Improved Qsofa Algorithm Based on PPG Wearable Device

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Abstract. This paper designs an improved Qsofa algorithm based on photoplethysmography measurement technology. The algorithm is mainly used to achieve accurate measurement of the subject’s heart rate and blood pressure and a more refined Qsofa health score. In terms of health data processing, this paper uses a combination of data threshold and mean stabilization algorithms to significantly improve measurement accuracy. In terms of health analysis, this paper greatly reduces the difficulty of the GCS coma evaluation method in the traditional Qsofa algorithm, and at the same time makes the final score of the evaluation more detailed in the same level, so as to more accurately show the health status of the subjects.

1. Introduction

In the era of epidemics, one of the mainstream symptoms of critical emergency patients is sepsis. Based on international research results in the Qsofa field, this paper designs an improved Qsofa measurement and evaluation algorithm based on the photoelectric volume module of wearable devices. Its main functions are accurate measurements of heart rate and blood pressure and evaluation of the coma of the subjects. In terms of heart rate and blood pressure detection, the current mainstream wearable device health detection algorithm design is relatively weak, and its core processing algorithm is the direct average method. This processing method is relatively simple and direct, but it is easy to cause data errors due to abnormal data. In this paper, based on the clustering idea of data cleaning of big data, a combination algorithm of data set stabilization and the threshold value is proposed to improve the accuracy of health data measurement. At the same time, this paper provides a simpler and more feasible evaluation plan for coma evaluation, which not only greatly simplifies the evaluation method of coma, but also retains the accuracy of coma evaluation. Besides, this paper combines the AHP analytic method to propose a more scientific health scoring method, so that the three evaluation scores of blood pressure, heart rate, and coma are calculated in a more scientific ratio to the final health score, so as to achieve a simple and efficient evaluation of critical patients.
2. Traditional Algorithm and Technology

2.1. Data processing mean value method
The traditional health data method in wearable devices is the mean value method, and its specific operation method is to accumulate a certain physiological index data set and divide it by the number of data to obtain the average value as the final data measurement result. This algorithm can only be used to eliminate errors caused by small numerical fluctuations. The accuracy of the algorithm will be greatly affected in terms of filtering out abnormal points or the maximum and minimum values.

2.2. APACHE II scoring methods
The APACHE II scoring system is called acute physiology and chronic health scoring system which includes APS, Age Score, and Chronic Health Status Score. The larger the final score, the more serious the condition. The total score of the APACHE II scoring system is 0 to 71 points. At the same time, the APACHE II scoring system proposed a formula for calculating the risk of death R. In the formula, A represents the estimated intercept, and B represents the estimated coefficient of each independent variable i, such as physiological disorder, age group, severe chronic health impairment, and diagnosis category. The method divided the sum of the R-value of each patient by the total number of patients to get the estimated mortality of all patients. The calculation formula is as formula 1:

$$\ln \left( \frac{R}{1-R} \right) = A + B_iX_i$$  \hspace{1cm} \text{formula 1}

The APACHE II system is easy to use, but it also has more limitations. First, the scoring accuracy (such as calibration-level) will decrease over time [4,5]. Secondly, unlike the SOFA scoring system, APACHE II is greatly affected by treatment, so it often needs to evaluate the patient within 24 hours of entering the ICU.

2.3. SOFA scoring method
The SOFA scoring standard is a simple and effective method to describe dysfunction/failure in critically ill patients. The total score is 0-24 points. The larger the score, the more serious the condition. The SOFA scoring system selects parameters based on the principle of being objective, easy to obtain, and independent from treatment interference [1], through continuous recording of data to better understand and monitor the patient's condition, and at the same time have a better response to the dynamic changes of organ function.

2.4. Photoplethysmography measurement technology mounted on wearable devices
The PPG is based on the ILED light source and detector, which measures the attenuated light reflected and absorbed by human blood vessels and tissues, traces the pulsation state of blood vessels, and measures the pulse wave. The way of its signal obtained is simple, the measuring device is easy to wear and other characteristics have made it gradually become the main method of measuring blood oxygen, pulse, and heart rate under non-hospital conditions. However, because the measurement is a point area and the measurement data is single, it will often cause a certain amount of invalid data due to noise errors, leading to deviations in the measurement results.

