Hemoglobin Prediction System from Pulse Signal

Khunawat Luangrat[1], Prapat Suriyaphol[2,3] and Yodchanan Wongsawat[1]

[1] Department of Biomedical Engineering, Faculty of Engineering, Mahidol University, Thailand
[2]Faculty of Medicine Siriraj Hospital, Mahidol University, Thailand
[3]Center for Emerging and Neglected Infectious Diseases, Mahidol University, Thailand

Abstract— **This paper proposes the translational research on developing the homemade pulse detector to predict the hemoglobin (usually need blood test) by using the non-invasive method. The system uses the peak of each pulse signal from homemade-single infrared LED to calculate the amount of hemoglobin compare with the commercial product.**

Keywords— **Pulse, Hemoglobin, Translational research**

I. Introduction

The vital signs for human life are very useful for medical treatment planning. Pulse signal is one of the useful vital sign to monitor the human symptom. Pulse signal occur continuously along with the heart signal. Hence, the rate of the pulse signal is close to heart rate.

Since pulse signal is widely used in medical diagnosis. Many medical devices can measure the pulse. Pulse oximetry is also one of the most used medical devices in the hospitals to monitor the amount of oxygen in the blood and also the pulse rate by placing the sensor on the finger. The device used the absorption of the light (red light and infrared light). One of the medical device that develops from pulse oximetry is the hemoglobin detection. The hemoglobin can measure from human blood by invasive and non-invasive method. For invasive method, the complete blood count (CBC) is one of the methods to determine the amount of hemoglobin by analyzing the blood component in the tube. Using biosensor is one of the methods to measure the amount of hemoglobin. For non-invasive methods, there are many researchers proposed to find the amount of hemoglobin and the disease that cause from hemoglobin. In 2001, Masakazu Iwasaka et.al [1] used optical absorbance to measure the red blood cell and hemoglobin under the magnetic field. In 2004, Carlos R. Valencio, et.al [2] used hemoglobin parameter visualization to identify the thalassemia from abnormal forms of hemoglobin. In 2007, Gregory D. Jay et.al [3] used fiber optic reflectance spectroscopy to measure the amount of hemoglobin. In 2009, Linda M. Head, et.al [4] developed wireless fNIR spectroscopy for Hb and HbO_2 detection. U. Timm, et.al [5] developed the system using optical sensor for hemoglobin determination. In 2011, Teng Yichao, et.al [6] used near-infrared spectroscopy to detect the cerebral hemoglobin concentration of newborns during inhalation.

In this paper, we propose another simple way and low cost system that can efficiently detect the hemoglobin non-invasively. Previously, the probe use at least three wavelength as a sensor, but for our system, we propose a single LED as a sensor and propose the algorithm to detect the pulse signal and map to the amount of hemoglobin.

II. Background

A. Hemoglobin

Hemoglobin is one of the important protein signs to represent the healthy of the human. The protein can transport the oxygen from lung to the parts of body. One of the diseases occurred from lacking of hemoglobin is Anemia. Patient feel tired, lack of power, some cases may lose the concentration. Once the body starts lacking of hemoglobin, the body also starts lacking of oxygen, patient will increase the cardiac output to balance the oxygen level. That may cause heart disease.

B. Pulse Signal

Pulse signal (Fig.1) is one of the vital sign which directly related with the electrocardiogram (ECG). The pulse signal can be monitored by using the light absorption for non-invasive method. Currently, the amount of hemoglobin can be measured by using the complete blood count (CBC) method. The disadvantage for this method is we need the amounts of blood for CBC test. So, in this paper, we try to develop the non-invasive system that can monitor the hemoglobin with low cost device.

III. Proposed method

For this study, we propose the low cost system that can monitor the hemoglobin. We first perform the experiment to acquire the relation between the pulse signal and hemoglobin. After that we demonstrate the algorithm to calculate the hemoglobin from the pulse signal.

