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Design of a Heart Rate Measurement System Using a Web Camera

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Abstract

In this paper, we design a heart rate measurement system using a web camera. In order to measure the heart rate, face image information is acquired and classified. The face image data is collected from web camera. The heart rate is measured using the collected face image data. We design a function to measure heart rate using input of face information using a web camera in non-contact manner. We design a function that reads face information and estimates heart rate by analyzing face color. An experiment was performed to compare the non-contact heart rate with the actual measured heart rate. The heart rate measurement system using a web camera proposed in this paper is a technology that can be used in various fields. It will be used in sports fields that require heart rate measurement at a low cost.

Key words: *Face Analysis, Heart Rate Measurement, Non-Contact, Web Camera, Experiment*

1. INTRODUCTION

Human life is becoming more convenient with the development of IT devices. In particular, the development of computer and smart phone technology is progressing rapidly. Various application fields using computer devices are making human life more convenient. As an application field using a computer, technology development using a camera is actively progressing. In particular, with the recent development of web camera technology, anyone can easily use high-resolution images at low cost.

There are various fields of application using a web camera. It is applied and used in various fields such as remote conference and access control system. Research for non-contact heart rate measurement is not active. Applications for non-contact heart rate monitoring are becoming a necessary technology for sports, telemedicine and other everyday life. In this paper, we design a non-contact heart rate measurement system using a general web camera used in a computer [1, 2].

Non-contact heart rate measurement technology has several advantages. In general, when we use the web camera, the cost of the system is low. And, it is not limited by time and space. It can be said that it is convenient because it can simply measure the heart rate. And, anyone can use it easily. Web cameras have become essential equipment for computer user. In the case of a smartphone, a camera module is installed by default. Various technologies using such equipment are being researched and developed. One of them is heart rate measurement technology using a web camera. In this paper, after photographing a person's face using a web camera, the photographed face image is saved. The stored face images are used for analysis. The

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analyzed information is used to suggest what the heart rate is. Then, the suggested heart rate and the actual heart rate are measured. The actual heart rate is measured using the heart rate measurement function provided by the Samsung Galaxy phone. The presented heart rate and measured heart rate information are recorded in Excel. If there is a difference in the recorded heart rate against real value, the program is modified to correct the difference. If a difference detected in the heart rate measurement result, a correction function was used to obtain a more accurate result by correcting the color analysis function. Through this feedback process, the heart rate is measured in this paper.

This paper is explained in the order of related research in Chapter 2, system design in Chapter 3, Experiments in Chapter 4, and conclusion in Chapter 5.

2. RELATED STUDIES

Due to the recent COVID-19 pandemic, people movement and contact are decreasing. Non-face-to-face related technologies are essential to perform necessary activities under these constraints. Non-face-to-face activities are on the rise at work and school than face-to-face. This can be called another change of human society. The necessary technologies for these changes in human society are non-face-to-face technologies.

The development of IT technology is leading to the 4th industrial revolution. IT technology is becoming an indispensable part of our daily life. The development of IT technology is making human life more convenient. Previously unimaginable technologies are being developed and enriching human life.

Researches are proceeding to apply these IT technologies to various fields. In particular, various studies using web cameras are being conducted. Research using a web camera has led to the development of non-contact heart rate measurement technology.

In this paper, heart rate measurement technology related to such non-face-to-face technology was designed. Existing studies related to heart rate measurement using a web camera are as follows. A study related to non-contact heart rate measurement was conducted at MIT University [1, 3].

This study is conducted by receiving human face information from a web camera and measuring heart rate by tracking facial color information. In addition, the accuracy is improved through continuous error correction by comparing the actual measured result value of the heart rate measurement device with the non-face-to-face heart rate measurement result [1, 2, 4, 5]. Face images were simultaneously acquired through a PPG (Photoplethysmography) sensor and a webcam to be used for signal verification as a previous study. Color components were extracted from the face in the image and classified [6, 7, 8, 9, 14, 15]. Due to COVID-19, research on technology development such as non-face-to-face non-contact body temperature measurement is being actively conducted [10, 11, 12, 13, 16].

