A Study on Biological Information Acquisition using Bluetooth Low Energy

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Due to the progress of the declining birth rate and aging population, it is necessary to take care of the expanding elderly population by a shrinking number of working class generations. This situation increases the cost of watching over this aging population and it makes it necessary that the elderly may have to operate specialized devices and equipment by themselves.

Health monitoring using wearable devices, which is currently the main monitoring method, is a burden on the user due to the feeling of wearing and monitoring. With the improvement of the wireless environment in the house, the improvement of the performance of the computer, and the development of the machine learning methods, the study on the acquisition of the biological information such as the respiration rate and heart rate of the resident in the house by using the change of the transmission state of the radio wave has been conducted. Using wireless monitoring techniques, biometric information can be acquired with little burden on the user, which is useful. However, there are barriers in introducing the measurement environment, namely construction costs and the problem of securing power to the monitoring devices.

Therefore, the study proposes a method of acquiring biometric information such as respiration and heart rate of a resident in the home by using radio waves of Bluetooth Low Energy (BLE). BLE is a wireless technology that can be used to easily construct a health monitoring and vitals measurement environment while also consuming low power. First, the study investigates existing biometric information acquisition technologies such as wearable devices, passive RFID, dedicated wireless, and Wi-Fi, compares them and identifies issues with these existing technologies.

This study shows that it is possible to perform high-frequency vitals monitoring with low power consumption by using the advertisement mechanism of continuously transmitting radio waves, which is a feature of BLE. The study focuses on the monitoring of respiration and heart rate.

The proposed method is realized by using the newly developed wireless communication standard called BLE, which has lower power consumption. Because BLE is a widely used radio technology, it can reduce the price of the sensing module compared to dedicated radio solutions such as Doppler radar. Furthermore, for passive RFID tags, the vital detection range is a few tens of centimeters, whereas BLE can cover the entire living room.

When operating a vital measurement system in a home, it is assumed that devices are placed in various places throughout the home. In many cases there is no need to worry about energy requirements of such a system since these needs can

be covered by energy harvesting techniques. Multiple radio devices are usually installed at different locations, making the presence of radio waves ubiquitous. As a result, the radio signals that can be used for vitals measurement become abundant and measurements can be performed with higher accuracy.

The Implementation makes use of the software defined radio (SDR) technology. The hardware is configured using universal software radio peripheral (USRP) manufactured by Ettus Research, and the software is GNU Radio which is an open source software for SDR. For transmission, a commercially available Bluetooth dongle is used, and the transmission setting of BLE advertising packet is set by BlueZ.

The received signal was analyzed in MATLAB in the time domain and in the frequency domain. Then, the signal is filtered by the Hampel filter and a wavelet transformation is performed in order to remove noise. The respiratory rate and the heart rate are calculated by performing a Fast Fourier Transformation (FFT) on this signal.

For comparison purposes, experiments were conducted in four different environments. In the first environment there is no BLE advertisement. In the second environment there is BLE advertisement and no obstacle on the transmission path. In the third environment, an aluminum balloon is attached to the end of the Fresnel zone where the change in wave intensity appears most strongly. Finally in the forth environment a person stands upright in the end of the Fresnel zone. For the third environment, the tempo for inflating and deflating the aluminum balloon is 15 bpm(0.25 Hz) simulating breathing and 70 bpm(1.16 Hz) simulating heartbeat. Inflating and deflating was conducted according to the rhythm of a metronome. In the case of humans, the experiment was performed with breathing stopped and with breathing at 15 bpm.

Experimental results showed the detection of a pattern which matches the artificial respiration when using an aluminum balloon. This pattern was detected by calculating the frequency spectrum of the incoming BLE signal by obtaining the envelope using wavelet transformation. For the rest of the cases, challenges remained and the results were inconclusive.

If this system can be realized, residents in the home can manage their health without any special assistance. By accumulating vitals measurements as big data on the cloud and performing analysis using AI, it is possible to detect diseases early and decrease medical cost and achieve a longer, healthier life. For this purpose, heart and respiration rate and their fluctuation is indispensable information. The ability to measure biological signals using BLE, which uses a modulation method different from Wi-Fi, can contribute to expanding the application range of wireless communication. If vitals measuring is implemented at the software level as an extended function of BLE, it will be possible to measure vitals using BLE devices owned by residents, thus becoming a technology with strong social influence. This

study establishes a respiration rate and heart rate estimation method that is the basis of biometric information utilization by BLE, and contributes to the realization of a society where people can live with peace of mind.