Registration and Processing System of Digital Speckle Images

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***Abstract*— In this paper, we discuss an application of the method of laser-speckle correlation for studying the process of fibrin formation in blood plasma. A module for recording and processing speckle images based on a debugging kit for the Atxmega128A1 microcontroller has been developed. The results of testing the developed module as part of a laboratory setup based on a diode laser using standard reagents are presented. The developed device allows obtaining a curve characterizing the process of fibrin formation in blood plasma, with the use of which it is possible to determine the clotting time.**

Keywords—blood coagulation, laser speckle, image processing, correlation.

I. Introduction

Blood coagulation (hemocoagulation) is the most important step in the work of the hemostasis system, which is responsible for stopping bleeding when the vascular system of the body is damaged. Disruption of the blood clotting process can be caused by various reasons and entail undesirable consequences. Estimation of hemostasis parameters in real time is an essential task, despite the large number of existing methods and means of measurement. Nowadays several methods have been developed to observe and measure the physical characteristics which accompanied the coagulation process, for example, blood viscosity [1-4], surface tension [5] or electrical conductivity [6]. The main disadvantages of the majority of known methods are invasiveness, the inability to carry out clotting monitoring in real time and performing point-of-care testing.

Currently, diagnostic methods are being developed based on analysis of laser speckle images [7, 8]. Optical methods based on laser speckles make it possible to analyze blood clotting non-invasively. In particular, our team is developing a device for estimating the clotting time of native blood based on the digital speckle image correlation method [8], and an electronic module is required, which is used for an automated processing of speckle images.

In use, the device, which will be developed based on the hardware-software complex presented in the work, makes it possible to carry out actions inaccessible to competitors, namely: carrying out express analysis and continuous monitoring. The first feature will be important for people who need constant monitoring of blood clotting factor. Too fast or too slow blood clotting time may indicate the presence of disorders of the cardiovascular system. The second feature will make a great contribution to surgery. Continuous monitoring of this factor during surgery significantly simplifies the work of the surgeon.

The purpose of this work is to develop an automated microprocessor system for recording and processing digital speckle images.

II. Technical Means

A. Experimental Setup

The flow chart of the developing module is shown in Fig. 1. The scheme involves the laser to illuminate the object of study (test sample) with coherent radiation, the registration of light scattered by the object using a digital video camera and digital processing using a microcontroller and personal computer. At this stage of the work, the function of the microcontroller is reduced to controlling a digital camera and transferring data to a personal computer to calculate the correlation coefficient. In the following, the calculation of the correlation coefficient is supposed to be performed on the board of the microcontroller and display the results of the calculations on the display. LCD is indicated by an asterisk, because it is currently was not used.

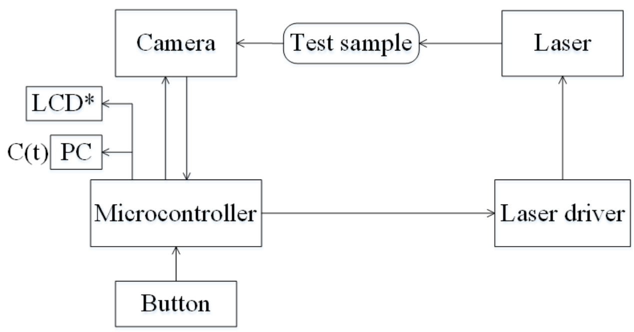

Fig. 1. The flow chart of the developing module. C(t) - correlation cofficient, PC – personal computer.

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For better clarity, the scheme of the experimental setup is presented in Fig. 2. The radiation source is supposed to be placed lower in relation to the sample so that the light passes through the cell. A cuvette for the plasma had 0.1 ml volume and was made from plastic using 3D printing technology. The advantage of this method of the cuvette manufacture is that the bottom of the cuvette serves as a diffuser. In the experiments described in [7], a separate diffuser was used for light scattering, which complicates the experimental setup.

