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The measurement technique of human's bio-signals

Yasuhiro Saeki, Komin Takamura, Kazushige Magatani
are Department of Electrical and Electronic Engineering , TOKAI University, Kanagawa, Japan

Abstract

A disaster like a big earthquake usually brings many destroyed buildings and many sufferers are generated in the disaster area. In this situation, sometimes a rescue person encounters a second disaster. This is the big problem to rescue sufferers. In order to avoid a second disaster, many kind of rescue robots are being developed. These robots can find sufferers and rescue them. However, they cannot measure the sufferer's condition at the disaster area. If the sufferer's condition becomes clear before rescue, the rescue efficiency will improve. Therefore, we are developing a rescue robot that can measure some vital signs of sufferer and send measured data to the medical doctor who is in safety place. In this paper, we will describe about a developed method that can measure the pulse and the arterial blood oxygen saturation degree (SPO2) by easy way. We think that these methods will be powerful and useful to rescue sufferers.

I. Introduction

A disaster like a big earthquake usually brings many destroyed buildings and many sufferers are generated in the disaster area. There is also possibility that a rescue person receives a serious injury or lost his/her life by a second disaster. In order to avoid these tragedies, robots that engage in rescue sufferers are being researched and developed. Most of the rescue robot can remove obstacles, make a route to a sufferer, and rescue him/her. However, they cannot measure the sufferer's condition. We think that if they can measure sufferer's vital signs (for example a body temperature, pulses, and so on) at the disaster area, it will be possible to evaluate a sufferer's condition and to realize the effective rescue ability. Our goal is the development of a rescue robot that can measure the sufferer's vital signs and send these data to a medical doctor. In this paper, we describe about a developed method that can measure the pulse and the arterial blood oxygen saturation degree (SPO2) by using pulse oximetry. Only touching sufferer's skin with a sensor, a correct sufferer's SPO2 is obtained in our method.

II. Methodology

II-I. Pulse Detection

The pulse is one of the most important vital sign of a human, and it is generated continuously while our life is lasting. The pulse is generated by blood flow that is caused by heart's beats. In other word, we can observe the pulse as a change of artery diameter from the result of a beat of a heart.

Hemoglobin in the blood absorbs infrared ray. Therefore, if we irradiate infrared ray to a vessel, absorption rate of infrared ray will change as increase and decrease of a blood flow. This absorption and reflection of infrared ray in the blood can be used to detect the pulse. It is possible to detect the pulse by measuring the blood flow of the capillary that is distributing to the skin of human body using infrared ray. In other word, change of reflection rate of infrared ray that is irradiated to a human skin expresses the pulse. Infrared ray has the following characteristics.

1) Infrared ray has permeability to all the substances including the skin.
2) Infrared ray has a characteristic of absorption toward blood.

In our method, the pulse is measured using these characteristics. Infrared ray from a infrared LED is irradiated to the skin. Even if there is a clothe between a LED and a skin, infrared ray can permeates through a clothe and reach to the skin surface. A part of this infrared ray is absorbed and the rest of it is reflected. We can observe the pulse as the changing intensity of this reflection.

By the way, red ray is also absorbed into blood. However, infrared ray is mainly absorbed into de-oxy-hemoglobin and red ray is mainly absorbed into oxy-hemoglobin. These characteristics are used to calculate SPO2 in our system. So, we developed two types of a pulse sensor. One uses infrared ray (900nm) and the other uses red ray (660nm). Both sensors consist of a LED and a photo sensor. These sensors are touched to the human body. A LED in the sensor emits infrared or red ray, and a photo diode detects the reflected ray as electric current. Fig.1 shows a pulse sensor using infrared ray, and Fig.2 also shows a pulse sensor using red ray.

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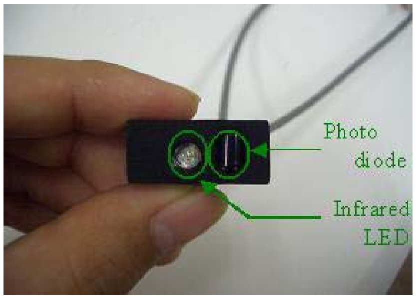

