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Year 2023	**Summary of Thesis**

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(Title)
Study on Accuracy of Non-contact Heartbeat Detection Using Depth Camera

Electrocardiograms (ECG) are often used to monitor heartbeats in cardiovascular medicine. The ECG monitors the heartbeats as electrical signal. Therefore, it is difficult to directly monitor cardiac dilation and contraction with ECG. Echocardiography, chest CT scan and MRI are used to monitor cardiac dilation and contraction. However, each method has its own physical burden and user limitations, and monitoring cardiac dilation and contraction is not easy. Therefore, there was a need to develop a new heartbeat measurement system that can monitor cardiac dilation and contraction non-invasively and easily.

I have proposed a non-invasive heartbeat measurement that allows visualization of cardiac dilation and contraction obtained by auscultation and palpation. In previous study, heartbeat could be measured from minute changes in the chest surface by using an INTEL depth camera and an IR pattern projector. However, further study was required to visualize the heartbeat in three dimensions. The accuracy of heartbeat detection also needed to be clarified.

In this study, I examined the detection accuracy of minute change caused by heartbeats measured by a non-contact heartbeat measurement system using the depth camera and the IR pattern projector, which was proposed for non-invasive measurement of cardiac dilation and contraction. Then, we attempted to visualize the heartbeats of the entire chest area in three dimensions.

IR dot matrix pattern light was projected onto the subject’s chest using the IR pattern projector and IR images were acquired using IR cameras of the Intel REALSENSE DEPTH CAMERA D435f. The amount of dot shifts due to heartbeats was calculated from the IR images, and heartbeat waveforms were acquired. Depth images acquired with the binocular stereo of the D435f were converted into point cloud information,

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and a 3D point cloud of chest was reconstructed.

The animation was generated by plotting the movement of dots based on the heartbeat waveforms superimposed on a 3D point clouds of chest.

For comparison with the proposed method, a method to detect heartbeats from depth images acquired by the binocular stereo is proposed. The method was expected to have the potential to realize heartbeat measurement in a compact device configuration.

In the accuracy validation experiment, a measurement system using the Intel REALSENSE DEPTH CAMERA D435f and an IR pattern projector (System 1) and a measurement system using only the D435f (System 2) were used. That is, the accuracy of microchange detection was compared between the pattern projector and binocular stereo. The two measurement systems simultaneously acquired IR and depth movies at seven different plate reciprocation amplitudes and estimated the vibration frequencies. As the results, the vibration detection of System 1 was considered to be the most sensitive to minute changes and effective in detecting heartbeats. On the other hand, in both measurement systems, the binocular stereo with a depth resolution of 1mm could not detect minute depth changes below the resolution.

Next, an experiment was conducted with subjects. System 1, which showed better detection accuracy in the accuracy verification experiment, was applied. The subjects were seven healthy males in their 20s. The pulse wave of the finger was measured simultaneously with the heartbeat measurement with the pattern light projection and the binocular stereo. The results of comparison showed that the heartbeat measurement by the pattern light projection was more stable and accurate than the binocular stereo, and measure more clearly the minute changes on the chest surface due to heartbeats.

The heartbeat animation was generated by using the subject’s chest shape and heartbeat waveform, and it confirmed the heartbeat was visualized over the entire chest area. This study suggests that a non-contact heartbeat measurement system that visualizes the heartbeats of the entire chest area has been realized by using the D435f and an IR pattern projector.

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