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Development Brief of A Body Area Network for Ubiquitous Healthcare : An Introduction to Ubiquitous Biomedical Systems Development Center

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Abstract: The fusion technology of small sensor and wireless communication was followed by various application examples of the embedded system, where the social infrastructural facilities and ecological environment were wirelessly monitored. In addition, this technology represents the primary application area being extended into the healthcare field. In this study, a body area network for ubiquitous healthcare is presented. More specifically this represents a wireless biomedical signal acquisition device characterized by small size, low power consumption, pre-processing and archiving capability. Using this device, a new method for monitoring vital signs and activity is created. A PDA-based wireless sensor network enables patients to be monitored during their daily living, without any constraints. Therefore, the proposed method can be used to develop Activities of Daily Living (ADL) monitoring devices for the elderly or movement impaired people. A medical center would be able to remotely monitor the current state of elderly people and support first-aid in emergency cases. In addition, this method will reduce medical costs in society, where the average life expectancy is increasing.

Key words: Body area network, Ubiquitous healthcare, Personal digital assistant(PDA), Wireless sensor network

INTRODUCTION

According to the Institute of Medicine's definition, telemedicine is the use of electronic information and communication technologies to provide and support healthcare when distance separates the participants, such as patient and healthcare provider. Internet technology added the participants, that is, payer and public authority, which made the field of e-Health. In addition, advanced wireless communication and embedded computing technology creates ubiquitous computing, expanding e-Health to provide mobile healthcare and ubiquitous healthcare[1,2,3].

Various types of portable and wearable devices for ubiquitous healthcare are currently available in the market[4,5,6]. These include the helmet, earring, belt, armband, pen, ring, watch, and mobile terminal. In Korea, the medical cost of elderly people in the 2004 financial year represents approximately 23% of total budget, the need to develop these devices is now.

In this study, a body area network(BAN) is presented. In Mobihealth[7,8,9], which was supported by the EU-IST project, the body area network represents the base technology for permanent monitoring and logging of patient vital signs, especially for patients suffering from a chronic disease. The associated devices include a Mobile Base Unit(MBU), a front-end, and wireless sensors. The system was designed to operate over 2.4 GHz Bluetooth communications. In Healthy Aims[10,11], a recent EU Framework VI project, a body area network represents wireless communication that connects implanted medical devices or on-body sensors with monitoring tools to provide patient health data in real-time. This systems used FCC dedicated 402-405 MHz RF communication for medical implant communications service(MICS). In this study, supported by UBDC(Ubiquitous Biomedical Systems Development

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Center), BAN is wireless communication in the area of wearer's body for ubiquitous healthcare, which uses 916MHz propriety RF and 2.4GHz Zigbee communication. For wireless medical telemetry service, three proprietary frequency bands with 13.5 MHz bandwidth are allocated in United States by FCC, these are 608-614 MHz, 1395-1400 MHz, and 1427-1429.5 MHz. These bands are for hospital use only.

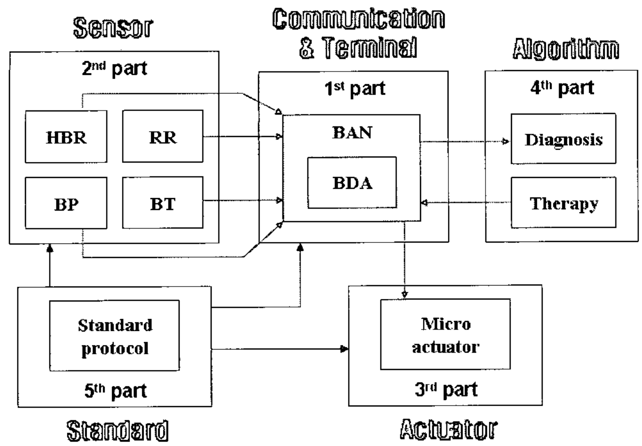

Fig. 1. Five sub-projects supported by UBDC

UBDC is a research center supported by Korea Health Industry Development Institute[12]. It carries out five sub-projects, which are developing the functional blocks shown in Fig. 1. The sensors developed by second part generate biomedical signals, which are acquired by the communication and terminal devices developed by first part. The data is analyzed by the algorithm developed by fourth part. According to the result, the micro-actuator developed by third part injects drug into patient. Fifth part develops the standard in the health data transmission process. For three years of the first step from 2004 to 2006, base technology has been and is to be developed and for the second step, clinical application and wearable devices are to be developed.

