Monitoring System of Body Movements for Bedridden Elderly

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Abstract: In this paper we propose a system to detect physical behavior of the elderly under bedridden status. This system is used to prevent those elderly from falling down and being wounded. Basic idea of our approach is to measure the body movements of the elderly using the acceleration sensor. Based on the data measured, dangerous actions of the elderly are extracted and warning signals to the caseworkers are generated via wireless signals. A feature of the system is that the senor part is compactly assembled as a wearable unit. Another feature of the system is that the system adopts a simplified wireless network system. Due to the network capability the system can monitor physical movements of multi-patients. Applicability of the system is now being examined at hospitals.

Keywords: dementia patient, monitoring system, vital sign, warning signal, wireless signal

1. INTRODUCTION

Increase of the aged people is becoming a serious social problem. In the care house for the elderly only a few care workers are working for many aged people. Typically in the nighttime care workers are too busy to deal with various kinds of tasks, since only two or three care workers are staying at night. Many of the care workers are doing their best but are too tired. One serious problem at care-houses is the injury of the aged caused by slipping and falling down on the floor. Once they broke their legs and feet, it is not easy for them to recover sooner. Typically in the case of dementia patient, they easily forget and neglect the request not to leave the bed alone by the caregiver. One simple answer to protect such cases is to fasten the patient onto the bed. But such kind of treatment means neglecting the human right of the patient. Touch sensors and pressure sensor is proposed to detect the escape or wake up motions of patient from the bed. But what required by the care workers is some technique to detect body movements of the patient and forecast occurrence of the risky actions of the patients. Of course, forecasting the risky actions with reliability is not easy matters. But smart care workers say every elderly represents individual physical behaviors. They also says an alert signal can be generated before the risky event occurs by preparing individual criterion for each elderly. Already some related researches are achieved, where techniques to measure vital sighs, like sleeping stages, heartbeat, respiration and snore [1], [2], [3], [4]. Image processing is also one technique to measure such sighs, but the technique is not preferred because of the violation of the privacy. Furthermore, the image processing costs a lot [5].

In this paper a monitoring system is proposed which measures body movements of the bedridden patient. The data measured is used to evaluate the current physical status of the patient and the possibility of risky actions. Considering practical application, the wearble sensor unit is compactly achieved employing a two-dimensional acceleration sensor, a one-chip computer and a wireless communication module. Due to the introduction of the simplified wireless network system, the system is applicable to the multi-user condition. The proposed system can recognize some kinds of physical movements like deep sleeping, a light sleeping, walking, standing up, slipping, falling down and jumping up. Furthermore, based on the criterion about the time sequences of these physical movement actions, the sensor sends an alert signal to care workers. The care workers considering the features of the physical behavior determine the criterion. The proposed system is now under examination at hospitals.

2. SYSTEM CINFIGURATION

A system configuration is shown in Fig.1 where patients are wearing sensor units on their chest. On the sensor unit, an acceleration sensor (ADXL202: Analog Device Co. Ltd.), a one-chip CPU (PIC16F84A) and a wireless communication module (iTRX315: itec Co.Ltd.) are implemented in a compact body as shown in Fig.2. The acceleration sensor detects two-dimensional acceleration. Of course, since the sensor detects the acceleration caused by the gravity, the sensor gives information about the posture of the sensor. Therefore, if a patient wears the sensor on his chest, the physical behavior or posture of the patient can be readily detected by the data obtained. A compact wireless communication module on every sensor unit enables to communicate with the master computer. Furthermore, by introducing an original communication protocol, every unit can communicate with each other. In each sensor unit, individual criterion is implemented considering the each patient's situation. Based on the each criterion, the one-chip computer recognized the risky condition of the patient. Once the one-chip computer recognizes the situation of the patient is dangerous, it sends the risky condition to the master computer.

It should be noticed that the sensor unit could detect extraordinary body movements like gastric spasm or spasmodic asthma as well.

