

Optical automated method for early diagnosis of pathologies of the structure of external tissues of biological objects

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ABSTRACT

The main method of applying optical principles of operation of the system for diagnosing pathologies of biological tissue at an early stage is proposed to use the formation of moiré effects. The aim of the work is to create theoretical foundations for a method of early determination of the state of the structure of biological tissue of objects, which contributes to the intellectualization of diagnostic processes and exposure, in particular, to light electromagnetic fields. This improves the quality of equipping scientific experiments in biology and medicine with modern technologies. The proposed method of diagnosing the condition of objects allows its use in early diagnosis of pathologies and, as a result, in the treatment of a wide range of diseases, as well as, for example, postoperative scar structures, a number of dermatological diseases.

Keywords: moiré images, diagnostic systems, biological objects, optical systems, machine learning, pathology of cells, surface tissue structures.

1. INTRODUCTION

The creation of modern diagnostic systems for biological and medical research, carrying out therapeutic manipulations (if necessary) requires high accuracy in determining the parameters of changes in structures that occur in the environment of the studied biological objects. The state of development of biology and medicine is characterized by the use of new technical methods for scientific research, diagnostic, and therapeutic purposes of achievements of technical sciences to solve the most important task - increasing the objectivity of research. This problem is also relevant in the creation of medical diagnostic devices, in particular integrated physiotherapeutic ones containing laser modules, etc. The state of the problem of monitoring the interaction of the environment with biological objects¹⁻³ proves that the most important factor in these phenomena is the influence of field structures, which determines the processes of biotechnical interaction⁴⁻⁶. Optical systems are known that have been used so far in medical and biological research practice for very reliable diagnostics of changes in cellular structures that affect the visual-sensory perception of optical images by the observer when analyzing the fluid state of an object. However, in this case, there are possible: unreliability of data, errors in diagnosis, especially if routine examinations are carried out after a sufficiently long period of time, which is due to the subjective parameters of the observer⁷.

The proposed complex method of early diagnosis and treatment uses automated means intended for contactless observation of objects during non-invasive studies, during minor surgical interventions, in preventive, postoperative examinations. The proposed methods of analyzing the structure of objects based on the processing of optical information characterizing these structures provide the possibility of tracking the pathology of cells, surface tissue structures of the body, which allows to increase the reliability of the conducted studies and automated diagnostics of the fluid state, archiving and accounting of patients. The proposed method of diagnosing the condition of objects allows its use in early diagnosis of pathologies and, as a result, in the treatment of a wide range of diseases, as well as, for example, postoperative scar structures, a number of dermatological diseases, etc.

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Determining the structure of objects and their fluid state during therapeutic exposure is a necessary task in developing new approaches to creating diagnostic and treatment methods¹²⁻¹⁴. Determining changes in the structural composition of biotechnical objects should be the basis for the operation of an automated system for diagnosing and irradiating biological objects for the purpose of treatment or research in scientific and research institutions¹⁵⁻¹⁷. Thus, the aim of the work is to create theoretical foundations for a method of early determination of the state of the structure of biological tissue of objects, which contributes to the intellectualization of diagnostic processes and exposure, in particular, to light electromagnetic fields. This improves the quality of equipping scientific experiments in biology and medicine with modern technologies¹⁸⁻²⁰.

2. OPTICAL PRINCIPLES OF DETERMINING STRUCTURAL DISORDERS IN BIOLOGICAL TISSUE

The main method of applying optical principles of operation of the system for diagnosing pathologies of biological tissue at an early stage is proposed to use the formation of moiré effects^{8,9}. The proposed optical system based on moiré images in the diagnosis of human skin pathologies uses the moiré phenomenon, which occurs when two regular structures, such as grids or stripes, are superimposed. This phenomenon allows the creation of images that can reveal hidden or difficult to discern details, which is especially useful in medical diagnostics, including dermatology. As is known, these principles are based on moiré measuring transducers for displacements and deformations. In this case, a moiré image is formed by superimposing two raster's made, for example, in the form of a periodic alternation of opaque and transparent linear or other configuration structures intersecting at an acute angle. When illuminating such a structure with a conventional flow of incoherent light radiation, due to the geometric laws of optics, combination moiré fringes will be observed on its surface, which on an enlarged scale repeat the combined structure of periodic raster's. The operating principle of such a system includes several key aspects. As is known, the moiré effect is created as an interference pattern that appears when two regular grids or stripes with a slight angular shift are superimposed on each other. Thus, it can lead to the appearance of additional stripes or patterns that are not present in the original images^{21,22}.

