TOWARD INTELLIGENT NURSING ENVIRONMENT BY USING WEARABLE SENSOR SYSTEM

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Abstract- **The constant hard work of providing nursing care, including handling emergencies, often causes medical accidents in hospitals. We have prototyped a wearable auto-event-recording system for medical nursing in order to capture the events that cannot be overlooked in analyzing such accidents. Our system consists of wearable sensors that record the footsteps and the posture tilt of the nurse in addition to the voice. We conducted experiments, and the results show that, without disturbing nurses' work, our sensors can record data and reconstruct nursing histories, including the important events that cannot be overlooked for analyzing medical accidents. In this paper, we show the results of sensor data analysis comparing a nurse's data taken in AM hours with those in the PM hours in order to study the effect of her fatigue on her motion. Also, we discuss on the possibility of detecting the nurse's fatigue by using our sensor system.**

Keywords **- wearable, nursing, incident, accident**

I. INTRODUCTION

One of the most urgent issues in hospitals is to construct an intelligent nursing environment to prevent medical accidents, since they damage the reputation of the hospital's reliability and thus its business success. Whenever an accident happens in a hospital, the analysis of the root cause depends on such sources as the doctors' and nurses' records. Lately, several intelligent environments have been introduced, where nurses input bar-code data into a special PDA that is infection-proof [1]. However, carrying and operating the PDA interferes with nursing duties such as lifting patients and carrying meals to patients. The PDA, therefore, is not user-friendly for nurses. In order to provide a user-friendly device for nurses, nurses must be free from carrying the device during their nursing duties, and their nursing cares should not be impeded by interacting with the device while inputting data. In addition, the device must not miss significant events that might be related to incident or accident cases, even if nurses fail to input the data of these events. In order to meet these requirements, we have developed wearable sensors attached to a nurse rather than using a PDA [2]. Our system records the footsteps and the posture tilt of the nurse in addition to the voice data. We adopt voice recording to obtain more detailed information on the nursing care, such as patient's name and names of other involved medical staff, by using the speech recognition [3]. A non-touch switch is introduced to change between recording time and privacy time while gathering voice data. Consequently, without disturbing nurses' work, our sensors can record data and reconstruct nursing histories, including the important events that are typically never recorded on written records [2]. In this paper, we focus on a sensor data analysis comparing a day-shift nurse's data taken in AM (the 7:00 to noon period) with those taken in PM (the noon to 16:00 period) in order to study the effect of her fatigue on her motion. Then, we discuss the possibility of detecting the nurse's fatigue by using our sensor system, since nurse fatigue is one of the possible causes of the medical accidents.

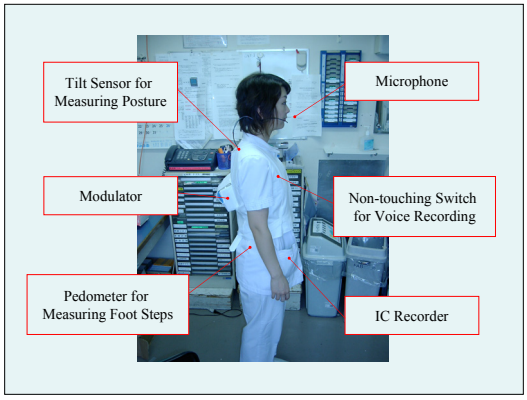

Fig. 1. Overview of wearable sensor system

II. OVERVIEW OF WEARABLE SENSOR SYSTEM

The motion of the nurse indicates the specific pattern of each type of nursing care, so we assume that it is possible to identify job units of nursing care by analyzing the features of the number of footsteps and the posture tilt of the nurse. We also assume that these patterns reflect the nurse's physical condition such as fatigue. In order to check the nurse's physical condition, it is desirable to utilize biomedical data such as heart rate, blood pressure, etc. However, the sensors used to measure these data impede the nurse's motion. In a real nursing environment, we cannot attach sensors to nurses as extensively as previous research efforts did [4]. Fig. 1 shows a nurse wearing our sensors. All sensor data are converted to sound by the modulator in order to record these data in an IC recorder. The IC recorder is able to continuously record sound for more than five hours, and it is easy for nurses to handle. Nurses only need to push the REC button before recording, and when it runs out of storage, they only need to replace it with a new one to continue recording. Of course, it would be advantageous to connect our wearable sensors via wireless LAN and to process data in real time, but there are many issues involved in using radio signals in a hospital. Therefore, as the first step in our approach, we do not use a wireless LAN. The sound data in the IC recorder is uploaded to a PC. Then, the software separates these data into the footsteps, the posture tilts and voice data by FFT.