Fig.1 Infrared ray sensor

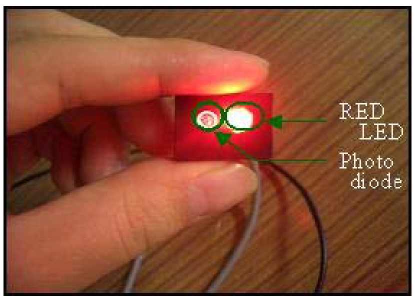

Fig.2 Red ray sensor

Electric current from a photo diode is converted to voltage and then amplified and filtered for noise reduction. Direct contact with human skin of the sensor is the best condition to detect a pulse. However, in many cases at the disaster area, it is difficult to touch a sensor to a skin directly, and there are sufferer's cloths between a sensor and a skin. For such cases, in our measurement system, the brightness of a LED and amplification gain of a photo detector are able to control in order to set their level optimal. These controls of the system are conducted by a one-chip microprocessor (PIC 16F874). In our system, intensity of LED is changeable 16 levels and gain of a photo detector is changeable 4 levels. A block diagram of this system is shown in Fig.3. And measurement results of the pulse are also shown in Fig4. The pulse that is measured using infrared ray is shown in Fig.4 (a) and using red ray is shown in Fig.4 (b).

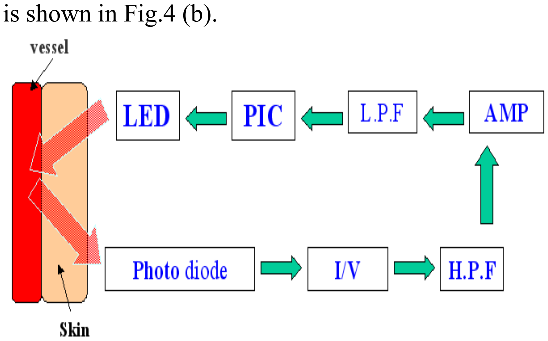

Fig.3 Block diagram

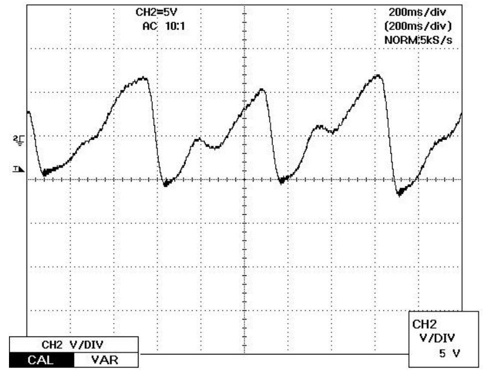

Fig.4(a) Pulse wave of Infrared

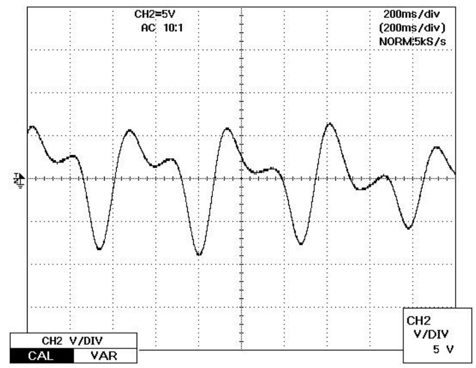

Fig. 4(b) Pulse wave of red

II-II. Calculation of SPO2

It is possible to calculate an arterial blood oxygen saturation degree (SPO2) by using 2 types of measured pulse wave. One is measured by using infrared ray and the other is by using red ray. SPO2 expresses the percentage rate of oxy-hemoglobin in blood. This value is one is the most important vital sign of a human. SPO2 reflects the body condition strongly. The body conditions for each SPO2 rate are shown in Table.1. It is said that about 96% and up of SPO2 is normal level in human. Some medical treatments will need in the condition from 91% to 95% of SPO2. And 90% and under of SPO2 means fatal condition, and a correct medical treatment is necessary as soon as possible.

Hemoglobin is in the red blood cell. And oxy or de-oxy hemoglobin makes change the color of red blood cell. Using this light characteristic of red blood cell, SPO2 can be obtained. In actuality, SPO2 is obtained as a ratio of a magnitude of the pulse for infrared ray and a magnitude of the pulse for red ray (that is called absorbing light constant).

Table.1 SPO2 value connect symptom of body

Oxygen Saturation Blood	Condition	Symptom of body
>97	Normal	Good health
>94	No damage	
90-94	Minor damage	Minor symptom
75-89	Middle damage	Cyanosis
<75	Serious damage	Damage to tissue Cellular death

III. Experiment and Results

III-I. Experiment 1

Four normal subjects were studied to measure absorbing light constant by using infrared ray (wave length: 900nm) and red ray (wave length: 660nm). To calculate this value, following formulas were used.

$$\Delta A = \log(I/(I-\Delta I))$$
$$\Delta B = \log(L/(L-\Delta L))$$
$$\varphi = \Delta A / \Delta B$$

Where, I means the maximum amplitude of infrared pulse signal, and L means the maximum amplitude of red pulse signal. ΔA and ΔB mean the difference between maximum and minimum amplitude of each signals. And φ is the absorbing light constant. The results of experiment are shown in Table.2. In this table, maximum and minimum amplitude for each light source are expressed as “minimum value to maximum value”. As shown in this table, the amplitude of a pulse that is measured using infrared ray is greater than the amplitude of a pulse that is measured using red ray. Because infrared ray is mainly absorbed into de-oxy-hemoglobin and red ray is mainly absorbed into oxy-hemoglobin. And the number of oxy-hemoglobin is greater than de-oxy-hemoglobin in normal person. From these reasons, the results of calculated absorbing light constant are almost same in all subjects.

