Development of a ubiquitous healthcare monitoring system combined with non-conscious and ambulatory physiological measurements and its application to medical care

doi: 10.1109/IEMBS.2011.6092025

33rd Annual International Conference of the IEEE EMBS
Boston, Massachusetts USA, August 30 - September 3, 2011

添付資料②

Development of a Ubiquitous Healthcare Monitoring System Combined with Non-conscious and Ambulatory Physiological Measurements and its Application to Medical Care

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***Abstract*—The demand for ubiquitous healthcare monitoring has been increasingly raised for prevention of lifestyle-related diseases, acute life support or chronic therapies for inpatients and/or outpatients having chronic disorder and home medical care. From these view points, we developed a non-conscious healthcare monitoring system without any attachment of biological sensors and operations of devices, and an ambulatory postural changes and activities monitoring system. Furthermore in this study, in order to investigate those applicability to the ubiquitous healthcare monitoring, we have developed a new healthcare monitoring system combined with the non-conscious and the ambulatory measurements developed by us. In patients with chronic cardiovascular disease or stroke, the daily health conditions such as pulse, respiration, activities and so on, could be continuously measured in the hospital, the rehabilitation room and subject's own home, using the present system. The results demonstrated that the system appears useful for the ubiquitous healthcare monitoring not only at medical facility, but also during daily living at home.**

I. Introduction

The demand for daily monitoring of health condition at home has been increasingly raised as prevention of lifestyle-related diseases. There is a need to perform such healthcare monitoring of inpatients and/or outpatients having chronic disorder requiring acute life support or chronic therapies. Recently, the medical care and rehabilitation at home are also important. Within this context "ubiquitous healthcare monitoring" would be most desirable.

Recently, commercially available devices for the home healthcare are networked using monitoring platform such as Continua Health Alliance. But, improvements of sensing techniques are not enough. For example, the healthcare monitor at home are very cumbersome, because those must need attachment of biological sensors and operations of the devices. This cumbersomeness should obstruct long-term daily monitoring at home. From these viewpoints, a new concept such as "non-conscious physiological measurement" without the need either to attach any biological sensors to the subject's body and any troublesome operations of measurement devices during normal daily life [1]. In this monitoring, necessary sensors are built in home facilities such as a toilet, a bathtub and a bed, which are inevitable during daily living. For example, a bathtub electrocardiogram (ECG) monitor [2] and bed-installed sensors for temperature distribution, ECG, pulse, respiration and body motion were showed [3]–[6].

In addition "ambulatory physiological measurement" such as the Holter-type ECG recorder [7] and the portable sphygmomanometer based on auscultation and/or the cuff-oscillometric method [8] are also widely used in clinical medicine in order to obtain the continuous vital signs. Moreover, some wearable instruments monitoring activities have been developed to keep the activities in high condition and avoid becoming bedridden [9]-[11].

On the other hand, within the sphere of the non-conscious physiological measurement, we designed some monitoring devices such as an ECG and respiration monitor in the bathtub [12], [13] a pillow-type sensor to measure body motion, pulse and respiration [12], [13], a body and excretion weight monitor installed in a lavatory floor [1], [12], [13] and a blood pressure monitor installed in a toilet-seat [12], [13]. Moreover, we attempted to monitor the vital signs in the subject with chronic diseases at the hospital room [14]. Within the ambulatory measurements, we developed a wearable system measuring the detailed postural changes together with walking speed, showing its usefulness for the gerontology and the rehabilitation field [15].

Furthermore in this study, in order to investigate those applicability to the ubiquitous healthcare monitoring, we have newly combined each monitors mentioned above and network system. We have measured the health conditions of some patients with cardiovascular disease or stroke, not only in the hospital, but also during daily living using the system.

Manuscript received April 18, 2011. This work was supported in part by Japanese Ministry of Internal Affairs and Communications under the Strategic Information and Communications R&D Promotion Programme (SCOPE; No. 102305004, 2010).

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II. MONITORING SYSTEM

Fig. 1 shows an outline of the ubiquitous healthcare monitoring system combined with the non-conscious and the ambulatory physiological measurements.

In the toilet, a platform-type scale is placed around a toilet bowl. This system can detect the change of the body weight during excretion with a weight resolution of 5 gf and sampling frequency of 100 Hz. Therefore, the excretion weight can be obtained from the difference of the body weight between before and after excretion [1], [12], [13].On the other hand, the pusher plate for local pressurization is installed in the toilet seat for the blood pressure measurement in the back of a thigh, based on the volume-oscillometric method previously proposed by us [12], [13].

