MEASUREMENT OF RESPIRATION BY A HYPER DIAPER WITH CONDUCTIVE RUBBER

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Introduction

The rapid aging of society requires a new system to support independent living of elderly people. In this context, we have proposed "the Hyper Hospital network system", in which an elderly person's family, hospital, and local supporters watch over her/his health condition and emergency situation through a computer network[1-3]. To access her/his health condition, a vital data of an elderly person is collected and analyzed in a functional unit of a wearable computer. We have developed a Hyper Diaper as one of wearable computers. In this paper, we propose a functional unit of the Hyper Diaper for monitoring respiration, where a conductive rubber was attached around abdomen as a sensor.

Materials and Methods

A respiration measurement unit using a conductive rubber as sensing element was designed so that it is used as the rubber belt of the Hyper Diaper as shown in Fig.1. The weight of the respiration measurement instrument was 220 g including battery (120 g) and the size of the instrument was 80 mm×30 mm×55 mm. We used a natural conductive rubber as the sensor. The density, the tensile yield strength, the volume resistivity value of the rubber are 1.16 g/cm³, 15.4 MPa and 0.9 × 10² Ω cm, respectively. The resistance of the rubber increases instantaneously at expansion and contraction due to breathing. The change of the resistance was converted to the voltage using a bridge circuit. The difference of voltage was amplified by instrumentation amplifier which was built in PSoC (Programmable System on Chip: Cypress MicroSystems). PSoC is a kind of one-chip micro computers and can make both analog circuit and digital one internally. We made Low Pass Filter (LPF) and A/D converter (ADC) in the same PSoC in similar way. Amplification rate of instrumentation amplifier, the cutoff frequency of LPF and the sampling frequency of ADC were designed to be 13 dB, 2.5 Hz and about 100 Hz, respectively. To connect an analysis module with Ethernet, we used Xport (LANTRONIX), which is a converter from serial line to Ethernet. The baud rate was 9600 bps and data length was 8 bit. Peaks of waveform of the voltage represented the beginning of inspiration and expiration. By counting the number of peaks and measuring the period of peaks, the unit could analyze the number of respiration and the change of breathing cycle.

For checking this system, we measured the number of respiration at three conditions, at rest, after exercise and during sleep. All the human experiments were conducted under an approval of the ethical review board of the engineering school of the Tohoku University.

Results and Discussion

Figure2 shows a typical measurement result of the raw data at rest. Inspiration was represented as clear peaks and expiration was represented as unstable behavior. After digital analysis, we counted the number of respiration. The mean error rate of the number of respiration was within 9 % between the measurement and the reference at rest.

We measured the number of respiration, the respiration cycle and the amplitude by the present system in three different

conditions as shown in Table1. The respiration cycle after exercise was shorter than the cycle at rest and during sleep. On the hand, the amplitude during sleep was the smallest among the conditions. Therefore we could classify in each condition by comparing the respiration cycle and the amplitude of waveform peaks.

Conclusions

We have presented the respiration measurement unit for a wearable computer. This system is unconstrained and non-invasive for users and we can use everywhere at anytime. Therefore, we can state that this system is thought of as being useful for practical use at home.

Attachment location of a conductive rubber

A measurement instrument

Fig. 1: A respiration measurement unit

Fig. 2: Typical example of a respiratory waveform at rest

Table 1: The number of respiration, the average breathing cycle and the normalized amplitude at three conditions

	The number of respiration (5 minutes)	The respiration cycle[s]	The normalized amplitude
At rest	68	2.21	1
After exercise	93	1.61	1.11
During sleep	61	2.26	0.30

References

- [1] Mizuno F: Doctoral thesis of Tohoku University, 2005
- [2] Yoshida T et al.: *Proc. 19th Bioeng. Conf., Sendai, Japan*, 192-193, 2006
- [3] Yoshida T et al.: *Telemedicine and e-Health*, in print