https://www.sworldjournal.com/index.php/swj/article/view/swj06-01-039
DOI: 10.30888/2663-5712.2020-06-01-039

УДК 57.087.1

MODELING AUTOMATED BLOOD COLLECTION SYSTEMS WITH BIOMETRIC IDENTIFICATION

Yakovenko I.
assistant
ORCID: 0000-0002-7740-4244
National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute»,
37, Prosp. Peremohy, Kyiv, Ukraine, 03056,
Hreben I.
ORCID: 0000-0002-0553-6942

Abstract. *This article substantiates the development of automated medical systems using biometric methods for identity identification. A structural and functional scheme was developed and 3D modeling of an automated biometric system of skin perforation with blood sampling was performed, which will ensure a high level of qualitative analysis of the sample, which in turn will minimize the cost of analysis. It is proposed the development an algorithm for selecting the basic indicators of blood volume indicators for human identification in an automated system for blood collection.*

Key words: *biometric identification, automatic system, dynamic methods, photoplethysmogram (PPG), blood sampling, perforation, classification of methods, structural-functional scheme, modeling.*

Introduction.

When diagnosing a patient, monitoring treatment, diagnosing the body, undergoing preventive medical examinations, the clinical tests of capillary blood are used to monitor the state of health. Significant threats to the safety of patients in hospitals and other medical institutions are errors in authentication and identification that occur during the stages of sampling, preparation of relevant documentation and announcement of the finished result, which are related to the human factor (targeted or accidental). Insufficient attention to this problem leads to errors that lead to the appointment of unnecessary medical and diagnostic manipulations, incorrect treatment, as well as erroneous clinical decisions based on laboratory and instrumental examination data, which are accidentally registered on the patient, but have nothing to do with him. Unfortunately, many of these errors can be fatal to the patient. For example, studies conducted in the United Kingdom [1] recorded 3273 cases of improper treatment in 13 years (administration of drugs not indicated to the patient or carrying out procedures not prescribed to him), associated with incorrect identification of the patient.

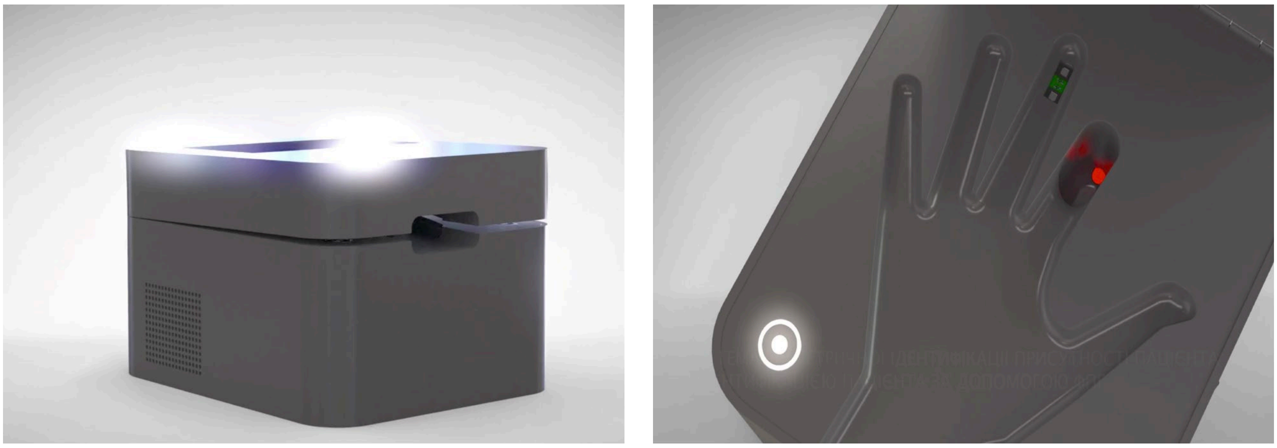
Also, a large number of such errors remain unrecognized. In one study [2], nurses and laboratory technicians were asked to perform the usual manipulations on mannequins, in the process of which they observed the correctness of the actions of medical staff to identify the patient. The study was performed on three mannequins, one of which had a discrepancy in date of birth and card number between the information on the identification bracelet and the direction issued to the nurse. The study participants did not know that it was dedicated to the correct identification of the patient. Only 61% of health professionals found an error, and 39% performed manipulations on the wrong patient, 15% of them did not understand what their mistake was. Unfortunately, there is no information on the prevalence of such errors in Ukraine, but we can assume that they occur at least as often as in other countries.

