

# РОЗРОБЛЕННЯ ПРОГРАМНО-АПАРАТНОГО ЗАБЕЗПЕЧЕННЯ ДЛЯ МЕТОДУ РЕАБІЛІТАЦІЇ ХВОРИХ ОБЛІТЕРУЮЧИМ АТЕРОСКЛЕРОЗОМ СУДИН КІНЦІВОК

## DEVELOPMENT OF SOFTWARE AND HARDWARE FOR THE METHOD OF REHABILITATION OF PATIENTS WITH OBLITERATION OF ATHEROSCLEROSIS OF THE LIMB VESSELS

*Яцишин С. П., д-р техн. наук, проф., Стадник Б. І., д-р техн. наук, проф.,  
Хома Ю. В., канд. техн. наук, ст. викл., Микийчук М. М., Музунів Д. О., д-р техн. наук, проф.,  
Національний університет "Львівська політехніка", Україна; e-mail: slav.yat@gmail.com  
Фрöліх Т., д-р техн. наук, проф., Мاستило Р., канд. техн. наук, пров. інж.,  
Технічний університет, Ільменау, Німеччина*

*Svyatoslav Yatsyshyn, Dr. Sc., Prof., Bohdan Stadnyk, Dr. Sc., Prof.,  
Yuriy Khoma, Ph. D., As.-lecturer, Mykola Mykyichuk, Dr. Sc., Prof., Dmytro Mihunov  
Lviv Polytechnic National University, Ukraine;  
Thomas Fröhlich, Dr. Sc., Prof., Rostyslav Mastylo, Ph. D., Eng.,  
Technical University, Ilmenau, Germany*

<https://doi.org/10.23939/istcmtm2019.01.024>

**Анотація.** Тематика статті стосується наукових досліджень у сфері охорони здоров'я та медичних технологій на основі подальшого розвитку і впровадження смарт-сенсорів, технік опрацювання біоінформаційних сигналів, їх нормалізації та використання для створення засобів гнучкого коректування фізіологічного стану людського організму методом електростимуляції, узгодженої в режимі реального часу з природними ритмами діяльності конкретного пацієнта.

Інтерес до вказаної теми зумовлений проявом, у міру збільшення тривалості активного періоду в житті людей, низки небезпечних захворювань, до яких належать насамперед захворювання серцево-судинної системи. Найчастіше причиною таких захворювань є вікові зміни, а також недалекоголядна поведінка і звички людини: куріння, брак фізичної активності, нездорове харчування та надмірне вживання алкоголю. Змінюючи поведінку, людина зможе знизити й ризик серцево-судинних захворювань.

**Ключові слова:** обладнання, програмне забезпечення, реабілітація, облітерація, атеросклероз, судини кінцівок.

**Abstract.** The theme of the project proposal relates to scientific research in the field of health care and medical technologies on the basis of the further development and implementation of hardware software, smart sensors, the technique of processing, normalizing and applying of information signals for the creation of means for adjusting the physiological state of the human body by the electro stimulation, agreed in real-time mode with cardiac rhythm.

Interest in this topic is due to the manifestation of increasing the duration of the active period in the lives of a number of dangerous diseases, which, in the first place, include diseases of the cardiovascular system. Often, the cause of such diseases is age-related changes, as well as non-future behavior and human habits: smoking, lack of physical activity, unhealthy eating and excessive alcohol. Changing behavior, a person can also reduce the risk of cardiovascular disease.

To realize the declared goal we have fulfilled a row of investigations in hardware and software. For instance, we have studied the ECG signals and their processing with the help of artificial neural network. Simultaneously we have developed the original method of enhancing the blood circulation in the limb vessels. The latter provides the extra blood wave pressure due to stimulation of muscles at the moment of natural flow from the heart was passing to the sick place. Therefore the complicated device was proposed on the basis of conjugated electrocardiograph and electro stimulator. As a result, we have obtained the possibility to expand the research applying the known instrumentation methods of studying the temperature, ultrasound, mass and admittance measurements.

