EXPERIMENTAL EVALUATION OF HOME-BASED UBIQUITOUS HEALTH MONITORING USING BLUETOOTH AND INTERNET

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Abstact: Advances in information technology have enabled ubiquitous health monitoring at home, which is particularly useful for patients, who have to live alone. We have focused on the automatic and unobtrusive measurement of biomedical signals and activities of patients. We have constructed wireless communication networks in order to transfer data. The networks consist of Bluetooth and Wireless Local Area Network (WLAN). In this paper, we present our systems for ubiquitous health monitoring.

Introduction

Recently, ubiquitous health monitoring has been one of great issues in the field of telemedicine. The rapid development of information technology has enabled tele-health monitoring at home. Several studies have been made on unconstrained health monitoring at home. Their papers are shown in References at the end of this paper.

The word 'ubiquitous' means 'being present everywhere at once'. Ubiquitous health monitoring allows biomedical signals to be measured without the individual's awareness. For successful ubiquitous monitoring the biomedical signals need to be measured unobtrusively and the data need to be transferred using a wireless communication system.

Biomedical signal measurement is very important in the field of telemedicine and health monitoring because it is the precursor of analysis and diagnosis. In previous studies unobtrusive biomedical signal measurement was not a main issue. M. Ishijima[1] presented a method to measure Electrocardiogram (ECG) in bed without any body surface electrodes. Instead of body surface electrodes, conductive textile electrodes were used in order to measure ECG signal. T. Tamura et al.[2] showed that it was possible to obtain ECG signal in the bathtub only using water.

The house is the best place to measure biomedical signals because people spend most of their time at home. Touch and movement from the bedroom to toilet can be used to retrieve medical information about the resident or elderly people who seldom go to hospital because of the cost or disabilities.

Bluetooth communication technology has many advantages for the field of telemedicine. It enables ubiquitous health monitoring unobtrusively. A lot of data has to be transferred and processed because biomedical signals, activities and environmental parameters are always being monitored. Wireless Local Area Network (WLAN) is needed in association with Bluetooth communication network. Using Bluetooth technology and WLAN, any problems regarding bandwidth and speed can be solved.

We have been trying to develop a ubiquitous health monitoring house (u-House) for several years. In this house, several biomedical sensors and wireless communication networks are installed. The purpose of this study is to introduce u-House and to show an experimental result on health monitoring.

Materials and Methods

The most important point of home-based ubiquitous health monitoring is that the resident does not feel uncomfortable on daily life. Therefore, we have been focusing on unconstrained biomedical signal measurement and wireless data transmission.

A. Unconstrained Biomedical Signal Measurement

Electrocardiogram (ECG) data can be obtained from resident using electrically non-contact ECG measuring technique on bed. It is usually measured at night when resident are sleeping. Body movements during sleep can be measured by load cells attached to four legs of the bed. In addition, we can monitor the snoring sound during sleep using a snoring detector. These biomedical signals are useful for the assessment of the quality of sleep.

1) ECG signal measurement on bed

An ECG signal can be obtained from the patient in bed using a conductive sheet. Whenever the patient lies on bed at night, ECG signals are measured by a

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conductive textile electrode attached to the bed sheet. In order to process the ECG signal an amplifier has been developed. This bio-amplifier has several filters, namely a low-pass, notch, and high-pass filter. Such filters can remove noise and it is possible to obtain a clear ECG signal comparable to the common Ag-AgCl direct contact electrode.

2) Body weight measurement on bed

Usually, beds have four or more legs. These legs can be used to calculate the body weight of the patient. In our system, four compression type load cells (MNC-100L, CAS Co. LTD, http://www.cas.co.kr) have been attached to the legs of the bed for the purpose of measuring the weight of the patients. The output of these load cells is voltage, so calibration is needed in order to convert the voltage value to the weight unit.

3) Body movement during sleep

During sleep, the patient moves around. The movement of patients can reflect their health. To analyze their health, movement needs to be measured. The four load cells can measure these movements.

4) Snoring detection during sleep

The number of patients who suffer from severe snoring has been increasing. It is necessary to detect snoring and assess how long he/she snores during sleep. Snoring detection equipment uses an electret condenser microphone (OBG415, BSE Co. LTD, http://www.bsecm.com) and RMS-to-DC converter (AD637, Analog Device Inc, http://www.analog.com).

B. Ubiquitous Behavioural Pattern Analysis

Behavioural pattern monitoring is important for the elderly. They sometimes fall down suddenly and stay on a specific place for a long time. The automatic location tracking system has been developed using many sensors such as light sensor, door contact detector, and infrared motion detector. These sensors are connected to the small unit for the data processing and transmission.