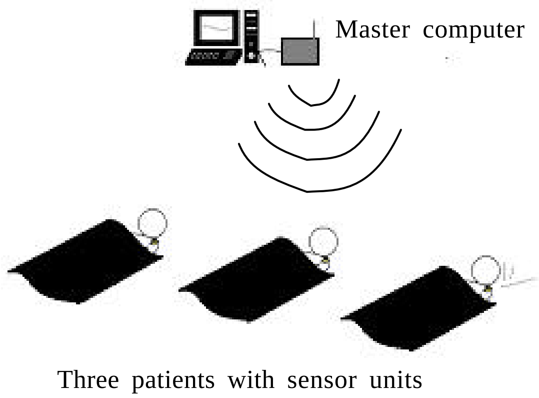

Fig.1 System configuration

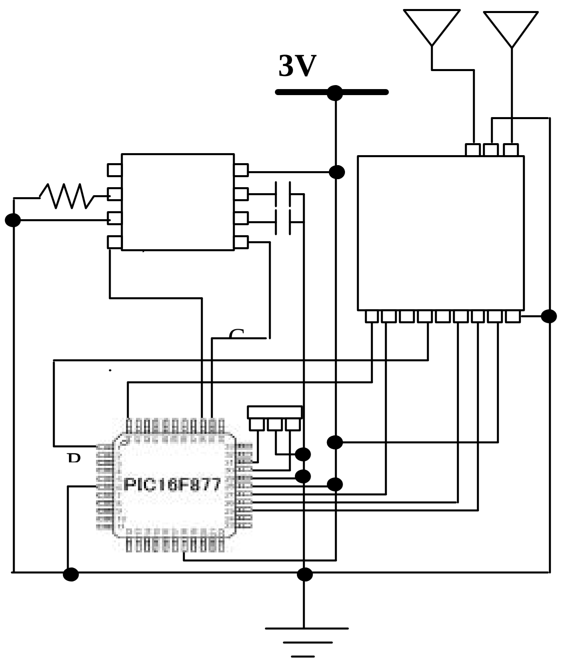

Fig.2 Electric circuit for sensor unit

2. NETWORK SYTEM

In the proposed system an original network protocol is introduced. The basic idea of the protocol is that every communication module communicates with each other synchronizing with the base synchronous signal emitted by the master computer. A feature of our protocol is that even if a sensor unit cannot detect the base synchronous signal emitted by the master computer, another sensor unit that can detect the base synchronous signal acts as an auxiliary master computer. This feature provides us a great benefit under the situation that only low power communication system is available.

Suppose the base synchronous signal can be detected in the range of sensor unit 1 to 5 as shown in Fig.3. And sensor unit 6 is out of the range. As everyone notice the master computer can recognize that sensor units 1 to 5 are in the accessible range and the sensor unit 6 is out of the range. In this situation, the master computer asks every sensor unit if some unit can access the sensor unit 6. After that, each sensor unit tries to communicate with sensor unit 6 sequentially. If one of the sensor units is able to communicate with the sensor unit 6, the sensor acts as an auxiliary master computer for the sensor unit 6. Thereafter, the sensor unit can communicate with the master computer via the auxiliary master computer. This means that even if the maximum accessible range of the communication module is less than 10 meters, by introducing relaying sensor units the accessible range can be expanded as far as we like. Therefore, our proposed system can be applicable to a hospital or nursing facilities even if only low power wireless communication is available. This feature is important since in most of medical facilities only low power wireless communication is allowed. Suppose this network system is realized in a nursing facility. Using this network features, we can detect the position of the patient in the facilities or detect the absence of the patient.

In the sensor unit consumption of the electricity needs to be suppressed since the compact battery is indispensable for comfortable wearable sensor unit. Therefore, the protocol of the communication was determined.

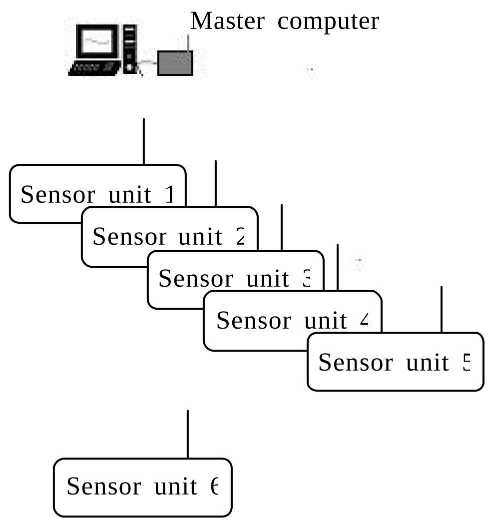

Fig.3 Sensor units and master computer

3. EXPERIMENT

Every components of the sensor unit could be realized in a compact body as shown in Fig.4. The reachable range of each wireless transmitter was around 10m.

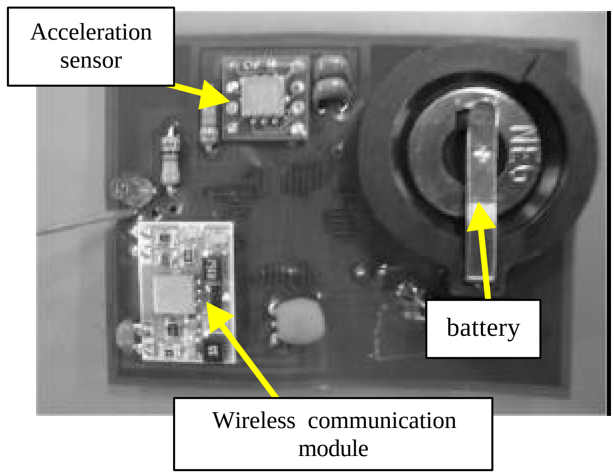

Fig.4 Arrangement of components in the sensor unit

This sensor is attached to an examinee to check the feasibility to recognize current status of body movements. An examinee wearing the sensor on his chest is requested to (1) lie on the bed, (2) roll over, (3) wake up and (4) walk around the bed. During the above body movements, the sensor measured the acceleration. Fig.5 shows the acceleration data toward the foot direction of the examinee. Fig.6 shows the acceleration data toward the leftward of the examinee.

