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Home Health Monitoring System in the Sleep

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Abstract: This paper describes a development of health monitoring system that uses a non-invasive type microphone based pressure sensor. The system can estimate the sleep stages from the heartbeats and body motion measured by the sensor. The algorithm for sleep stages estimations as implemented to the single chip microcomputer. The validity of the proposed system is confirmed by comparing the conventional sleep stage estimation results.

Keywords: home health monitoring system, the sleep stages, heartbeats, the single chip microcomputer

1. Introduction

TMedical treatment at home is important key words for keeping the quality life high. Among the medical treatments, the health monitoring is substantially important. The perquisite requirements that the heath monitoring at home should satisfy are (C1) easy in operation, (C2) noninvasive, (C3) stress free in physical and mental, (C4) reasonable price. This paper describes a novel sleep stage estimation equipment that satisfies the above four requirements. The hardware of the equipment is based on the pneumatic microphone senor named air cushion sensor[1)] and the software is based on the sleep estimation method[2)]. The software was implemented in a microprocessor.

2. Asumptions Design Specification And Problem Descriptions

The equipment to be developed here must satisfy the same assumptions that were cited in the sleep stage estimation method in the literatre[2)]. The most restrictive assumption comes from the fact the estimation algorithm was developed based on the data of normal sleepers. I.e., we must assume; (A)The probability of frequencies of each sleep stage is that of normal sleeper. I.e., awake 10.2Non-REM3 8.9To satisfy the above four perquisite requirements of the equipment, we specify the following design speciation; To satisfy (C1), operations are all sequential bottom pushing. Basic monitor modes (Time, Sleep monitoring, Health monitoring) can be selected by single pushing. To bottom satisfy (C2) and (C3), the pneumatic noninvasive method is selected. To satisfy (C4), a micro-processor based system is selected. Under the above assumption and the design specifications, we develop the equipment and evaluate the equipment.

3. Health Monitoring System

Fig.1 shows the proposed health monitoring system. The hardware is composed of (H1) air cushion, (H2) super sensitive pressure sensor (primo S11), (H3) filters, (H4) microprocessor and the peripheral (SH2 microprocessor, liquid crystal display, push buttons, real time clock, LED indicator). The software are basically (S1) FFT to calculate the heartbeat and respiration and (S2) the real time sleep estimation algorithm and (S3) the sleep estimation by batch processing which provides the sleep estimation after wake of the next morning.

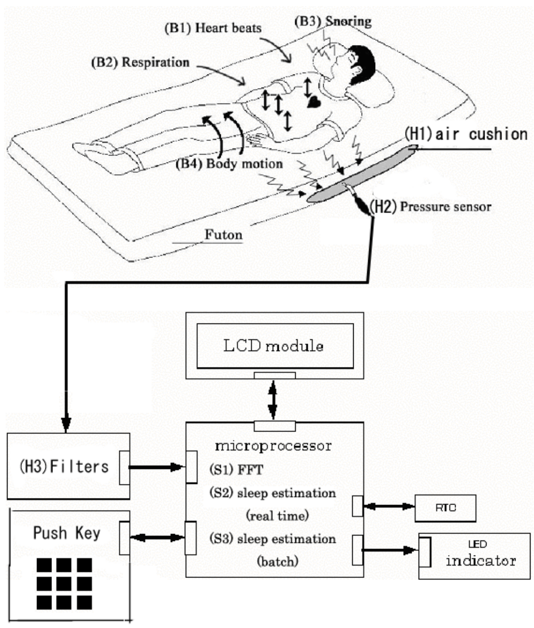

Figure 1: Health monitoring equipment

4. Measurement By The Proposed Equipment And The Personal

In order to check the validity of the proposed equipment, we measured the heartbeat and body motion and estimate the sleep stages both by the proposed equipment and the personal computer system which has been used for laboratory. Photo.1 shows the microprocessor part and Photo.2 shows the measurement situation in which a thin cushion is laid under the bed cushion. The pressure of air in the air cushion changes in synchronizing with the vital motion such as the heart beating, respiration, snoring and body movement and the super sensitive pressure sensor detects the change by the vital motions above. The filters discriminates the above four different vital signals.

