Implementation of Ubiquitous Health Care System for Active Measure of Emergencies

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Abstract

The present study discusses the construction of a ubiquitous health care system that can cope actively with urgent situations of chronic disease patients who can lead everyday life despite their chronic diseases. If a patient's emergency is detected by personal health care host (PHCH), which is composed of USN, electronic stethoscope, GPS, CDMA and RFID, a text message containing position information is sent immediately to the hospital and the guardian's mobile terminal so that they can take an action immediately. In particular, data from accelerometers and vibration sensors, which are composed of ubiquitous sensors, are learned using the back-propagation network algorithm, therefore emergencies such as syncope and convulsion are determined actively. The experiments show that this system is very effective to find emergencies promptly for chronic disease patients who cannot take care of themselves and it is expected to save many lives.

1. Introduction

The potential of information technologies (IT) in particular ubiquitous technology as a driving force for massive changes in the 21st century will rise as a key factor for richer and more convenient life and for national economic development. As the foundation, information telecommunication technology is leading the growth of national industries and changing people's lifestyle [1].

In this trend, ubiquitous society is being implemented into future information society. That is, ubiquitous society is evolving into 'programmable society' where the society can serve the diversity of individuals by integrating IT technologies like wired/wireless Internet, mobile convergence and RFID. Today is a period for digital convergence of high-speed Internet, mobile devices, etc., namely, a transitional period to ubiquitous society, but within several decades, ubiquitous networks will be settled throughout the society. The new and rapid development of ubiquitous technology is expected not to be confined in specific area but to spread to every part of human life and initiate changes [2].

However, due to the environmental problems from the advance of industries, the emergence of new diseases, and aging, there is an increasing number of chronic disease and heart disease patients as well as sudden deaths of heart failure out of high stress [3]. Many heart disease patients die untreated although their life can be saved if their symptoms are treated within several minutes.

Thus, to cope with emergencies, the present study implemented Personal Health Care Host (PHCH) based on Ubiquitous Sensor Network (USN). This system monitors the patient's condition continuously and if an emergency happens it sends a text message containing the emergency code and location information to the caregiver and the hospital. In this study, the system is called Ubiquitous Health Care System (UHCS). Using UHCS, patients in very dangerous situation like fainting or fit can get prompt first-aid treatment.

2. Related Work

With the development of internet based information technologies and facilities, several telemedicine services have been developed[4-6]. Furthermore, a number of pilot projects on intelligent tele-monitoring for homecare purpose have been conducted in recent years[7]. Ohta et al. presented a health monitoring system for elderly people living alone, and monitored in-house movements by placing IR sensors[8].

In a ubiquitous environment using wireless communication, several researches on e-health system have been proposed. Dulay et al. proposed e-health system in ubiquitous computing environment[9]. They

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advocated the concept of the self-managed cell (SMC) as an approach for implementing autonomic ubiquitous systems. Choi et al.[10] have constructed a ubiquitous health monitoring system in the bedroom using bluetooth network and wireless local area network. Ishijima[11] presented a method to measure Electrocardiogram (ECG) in bed without any body surface electrodes. For a commercial product, HealthFrontier company sells ecg@Home which records and stores the electrical heart signal obtained from the first or second standard ECG leads in a non-invasive manner. The recorded data is sent to a data warehouse via the Internet, wireless device, email, or via the built-in trans-telephonic coupler to tele-health center, where it can be immediately tracked, scanned, and analyzed or alternatively transmitted to a caregiver[12].

3. Design of UHCS

3.1 System Configuration

Figure 1 shows the structure of UHCS proposed in this study. As in Figure 1, the system is composed of PHCH that measures and analyzes data about the user, namely, the patient, the control center that collects patient data and stores them, and the ubiquitous hospital that gets reports on patients' conditions periodically and takes prompt actions in emergency.

