LATVIAN JOURNAL OF PHYSICS AND TECHNICAL SCIENCES
2014, N 5
DOI: 10.2478/lpts-2014-0031

BIOPHOTONICS

MULTISPECTRAL VIDEO-MICROSCOPE MODIFIED FOR SKIN DIAGNOSTICS

U. Rubins, J. Zaharans, I. Ļihačova, J. Spigulis

Biophotonics Laboratory, Institute of Atomic Physics
and Spectroscopy,
University of Latvia,
19 Raina Blvd., Riga, LV-1586, LATVIA
e-mail: uldisrubins@yahoo.com

Commercial *DinoLite* AD413 digital microscope was modified for skin diagnostics purposes. The original LED ring (4 white and 4 ultraviolet light emitters) of microscope was replaced by a custom-designed 16-LED ring module consisting of four LED groups (450, 545, 660 and 940 nm), and an onboard LED controller with USB hub was added. The video acquisition and LED switching are performed using custom-designed Matlab software which provides real-time spectral analysis of multi-spectral images and calculation of skin chromophore optical density. The developed multispectral video-microscope is mainly meant for diagnostics of skin malformations, e.g. skin cancerous lesions.

Keywords: *video microscope, dermascope, skin malformations, skin diagnostics*

1. INTRODUCTION

For assessment of human skin, diversified diagnostic devices exist. Many of them – e.g. skin moisture analyzers, wrinkle analyzers, pore analyzers, microscope, etc. – are used in cosmetics. Some of such devices (dermascope, confocal microscope) are employed in the medical diagnostics of skin malformations [1,2]. More advanced systems use multi-spectral data capture and sophisticated computer algorithms to automatically acquire and analyze lesions from under the skin in order to help dermatologists detect melanomas (Siascope, Melafind) [3].

The digital microscope is a compact device that can be used for skin surface monitoring. A typical digital microscope consists of webcam with a high-powered macro-lens and a built-in LED light source. An advantage of digital microscope is its small size, low power consumption and commercial availability. Most of digital microscopes (e.g. model *DinoLite* AD413, series AM-4013) have a source of white illumination, and some of them – also of ultraviolet [4]. These devices are adapted for skin microscopy while cannot be used for detailed spectral analysis of skin. However, a standard digital microscope can be improved by adding specifically selected LED spectral illumination and appropriate software. After such improvements, this microscope is usable for skin multispectral imaging.

The goal of this work was to build, based on a standard digital microscope, a simple inexpensive device intended for multi-spectral assessment of skin malformations.

2. METHODS

2.1. Hardware

Figure 1 shows a block diagram of the custom-designed microscope. The illumination system of commercial video-microscope (model *DinoLite* AD413 [4]) was modified to enable obtaining a set of images of the skin surface at different wavelengths. A standard white/UV LED illuminator ring was removed and replaced by a custom-designed illuminator with 16 LEDs combined in groups: 1) four infrared 940 nm LEDs, 2) four red light 660 nm LEDs, 3) four green light 545 nm LEDs, and 4) four blue light 450nm LEDs. To each group of LEDs a current of 80mA is fed by LED drivers that can be controlled by an FTDI USB controller. The two-port USB hub provides control over the LEDs and the CMOS sensor of microscope. The power support, the LED switching and the CMOS control are executed through USB interface.

