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A New Blood Pressure Estimation Method Based on Neural Network Algorithm Model

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Abstract. Measuring blood pressure is one of the main approach of assessing cardiovascular status and heart disease. The method of using PWTT to estimate blood pressure in clinical practice has matured. However, some uncontrollable subtle changes are likely to affect the measurement accuracy of pulse wave transit time. To solve the above problems, a new blood pressure estimation method based on neural network algorithm model is proposed based on the data of a hospital in Nanjing. The blood pressure is first calculated in advance by traditional PWTT algorithm through data analysis, and then modified with the algorithm of BP neural network algorithm.The method is divided into four steps: signal preprocessing and feature points extraction, PWTT computing BP value, neural network algorithm, 4 significant factors selection and blood pressure calculation, and finally combined with PWTT algorithm to estimate the final blood pressure. Compared with the real blood pressure data of 100 hypertensive patients, the error of our new method is less than 5 mmHg and the standard deviation is less than 9 mmHg. The results show that using this method to estimate blood pressure can meet the clinical needs and has good practical value.

1. Introduction

In recent years, the incidence and mortality of hypertension in the world are increasing year by year, and have become a medical problem that can not be ignored[1]. The blood pressure value as one of the most important physiological indicators can continuously reflect the status of cardiovascular function, and usually as an important means to assess cardiovascular disease[2].

We know that uninterrupted blood pressure measurement is a traditional research topic in recent years. The advantages of rapid noninvasive measurement are getting more and more people's attention. There are many traditional methods of blood pressure measurement, such as auscultation and oscillometry [3]. The basic principle is based on pulse transit time (PWTT), which is mainly meatured from human optical capacitive pulse wave (PPG) signal[4]. The original calculation of pulse wave transit time was proposed by Moens and Korteweg in 1871 and has been continuously optimized to make continuous noninvasive blood pressure measurements possible[5] .Although PWTT-based BP algorithm has been developed and applied to clinical [6], its measurement accuracy still remains a major controversy [7-9]. Experimental results show that systolic blood pressure (SBP) is usually strongly correlated with pulse wave transit time, whereas DBP is less correlated with pulse wave transit time [10]. And we found that the problem is more complicated, and it is difficult to completely solved by optimizing the PWTT model only. By consulting the relevant literature, we know that the combination of PWTT and neural network algorithm model seems to be a good solution to this problem [11].

In recent years, neural network algorithm model has achieved great success in many fields, but also gradually applied to the estimation of human blood pressure values. For example, Yuriy Kurylyak

estimates the blood pressure value from the PPG signal using the neural network algorithm model[12]. Neural network algorithm model has the advantages of accuracy and stability, and it will surely play a decisive role in the field of hypertension measurement.

Therefore, in this paper we propose a new blood pressure estimation method based on the neural network algorithm model. This article is divided into five parts in total: The first part we briefly introduce the research background and purpose of this article; The second part we propose the overall realization of the new method; The third part builds the new method algorithm model; The fourth part introduces the new method; The fifth part verifies the results and summarizes the direction and limitations of future research.

2. The overall implementation of the new method

We use the human finger tip PPG signal as input in this method. Firstly, we pretreat the PPG signal: 5 smoothing filter to remove the DC component, remove the baseline drift and frequency noise interference [13]. Secondly, we extract the characteristic points of PPG signal, such as the crest, trough, maximum amplitude and so on. The third one is to establish the neural network algorithm model based on four significant factors related to age, height, weight, and family history of hypertension.These salient factors are obtained from a multi-parameter intelligent monitoring waveform database (Healthme). Fourthly, the BP neural network algorithm trained with all the feature factors and the PWTT model are used to optimize the blood pressure values. The new data model obtained is also incorporated into the database.

3. Build the new algorithm model

The new algorithm can be divided into two parts as follows:

3.1. PWTT algorithm

In the PWTT model, we added an additional parameter of heart rate to improve the accuracy of blood pressure calculation, the formula as follows:

$$SBP = A_1 * PWTT + B_1 * hrate + C_1 \tag{1}$$

$$DBP = A_2 * PWTT + B_2 * hrate + C_2 \tag{2}$$

Where A1, A2, B1, B2, C1, C2 are constants. PWTT value is calculated from PPG signal waveform. The hrate value is calculated by calculating the time interval between peaks.

