Proposal of Field Oriented Event Messaging System

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***Abstract*— Several kinds of communication systems have been provided to hospitals in recent years. In these network systems, connected terminal equipment is managed and operated on a central console. This means that an operator is needed to do the job. To address this problem, we have proposed and developed a novel event messaging system for hospitals in which a sensor device paired with a mobile terminal reads a Quick Response Code (QR-code) on a display of sensor devices at a patient's bedside. When the device detects a patient is having trouble, it sends event messages to the terminal. The system enables hospital workers to take over the handling of patient monitoring operations by reading the original QR-code on their own mobile terminal.**

Keywords-hospital; communication system; nurse call; patient monitoring system; QR-code.

I. INTRODUCTION

Several kinds of communication systems have been provided to hospitals in recent years. They are roughly classified into call systems and remote patient monitoring systems. The latter are divided into event monitoring and data measuring types, which are sometimes integrated as a comprehensive network system. In Japan for example, Carecom Inc. provides a patient-nurse hotline system [1]. In this system, several kinds of sensor devices are connected to the hotline. One such device is a mat sensor to detect patients leaving their bed [2]. The mat is beside the bed and if a patient steps on it, an alert is sent to a nurse station. Honeywell provides a tracking and localization system integrated with a patient communication system and a call system [3]. General Electric Company (GE) provides many kinds of patient monitoring equipment [4]. They are connected to a central computer server through an intranet in a hospital. This makes it possible for medical professionals to monitor measured data.

In these network systems, connected terminal equipment such as patient monitoring equipment that allows measured data to be accessed is managed and operated on a central console. This means that an operator is needed to do the job, which is not always the case in emergency situations.

To address this problem, we propose a novel event messaging system in which a monitoring terminal by the patient's bedside is connected to a wireless relay unit such as a smartphone or PC. The wireless relay unit is connected to a remote monitoring terminal and a QR-code is read on the latter. This operation can be done at the bedside of a patient. We assume that this operation would be done by a medical worker such as a nurse who has a remote monitoring terminal. When the device detects a patient is having trouble, it sends a message to a remote monitoring terminal. A medical worker who receives the message would go to the monitored patient. We developed a wireless relay unit and a remote monitoring terminal using an Android smartphone. This makes it possible to hand the patient monitoring operation to another worker merely by having the latter read the QR-code on the preceding smartphone. This operation is the same as reading the original QR-code.

We developed two patient monitoring systems that use this messaging system. One monitors cases when intravenous feeding devices are removed from a patient and the other monitors cases when the patient leaves the bed.

After introducing related work, we will describe the concepts of this system in Section III. Practical monitoring systems are introduced in Section IV. Conclusions and future work are described in Section V.

II. RELATED WORKS

Remote monitoring systems for patients have been put to use ever since communication systems for sending messages from monitoring equipment to hospital personnel first started to be used.

One example is the "Risho Catch" system Paramount Bed Inc. has developed [5]. "Risho" means getting out of a bed in Japanese. This system detects when a patient sits up in bed, sits on the side of the bed, or leaves the bed and walks around the room. When this happens, it sends a message to a nurse station through a patient-nurse hotline system. The system structure is shown in Fig. 1.

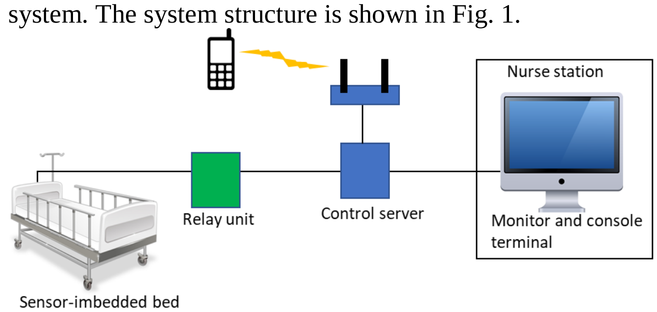


Figure 1. System and network structure of "Risho Catch."

A load sensor unit in the bed is connected to the patient-nurse hotline system through a relay unit located at the patient's bedside. The nurse station has a monitor and console terminal through which messages are sent to mobile devices.

Balaguera et al. evaluated decreasing the number of falls from bed using the SensableCare System [6]. Its architecture is shown in Fig. 2. The sensor pad in the system sends data through a cable to the control box located at the patient's bedside. The control box wirelessly transmits this data to Bluetooth routers located throughout the ward. This information then travels through the hospital network to the dashboard and docking server where the data is analyzed. When an alert is sent to the nurse via an application on his/her mobile phone, it is wirelessly transmitted through the hospital's Wi-Fi network. The patient's condition is monitored on the dashboard terminal.