3. The Algorithm in This Paper

3.1. Based on the characteristics of blood pressure and heart rate data of wearable devices
At present, the single-point measurement of the PPG heart rate and blood pressure carried on wearable devices is likely to cause unstable measurement data and invalid data during data transmission. This paper use algorithm to correct received data on the receiving end of the physiological indicators because of the above phenomena and combines the corrected heart rate and blood pressure data to evaluate and analyze human health.
3.2. Receive data processing

(1) Data validation

To improve the validity of the received data, this step is mainly used to delete abnormal data transmitted from the wearable device to the processing terminal. First, set the heart rate and blood pressure threshold, and if the received data exceeds the threshold, it will be eliminated. Combined with clinical data, this paper sets the human body’s limit heart rate, which is 220 beats per minute as the heart rate threshold, and sets the human body’s limit high-risk systolic pressure which is 200 mmHg as the receiving blood pressure threshold [1,2]. At the same time, during the PPG measurement process, the data transmitted by the hardware will contain a large number of values 0, and this step only retains non-zero values as valid data. The specific implementation process is as formula 2 and 3:

\[ f(x)_{\text{heart rate}} = \begin{cases} x, & x < 220 \\ \text{Null}, & x \geq 220 \end{cases} \]  
formula 2

\[ f(x)_{\text{systolic pressure}} = \begin{cases} x, & x < 200 \\ \text{Null}, & x \geq 200 \end{cases} \]  
formula 3

(2) Data stabilization

To improve the stability of each datum in the received data group effectively, this step calculates the relative distance between the data in the heart rate and blood pressure data group after threshold processing and data group mean, which is based on the principle of mathematical statistics. The specific calculation formula is as follows:

\[ d = \frac{x - E(x)}{\sqrt{D(x)}} \]  
formula 4

The relative distance of the processed data will be in the range of [-1, 1]. Combined with clinical experience [3], this paper will eliminate the physiological data whose absolute relative distance exceeds 0.5.

(3) Data averaging

Calculate the average value of the two sets of physiological data after stabilization and the value will be the final blood pressure and heart rate value of the subjects. The specific formula is as follows:

\[ x_{\text{average}} = \frac{\sum_{n=0}^{i} x_n}{i} \]  
formula 5

3.3. Analysis of processed data

(1) IGCS Coma scoring algorithm

Drawing lessons from the same field awareness evaluation methods such as the CRS-R and PVS [4], this paper improves the problem that Qsofa’s original collocation GCS awareness evaluation method is difficult to implement among non-medical practitioners and proposed the IGCS algorithm. Besides, the algorithm in this paper adds more evaluation items based on GCS to improve the accuracy of consciousness evaluation and combines the human hearing, vision, language, and perception for consciousness evaluation [5].

To improve the operability and accuracy of the evaluation of coma for non-medical people, the algorithm in this paper examines the auditory ability of the subjects from the following five levels, and sorts them in order of auditory integrity from high to low, they are complete the corresponding instructions independently according to the content of the tester, repeat the same content according to the content of the tester, can only complete the listening position, voice response and no response. The lower the limit content that the subjects can complete, the lower the score and also shows that the higher the degree of hearing loss in the subjects’ consciousness. In the actual scoring process, this paper regards the subjects’ best performance in the consciousness in a hearing test as the final result of this part and scores as follows: complete the corresponding instructions independently according to the content of the tester gets 4 points, repeat the same content according to the content of the tester gets 3 points, can only complete the listening position gets 2 points, voice response gets 1 point and no response gets 0 points.

In the visual part of consciousness detection, this paper divides the visual test score into 4 levels, according to the visual retention integrity from high to low, are the eye can recognize objects and achieve natural blinking, natural blinking but blurred object recognition, eyes can be opened only under external stimuli and unable to open eyes. If the subjects can complete the content later, the score will be lower
and it indicates that the subjects have a higher degree of loss of visual awareness. In the evaluation scoring, this paper takes the subjects’ best situation in conscious vision as the final result of this part and scores as follows: the eye can recognize objects and achieve natural blinking gets 3 points, natural blinking but blurred object recognition gets 2 points, eyes can be opened only under external stimuli get 1 point, and unable to open eyes get 0 points. In actual operation, if the subject opens eyes periodically and blinks smoothly during the observation process without irritation or foreign body sensation, it is judged as natural eyes opening. If the subject can recognize the basic daily necessities, it is judged as the subject can realize object recognition.