METHODS

Fig. 2 presents three domains in ubiquitous healthcare, which are body area network domain, m-health domain, and tele-health domain[7]. Wirelessly networked sensors in body area generate health data, which is acquired by mobile base unit and transmitted to a remote server of medical center over the cellular phone network.

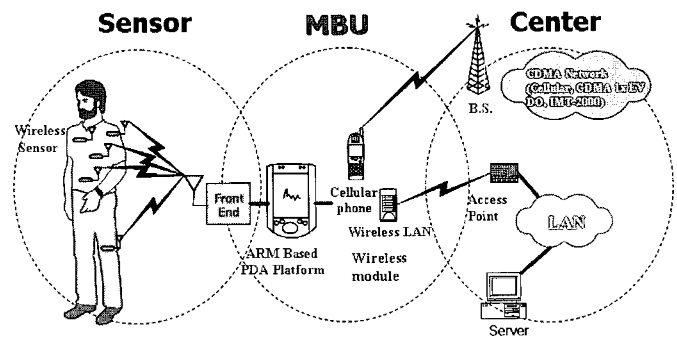

Fig. 2. Three domains in Ubiquitous Healthcare

Based on this concept, Fig. 3 presents the system configuration developed in this study. Analog signals generated by various types of sensors are converted to digital data by a micro-controller, and wireless data generated by RF chip is transmitted to the PDA, where health data is stored and processed and transmitted to a remote server over the cellular phone network. The biomedical digital assistant(BDA) is composed of PDA and RF and CDMA communication devices. The body area network manages all wireless data transmission processes between BDA and sensors. In this study, biomedical sensors target vital signs, such as heart beat rate, respiratory rate, blood pressure, and body temperature. In addition, fusion with ubiquitous sensor, such as, an accelerometer is attempted.

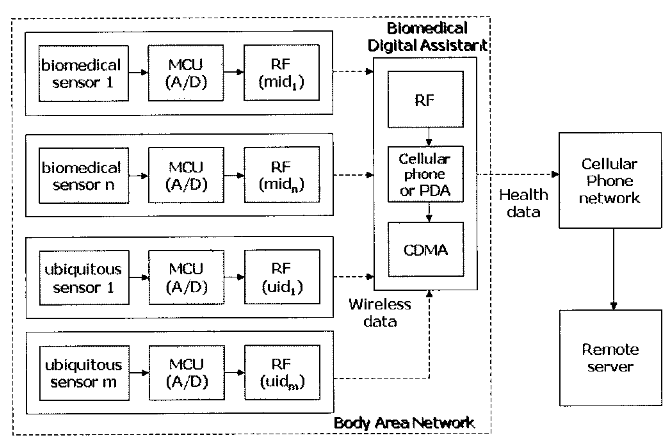

Fig. 3. System configuration

RESULTS

Wireless Sensor Network for Human Motion Analysis

The application program using wireless sensor network was developed to acquire the technology used in UC Berkeley MICA Mote, which uses TinyOS and network embedded system C language[13]. Human motion analysis is made possible through programming the embedded accelerometer. MICA used TR1000, CC1000, and CC2420 as RF chips, whose modulation technologies include amplitude shift key, frequency shift key, and quadrature phase shift key respectively. Using MICA Mote, wireless devices for human motion analysis can be developed. The transmitter, antenna, and receiver were constructed as shown in Fig. 4.