Table.2 Other subject’s constant

	Subject1	Subject 2	Subject3	Subject4
Infrared	60 to 51	51 to 40	85 to 43	60 to 52
Red	37 to 30	34 to 25	62 to 26	35 to 39
Constant	1.291	1.284	1.275	1.333

III-II. Experiment 2

The SPO2 was experimentally measured by using the method as mentioned earlier. Fig.6 shows the general view of the SPO2 measurement system. Fig.7 shows an appearance of the experiment. An infrared ray sensor was put on left first finger and red ray sensor was put on left second finger. And as a reference, SPO2 was measured using left third finger by the pulse oxy mater on the market.

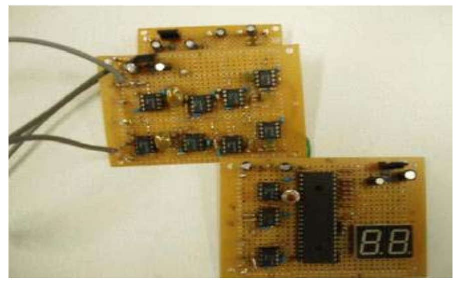

Fig.6 General view of the device

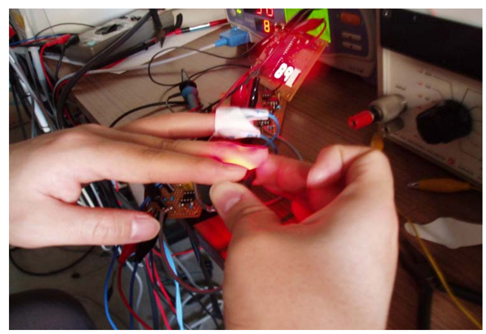

Fig.7 how to detected pulse

Fig.8 shows measured pulse wave by using infrared ray and red ray. Fig.9 shows the calculation results of SPO2 of our system and the output of a pulse oxy mater on the market. In Fig.9 (a) 97% is the result of our system and reference is 98%. In Fig.9 (b) 98% is the result and reference is 99%. The calculation results of our system are a little bit lower than a reference. However, the calculation results and references were almost same.

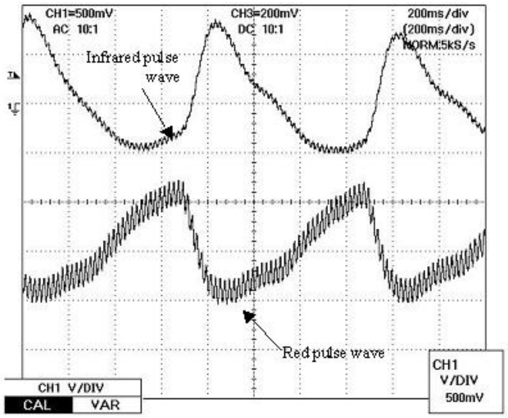

Fig.8 pulse waves at same time

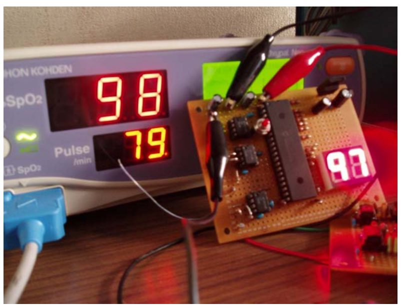

Fig.9 (a) Result 1

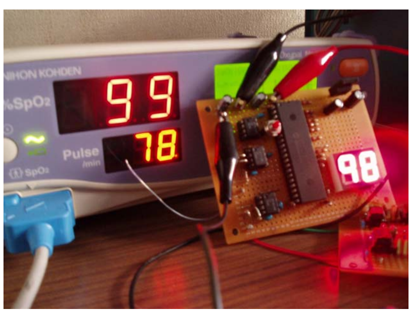

Fig.9 (b) Result 2

IV.Conclusion

In this paper, we described about the developed devices for the measuring vital signs of suffered person under the disaster. A pulse measurement system by using infrared ray and red ray is developed. This system can measure the human pulse on subject's cloths. And SPO2 measurement system is also developed. This system can measure the arterial blood oxygen saturation degree by using 2 types of the light.