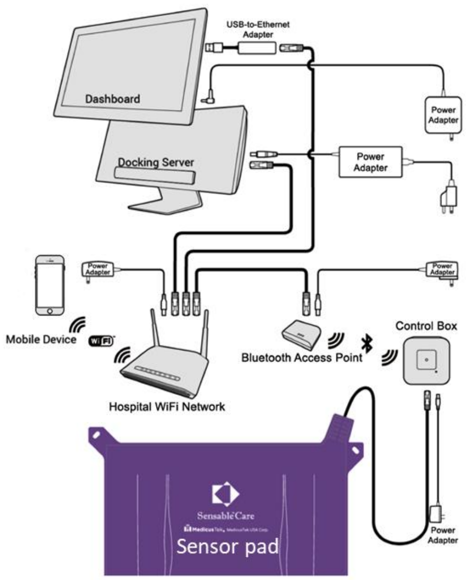


Figure 2. Architecture of the SensableCare System.

In both systems, the console terminal in the nurse station must be connected to the sensor unit, which the terminal must operate. This makes it hard to change monitoring terminals to other patients.

In the early 2000s, there were several remote patient monitoring systems that used the General Packet Radio Service/Wireless Local Area Network (GPRS/WLAN) as the wireless network and the Personal Digital Assistance (PDA) as the mobile device [7]-[10]. In these systems, sensor devices were connected to a monitor terminal or server through a wireless network. Since they were experimental systems, they had no fixed destination address. In recent years, several companies have been providing not only patient remote monitoring devices but also cloud services. GE provides a "GE Health Cloud" system along with many kinds of sensor devices and monitor devices [11]. The cloud manages the connecting of sensor devices to the hospital network and operates them on the console terminal. This scheme maintains a high security level but lacks flexibility. It makes it difficult for medical workers to install and pair sensor devices at the patient's bedside.

III. EVENT MESSAGING SYSTEM

In this paper, we describe the novel messaging system. We designed the system so that:

(1) Medical personnel could install sensor devices.
(2) They could pair the sensor devices with their own mobile terminals at the patient's bedside.
(3) Pairing situations could be monitored from a console terminal.
(4) Mobile terminals belonging to other organizations would be excluded.

Therefore, no operations are performed with the console terminal and monitoring sensors can be easily installed at the patient's bedside. The system configuration is shown in Fig. 3. The system consists of two programs; one is for the wireless relay unit and the other is for the mobile terminal. They collaborate with the Google Firebase Cloud Service (GFB) [12]. The GFB has many functions. This time, we use an authentication functions to exclude non-registration terminals, real time database to manage and monitor a status of pairing, and push messaging function to send notifications.

When a mobile terminal establishes pairing with a wireless relay unit, the ID of the wireless unit (WR-ID) must be entered. We used the QR-code for a worker to enter a WR-ID easily. A WR-ID is inputted merely by reading a QR-code on a display of a wireless relay unit. This system using a QR-code is useful for handing monitoring work to another worker. The handing operation is done by a worker reading a QR-code on the preceding mobile terminal. This QR-code is created from the WR-ID read from the wireless relay unit. In the case shown in Fig. 3, the first message "Mr. P has woken up." was sent to Worker A, and the second message "Mr. P has fallen." was sent to Worker B.

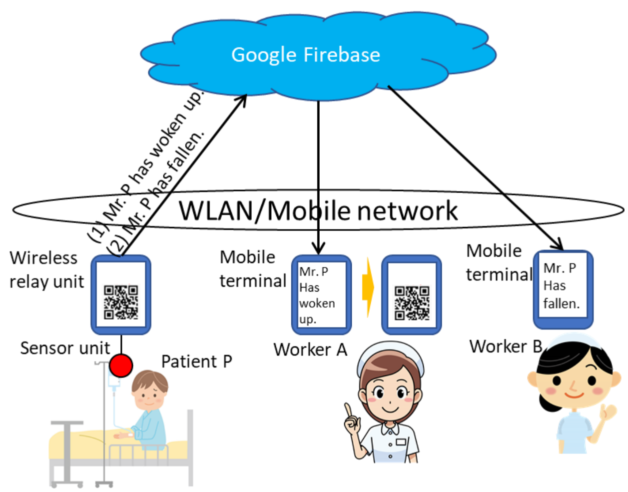


Figure 3. Configuration of the event messaging system.