III. EXPERIMENT / DISCUSSION

We conducted our experiment at Tokyo Women's Medical University (TWMU) Hospital. The subjects were five nurses in the general ward and one nurse in the ICU. They performed their normal duties for a day (from 7:00 to 16:00) while wearing our wearable sensors. In order to evaluate the proposed sensor system, we have already reported that by analyzing the feature vectors of the

footsteps and the posture tilt of the general ward nurses, their job units could be statistically categorized into at least four groups [2].

Then, in order to analyze the effect of fatigue from the feature vectors of the sensor data, we compared the feature vectors in AM and those in PM, because it is quite natural that a nurse would get much tired in PM than in AM. We also confirmed that nurses subjectively felt more fatigue in PM than in AM. Therefore, it might be possible that this fatigue influences a nurse's motion. For this analysis, it is necessary to compare samples of the same job that were performed for the same patient by the same nurse in order to eliminate the effects of job type, patient and nurse. We used the ICU nurse's data because, in the TWMU Hospital, the ICU nurse is usually assigned as the primary nurse to one or two patients, while the general ward nurse is assigned as the primary nurse to five or six patients. Consequently, the ICU nurse has more chances to perform the same care for the same patient than the general ward nurse in a single day. From the ICU nurse's voice data, three main types of jobs were identified as shown below, and the group means of these categories were statistically different from each other. Fig. 2 shows the results of principle component analysis.

I. Writing Record
II. Communication
III. Taking Care of Patient in bed

There were not enough samples of Type I for comparing AM and PM samples. Then, we analyzed the Type II and III samples. Fig. 3 shows the results of principle component analysis. According to Fig. 3, it is obvious that the AM and PM data were separated by the 1st principle component, and their group means were statistically different. In the 1st principle component, the average of the posture tilt (positive) and the variance of the posture tilt (negative) are dominant. It can be intuitively understood that the posture tilt would increase and the frequency of changing it would decrease by fatigue. This suggests that by monitoring the feature vector, the nurse's fatigue can be detected. However, the number of footsteps (positive) was also dominant in the 1st principle component, and we do not yet have an explanation for the effect of this factor.

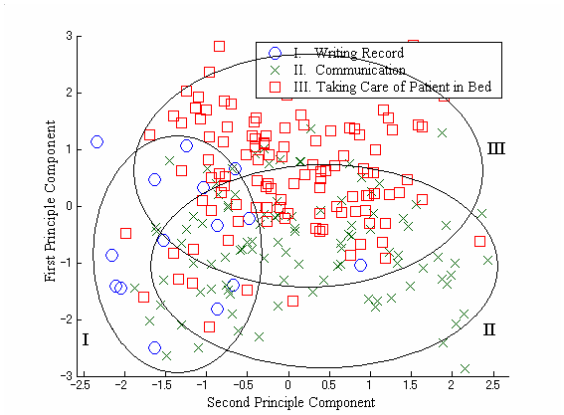

Fig. 2. Result of principle component analysis of ICU nurse comparing types of jobs

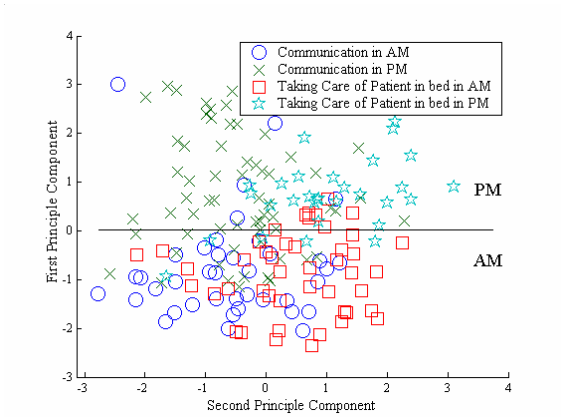

Fig. 3. Result of principle component analysis of ICU nurse comparing AM and PM data

IV. Conclusions

We introduced a wearable sensor system in order to capture the important events related to medical accidents. From the results of our experiment in an actual nursing environment, an ICU nurse's job units could be classified into three categories by using the feature vector analysis of the sensor data. Furthermore, we found that the feature vectors in the AM hours and those in the PM hours for the same kind of job were statistically different. We plan to use this result to detect nurse fatigue, but we need more samples for further analysis and study. For future work, in order to establish an intelligent nursing environment where our system detects possible dangers of the medical accidents and alert nurses proactively, our sensors will be connected via a wireless LAN to process sensor data in real time and return it as feedback to the nurse. Accordingly, we are discussing the possibility of using a wireless LAN in a ward with hospital staff. Also, we are designing a ubiquitous sensor system that cooperates with our wearable sensors in order to capture the significant events that might lead to the medical accidents throughout a hospital.

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