In the case of diagnosing human skin diseases, such moiré images of selected areas of the skin surface can enhance the contrast between the different layers of the skin of this area and reveal pathological changes. Such changes can occur in the presence of diseases such as tumors of the outer surfaces of the skin, mucous organs, inflammation, or changes in the structure of tissues. Such phenomena determine the degree and stage of development of the patient's disease. At the same time, it is necessary to determine that the tissues of the studied biological object are heterogeneous structures of the layered type, with certain characteristics of nonlinearity, dispersion, dielectric and magnetic permeability. Such a representation of the real model of the studied biological object is a condition for creating new diagnostic and treatment methods, new technical solutions for creating methods, building medical equipment, in particular based on optical phenomena, which increases the accuracy of diagnostics.

Creation an optical system for skin diagnostics based on moiré images requires a combination of optical components, sensors, software, and data analysis. The main stages that can be distinguished for creating an automated system using the proposed method of diagnosing pathologies can be the following. To create moiré images, it is necessary to use a light source that will illuminate the skin surface being examined. It is necessary to identify the main components of the optical system (fig. 1). In this case, the light source is selected. The light source should provide uniform illumination of the skin surface and minimize shadows and glare. These can be, for example: light-emitting diodes (LEDs), laser diodes with a specific wavelength suitable for skin examination (e.g. near infrared or visible light). It is also necessary to select optical gratings or filters (matrices). The moiré effect occurs when two regular patterns are superimposed on the skin surface. The following are used for this optical gratings or diffraction gratings, which are grids with regular intervals. These gratings can be placed in different parts of the system (for example, in the path of the light beam or in the field of view of the camera), creating an interference pattern that can be analyzed¹⁰. Sometimes in certain cases flat filters with regular lines can be used and superimposed on the skin image to create a moiré effect (fig. 2). In addition, one of the main elements of the optical diagnostic module based on the principle of moiré effects is various lenses are used to focus the image and control lighting.

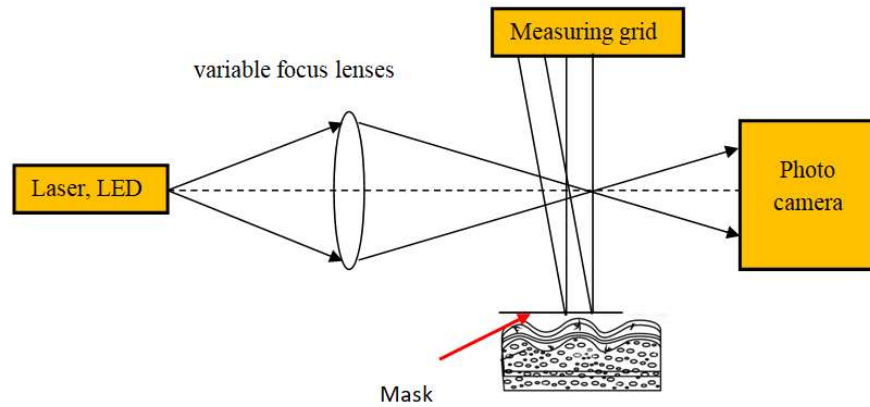


Figure 1. Optical module general diagram.

The module's optical system uses variable focus lenses to fine-tune the focus on the skin, including fine structures. For a special case of the diagnosed area of the object, the optical system of the diagnostic module uses macro lenses for detailed visualization of the skin and high image resolution. Such a choice of the element base of the optical module of the diagnostic system provides, thanks to the high values of the optical image resolution, the corresponding necessary quality of diagnostics of violations of the standard structure of biological tissue. In this case, it is possible to clearly determine the degree of pathological changes in the tissue and prescribe either a course of treatment or recognition of the necessary operability of the patient. An important element of the optical system of the diagnostic module is a camera that records an optical image for further conversion and transmission to the processing unit. The camera must have high resolution and sensitivity to changes in the image. A digital camera with the ability to capture high-resolution images, the camera must support various shooting modes, such as high-speed shooting (for analyzing the dynamics of image changes). It is important that the camera has the ability to operate in the infrared or visible spectrum, depending on the type of study.

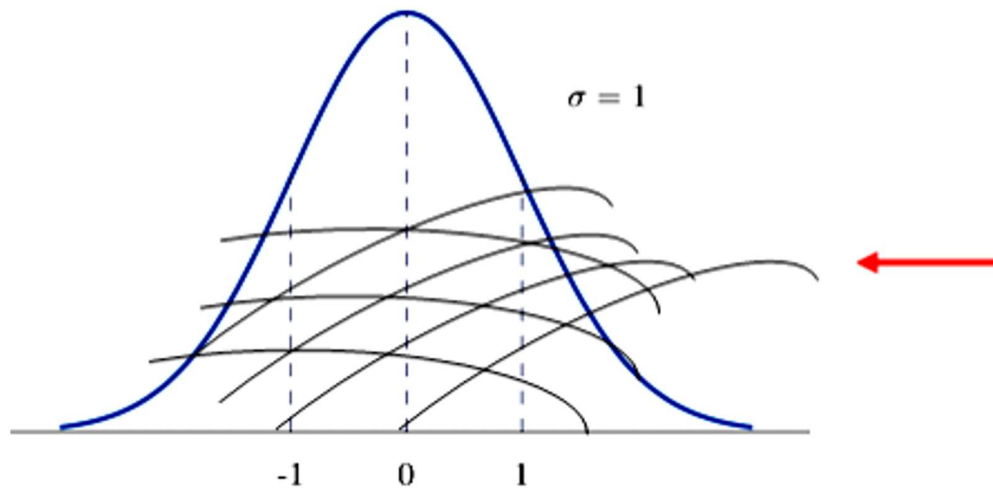


Figure 2. Obtaining moiré images on the surface of biological tissue.

