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Multispectral method and means for determining the distance of the shot on the basis of the study of gunshot injuries of the skin tissues

Abstract. *The work carried out research and development of methods and means of multispectral vision measurement control and diagnosing of parameters of inhomogeneous biological media for biomedical diagnostics with the use of the n-dimensional multispectral data for each pixel of the array of digital images obtained by the CCD camera. Application results can use to diagnose the nature and severity of gunshot injuries to the biomannequins, biological and physiological properties of the skin tissues that are close to the morphological and functional characteristics of human.*

Streszczenie. *W pracy przedstawiono badania oraz opracowanie metod i środków multispektralnych pomiarów wizyjnych i diagnozowania parametrów niejednorodnych mediów biologicznych dla diagnostyki biomedycznej z wykorzystaniem wielospektralnych n-wymiarowych danych dla każdego piksela tablicy cyfrowych obrazów uzyskanych z aparatu z matrycą CCD. Wyniki aplikacji mogą być użyte, do diagnozowania rodzaju i skali obrażeń postrzałowych bio-manekinów, właściwości biologicznych i fizjologicznych tkanek skóry, zbliżonych do ludzkich cech morfologicznych i funkcjonalnych. (**Multispektralna metoda oraz środki do określania odległości strzału na podstawie badania urazów postrzałowych tkanek skórnych**).*

Słowa kluczowe: diagnozowanie multispektralne, heterogeniczne środowisko biologiczne, tkanka biologiczna, obrazy cyfrowe, CCD.
Keywords: multispectral diagnosing, heterogeneous biological environment, biological tissue, digital images, CCD camera.

Introduction

Multispectral vision measurements play an important role in the solution of applied problems of biomedical diagnostics. However, at present, they are not well developed and require for research to improve diagnosis accuracy, speed and reliability.

Multispectral method can be used with electrically tunable optical filter and specialized microscope for investigating the spatial distribution of certain biochemical compounds with a high resolution [1]. In [2] a method used for the multispectral analysis of histological specimens, thus improving the efficiency of invasive diagnosis of tumors compared to the traditional method based on the color change under the influence of dyes. In [3] multispectral technique used to study the biological tissue imaging in reflected light and fluorescence. The instrument used interchangeable filter sets for the CCD camera and the radiation source to operate in the visible and near-IR range. In [4] multispectral technique used to study the blood vessels in the surface layer of the skin. At the same time as the filter uses four replaceable filters based on periodic nanostructures on a gold film with holes, the distance between which determines the wavelength of radiation at which the transmittance of the greatest. This method of implementation is the most high-tech filters and allows you to make the necessary set of filters with specified bandwidths. In [5] suggested multispectral image processing algorithms to improve the resolution and with greater accuracy to determine the spatial distribution of certain pigments in heterogeneous environments.

The purpose of work – improvement of the speed and accuracy of diagnosis by improving the methods of multispectral television measurement control and diagnostic parameters of inhomogeneous biological media.

The tasks that need to be addressed to achieve the goal:
– development and analysis of mathematical models for applications multispectral television measurement control and diagnostic parameters of inhomogeneous biological media;
– development and improvement of methods and means of multispectral television measurement control and diagnostic parameters of inhomogeneous biological media;
– development of specialized software tools multispectral television measurement control and diagnostic parameters of inhomogeneous biological media, namely performance management software tools, the introduction of personal data during the experiment, using a graphical user interface routines array processing multispectral images, an expert decision of the diagnostic decision support system using fuzzy logic and neural networks;
– development of experimental methods for multispectral television measurement control and diagnostic parameters of inhomogeneous media for biological applications.

Analysis of current research on the subject has shown that a large number of researchers in the world uses multispectral method in scientific research, but the metrological aspects of its application are not well understood, so the current will be the analysis of metrological characteristics of multispectral measurement means, the development of methodologies for multi-spectral studies in accordance with standard applications that will make it possible to include multispectral measurement means in the register of measuring instruments.

Relevance of the theme due to the need to continuously improve the reliability of the control parameters of inhomogeneous biological environments in applications for environmental monitoring, biomedical diagnostics and quality control, which leads to the need to develop a new multispectral television methods and means.

Multispectral television measurement control and diagnostics parameters inhomogeneous biological media is based on processing the array of multispectral images of the object obtained by the CCD camera into n wavelengths from the selected range of wavelengths in each of measuring channels. Selection of the optimal number of

wavelengths, the wavelength range of each channel and the required resolution of the CCD camera is performed by optimization based on finding differences measuring means structure at the statistical processing of the spectral characteristics of the diffuse reflectance of the objects, with a priori known state provides the necessary parameters of speed, reliability control or accuracy of diagnosis. The difference between fit and unfit object is defined as the distance in n-dimensional multispectral space for each pixel of the array of multispectral images. In addition, the coordinates in the n-dimensional space multispectral image elements are compared with the coordinates of the scale corresponding to known states of the test object. For multispectral imaging array processing will be used an expert system diagnostic decision support solutions using fuzzy logic and neural networks.

