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Research Article

System of Trans-Operative Monitoring Determination of the Viability of Thoracic and Abdominal Biological Tissue and Devices for its Implementation

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Abstract

The article solves the problem of increasing the objectivity of the visual analysis of internal organs during surgery. Because of the analysis, the authors found that spectral research in the visible spectrum and in the field of infrared radiation allows the practicing surgeon to determine the presence of pathologies of internal organs, as well as the location of their boundaries. At the same time, the use of the infrared range allows one to abstract from the color of the biological tissue to obtain information about the structure of its surface, while the applied HSV color model allows for research in the visible spectrum with conversion of dominant reflected radiation into wavelengths.

Keywords: Internal Organs Research; Operative Intervention; Optical Sensing; Spectral Analysis; Biotissue Structure; Infrared Range; RGB; HSV Color Model; Area of Necrosis

Introduction

Instrumental methods for the study of human internal organs are used mainly to detect the affected internal organs and determine the presence of pathological processes occurring in them. In medical instrument making, there is a clear tendency to form a new direction associated with the use of parameters for the interaction of optical radiation with biological tissues for noninvasive or minimally invasive diagnostics.

The electromagnetic radiation of the infrared, visible and ultraviolet ranges interacts with any substances, including bioobjects, and the study of these interactions provides important information about the molecular structure of these objects, as well as about the processes occurring in them at the atomic and molecular levels. The dependence of the absorption of a substance on the frequency or wavelength of radiation is called the absorption spectrum (absorption spectrum) of this substance. However, the scattering spectra are considered to be more informative for solving the problems of medical diagnostics. Any substance under certain conditions is capable of emitting electromagnetic waves and has its specific emission spectrum. The dependence of the intensity of electromagnetic radiation of a substance on the frequency or wavelength is called the emission spectrum of this substance.

The spectra of atoms and molecules reflect bonds energy; therefore, the optical spectra of substances are very sensitive to changes in the chemical bonds of atoms and molecules, to changes in their environment, the pH of the medium, to the effects of external electric and magnetic fields and other factors.

For these reasons, spectral analysis is one of the most important non-destructive research methods, both the structure of matter and the physical and chemical processes occurring in matter at the atomic and molecular levels. This is due to its widespread use as a research method in biochemistry, molecular biology and medicine.

Due to the internal conversion, the emission of electromagnetic quanta occurs from the lower electronic sublevels of excited states to even lower vibrational and rotational energy levels of atoms and molecules. As a result, the first, second, etc. emission bands (luminescence) are formed, which are significantly shifted relative to the absorption bands towards lower frequencies. This pattern of molecular spectra is known as the Stokes' law.

If all three types of energy change when a molecule transitions from one state to another, then the spectra are called electron-vibrational-rotational. They have the form of rather wide spectral bands located in the ultraviolet (UV), visible or infrared regions of the spectrum. Emission spectra are more commonly referred to as fluorescence spectra. They are observed almost immediately after the absorption of external radiation, quickly fall off ($T=10^{-7}$ - 10^{-6} s.) And disappear as a result of collisions of the radiating molecule with other molecules in solutions, gels or biotissues. Vibrational spectra provide information about the energies of the valence bonds of a molecule, the energies of intermolecular interactions, conformational and other changes in the structure of molecules and therefore are widely used in spectral studies of molecules [1]. Biological tissues have a complex structure, which is a complex of various substances, fibers and interstitial fluid, they are optically heterogeneous media. In turn, the heterogeneity of the medium leads to the scattering of the light incident on it; therefore, biological tissues have a strong scattering.

Optical non-invasive diagnostics generally involves the use of optical (including laser) radiation for *in vivo* sensing of the patient's tissues and organs in order to obtain diagnostic information on the reflected radiation on the structure of the biotissue under investigation [2].

The use of various wavelengths for diagnosis can help to obtain information on the presence in tissues of various chemical compounds, indicating specific processes occurring in tissues. Using the wavelengths of the infrared range, respectively, to search for biomarkers of the pathologies under investigation, which allows one to abstract from the color of the tissue and reduce the errors caused by the external illumination of the measuring path.

A device for assessing the state of the structure of the surface of a patient's tissue during surgery can be based on the method described above. At present, the state of the tissues is assessed visually, i.e. qualitatively; The surgeon's experience has a significant impact.