3. PROCESS OF OBTAINING A MOIRÉ IMAGE BY OPTICAL SYSTEM OF THE DIAGNOSTIC MODULE

The process of obtaining a moiré image according to the proposed method for diagnosing pathologies of biological tissue structures is as follows. First, the patient's skin is illuminated using a light source. The light may be polarized to reduce the effects of reflections and improve the visibility of moiré patterns. This is the first stage in the operation of the optical diagnostic module, which consists of irradiating a specific area of the object's tissue. Next, an optical grating overlay is provided so that the foreground of the system contains optical gratings or diffraction filters. These elements create regular patterns that are superimposed on the image, creating moiré patterns when interacting with the skin or other tissue of the biological object. The next stage of forming a moiré optical image of a designated area of a biological object is image registration. In this case the camera records the resulting image, including the moiré effect that occurs due to the interaction of light with the skin and the optical grid. The next stage of diagnostics is the processing and analysis of the obtained images of the moiré pattern, which, provided the high resolution of the optical system, will allow recognizing the details of changes in the structures of biological tissue, which is caused by the occurrence of pathological effects, diseases. The resulting images are transferred to a computer where they are processed. In particular, the algorithms of the automated image processing system can provide calculate contrasts between healthy and pathological areas of the skin.

This will allow us to determine and identify moiré patterns that may indicate abnormalities in skin structure. In this case, the proposed optical system can perform such a function as analyze the texture of the skin to detect changes such as swelling, inflammation, or pigmentation changes. This is the most important function of the diagnostic system, which in an automated mode allows for early diagnosis of many diseases without resorting to invasive methods of taking a laboratory sample such as tissue biopsy. Thus, the main method for diagnosing pathologies of microstructures, even cellular structures of biological tissues of the body, is proposed to obtain moiré patterns by the optical system of the automated module and their recognition and identification. Such approaches allow for early diagnostics of problem situations.

4. RESULTS OF THE STUDY OF DETERMINING PATHOLOGICAL STRUCTURES BY OPTICAL METHOD

Automated data processing and analysis of the obtained moiré images of biological tissues of the object can be obtained using methods for improving the quality of optical images. Thus, once the images have been acquired, they need to be analyzed, which may include the first step, as image preprocessing, noise removal and illumination correction. In this case, the following actions are performed, as extraction of moiré patterns using filters and image processing algorithms. The presence of an automated module in the diagnostic process control system can allow the use of machine learning of the system, since precise operations for determining the difference values, when comparing optical moiré images of objects are required here.

Machine learning methods will allow develop and train machine learning models to analyze the resulting moiré images¹¹. For example, convolution neural networks (CNN) can be used to classify skin changes and diagnose diseases. Thus, software will automatically analyze moiré images, extract key features and compare them with databases to identify pathologies. Development of an interface for the doctor, which will allow information about the patient's skin condition to be obtained based on image analysis. Based on the detailed process of organizing the diagnostic and treatment process, it is necessary the visualization of results on the screen with the ability to display diagnoses or recommendations. As a use case, it can be the creation of a user interface (e.g. using graphical software) where the physician can see both the original skin images and the analysis results.

A necessary action for conducting diagnostics when using the optical moiré image method is the accuracy of determining image elements. Then It is important to calibrate the system using control samples (e.g. healthy skin and skin with known pathologies) to ensure diagnostic accuracy. Testing on real data with patients can also be done to ensure the system is effective. It is important to calibrate the system using control samples (e.g. healthy skin and skin with known pathologies) to ensure diagnostic accuracy. Testing on real data with patients can also be done to ensure the system is effective.

5. CONCLUSIONS

The advantages of this diagnostic method are its non-invasive that is unlike biopsy or other methods, optical technologies do not require intervention in the skin. And here we can once again emphasize such an advantage of using an optical system based on obtaining moiré effects as high sensitivity. At the same time, moiré images can reveal the smallest changes in the skin structure. A system created based on the principles of registering a moiré image of an object's structure can be relatively simple and cheaper compared to more complex diagnostic methods. In conclusion, the development of a moiré-based optical system for skin pathology diagnosis requires a combination of various optical components, image processing technologies and data analysis algorithms.

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