BOOK MANAGEMENT SYSTEM USING VARIOUS SENSOR NETWORK

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ABSTRACT

This paper proposes a system for managing users and books in a room using various sensors. The proposed system consists of an RFID (Radio Frequency Identification) sensor, a non-contact IC card sensor and camera sensors. When a user enters a room, he/she is identified using IC card, and a tracking process by camera sensors starts at the same time of the identification. Users in the room are tracked by multiple camera sensors. Each book has an RFID tag, and an RFID sensor is attached to a bookshelf. An existence of the books is observed by the RFID sensor. In addition, a user who takes out or returns the book can be recognized by the camera sensors. A prototype was implemented, and the system has demonstrated that the users and books were observed without cumbersome procedures.
Keywords: Book management, Sensor network, RFID, IC card, Camera sensors

1. INTRODUCTION

Books in existing libraries are managed manually by librarians when the books are taken out or returned. The works are expensive labor for the librarians, and the collections are missing easily. It is highly desirable to manage the collections without increasing the works of the librarians.

To manage the books certainly, several book management systems have been proposed. A Radio Frequency Identification (RFID) technology is one common technology for managing books automatically [1][2]. Each book has a unique RFID tag and an RFID tag reader is installed at a counter or gates. The book is checked at the counter or the gates. Such RFID systems have been introduced in many libraries [3]. However, the conventional systems check only the books. And the books are checked only when they have been taken out or brought into the library at the counter or the gates. To check the books more certainly, it is desirable that people in a room is observed at the same time in addition to the books, and the books are observed continuously while the books are in the room.

We propose a novel book management system without any procedures for checking out books. The proposed system consists of non-contact IC card sensors and camera sensors in addition to the RFID sensor (Figure 1). A user has an IC card corresponding to the unique ID. The user is identified using the IC card when the user enters a room. An RFID sensor is attached to each bookshelf. When a displacement of the books is detected by the RFID sensor, the RFID node refers who is in front of the bookshelf to the camera sensor. The books are observed continuously in the proposed system. Therefore, books are managed more certainly. A framework of the proposed system is described in this paper. In addition, a prototype is implemented and demonstrated in multiple situations.

This research is partly supported by 21st Century Center Of Excellence (COE) Program "Ubiquitous Networked Media Computing" of Nara Institute of Science and Technology (NAIST).

2. BOOK MANAGEMENT SYSTEM USING RFID

Several methods have been proposed for managing books automatically and certainly. RFID is one of the common technologies for managing books in libraries [1][2][4]. Each book has a unique RFID tag, and an RFID sensor is placed at a checkout counter or gates. The books are checked automatically when a user goes through the counter or the gates. Because the conventional systems only check the books, a user who takes out and returns books should be checked using other technologies. In addition, the books are checked only when they have been taken out or brought into the library. It implies that the books are checked manually by the librarians, therefore the conventional methods would not reduce the labor for the librarians completely. And it is difficult that the books are managed strictly using the conventional methods. To manage the books more certainly in libraries, we propose a book management system to fulfill following requirements using an IC card sensor and camera sensors in addition to the RFID sensor:

- Users are identified automatically and only one; the identified information are used in the other actions.
- Books are checked continuously while in a room, not only checked at gates,
- Displacements of the books are observed without any procedures for users and librarians.

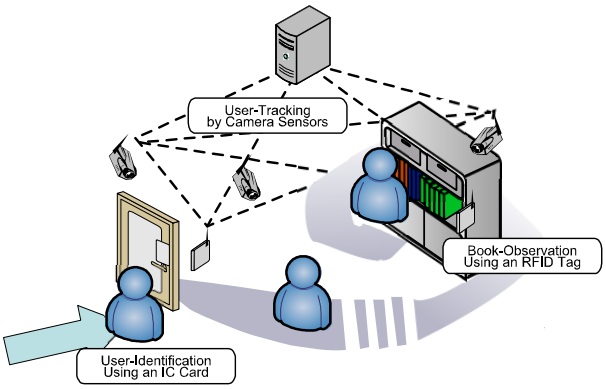
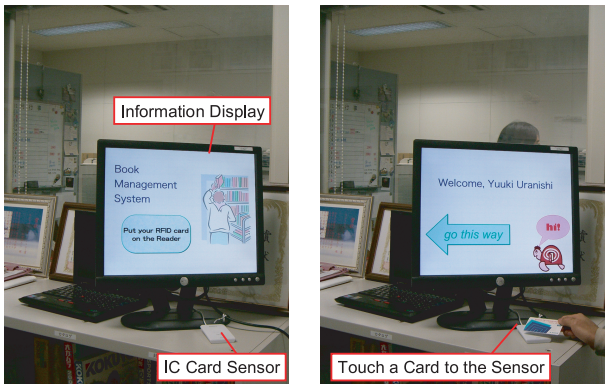


