Intelligence Integration in Distributed Knowledge Management

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Chapter X
An Agent-Based Library Management System Using RFID Technology

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ABSTRACT

The objective of this research is to describe a mechanism to provide an improved library management system using RFID and agent technologies. One of the major issues in large libraries is to track misplaced items. By moving from conventional technologies such as barcode-based systems to RFID-based systems and using software agents that continuously monitor and track the items in the library, we believe an effective library system can be designed. Due to constant monitoring, the up-to-date location information of the library items can be easily obtained.

INTRODUCTION

One of the primary objectives of a library is to provide a collection of information artefacts and enable easy and fast access to those artefacts. Most modern libraries provide open stack access for browsing and retrieving of the items available. This open access may lead to misplacement of items in various sections of large libraries. When an item is misplaced it cannot be reached by its potential users. It is tedious for the library staff to find and track a misplaced book that is needed by another user. In addition, it can be costly to locate the item, and possibly replace the item (when it is not possible to locate the item at the time that is needed). In this chapter, we describe an approach that can reduce the effort associated with finding such items.

RFID is an upcoming technology that facilitates easy object identification, in particular, when voluminous entities have to be tracked and monitored (such as products in the supply chain context, library items in a library). An item that is marked with an RFID tag can be read by a RFID reader. This information can be used in tracking and managing the tagged items. The cost of RFID tags (in particular, the passive ones) are low enough to make it feasible to be used for the identification of large quantities of items. Currently, more than 20 million books worldwide are embedded with RFID tags (Research Information, 2007) in more than 300 libraries (RFID Gazette, 2007).

Software agent systems are one of the well studied areas of artificial intelligence, as agents can be embedded with intelligent decision-making capabilities. Robots are physical embodiments of software agents. Software agents when embedded in a robot can be used for a variety of purposes such as planet exploration, handling nuclear wastes, and fire rescue. The study of collaboration using agents is important because they are indispensable for carrying out tasks in unmanned zones and industrial automation.

In our approach, the agents interact with each other in order to ensure up-to-date information in the central library database. They read the tag in the environment using a RFID reader, undertake appropriate processing and communicate the information to another agent. To provide inter-agent communication they can use languages such as FIPA (The Foundation for Intelligent Physical Agents (FIPA), 2007) ACL over WI-FI network. In this project, an agent is used to identify and obtain the location of a misplaced book.

BACKGROUND

Some researchers have worked in integrating agent-based systems with RFID technology for tracking and monitoring purposes (Mamei & Zambonelli, 2005). Our work is inspired by their approach in adopting the RFID technology with agent-based systems.

Related Work in the Context of Library Environment

In the previous works (Choi, et al., 2006; Molnar & Wagner, 2004) that have used RFIDs for library management system, most of the focus has been on automating the process of check-in and check-outs carried out at the circulation desks, automation of inventory management process and sorting returned items (RFID Sorting, 2007). The RFID technology has also been used in enabling antitheft functionality by requiring the gate sensors to check whether an item has been issued or not.

The authors of R-LIM system (Choi et al., 2006) describe how the position of tagged items in the library can be identified within a shelf, based on the shelf locator tags that indicate the relative position of the books in a particular rack of the bookshelf. In their approach, manual scanning (using a hand-held scanner) was employed to read the tags of the library items in a shelf. It was assumed that the library items are placed in their

correct location. This may not be easily assumed in an open library stack where numerous patrons interact with the library artefacts. To ensure consistency, the library staffs need to periodically check the shelves for possible misplaced items. This is a tedious and time consuming operation. To our knowledge, not much work has been done that identifies the location of misplaced items in an automated manner.

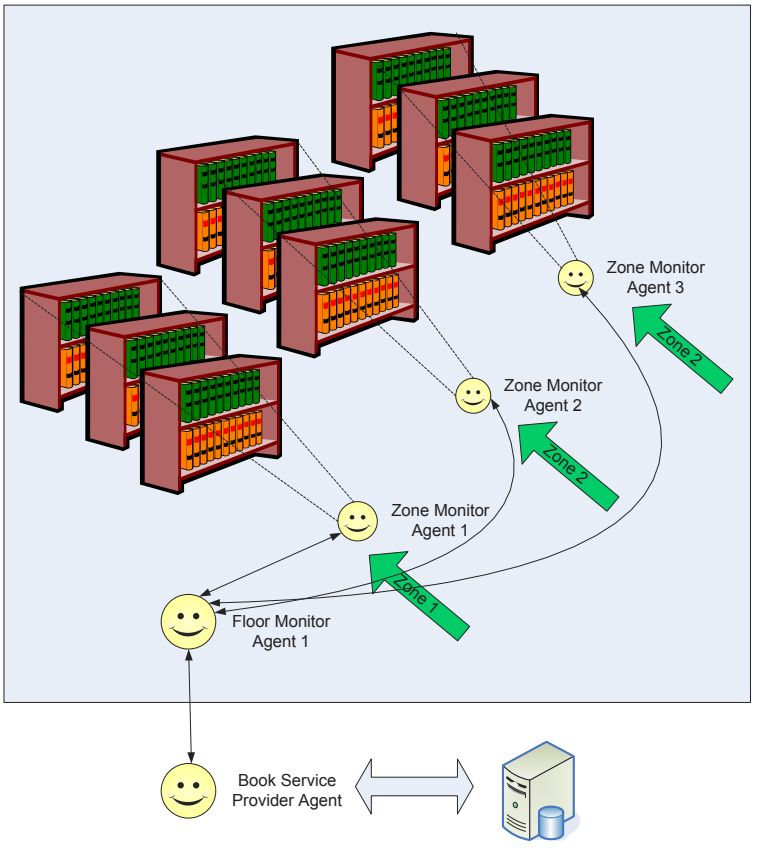
In our system we have incorporated the idea of continuous monitoring of the library items which facilitates easier identification of misplaced items and their locations.