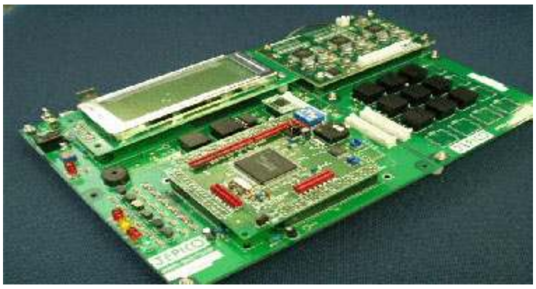

Photo.1 Measurement system

Photo.2 Measurement

Fig.2 and Fig.3 show the heart beats per minute for one night by the new equipment and the conventional personal computer. Both are very similar and the equipment has less errors. To check more precisely, Table 1 shows the heart beat frequency for the same sampling interval. The error is very small and no problem exists in the real applications.

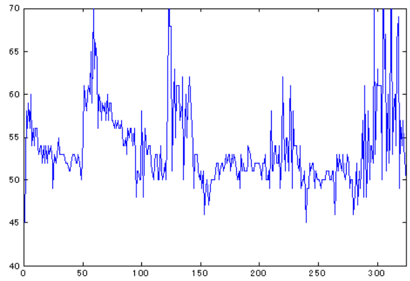

Figure 2: data of conventional monitor measurement system

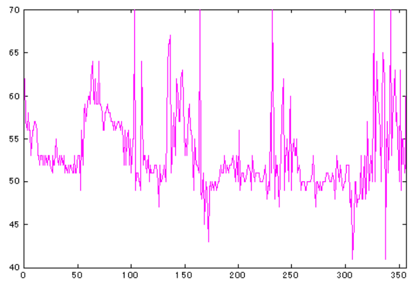

Figure 3: data of the home health system

5. Comparison Of The Results By The Batch Prosessing

5.1 Estimation of continuous sleep stage

The continuous sleep stage estimated by the (S3) batch sleep estimator and that by the conventional personal computer in the middle frequency range in the literature[2] are compared. Fig.4 shows the estimation results by the conventional method in the literature [2]. Fig.5 shows the estimation by the new equipment. Both estimations show the very similar characteristics.

Table 1: Comarison by the conventional personal computer and the proposed equipment

Conventional (Hz)	proposed (Hz)	The error (Hz)
0.821	0.823	0.002
0.905	0.919	0.014
1.000	1.014	0.014
1.089	1.091	0.002
1.204	1.225	0.021
1.315	1.308	0.007
1.406	1.416	0.010
1.474	1.474	0.000

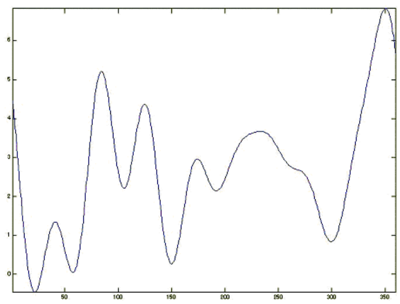

Figure 4: Continuous sleep stage by paper[2)]

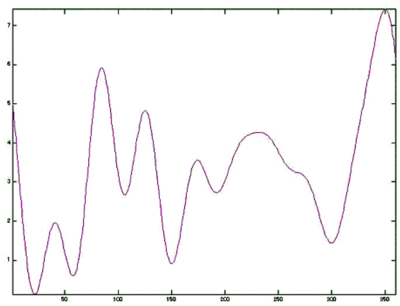

Figure 5: Continuous sleep stage by microcomputer

5.2 Estimation of six stages sleeps

From the continuous sleep stages in 5.1, we obtain the slee p stages given by six categories which are common in sleep medical science. The categorization is carried out by applying the Fuzzy logic. In the new equipment to simplify the algorithm we employ the crisp categorization by the data in assumption (A).