Fig. 1. An overview of the proposed system. The proposed system consists of an IC node, an RFID node and camera nodes. Each user has an IC card to identification, and each book has an RFID tag. Users are tracked and books are managed automatically, and user can take out or return books without procedures.



(a) (b)

Fig. 2. A configuration example of an IC card sensor node. The sensor is placed nearby the entrance for controlling admittance. (a) The IC node consists of an IC card sensor, a computer and a display to show information. (b) When the user touches the IC card to the sensor, the system identifies and admits the user.

3. PROPOSED SYSTEM

Figure 1 shows an overview of the proposed system. The system consists of three kinds of nodes: an IC node, a camera node and an RFID node. Each node contains a sensor and a computer basically, and they form a sensor network. Processing on each node of the system is described below.

3.1. User Identification Using IC Card Sensors

Nowadays, non-contact IC card is widely used for electronic identification, such as an admittance control system. In the proposed system, the non-contact IC card sensor is used to identify users when the users enter a room. Figure 2 shows an example of the IC node. The IC node consists of a display in addition to an IC card sensor and a computer as shown in Fig. 2 (a). The user is identified by touching the user's IC card to the sensor (Fig. 2 (b)).

3.2. User Tracking Using Camera Sensors

Users in the room are tracked using camera nodes. A background subtraction method is used to track the users in combination with an inter-frame subtraction.

3.2.1. Extract and track user regions

The users are tracked using camera nodes, and trajectories of the users are recorded. Figure 3 shows an example of tracking and estimating the position of the users. The node starts tracking when the user is identified by the IC card sensor. A background subtraction method is employed to extract user regions in combination with an inter-frame subtraction. A region of a user is extracted using background subtraction and labeled. And a gravity of the user region is tracked using a nearest neighbor method.

3.2.2. Update a background image

To adapt the tracking method to variable environment, a background image is updated dynamically. The captured image is divided into two regions: a region including a moving object, or not. The region including a moving object is extracted using inter-frame subtraction (Fig. 3 (a)). It is assumed that the region not including the moving object is a background region, and the background image is partly updated every frame (Fig. 3 (b)).

3.2.3. Estimate a geometric location of the user

A geometric location of a head of the user in the room is estimated from the extracted region as shown in Fig. 3 (c) and (d). For the estimation of the location, it is assumed that the pixel which has the smallest value of v (e.g. The marked pixel in Fig. 3 (d)) is the top of the head, and the users' height is assumed as a fixed height. Reference points in the room are given at the fixed height point in advance (Fig. 3 (c)). The reference points are projected onto the captured image. The geometric location of the user is estimated by interpolation using the nearest three points on the captured image as shown in Fig. 3 (d).

3.3. Book Observation Using RFID Sensors

RFID nodes are placed to each bookshelf. Figure 4 shows an example of implementation. An RFID sensor is attached to the bookshelf as shown in Fig. 4 (a). Each book has a unique RFID tag (Fig. 4 (b)) and the books are observed automatically by checking a reply from RFID tag.

The RFID node queries the tags on the books once for every time interval. In case that a book does not reply and the book has replied the previous query, it is assumed that the book is taken out at that time. Meanwhile, if it replies newly then the book is returned to the bookshelf.