3. SYSTEM DESIGN

In this paper, we design a heart rate measurement system using a web camera. To measure the heart rate, the user's face image information is collected using a web camera. After collecting face image information, color analysis is performed using the collected face image. After color analysis, the estimated heart rate is presented. The conventional heart rate measurement method is a contact method, while in this paper the heart rate measurement is performed in a non-contact method.

The user who wants to measure sits in front of the web camera. Face images are collected for the user in front of the web camera. At this time, in order to collecting data against a difference with the actual heart rate, the following systematic management is performed.

Through this systematic management, corrections are made through the analysis of the cause of the

difference heart rate. Through the modified function, more accurate heart rate measurement is possible. The system structure for non-contact heart rate measurement proposed in this paper is Fig. 1.

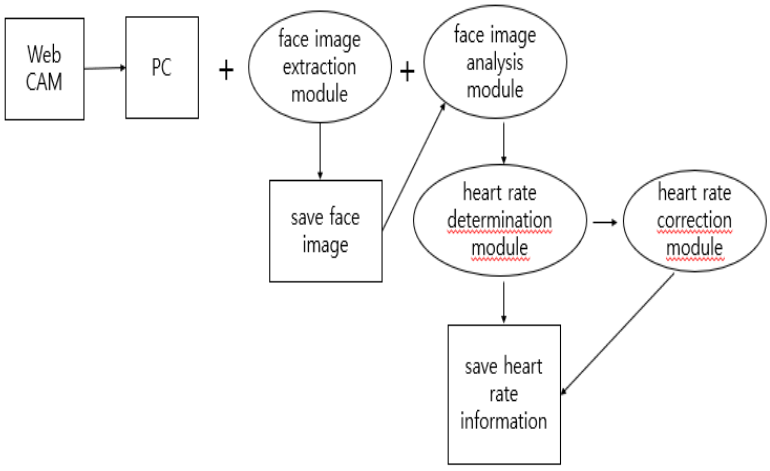

Figure 1. System structure

Fig. 1 shows the system structure for measuring heart rate using a web camera. The user's face image is received as input using a web camera connected to the computer. When a user's face image is input, face image information is stored for each user. When finishing stored the image, this image is used for analysis for heart rate measurement.

The face of the user in front of the camera is stored, and the data to be stored is systematically classified and stored. If you enter a user name, this name will be created and managed as a folder. This name is recorded and managed in an Excel file.

Fig. 1 shows the structure of a user face image classification system for heart rate measurement using a web camera. User face information is stored in the user folder as a photo file at regular time intervals. In case of multiple measurements for the same user, data is managed by organizing subfolders in the form of "year, month, day, hour, minute, second".

The process for estimating the heart rate is as follows.: To calculate the heart rate, center-based K-means is used , among the non-hierarchical cluster analysis techniques. Given a set of n d-dimensional data objects (x_1, x_2, …, x_n), the k-means algorithm calculates n data objects as k sets $S = \{S_1, S_2, \dots, S_k\}$. When μ_i is the central point of the set S_i

$$\arg\min_{S} \sum_{i=1}^{k} \sum_{x \in S_i} \| x - \mu_i \|^2 \qquad (1)$$

The goal of this algorithm is to find a set S that minimizes the sum of squares of the distances between the central point of each set and the objects in the set. After storing the found face image information, the color of this image data is analyzed. The heart rate measuring method in this paper is color analysis on the user's face image. The color analysis method is as follows. First, color analysis is performed on the face image. In order to obtain color information, color information about clusters is arranged in a face image. The color calculation method is the same as the above formula (1). Get the maximum color ratio information. After color analysis, the heart rate is estimated according to the degree of color R (Red).