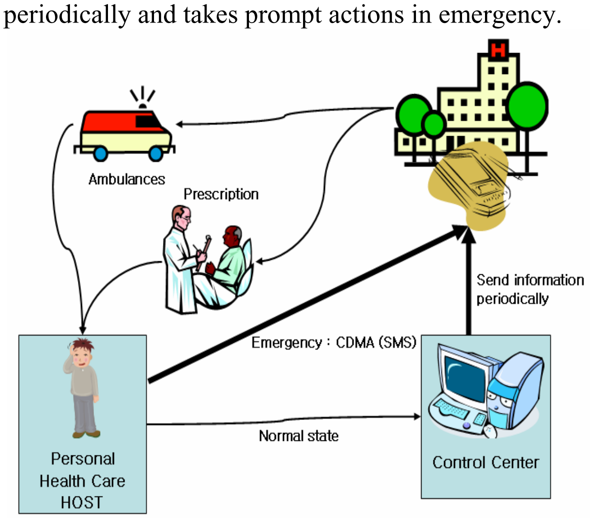

Fig. 1. The architecture of Ubiquitous health system

3.2 PHCH

PHCH is a core part of UHCS. Attached to the patient, it monitors the patient's physical condition, analyzes sensor data, and process the data. Figure 2 shows the composition of PHCH.

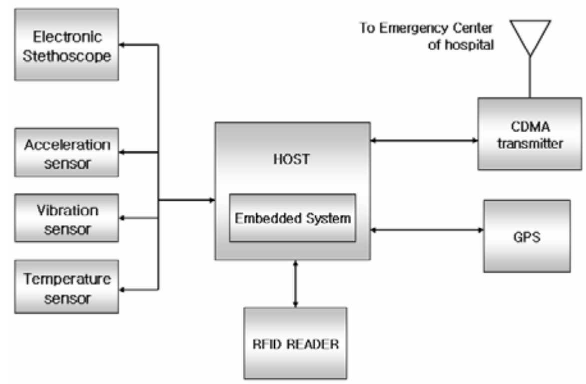

Fig. 2. Functional diagram of personal health care host

PHCH is composed of electronic stethoscope module, patient state monitoring module, position tracking module and communication module. The electronic stethoscope module records and process patients' heart sound and bowel sound using an electronic stethoscope. The patient state-monitoring module analyzes data about patients' state obtained from USN such as accelerometers and vibration sensors using the back-propagation network model and determines whether the patients are in emergency. When a patient is found to be in emergency, the position tracking module and the communication module send GPS information, which tracks the patient's position, and the patient's emergency information to the hospital or the guardian by a text message using CDMA.

Table 1 shows the functions of the modules composing PHCH

Table 1. The module and its functions of PHCH device

Module	Functions
PHCH	Receive data from each module and send the monitoring data to the Control Center.
Electronic stethoscop e	Measure the patient's heart sound, pulmonary sound and bowel sound and send the data to the host.
Wireless sensor	Monitor the patient's emergency using USN.
GPS	In emergency, trace the patient's location and send the location information to the host.
CDMA	In emergency, send a text messages containing the emergency code and location information.
RFID	Store and manage the patient's basic information in a RFID tag.

PHCH is built as a embedded system using Intel Xscale CPU. The electronic stethoscope is connected by USB, and receives data from the sensor module, the CDMA module, the GPS module, and the RFID reader. It analyzes data from wireless sensors, and processes the signals of the patient's heart sound, pulmonary sound and bowel sound received from the electronic stethoscope. The patient's basic information necessary for analysis is obtained from data stored in the RFID tag. If an emergency is detected from the sensors and the electronic stethoscope, the host sends the hospital and the caregiver a text message containing the emergency code and location information from the GPS module using the CDMA module and, at the same time, it sends information on the patient's condition to the Control Center. Even if not emergency, report on the patient's condition is made periodically to the Control Center.

Some data such as arrhythmia are sensed by electronic stethoscope, and sensing operation is usually examined by the patients at home. Then these data are transmitted to the MCC for storing and analyzing the state of the patients via CDMA wireless mobile network. Electronic stethoscope is connected to the PHCH by USB interface, and the signal is amplified over 15 times by using operational amplifier. At that time, noises are removed using a FIR filter.

Figure 3 shows the waveform of heartbeat signal after FIR filtering.