Figure 1 shows a generalized functional diagram of the device for the optical study of biological tissues. When designing a device, attention should be paid to the location of emitters and radiation detectors both with respect to the tissue being examined and with respect to each other: it may depend on the type of radiation detected (Fresnel, Rayleigh). Shielding from radiation from external sources of radiation can also improve the accuracy of a diagnostic study [3].

Radiation from source 1 hits the object under study 11. The radiation reflected from the surface of the object under study 11 is transmitted to the radiation receiver 2 and then to the processing unit of the received data.

The received signal is fed to the photocurrent to voltage converter 3. Next, the output signal of the photocurrent converter is fed to the amplifier 4 for amplification, then the amplified signal is fed to the ADC (Analog-to-digital converter) 5 and converted to binary code.

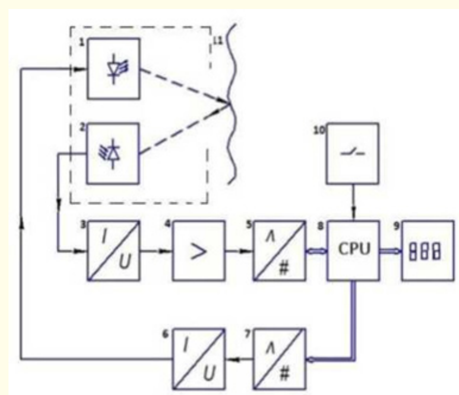

Figure 1: Functional diagram of the device for the optical study of the structure of biological tissues.
1- Radiation source; 2- Radiation receiver; 3-Photocurrent to voltage converter; 4- Amplifier; 5-ADC; 6 - Voltage to current converter; 7- DAC; 8- CPU- calculator; 9- indicator; 10- Keyboard; 11- Investigated surface of biological tissue.

Indicator 9 displays changes in the monitored parameter of the object under study. The obtained data is processed using the CPU 8, which is the basis of the entire structural scheme, which controls all the procedures relating to the collection and processing of information [3].

The limiting case of the state of a bioobject is tissue necrosis. The causes of necrosis can be a violation of the venous or arterial circulation, infection with microbes. The list of causes also includes diseases of the central nervous system [4]. In this case, the solution to the problem of finding ways to determine the boundaries of tissue necrosis is important, since functional disorders of the internal organs, necrosis of their areas is a common phenomenon in surgery. Therefore, reliable and accurate methods of determining the functional state of the internal organs and the boundaries of pathologies are required. There are methods for determining the boundaries of necrosis by introducing contrast agents, but they can only be used when opening an organ. There are methods for assessing the state of the tissues of the intestine using the assessment of blood circulation in the vessels of the investigated area. There are also methods for estimating the bioelectromagnetic reactivity index, estimating the reflectivity of the microwave signal of a tissue, determining the polarization coefficient of a tissue, etc.

There is also a method in which the boundaries between healthy and diseased intestinal tissue are visually identified by the color of the serous membrane, the frequency of intestinal motility, and the pulsation of its blood vessels.

Despite the availability of technical solutions, so far most of the clinics use routine simplest methods that are based on assessing the appearance of the affected intestinal area (color, shine), motility, pulsation of the mesentery vessels [5]. However, the listed signs allow subjectivity in diagnostics and, therefore, do not exclude the possibility of an error in determining the viability of an organ.

The proposed method involves estimating the color of the tissue using a video camera and a virtual device for determining color developed specifically in the LabView environment [6]. The proposed method allows to eliminate the subjectivity in assessing the color inherent in the human visual system. The method can be used both for abdominal operations (using digital video cameras, digital microscopes) and for laparoscopic (using special laparoscopic digital cameras).

Color models of RGB or HSV (Figure 2) can be used to measure the parameters of the tissue studied in the visible spectrum. These models provide the most convenient for perception information about color in the wavelength range from Amin = 380 nM to Amax = 780 nM.

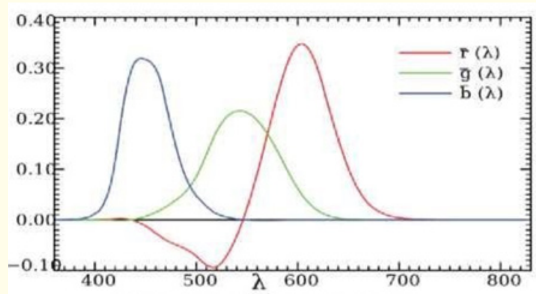

Figure 2: RGB spectrum of the visible range.