**Key words:** Hardware, Software, Rehabilitation, Obliteration, Atherosclerosis, Limb vessels.

### Introduction

Dangerous diseases of our time include diseases of the cardiovascular system. Mortality from cardiovascular disease in Ukraine is about 60 % of the total. They rank first in the structure of the diseases causing almost two thirds of all deaths and a third of the causes of disability. Often, the cause of such diseases is age-related changes as well as non-future behavior and human habits: smoking, lack of physical activity, unhealthy eating and excessive alcohol. Changing behavior, a person becomes able to reduce the risk cardiovascular diseases [1].

Obliterating atherosclerosis of the vessels of human limbs covers the detection rate up to 2 % of the population. With the age it happens more often, reaching 15–20 % for human older than 60 years. The effective methods of treatment are not sufficiently developed [2], which allows justify the current issue as actual.

For treatment, conservative, operational and non-invasive methods are used. As for the first one, it involves the use of drugs, courses of physiotherapy with stress therapy, as well as therapeutic physical training. It cannot be conclude that there are the drugs that can completely cure atherosclerosis, restoring the normal

flow of blood in the limb vessels. And the main purpose of conducted therapy is expanding the smaller channels to compensate for inferior blood circulation. Stenting and other endovascular methods of treatment of atherosclerosis are also not considered, as we believe that it is an invasive method. Surgical intervention is rejected as such.

### **Aim of the work**

The aim of the considered work is the development of hardware and software for the methodology of health care and physical therapy at the area of healing the obliteration of atherosclerosis of the limb vessels by in situ electro stimulation of muscles taking into account the cardiac rhythm.

### **Method of the research**

Due to a certain gap between the current state of informational technologies, based on the use of smart sensors; on progressive technologies of normalization and processing of signals, including bio signals; on the uncertainty approach regarding the statistical processing of studies of persons of various professional and age groups - with the theoretical foundations of the majority of existing medical rehabilitation technologies and their practice applying means with limited set of intelligent functions, there exists opportunity to satisfy the social demand and real possibilities for further developments in the field of health care, applied gerontology, and physical therapy.

As a result of this project it is planned to develop hardware and software for the instrumental method of rehabilitation of patients with obliteration of atherosclerosis of the vessels of the limbs by in situ electro stimulation taking into account the heart rate. It is planned to involve a number of specialists: from contactless thermometry; from ultrasound diagnostics, from theoretical and applied metrology, modern instrumentation, with the creation of a virtual means for measuring and signaling electro stimulation, etc.

Conducting scientific and technical research demands the development of the basis of the proposed method of removing information from the human body (electrocardiograms (further – ECG), temperature and ultrasound studies). The ECG as biometrical feature has many advantages, but satisfactory results can only be obtained through using some artificial intelligence methods for the biometric system construction. For improvement of the classifier operation we have applied the advanced method of outlier detection and correction for ECG records conditioning. The previous research results allow conclude that for relatively heterogeneous ECG data of limited number of classifier classes built upon a neural network there is no quantifiable advantage compared to some simple models (Logistic Regression

or K-nearest Neighbor). Artificial neural network as classifier of ECG data has shown a good scalability and stable results, which can result in their efficient usage in biometrical systems [3].

Also the definition of certain categories of informative cardiac signals and the peculiarities of the passage of the arterial blood pressure wave, in particular, of the limbs; statistical processing of the received information, in different phases of the disease, as well as in different patients (sex, age, depth of disease), etc. has to be provided. It requires a number of special equipment, measuring instruments, creating a virtual measure based on a variety of different research of biological, medical, and recreational character.

In particular, for conducting previous studies prior to the creation of the device, an electrocardiogram and an electrical stimulator (for muscle strengthening of the arterial blood flow) are necessary. In addition, we consider it necessary to use an ultrasonic device research (to evaluate the current condition of the patient and to study the change of his state), the infrared thermometer with an adjustable emissivity factor of the skin limbs, and a number of smart sensors, for example of IFM company. The issue of purchasing NI USB 6008/6009 Bus-Powered Multifunction DAQ USB Devices and the National Instruments LabVIEW hardware/software platform for the preliminary creation of a virtual mean of the heart rate accessing and synchronized electro stimulation signaling would be considered [4].

In the course of applied research on a number of patients, taking into account their initial state, type and stages of illness, age, etc., the computers for accounting, modeling, and processing of information become necessary. The block diagram of the mean for measuring and analyzing the characteristics of the patient's blood circulation, accumulation and processing of information, electro stimulation strengthening the blood circulation in problem areas of the limbs by synchronizing in situ each alternating wave of blood pressure with the control signal is developed. It has to provide recreating the affected blood vessels by taking into account the frequency of cardiac contractions.