The main reason for incorrect identification of the patient is the human factor (purposeful or accidental). Today, in the current problem of COVID-19, the intensive pace of work of doctors and medical staff, panic among the population, simultaneous requests for thousands of patients, admission of patients with the same name, twins, hospitalization of foreigners with names that are difficult to pronounce and difficult to remember, lead to the fact that patients are not examined, make false diagnoses, which leads to incorrect actions and medical decisions [3,4].

Modeling automated blood collection systems with biometric identification

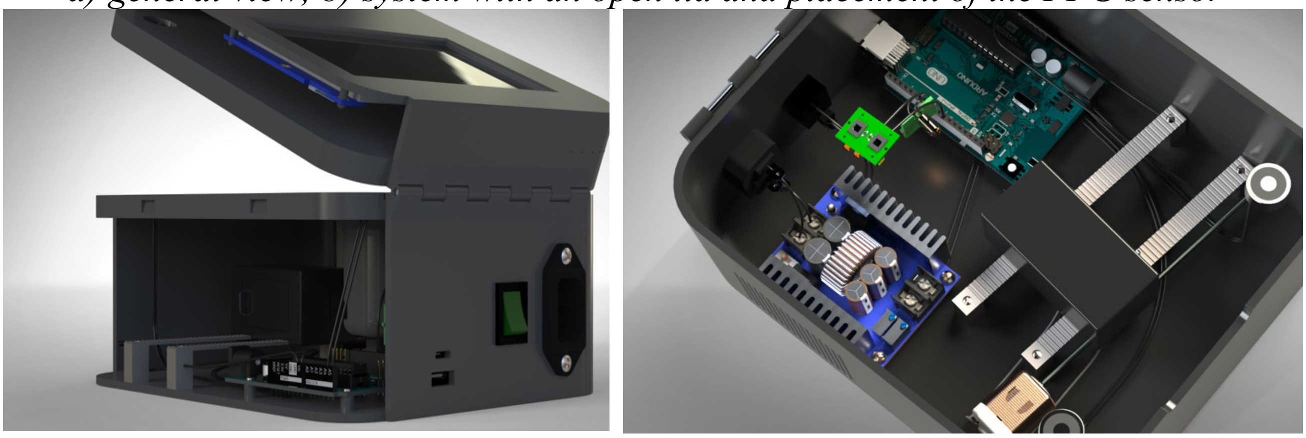
In the work was simulated an automated system for blood collection with biometric identification (Fig.1) of the patient simultaneously with the analysis, which will remove the human factor, thereby minimizing errors in establishing the patient's identity and compliance with the results of analysis studies.

Was make modeling of 3D-visualization of the automated system for blood collection with identification of the patient according to the photoplethysmogram (PPG) presented in fig. 1. The development was carried out in the SolidWorks 2020 computer-aided design system with the involvement of the SolidWorks Visualize 2020 visualization module. Figure 2 shows the structure of the component blocks.



a) b)

Fig. 1. Automated system for blood collection with biometric identification:
a) general view; b) system with an open lid and placement of the PPG sensor



a) b)

Fig. 2. Visualization of an automated system:
a) controls; b) material collection system and scanning unit

Since the maximum detail and accuracy of the system design (Fig.3) was the leading idea of creating a three-dimensional model, but the perforation unit is shown conditionally, for a complete picture of the system, it was modeled as realistically as possible in other works.