In the language part of consciousness detection, this paper divides the language test into 4 levels, ranked according to the language function retention integrity from high to low, they are responding correctly to the questions asked by the tester, incoherent expression of the problem, can only pronounce intermittent phrases and no response. If the subjects can complete the content later, the score will be lower and it indicates that the subjects’ loss of language consciousness is higher. In the scoring process of this item, this paper takes the best achievable situation of the subjects in language awareness as the final result of this part and scores as follows: respond correctly to the questions asked by the tester gets 3 points, incoherent expression of the problem gets 2 points, can only pronounce intermittent phrases gets 1 point and no response get 0 points.

In the perception part of consciousness detection, this paper uses the stinging response to realize the perception evaluation. The specific operation is as follows, by puncturing the subjects’ fingertips and dividing the response into the following two situations, ranked according to the degree of perceptual retention from high to low, they are the subjects was stabbed to avoid faster, the subjects have no response or only a weak response. If the subjects meet the former gets 2 points, otherwise gets 0 points.

Finally, this section summarizes the consciousness evaluation score scale as follows:

| IGCS score | 4 | 3 | 2 | 1 | 0 |
|------------|---|---|---|---|---|
| **Auditory ability** | Complete the corresponding instructions independently according to the content of the tester | Repeat the same content according to the content of the tester | Can only complete the listening position | Voice response | No response |
| **Visual ability** | The eye can recognize objects and achieve natural blinking | Natural blinking but blurred object recognition | Eyes can be opened only under external stimuli | Unable to open eyes |
| **Language ability** | Respond correctly to the questions asked by the tester | Incoherent expression of the problem | Can only pronounce intermittent phrases | No response |
| **Perception ability** | Stabbed to avoid faster | No response |

Fig.1 IGCS coma score scale

(2) Heart rate and blood pressure classification

To better evaluate the extent to which the user's health indicators exceed the health level, this paper adopts the idea of tiered scoring to score the health indicators of the tested. Based on medical clinical data, the upper limit of normal human systolic blood pressure is 130mmHg, and the upper limit of
healthy resting heart rate is 90 beats per minute [6]. At the same time, the relationship between heart rate and respiratory rate is 4 times [7]. The specific relation formula is as follows.

\[ x_{\text{Heart rate}} = 4 \times x_{\text{Respiratory rate}} \]  

formula 6

Based on the above theoretical basis and Qsofa’s original scoring principle, this paper divides the heart rate and blood pressure scores into the following levels as shown in the figure:

| Score | 0.00 | 0.85 | 0.90 | 0.95 | 1.00 |
|-------|------|------|------|------|------|
| Heart rate, Systolic pressure, mmHg | <90 | 90-110 | 110-130 | 130-160 | 160-220 |
|       | <130 | 130-140 | 140-150 | 150-170 | 170-200 |

Fig.2 Improved blood pressure and heart rate rating scale in Qsofa algorithm

(3) IGCS score normalization

After all the above steps are processed, the blood pressure and heart rate scores of the subjects were inversely correlated with the index health, while the coma score was positively correlated with the conscious health. To make all the indicators like Qsofa score, the score, and health is inversely correlated, this step will combine the data processing ideas TOPSIS to forward the data so as to achieve the effect that the higher the score [8], the more critical the subject’s situation. The processing formula is as follows:

\[ z_{\text{Normalization}} = z_{\text{max}} - z \]  

formula 7

(4) Score standardization

To better show the relative severity of the three indicators of coma, blood pressure, and heart rate, this project normalizes each evaluation to obtain the relative score of each item. The specific formula is as follows

\[ S_{\text{standardization}} = \frac{s_i}{S_{i,max}} \]  

formula 8

\( S_i \) is the score of the subject in this item and \( S_{i,max} \) is the highest score that a subject can obtain theoretically.