The sequence to establish pairing between a wireless relay unit and a mobile terminal is shown in Fig. 4. After making a project to develop a messaging program, the GFB sends the Project code and Software Development Kit (Google-service. jason) to a developing PC (D. PC). These are installed to the wireless relay unit program and mobile terminal program. The wireless relay unit program creates a QR-code from the wireless relay ID (WR-ID). This is named by a developer or a user and is unique within an organization such as a hospital. When the mobile terminal program first accesses the GFB, a terminal ID (T-ID) is sent from the GFB. The mobile terminal program reads a QR-code on a wireless relay unit and sends the MT-ID and WR-ID to the GFB. The GFB makes a pairing between a wireless relay unit and a mobile terminal based on the Key. When a sensor device detects a change of state, the wireless relay unit of the sensor device sends a message to the GFB. The GFB then pushes the message to a paired mobile terminal.

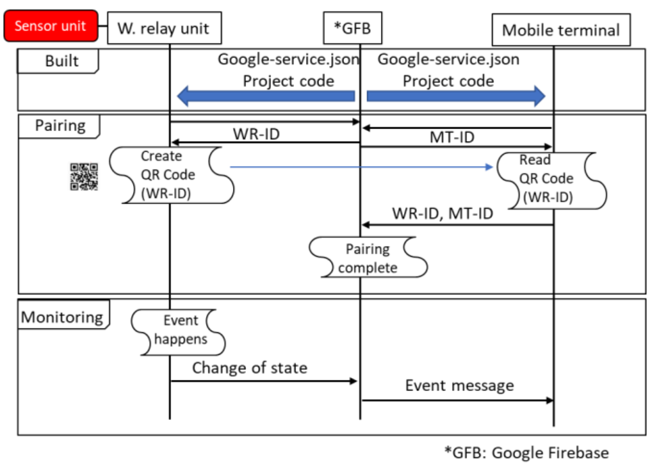


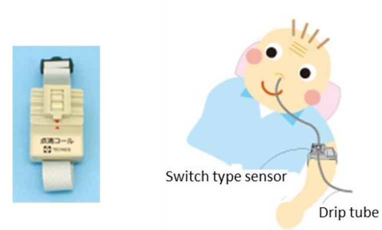
Figure 4. Sequence flow of pairing and monitoring.

IV. Monitoring Application

We developed two monitoring applications that adopt the proposed event messaging system. One is a intravenous drip monitoring application; the other is a fall monitoring application. We will describe their details in this section.

A. *Intravenous drip monitoring*

Some cognitive impairment patients sometimes remove an intravenous drip set by themselves. One existing intravenous drip monitoring system uses a switch type sensor that fastens a drip tube to detect when a drip set is removed as shown in Fig. 5 [14]. In case of a "Tenteki call", if a patient removes the switch type sensor together with the drip set, the sensor cannot detect the removal.



(a) Switch type sensor. (b) Example of use.

Figure 5. "Tenteki" call (Japanese), Technos Japan Co., Ltd.

We use a magnetic patch and a wireless magnetic sensor to remove a drip set, as shown in Fig. 6. The magnet is fastened to the body with an adhesive film in a place such as an arm. An intravenous drip tube is also fastened to the wireless magnetic sensor and the sensor is fastened to a magnetic patch with a medical fixing film. When a patient removes an intravenous drip set, the sensor is also removed from the body part. However, since the magnetic patch is fastened to the body part with an adhesive film, it must remain on the body part.

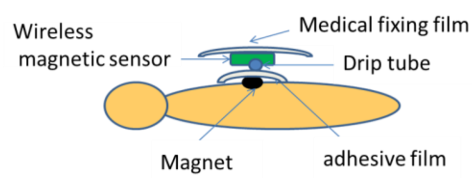


Figure 6. Structure

We developed the prototype system shown in Fig. 7. We used the STEVAL-WESU1 [15] developed by STMicroelectronics as the wireless magnetic sensor (see Fig. 7 (a)), and an Android smartphone as the wireless relay unit and mobile terminal. The muscle stiffness obtained by equipment manufactured by PIP Co., Ltd. was used as the magnetic patch [16] (see Fig. 7 (b)). In this prototype system, the program for detecting removal is integrated with the wireless relay program.

While a magnetic sensor is on a magnetic patch (see Fig. 7 (c)), the measured magnetic strength is bigger than the decision level (see Fig. 7 (e)). When the magnetic sensor is removed (see Fig. 7 (d)), the measured magnetic strength is less than the decision level; the detecting program has determined that an intravenous drip set has been removed (see Fig. 7 (f)). The wireless relay program sends a message "Yoshida's tube has been removed." That message is displayed on the mobile terminal (see Fig. 7 (g)).