The operation of the system is as follows (Fig. 4): the patient's hand is fixed using a module for fixing the hand. In turn, this module records the position of the hand during analysis for more accurate detection of the capillary by the needle positioning system and painless blood sampling [5].

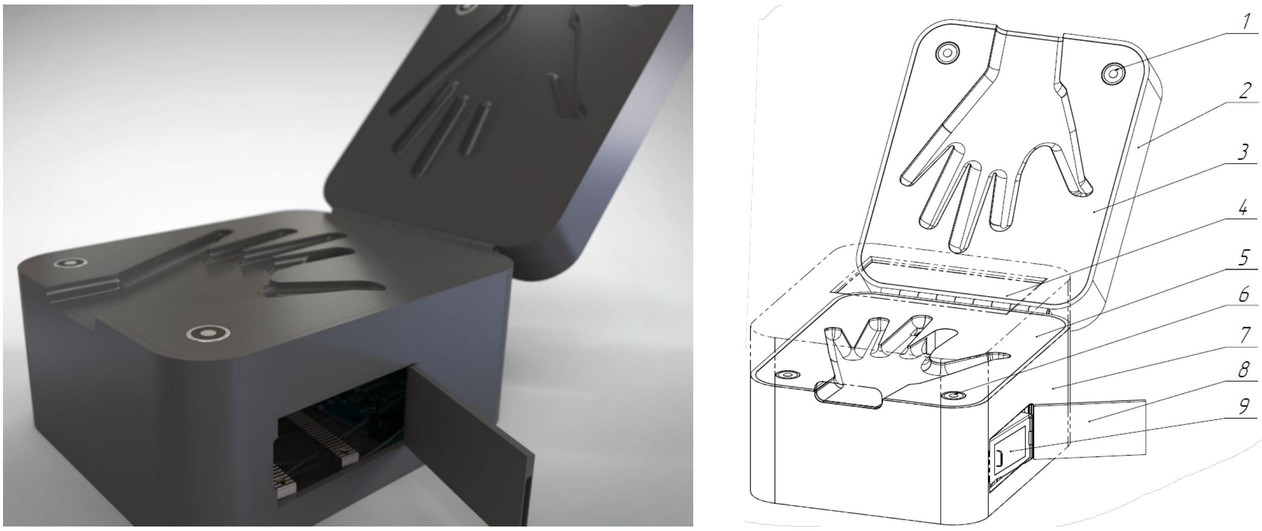


Fig. 3. General view of the system: *1- contact plate; 2- front cover; 3 - top panel; 4 - touch screen; 5 - lower panel; 6 – electromagnet; 7 - body; 8 - side cover; 9 – perforation unit*

The positioning system is responsible for receiving information about the capillary net from the ultrasonic receiver, after which, using an ADC, the signal is converted into digital [5]. The stepper motor provides movement of the skin perforation module, using a needle positioning system that perforates the skin of the patient's hand.