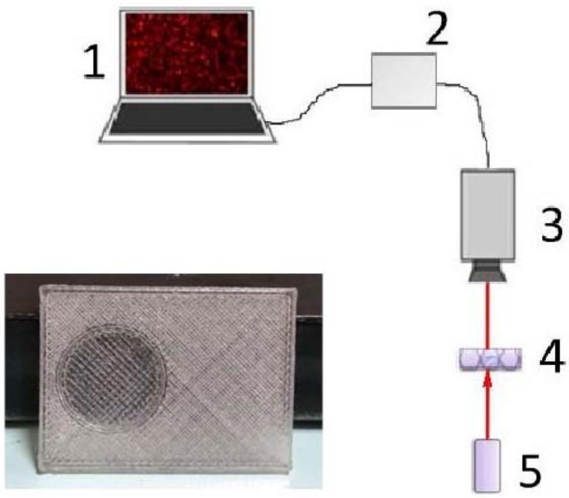

Fig. 2. Scheme of the experimental setup and cuvette. 1 – PC, 2 – microcontroller Atxmega128A1, 3 – cubCamera module OV7670, 4 – testing sample, 5 – a continuous diode laser with the radiation power of 10 mW.

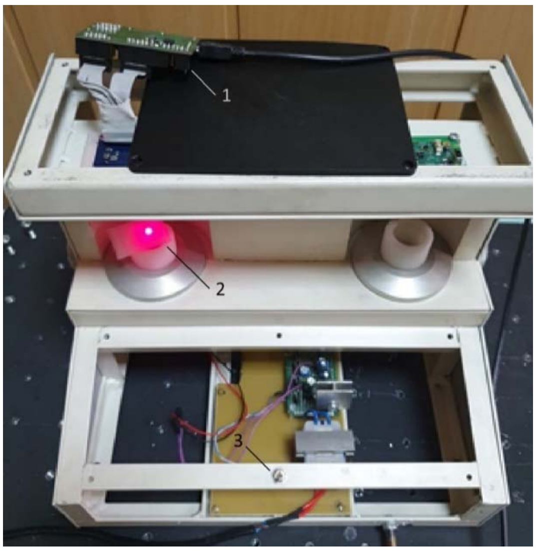

Fig. 3. Experimental setup. 1 – developed module, which consist of camera and microcontroller, 2 – control plasma in a cuvette on the sample table, 3 – laser driver switch on button.

The experimental part was carried out using the existing prototype of coagulometer, which is shown in Fig. 3. The prototype consists of two channels. In this study, we used one. The second channel can be used for the comparative study, for example, with different wavelength or light sources. Before the experiments, the camera with microcontroller was fixed in the experimental setup. For the experiment, a continuous diode laser with the radiation power of 10 mW and 650 nm wavelength was used, a control blood plasma and a Techplastin reagent (Technologiya Standard, Russia) with a given coagulation time [9]. There is an opportunity to change the height of the sample table in the experimental setup. We chose optimal one to get big and precise enough speckles.

During the process of fibrin formation as well as blood clotting, the movement of micro particles occurs, and clots form in the sample under study. The illuminating laser beam, due to scattering, forms a speckle image. In this case, there is no conversion of the frequency of the laser radiation or excitation of the medium of the object of study with subsequent radiation, so the information about the wavelength of the scattered light is not important for us. In this case, registration of full-color images is not expedient, since redundant information is recorded and saved, which increases data size and processing time. Thus, we used a monochrome camera mode for recording speckle images. A typical view of speckle images during the plasma clotting is shown in Fig. 4.

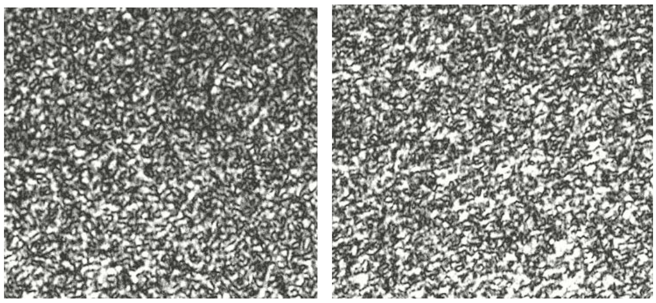

Fig. 4. Laser speckle images during the process of control plasma clotting. Moments of time are random.

B. Hardware Selection

In the process of working on the hardware and software part, a device was created for recording and processing digital speckle images. First of all, the hardware was selected according to the requirements specification. The requirements were the following: the speed of registration of speckle images – 30 frames per second, the frame resolution – 100×100 pixels and the time of continuous recording – 10 minutes.