In the bathtub, the three stainless steel electrodes are fixed to the inner wall of the bathtub around subject's chest, so as to place them with Einthoven's triangle configuration. The potential differences between the two electrodes, similar to the lead-I, -II and –III, are recorded with sampling frequency of 300 Hz to obtain a raw ECG signal and a base-line fluctuation due to respiration [12], [13].

In the bed, the pillow-type sensor using the vinyl tubes filled with silicon-oil can measure the signals of the pulse, the respiration, the body motion and the snore. Moreover, using the sheet-type multipoint pressure sensor, body contact pressure distribution can be monitored. These data can be recorded with sampling frequency of 100 Hz [12], [13].

As shown in the middle part of this figure, the data during measurement by the non-conscious healthcare monitoring system installed at the home facilities (N) are also led to the data server located in subject's home and the hospital in real time through the LAN and WAN.

On the other hand, using the wearable sensor units which 3 axes accelerometer and gyro-sensor, amplifier, Micro SD card, transmitter, battery, CPU are installed, the posture changes and walking speed can be measured with sampling frequency of 25 Hz [15]. The system can record the activities for about 6 hours with real time monitoring using the wireless system and for about 12 hours with off-line monitoring using only memory card. As shown in the upper and lower part of this figure, the data obtained from the ambulatory activities monitor (A) can be also transmitted to the portable data server using the wireless body area network (WBAN) in real time. In the WBAN, the Bluetooth (Ver. 2.0, Class 2) is installed and thus commercially available smart phone can be also used as the portable data server. These are also led to the data server through the wireless local area network (WLAN) and/or the wide area network (WAN) in real time.

The data obtained from the each monitors are combined with the extended markup language (XML) and browsed using a web application, no matter when or where the medical staff need the data. The data are securely transferred using the secure sockets layer (SSL) and/or the virtual private network (VPN). Also, when the medical staff view the data, the input of ID and password are also required.

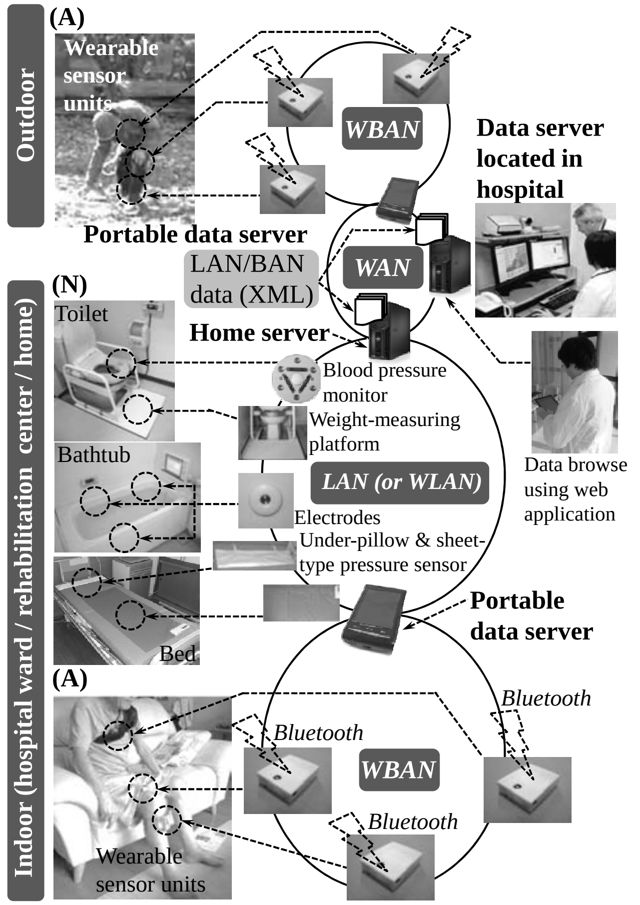

Fig. 1. Outline of the ubiquitous healthcare monitoring system combined with the non-conscious and the ambulatory physiological measurements. The non-conscious healthcare monitoring system installed at home facilities (N) and the ambulatory postural changes and activities monitoring system (A) are combined through the wireless body area network (WBAN), the local area network (LAN), the wireless LAN (WLAN) and the wide area network (WAN). The obtained data from the LAN and BAN are integrated in the data server with the extended markup language (XML).

III. EXPERIMENTS

We have been carrying out the daily health status monitoring in six patients with chronic cardiovascular disease (59-79 yrs) and 17 patients with stroke (40-85 yrs) using the present system, not only in the hospital, but also during daily living at subject's own home. The data obtained from the non-conscious and the ambulatory measurements are accumulated in the subject's home server and the data server located at the Imizu City hospital and Fujimoto Hayasuzu Hospital. The medical and care staffs have been checking the daily vital signs of the patients, using the network system.