(5) Point weighting

In the Qsofa evaluation [9], the evaluation considers that blood pressure, heart rate, and coma are equally important. Therefore, in the final calculation process, the relative scores of the three indicators give equal importance and the weights of the three indicators are calculated based on the AHP weight algorithm [10]. The weight calculation algorithm is as follows:

First, set the important level \( A_i \) of blood pressure, heart rate, and coma to 1. That is:

\[ A_1 = 1 \]  

formula 9

\[ A_2 = 1 \]  

formula 10

\[ A_3 = 1 \]  

formula 11

Then list the analytic hierarchy process matrix based on the AHP algorithm:

\[ \begin{pmatrix}
   A_1 & A_1 & A_1 \\
   A_1 & A_2 & A_2 \\
   A_1 & A_2 & A_2 \\
   A_2 & A_3 & A_3 \\
   A_2 & A_3 & A_3 \\
   A_3 & A_3 & A_3
\end{pmatrix} \]  

formula 12

After that, calculate the weight of each item \( B_j \) according to the algorithm:

\[ B_1 = \frac{A_1}{A_1} \cdot \frac{A_1}{A_1} \cdot \frac{A_1}{A_1} \]  

formula 13

\[ B_2 = \frac{A_2}{A_2} \cdot \frac{A_2}{A_2} \cdot \frac{A_2}{A_2} \]  

formula 14

\[ B_3 = \frac{A_3}{A_3} \cdot \frac{A_3}{A_3} \cdot \frac{A_3}{A_3} \]  

formula 15

Finally, normalize each weight:

\[ C_i = \frac{B_i}{\sum_{n=1}^{n} B_n} \]  

formula 16
In the above formulas, \( A_1 \), \( A_2 \), and \( A_3 \) represent the importance-level of heart rate, blood pressure, and coma, \( B_1 \), \( B_2 \), and \( B_3 \) represent the non-standardized importance-weights of heart rate, blood pressure, and coma, and \( C_1 \), \( C_2 \), and \( C_3 \) represent the normalized weight of heart rate, blood pressure, and coma.

(6) Calculate weighted score

After the steps above are finished, the final score \( \delta \) of the subject is calculated based on the formula 17. To make the partitions consistent with the traditional method, this paper uses the following method to restore the weight. If the score is greater than 2, it is judged as unhealthy.

\[ \delta = 3 \sum_{i=1}^{3} C_i \cdot S_i \]  

**formula 17**

### 4. Test Results and Discussions

#### 4.1. Experiment design

To verify the effectiveness and reliability of the algorithm in this paper, we used photoplethysmography technology and improved the Qsofa evaluation method to test and evaluate 100 people randomly and record relevant data. After the test, the detected data was compared with the use of medical equipment and the traditional Qsofa evaluation algorithm. Besides, this paper selects 50 people (including medical professionals and non-medical practitioners) randomly to improve the manual operation of improved Qsofa and traditional Qsofa and compares the operating difficulty of the two algorithms based on the difficulty calculation formula. The difficulty calculation formula is as formula 18:

\[ P = 1 - \frac{x}{w} \]

**formula 18**

In this formula, \( p \) represents the difficulty, the greater the value of \( p \), the greater the difficulty, \( x \) represents the number of correct items per capita, \( w \) represents the total number of items manipulated, and \( x/w \) represents the per capita correct rate of the experimenter operation.

#### 4.2. Experimental results and discussion

Comparing the scores of the subjects on the original Qsofa and the improved Qsofa, we get the following comparison results:

| Subject number | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|----------------|---|---|---|---|---|---|---|
| Qsofa          | 1 | 2 | 2 | 1 | 2 | 0 | 0 |
| Improved Qsofa | 1.5 | 2.61 | 2.33 | 1.68 | 2.43 | 0.90 | 0.83 |
| Result         | healthy | unhealthy | unhealthy | healthy | unhealthy | healthy | healthy |

Fig.3 Comparison of the scoring results between the improved Qsofa algorithm and the traditional Qsofa algorithm

As can be seen from the above figure, the subjects use traditional Qsofa evaluation scores only in 4 grades from 0 to 3 points. After the improved evaluation algorithm in this paper, the score of the subjects is composed of integers and decimals, and the integer part of the user’s score in the improved algorithm is consistent with the traditional Qsofa integer score. This shows that the algorithm in this paper not only can judge the condition of sepsis with the same correct rate as Qsofa but also realizes the refinement of the severity of the condition of the subjects with the same integer part score, which greatly improves the accuracy of the condition judgment.