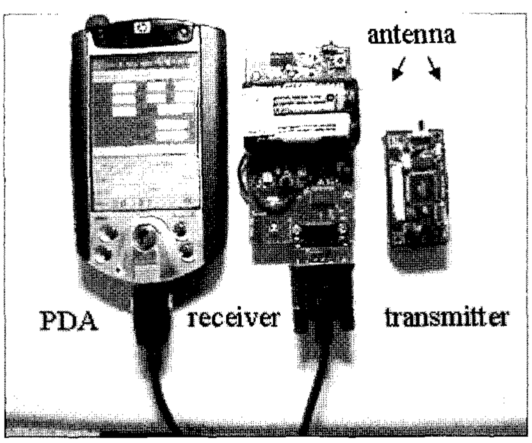

Fig. 4. Wireless sensor network for human motion analysis

RF data from the acceleration sensor was transmitted to the PDA through a serial port and stored by a data logging program using the C# language. Fifty motions of lying-to-sit and stand-to-sit were stored when the sensor was attached on a wearer's chest. Four types of human motion can be classified using the PC program, by analyzing the longitudinal component of acceleration. The principal component analysis(PCA) and support vector machine(SVM) method were used to classify the first and second principal data components. Four types of motion could be clearly classified using this method. The estimated optimal boundaries could be transformed to three region-segmenting lines. A supervised learning method was used to determine the motion type. The algorithm, based on a learning data set, could successfully classify real data. In Fig. 5, the circles and the triangles are classed as input data, and the pluses of the stars represent the learning data set. This study used one accelerometer located on the subject's chest and used the PCA followed by the SVM algorithm. The PDA was used as a wireless data logger and the small sensor was wearable. Therefore, the comparative mobility of this system is excellent[14,15].

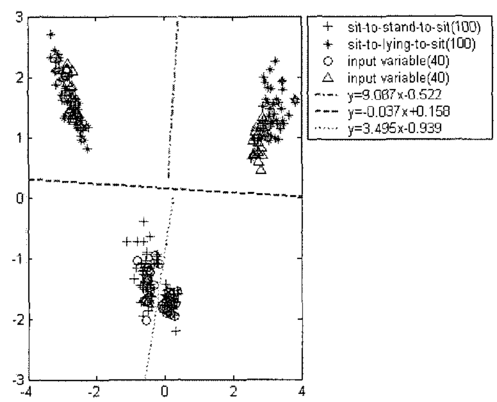

Fig. 5. Classification of human motion by PCA & SVM

Zigbee Based Body Area Network

A Zigbee based body area network with one channel ECG was developed as shown in Fig. 6. As RF chips, CC2420 was used for Zigbee communication. The objective in this study was to develop a PDA based portable ECG with functions of one channel ECG display and logging fused with a motion measurement sensor. The wireless transmitting ECG waveform can be shown on the PDA screen in Fig. 6.

Fig. 6. Zigbee based body area network

The packet size used in this device does not exceed a maximum payload size of 116 bytes. One packet consists of two segments, which further consists of a start byte, ten ECG data, three acceleration data, and an end byte. The transmission speed was 21 packets per second, 420 ECG samples per second, and 42 acceleration samples per second. This speed corresponds to 18.4 kbps effectively and thought to be sufficient for a body area network.

For each heartbeat, the Zigbee sensor detects the R-R interval and calculates the heart beat rate. In addition, walking steps are counted with an embedded 3-axial accelerometer. These two data are transmitted to a PDA and logged. Fig. 7 presents a subject's heart beat rate and walking steps for about 18 minutes, in particular, this consisted of, sitting on a chair for 4 minutes, working in a laboratory for 4 minutes, and walking along a corridor for 10 minutes.

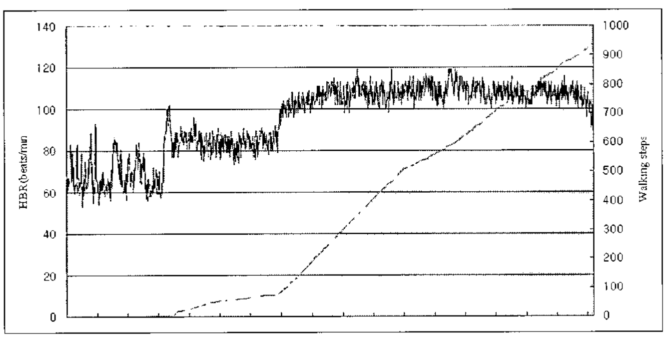

Fig. 7. Heart beat rate and Walking steps

Fig. 8 presents a scatter chart with coordinates representing current heart beat rate and activity level, calculated from the walking step per minute. As the activity level increases, heart beat rate is inclined to increase.