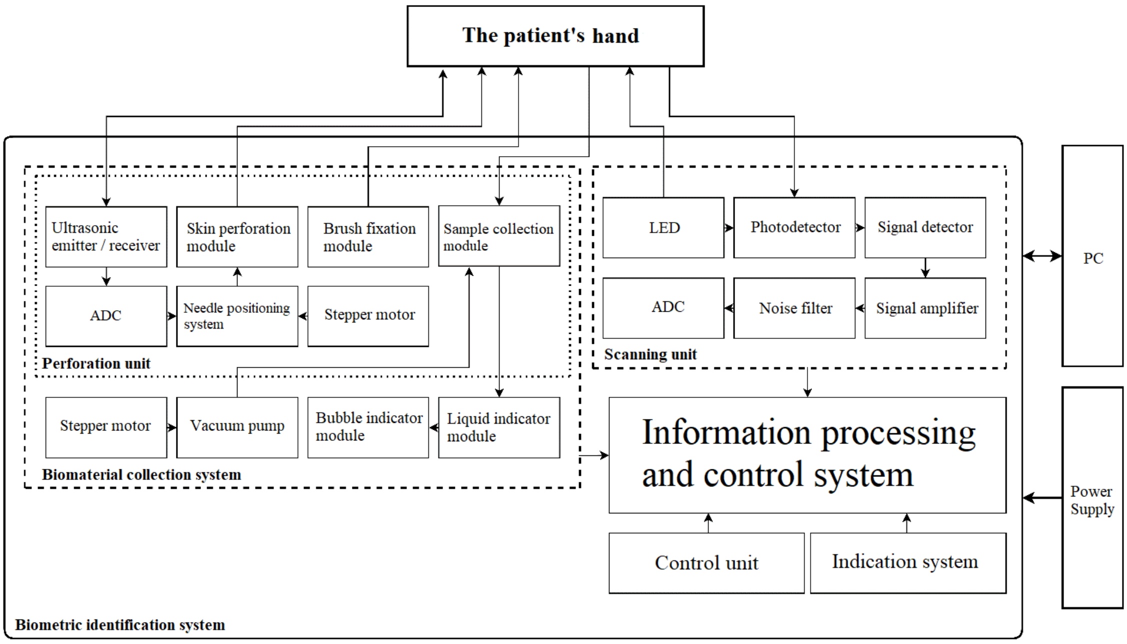


Fig. 4. Structural and functional scheme of the automated blood collection system

The sampling module receives blood using a vacuum pump, which fills the required volume of blood in the sampling module. The stepper motor is responsible for the movement of the pump. From the liquid indicator, which detects the presence of biomaterial in the system, the blood passes to the bubble indicator module, which is responsible for assessing the presence of air bubbles in the resulting sample. The information enters the information processing and control system, in the case of correct taking sample. To identify the LED illuminates the skin of the finger. Then the light enters the photodetector, which generates an analog signal. Signal detection is performed using a signal detector. Then the signal from the detector goes to the amplifier, where due to the amplification of the signal there is extra noise, which is removed by the noise filter. Then the signal enters the analog-to-digital converter (ADC), from the digitized signal enters the information processing and control system.

The development is based on algorithms [6] of comparison of different iterations with each other and selection of general characteristics of a pulse wave at each patient individually.

In this development, the authors proposed an alternative approach to the analysis of the characteristics of photoplethysmogram (PPG) - a signal that can be used for further biometric identification of a person by machine learning methods. Namely, the calculation of time (TDF) characteristics of PPG's was performed, based on the principles used in the study of surface electromyogram signals [6,7]. As time characteristics of the signal, the following were used: maximum amplitude value (MAX), variance (VAR), mean absolute deviation (MAD), Willison amplitude (WAMP) and total sum of signal amplitude values (SUM). The calculation of the parameters of TDF characteristics was performed according to formulas (1-5):

$$MAX = \max_{i=1..n}(x_i) \tag{1}$$

$$VAR = \frac{1}{N}\sum_{k=1}^{N}(x_i(k) - \overline{x_i})^2 \tag{2}$$

$$MAD = \frac{\sum_{i=1}^{n}\left|x_i - \overline{x_i}\right|^2}{n} \tag{3}$$

$$WAMP = \sum_{k=1}^{N} f(\left|x_i(k) - x_i(k+1)\right|) \tag{4}$$

$$SUM = \sum_{i=1}^{n} x_i \tag{5}$$

An algorithm for selecting iterations of pulsed PPG waves was created, which is based on algorithms for comparing different iterations with each other and selecting the general characteristics of the pulse wave in each patient individually. In the minimum value search mode, the developed program uses an algorithm: if the previous and next values of the signal amplitude are greater than the current, the system considers the current value minimal and separates from the whole array of measurement values, those values that were previously presented in it.

Summary and conclusions.

