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# A daily living activity remote monitoring system for solitary elderly people

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***Abstract*— A daily living activity remote monitoring system has been developed for supporting solitary elderly people. The monitoring system consists of a tri-axis accelerometer, six low-power active filters, a low-power 8-bit microcontroller (MC), a 1GB SD memory card (SDMC) and a 2.4 GHz low transmitting power mobile phone (PHS). The tri-axis accelerometer attached to the subject's chest can simultaneously measure dynamic and static acceleration forces produced by heart sound, respiration, posture and behavior. The heart rate, respiration rate, activity, posture and behavior are detected from the dynamic and static acceleration forces. These data are stored in the SD. The MC sends the data to the server computer every hour. The server computer stores the data and makes a graphic chart from the data. When the caregiver calls from his/her mobile phone to the server computer, the server computer sends the graphical chart via the PHS. The caregiver's mobile phone displays the chart to the monitor graphically.**

## I. Introduction

In Japan, the population of elderly people is increasing and is expected to reach 36 million, or 29%, by 2020 [1]. Ten percent of the elderly live alone. Therefore, it is important to remotely monitor health conditions and living patterns. The parameters of activity/rest time periods, general activity level and circadian rhythms are obtained by recording heart rate, respiration rate, posture, behavior and activity data.

Many systems have been developed for recording posture, behavior and activity [2]-[9]. However, these systems use several various sensors. So, we developed a remote monitoring system employing only one; a tri-axis accelerometer, which can record the heart sound, respiration, posture, behavior and activity.

The system enables the caregiver to monitor the health conditions and living patterns from a remote place at any time.

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## II. System description

Fig 1 shows the daily living activity remote monitoring system. The system consists of an activity recorder, a conventional server computer at home and a caregiver's mobile phone. The activity recorder, with a low power mobile phone installed, is attached to the subject's chest with an elastic band. The heart sound and body movements are continuously recorded for 24 hours. The heart rate, respiration rate, posture and activity are detected from the recorded heart sounds and body movements. These data are stored into a SD flash memory card. The stored data are sent to the server computer via telephone every hour. The server computer receives the data, which is stored as a graphic file. When the caregiver calls from the mobile phone to the server computer, it sends the graphical file via the telephone. The caregiver's mobile phone graphically displays the data to the monitor.


Fig. 1. The daily living activity remote monitoring system

Fig 2 is the daily living activity recorder block diagram. The recorder employs a 3-axis accelerometer (Kionix, KXM52- 1050), six low-power active filters, four low-power amplifiers, a low-power 8-bit microcontroller MC (Microchip Technology, PIC18F452), a 1GB SD memory card SDMC (SanDisk, SDSDQ-1024) and a 2.4 GHz low transmitting

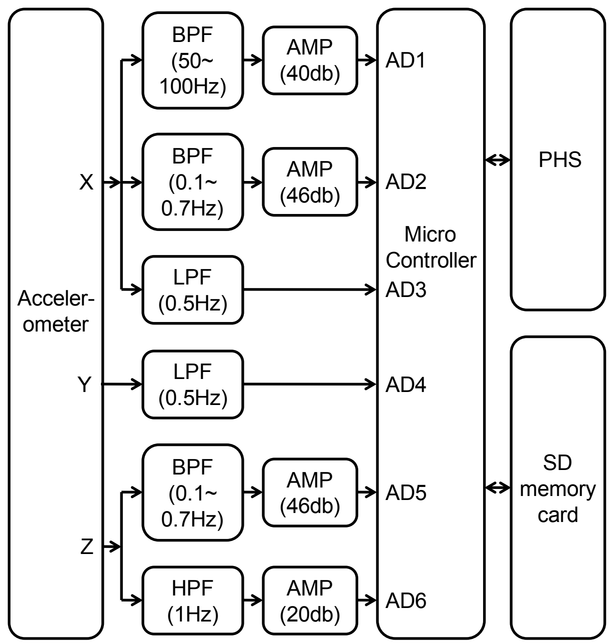



Fig. 2. The block diagram of the daily living activity recorder

power mobile phone PHS (WILLCOM, W-SIM RX420IN).