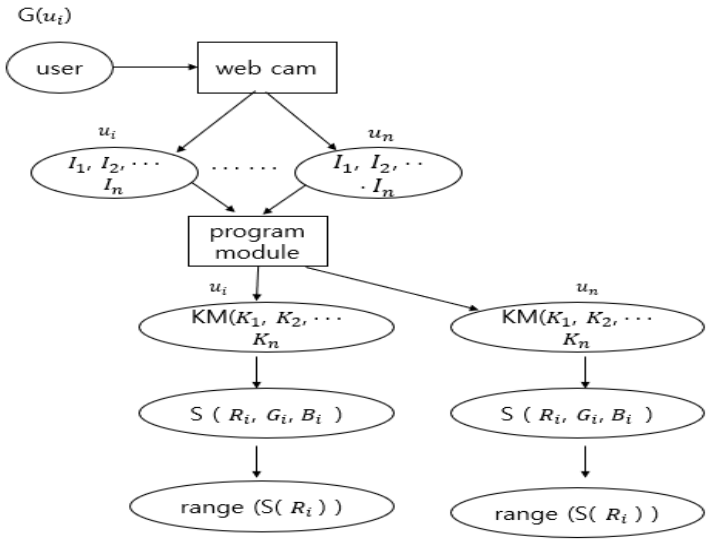

Figure 2. Heart rate measurement process using web camera

In Fig. 2, the web camera reads face image information from the user (u_i, …, u_n). For each user, face information of I_1, I_2, $\cdots$ I_n is stored into local PC. The heart rate measurement module analyzes each user's face image using the KM algorithm (KM(K_1, K_2, $\cdots$ K_n)). After KM algorithm executing, color clusters are classified into R, G, and B (S(R_i, G_i, B_i)). The range of the red color is determined from the classified color cluster. Finally, the heart rate measurement value is estimated using this red color range value.

After the user's face image information is normally stored into PC, color analysis is performed using this user's face data. When color analysis is finished, an estimated heart rate value is determined. At this time, the estimated heart rate value, the user name, the heart rate measurement time (the folder name where the user's face is stored), etc. are stored in the Excel file. The information recorded in Excel records the estimated heart rate and actual heart rate measured in this paper. This record is used to analyze and correct the actual heart rate and the estimated heart rate difference.

In order to measure the heart rate using the web camera, the user's face image information is received from the web camera. The user's face image is received and systematically saved as a file. The program for measuring heart rate was written in Python language.

(1) I_i <- G(U_i)

(2) write(I_1,I_2, ..., I_n)

(3) K_i <- read(I_1,I_2, ..., I_n))

(4) S(R_i, G_i, B_i) <- KM(K_1, K_2, ..., K_n)

(5) range(S(R_i))

Figure 3. Heart rate measurement using web camera

Fig. 3 shows the heart rate measurement algorithm using a web camera. The heart rate measurement module reads the stored user face image data ((1) I_i <- G(U_i)). It saves the reading user face image data in the computer ((2) write(I_1,I_2, ..., I_n)). The stored user face image data is read from the computer ((3) Ki <- read(I_1,I_2, ..., I_n)). The reading user face image data is analyzed ((4) KM(K_1, K_2, ..., K_n)). During the analysis, color analysis is performed on the user's face image data ((4) S(R_i, G_i, B_i) <- KM(K_1, K_2, ..., K_n)). At this time, color analysis of the user image data is completed, and the range of the distributed color is determined

((5) range($S(R_i)$)). Once the color range is determined, the heart rate is estimated.

4. EXPERIMENT

The experimental environment of the non-contact heart rate measurement program using the web camera proposed in this paper is as follows. The programming language used for heart rate measurement in this paper is Python. A library provided for face recognition was used using a Python program. This library uses the face recognition module running on Python. Also, it was programmed using the OpenCV module provided by Python. The following shows an experimental scene in which a face image is read from a web camera.

Figure 4. Experiment Screen for Face Image Recognition

In order to measure the heart rate using the web camera, after checking whether the web camera is operating normally, if there is no abnormality, only the face area is extracted from the image input from the web camera and stored. The stored images are compared with the case of measuring the actual heart rate through systematic classification to determine whether there is a difference. When measuring heart rate, all data should be stored in an Excel file.

Fig. 4 shows the experiment for performing heart rate measurement. Fig. 4 (a) is a heart rate measurement experiment while wearing glasses. Fig. 4 (b) is a heart rate measurement experiment without glasses.

Figure 5. Real heart rate measurement screen

The images are analyzed by the heart rate measurement module using the face images read from the camera like Fig. 4. The experimental scene analyzing the images is shown in the Fig. 6. Fig. 5 shows the screen for measuring the actual heart rate using the heart rate measurement program provided by the Samsung Galaxy smartphone. The actual heart rate is measured. The actual value and estimated value is checked the difference.