1) Door Sensor

a. Main Entrance

Magnetic switch is attached to the door and hinge. It can detect whether the door is opened or closed. However, the door often remains opened without any relation of the patient's movements. For this reason, magnetic switch is only attached on the main entrance door.

b. Refrigerator

Accelerometer is attached to the door of refrigerator in order to monitor how often a subject uses the refrigerator. It can detect whether the door moves inwards or outwards. It is a kind of monitoring of appliances usage

2) Motion detector

Pyroelectric infrared (PIR) sensor is used for detecting body movement through doors of rooms. It has been widely used for monitoring daily living style of the elderly or disabled. It can sense the radiation of a thermal object like a man and an animal.

3) Load cell

Load cell has been widely used for measuring weight of body, so we can devise a threshold using flat type load cell. If a subject walks on the load cell, we can notice their movement. It is used together with a pyroelectric infrared sensor.

4) Flame Detector

The subject sometimes uses the gas range in order to cook in a daily life. Flame sensor can detect flames very quickly by sensing ultraviolet ray. Due to its fast response pulse, the sampling rate is a little faster than that of other sensors.

5) Sound detector

Using a microphone together with RMS-to-DC converter, we can detect sound level. It is designed not to classify sounds into speech or washing sound, but to notice whether there is sound or not. It is used to have information whether a TV is turned on or off.

6) Computer on-off detector

If a subject is using computer which is located in the room, he/she may be in the room. Just attaching a sensor to the computer power, we can notice whether the computer is on or off.

7) Light on-off detector

Cadmium Sulphide (CdS) resistor can be used for light detection. If a subject goes to the room and turns on the light, light sensor can detect this activity.

C. Bluetooth-based ubiquitous monitoring unit for sensors (BUMUS)

Figure 1 shows Bluetooth-based ubiquitous monitoring unit for sensors (BUMUS). The function of this unit is converting analogue signals to digitized data and transmitting these data to the Home server using Bluetooth.

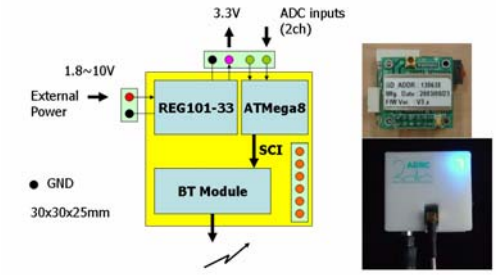

Figure 1: Bluetooth-based ubiquitous monitoring unit for sensors.

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In Table 1, sensing elements and locations of each sensor are displayed.

Table 1: Sensors, sensing elements, and locations

	Sensor	Location
Light	CdS	Room[Lamp]
Motion	PIR	Door
Sound	Microphone	TV
Door Contact	Magnetic Switch	Entrance Door
Flame	UVTron	Kitchen
Door Moving	Accelerometer	Refrigerator

Results

A. Unobtrusive Biomedical Signal Measurement

1) ECG signal measurement in bed

Figure 2 shows the ECG signal in bed during sleep.

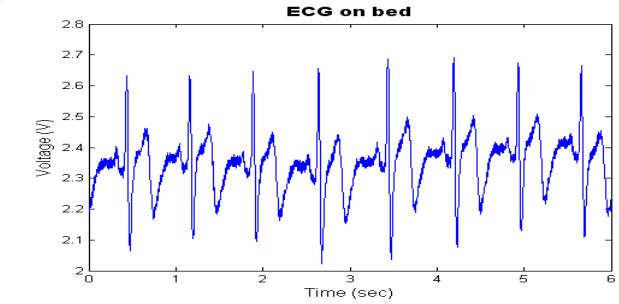


Figure 2: ECG signal obtained from conductive textile electrodes

2) Body weight and movement measurement on bed

When the patient lay on the bed at night, the load cells automatically measures the body weight of the patients and start to monitor the body movement during sleep.

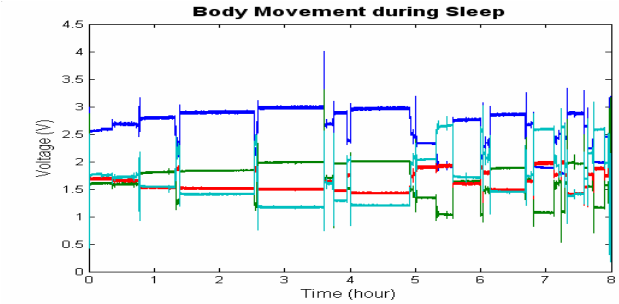


Figure 3: Body movement data during sleep obtained from 4 load cells

3) Snoring detection during sleep

Fig 4 shows the snoring data of the patient who suffer from mild obstructive sleep apnea (OSA). At the beginning of sleep, the patient snored severely.