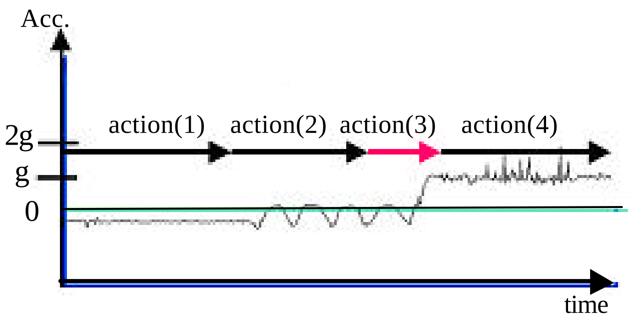

Fig.5 Sensor signal toward foot direction

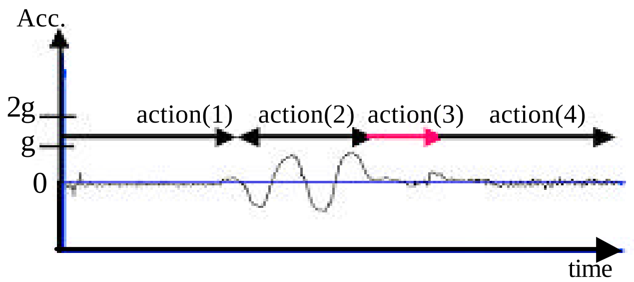

Fig.6 Sensor signal toward leftward

Corresponding actions are shown in Fig.7. During the period of the action (1), where the examinee lies on the bed, the acceleration toward foot direction was negative. This means the sensor unit on the chest inclined slightly upward. During the period of the action (2), the examinee repeated roll over twice from rightward and leftward. During the period of the action (3), because of wake up action the acceleration toward the foot direction increased till around 1.0g. During the period of walking around the acceleration toward the foot direction fluctuated around 1.0g.

4. ALGORITHM TO RECOGNIZE BODY STATUS

Denote the acceleration toward the foot direction as A_F, and the acceleration toward the leftward as A_L. From the data obtained in section 3, a simple criterion to recognize current body status becomes as follows.

(Status 1: Lying on the bed) when A_F is around zero.

(Status2: Rolling over) when A_F is around zero and A_L is fluctuating.

(Status3: Waking up) when A_F is increasing up to 1.0g.

(Status4: Walking) when A_F is fluctuating around 1.0g.

In order to prevent the bedridden elderly from falling down and being wounded, another criterion to determine degrees of risk can be proposed as follows.

(3rd degree: risky level) when impulsive behaviors of the acceleration is detected.

(2nd degree: nearly risky) when frequent fluctuations of the acceleration are detected.

(1st degree: slightly risky:) when different pattern of the time sequences of the acceleration fluctuations are detected.

Fig.7 Sequences of actions

The above criterion comes from one idea that before the risky action occurs some specified body movements' occur.

The criterion should be determined based on the behavior of the elderly.

5. DISCUSSIONS

We built a prototype composed of one master computer and three sensor units. At every one second the master computer checked accessibility of three sensor units. And at every one second, every sensor unit responded that the sensor unit was accessible with the current body status. In case one sensor unit was not accessible by the master computer, the accessible sensor unit acted as an auxiliary master computer. In case that one sensor is not accessible with any other sensor unit and the master computer, the master computer could recognize the situation.

4. CONCLUSIONS

We developed a monitoring system of physical behavior of the elderly under bedridden condition. The sensor can b e effectively applicable to suppress the number of the accidents caused by the slipping and falling down on the floor. The system can be readily connected to the Internet system. Due to the developing ability of Internet, our system can b e

expanded to more advanced system like remote care of the p atients in the far place. Furthermore, patients could be cared s afely in the care house even if the caseworkers are busy.

We are now testing a prototype system at hospitals in Nagasaki city. The results of the test will be demonstrated sooner.

REFERENCES

[1] T. Togawa, Home health monitoring, J.Med. Dent. Sci, 45, 151-160, 1998.

[2] B.W.Carlson,et al., Evaluation of a Non-Invasive Respiratory Monitoring system for sleeping subject, Physiol.Meas., 20, 53-63, 1999.

[3] H.Andoh, et.al., Network Health Monitoring System in the Sleep, Proc. SICE Annual Conf.in Sapporo, 1421-1424,2004.

[4] K.WEatanabe,et.al., Estimation of Sleep Stage Based on Heart Rate Fluctuation and Body Movement, Proc. SICE Annual Conf.in Sapporo, 2153-2156,2004.

[5] R. Satoh, et al., Non-contact sensor to detect movement of dementia patient, ICCAS, 2001.