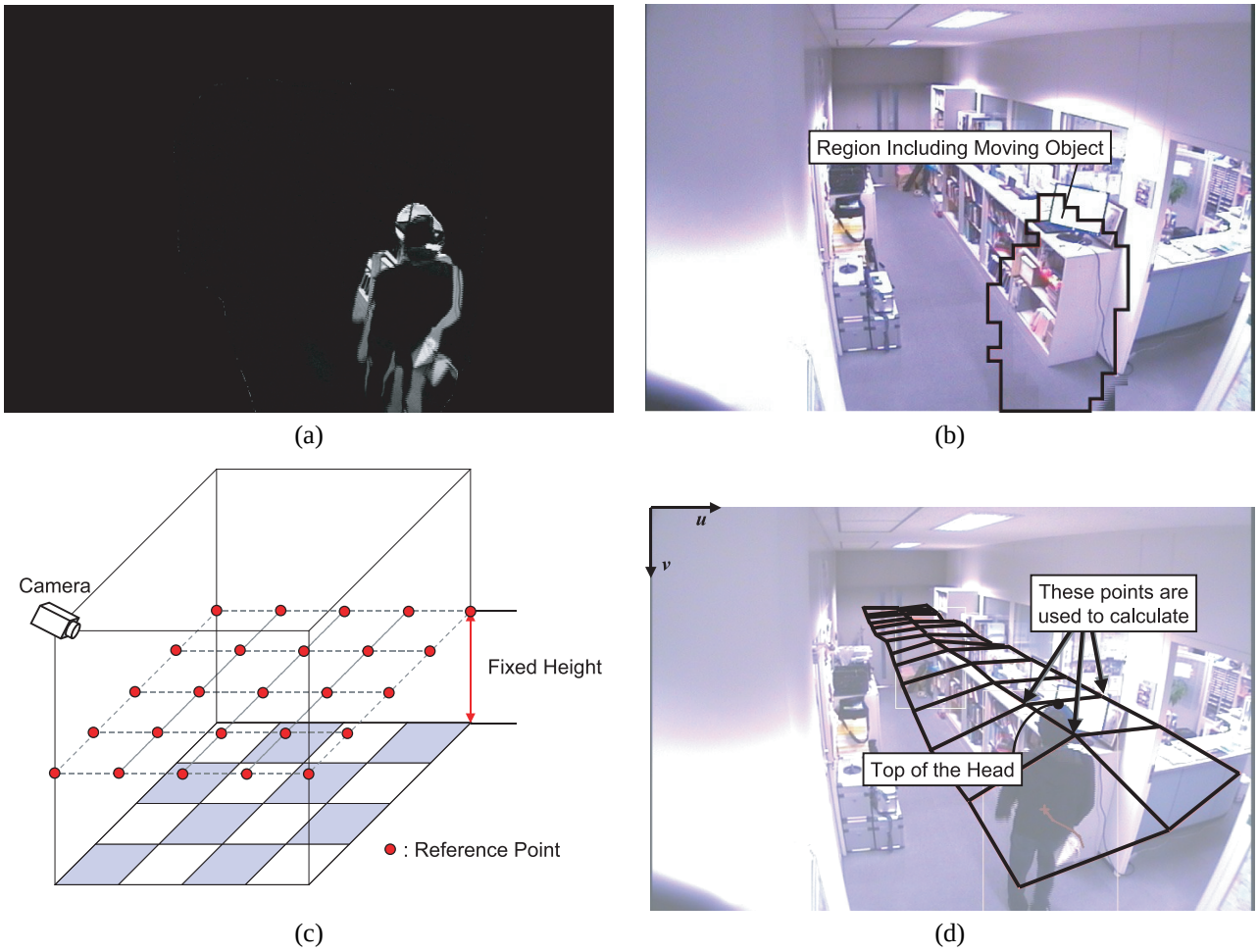


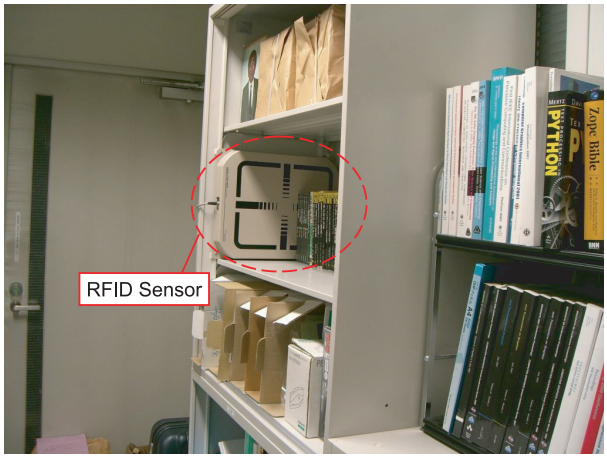
Fig. 3. An algorithm for tracking users in a room. (a) Moving objects are extracted using inter-frame subtraction method. (b) A background image which is made dynamically. The captured image is divided into two regions: a region including moving objects or not. The region not including any moving objects is assumed as a background. The background image is partly updated every frame. The background image is used for extracting user regions. (c) The room is calibrated in advance, and reference points are given at fixed height (170 centimeters in this case). The reference points are used to estimate the users' geometric location. (d) An example of the user tracking. The reference points are imposed onto the camera image. The geometric location of the user is estimated using the nearest three points from the user region.

3.4. Cooperation of Sensors

Figure 5 is a data-flow of the system. A procedure of book management is explained based on Fig. 5.

At first, a tracking process is started by camera when a user touches to IC card sensor (1). And a camera node refers the user ID of the user who has touched to the IC card sensor to associate the user ID with the captured image of the user (2), the camera node keeps tracking the user using multiple camera images. When books are taken out from a bookshelf or returned to the bookshelf, the RFID sensor detects a displacement of the books. Then, the RFID node requests the user ID of the user who is in front of the bookshelf to the camera node (3). At last, a series of events is added to a history database (4) and the managing procedure is completed automatically.

We implement the communication part of this system by utilizing PIAX (P2P Interactive Agent extensions) [5] which is a framework to develop P2P applications. It integrates mobile agent based messaging and P2P discovery mechanisms transparently. The mobile agents are written in a Java library based on Aglets [6]. And, developers can choose any kind of P2P network to construct