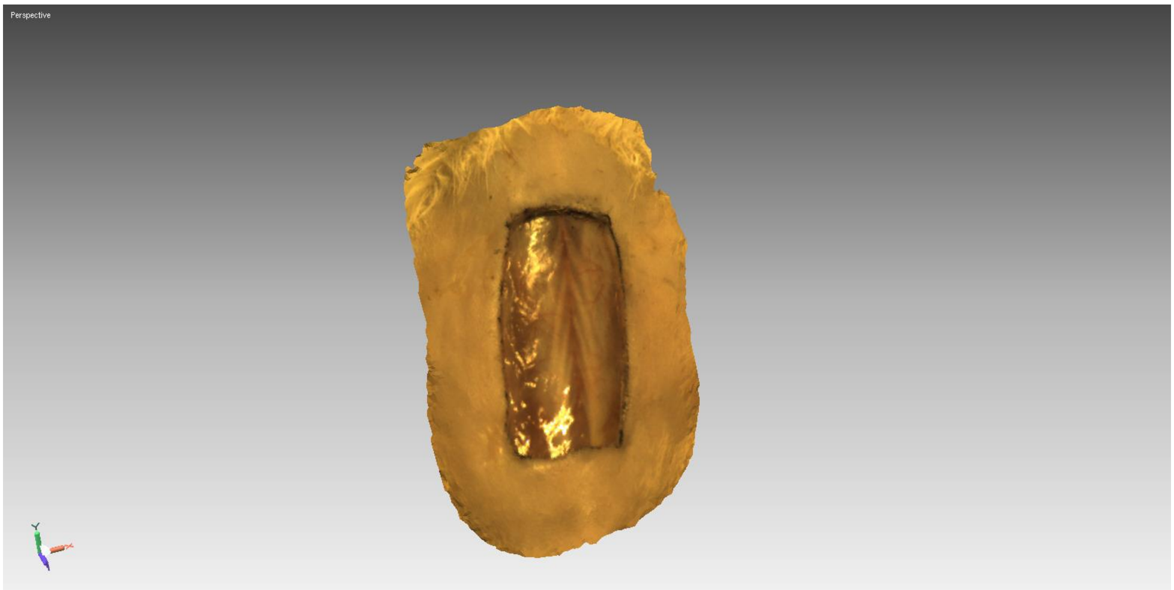

Figure 10. 3D model color mapped with a RGB picture.

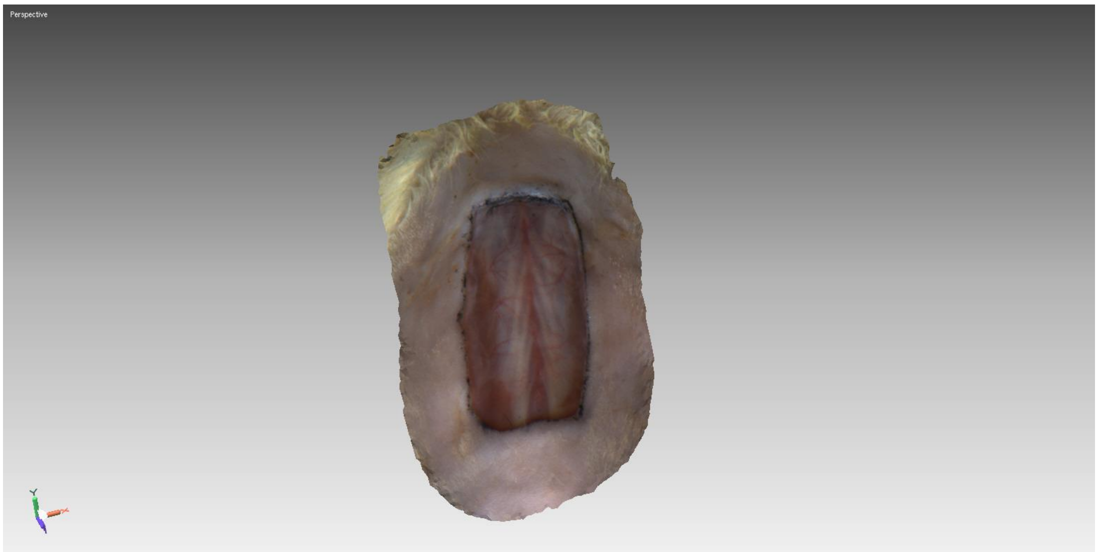

Figure 11. 3D model color mapped with a reconstructed RGB picture recorded with the colorimetric module.

5. CONCLUSION AND PERSPECTIVE

We have shown the potential brought by both multispectral and three dimensional acquisition in the field of dermatology. On top of that a more realistic rendering of the skin can be achieved. Further works have to be made in order to take advantage of the obtained spectra, which would allow an automated diagnosis. A clinical study about the efficiency of a cicatrizing product is scheduled.

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