R&D

Feasibility Experiments for an RFID and Sensor Enabled Medical Safety System

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Abstract

In the field of medical care, the safety check procedure and the collection of medical incidents are always required, even in cases of emergency. The authors have developed a medical information system utilizing RFID and sensors, and have confirmed via experimentation that the system enables safety checks and incident information collection without any burden on medical staffs.

Keywords

RFID, IC tag, sensor tag, medical care, safety check, incident, traceability

1. Introduction

The effective prevention of medical accidents in hospitals is a critical social issue.

In order to prevent medical accidents, it is important to recognize trends of accidents via the collection and analysis of incidents and necessary to eliminate the possible causes. Incidents refer to events that might have led to serious accidents but have not actually resulted in such. A wide range of incidents occurring in medical sites are needed to identify trends of accidents. However, since overwork is already a major problem in the context of medical sites, it is not reasonable to expect medical staffs to efficiently perform the additional task of incidents collection.

We have developed a medical safety system that is more effective and easier to use than that used hitherto. Our system features the capability of collecting incidents related not only to the combination of objects (e.g. the order of medicines and the patients), but also the status of the object (e.g. temperatures of the medicines). This has been achieved by applying previously developed technologies for the advanced utilization of RFID. The experimentation at Akita University Hospital has verified that the developed system can be introduced at actual medical sites.

2. Technologies for the Advanced Utilization of RFID

Since FY2004, NEC has been developing the following two technologies within the framework of a 4-year project entrusted by the Japanese Ministry of Internal Affairs and Communications entitled "R&D on Technologies for the Advanced Utilization of Radio Frequency Identification (RFID)." These are 1) the context composition technology for a linked use between traditional RFIDs that contains only ID information and the advanced RFIDs that incorporate sensing, storage and notification functions, and 2) the IPv6 protocol stack technology for incorporation into advanced RFIDs. NEC has contributed primarily to the advancement of food traceability systems until FY2006 [1]. In FY2007, we have expanded the application of the technologies to the field of medical care.

(1) Context Composition Technology

This technology is used in an environment that features a mixed presence of information sources such as RFIDs, advanced RFIDs and sensors. It synthesizes the status (context) of management targets (objects) from the data collected by the information sources that are located nearby the object. The proximity relationships between the object and information sources are represented in an Association Graph. This graph enables developers to use several service execution triggers for that approaching/leaving the object and information sources and/or changing context of the object.

(2) IPv6 Protocol Stack Technology for Ultra-Small Nodes

This protocol stack enables IPv6 communications via an ultra-small computer such as an advanced RFID by optimizing the memory usage and battery power consumption. It incorporates Proxy Mobile Internet Protocol [2] so that communication is possible even when the advanced RFID is moved across a broad area.

3. Ubiquitous Medical Safety System

This system has been developed to be capable of integrating the information collected from traditional passive RFIDs, advanced tags with an automatic position detection function (position tags), and advanced tags with sensors (sensor tags) in real time. It uses the context composition technology, and extracts the object's context "which object is in which status and in which position at which moment." The extracted information is processed using verifying logic to ensure the validity of "which action is executed how and on whom."

Fig. 1 shows the architecture of the developed system. The information collected from the passive RFIDs and the position tags is managed by the association manager and is used to update the association graph. The information collected from the sensor tags is managed by the data manager and is used to compose the context of the object. The change histories of the association graph are managed so that they may be used in incident analyses.

3.1 Incorporation of Safety Check Processes in Ordinal Work Operations

Based on the knowledge accumulated by Akita University Hospital, we have decided to incorporate a safety check process and an incident collection process into an ordinal work process executed by medical staffs. This incorporation decreases the burden of the medical staffs and guarantees a safety level in an emergency situation.

In the bedside safety control system using RFID [3] introduced by Akita University Hospital, the medical staff carries a Personal Digital Assistant (PDA) with a built-in passive RFID reader in order to read the RFID attached to the drip-bag and the patient's RFID wristband, and confirms the combination of the drip and the patient. If a wrong combination is confirmed, the PDA displays an alarm in order to prevent mistaking an injection.

