CUFF-LESS MEASUREMENT OF BLOOD PRESSURE BY USING NEURAL NETWORKS

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Summary. This article attempts to consider a new approach to continuous measurement of blood pressure (BP), based on the pulse propagation time between two points of a blood vessel (PTT). The measuring of PTT based on the signal processing and analysis of the electrocardiogram (ECG), photoplethysmogram (PPG). The PTT-based blood pressure estimation algorithms, used by most authors, suggest their individual calibration for each patient. More flexible is a different approach - the use of machine learning. It is especially noted that the use of machine learning reduce the error in blood pressure measuring.

Keywords: blood pressure; electrocardiogram; photoplethysmogram; systolic blood pressure; diastolic blood pressure.

High blood pressure (BP), or hypertension, is an extremely common and dangerous condition that affects more than 35 percent of the world’s population and is the cause of many cardiovascular diseases (CVD), which cause about 31% of deaths worldwide (in Ukraine - more than 50%). However, 85% of these deaths occur as a result of heart attack and stroke [1]. Unfortunately, many hypertensives are not
even aware of their disease, while it slowly and imperceptibly damages their internal organs (brain, eyes, kidneys, blood vessels). Therefore, hypertension is often called the silent killer [2]. Worst of all, in recent years, the risk of hypertension has spread from the elderly to younger populations, significantly increasing the number of people who need periodic, and sometimes continuous, constant blood pressure monitoring. All existing methods of measuring blood pressure can be divided into two groups: methods of direct and indirect measurement. Non-invasive methods [3] - [4] are not based on direct measurement of vascular blood pressure, but on the processing and analysis of hemodynamic parameters associated with blood pressure, and are much safer and easier to use. Traditional non-invasive methods of measuring blood pressure are based on the use of an occlusive cuff, which makes them unsuitable for continuous measurement. Therefore, in the last decade, particularly active research has been conducted to find alternatives to cuff methods of measurement and continuous monitoring of blood pressure. The basis for the development of such methods is the use of the connection of blood pressure with various manifestations of cardiac activity and hemodynamics (electrical, acoustic, mechanical), and their parameters - such as pulse wave velocity (PWV), which can be registered without the use of a compression cuff and simple technical means.

The relationship between blood pressure and PWV was first theoretically substantiated by Moens and Korteweg (Moens-Korteweg equation, MK) [5]. Their reasoning was as follows: the rate of propagation of the pulse wave (PW) depends on the biomechanical properties of blood vessels - elasticity E, wall thickness h, and the inner diameter of blood vessels d, as well as blood density ρ, and is associated with these values equation (M-K):

\[
PWV = \sqrt{\frac{Eh}{\rho d}}
\]  

(1)

Accordingly, the propagation time of the pulse wave (PWV) over a section of the vessel of length L, will be:

\[
PTT = \frac{L}{PWV} = \frac{L}{\sqrt{\frac{Eh}{\rho d}}}
\]  

(2)

In turn, for vessels with flexible walls, there is an empirical relationship between the elasticity of the vessel E, and the pressure in it P:

\[
E = E_0 e^{\alpha P}
\]  

(3)

where E_0 is the initial value of elasticity, a is the coefficient determined by the properties of the vascular wall. Substitution (3) in (2) allow to obtain an expression for the relationship between blood pressure and PTT [5]:

\[
BP = -\frac{2}{a} \ln T + \frac{1}{a} \ln \left(\frac{L^2 \rho d}{h E_0}\right) \approx -a \cdot PTT + b
\]  

(4)

This expression shows that at constant values of the coefficients in (4), which determine the parameters and condition of blood vessels, changes in blood pressure are almost proportional to the time of propagation of the pulse wave. But it should be noted that the coefficients for different people will be different, and their calculation must be performed using the reference method of measuring blood pressure. In the course of the work, using signals from the open MIMIC database, the coefficients for (4) were calculated and the following dependences were obtained
Systolic BP = 260 - 0.6459 * PTT (5)
Diastolic BP = 260 - 1.1175 * PTT (6)

The results of blood pressure assessment using expressions (5) and (6) was shown on figure 1.

Fig. 1. Results of BP computation by using PTT parameter

The general idea of the machine learning calibration method is as follows: a set of some physiological signals related to blood pressure is registered, and, at the same time, blood pressure is measured by any reference method. Next, surrogate cardiovascular indices (signs) are extracted from the registered signals, and with the use of these signs (training sample) machine learning of the model is carried out. Finally, using a trained model and a new (control) set of physiological signals, blood pressure is predicted. Figure 2 presents the results for predicting systolic and diastolic pressure for the same patient, but using the developed model based on machine learning.

Fig. 2. Evaluation of systolic and diastolic pressure using machine learning strategy
Conclusions. The paper presents a method of non-invasive assessment of blood pressure values using the connection of CRPH with blood pressure. The results of experimental studies show that the average deviation of the obtained values and actual blood pressure values above the allowable range of ± 5 mmHg. In this regard, it was decided to use calibration using machine learning methods. The results of experimental studies show that the average deviation for systolic pressure is 2.62 mmHg; and for diastolic - 1.91 mmHg. Testing was performed on real signals taken from an open MIMIC database.

References: