International Journal of Engineering Research and Technology.
ISSN 0974-3154 Volume 11, Number 3 (2018), pp. 493-500

http://www.irphouse.com

Remote Heart Rate Monitoring Method Using Infrared Thermal Camera

Yoonkyoung Kim
Department of Computer Science, Sangmyung University, Seoul, Republic of Korea

Yosep Park
Department of Computer Science, Sangmyung University, Seoul, Republic of Korea

Jinman Kim
Research Institute for Intelligent Engineering Informatics, Sangmyung University, Seoul, Republic of Korea

Eui Chul Lee*
Department of Intelligent Engineering Informatics for Human, Sangmyung University, Seoul, Republic of Korea

Abstract

The heart rate and heart rate variability are types of biometric information that are used in healthcare and wellness applications. Although attached-sensor-based photoplethysmography methods are widely used, they are not suitable for athletes, patients, and babies, who have difficulty wearing sensors. Generally, the human skin exhibits minute temperature changes due to blood flow. These changes are challenging to visually grasp, even with a thermal camera. In this paper, a thermal camera and some image processing methods are used to amplify the minute temperature changes due to facial-skin blood flow, and the heart rate is calculated using the amplified temperature signal. Results showed that the proposed method estimated heart rate of about 95% accuracy in cases of accurately detected blood vessel.

Keywords: Heart Rate, Physiological Signal Detection, Signal Amplification, Skin Temperature, Thermal Camera.

* *Corresponding Author*

I. INTRODUCTION

Biometric information is now used in many fields. Heart rate and heart rate variability(HRV) are types of biometric information that are often used in used in health and wellness fields, such as sports and medical care. For example, heart rate changes of athletes are measured and analyzed to improve performance [1][2]. In the medical field, heart rate is used in psychotherapy to evaluate a patient's emotions, estimate the sleep quality [3]. The heart is a representative organ controlled by the autonomic nervous system (ANS); thus, ANS can reflect emotional changes [4][5]. HRV also has been used to assess cardiac autonomic activity in critically ill patients. Several clinical and technical factors can interfere with the measurement and/or interpretation of HRV [6].

Photoplethysmography (PPG) methods using sensors attached to the body are widely used [7]. However, this approach is not a suitable for sensor-attachment to sweating patients, babies, athletes, and other subjects who may experience discomfort or inconvenience. Recently, non-contact heart rate detection technology using a camera has been studied [8][9][10]. In this approach, skin color changes due to heartbeats, which cannot be visually confirmed, are optically obtained and amplified to calculate the heart rate. However, it may not be accurately detected depending on the illumination of the experimental environment and the skin color of the subject.

In this paper, we therefore propose a non-contact heart rate detection algorithm using a thermal camera. A thermal imaging camera is used to detect the area of the blood vessel and it observes the minute temperature changes of the blood vessel. By calculating the heart rate using the temperature changes, the detection performance is improved without being affected by the subject's skin color or the illumination environment.

II. PROPOSED METHOD

II. I Algorithm Overview and Images

The proposed method is outlined in Fig. 1.

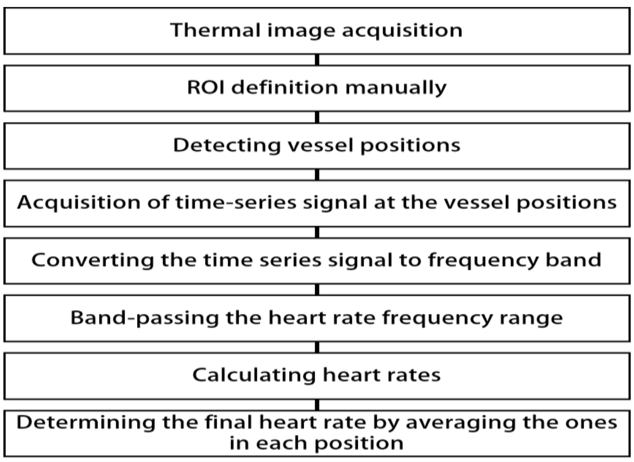
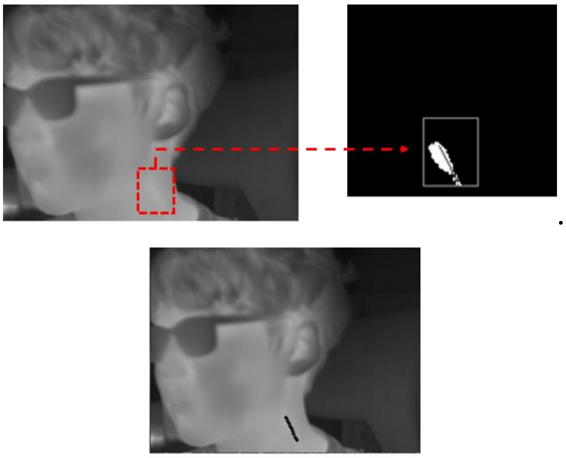


Fig. 1. Overview of the proposed method.

II. II Blood Vessel Detection

Accurate blood vessel detectors are needed to obtain accurate temperature information. The blood vessel temperature changes in accordance with the blood flow. If the accurate position is not known and it is acquired together with the surrounding information, the minute temperature change information may be lost because of the ambient temperature.



(b)

Fig. 2. Vascular detection algorithm step. (a) Thermal image and binarization. (b) Detected vessel location.

In this paper, we use the following algorithm to detect blood vessels using the point where the blood vessel is higher than the ambient temperature. To distinguish the bright and dark skin areas, the binarization proceeds to designate the areas where the blood vessels are present. Then, each center point of the bright region is calculated to detect the blood vessel position

II. III Noise Removal and Signal Amplification

A temperature change due to blood flow is almost imperceptible. It is difficult to detect an accurate heart rate using such minute changes, and a temperature error (−2 °C ~ 2 °C) can occur based on the thermal camera performance. By using the bit-shift operation, the lower bits are discarded to remove noise from the hardware.

Fig. 3(a) shows the original signal obtained by using the thermal imaging camera on the graph. Fig. 3(b) shows the time-series signal with noise removed using bit shift operation toward the least significant bit direction.

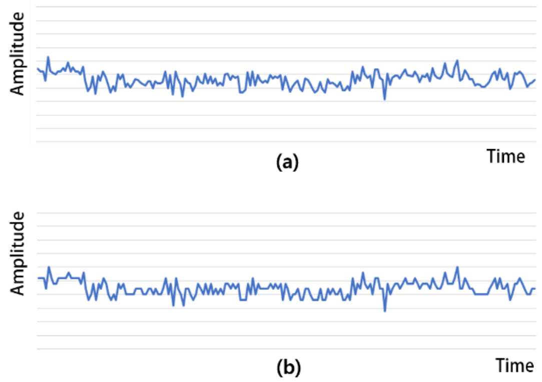


Fig. 3. Noise removal example. (a) Before removal. (b) After removal.

Fig. 4(a) shows the noise removed signal. In this case, because the temperature change is negligible, it is difficult to recognize the heartbeat-like signal on the graph. Therefore, in order to calculate the heart rate at a minute temperature change, the temperature signal is magnified to obtain amplified signal by bit-shifting toward the most significant bit direction. As shown in Fig. 4(b), the heartbeat-like fluctuation can be confirmed even though the signal has much high frequency noise component.

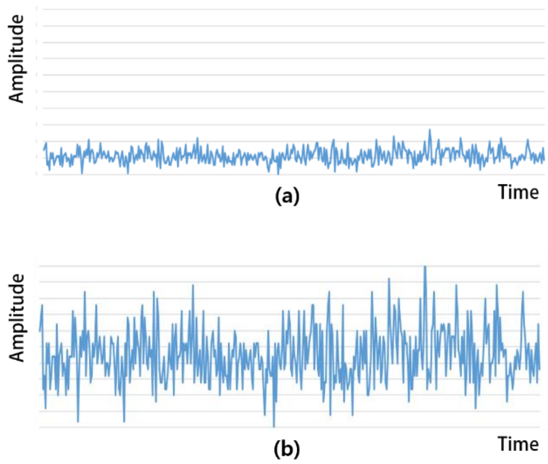


Fig. 4. Signal amplification example. (a) Before amplification. (b) After amplification.

II. IV Heart Rate Extraction

The proposed method uses the frequency-domain signal to calculate the heart rate in real time. In the time-series signal, although the noise is removed in the previous step 2.2, it is impossible to remove all the noise, and it is impossible to measure an accurate heart rate. To convert a time-series signal into a frequency-domain signal, we use the discrete Fourier transform (DFT). It converts the amplified time-series signal of Fig. 5(a) into the frequency-domain signal of Fig. 5(b).

In the proposed method, only the frequency corresponding to the heart rate band is used. The heart rate component is analyzed by selecting the 0.9 Hz to 1.6 Hz frequency band corresponding to the heart rate of 54 to 96 beats per minute as the available heart rate interval. The frequency—including the greatest magnitude of the available heart rate range, shown as 1.3Hz (red line) in Fig. 5(b)—corresponds to the current heart rate and can be converted to calculate the standard heart rate. Based on the DFT algorithm, the final heart rate is determined by averaging the multiple heart rates calculated from the multiple positions on the detected blood vessel region, as shown in Fig. 2(b).

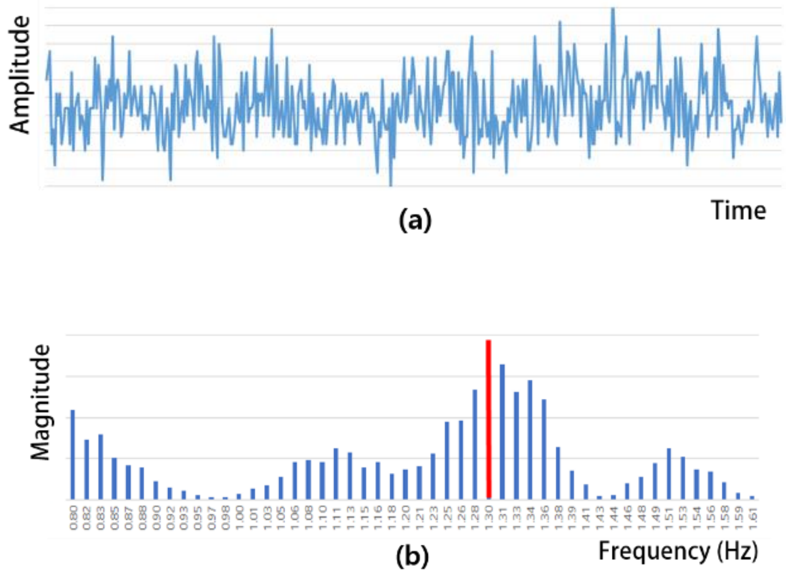


Fig. 5. Time-series and frequency-domain signals. (a) Time-series signal. (b) Frequency-domain signal.

III. EXPERIMENTAL RESULTS

The thermal imaging camera used in the experiment was a FLIR T430sc camera. Experiments were conducted at a distance of approximately 1 m between the camera and subject. The spatial resolution and frame rate of the camera were 320 × 240 pixels and 12 fps, respectively. Twenty subjects were participated who were early 20’s to early 50’s. In the experiments, the subjects were measured for 30 seconds.

Table. 1 shows the results of heart rate estimation for 10 subjects whose blood vessels were not accurately detected and the results of comparing them with the data measured by the contact type PPG sensor. On the other hand, table. 2 shows the results for the top 10 subjects whose blood vessels were correctly detected. From the experimental results, it was confirmed that the blood vessel detection performance is very important factor for the heart rate estimation result.

Table. 1. Heart rate measuring results in inaccurately detected cases of blood vessel

PPG	Thermal	Accuracy
83.50	62.20	74.49%
81.04	57.38	68.71%
77.18	57.45	74.44%
83.43	58.48	75.77%
81.90	62.84	81.42%
80.00	67.85	84.81%
83.00	75.00	93.75%
84.40	68.84	81.57%
87.23	64.90	74.41%
88.00	67.30	77.16%

Table. 2. Heart rate measuring results in accurately detected cases of blood vessel

PPG	Thermal	Accuracy
71.97	71.10	98.80%
72.28	71.28	99.05%
73.23	74.77	96.11%
73.63	77.31	92.58%
73.77	77.98	94.28%
73.93	78.40	93.72%
73.95	74.07	99.59%
73.10	73.58	99.75%
74.67	68.62	91.90%
74.65	66.50	89.06%

Experimental results show that heart rate can be estimated to 95.48% accuracy compared to groundtruth data when blood vessel is detected correctly. On the other hand, when the blood vessels were not detected well, the accuracy was about 78.65%, and it was confirmed that the blood vessel detection performance was greatly influenced.

IV. CONCLUSIONS

In this paper, we proposed a method of detecting a heart rate at a distance using a thermal camera without attaching a sensor. The bit shift operation is used to remove noise and amplify the signal. Then, the frequency band corresponding to the heart rate is detected using the DFT algorithm. As a result of the experiment, the heart rate could be measured with 92.7% accuracy compared to the actual heart rate, except for the case where the blood vessel was not detected. Thus, the proposed method can be used to measure the effective heart rate in cases where the sensor cannot be attached.