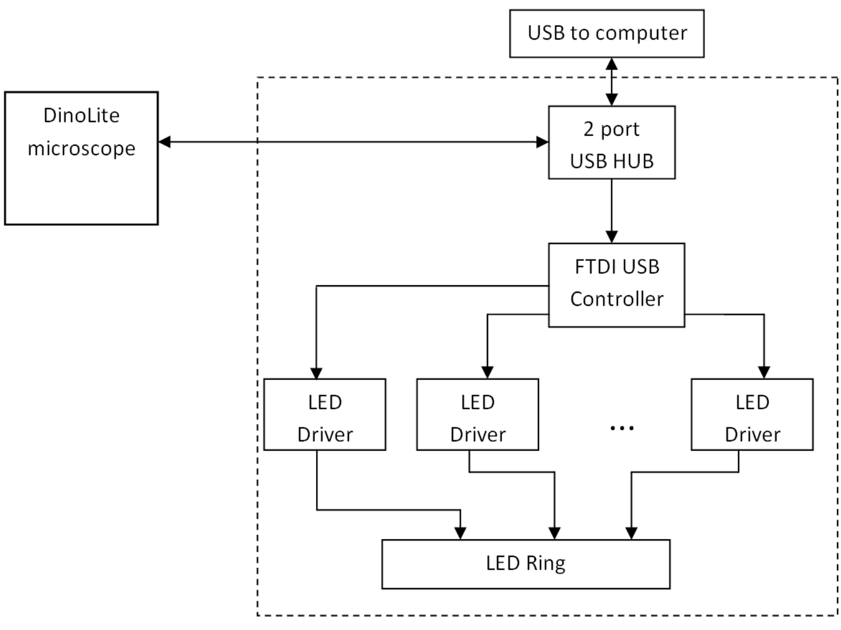
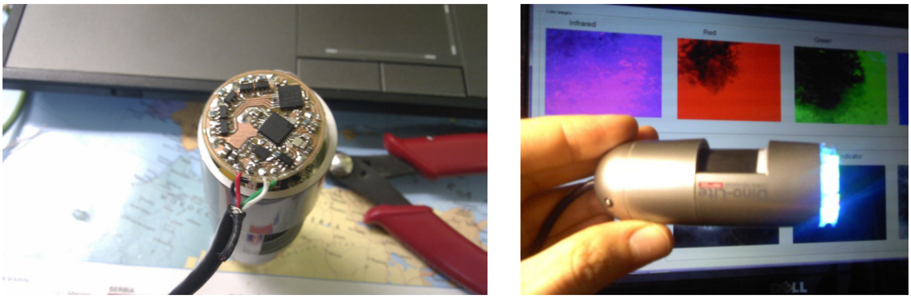


Fig. 1. A block diagram of custom-designed 16-LED ring control unit

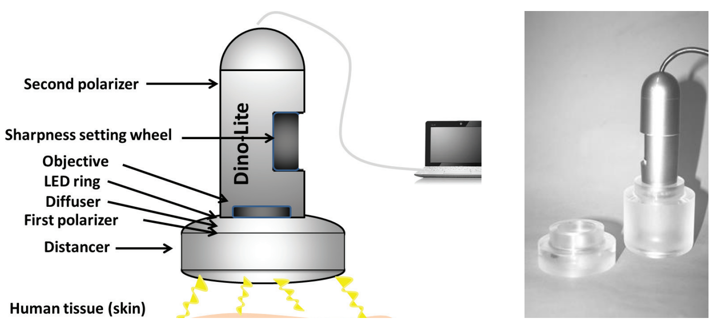
The custom-designed module of *DinoLite* control unit installed on the back side of microscope is shown in Fig. 2*a*. The module is compact enough and can easily be fitted in the body. In the front side a 16-LED ring is seen (Fig. 2*b*), which is more compact as compared with a standard 8-LED *DinoLite* ring.



a b

Fig. 2. 16-LED ring control unit (a) and modified *DinoLite* microscope (b)

Figure 3 shows schematically the modified *DinoLite* microscope. A cylindrical Plexiglas distancer was used for fixing the microscope at the focusing distance from the skin. A LED ring was placed in front of the microscope to provide multispectral illumination of skin. For better homogeneity of skin illumination, to the front of LEDs a diffuser was added. To avoid the directly reflected radiation from the skin surface (thus distinguishing the diffusely reflected radiation from the upper layers of skin) the orthogonally-oriented polarizing filters were added: one of them directly after the diffuser, and the other – in front of the camera sensor matrix. Backscattered light from the skin passes through the microscope lens system to the video sensor. The sharpness setting wheel allows correction of the focus.



a b

Fig. 3. Schematic of the modified *DinoLite* microscope (a); the microscope with a distancer (b).

