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 RFIDTag that contains only ID information and the advanced RFIDTag that incorporate sensing, storage and notification functions, and 2) the IPv6 protocol stack technology for incorporation into advanced RFIDTag. NEC has contributed primarily to the advancement of food traceability systems until FY2006. 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 RFIDTag, advanced RFIDTag 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 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 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.

However, an injection may be applied even if staff forgets 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
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. 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”. 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...
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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References
1) NTT Communications, etc., “DENSHI TAGU NO KODO RIKATSUYO NI KANSURU GAIDOBUKKU - INTAFESU SHIYOSHO Draft ver.1.0” (Guidebook on Advanced Use of Electronic Tags - Interface Specifications Draft Ver. 1.0)” July 2007
http://www.ubiquitous-forum.jp/documents/tag_guidebook/guidebook_if_draft1.0.pdf
3) KONDO Katsuyuki: “IRYO JOHO SISUTEMU TO IC TAGU NO KATSUYO: <TOKUSHU> IC TAGU TO IRYO KANKYO (Medical Information System and Use of IC Tags (in an IC Tag and Medical Information environment),)” Journal of Information Processing, Vol. 48, No. 4 (20070415), pp.338-343, April 2007,
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