We have carried out a series of relevant studies that complement the history of the disease, clarify its course and the possibility of involving other methods for in-depth diagnosis. In particular, based on previous experience, it may be advisable to prioritize attracting smart sensors [5] and other nano technological units in the considered area. It is provided the strain-gauge methods for the study of swelling of tissues, the methods for studying their impedance [6], which can characterize contactless changes in the chemical composition of blood, and so on.

### **Expected results**

Creating a prototype of device must combine the functions of the electrocardiogram and the electro

muscle stimulator, taking into account the frequency of heart rate. In general, it will promote, in combination with other therapeutic and rehabilitation measures, to achieve the best result. While developing the method we have designed a virtual mean for measuring the heart rate and for synchronizing the signal of electro stimulation with the blood pressure wave in the limb vessels. There was applied the platform LabVIEW, National Instruments [4]. For this purpose there were thoroughly studied the capabilities of the considered platform and formed the block diagram of the constructed device. The technical capabilities and characteristics of the method as a whole as well as the mean for its realization are determined. In the future, if necessary, the specified virtual mean can be easily reproduced by any research team if only a NI USB 6008/6009 device and a personal computer would be available.

A developed block diagram of the investigated mean for measuring and analyzing peculiarities of a patient's blood circulation, electro stimulation of blood circulation in problem areas of the limbs has envisaged the next. Taking into account the frequency of cardiac contractions, it becomes possible to synchronize in situ each alternating blood pressure wave in the limbs with electro stimulation signal of appropriate muscles, increasing the throughput of the affected blood vessels.

In order to improve the effectiveness of the developed method, it was proposed to reconcile the presentation of the mean control signal with the moment when the pulse from the heart arrives. Thus, even when differences between each successive heart attack and, accordingly, the arrival of the wave of blood flow are happened, the control signal automatically agrees with the change in rhythm. In addition, when you change the location of the electro stimulator on the limb, the device automatically shifts the start moment of the pulse.

### Conclusions

1. The developed method of the healing the obliteration of atherosclerosis of the limb vessels seems

to eliminate the causes of the disease, providing improved blood circulation to the limbs, significantly slow down the process of dying tissue and anesthetizing the movement of the patient.

2. The proposed device combines an electrocardiogram for determining the heart rate and an electrical stimulator for muscle strengthening of arterial (venous) blood flow, taking into account heart rate. Its use in combination with modern therapeutic and rehabilitation measures can get the best result in healing.

### Acknowledgment

The authors express their gratitude to the staff of the Department of Information-Measuring Technology of the Lviv Polytechnic National University, Ukraine, for the assistance and all possible assistance in the preparation of this article.

### References

- [1] J. Frostegård, "Immunity, atherosclerosis and cardiovascular disease", *BMC Med.* 2013; 11: 117. Publ. online 2013 May 1.
- [2] R. Lathe, A. Sapronova, Yu. Kotelevtsev, "Atherosclerosis and Alzheimer – diseases with a common cause? Inflammation, oxysterols, vasculature", *BMC Geriatr.* 14: 36, 2014. Publ. online 2014 Mar 21.
- [3] V. Khoma, M. Pelc, Yu. Khoma. Artificial Neural Network Capability for Human Being Identification based on ECG, in Proc. 23rd Int. Conf on Methods and Models in Automation and Robotics, Miedzyzdroje, 27–30 August 2018. IDAACS, 2018.
- [4] LabVIEW 2017. [Online]. Available: <http://www.ni.com/download/labview-development-system-2017/6698/en/>
- [5] J. Sauerer. Smart sensors, AMA•FVEE•Workshop 2013. [Online]. Available: [http://www.fvee.de/fileadmin/publikationen/Workshopbaende/ws2013/ws2013\\_03\\_02.pdf](http://www.fvee.de/fileadmin/publikationen/Workshopbaende/ws2013/ws2013_03_02.pdf)
- [6] B. Stadnyk, T. Fröhlich, Yu. Khoma, V. Herasymenko, O. Chaban, "Impedance analyser error correction using artificial neural networks", 59th Ilmenau Sc. Coll. (IWK), Sept. 11–15, 2017.