3.2. Establishment of a new algorithm mode

We use BP neural network algorithm algorithm to build the neural network algorithm model. The sample data including age, height, weight, with or without hypertensive family genetic disease. We use the data as input, while SBP and DBP as output.

3.2.1. forward algorithm

Each level of neurons connected by a quantity, and its value is equal to the sum of the input.

$$u_n = f\left(\sum\nolimits_m u_m \bullet w_{nm}\right) = f\left(Net_n\right) = \frac{1}{1+e^{-Net_n}} \tag{3}$$

Where Net_n is the input of the n-layer network element. Then we add the threshold of neurons to the formula.

$$u_n = f\left(\sum\nolimits_m u_m \cdot w_{nm}\right) = f\left(Net_n\right) = \frac{1}{1+e^{-\left(\sum_m u_m \cdot w_{nm} + \theta_n\right)}} \tag{4}$$

Where θ_n is the deviation of element n, and also called the fixed input weight.

3.2.2. BP algorithm

We created a new BP algorithm.

If $\frac{\partial u_m}{\partial Net_n} = u_m \cdot (1 - u_m)$, then the output deviation is:

$$\Delta out_n = (t_n - u_n) \cdot u_n \cdot (1 - u_n) \tag{5}$$

At the same time, consider the equationsof the system:

$$\Delta w_{nm} = -\frac{\partial E}{\partial w_{nm}} \tag{6}$$

$$E = \frac{1}{2} \sum_K \left(t_{pk} - f_k \left(\sum_n w_{kn} \cdot u_{pn} + \theta_k \right) \right) \tag{7}$$

Where E is the error, t_k is the input and u_k is the output. We can calculate the sum of Δout_n and Δw_{nm} :

$$\Delta hidden_m = u_m \cdot (i - u_m) \cdot \sum \Delta out_m \cdot \Delta w_{nm} \tag{8}$$

Which $\Delta hidden_m$ is hidden unit error.

Then we can deduce the correction of the weight:

$$\Delta w_{mk} = r \cdot \Delta hidden_m \cdot u_k \tag{9}$$

Among them, Δw_{mk} is the error of the input weight.

Finally we get all the weight from the formula:

$$w_{mk(n+1)} = w_{mk} + \Delta w_{mn} \tag{10}$$

3.3. The workflows of the new algorithm

The workflows of the new algorithm is as **Figure 1**:

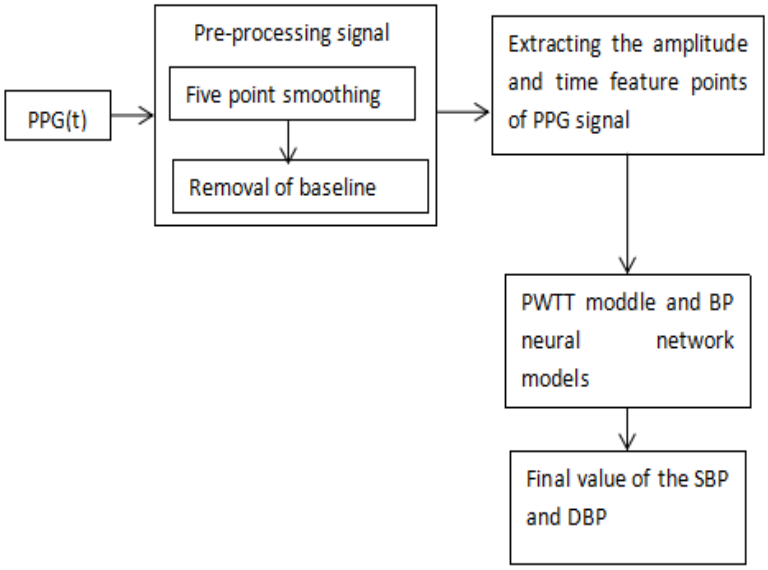

Figure 1. The workflows of the new algorithm. During the caculation, if PWTT (SBP) = BP (SBP) and PWTT (DBP) = BP (DBP), and we can get more accurate blood pressure values. If it is not equal, the average value is taken to modify the PWTT model and the BP neural network algorithm model.

4. The concrete realization of the new algorithm

In order to ensure the effectiveness of the experiment, we recorded the continuous PPG signals and corresponding blood pressure values of ten hypertensive patients from the multi parameter intelligent monitoring (Healthme) database, and processed the sample data to remove abnormal signals.The process of filtering methods includes 5 points smoothing filtering, removing direct current component, removing baseline drift and so on.