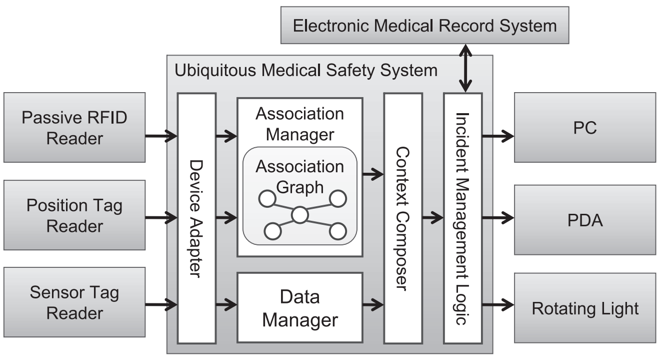

Fig. 1 A ubiquitous medical safety system utilizing context composition technology.

However, an injection may be applied even if staff forget to confirm verification with their PDAs. There is thus still a risk of executing an injection without performing the appropriate safety checks, especially in a case when emergency treatment is required, and such incidents are not automatically recorded when it occurs.

In order to solve this problem, the developed system integrates the information collected from multiple means of input. This strategy enables identification of the actions of the medical staff, executes safety checks in linkages via an electronic medical record system and distributes the results to an appropriately selected means of output. The experiments carried out at Akita University Hospital have shown that the developed system has improved the work efficiency compared to the traditional operations.

3.2 Collection and Utilization of Incidents Related to the Status of Objects

Traditionally medical safety systems have secured "appropriateness of combination" between human and object using either passive RFIDs or position tags.

The newly developed system additionally uses sensor tags in order to also secure the "appropriateness of status" of objects.

Moreover, the history of changes in the position and status of objects can be mapped on the flow-line charts of the objects. When the flow-line charts of multiple objects are overlapped, it is possible to identify the locations where specific events tend to occur (e.g. places where patients stumble or fall down easily, places where medical devices may collide with each other or are easily dropped, places where inappropriate temperature management procedures, etc.). This strategy will contribute to the discovery of issues that may be hidden in the prevailing procedural environment.

3.3 Use Cases

We have selected five use cases matching the current work flow based on the frequency and importance of medical incident occurrences (**Fig. 2** and **Fig. 3**). Dealing with use cases

Information Source	Management Target				
	Human		Object		
	Patient	Medical Staff	Drip	Medical Equipment	Blood Product
Passive RFID	✔	✔	✔		
Position Tag	✔	✔		✔	
Acceleration Sensor Tag	✔				
Shock Sensor Tag				✔	
Temperature Sensor Tag					✔

Fig. 2 Devices and objects used in the demonstration experiments.

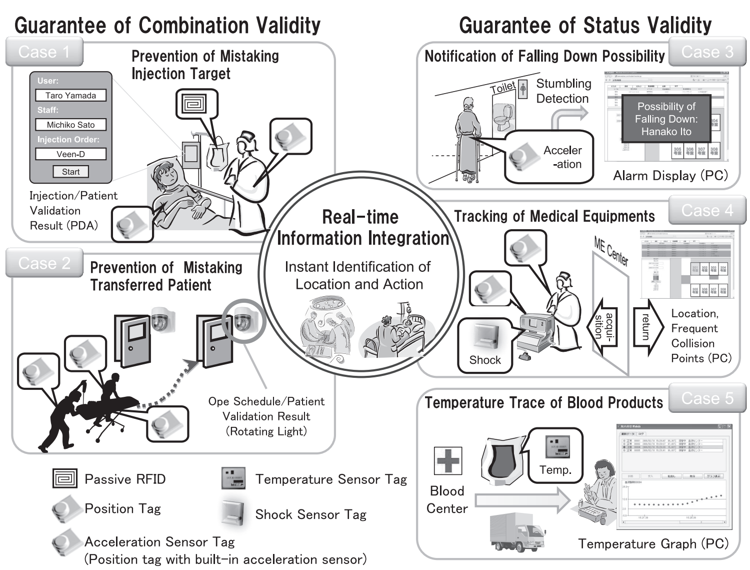

Fig. 3 Use cases adopted for the demonstration experiments.

other than those listed below is also possible by adding the relevant service applications to the system.