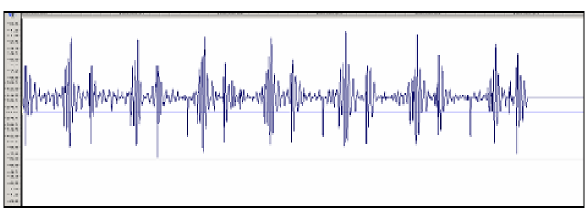

Fig. 3. A waveform of heartbeat signal after FIR filtering

USN and PHCH communicate with teach other through Zigbee. The module detects the patient's emergency through USN composed of sensors attached to the patient's body including vibration sensor, acceleration/inclination sensor and temperature sensor.

If the patient is suddenly attacked by a stroke, an acute anemia or a heart failure and falls down helplessly, the emergency is detected by the emergency pattern of sensor data and an emergent text message is sent to the hospital or the caregiver so that a proper action can be taken promptly. In case of a fit like epilepsy, the system detects it in the same way using the pattern of signals from the sensors.

As in Figure 4, in emergency, PHCH connects to the data line of a telecommunication carrier through CDMA and sends a text message to the designated hospital.

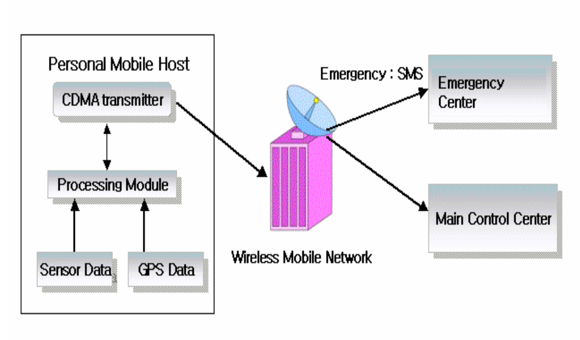

Fig.4. Communication routes for emergency text messages in ubiquitous environment

Due to the short text message limitation, we proposed some interpretation codes that indicate specific situation of the patients. Table 2 shows the emergency codes for short text message.

Table 2. Emergency interpretation codes for short text messages

Emergency codes	State
ER01	Loss of consciousness
ER02	Syncope, but awakened
ER03	Convulsion
DG01	Hypertension
DG02	Hypotension
DG03	Arrhythmia
DG04	Irregular breathing

3.3 Control Center (CC) and Emergency Center of Hospital

CC stores data of the patients sent from PHCH. Emergency center of hospital receives the text messages and decodes the emergency interpretation codes, and connect to the CC to analyze stored data of the patients.

4 Experimental Results for Ubiquitous e-Health System

4.1 Emergency Monitoring

Figure 5 shows the user interface program of main control center, which monitors the personal mobile host.

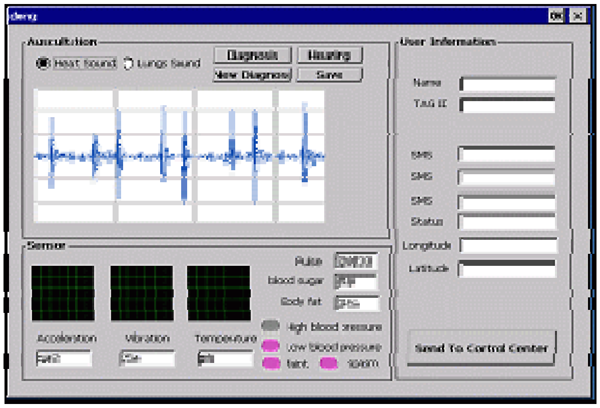

Fig. 5. User interface of PHCH

Figure 6 shows the waveform of acceleration sensor and vibration sensor in the normal walking state. Output signals from each sensor are measured for 10 seconds, and measurements are taken 20 times for each normal walking, syncope, and convulsion state respectively.

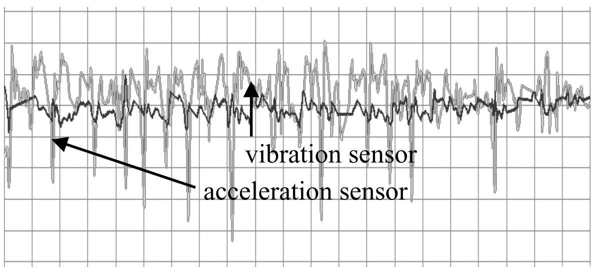

Fig. 6. Waveform of acceleration and vibration sensors for normal walking

When the patients have convulsions, then the signal from sensors become different from previous one. Figure 7 shows the waveform..