In this paper, we show three examples such as (1) recordings using the non-conscious healthcare monitoring system placed at subject's own home in Imizu, Japan, (2) comparison between the gait motion during training in the rehabilitation center and those during the daily living and (3) long term measurements of activities during daily living, using the ambulatory postural changes and activities monitoring system, in Miyakonojo, Japan.

Before measurement, we acquired permission from the ethical review board at the hospital and the informed consent was obtained in each patient.

IV. Results & Discussion

Fig. 2 shows the recording examples of the pulse rate, the respiration rate and the in-bed time obtained from the under-pillow sensor, in two patients of the female (63 yrs) and the male (78 yrs) with chronic heart failure. The term detecting the contact pressure over the threshold was also shown. The threshold values of the pressure and the applied time could be adaptable because some discussions are reported [16].

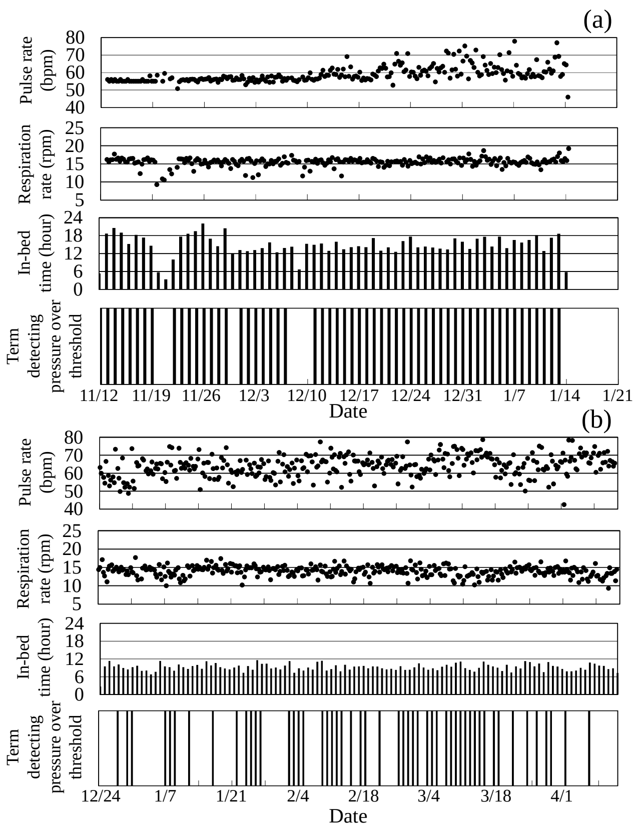

Fig. 2. Recording examples of the pulse and respiration rate and the in-bed time obtained from the under-pillow sensor. Using the sheet-type sensor, the term detecting the contact pressure over the threshold was also shown. The results of two patients of the 63 yrs female (a) and the 78 yrs male (b) with chronic heart failure are shown. The pulse and respiration rate are shown as the average for 6 hours, and the in-bed time is accumulated for one day.

From the results (a), the daily changes of the pulse and respiration rate were successfully monitored. The in-bed time shows that the patient was living in the bed for a long time, therefore the increase of activities were not observed. Also, many detection of the contact pressure were observed (using the threshold of pressure; 32 mmHg and applied time; over 90 minutes, based on the request by the medical and care staffs), showing the need to pay attention to the bedsore. Then, the patient entered to the hospital in January 14th, because the fluctuation and increase of the pulse rate and the long-term in-bed time were detected. On the other hand, in the result (b), the in-bed time was shorter than those obtained in the patient (a) and stable. The detections of the high contact pressure were also a few, showing that the patient could be keeping the good health condition during daily living at the home.

As mentioned above, using the non-conscious healthcare monitoring in the bed, the medical staff could continuously obtain the daily health and sleep condition of the patients with chronic cardiovascular diseases at the home, demonstrating that the system can be useful for less burdensome monitor in the home medical care.

Fig. 3 shows the comparison between the postural changes of the walking during the rehabilitation training and those obtained during daily living at the hospital ward, in the male patient with hemiplegia by stroke (40 yrs). In this figure, the average values of the trunk angle in heel off, the ranges for angle changes of thigh, knee and shank, and the walking speed, are shown. From these results, the angle range of the thigh, knee and shank and the walking speed increased by the rehabilitation. On the other hand, the motion during the daily living at the hospital ward is smaller than those obtained at the rehabilitation room, especially in the initial phase of the rehabilitation term, showing that the patients was walking carefully. But, in the later phase, the differences between the motion obtained at the rehabilitation room and those obtained during daily living are very small. Therefore, it is demonstrated that the data obtained from the system can be useful for the therapist to evaluate whether the patient can also walk during daily living with motion improved by the rehabilitation program.