The limitation of this study is that the heart rate cannot be measured if the blood vessel cannot be accurately detected. Figs. 6(b) and (d) depict the exact vessel position. However, Figs. 6(a) and (c) do not accurately locate the position of the blood vessel, which causes an error because the accurate heart rate cannot be measured. If the correct vessel is not found, the expected heart rate falls below 74. Typically, a person who is obese or has thick skin cannot accurately detect the blood vessel because the difference between the blood vessel temperature and the temperature of the surrounding skin is insignificant.

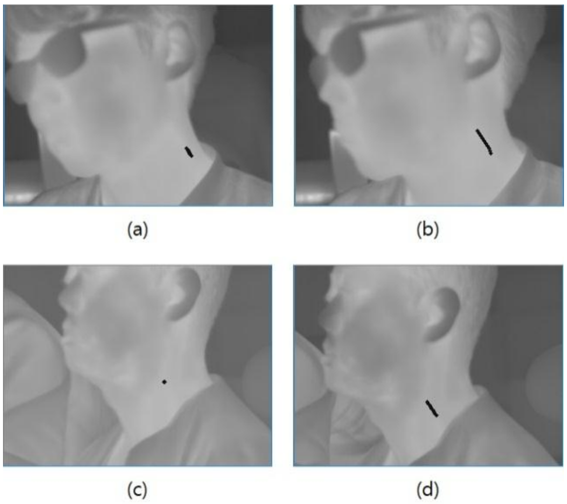


Fig. 6. Examples of detecting blood vessel regions. (a) and (c) are inaccurately detected cases. (b) and (d) are accurately detected cases.

In future studies, it is planned to improve the accuracy of heart rate estimation through accurate detection of blood vessels by applying existing blood vessel and human area detection algorithm [11][12][13].

ACKNOWLEDGEMENTS

This work was supported by the Industrial Strategic Technology Development Program (10073159; Developing a mirroring expression-based interactive robot technique by non-contact sensing and recognizing human intrinsic parameters for emotion healing through heart-body feedback) funded by the Ministry of Trade, Industry & Energy (MI, Korea).

REFERENCES

[1] D. H. Hwang, Effects of 12 weeks exercise to vital capacity, heart rate, blood lactic acid, of middle age women, Thesis, Changwon University, 2011.

[2] O. P. Keskinen, , K. L. Keskinen, A. A. Mero, Effect of pool length on blood lactate, heart rate, and velocity in swimming, International journal of sports medicine, 28(5), 2007, 407–413.

[3] D. S. Wilhelm, F. Daniel, R. V. Oana, S. Ralf, M. M. Natividad, Heart rate spectrum analysis for sleep quality detection, EURASIP Journal on Embedded Systems, 2017(26), 2017.

[4] H. M. Lee, D. J. Kim, Development of a human sensibility evaluation and biofeedback system using PPG, Int. J. Sports Med, 28(5), 2007, 407–413.

[5] S. C. Moon, J. Y. Jeong, Y. J. Cheon, Y, H. Lee, Emotion measurement using Arduino and heart sensor, Journal of KIIT 6, 2015, 344–346.

[6] N. K. hamir, S. Alberto, M. M. Shaun, L. A. Gareth, Heart rate variability in critical care medicine: a systematic review, Intensive Care Medicine Experimental, 5(33), 2017.

[7] G. Hernâni, P. Paula, S. Manuela, A. Diogo, B. João, Electrocardiography versus photoplethysmography in assessment of maternal heart rate variability during labor, SpringerPlus, 5(1079), 2016.

[8] C. Takano, Y. Ohta, Heart rate measurement based on a time-lapse image, Medical Engineering & Physics, 29(8), 2007, 853–857.

[9] M. Z. Poh, D. J. McDuff, R. W. Picard, Non-contact, automated cardiac pulse measurements using video imaging and blind source separation, Optics Express, 18(10), 2010, 10762–10774.

[10] M. Lewandowska, J. Ruminski, T. Kocejko, J. Nowak, Measuring pulse rate with a webcam a non-contact method for evaluating cardiac activity, In Computer Science and Information Systems, 2011 Federated Conference on IEEE, 2011, 405–410.

[11] L. Chen, HC Chen, Z. Li, Y. Wu, A fusion approach based on infrared finger vein transmitting model by using multi-light-intensity imaging, Human-centric Computing and Information Sciences, 7(35), 2017.

[12] D. Bhattacharjee, Adaptive polar transform and fusion for human face image processing and evaluation, Human-centric Computing and Information Sciences, 4(4), 2014.

[13] S. H. Benziane, A. Benyettou, Dorsal Hand Vein Identification Based on Binary Particle Swarm Optimization, Journal of Information Processing Systems, 13(2), 2017, 268-283.