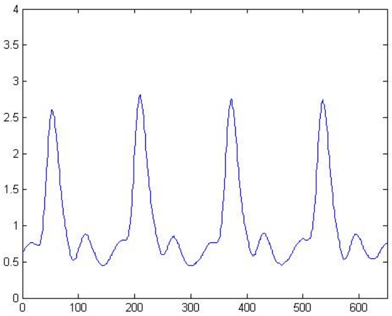

Fig. 1 Raw pulse signal

A. Experiment: Relation between pulse signal and hemoglobin

We use the pulse BIOPAC^{TM} system to record the pulse signal and use MASIMO^{TM} radical-7 to record the hemoglobin. Eight healthy volunteers was recorded the pulse signal and hemoglobin at the same time. This experiment is separated into three periods, before drinking the water, between drinking the water and after drinking the water. The result shows that after drinking the water, the pulse amplitude increase. Meanwhile, in Fig.1, we can also see that the hemoglobin also decreases. Hence, the pulse amplitude and the hemoglobin should have some relationships.

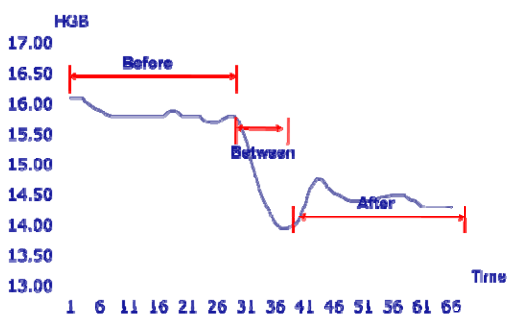

Fig. 2 Hemoglobin monitoring during experiment I

B. Hemoglobin calculation from pulse signal

The 8 healthy volunteers were recorded the pulse signal and hemoglobin at the same time for 10 minutes. Pulse amplitudes, maximum pulse amplitudes and minimum pulse amplitudes are recorded. Fig.3 shows the recorded pulse signal for 1 minute. The red stars show the maximum pulse amplitude of each pulse signal and the green stars show the minimum pulse amplitude of each pulse.

The mapping coefficient from pulse signal to hemoglobin level can be calculated by let $\boldsymbol{x}$ be the mapping coefficient with order six, $\boldsymbol{b}$ is the known hemoglobin level, **A** is the matrix of parameters that acquired from pulse signals. Each row of **A** represents the parameters in 60 second (10 second per one row coefficients). In this work, we compare the results among 4 differences parameters of **A**. Each element in row of **A** represent the average of the following parameter in 10 seconds, i.e. 1) maximum peak (Max peak), minimum peak (Min peak), difference between maximum and minimum peaks (Max-Min), and ratio between maximum and minimum peaks (Max/Min). Since we have a data of 10 minutes of 8 subjects, **A** will have a size of 80×6. According to Eq. (1), $\boldsymbol{x}$ can be solve using pseudo-inverse as shown in Eq. (2),

$$\mathbf{A}\boldsymbol{x} = \boldsymbol{b}, \quad (1)$$

$$\boldsymbol{x} = (\mathbf{A}^{T}\mathbf{A})^{-1}\mathbf{A}^{T}\boldsymbol{b}. \quad (2)$$

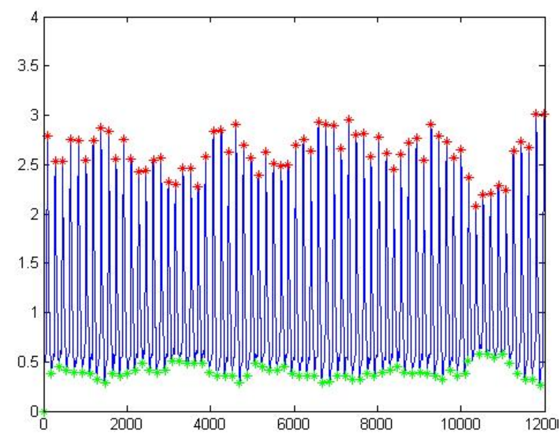

Fig. 3 Components of pulse signal for 60 seconds

C. Proposed device; Pulse detector

The homemade device (Fig.4) uses the single infrared light as a sensor to detect the pulse signal. The TX (infrared LED) and RX (receiver) were place at the same side. The user place finger covers the LEDs and the device will show the rhythm of the pulse signal. After that, we compare the signal between our homemade device and the BIOPAC^{TM} system. The result is shown in Fig.5.