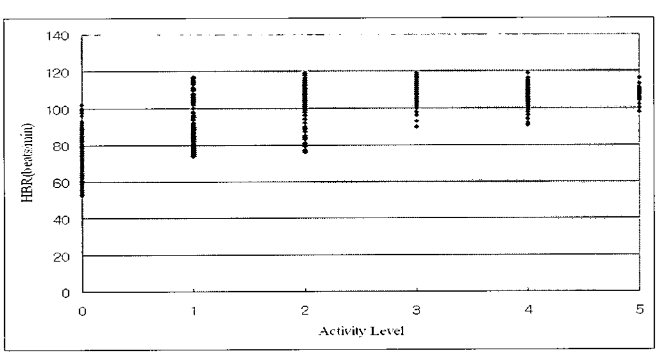

Fig. 8. Activity level and Heart beat rate

DISCUSSION

The accelerometric data measurement is known to be useful for the evaluation of patient's physical activity level during ambulatory ECG monitoring[16]. Therefore, the awareness of patient's motion context is important in ubiquitous healthcare[17]. Context represents information that can be used to characterize a situation, such as user, place, time, activity, application, and so on. In ubiquitous healthcare, this information includes patients' heart rate, temperature, blood pressure, and respiratory rate. In addition, patients' motion can be another clue for monitoring their physiological condition in case of an emergency. The fusion of multiple biomedical and ubiquitous sensor data may assist physicians in making more accurate clinical decisions. The developed algorithm of motion context classification is tested in off-line PC environments and real-time algorithm should be implemented on the micro-controller or PDA, which is also the next research topic. The speed of the body area network based on Zigbee is sufficient for transmission of total ECG and motion data. However, for low power consumption, it is necessary to use Zigbee in low duty cycle mode. Therefore, abnormal rhythms need to be detected by a sensor module and only its waveform should be transmitted to the PDA. Otherwise, the wireless sensor itself should have enough memory to store all data, and be synchronized daily with a networked PC through a high-speed data channel. In this case, a trade-off between size and power should be made and serious consideration regarding memory and processing speed should be taken into account.

Ongoing laboratory research is being conducted regarding a phone-type pedometer embedded in a battery pack. A three-axis accelerometer is inserted in a battery pack with a micro-controller. Another is a biomedical digital assistant, which uses a XScale CPU and the Windows CE.net operating system. The weight is high and the size is large, but thought to be applicable to wearable terminals.

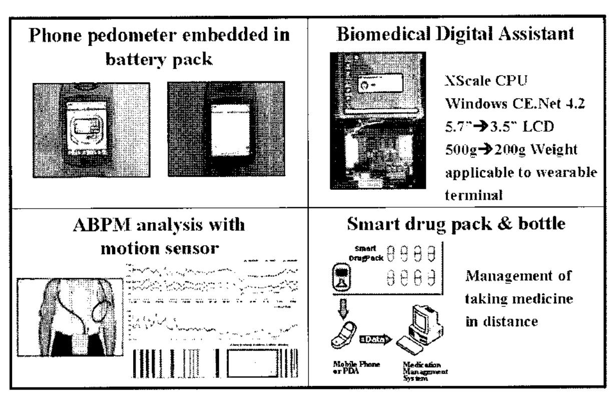

Fig. 9. Ongoing researches in this laboratory

Miniaturization is planned in the future. The others are ambulatory blood pressure monitoring analysis with motion sensors, smart drug packs and a bottle for the management of taking medicine at various locations.

Fig. 10 represents configuration of the targeted system. In the area of patient and doctor, mobile terminals monitor the present status of patients with chronic disease using biomedical, ubiquitous sensors and alarms. To secure a patient's medical information on a remote server, automatic user identification badges are used with a RFID sensor. To alert patients taking medicine, a smart drug pack is to be used in the patient area network.

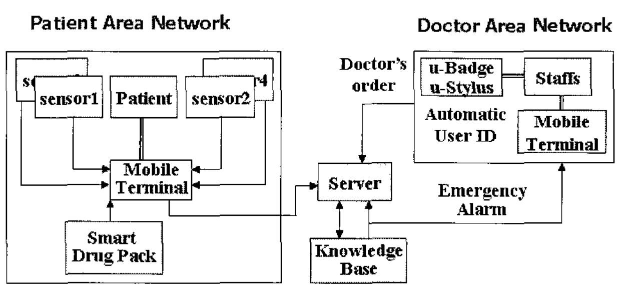

Fig. 10. Configuration of targeted system

CONCLUSION

A wireless biomedical signal acquisition device was developed with small size, low power consumption, pre-processing and archiving capability. Using this device, a new method of monitoring vital signs and activity is created. A PDA-based wireless sensor network enables patients to be monitored during their daily living without any constraints[18]. Therefore, the proposed method can be used to develop Activities of Daily Living (ADL) monitoring devices for the elderly or movement impaired people. The medical center will be able to remotely monitor the current state of elderly people and support first-aid in emergency cases. In addition, this method will reduce medical costs in society, where the average life expectancy is increasing.

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