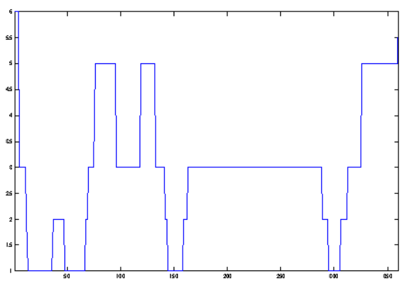

Figure 6: Estimation of the sleep stage by the conventional system

The new equipment shows the characteristics that more awake stage occurs, which is closer to the results by R-K international method.

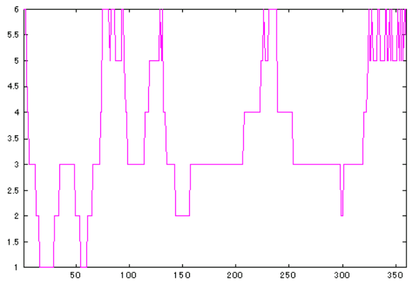

Figure 7: Estimation of the sleep stage by the proposed system

6. RealTime Sleep Estimation

Real time sleep estimation is a new scheme. The sleep estimator described in the literature[2)] is based on the batch processing. The real time sleep estimator is composed of four steps. (P1) Hear beat normalization by the data of last night data. (P2) Real time filtering[4)5)] of the low frequency change. (P3) Real time extraction of the sleep depth change in the middle frequency range. (P4) The conversion of the heart rate change in the middle frequency range to the sleep stage by the conversion difference equation. (P5) Synthesis of the continuous sleep stage by the low, middle and high frequency changes of the sleep stage. (P6) Categorization of the continuous sleep stage into six categories of sleep by using the data of last night. Fig.8 shows the results. First row shows the change in the heart rate, second row shows the middle frequency components of the heart beat, third row shows the continuous sleep stage estimated by process in (P1) to (P5). The last row shows the categorized sleep stages. Fig.9 shows the results by the conventional batch processing using the personal computer. Again the first row shows the change in the heart rate, second row shows the continuous sleep stage and the final row shows the categorized sleep stage.

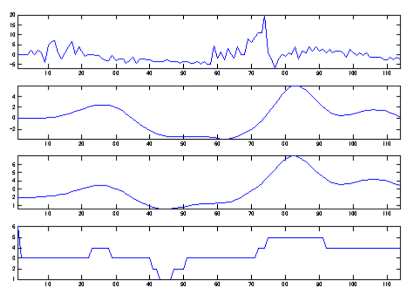

Figure 8: result of real-time sleep estimation

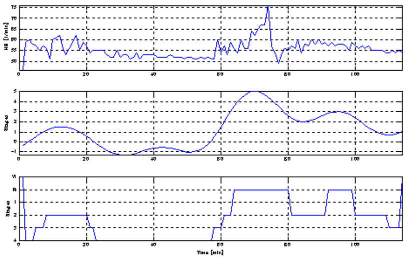

Figure 9: result of sleep estimation by batch processing

7. Conclusions

7.1 perquisite requirements

The system proposed satisfies the requirements described in INTRODUCTION. The sensing air cushion is under the bed cushion and existence of the sensor is not noticed by which the requirement (C2) and (C3) is satisfied. The equipment was realized by SH2 microprocessor reasonably available and thus the equipment itself can be also reasonably, realized thus the requirement (C4) is satisfied. In the normal operation only three different bottom pushing is enough to monitor the health condition and the sleep stage estimation. Thus the requirement (C1) is also satisfied.

7.2 Accuracy as the estimator

Here we newly proposed online sleep estimation equipment. The accuracy in comparison with the comparison with the conventional batch processing estimator is almost same. Further in comparison with the R-H international method, the new equipment provides the closer results when applied to normal sleeper. In the new equipment the new online sleep estimation strategy is employed. This yields the equipment is used a sleep senor to control the room environment and bed attitude for bedridden patients

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