(1) Use Cases for Guarantees of Combination Validity

1) Case 1: Prevention of Mistaking an Injection Target at a Bedside

Incidents related to "prescription and administration of medicines" have been reported most frequently [4]. In this use case, we demonstrated that the system displayed whether the combination of the patient and the drip was appropriate when the medical staff and the prepared injection were gathered around the drip stand to be used on a patient. In order to enable safety checks in the natural action of hanging the drip-bag on the stand, a position tag is carried by the staff, and a passive RFID reader and a PDA is installed on the stand. When the staff approaches the stand, the action of simply hanging the drip on the stand causes the PDA to display the result of the correlation between the patient and the drip.

2) Case 2: Prevention of Mistaking a Transferred Patient to an Operation Room

It was after a fatal accident caused by mistaking an operating room that social interest into medical malpractices was aroused in Japan. In this use case, we demonstrated that the patient/operation schedule correlations were evaluated at the moment the patient entered the operating room and the result is displayed using the rotating light installed in the operating room.

(2) Use Cases for Guarantees of Management Target Status Validity

1) Case 3: Notification of a Patient Falling Down Possibility

Falling over occupies more than half the incidents in "care for medical treatment" [4]. Sudden changes in the condition of a patient outside the supervision of medical staff should be noticed promptly. In this use case, an acceleration sensor tag is attached on the waist of a patient. We demonstrated that the system notified to the medical staff the possibility of falling down of the patient and with the location.

2) Case 4: Tracking of Medical Equipments

If the acquisition and return of medical equipments are managed on paper, omissions of entries may occur in emergencies and lead to a problem of missing equipments. Even after equipment is subject to an impact during transport, no one may have noticed it and the device may not be inspected. In this use case, we demonstrated that when the equipment was exited from (or entry into) the medical equipment maintenance room by medical staff, the system recorded who acquired (or returned) the equipment. In addition, with a shock sensor tag attached it becomes possible to record impacts received during transport.

3) Case 5: Temperature Trace of Blood Products During Transport

The blood products prepared and stored at the blood center are transported according to requests from medical institutions. Keeping the temperature of blood products in an appropriate range is important, even during transport. In this use case, we demonstrated that a temperature sensor tag with a built-in IPv6 protocol stack for ultra-small nodes attached to each blood product was monitoring its temperature during transport.

4. Evaluation

We have installed service applications to deal with the above five use cases into the ubiquitous medical safety system and have confirmed in those test fields that the applications improves the tasks of medical staffs. We have also confirmed that the radio wave emitting-devices have not affected the three medical devices (artificial respirator, infusion pump and syringe pump) installed in those test fields.

Work Time Comparison with Existing Systems

Information systems already have existed for the tasks performed in use cases 1 and 4 at Akita University Hospital. In order to evaluate the effect of the newly developed system from the view point of the burden of the medical staff, we compared recorded work times of the new system with those of existing systems and paper operation. As a result, we have confirmed that the newly developed system has achieved the least work time between them in both use cases (**Table**).

In both cases, the work time record was started when the medical staff was at the start point at a distance of 3 meters from the work position and ended when the staff returned to the start point. The measurements were repeated for 10 times.

In the table, "Existing electronic tag" and "Existing barcode" for use case 1 refer to the existing bedside safety control system, and "Existing barcode" for use case 4 refers to the existing medical equipment tracking system. In the case of "Paper operation" for use case 1, the patient told his or her name to the medical staff and the staff then checked the injection prescription. In the case of "Paper operation" for use case 4, the medical staff filled out the acquisition book.

Table The least work time in 10 trials.

		Experimental system	Existing electronic tag	Existing barcode	Paper operation
Case 1	Injection control	21.2 sec. (23.3 sec.)	31.2 sec. (38.3 sec.)	42.8 sec. (54.2 sec.)	28.7 sec. (36.8 sec.)
Case 4	Device acquisition	17.3 sec. (18.4 sec.)	N/A	22.6 sec. (23.7 sec.)	26.6 sec. (29.7 sec.)
	Device return	14.5 sec. (15.1 sec.)	N/A	20.4 sec. (21.3 sec.)	21.7 sec. (22.7 sec.)

* Figures inside ( ) indicate average work time.

5. Conclusion

We have developed a new medical safety management solution by applying an RFID utilization technology and have verified via experimentation that it can be effectively introduced at actual medical sites.

We will continue R&D aimed at fusion with other medical information systems such as the electronic medical record system and will promote the results as suitable infrastructures for the utilization of RFID and sensors inside and outside of hospitals.

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