2.2. Software

The microscope is computer-controlled. The custom-developed program written in MatLab with a standard FTDI USB driver and a custom LED driver (written in C programming language) performs the control over LEDs and the acquisition of images. The software provides two image processing modes: 1) the preview mode, for focusing the microscope to the skin object, and 2) the video acquisition/processing mode, where the software performs the sequential switching of LEDs and the triggering of video sensor (for the algorithm see Fig. 4). Each single measurement includes capturing of four frames at four wavelengths. After recording, the images are stored in a 4-image matrix and saved as a data file for further processing.

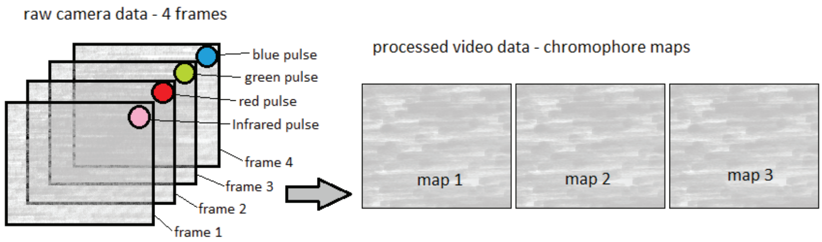


Fig. 4. Video-processing algorithm.

The software includes real-time processing algorithm that calculates the image maps from the recorded multispectral images. The image map shows a 2D optical density distribution for the object under investigation (e.g. skin chromophores). The optical density map can be calculated by the following equation:

$$M_{i,j} = F\left(I_{i,j}^{450}, I_{i,j}^{545}, I_{i,j}^{660}, I_{i,j}^{940}\right), \quad (1)$$

where $M_{i,j}$ is the map of optical density containing the *i*-th row and the *j*-th column of a rectangular image matrix, F is the transform function of multispectral images with the intensity (I) of reflected radiation at 450, 545, 660 and 940nm.

The simplest form of transformations is dividing of two images. For example, the erythema index of skin can be calculated based on comparison of the skin optical density in the green (~ 560 nm), where haemoglobin absorption is high, and red (~ 650 nm), where haemoglobin absorption is low [5-7], by the formula:

$$E = I_{660} / I_{545}, \quad (2)$$

where I_{660} and I_{545} are the intensities of diffuse red and green light reflected from the skin.

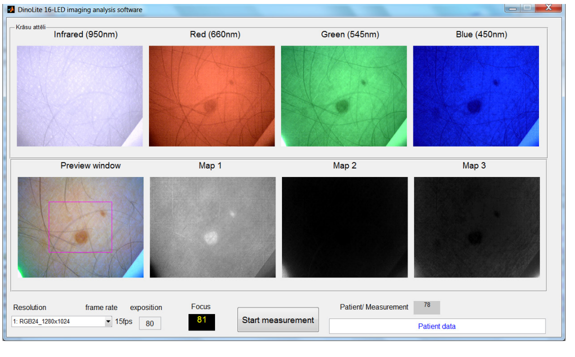


Fig. 5. The software for video acquisition.

Figure 5 shows the interface of video acquisition software. The interface displays four windows of captured images in red, green, blue and infrared illumination. The preview window and three images of chromophore maps are calculated by Eq. (1). The type of maps can easily be chosen in a computer program code – e.g. the erythema map is derivable from Eq. (2). The software allows controlling the sharpness of skin image in the cases when the structure of skin is not clearly visible. While the operator adjusts focus by the sharpness wheel, the maximum sharpness can be found from the following formula:

$$D=\sum_{j=1}^{m}\sum_{i=1}^{n}\sqrt{\left(\frac{\partial I_i}{\partial x}\right)^2+\left(\frac{\partial I_j}{\partial y}\right)^2}, \qquad D\to\max \tag{3}$$

where D is the depth of focus, I is the intensity of image in the i-th pixel in column and the j-th pixel in row.

After measurements, the multispectral images are stored in the BMP format files for further analysis. For better classification of measurements, each image file is marked by its unique number, with date and time indicated.

