HANDHELD HYPERSPECTRAL IMAGING SYSTEM FOR THE DETECTION OF SKIN CANCER

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ABSTRACT

Skin cancer detection is currently carried out using visual inspection through the dermoscope. Later, histological examination with a surgical extraction of the lesion is required for a complete and precise diagnosis. In this study, a new handled tool based on a hyperspectral system is proposed as a means of obtaining objective color and spectral information of the lesions to help in the diagnosis of skin cancer. The system includes light-emitting diodes (LEDs) as a light source as well as a digital camera. Preliminary images taken with the system and the corresponding results indicate the usefulness of the system. The prototype presented in this study will be integrated in the near future in a multiphotonic platform, including also 3D images, blood flow analysis and confocal microscopy, for in-vivo imaging of skin cancer lesions as a diagnosis service.

1. INTRODUCTION

Skin cancer represents one in three of all cancers worldwide and its incidence in Europe, USA and Australia is increasing rapidly. The melanoma, which only represents 4% of all skin cancers, is the most aggressive one causing the greatest number of deaths (Kuzmina et al., 2011). About 90% of skin cancers are caused by ultraviolet light from daylight or tanning booths. The World Health Organization estimates that 60,000 people die every year for sunlight excess: 48,000 from melanoma and 12,000 from another type of skin cancer. On the other hand, the survival rate in 5 years really increases if the pathology is detected and treated early.

Nowadays, visual inspection through the dermoscope is the technique most widely used by dermatologists for the detection of skin cancer. It consists of a handheld device with a magnifying lens and a white and uniform illumination field. The light is often polarized to remove specular reflection from the skin surface to obtain information of deeper layers. Dermoscopy allows the specialists identifying different structures, patterns and colors of the skin lesions suggesting if they are benign (seborrheic keratosis, haemangiomas, lipomas, warts) or malignant (melanoma, basal cell carcinoma). This is confirmed by a histological examination later on requiring a surgical extraction of the lesion, which is the gold standard for clinicians. By means of this procedure, a lot of false positives are still obtained and thus, the direct annual costs of diagnosis and treatment of skin cancer are high (Braun et al., 2005).

In order to improve the detection and diagnosis of skin cancer, in the last years color and spectral imaging technology have started to be used to enhance and analyze color and spectral properties of skin. They are caused by chromophores such as melanin, hemoglobin, water etc., which might differ among skin lesions of different etiologies.

In this context, some prototypes such as those developed by Spigulis et al. (Bekina et al., 2012), Kapsokalivas et al. (Kapsokalivas et al., 2013), and also some commercial devices such as the SIAscope V system (Emery et al., 2010), have already been proposed as a means of improving skin cancer diagnosis. However, most of them only use three spectral bands in the visible range (typically three colour RGB channels) and additionally another one located at the near infrared range.

For the reasons exposed above, in this study we propose a new handheld hyperspectral system with more spectral bands for the diagnosis of skin cancer, trying to improve the results obtained with the existing devices. In this work, we present the methodology carried out to setup and characterize the whole system, including the protocol followed in order to select the most suitable spectral bands to detect skin cancer lesions. Furthermore, the first results corresponding to real lesions analyzed at a clinical site are also presented. This work is within the framework of the European Project DIAGNOPTICS "Diagnosis of skin cancer using optics" (ICT PSP seventh call for proposals 2013), the aim of which is developing a multiphotonic platform including hyperspectral and 3D techniques, blood flow analysis and confocal microscopy for in-vivo imaging of skin cancer lesions as a diagnosis service (Ares et al., 2014). These technologies are envisaged to improve the detection ratio and the evaluation of the prognosis of skin cancer at earlier stages, compared with the conventional approach used nowadays.

2. METHOD

2.1 System design and components

The system developed has a cylindrical shape of about 10 cm in length, 7.5 cm of width and a weight of 0.5 kg. It includes a 12 bit-depth monochromatic camera and an objective lens, which allows recording skin lesions at 4 cm with a 15x20 mm field of view as their size is usually smaller.

A ring light source including light-emitting diodes (LEDs) with different spectral emissions within the visible and near infrared range (400 nm to 1000 nm) was designed to illuminate the sample. This illumination source was located onward of the objective lens to avoid the light of the LEDs reaching the sensor directly. The spectral bands of the system were chosen according to the spectral properties and absorption peaks of the skin chromophores and also taking into account market availability of LEDs. In order to obtain a uniform field of illumination on the sample and enough energy to acquire spectral images with low exposure times, 32 LEDs were finally included in the light source.