The 3-axis accelerometer measures body movements produced by heart sounds, respiration, posture, and activity. The accelerometer is a complete acceleration measurement system on a single monolithic integrated circuit and has sensitive axes in the same plane as its silicon chip. Three sensitive axes are orthogonal to each other. The accelerometer can measure both dynamic and static acceleration forces simultaneously. Both X and Y axes (Fig1) of the accelerometer are set in parallel with the Earth's surface.

The 50 to 100 Hz band-pass filter detects the major heart sound components of the X axis dynamic acceleration force. The detected heart sound is amplified by a 40 dB gain non-inverting amplifier.

The 0.1 Hz to 0.7 Hz band-pass filter detects the respiratory components of the X and Z axis dynamic acceleration forces. Each of the filter outputs is amplified by a 46 dB gain non-inverting amplifier.

The 0.5 Hz low-pass filters detect static acceleration forces, which indicate the two axis tilt angles to the Earth's surface.

The 1 Hz High-pass filter detects the activity component of Z-axis dynamic acceleration force produced by body movements. A 20 dB gain non-inverting amplifier amplifies the filter output.

The amplifier outputs and filter outputs are fed into the MC, which is an 8-bit CMOS RISC-like CPU with eight analog to digital converters. The A/D1 converter samples the amplified heart sound at 200 Hz. The other A/D converters sample the amplified respiratory components and filter outputs at 50Hz. Therefore, the MC detects heart rate, respiratory rate, posture and activity.

Fig 3 shows the daily living activity recorder flow chart.

Heart rate is obtained by calculating the period between two successive the first heart sound waves. The first heart sound is detected by both rectified heart sound and smoothed heart sound as shown in Fig. 4. The rectified heart sound has a steeper slope at its rising and falling edges than the other signal components in the neighborhood of the baseline. Therefore, the first and second heart sound peaks are detected by sequentially comparing the amplitude and duration from the pre-peak nadir to the peak. On the other hand, the heart sound part is detected by the smoothed heart wave including the first and second heart sounds. The first heart sound wave is obtained by the first peak detected at the heart sound part.

The respiratory rate is detected by the period between two successive the respiratory wave peak amplitudes.

The posture and behavior such as lying, moving and resting are detected from the X and Y axis tilt angles and Z dynamic acceleration force, respectively. When the X and Y axis tilt angles are greater than 80 degrees, the posture is determined as lying.

Whether the subject is resting or moving can be detected from the rectified and integrated Z dynamic acceleration force for 5 seconds. When the rectified and integrated Z dynamic

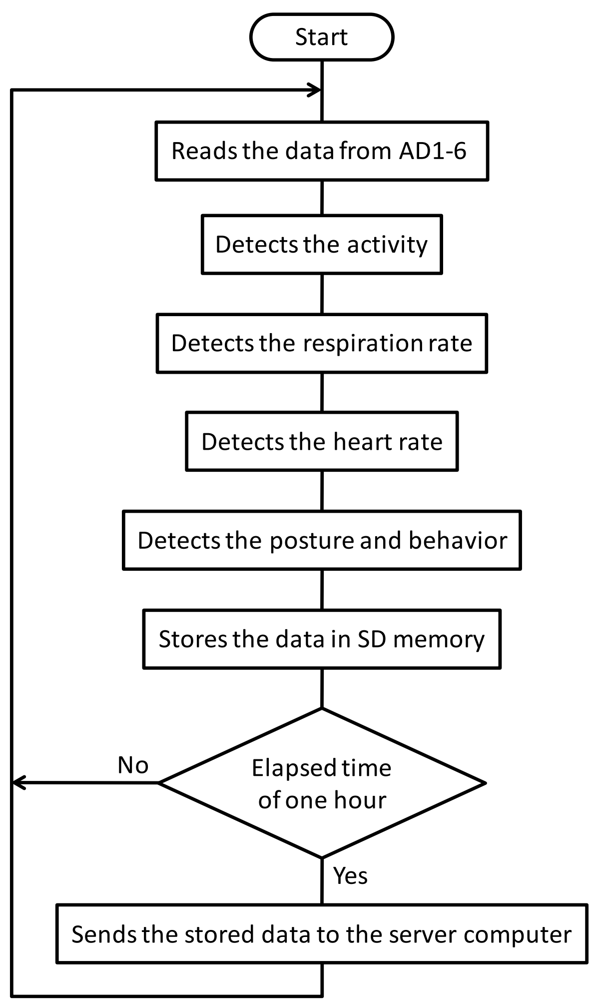



Fig. 3. The daily living activity recorder flow chart.