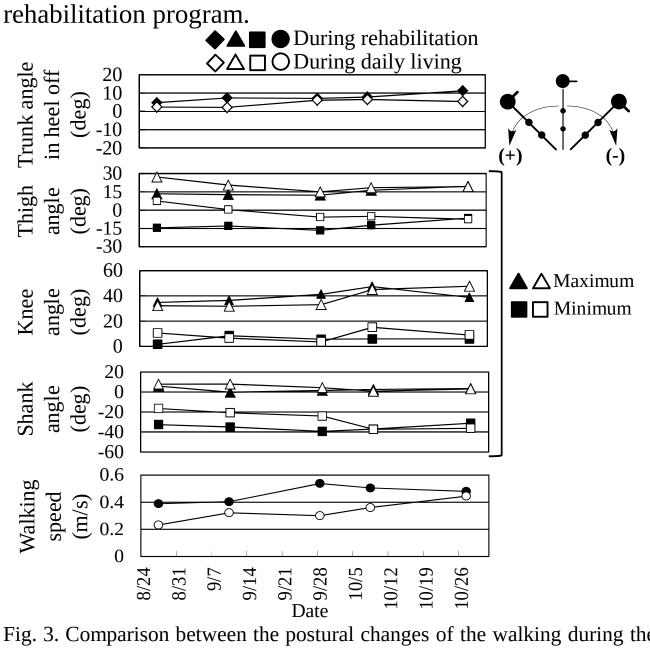

Fig. 3. Comparison between the postural changes of the walking during the rehabilitation training and those obtained during daily living at the hospital ward, in the male patient with hemiplegia by stroke (40 yrs).

Fig. 4 shows the recording results of the activities during daily living from just after leaving the hospital to after three months, in the female patient with hemiplegia by stroke (79 yrs). The activities just before leaving the hospital were also measured during daily living at the hospital ward. The patient had measurement of the postural changes during two hours at morning when the therapist wants to keep and improve subject's activities. The patients had the rehabilitation from just after leaving the hospital and the occupational therapist needed to evaluate its efficacy for patient's daily activities. From these results, the rate of the lying term is short after leaving the hospital, showing that the patients could get out of the bed. While the percentage of the sitting position with rest is high, the walking and the standing positions increased. From these results show the efficacy of the rehabilitation for maintaining this patient's activities and prevention of the bedridden.

As described above, using the ambulatory posture changes monitoring system networked in this study, the therapist could continuously observe the detailed changes of the characteristics of the activities not only in the rehabilitation room, but also during daily living at the hospital ward and patient's own home. It is demonstrated that the quantitative data obtained from the system can be helpful means for evaluating the efficacy of the rehabilitation.

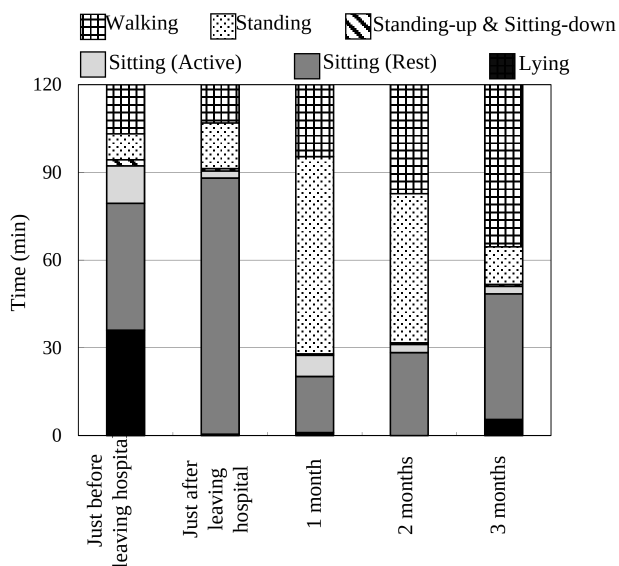

Fig. 4. Recordings of the activities during daily living in the female patient with hemiplegia by stroke (79 yrs). The patient had measurement of the postural changes during two hours at morning when the therapist wants to keep and improve subject's activities.

V. Conclusion

Using the present system, no matter when or where the medical and care staff need the data, the health condition can be obtained using the non-conscious and the ambulatory monitoring and also browsed using a web application. Especially in this study, it is shown that the pulse, the respiration, the posture changes, the activities, and so on, could be measured continuously in the hospital ward, rehabilitation room and subject's own home, in 3 patients with chronic cardiovascular disease or stroke. The results demonstrated that the system appears useful for the ubiquitous healthcare monitoring at not only medical facility, but also subject's own home.

Further investigations will be needed such as availability of measurements by the monitor in the toilet and the bathtub and the analysis method for the sheet-type contact pressure sensor to prevent the bedsore, through the use of the hospital and measurements at ordinary home.

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