Mathematical models of the formation of non-uniform arrays of multispectral images of biological media are scientifically justified based on the radiative transfer theory in the light-scattering media and the approximate model for each layer.

The advantages of the improved method of multispectral television measurement control and diagnostic parameters of inhomogeneous biological environment that provides a higher reliability of the control and accuracy of diagnosis will be based on scientifically proven calculations compared to traditional.

Theoretical bases of construction of optimal tools multispectral television measurement control and diagnostics, provide the necessary parameters will be scientifically substantiated and proven based on the calculations of metrological characteristics of measuring instruments.

Development of specialized software and expert system decision support to handle arrays of multispectral images, as well as the development of experimental techniques for applications for environmental monitoring, biomedical diagnostics and quality control of products will be useful methodological and technical know based on practical experience.

Multispectral method of determining the distance of shooting

Multispectral vision measurement control and diagnostics parameters inhomogeneous biological media may be based on processing arrays of multispectral images of the object obtained by the CCD camera on the characteristic wavelengths. The study continues research area of authors in the research of methods and means of spectrophotometry, spectropolarimetry, digital and colorimetric measurement of color coordinates, vision control of a condition of biological objects. In the case of application of diagnosing problems determined statistical differences in the spectral characteristics of two or more states of the object. The difference in the coefficient of diffuse reflection measured at a specific wavelength and at a certain value for the wavelength range of the measuring channel with a certain probability allows to distinguish suitable object or unusable. In the transition from the diffuse reflectance spectrophotometry to the multispectral vision method it is possible to compare the diffuse reflectance or transmittance for each pixel on *n* wavelengths. When using a digital colorimetry determined by the difference in the color for normal and abnormal biological tissue area, the distance between points in three-dimensional color coordinate space CIEXYZ or CIELAB [6, 7]. When changing from digital colorimetry to the multispectral vision method, the difference between normal and abnormal portion is defined in n-dimensional multispectral space for each pixel of the image, allowing you to optimize the means of a structure to work at those wavelengths in the range where the differences will be most noticeable and improve control the accuracy [6-9].

Mechanical effects of traumatic weapons on the biological tissue of the skin accompanied by the defeat and break the subcutaneous and deep-seated vascular bleeding from them. The accumulated in the lesion is observed blood through the skin and forms a bruise.

The concept of "bruise" unites different origin and intensity of blood accumulation in soft tissue thickness and in the intervals between them. Bruising in mechanical lesions are caused by bleeding mainly of arterioles and small arteries. Immediately after application of the injury as a result of mechanical damage to the human skin is damage biological tissue microvessels and capillaries in the dermis and the outpouring of a large amount of blood in the near-surface layers of the skin.

In experimentally derived concentration of hemoglobin derivatives in pathological biological tissues at different time intervals after the application of the injury count in Mathcad 13.0 diffuse reflection coefficient of the skin (Figure 1).

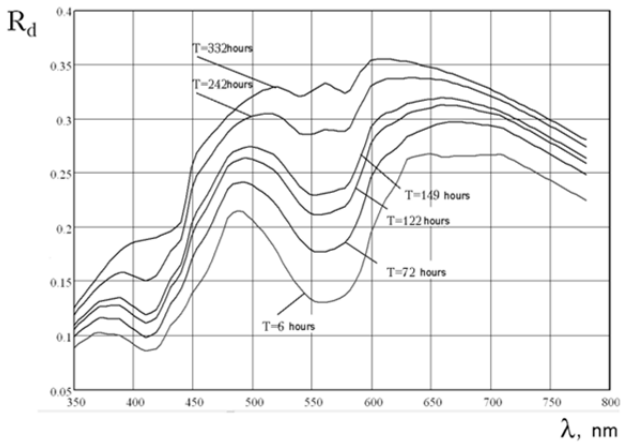

Fig.1. The spectral characteristics of diffuse reflectance of the injured skin area

On the basis of the spectra of diffuse reflectance of normal and pathological biological tissues of the skin color coordinates expect X, Y, Z additional standard colorimetric CIE 1964 system of designation and their dependence on the main skin chromophores for standard light source D65 in the Mathcad 13.0 (Figure 2).