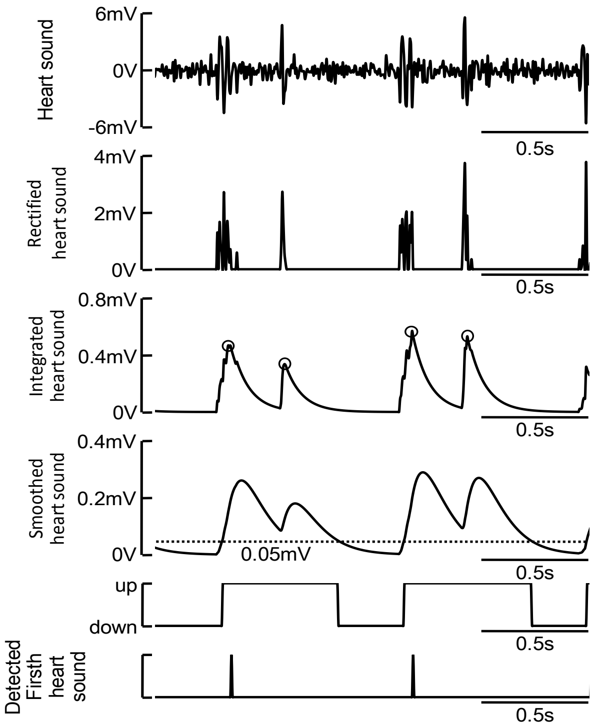



Fig. 4. The heart rates detected from heart sound.

acceleration force is greater than 0.4 g, the system detects that the subject is moving. When the rectified and integrated Z dynamic acceleration force is less than 0.4 g, the subject is resting.

The activity level is obtained from the rectified and integrated Z dynamic acceleration force for 1 minute.

Mean heart rate and respiration rates are calculated for successive 1 minute periods over 24 hours. The posture and behavior are detected every 5 seconds.

These obtained data are stored in the SDMC.

The server computer receives the data from the daily living activity recorder via the PHS. The received data are stored and the computer monitor graphically displays the data every one hour. The graphical data are also stored.

The caregivers can download the graphical data to their mobile phone and display the data on a liquid crystal display

## III. Results and Conclusion

Measurements were performed on five normal male subjects age 22-34 years. To evaluate the developed system, three disposable ECG electrodes and a piezoelectric sensor (Pennwalt, Kynar Piezo Film) were attached on chest for recording ECG and respiration waveforms.

The sensor program is changed for these measurements. The program stores the original heart sound and respiratory waveforms in the SDMC.

Figure 5 (a) shows the original heart sound and ECG waveforms simultaneously recorded by this system and an ECG monitoring system.

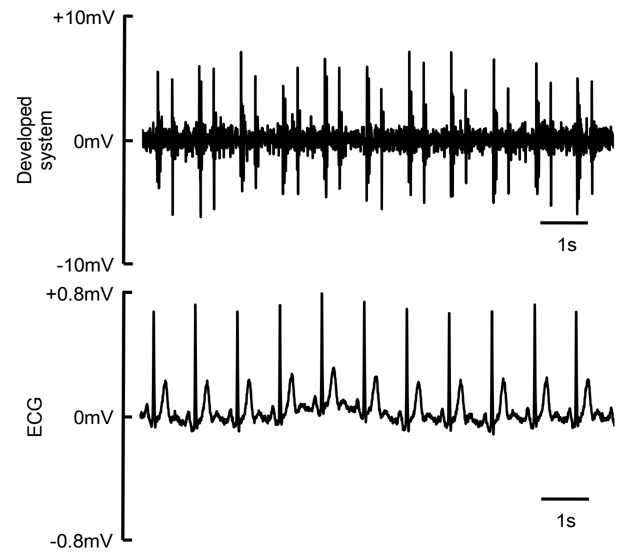
The original heart sound has two separate parts, known as the first and second heart sounds of every heart beat.

These waveforms have the same period and are synchronized.