systems. We implement IC nodes, RFID nodes and camera nodes as mobile agents on PIAX. When they start communicating, a callAgent function in Java codes is called with some arguments as transmission data as shown in Fig.5. If the called node has a reply, the sender can get the reply from the return value of the function. So, developers can construct a distributed system with less difficulty to implement a communication part of a system. Since it is difficult to implement all parts of this book management system in Java, we only write Java codes for a communication part. Communications between a node reading application and a mobile agent deal with socket protocols through a loopback device IP address.



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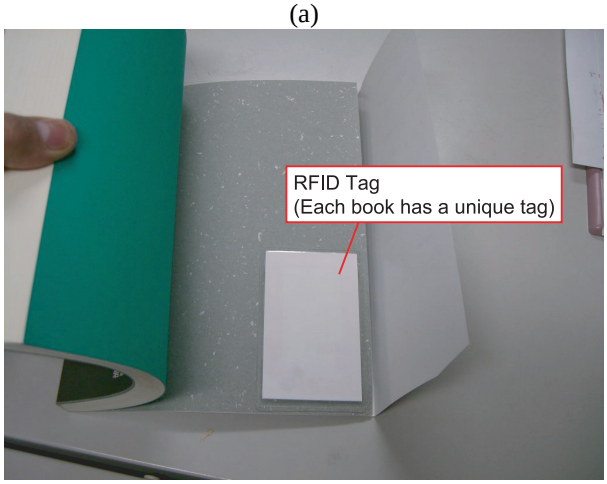


(b)

Fig. 4. An example of RFID-installed bookshelf and tag-attached book. (a) In this case, an RFID sensor is set to a side wall of the bookshelf. Appropriate location of the sensor depends on a characteristic of the sensor. (b) Each book has a unique RFID tag, and the books are observed automatically.

Despite increasing nodes, PIAX has P2P network architecture to enable scalability and search nodes rapidly. A node on PIAX can search other nodes by given name or some range of location. Even if some nodes have changed their own IP addresses, a node can search other nodes. Unlike that, in conventional distributed systems, all nodes constantly had to know their IP addresses each other. So, developer can construct distributed system with less cost because they do not have to concern some network managements. Now, PIAX has mainly two types of P2P network that are DHT (Distributed Hash Tables) [7] and LL-Net [8]. P2P nodes can search other nodes by exactly matching with given name. So, if all nodes have a common rule for naming nodes, they can search other nodes rapidly. LL-net set nodes on the P2P network based on their locations. It's useful if sensors are mainly named by location (Ex. IC node "at the entrance", or Camera node "on the wall"). So, we choose LL-net.

