DIGITAL BLOOD ANALYSIS TECHNOLOGIES.

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Abstract

The article is devoted to the formulation of a new approach to blood analysis related to differential methods for measuring the number of blood cells and the speed of blood movement based on the use of optical methods and the use of fitness wristband devices that use **photoplethysmography** to solve these problems.

Keywords: blood, blood cells, **photoplethysmography**, matrix determinant, blood velocity, glucose level, blood composition, linear relations, optics, LED, monochrome radiation, coherence.

INTRODUCTION

Currently, the penetration of digital technologies in medicine is primarily associated with the "digitization" of data and the accumulation of big data. On the one hand, this is an understandable trend of medical digitalization, and on the other hand, it is only qualitative changes that are not yet associated with a new approach to the diagnosis of various conditions.

Blood tests, primarily glucose blood tests are a very effective tool for the diagnostician and therapist [1]. The disadvantage of the modern approach to the analysis is their comparative rarity. Even in a hospital, a blood test is taken once, rarely twice a day. Patients with diabetes also do an independent analysis once or twice a day. This is due to the invasiveness of the analysis when it is necessary to make skin punctures for the blood collection.

Therefore, there is an issue of more frequent blood analysis for such an indicator as glucose, and on the other hand, the transition to non-invasive methods of analysis.

PROBLEM STATEMENT AND ITS CONSIDERATION

The solution to the problem is to use optical sensing of vessels using coherent light sources, coupled with the highly accurate reception of a reflected light signal.

The fact is that blood cells reflect and absorb light radiation to varying degrees. In addition, the blood flow rate changes in various clinical conditions (pregnancy, diabetes, etc.). For instance, when the level of glucose increases, the speed of blood movement increases [2,3].

This effect is partly used in wrist bracelets-heart rate monitors. In this device, there is a period of low reflection (the vessel is filled with blood, systolic pressure) and strong absorption, and vice versa when the vessel is low in fullness (diastolic pressure).

However, both the speed and composition of blood cells in the field of optical sensing can be objectively evaluated only if the probing pulses are sent frequently enough.

Let's assume that we have identified three types of blood cells that absorb light radiation in different ways (to a strong extent) – we will call them "type i cells".

If n_{1t}, n_{2t}, n_{3t} are numbers of blood cells of type 1, 2, 3 at time t, then with the intensity of r_1, r_2, r_3 captured in the optical receiver, we can form a system of linear relations:

$$an_{1t1}+bn_{2t1}+cn_{3t1}=r_1$$

$$an_{1t2}+bn_{2t2}+cn_{3t2}=r_2$$

$$an_{1t3}+bn_{2t3}+cn_{3t3}=r_3$$

where *a*, *b*, and *c* are constant light absorption coefficients for cells of type 1, 2 and 3.

Thus, we have an analogue of a system of linear equations in which the solution (a, b, c) is known, but the coefficients for "variables" are unknown. The only solution is if the determinant of the matrix is not 0.

$$\begin{bmatrix} n_1t_1 & n_2t_1 & n_3t_1 \\ n_1t_2 & n_2t_2 & n_3t_2 \\ n_1t_3 & n_2t_3 & n_3t_3 \end{bmatrix}$$

Fixing the values for time samples (t_1, t_2, t_3) produced quite often, for example, 50-100 times per second, allows you to accurately measure the speed of cell movement in blood vessels. Besides, determining the number of different cells in the field of observation will allow you to draw conclusions about haemoglobin and its changes, the amount of glycated haemoglobin, and other indicators.

STATE OF THE PROBLEM

There is a CNOGA solution available (Combo Glucometer, Israel [4]). https://cnogacare.co/

The Israeli company CnogaCare positions itself as a digital medical company with solutions for remote monitoring of patients. It created a hybrid device – "invasive/non-invasive". The device requires invasive calibration within 3 days and can be configured individually for a person. Its measurement time is about 40 seconds. A trained neural network is used to assess glucose levels.