HIGH LEVEL DESCRIPTIONS OF APPLICATION AND ARCHITECTURE

We describe the design of an agent-based system that can be used for library book tracking. One of the common problems in a large library is that the books are often moved around and misplaced in different sections of a library. This problem can be solved by placing RFID tags on each book and using robotic agents to locate and track the books.

Assume that the library is made up of different floors. Each floor is partitioned into different reading zones. Each zone contains a certain number of bookshelves. Each shelf is made up of a number of racks where tagged books are kept.

Figure 1. Architecture of the RFID-based library system



The tag embedded in each book contains information such as unique id, floor, zone, shelf, rack and availability details using a simple encryption mechanism.

In our system, there are different types of agents (shown in Figure 1), such as library service provider agent, floor agent, zone monitor agent, and tracker agent.

The book service provider agent is the agent to whom book tracking requests can be submitted. It performs the following tasks:

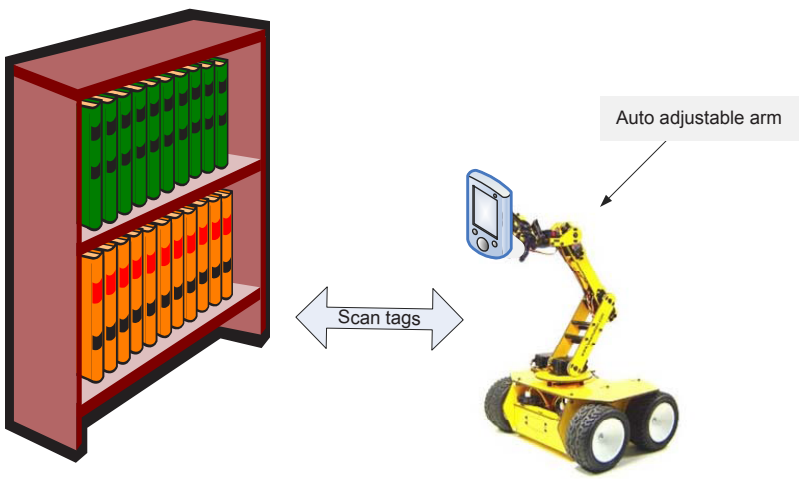
- Initializes the library items with appropriate location information
- Maintains the changes made to the location of library items
- Provides status information of the library items

The floor agent resides at appropriate entry/exit points of a floor. The floor agent monitors when a book enters or leaves a floor. It updates the current floor information in the database while resetting the other attributes (zone, shelf, and rack). It also interacts with tracker agents assigned to that floor.

The zone monitor agent is responsible for monitoring the library items placed in shelves assigned to it. The zone monitor agent performs the following tasks:

a. Periodically takes a snapshot of the tagged items within its reach.
b. It finds the discrepancies between the currently read books and the expected book list for its zone. This includes the items that have been removed and the items that have been added which do not belong to the current zone.
c. The database is updated to indicate that a particular item is not in its correct place. In addition, the approximate position of the misplaced item is recorded (the current position). This includes the information with regard to the zone. For the removed items all the current position attributes are reset except the floor information. The misplaced items are recorded in a log file called "misplaced-location.log" stored locally in the memory of zone agent. The log files are sent periodically to the service provider agent. Because the order in which the reader reads is not known, the zone agent can only

Figure 2. Scanning the books in a bookshelf using a robot equipped with a RFID reader



indicate that an item belonging to another zone is present within its zone and obtain the corresponding tag values (which indicate the correct location of the misplaced item). To find the exact location of the misplaced book, we use a tracker agent.

Finding the Location of the Misplaced Item

In this scenario, we know only the existence of a misplaced item within a zone but not the current location of the item. To find this information, we need to use RFID readers with lower range of readability. In our approach, we use robotic agents that are equipped with the RFID readers and they can be used to scan the tags (shown in Figure 2). Based on the log file entries, a particular misplaced item can be identified by the robot. The robot is capable of moving back and forth across a shelf and it is equipped with an automatic adjustable arm which can read items in different (higher) racks. Shelves will be equipped with the beginning of the shelf and end of the shelf tags. The end shelf tags will have directional information which is used by the robot to locate the next shelf within a zone.