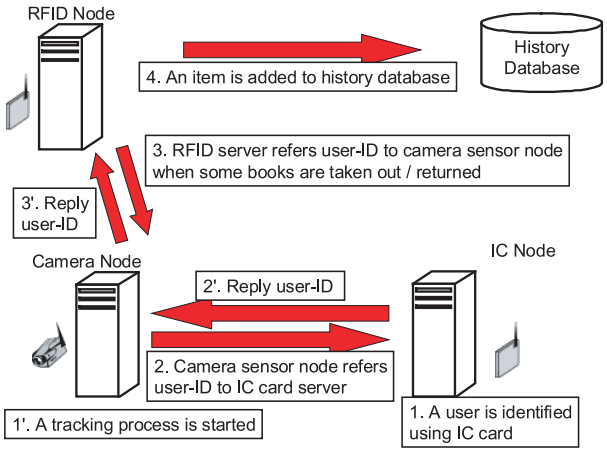


Fig. 5. Data-flow of the proposed system. A tracking process starts when a user is identified by his/her IC card. And a camera node refers a user ID to an IC node to associate the user ID with the user captured by the camera sensor. The next event is triggered when some books are taken out or returned. an RFID node refers a user ID to the camera sensor node, because the people who is in front of the bookshelf is tracked by the camera sensors. And then the event is added to a history database.

Table 1. Devices for the prototype.

Device	Model Number
RFID Reader Unit	OMRON V720-HS04
RFID Sensor	OMRON V720S-BC5D4A
RFID Tag	OMRON V720S-D13P01
IC Card Format	SONY FeliCa [9]
IC Card Sensor	SONY PaSoRi RC-S320

4. DEMONSTRATION AND DISCUSSION

A prototype was implemented to demonstrate the proposed system. Table 1 shows devices which are employed for the prototype.

4.1. Demonstration Environments

The prototype consists of a single bookshelf, a single RFID tag sensor, an IC card sensor, two camera sensors and a history database. In addition, the prototype has a terminal to show a status of books. Figure 6 (a) shows an overview of the prototype. The history database has a table as shown in Table 2. The time interval of a query by the RFID sensor is 1 second, and the size and the framerate are 720×480 pixels and 10 frames per second, respectively. The prototype was demonstrated in three environments: in our laboratory, in a convention hall and a lobby of an office. Each space for the demonstration is approximately 7×2 meters. Figure 6 (b) shows an example of a result in the laboratory. In addition, another configuration of the prototype is shown in Figure 7.

Table 2. A table structure on the history database.

Name	Supplement
rfid	A unique ID of the book
idm	A unique ID of the user who transport the book
starttime	A time when the user is started to track
endtime	A time when the book is taken out or returned
state	The book is in the bookshelf (true) or not (false)
trajectory	A tracked path of the user
snapshot	An image taken when the book is moved

4.2. Discussion

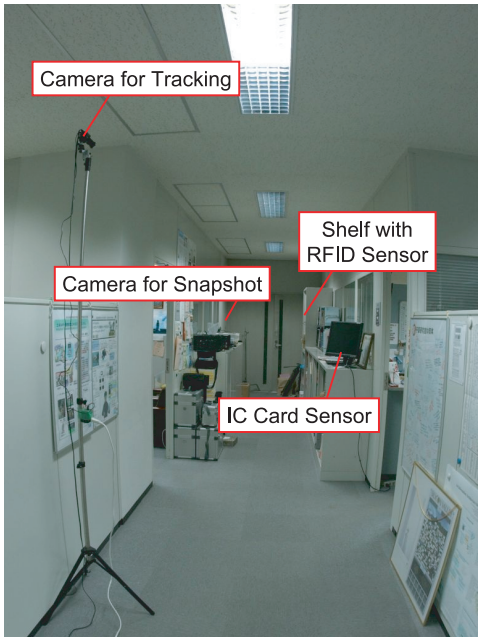
A limitation and problems of the proposed system are discussed below.