Moreover, two polarizers allow changing the degree of polarization of light and thus obtaining information from different skin depths. Specifically, the first polarizer is located in front of the LEDs and the second in front of the objective lens. Light polarization can be changed into 3 different positions: 0º - parallel polarizers, 45º and 90º - crossed polarizers.

The first prototype developed, which is a light, compact and ergonomic device to be used at a clinical site, is shown in Figure 1. The handheld hyperspectral head can be placed on a base between measurements, making all the procedure comfortable for the physician. Moreover, this base has also a storing function as the power supply and the electronic boards and other parts of the system are placed inside.

Figure 1: Different views of the handheld hyperspectral system.

Furthermore, the base also incorporates a calibrated sample resembling the light human skin that can be sheltered from external agents like dust by positioning it in the "in" and "out" positions (Figure 2). This sample is used in the preliminary calibration of the system that is done every day before starting measurements and that will be a key step when computing spectral results from the images acquired (see next section).

Figure 2: View of the base of the handheld hyperspectral system with the calibrated sample in the "out" and "in" positions, respectively.

2.2 Software development

A specific software was developed for controlling all components of the system (camera and LEDs), allowing for its proper operation. The software (Borland Builder C++) included autoexposure algorithms for adjusting the exposure time of each spectral band taking into account the LED emission level and also the typical reflectance and absorption properties of the skin. It also includes security controls avoiding LEDs to be switched on if the program is not running. A user interface was also developed for its use at a clinical site. A complete acquisition lasts 40 seconds approximately.

An additional software implemented in Matlab® was created to process all the images of the lesions. It included calibration algorithms as a means of computing reflectance values, chromaticity coordinates, colour differences etc., which might enhance subtle differences between benign and malignant lesions enabling a better diagnosis.

3. RESULTS AND DISCUSSION

Figure 3 shows spectral images obtained with the developed system corresponding to a common nevus lesion at different spectral bands between 400 nm and 1000 nm, and different degrees of polarization. As it can be seen, the degree of polarization allows removing the specular reflection of the skin surface (0º), obtaining information from deeper layers (90º), basically in the case of short (blue) wavelengths. This is important as for instance, melanomas can grow deeper than other lesions.