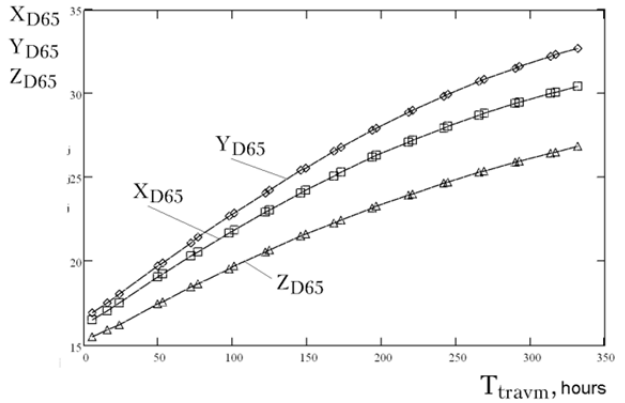

Fig.2. The dependence of the color coordinates of pathological biological tissue when you change the time after injury

We solve the inverse problem of determining the time of damage based on the color coordinates in the more

standard colorimetric system CIE 1964 for a standard light source type D65:

$$(1)\quad \begin{cases} T = 389,6264 - 111,7349X + 9,4145X^2 - 0,3103X^3 + 0,0039X^4, \\ T = 250,9716 - 78,3055Y + 6,5484Y^2 - 0,2059Y^3 + 0,0025Y^4, \\ T = -286,511 - 2,4254Z + 2,5676Z^2 - 0,1378Z^3 + 0,0027Z^4. \end{cases}$$

We use the following geometry illuminator/observer – lighting diagnosis object (biological tissue of the skin) is carried out by diffuse light source (D65 standard source of radiation such as a frosted glass filter) that provides uniform illumination of the investigated area of the object. The unevenness of illumination on the test area should not exceed 1%. Multispectral CCD camera captures the image of the biological tissue and at the same time a set of samples with known spectral parameters, which allows for auto-calibration device before starting work and constant adjustment characteristics during operation. The resulting digital image is sent for further processing to a personal computer via a USB port. The resulting image with the camera hardware dependent converted into a digital image, which completely compensated influence the spectral characteristics of the radiation source and the camera. Compensation shall be effected by the introduction of corrective coefficients calculated using known values of a set of spectral parameters of the samples used for the auto-calibration device. The settings for each image pixel in the n-dimensional multispectral space compared with the parameters of the selected set and classified to the nearest one. Defines the number of pixels of the image corresponding to each set of samples, and the area in percent relative the total number of pixels.

Analysis of experimental results

For the research was used Flaubert's cartridge caliber of 4 mm and a length of 0.64 cm. The shots were made from Ekol revolver, model Viper 2,5 inches Cal. 4 mm, fixed in the special machine. For the target biomannequin, biological and physiological properties of the skin tissues which are close to the morphological and functional characteristics of human. Shoots were performed at a distance of 2, 5, 10, 20, 30, 40, 50, 60, 70, 80 cm and 1 m.

In determining the distance of shooting described processing procedure is performed for the three parts of the image (Figure 3):

– 3 cm in diameter circle in the center of the image;

– ring with a diameter of 3 to 6 cm from the center of the image;

– ring with a diameter of 6 to 12 cm from the center of the image/

Built in one coordinate system color indicators for normal and pathological biological tissues of the skin at different volume content of blood and melanin using a standard light source D65 (Figure 4). On the basis of the color chromaticity coordinates and additional standard colorimetric system CIE 1964 may accurately diagnose skin biological tissue for forensic diagnostic problems

The values obtained for the relative number of pixels in the n-dimensional multispectral space for each part of the circle around the gunshot wounds are transferred to the input of an expert system based on neural network (Figure 5), which should give the output value of shooting distance. Education expert system was based on the large number of images gunshot injuries to the known values of the cartridge type and shooting distance.

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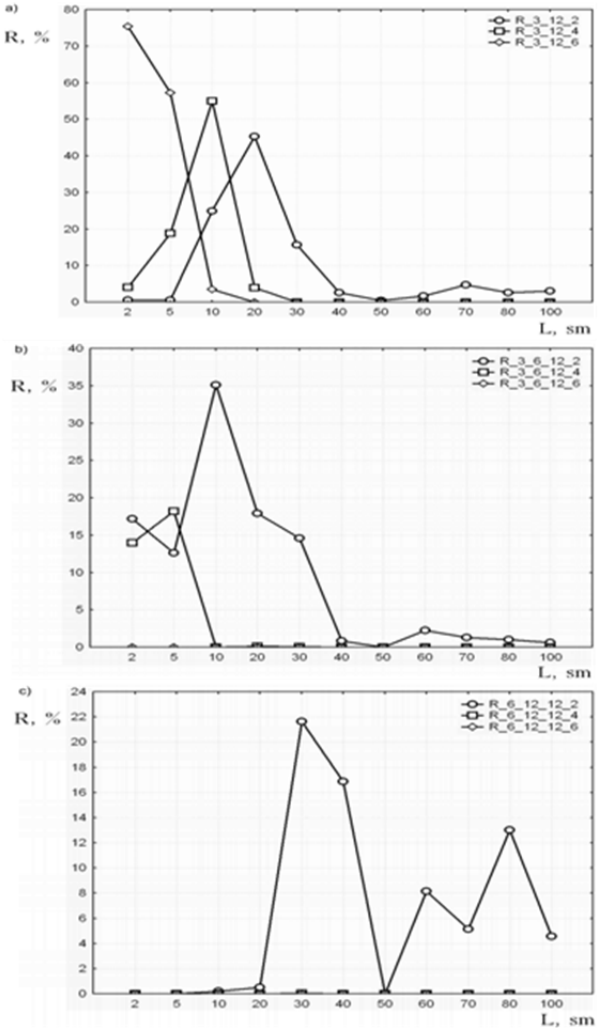