4.2.1. Problems of Camera Sensors

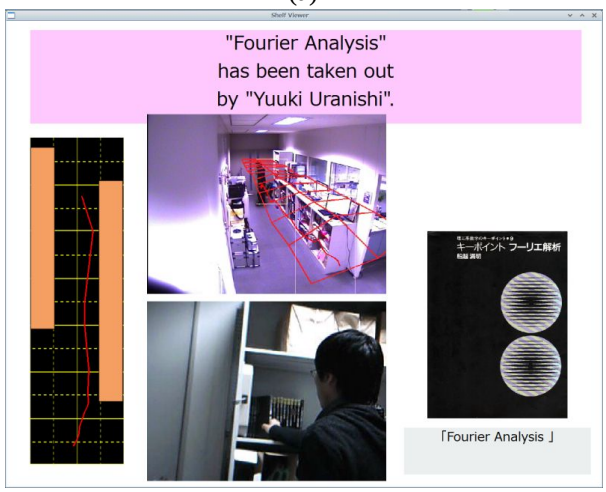
First, our prototype could not estimate the accurate position of users because of our two assumptions. In the practical scene, each user's height is variable and the head point cannot be fixed at a point which has the smallest value of v in the extracted region of the image. Second, the present tracking method fails to track if a user is occluded by other users or objects. Such occlusions are unavoidable problems in a real library. Improved methods, such as usage of stereo cameras, a model-based tracking method [10], a method using body parts [11] and color statistics-based method [12] are highly desirable.

4.2.2. Flicker of the RFID Sensor

Using the prototype, some displacements of books were not detected correctly due to flickering of the RFID sensor. There are at least two factors to flicker: a position and a sidelobe characteristic of the RFID antenna. It was difficult to check the tags when the RFID antenna was set vertically from the RFID tags. Furthermore, the RFID antenna had a flicker when the book passed through a sidelobe of the antenna. The flicker leads to false detection of the displacement of the books. Therefore, a flicker reduction mechanism must be implemented.



(a)



(b)

Fig. 6. A prototype system. (a) An overview of the prototype. the prototype consists of a single bookshelf, a single RFID tag reader, an IC card reader, two cameras and servers. Five tag-including books were prepared for the demonstration. (b) A screenshot of the viewer terminal. The viewer shows the user who has taken or returned a book, a trajectory of the user, and the book which has taken or returned. And a snapshot of the user is captured and shown.

5. CONCLUSION

In this paper, a novel book management system has been proposed. In the proposed system, an IC card sensor camera sensor is employed in addition to the RFID sensors. These sensors are in a sensor network and they work jointly. A prototype demonstrated that the proposed system managed book without cumbersome procedures for users and librarians, and the books were observed continuously unlike conventional management systems.

Future work will aim at implementing user-tracking method with higher accuracy and flicker reduction method. And we are planning to replace IC sensor by a gate-type sensor to identify users. In addition, it is desirable that the proposed system is demonstrated and evaluated in larger spaces and practical libraries.

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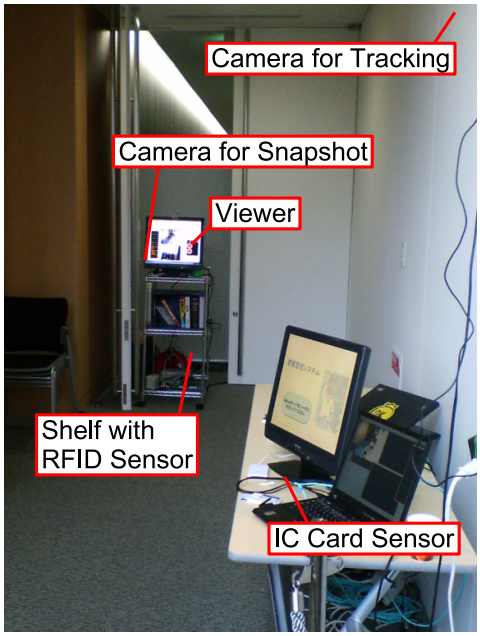

Fig. 7. Another configuration of the prototype. The prototype was demonstrated in a convention hall. Captured images were not stable due to illumination changes.

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