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METHOD OF THE DYNAMIC BIOSPECKLES IN ESTIMATION OF THE FUNCTIONAL STATE OF HUMAN SKIN

T.V. Hardzeichuk, D.A. Zavatskiy, M.M. Mezhennaya, S.K. Dzik

Non-invasive methods are optimal to monitor the optical properties and blood flow of human skin. One of them is a promising method of dynamic speckles monitoring. We used a specialized camera and a low-power laser source to register the change of skin microcirculation before and after mechanical stimulation. The results of dynamic speckles monitoring confirm the effectiveness of this method in the express estimation of the functional state of human skin.

Introduction

Non-invasive speckle-optical diagnostic methods are based on the analysis of the dynamic speckle field settings, which is formed by the interference of the coherent radiation, reflected or scattered by biological object. Speckle field forms a pattern consisting of a plurality of speckles (spots), which light intensity and shape change if the object has moving scatterers. At the same time the speed of speckle pattern change (speckle dynamics) depends on the speed of the scatterers [1].

Human skin as a biological tissue is a heterogeneous optical absorbing medium with a higher (relative to air) the refractive index [2]. Dynamic speckle-field is formed when laser radiation acts on the human skin. This speckle field is a result of coherent combining of many elementary waves scattered by the cells in epithelial tissue (dermis, epidermis) and blood cells (primarily red blood cells) [1].

This paper presents the results of applying the method of dynamic biospeckles for estimation of the functional state of human skin.

Material and methods

The device of dynamic measurement of skin biospeckles implemented on the basis of the laser with power of 3 mW and wavelength of 660 nm and the high-speed camera with GigE interface, CCD-matrix and frequency of 120 frames per second in VGA resolution.

The pre-recorded on a personal computer video stream has been read and processed by a given algorithm. The original image and the processing result were displayed on the screen at 30 frames / sec, which corresponds to the real time (the video stream was neither slowed down nor speeded up). The algorithm of the program includes four main stages: initialization and data preprocessing; accumulation and simultaneous preparation of pixel intensity values of the n frames; carrying out calculations speckle contrast values for each pixel; visualization of the data obtained using color for the best perception of the operator. The algorithm is based on calculating the speckle contrast value by the formula (1) given for a window of 3 × 3 pixels:

$$K_{tLASCA(i,j)} = \frac{1}{9} \cdot \sum_{r=i-1}^{r=i+1} \sum_{c=j-1}^{c=j+1} \frac{\sigma_{i,j,t}}{\langle I_{i,j,t} \rangle}, \qquad (1)$$

where $\sigma_{i,j}$ – the standard deviation of all pixels (*i, j*);

$\langle I_{i,j,t} \rangle$ – the arithmetic mean of all pixel intensities (*i, j*) among *n* frames.

The algorithm implements the Temporally Derived Contrast (tLASCA) method in the Python programming language [3]. TLASCA method schematically represented in Figure 1.

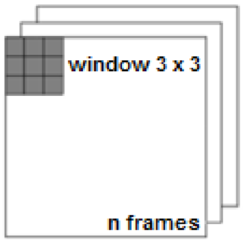

Fig. 1. Schematic representation of algorithm for calculating the contrast in the tLASCA method.

The main features of the developed and implemented algorithm are the following: the speed of the program, which provides data processing and smaller losses in the resolution of the final image through the use of minimum window size, loss of input data is compensated using the intensity values of pixels of several previous frames.

Qualitative estimation of the functional state of human skin was carried out using the above devices and software for the area of skin in the form of a square 1 × 1 cm. The initial state of the test area corresponded to the norm. Next, the test area was exposed to mechanical action, which appeared superficial scratches. Monitoring the skin state using the laser irradiation of the test area and simultaneous recording of the video information in real time was performed from the moment of the initial condition, during mechanical action and up to 5 minutes after it.

Results and discussion

The initial state of the test area of human skin after processing received video was characterized by a uniform pulsation of blood flow on the whole surface (Figure 2, a).

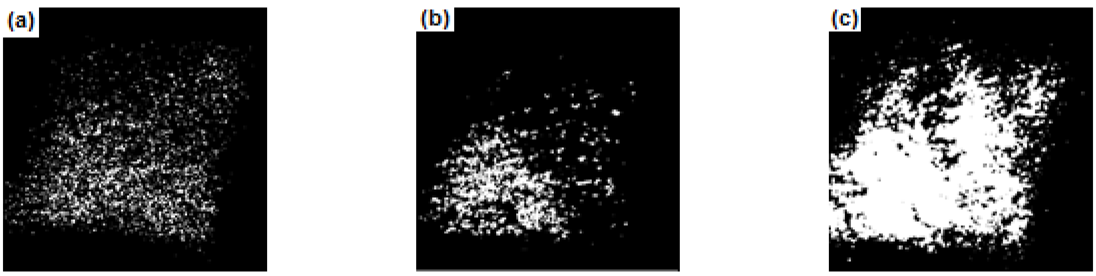

Fig. 2 (a, b, c). The speckle images after processing: (a) for the skin in the initial state, (b) for the skin immediately after mechanical impact, (c) for the skin 5 minutes after mechanical impact.

After the mechanical action, in addition to uniform pulsations of blood flow in the speckle image is observed the hotbed of constant illumination in the areas of greatest damage to surface cover (Figure 2, b). Over time the focus of illumination on the target area of the skin is increased, as evidenced by the results of processing video information shown in Figure 2, c.

Conclusions

The results of dynamic speckles monitoring confirm the effectiveness of this method in the express estimation of the functional state of human skin as well as monitoring the effectiveness of therapeutic procedures. This technique can be used in research and clinical practice.

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Гордейчук Татьяна Валерьевна, аспирант кафедры инженерной психологии и эргономики Белорусского государственного университета информатики и радиоэлектроники, tatyanagordeychuk@gmail.com.

Завацкий Дмитрий Андреевич, аспирант кафедры электронной техники и технологии Белорусского государственного университета информатики и радиоэлектроники, zavatskida@gmail.com.

Меженная Марина Михайловна, доцент кафедры инженерной психологии и эргономики Белорусского государственного университета информатики и радиоэлектроники, кандидат технических наук, mmmarina@tut.by.

Дик Сергей Константинович, проректор по учебной и воспитательной работе Белорусского государственного университета информатики и радиоэлектроники, кандидат физико-математических наук, доцент, академик Белорусской инженерной академии, sdick@bsuir.by.