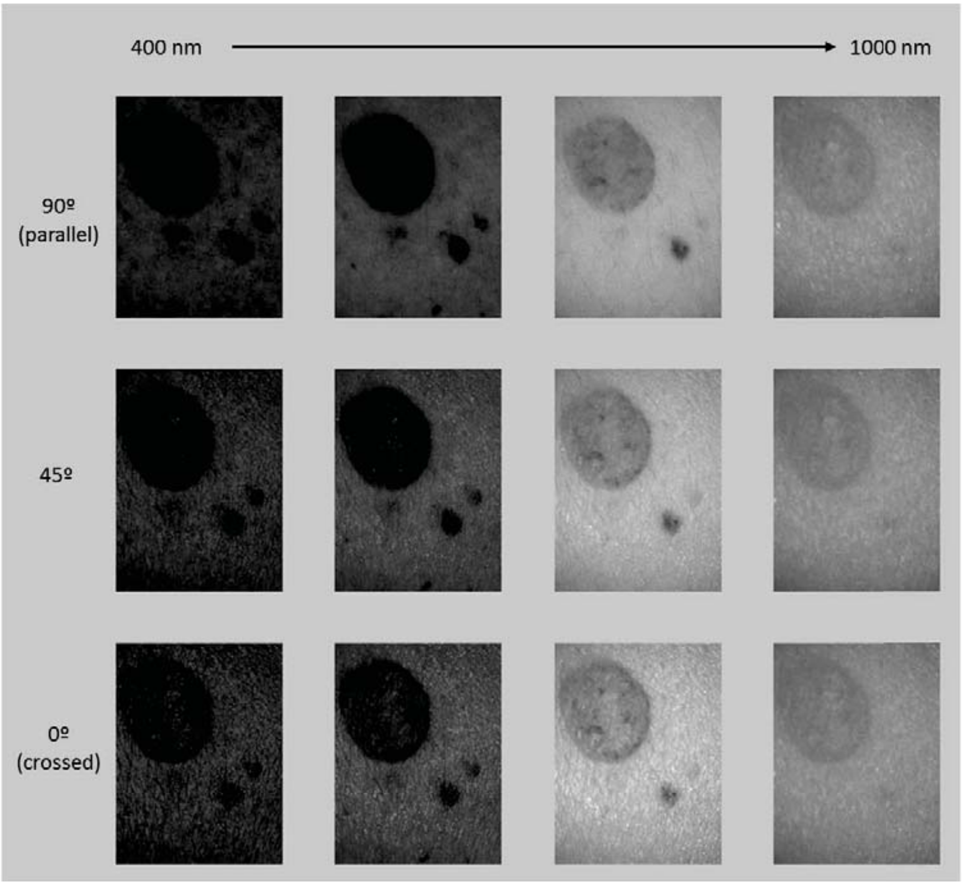

Figure 3: Images of a benign lesion (common nevus) obtained with the system using different spectral bands and three degrees of polarization (0º, 45º, 90º).

Figure 4 shows the spectral reflectance curves computed from two different areas of a skin sample: one corresponding to common skin and the other to a nevus. As it is shown the reflectance curves associated to each of them differ completely. As it was expected, nevus had lower reflectance values because its higher amount of melanin absorbs more light.

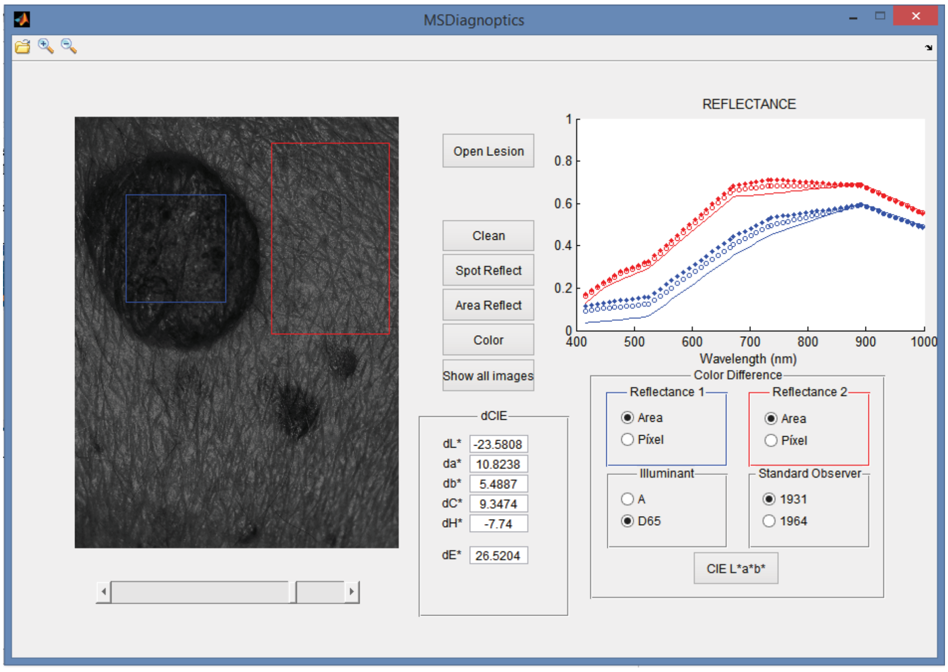

Figure 4: Spectral reflectance of common skin (red area) and common nevus (blue area)

4. CONCLUSIONS

In this study, a first prototype of a handheld hyperspectral system with several spectral bands in the visible and near infrared ranges of the electromagnetic spectrum for improving the diagnosis of skin cancer was presented. The developed system allows obtaining precise spectral information from the skin lesion analysed with a high spatial resolution in a fast and easy way. The use of LEDs as a light source enabled to build a system with reduced size and cost.

Current work is focused on the acquisition of images from a great variety of skin lesions in a clinical environment, including benign and malignant lesions (Hospital Clínic i Provincial de Barcelona, Spain), as well as the development of algorithms to obtain more reliable and objective diagnosis, helping dermatologists in their daily clinical practice. Skin lesions can be generally categorized according with their clinical presentation, taking into account different easily recognizable aspects, including from shape to colour. Therefore, it is expected that this last one will be a key in the diagnostic procedure as spectral reflectance profiles obtained with the new system will be related with the lesion etiology.

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