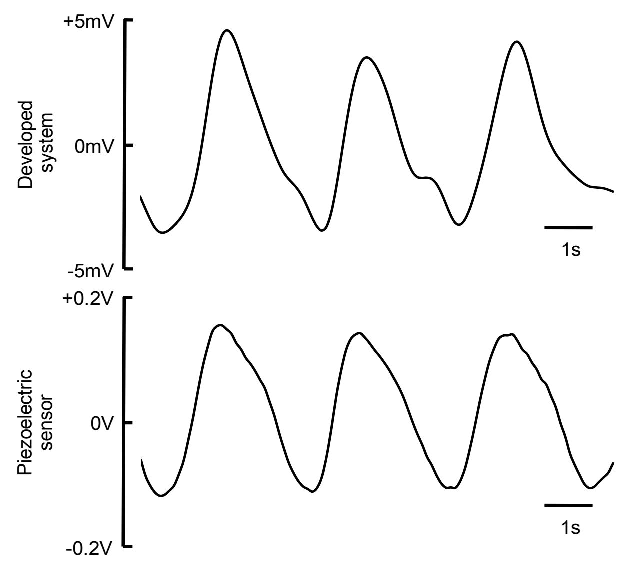
Fig 5 (b) shows the original respiratory waveforms simultaneously recorded by our system and the piezoelectric sensor. The respiratory waveforms recorded by our system delayed slightly from the piezoelectric sensor and also distorted. However, these waveforms have the same period and are synchronized.

These results indicate that our system records appropriate heart sound and respiration waveforms.

The daily living activity was recorded from a normal age 34 male subject, who wore the system on the center of the chest




(a) Heart sound waveforms and ECG waveforms simultaneously recorded by this system and an ECG recording system




(b) Respiration waveforms simultaneously recorded by our system and the piezoelectric sensor

Fig. 5. Heart waveforms sound and respiration waveforms recorded by the developed system.

with an elastic band.

Figure 6 shows the activity, respiration rate, heart rate, posture and behavior, as displayed on the caregiver's mobile phone liquid crystal display for 24 hours.

The activity data indicated that the body movement frequency during sleep was relatively less than during the daytime. The mean frequency of respiration decreased from

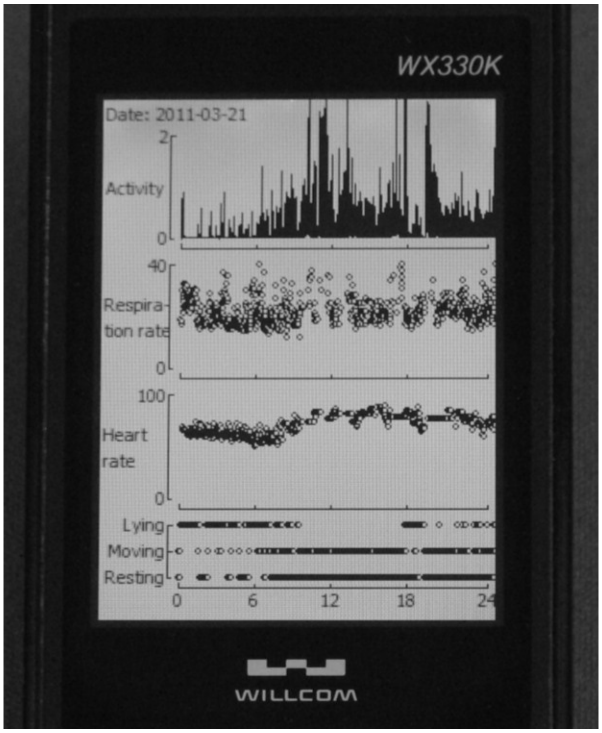



Fig. 6. The activity, heart rate, respiration rate, and posture behavior for 24 hours, that was displayed by a mobile telephone.

22/minute while awake to 20 during sleep.

The mean heart rate was 77 bpm during the daytime; on the other hand, the heart rate decreased to 61 bpm during sleep from 0:00 to 7:00.

These results indicate that respiration rate, heart rate and activity are closely influenced by each other and that the subject's general health condition and living patterns can be obtained from these data.

The developed daily living activity remote monitoring system has been designed for heart rate, respiration rate, posture, behavior and activity monitoring by only one tri-axis accelerometer. The system does have one limitation; it cannot detect respiration and heart rates when the patient is moving However, the patient's general health condition and living patterns can be inferred by the system.

The system is not only applicable to at-home solitary elderly people, but could also be useful for monitoring hospital patients, especially in outlying hospitals.

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