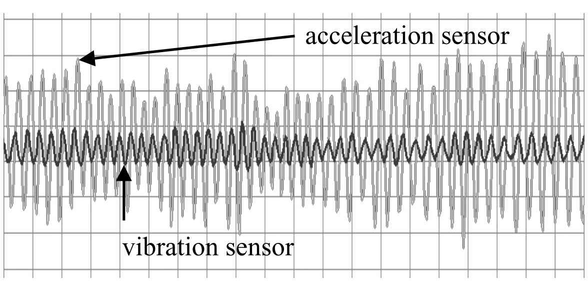

Fig. 7. Waveform of acceleration and vibration sensors for convulsion

When the patients have syncope, then the waveform of sensor signals is flatter than the previous cases. Figure 8 shows the waveform. In this state, there is small difference between high peak and low peak.

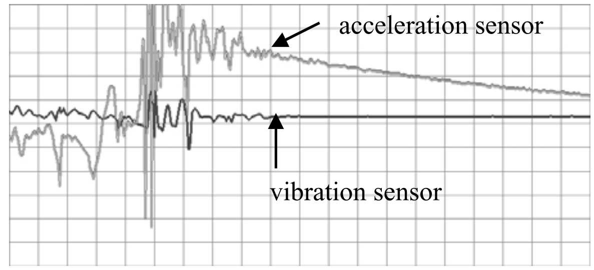

Fig. 8. Waveform of acceleration and vibration sensors for syncope

4.2 Emergency Detection Using Sensor Data

4.2.1 Backpropagation Network Learning This study used the back-propagation network model in order to detect emergent situations using input data on patients' state from USN sensors. If the hidden layers are given a sufficient number of units, the back-propagation network model can learn for a continuous function model. As in Figure 9, output(y) is produced if the weight of neural network are multiplied by and added to input (i). Here, output(y) is different from desired output(o) given in learning data. There is an error e (y-o) in the neural network, and the weight of the output layer is updated in proportion to the error and then the weight of the hidden layer is updated. The direction of weight update is the opposite of the direction of neural network processing. This learning process is repeated until error e reaches the adequate level. At that time, the number of inputs in the input-output layers is different according to application area, and control constants used inside the network should also be optimized through experiment [13].

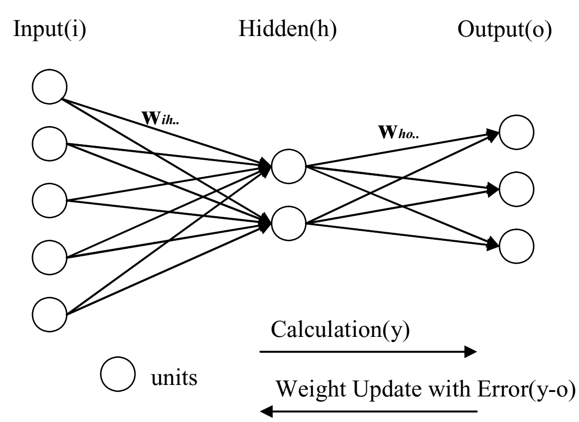

Fig . 9. Learning method of back-propagation network

4.2.2 Network Input In this study, the input of the back-propagation network was data from USN sensor such as acceleration sensors and vibration sensors. In order to create the input vector of the back-propagation network, 200 data were extracted from an acceleration sensor for 10 seconds, and were divided at one-second time intervals. Another input vector was also prepared with data from a vibration sensor in the same way as data from the acceleration sensor.

That is, an input vector for the acceleration sensor and another for the vibration sensor were prepared, and each was learned as the input of one of two back-propagation networks in order to detect emergent situations.

Figure 10. shows the system architecture, in which PHCH receives input data from two sensors and detects or determines emergent situations.