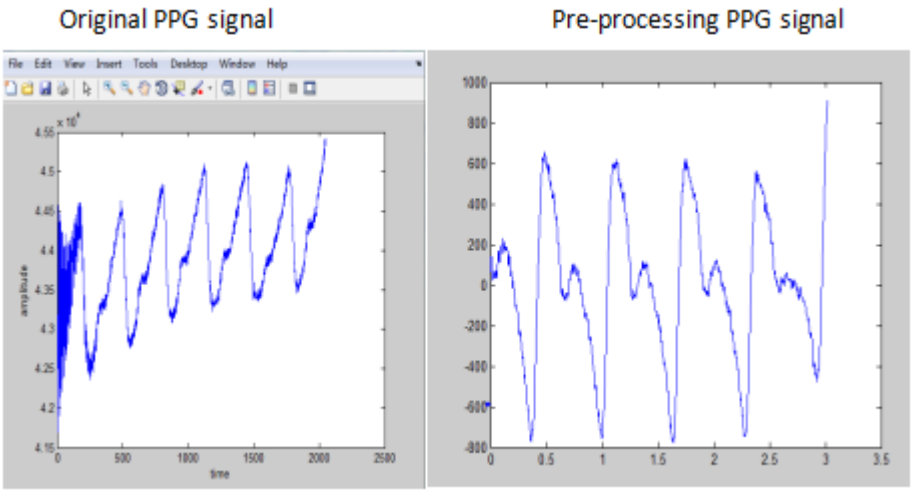

Figure 2. Signal processing process diagram.On the left is the signal before processing and the right one is after processing.

The initial filtered PPG signal is further analyzed by wavelet transform. The tiny pulse spike is removed, and a relatively smooth pulse wavefoWe calculated the heart rate from the peak interval time,

and calculated the PWTT and systolic pressure from the peak and valley intervals.Finally, according to the linear relationship between systolic and diastolic pressure, the diastolic pressure is calculated.

In the Matlab environment, the relevant settings are set up. Based on SBP and DBP, a BP neural network algorithm model is established. The model achieves the lowest accuracy of 90%, and the prediction error of the model is 4.6%. In the process of computation, we first use sample data to train and learn neural network algorithm. Then we import neural network algorithm into learning sample data and calculate SBP and DBP values.

5. Test results verification

According to the results of the model operation, we ranked the importance of four significant factors affecting hypertension: the age to height, body weight, height and family history of hypertension.

The difference between SBP and DBP was calculated by comparing the blood pressure values calculated with the intelligent monitoring equipment of multifunction physiological parameters. From figure 2, we can see that the systolic pressure of the population in the data collection sample is between 130-170mmHg and the diastolic pressure range is between 80-100mmHg, and close to the blood pressure value in patients with hypertension.