Hereafter this paper compares the time-consuming algorithm. After test records, the algorithm in this paper and traditional algorithms take time to evaluate users as follows:
Fig.4 Comparison of algorithm operation time

(a) Improved Qsofa algorithm operation time
(b) Traditional Qsofa algorithm operation time

It can be seen from the above figure that if the algorithm in this paper is used, more than 90% of the evaluation time of the subjects will be about 40 seconds. The traditional Qsofa evaluation takes most of the time between 40 seconds and 50 seconds, that is, there is no significant difference between the time consumption of the algorithm in this paper and the traditional algorithm.

Combined with the comparison of the results of the traditional Qsofa and the improved Qsofa in the previous part, the improved Qsofa algorithm in this paper is more accurate than the traditional Qsofa in the evaluation results, and the time-consuming is not significantly different from the traditional Qsofa algorithm. This also shows that the operating efficiency of this algorithm is slightly higher than the traditional Qsofa algorithm.

To better verify the correctness of the heart rate and blood pressure obtained by the algorithm in this paper, this paper uses a standard medical monitor to calibrate the algorithm index measurement accuracy of this paper. The results are as follows:
(a) Distribution of accuracy of blood pressure and heart rate measurement results based on improved Qsofa algorithm

From the above figure, 96.2% of the heart rate and blood pressure data of the algorithm in this paper have errors within 2.00% compared with the standard heart rate and blood pressure data. While the heart rate and blood pressure data obtained by the traditional mean method of wearable devices have errors around 10% compared with the standard heart rate and blood pressure data. Therefore, the algorithm in this paper significantly improves the accuracy of blood pressure and heart rate detection by wearable devices.

At last, this paper calculates the experimenter’s operation accuracy rate of the improved Qsofa algorithm in this paper and the operation accuracy rate of the traditional Qsofa algorithm and then finds the difficulty of the two methods. The higher the P-value, the greater the difficulty. To better compare the operating difficulty of the two algorithms between medical and non-medical practitioners, 22 of the 50 experimenters were engaged in medical-related positions and had certain medical clinical experience. The experimental results are as follows:

(b) Distribution of accuracy of blood pressure and heart rate measurement results based on traditional Qsofa algorithm

Fig.5 Comparisons of algorithm accuracy
From the above results, it can be seen that among non-medical practitioners, the per capita operating accuracy rate of traditional Qsofa is less than 10%, that is, the operating difficulty of traditional Qsofa for non-medical practitioners is about 0.9, while the per capita operating accuracy rate of improved Qsofa is 62.3%, that is, the difficulty value $P = 0.377$. Among medical practitioners, the per capita correct rate of traditional Qsofa is 82.7%, that is, the difficulty value $P = 0.173$, and the per capita correct rate of improved Qsofa is 98.4%, $P = 0.016$. From the above data, it can be concluded that the improvement of Qsofa greatly reduces the difficulty of algorithm evaluation, whether in medical practitioners or non-medical practitioners. Among them, the improved Qsofa reduces the difficulty of operation by about 58% among non-medical practitioners and improves the accuracy of the algorithm operation by about 18.98% among medical practitioners.

5. Conclusion

According to the experimental results, in the process of data processing, the algorithm in this paper greatly improves the accuracy of the photoelectric volume module of the wearable device in the measurement of heart rate and blood pressure. In terms of comprehensive health assessment, the algorithm in this paper simplifies the coma evaluation method, thereby greatly reducing the difficulty of Qsofa evaluation. Among them, from the perspective of the difficulty of operation by non-medical practitioners, the difficulty of implementing the algorithm in this group is 58% lower than that of the original algorithm. From the perspective of medical practitioners, the accuracy of the algorithm in this paper is 18.98% higher than that of the original algorithm. In terms of the algorithm operation process and effect, the algorithm in this paper not only shows the health of the subject in a more precise manner but also the running time of the algorithm is not significantly prolonged, which also shows that the algorithm in this paper operates better. In general, the algorithm in this paper has a significant improvement in heart rate and blood pressure numerical processing and health analysis compared to traditional algorithms, and it has good significance for the analysis of emergency sepsis health in wearable devices.

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