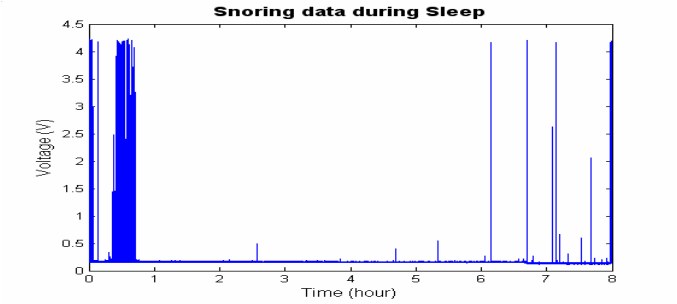
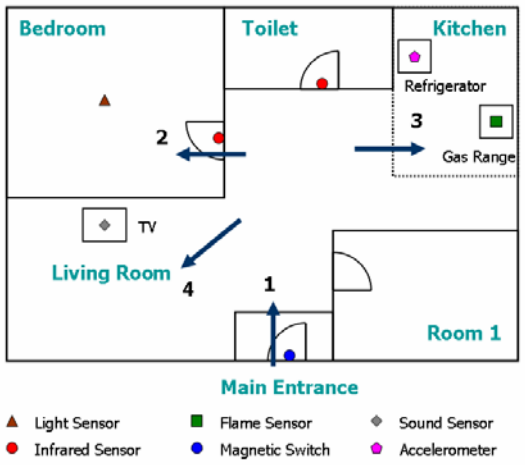


Figure 4: Snoring during sleep

B. Ubiquitous Behavioural Pattern Analysis

Figure 5 shows an experimental protocol and its result. This simulation experiment is performed in u-House in order to prove the accuracy of our automatic location tracking and behavioural monitoring system. This experiment includes four behaviours – entering the house, going to the bedroom, turning on the light, going to the kitchen and using a gas range, and going to the living room and watching TV. All events are recorded in the Home sever.




```
Entrance Door 2005-03-10 PM 7:08:00 Opening
Entrance Door 2005-03-10 PM 7:08:02 Closed
Bedroom       2005-03-10 PM 7:08:05 Moving
Bedroom       2005-03-10 PM 7:08:05 Moving
Bedroom Light 2005-03-10 PM 7:08:07 Turn on the light
Bedroom       2005-03-10 PM 7:08:55 Moving
Gas Range     2005-03-10 PM 7:09:12 Flame
Gas Range     2005-03-10 PM 7:09:12 Flame
Gas Range     2005-03-10 PM 7:09:13 Flame
Gas Range     2005-03-10 PM 7:09:14 Flame
Gas Range     2005-03-10 PM 7:09:14 Flame
                    ~~~
TV            2005-03-10 PM 7:09:22 Turn on the TV
Gas Range     2005-03-10 PM 7:09:22 Flame
Gas Range     2005-03-10 PM 7:09:23 Flame
                    ~~~
TV            2005-03-10 PM 7:12:22 Turn off the TV
Gas Range     2005-03-10 PM 7:12:33 Flame
Bedroom       2005-03-10 PM 7:21:05 Moving
Bedroom       2005-03-10 PM 7:21:05 Moving
```

Figure 5: Simulation experiment and event logging

Discussion

There are a lot of sensors which can measure biomedical signals, activities and environmental parameters unobtrusively. Among them, just a few sensors were used in our installation. In the future, other useful sensors will be used in experiments. For body fat

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measurement, a method which can estimate bio-impedance will be applied. In addition, infrared sensors will be used for movement detection and humidity sensors also will be used for humidity monitoring. Other sensors can be easily incorporated into our system because we have already developed the small-size data processing and transfer unit.

In this paper, we are focusing on the multi-modal methodology, which do not cause any problem of privacy. In addition, the algorithms to detect the direction of the subject have been being developed. In order to validate our system and algorithm we are planning an experiment of using CCD camera.

If there are several people in the house, it will cause a problem. We are developing the schemes using RF-ID in order to solve this problem.

There might be some problems such as timing consistency among sensors, data loss via wireless communication channel. Especially, for acquiring long-term data, it is essential to insure the accuracy of timing information among sensors. We should have a plan to solve these problems

Bluetooth is a powerful wireless communication technology. It enables unconstrained activity monitoring for patients. However, it has also some shortcomings. First, it consumes a lot of power. For this reason, it is impossible to use batteries and we could not avoid using an AC-DC adapter. In the future, if we are able to design an effective communication protocol we can solve this power consumption problem. Second, the Bluetooth access point which was used in this paper can include seven modules. It was a critical limitation until now, but it is expected that a new product will be released soon. Third, the wireless communication method like Bluetooth can not insure the perfect transmission. It means that data loss is avoidable when Bluetooth is used. There are several walls in the house, these walls might be obstacles against the wireless transmission. More sophisticated algorithms should be needed considering data loss and timing missing.

Conclusions

It is possible to monitor biomedical signals of resident and to analyze his/her behavioural patterns with unconstrained methods using Bluetooth.

Unobtrusive biomedical signal measurement and data transfer via wireless communication has enabled ubiquitous health monitoring. Just sleeping on bed and walking around the room allows measurement of some biomedical signals. In addition, activities of patients and environmental parameters such as temperature can be recorded without any notice of the patients.

Through the activity monitoring system we can monitor the behavior of a subject at home. It will be useful to estimate daily living patterns according to the time. In addition, the advanced wireless communication technology has enabled the ubiquitous health monitoring with unobtrusive methods.

References

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