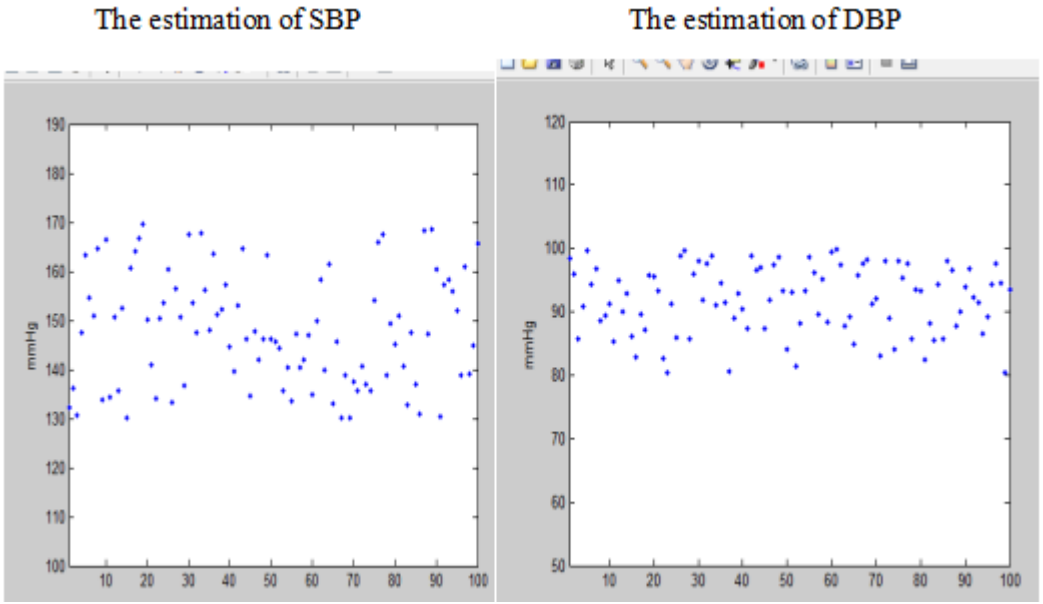

Figure 3. The value of SBP and DBP calculated by the new method.

From figure 3, we can see that the average difference of SBP calculated by the two methods is less than 5.3mmHg and the average value of DBP difference calculated is less than 3.8mmHg. The maximum standard deviation of DBP is less than 3.37mmH and the standard deviation of SBP is less than 6.13mmHg.

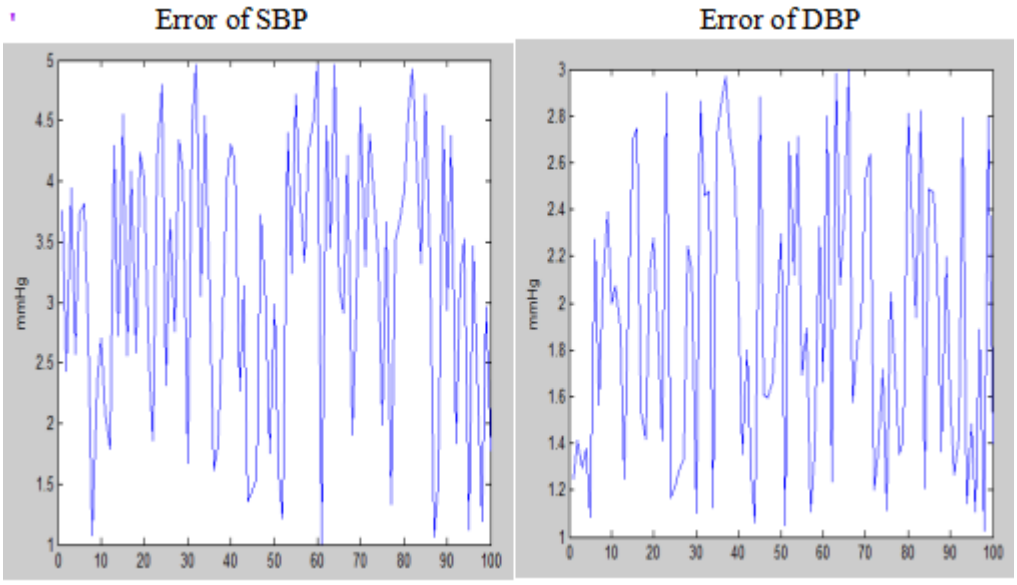

Figure 4. The calculated erro of SBP and DBP by our new method Compared with the simulator data.

In order to further ensure the accuracy of the data, we have also made an accurate measurement of blood pressure in ten patients in Nanjing Gulou Hospital.The results show that the DBP and SBP values estimated by our new method and the measured error of the hospital are within 5mmHg, which means that our method is in fully compliance with the medical needs.

6. Summary and discussion

Based on multi parameter physiological monitoring (Healthme) platform and neural network algorithm, a new blood pressure estimation method is put forward to achieve the purpose of calculating blood pressure and provide a reliable basis for doctors to diagnose hypertension.The BP estimation method based on neural network algorithm can well predict the value of SBP and DBP, and has high practical value.

Now the neural network algorithm is widely used in the medical field, and the rise of various medical platforms provides a unique condition and basis for it.But in this experiment there are various problems in the health data of the medical platform, which affect the accuracy of the neural network algorithm model and algorithm established in the actual application process.In addition, due to the limited number of samples, we can not get more accurate measurement results. Therefore, we will increase the number of samples and improve the algorithm model.

Combined with the application of neural network algorithm, model algorithm and future big data, the health care system in China will undergo a historic transformation, which will have a great impact on China's economy, society, technology and people's life. In order to ensure the smooth development of health care system, we should build a scientific and applicable algorithm application system for collection, processing, storage, mining, analysis and privacy protection, and achieve the integration application of multi source, multi-level, multi type and multi format health care data.

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