A USB RGB camera with three photodetectors with their sensitivity values r(A), g(X), b(X) can be used to register the reflected radiation. In this case, the output signals of photodetectors for radiation will be expressed in the following form [7].

$$R = \int_{\lambda_{\min}}^{\lambda_{\max}} S(\lambda) r(\lambda) d\lambda\,; \qquad G = \int_{\lambda_{\min}}^{\lambda_{\max}} S(\lambda) g(\lambda) d\lambda\,;$$

$$B = \int_{\lambda_{\min}}^{\lambda_{\max}} S(\lambda) b(\lambda) d\lambda$$

The HSV color channel is close to the representation of color as wavelengths, although it is not a complete equivalent due to the absence of a unique mathematical connection between the wavelength and the color representation in digital form. For convenience of perception, the chromaticity information is close to the type of representation of the wavelength. The brightness and saturation channels also help to get a clearer idea of the color of an object (in comparison with the RGB color space).

The functional diagram of the device designed in the LabView environment is presented in Figure 3. The development is a simulation model of a measuring channel that determines the color of an object.

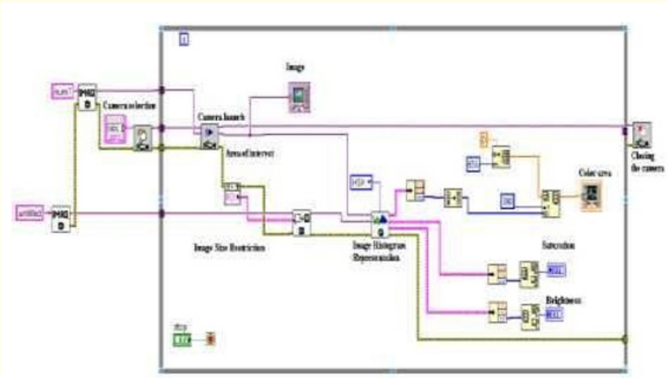

Figure 3: Functional diagram of the device implemented in the LabView environment.

A prototype model of the developed device was used in practice to conduct experiments to determine the boundaries of necrosis of intestinal areas (City Clinical Hospital No. 7). The results of the work are presented in Figure 4 and Figure 5.

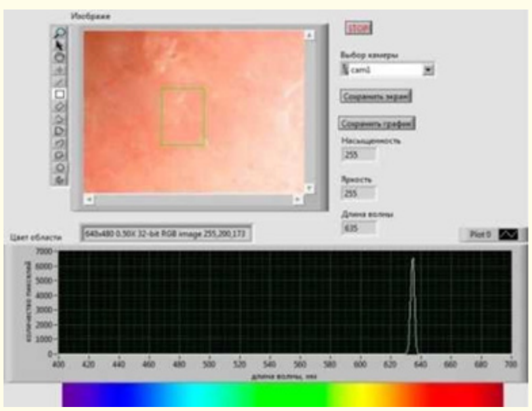

Figure 4: Determining the color of a healthy part of the intestine.

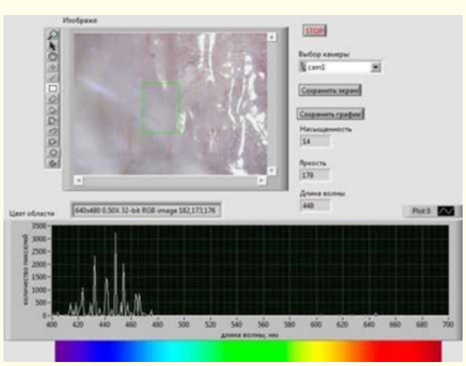

Figure 5: Determining the color of the affected intestine area.

As follows from figures 4 and 5, visually different sections of tissue have different values of the distribution of parameters (chromaticity, saturation). Based on the appropriate processing of experimental results, conclusions can be drawn about the functional state of the tissues under study. It is possible to use differential processing of the obtained images: making a decision on the viability of the tissue based on the difference of the optical parameters of the healthy part of the tissue and the affected one.

Conclusion

Thus, the integration of diagnostic methods using radiation in the visible spectrum and in the infrared range can significantly increase the information content of the results, and hence the objectivity of diagnosis. The color differentiation of the parts of the organs allows to form a conclusion about the presence of the inflammatory process by changing the color of the biotissue, and the infrared signal, which is abstracted from the color component, carries information about the surface structure that changes during the course of the disease.

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