TECHNICAL SOLUTION

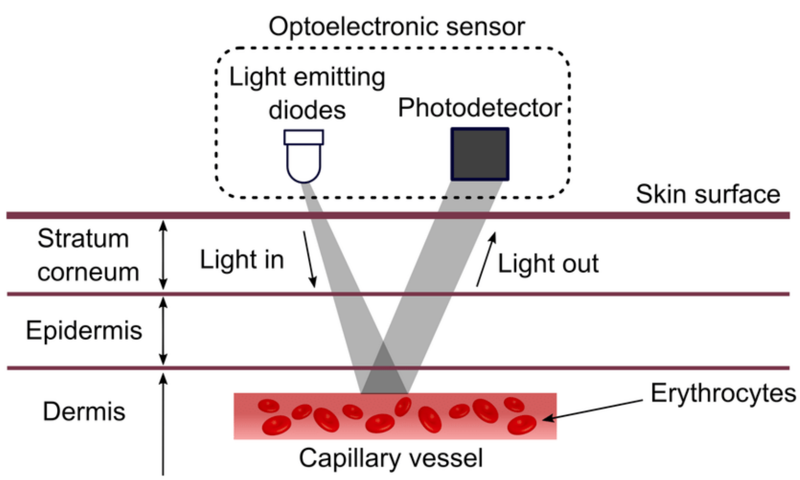
The blood composition analyzer and glucose meter Accofrisk™ is a revolutionary mathematical and medical development that helps determine both blood sugar levels and other blood composition indicators. The device is non-invasive (does not require skin punctures) and belongs to the category of high-accurate equipment.

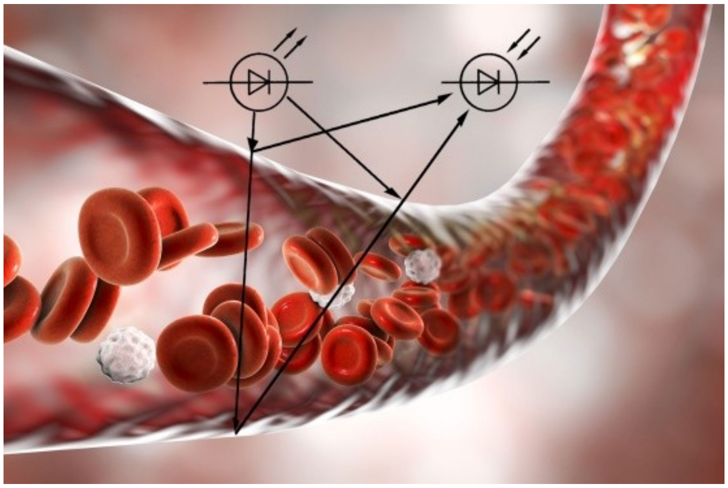
With this device, a person can independently monitor the blood composition and, first of all, the glucose level and monitor deviations. This is an ideal solution for both diabetics and people with a predisposition to this disease. The device can also be used as a preventative solution for health monitoring or dietary adjustments. Early detection of diabetes increases the likelihood of treatment by 95%.

This new solution in the field of medicine allows you to avoid piercing the epidermis several times a day.

This non-invasive equipment has no analogues or cheaper analogues, and the technology of establishing relative parameters of blood flow velocity based on the reference time for which the blood sugar content is known has not been massively mastered to date. An increase in speed and a lighter blood colour indicates an increase in sugar content.

The technical basis is a wrist bracelet for measuring the heart rate (HR – heart rate). The device is equipped with a led that emits monochrome coherent light radiation in a narrow frequency range. Pulse measurement is based on the photodiode receiving radiation reflected from subcutaneous capillaries, which changes synchronously with the pulse. The more blood there is in the capillary, the more light is being absorbed (when it is full, it absorbs light strongly; when it is not full, it absorbs light weakly).