Fig.3. Dependence of the histogram of multispectral images for traces of gunpowder on the distance to the target (Flaubert's cartridge): a) 3 cm in diameter circle in the center of the image; b) ring with a diameter of 3 to 6 cm from the center of the image; c) ring with a diameter of 6 to 12 cm from the center of the image

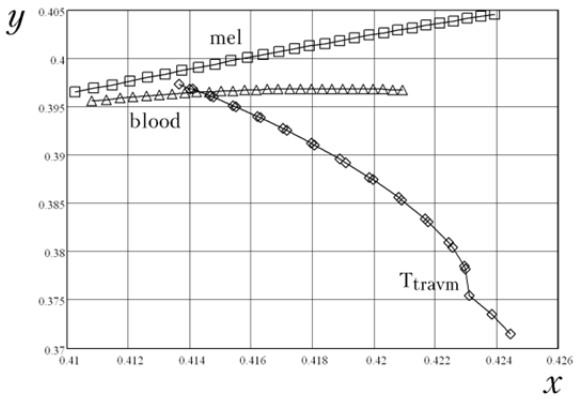

Fig.4. The dependence of the chromaticity coordinates of the normal and pathological biological tissues of the skin

We solve the inverse problem of determining the time of damage, based on the system in the CIE 1964 chromaticity coordinates for the standard light source type D65:

$$(2)\quad T = 1,8088 \cdot 10^8 - 2,0491 \cdot 10^9 y + 8,7046 \cdot 10^9 y^2 - 1,6434 \cdot 10^{10} y^3 + \\ +1,1634 \cdot 10^{10} y^4.$$

The output of the expert system is to generate diagnostic solution in the form of the distance to the target. To build an expert system diagnostic decision support solutions distance to the target using the package STATISTACA 6.0 Neural Networks (Figure 5).

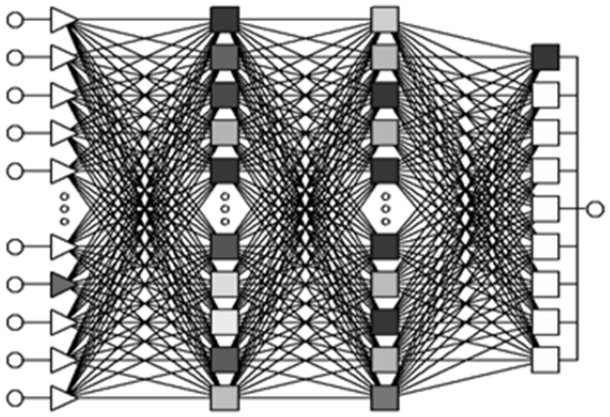

Fig.5. The architecture of the neural network based on multi-layer perceptron with two hidden layers

To build the neural network using the network architecture based on a multilayer perceptron with two hidden layers. After training the neural network on the basis of test sequences received control error value is not more than 5.6%.

Conclusions

In comparison with existing analogues [1-2] use an improved method and controls, will provide higher performance characteristics and reliability of the control.

An improved method for multispectral television measurement of biological tissues in vivo diagnosis will improve the accuracy of diagnosis using biochemical markers of drugs, isolate the damaged section of biological tissue as compared to the traditional methods based on the comparison of pathological changes in the color sections, as well as invasive histological analysis [3]. Since the measurement means has spectral characteristics that are consistent with the characteristics of biomarkers will increase the diagnostic accuracy compared with existing analogues [4, 5].

The proposed methods of processing arrays of multispectral images and decision support will improve metrological parameters measuring devices over existing methods [6-11].

Multispectral improved method and means for determining the distance of shooting on the basis of the study gunshot injuries of the skin tissues, which allows to register the skin damage biological tissue forensic expert and use the findings as an evidence base. Developed algorithms and software diagnostics of human skin tissues, to determine the histogram of multispectral images for gunpowder traces. It developed and analyzed the work of the expert system of support of acceptance of diagnostic solutions in determining the distance to the target. Check the possibility of application architecture neural network based on multi-layer perceptron with two hidden layers. After training the neural network for on the basis of test sequences studied performance results and errors.

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