The proposed development of biometric identification for automated blood analysis system will allow to use it as an alternative to existing tools and provide high protection against intentional substitution of research results and the occurrence of errors from the human factor.

In turn, the developed algorithm for selecting iterations of pulse waves of the photoplethysmogram is based on algorithms of comparison of different iterations among themselves and selection of the general characteristics of a pulse wave at each patient individually. The proposed approach to the calculation of individual parameters of the PPG signal in order to further classify them by machine learning methods may be an acceptable solution for biometric patient identification systems.

References:

1. Seiden S.C., Barach P. Wrong-side/wrong-site, wrong-procedure, and wrong-patient adverse events: are they preventable? Arch. Surg. 2006; 14 (1): 931—9. DOI: 10.1001/archsurg.141.9.931

2. Henneman Ph.L., Fisher D.L. et al. Patient identifi cation errors are common in a simulated setting. Ann. Emerg. Med. 2010; 55 (6): 503-9. DOI: 10.1016/j.annemergmed.2009.11.017

3. I.Yakovenko, A. Rudoy and M.Turchyna, "IMPROVEMENT OF THE CREDIBILITY OF ANALYSIS OF ELECTROCARDIOGRAMS FOR BIOMETRIC PERSONAL IDENTIFICATION", *Перспективні технології та прилади*, no. 15, pp. 125-130, 2020. doi:10.36910/6775-2313-5352-2019-15-18.

4. I.Yakovenko, V.Martynenko and M.Turchyna,, "BIOMETRICAL IDENTIFICATION ON THE BASIS OF PHOTOPLETHYSMOGRAM FOR AUTOMATED MEDICAL SYSTEMS", *Перспективні технології та прилади*, no. 15, pp. 120-124, 2020. doi:10.36910/6775-2313-5352-2019-15-17.

5. І.О. Яковенко, К.П Вонсевич, І.Є. Гребень "Метод виділення ітерацій пульсових хвиль фотоплетизмограми для біометричної ідентифікації", Наукові вісті КПІ : міжнародний науковотехнічний журнал, № 3(2020), С. 73–78, 2020. DOI: 10.20535/kpi-sn.2020.3.209881

6. Y. Mamontov " Analysis and classification of photoplethysmograms using the Hopfield neural network ", *Vestnik Novosibirskogo gosudarstvennogo universiteta. Seriya: Informaczionny`e tekhnologii*, vol. 12, no. 4, pp. 53-58, 2014.

7. K. Vonsevych, M. Bezuglyi and A. Haponiuk, "Evaluation of Electromyogram Time Characteristics of the Wrist Functional Movements for Intuitive Control of Bionic Prosthesis", *Research Bulletin of the National Technical University of Ukraine "Kyiv Politechnic Institute"*, vol. 0, no. 1, pp. 45-53, 2018. doi: 10.20535/1810-0546.2018.1.115941.

8. K. Vonsevych, M. Goethel, J. Mrozowski, J. Awrejcewicz and M. Bezuglyi, "Fingers Movements Control System Based on Artificial Neural Network Model", *Radioelectronics and Communications Systems*, vol. 62, no. 1, pp. 23-33, 2019. doi:10.3103/s0735272719010047.

Анотація. *В даній статі обґрунтовано розробку автоматизованих медичних систем з використанням біометричних методів для ідентифікації особистості. Виконано розробку структурно-функціональної схеми та проведено 3D моделювання автоматизованої біометричної системи перфорації шкіри з забором крові, що дозволить забезпечити високий рівень якісного аналізу зразка, що в свою чергу дозволить мінімізувати затрати на проведення аналізу. Запропоновано розробку алгоритму виділення основник показників дослідження об'єму крові (ФПГ) для ідентифікації людини в автоматизованій системі для забору крові.*

Ключові слова: *біометрична ідентифікація, автоматична система, динамічні методи, фотоплетизмограма, забір крові, перфорація, класифікація методів, структурно-функціональна схема, моделювання.*

Article sent: 29.12.2020 г.