After measuring the heart rate measured by the web camera, the difference with the actual heart rate is

measured. The actual heart rate is measured using the heart rate measurement function installed in the Samsung Galaxy Note 10. The experimental result screen of the non-contact heart rate measurement program proposed in this paper is Fig. 6.

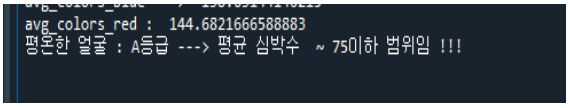

Figure 6. Heart rate test result screen

The experiment was conducted by measuring the heart rate using the web camera proposed in this paper and measuring the actual heart rate measurement result. As a result of performing the experiment, the results in the saved Excel are Fig. 7.

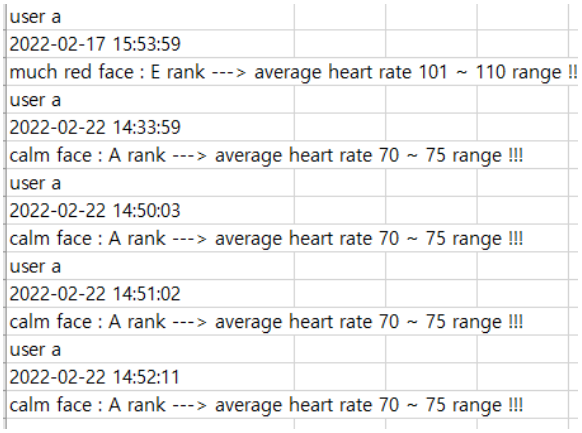

Figure 7. Heart rate test result

The difference between the actual heart rate value and the non-contact heart rate value proposed in this paper is summarized using an actual heart rate measuring device. And, it is possible to reduce difference value through re-analysis of experimental data. The difference value between the actual heart rate and the experimental heart rate will be summarized.

Experiments on the results of heart rate measurement and actual heart rate measurement using the web camera proposed in this paper were performed. Table 1 shows the experimental results.

Table 1. Heart rate measurement results

# of Experiments	# of Normal Experiments	# of Error Experiments	Error Rate(%)
20	16	4	20
50	42	8	16

Table 1 shows the experimental results of the design of the heart rate measurement system using a web camera. As a result of the experiment, difference value of 50 trials to 16% occurs in the number of experiments. That is, about 84% of the accuracy is shown. The heart rate measurement system using the web camera proposed in this paper shows an accuracy of 84%. This level of accuracy is expected to be applicable to fields that require heart rate measurement, such as sports fields that allow a slight error.

5. CONCLUSION

In this paper, a heart rate measurement system using a web camera was designed. After collecting user's face image data using a web camera of a computer system, a non-contact heart rate is measured using these face images. It collects and stores user face image data using a web camera. The collected and stored user face image data is read by the heart rate analysis module.

Color analysis is performed on the user's face image data read by the heart rate estimation module. (R, G, B) color analysis is performed on the user's face image data to analyze the red color distribution.

The heart rate estimation module finally determines the heart rate using the result of color analysis on the user's face image data. The determined heart rate information is systematically stored into PC and managed in an Excel file. And, in order to measure the actual heart rate, it is measured using the Samsung Galaxy Note 10 heart rate measurement function. The actual measured heart rate data is also recorded in Excel file. By doing so, we intend to develop a program capable of more precise heart rate measurement by reducing errors in non-face-to-face heart rate measurement.

An experiment was conducted to measure the heart rate in a non-contact manner using a computer web camera proposed in this paper. As a result of the experiment, it was confirmed that the heart rate measurement function using the web camera works well. For the accuracy of heart rate measurement, if difference occurs with the actual heart rate value after heart rate measurement from face image, the difference is corrected through re-analysis of the face image. With these modifications, the heart rate measurement algorithm function was continuously improved. The difference rate which is the between the actual heart rate and the measured heart rate is about 16% to 20%. The heart rate measurement system using a web camera proposed in this paper is a system that can obtain heart rate information in a non-contact manner at a low cost. It will be applicable to fields that want to obtain heart rate information without contact, such as sports fields.

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