IV. RESULTS

According to our 4 training parameters from pulse signal, we will get 4 different $\boldsymbol{x}$ coefficients as shown the Table 1. We can predict the hemoglobin from each components of pulse signal. The average errors of hemoglobin predicted from 40 sets of pulse signal are compared with the hemoglobin level from MASIMO™Radical-7 as shown in Table 2. The amount of hemoglobin from MASIMO™ Radical-7 show between 16-17 g/dl^3 and the nearest prediction is the prediction from maximum peak (Max peak).

According to Table 2, the max peak and max-min have the same average minimum error but the max peak has more stable trend line (Fig.6).

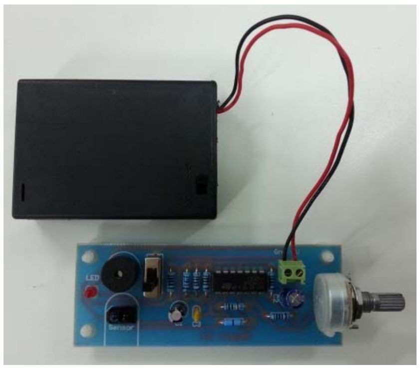

Fig. 4 Homemade device: Pulse detector

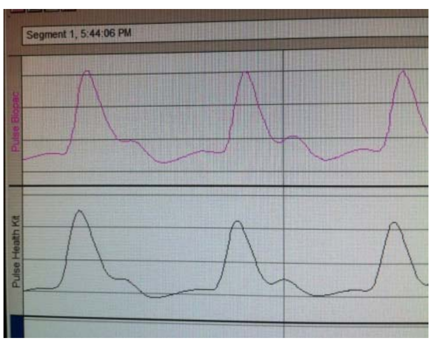

Fig.5 Pulse signal from different device. Top is the pulse from BIOPAC™,bottom is the pulse from homemade device.

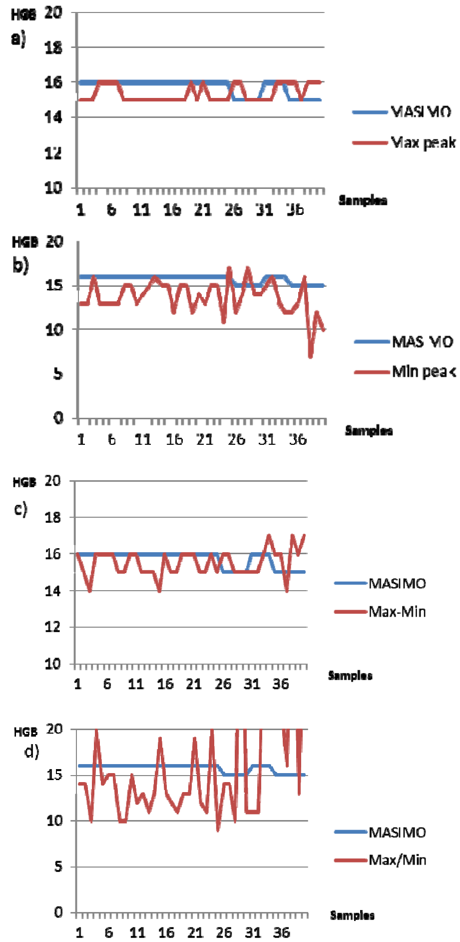

Fig. 6 Comparison of hemoglobin between MASIMO™ Radical-7 and our prediction from each pulse component: a) max peak b) min peak c) max-min d) max/min

Table 1 Resulting coefficient ***x***

Coefficient ***x***						
Min peak	7.75	5.71	5.58	7.03	9.36	9.84
Max peak	0.33	1.21	0.66	1.09	1.27	1.03
Max-Min	0.53	1.32	0.75	1.22	1.37	1.14
Max/Min	0.03	0.06	0.05	0.14	0.56	0.52

Table 2 Average errors

Max peak	Min peak	Max-Min	Max/Min
4%	14%	4%	37%

V. CONCLUSIONS

In this paper, we have presented the homemade hemoglobin prediction system from the pulse signal. We can also conclude that hemoglobin prediction from maximum peak has minimum error compares with other pulse components. According to our proposed system, we can make real-time hemoglobin prediction possible. This can also make the biofeedback to some diseases and real-time effects of drugs possible.

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