Attempts of Fully Automated Home Health Monitoring Systems

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Abstract: Monitoring of daily activity and health condition at home using fully automated instruments is proposed. As a preliminary study, monitoring temperatures on a bed, and automatic recording of ECG in a Japanese-style bath tub were attempted. Automatic personal identification in ECG measurement was attempted using the wavelet transform and neural network. Further possible items of home health monitoring are discussed.

INTRODUCTION

In the forthcoming aging society, hospitals and other medical facilities will hardly provide all kinds of medical and health care services, and therefore home health care technologies will have to be considered. However, most of existing instruments for medical and health care services are designed to be used in medical facilities or at least under supervision of medical personnel so that such instruments are unsuited to apply for home health care. Even the instrument is simple enough, such as an electronic manometer, frequent measurements performed by the subject or family can not be expected as long as the subject is apparently healthy. A possible solution to obtain health data at home regularly in such subject is to make the instrument fully automatic so that the subject does not need to aware the measurement. Although fully automated health monitoring is uneasy, and available information is limited, there are still some possibilities of realizing by present technologies. As the preliminary study, we had attempted two methods, temperature distribution measurement in the bed and ECG recording in the bath tub [1,2,3]. This paper shows some latest results relating to an attempt of personal identification which is required in automated measurement when two or more peoples are living in a house.

METHOD

Bed temperature measurement: 16 small thermistors were arranged linearly beneath the bed sheet perpendicularly to the body axis at the chest or thigh level. Temperatures were automatically measured in 5 - 10 min interval and stored in a data logger for several days. Stored data was read out to a computer, and either the time course of temperature profiles along the sensor array or that of maximum temperatures were displayed on a screen. Measurements were performed in healthy volunteers and aged subjects. The detail of the method was described in the previous reports [4,5].

Bath tub ECG measurement: Four metal plate electrodes were attached on the inside wall of a Japanese-style bath tub so that two were locating near the shoulder and other two were near the feet. ECG recorder of increased gain was connected to the electrodes similar as the conventional limb lead. ECG was stored in a data recorder, and was analyzed by a computer.

Personal identification for bath tub ECG: In order to realize personal identification, the discrete wavelet transform of ECG wave form of one cardiac cycle was applied using Daubechies-4 functions. A neural network with back propagation learning algorithm was introduced in which 20 points from level -6 of discrete wavelet transforms were used as inputs, and 23 elements in the hidden layer were used. Personal identification was attempted in an actual family members. ECGs were recorded for 3 days. 100 cardiac cycles were sampled and used for learning of each member. Data of the 1st and 2nd days were used for learning, and that of the 3rd day was used for evaluation.

RESULTS

Bed temperature measurement: Smooth temperature profiles along the sensor array could be obtained by curve fitting to spline functions. The obtained profiles through a night clearly showed the elapsed time in the bed. Body movements were recognized by the changes of temperature profiles, and could be automatically identified by the first and second derivatives of the integrated temperatures along the sensor array. In observing elderly peoples, episodes of leaving the bed were easily recognized by the time course of maximal temperatures. Changes in sleep habit could be recognized from the records of successive nights.

Bath tub ECG measurement: ECG could be successfully recorded through the tap water. The signal amplitude changes with the electric conductivity of the water, but it was shown that the conductivity of the tap water falls in the adequate range. While the QRS amplitude was about 1/3 of that of the standard limb lead, almost similar wave forms as the limb lead ECG were observed.

Personal identification for bath tub ECG: In a family consist of 5 members, the learning was converged in each individual. The overall true positive rate of personal identification was more than 90 %. Similar result was obtained also in a group of 8 members.
DISCUSSION

Although many kinds of physiological quantities will be considered to be monitor in daily life, realizable items will be limited if the data acquisition has to be fully automated. The bed will be the most convenient situation in ordinary life at home. Our attempt of temperature measurement shows a possibility of obtaining some information automatically. We already confirmed in previous studies that temperature distribution record can be a convenient tool of assessing body movements by comparing the video records [5]. Our present results shows that the temperature monitoring in the bed is effective to obtain objective data relating daily life in elderly. Other than temperature, there are many possibilities of monitoring in the bed. Actually, Ishijima [6] showed that ECG can be recorded using conductive sheet without attaching body surface electrodes. Monitoring body movement was also attempted using pressure sensors [7]. Monitoring respiration, sweating, cough, snore, grind teeth, or even magnetocardiogram will be technically possible.

Bath tub ECG measurement was first proposed by Kwastra and Jain [8], and we proposed an improved method [9]. This technique is especially suited in Japan, because most Japanese peoples take bath almost everyday in deep tubs where water covers the shoulder. Other techniques such as ultrasound and optical measurements will be able to perform in a bath tub, and will provide information relating respiration, heartbeat, blood circulation, blood gas, and even fetal heart beat. It was also shown that the amount of sweating can be estimated from the change in water conductivity [10]. All observed quantities will be able to utilize for personal identification.

The toilet is considered also as a possible and convenient site of home health monitoring. Actually, Yamakoshi et al. [11] developed a body weight measuring system at the toilet seat. It consists of a precision load cell system having resolution of about 5 g, and it can measure the weight of urine and feces. This study also showed that ballistocardiographic signal can be detected by the load cell, and it will provide information relating cardiac function. Chemical measurements in urine and feces will be possible if the analyzers can be fully automated. The thigh has a direct contact to the toilet seat when seated, and electrical and optical measurements will be able to perform to the skin. We confirmed that ECG signals can be obtained at the seat [1-3]. Even the wave forms obtained were contaminated with EMG and other noise, heart rate could be easily determined.

CONCLUSIONS

Home health monitoring will be an important issue in the forthcoming aging society. This study showed two possibilities, monitoring in the bed and bath tub, but many other technical possibilities can be conceived. The concept of fully automatic home health monitoring will provide impact of developing new technologies such as the personal identification. This kind of technologies will contribute not only for expand longevity but also to keep health in better condition. Beside that, accumulation of data of normal and pathological subjects can be a valuable medical database.

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