We used the registration speed of speckle images 30 frames per second, because it is the average speed that enough to record speckles and in order to optimize the performance of selected resources. The frame resolution is also average, because minimum is 50×50, when it is possible to recognize speckles. The time of continuous recording is 10 minutes because in future we are planning to work with the whole blood and the time of the whole blood coagulation is 3-5 minutes, we take 10 minutes to record pathologies or disorders if they exist.

To develop an automated microprocessor system, microcontroller ATxmega128A1 (Atmel) and video camera module OV7670 with the with parallel connection interface (Omni Vision) were chosen. Most commercially available cameras involve batch video recording with data transmission via USB interface. Accordingly, the microcontroller module must have a USB controller with the appropriate driver, which is not desirable for our task due to the complexity of batch data processing. The advantage of the selected camera is the ability to shoot individual frames and a parallel interface for fast data transfer to the microcontroller. The debug module has a compact size and is equipped with a USB interface for transferring data to a personal computer, which is important at the initial stage of developing the device and the data processing algorithm. In the future, the personal computer will be connected via USB optionally. The results will be displayed on LCD.

The frame resolution of chosen video camera is 640×480 pixels, but we used reduced mode of frame resolution to optimize the system. The selected hardware in connection is shown in Fig. 5.

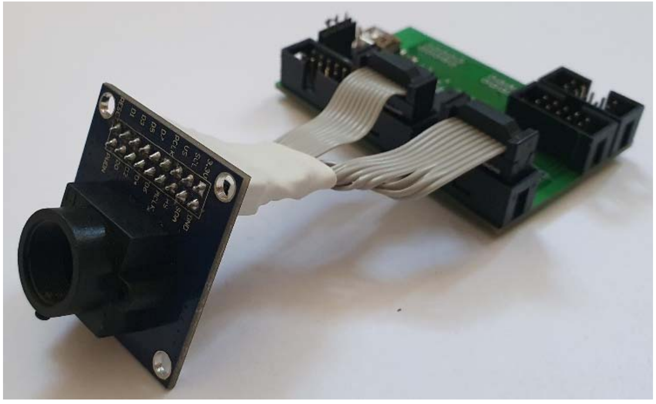

Fig. 5. The selected hardware in connection.

The chosen hardware meets the requirements and sufficiently productive. Important factor is that it is possible to write a script for every register either of camera or of microcontroller.

C. *Software Selection*

To write scripts for the microcontroller and the video camera, the XRobot (developed in TUSUR, Russia) [10] programming language was used to simplify the writing of scripts. The implemented script was loaded into the LabView software product, with the help of this modeling environment a virtual device – programming unit for the microcontroller ATxmega128A1 was developed.

To process the speckle images, the multi-level computer simulation environment MARS, also developed in TUSUR, was used [11]. In computer studies of complex technical objects and their virtual analogs, the actual question is the visualization of measurement and simulation results in their natural form, as well as the implementation of the ability to control the topology and parameters of the object model. MARS has a multi-layer editor that makes it possible to visually separate the computer model of the object under investigation, the system for processing the simulation results and the means for visualizing them and controlling the parameters of the technical object.

D. *Data Processing*

The camera registers the speckle image, then, with the help of the microcontroller and the multi-level computer simulation environment MARS, the obtained frames are processed to get the correlation coefficient curve during the plasma clotting.

The developed software script allows calculating the correlation coefficient automatically by the formula given in [12], which compares the subsequent image with the previous one. The graph of correlation coefficient versus fibrin formation time is plotted in real time.

III. Experimental Results

To test the work of the developed software and hardware module, we conducted eight experiments with the same reagents. The primary calculation of the correlation coefficient is a curve with quite intense noise (Fig. 6, 7). On the curves, the decrease of the correlation coefficient to zero is the moment of adding the Techplastin reagent in the cuvette, that is, the moment of the beginning of the process of fibrin formation.