3. RESULTS AND DISCUSSION

Figure 6 shows the multispectral images at 450 nm, 545 nm, 660 nm, 950 nm and the calculated erythema map of skin malformation (benign papilloma). The erythema map highlights the areas with higher blood concentration compared with normal skin around malformation. The map shows a white malformation area where the absorption of red light (660nm) is weaker than that of green light (545 nm). This exemplifies application of multispectral measurements to the skin diagnostics where the differences cannot be clearly visible with naked eye.

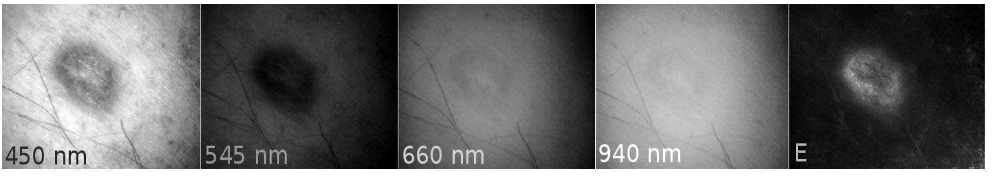


Fig. 6. Multispectral images and parametric maps of a skin papilloma at intensities of blue (450 nm), green (545 nm), red (660 nm), and infrared (940 nm) illumination; E: the erythema map.

The modified digital microscope makes it possible to obtain the parameters that characterize the nature of particular malformations. The Matlab software allows relatively easy real-time image processing. If needed, the algorithm for calculation of maps can readily be adjusted for clinical applications.

4. CONCLUSION

The system for analysis of multispectral images based on a *DinoLite* commercial digital microscope was successfully tested and has shown good results as applied to skin chromophore analysis. This was achieved by adding a multiple-wavelength light source and the custom-designed software. The system is simple and inexpensive, and shows a potential for clinical diagnostics. For its better adaptation to the clinical requirements further tests are required.

ACKNOWLEDGEMENTS

This work has been supported by The European Regional Development Fund project "New optical technologies for complex non-contact skin diagnostics," No. 2010/0271/2DP/2.1.1.1.0/10/APIA/VIAA/030.

REFERENCES

1. Scalvenzi, M, Lembo, S, Francia, M.G., & Balato, A. (2008). Dermoscopic patterns of superficial basal cell carcinoma. *International Journal of Dermatology, 47* (10), 1015–8.
2. Moncrieff, M., Cotton, S., Claridge, E., & Hall, P. (2002). Spectrophotometric intracutaneous analysis: a new technique for imaging pigmented skin lesions. *British Journal of Dermatology, 146*, 448–457.
3. http://www.melafind.com/
4. http://www.dino-lite.com/
5. Diebele, I., Kuzmina, I., Derjabo, A. , Kapostinsh, J., Bekina, A., & Spigulis, J. (2012). Analysis of skin basalioma and melanoma by multispectral imaging. *Proc.SPIE, 8427*, 842732.
6. Diebele, I., Kuzmina, I., Kapostinsh, J., Derjabo, A., & Spigulis, J. (2011). Melanoma-nevus differentiation by multispectral imaging. *Proc. SPIE, 8087*, 80872G.
7. http://omlc.ogi.edu/spectra/hemoglobin/summary.html

MODIFICĒTS MULTISPEKTRĀLAIS VIDEO MIKROSKOPS ĀDAS DIAGNOSTIKAI

U. Rubins, J. Zaharans, I. Ļihačova, J. Spigulis

K o p s a v i l k u m s

Šajā darbā digitālais mikroskops tika modificēts, lai to varētu izmantot ādas diagnostikai. Mikroskopa oriģinālais led gredzens (4 baltās un 4 ultravioletie gaismas avoti) tika nomainīts ar pašdarinātu 16-LED gredzena moduli, kas sastāv no četriem LED blokiem (450, 545, 660 and 940 nm), un tika papildināts ar LED kontrolieri un USB kontrolieri. Video ieraksts un LED kontrole tiek veikta ar Matlab datorprogrammas palīdzību. Datorprogramma iekļauj reālā laika multispektrālo attēlu spektrālo analīzi un ādas hromoforu optiskā blīvuma aprēķinu. Multispektrālais video-mikroskops galvenokārt paredzēts ādas patoloģiju (ādas audzēju) diagnozei.

20.08.2014.