B. *Fall monitoring*

Elderly people, especially cognitive impairment patients, have an increased risk of falling and consequently injuring themselves. They need to be prevented from falling to maintain their health because injuries from falling are a major reason for them to prolong their staying in a hospital.

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(a) Magnetic sensor and attached tube.

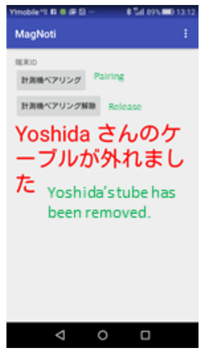
(b) Magnetic patch on an arm.

(c) Magnetic sensor on a magnetic patch.

(d) A removed drip set.

(e) W. R. display :monitoring

(f) W. R. display : detecting tube removing



(g) M. T. display : receiving a message

Figure 7. Drip monitoring system prototype.

Therefore, many kinds of fall prevention systems have been developed. Most of them are classified into three schemes. The first type uses a mat type sensor like the systems described in Section II, the second one uses load sensors that are mounted in the legs of a bed, and the third one uses a camera. We developed a fall prevention system in which MS-KINECT was used. This is one of the third types. M. J. Rantz developed a fall detection system that uses MS-KINECT [17]. A medical worker monitors and judges whether a patient falls through the depth image of a patient on a monitor display.

On the other hand, our developed system detects whether a patient in a bed wakes up, sits up, stands up, or falls on the floor with a skeleton image of the patient. The detecting algorithms are as follows;

(1) Waking up: detecting that the head's height position is higher than the judging height 1.
(2) Sitting up: detecting both shoulders and a spine base angle of 25 or more degrees.
(3) Standing up: detecting the head, both shoulders and both hips, and a head is higher than the judging height 2.
(4) Falling down: detecting that the head's height position is lower than the judging height 3.

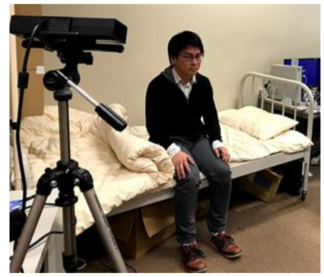
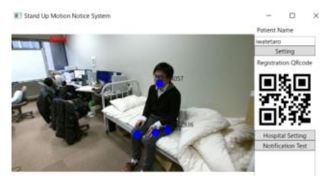


Figure 8. Experimental image.

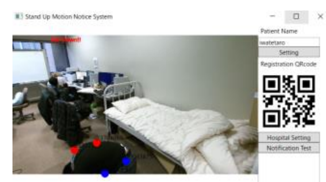
We experimentally tested whether the developed system can detect the four conditions given above. The MS KINECT was positioned diagonally in front of the bed so that the front of the patient could be observed as shown in Fig. 8. Experimental results are shown in Fig. 9. Since MS-KINECT works on a PC, the sensor device program that detects patient conditions with MS-KINECT and the wireless relay unit program are combined on a PC. Monitoring images of participants as patients and the QR-code for pairing are shown on the PC display.

(1) Waking up

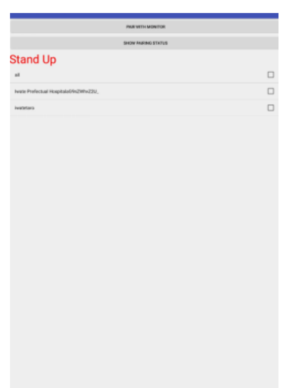


(2) Sitting up

(3) Standing up



(4) Falling down



(5) Screenshot of a mobile terminal that detects a "standing up" message

Figure 9. Experimental results for patient monitoring.

The developed system can detect four conditions for a patient. With it, a mobile terminal receives a “standing up” message sent from a wireless relay unit. However, the system sometimes makes mistakes in detecting conditions. Accordingly, we plan to improve our algorithms so that detection accuracy will be increased. We should also mention that a patient using this experimental system is presented with color images. We plan to change these color images to depth images to maintain a patient’s privacy.

V. CONCLUSION AND FUTURE WORK

We have developed a novel event messaging system in which a sensor device is paired with a mobile terminal by reading a QR-code on a display of sensor devices. Therefore, it is possible to pair them at the bedside of a patient. When the sensor devices detect a patient is having trouble, event messages are sent to a mobile terminal. We also developed a drip monitoring system and a fall monitoring system for use with the proposed event messaging system. The systems have not yet been used in hospitals. Accordingly, as a subject for future work, we plan to improve them and have them evaluated in hospitals.

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