The principle of heart rate measurement used in "smart" wrist bracelets differs from that used in conventional medical devices with mechanical or electrical action. This is due to the sensors built into the inner side of the bracelet. For their work, the method of **photoplethysmography** is used [5,6], which allows you to determine changes in blood volume using optical radiation. When contracting, the heart muscle provokes an increase in blood pressure. Capillary blood flow increases, resulting in more light being absorbed. The sensor registers this, and by counting the number of such bursts per minute, the device determines the heart rate.

The photoplethysmogram is a method for recording blood flow using an infrared or light source and a photoresistor or phototransistor. The greater the blood flow, the more light is absorbed by red blood cells in the body's tissues, so less light comes to the photoresistor.

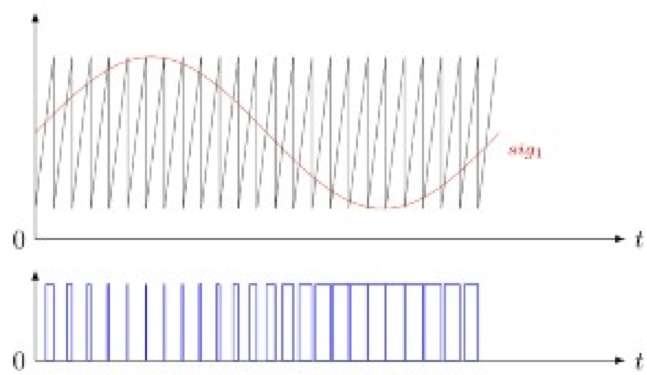
The rate of blood flow in the capillaries is slow and is about 0.5-1 mm/s. Thus, each blood particle is located in the capillary for about 1 s. the Small thickness of the blood layer (7-8 microns) and its close contact with the cells of organs and tissues, as well as the continuous change of blood in the capillaries, make it possible to exchange substances between blood and tissue (intercellular) fluid.

The photoplethysmogram allows you to measure the volume pulse of blood caused by periodic changes in blood volume with each heartbeat, heart rate, and heart rate variability.

The photoplethysmogram, using a fine spectrum analysis, will also allow you to find out the percentage of glycated haemoglobin since glycated erythrocyte cells absorb light differently than normal ones.

THE APPROXIMATE ALGORITHM IS AS FOLLOWS

1. More than 50 light pulses are generated on the led of the wrist bracelet per second (for example, analogues of Delta functions, sawtooth and reverse sawtooth signals, and the response from blood vessels is received with high accuracy on a single time scale) - photo location is performed.



2. The received signal is subjected to rapid processing by means of the bracelet and hazardous events are highlighted, for example, changes in blood density, its density (at the minimum and maximum of the absorbed signal), or " colour " (changes in the absorption band relative to the main frequency of the photodiode radiation).

3. The received signal is transported to your smartphone, where the Fourier transform is performed with identifying and comparing the emitted spectrum and received signals (a few tens of harmonics) with each other.

4. The "capillary model" is being created and its changes are being monitored. The capillary model is an operator for changing the spectrum of a light signal when light passes through a vessel. In practice, we consider the capillary as a dynamic optical filter and associate its parameters with the parameters of blood flowing through it (see the «Consideration» in this article).
5. The device is calibrated using external parameters (a certain set of parameters corresponds to a certain sugar level, haemoglobin level, etc.).
6. The display of sugar and haemoglobin parameters after calibration on the bracelet occurs in continuous mode.
7. Next, the level of glycated haemoglobin is calculated and displayed.

CONCLUSIONS

Compared to other methods of non-invasive assessment of blood composition and glucose levels [7,8], this method allows you to quickly assess the patient's condition and perform diagnostics and monitor blood glucose levels, as well as make recommendations for eliminating identified issues in real-time. At the same time, a fully operational, reasonable and documented conclusion is made about the patient's condition, which may be important for insurance medicine. The method of speed measurement using linear ratios and spectrum analysis reduces external interference and measurement errors and does not require additional complex devices for assessing blood composition and glucose levels. There is no need as well to pierce the patient's skin or attach sensors to the body, which is convenient for the patient. It also informs you of any increases or decreases in glucose levels and allows you to evaluate glucose levels and other parameters several times per hour.

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