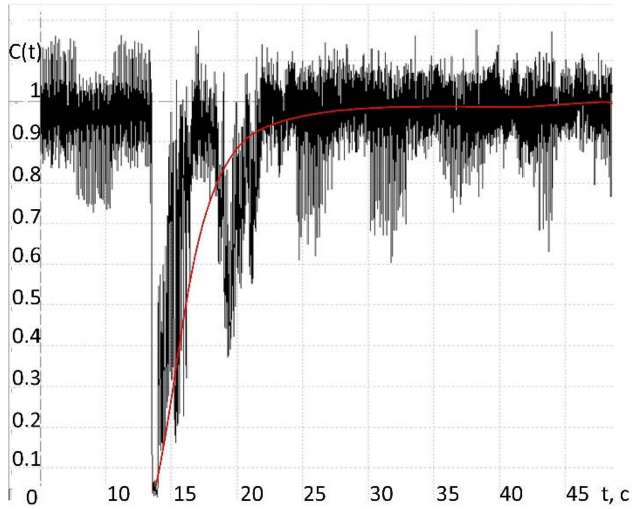

Fig. 6. Real and smoothed correlation coefficient versus time of fibrin formation.

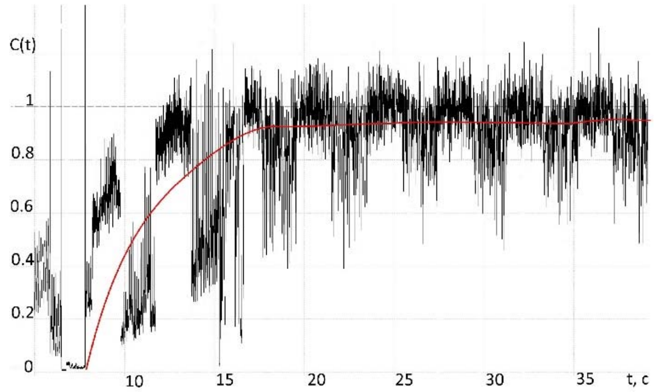

Fig. 7. Real and smoothed correlation coefficient versus time of fibrin formation.

The appearance of noise is a typical situation in working with laser speckles. The reason is that the laser speckle method is based on the interference of the coherent laser light and has a high sensitivity to vibrations. In paper [7], the experiments were carried out on a massive metal table, which made it possible to minimize the influence of vibrations. In the present work, we conducted experiments in the conditions close to real, which can be in the operating room, in the ward, or at home.The prototype was placed on a small aluminum plate, which was placed on the office desk. People worked in the neighboring rooms, in the immediate vicinity worked the system unit of a personal computer. In addition, a fluorescent lighting lamp was turned on in the room. Therefore, the data were smoothed using the sliding averaging method (red line in the figure). For smoothing the Mathlab software was used. According to the curve obtained, it is possible to determine the time of fibrin formation using the designed electronic module. The obtained time coincides with the visually observed change of speckles during the coagulation recorded on a video camera.

The resulting time was 11-13 seconds and it is coinciding with the known coagulation time of the reagent. The results of 8 experiment are shown in Fig.8, which shows the boundary curves and averaged one.

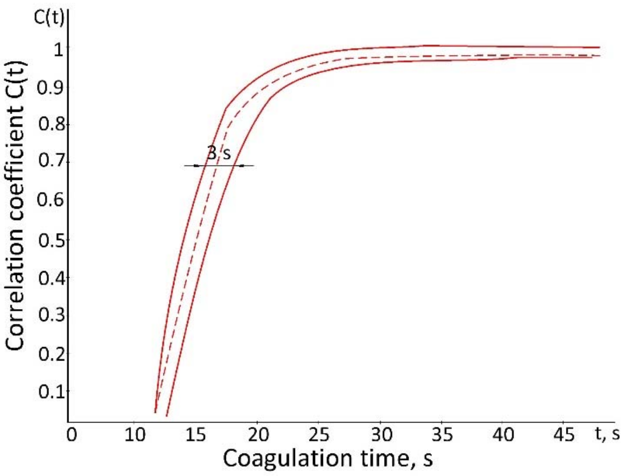

Fig. 8. Range of curves of correlation coefficient versus fibrin formation time

IV. CONCLUSION

In this work, an automated module based on ATxmega128A1 microcontroller was developed. The module allows to record and process digital speckle images. Image processing is carried out in real time with a slight delay.

The module was tested using the standard reagents for blood clotting time measurement.

In the future, it is planned to improve the algorithms of the system, to work out the method of analysis of blood coagulation, to install visualization tools onboard to display the dependence of the correlation coefficient on the fibrin formation time.

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