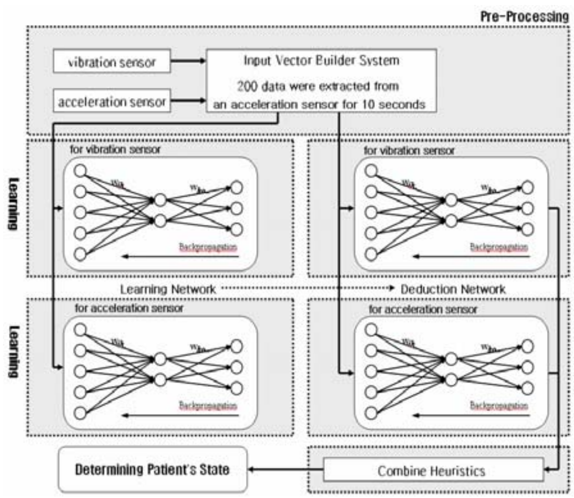

Fig 10. Learning & Detection System Architecture

For the learning of the back-propagation network, we collected 100 data for normal situation, 100 for syncope situation, and 100 for convulsion situation, and trained the network with the data. An input vector from a sensor was designed to have 200 input nodes and to use one of three output nodes. The three output nodes mean normal situation, syncope situation and convulsion situation, respectively.

AS in Table 3, the number of hidden layers in the learning network and the values of the internal parameters were set at experientially optimal values.

Table 3. The parameter values of back-propagation network

No. of Hidden Layer	Weight Change Step	Iteration Count of Training	Momentum	Threshold
30	0.1	5,000	0.1	0.005

4.2.3 Evaluations To analyze the results of learning according to the determination of emergent situations, we measured recall and precision by the tenfold cross validation method and obtained results as in Table 4.

Based on contents presented in [14], we measured with TP (Ture Positive), FP (False Positive) and FN (False Negative) pages.

Table 4. Results of experiment upon back-propagation network

Patient's state	normal walking	convulsion	syncope
No. of pages	100	100	100
Recall(%)	72%	76%	82%
Precision(%)	100%	96%	98%
TP	58	61	66
FP	0	2	1
FN	22	19	14

According to the result of the experiment, the accuracy of determining patients' state was somewhat lower than the expected value. It was because data values are various according to patients' physical condition such as weight, height and age although the patterns of sensors are similar. Accuracy will be enhanced in the future if more experimental data on various physical conditions are accumulated and learned. What is more, we need to find and apply more optimized internal parameters through additional experiments.

4.3 Communication Protocol

The communication protocol between CDMA communication module in PHCH and emergency center in hospital is shown Figure 11.

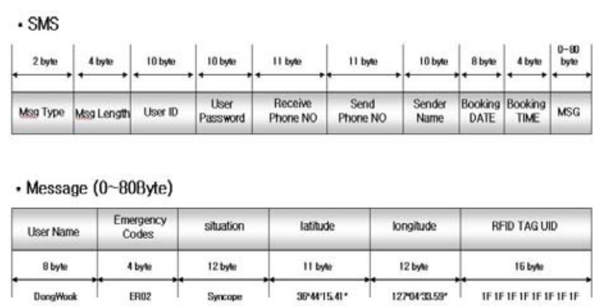

Fig. 11. Communication protocol for emergency short text message

The text messages are sent to the emergency center via the wireless mobile network using CDMA air interface. The message includes the GPS information of the PHCH which is carried by the patients.

5. Conclusion and Future Work

The present study discussed a u-health care system using USN, GPS, CDMA and RFID. With the system, a ubiquitous hospital can diagnose patients' condition remotely by using an electronic stethoscope and transmitting the patients' heart, chest or bowel sound. In addition, using USN, the system can detect chronic disease patients' emergencies such as syncope and convulsion through back-propagation and send the guardian the urgent situation code and GPS position information so that the guardian can cope actively with the emergencies. Although the accuracy has not reached the expected level because experimental learning data are not enough to be satisfactory, accumulating more experimental data will solve this problem. We confirmed that the use of the u-health care system implemented in this study save many patients in emergency.

In future research, we need to make PHCH analyze data from electronic stethoscopes by itself using learning algorithm such as back-propagation or pattern analysis algorithm in order to cope with more various emergent situations. What is more, we need to improve the system in a way of measuring patients' ECG, pulse, blood sugar, body fat percent, etc. using bio-sensors so that it can predict and prevent emergent situations rather than taking an action after an emergent situation has occurred.

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