The tracker agent is capable of finding items misplaced across zones as well as within its current zone. The tracker agent locates an item that belongs to another zone, by reading each tag in its range and comparing it with the tag code of the target item (misplaced book recorded in the log file). After locating the item, it derives the location of the misplaced item by obtaining the location information from its neighbouring items. The current location of the misplaced item is stored in another log file called "found-location.log" and the database is updated accordingly.

In this process, the tracker agent is also checking the correct relative order of items that are being read. Whenever it finds an item that is out of order, it identifies it as a misplaced item and derives its location information based on its neighbourhood and stores it in the "found-location.log" file. This process ensures identification of items that are misplaced both within and across zones.

The library staffs periodically check the log files updated by the tracker agent and place the misplaced items in their correct location.

Operational Scenarios

Initial Configuration

All the library items are labeled (tagged) appropriately. All the items are recorded in the database. Whenever new items are added to the library, some adjustments to the neighbouring items may be required.

The library database consists of the following details associated with each item:

a. Call number
b. Unique identifier
c. Availability
d. Correct position (original location , as specified by the administrator)
    i. Floor, Zone, Shelf, Rack
e. Current position (as indicated by the floor and the zone agents)
    i. Floor, Zone, Shelf, Rack

When the items are initialized, the correct position and current position of an item are the same. When an item is moved from one location to another, the current position is updated. The correct position of an item remains the same (unless the administrator resets it to accommodate the growth of the library).

The database would have more details other than the above information such as due date and reserve status. The unique code, current position (in the encoded format) and the availability information are placed on the tag belonging to each library item.

Requesting a Book Scenario

When a request for locating the current position of an item is made, it may be an item that is in its original correct place. In this case, the user is informed of the item location details.

If the requested item is identified as a misplaced item, then the current zone is known. In this case, there could be two possibilities:

1. It can be found in the "found-location.log" file. In that case, the staff can fetch the item from the location and update the database, and the log-file.
2. Otherwise, the item details are found in the "misplaced-location.log" file. In this case the staff can use a hand-held reader to locate the item and update the relevant information such as database and log file. Alternatively, the tracker agent can be assigned to look for the location of the misplaced item.

It is possible that a misplaced book is in an unzoned area of the library floor such as a reading area. In this case, it is assumed that the library staff will collect all these books at the end of the day and place them in a designated shelf for further processing (to be placed in their correct location).

DESIGN CONSIDERATION AND IMPLEMENTATION

RFID Infrastructure

We are planning to use the RFID-chips conforming to ISO 15693 and avoid any proprietary tags belonging to one particular vendor. Our system uses two kinds of RFID readers. The long range RFID reader covers 3-5 meters while the short range reader used by the robotic agent covers 10-50 centimetres. A RFID tag can only be read if the reader has the appropriate authorizations.

Implementation Details of the Robotic Agent

We are using Garcia robot (Acroname Robotics, 2007) which is embedded with a RFID reader. Each robot has an onboard processor called Stargate (Crossbow Technology Inc, 2006). The brainstem C development kit (Acroname Robotics, 2007) installed in the robot provides the API for the control of Garcia robot movement (moving forward, turning left and right). We are currently working on implementing a controller for the automatic arm adjustment (moving up and down).

Otago Agent Platform (OPAL) has been used to support multi-agent cooperation (Purvis et al., 2002). OPAL is a FIPA-compliant agent platform. Tracker agent is an OPAL agent which is made up of two components, namely Garcia robot controller and RFID reader. The instructions for the robot to perform certain operations can be issued using the FIPA ACL (The Foundation for Intelligent Physical Agents (FIPA), 2007) standard.

In our system, when a particular request is made for an item that is misplaced, then the service provider agent communicates this information to the tracker agent in order to find the current location of the item. For communication between zone monitor agent and tracker agent, we are using WIFI protocol.

Upon receiving a request for finding a particular book from a service provider agent, the tracker agent (which is an OPAL agent) instructs the Garcia robot to initiate a search using its RFID reader. In this process, when the end of rack tag is read, the robot agent is instructed to adjust the arm to reach to the next rack and also turns the robot around in order to be able to read the next rack. If the end of shelf tag is read, then the robot agent is directed to adjust the arm to its lower position and move to the next shelf using the directional information that is placed on the end of the shelf tag. When the requested book tag is found, the position of the book is calculated as described earlier.

Figure 3. Psuedocode for a tracker agent locating the position of a misplaced book

```
Find-tag(tag-code)
{
      Read till the-end-of-zone-tag
     {
           Read till the-end-of-shelf-tag
          {
               Read till end-of-rack-tag
               {

                    MessageToReaderAgent(readNextItem());
                    if (book found)
                    {
                         ProcessInformation();
                         Exit();
                    }
               }
               MessageToRobotAgent(goToNextRack());
          }
          MessageToRobotAgent(goToNextShelf());
     }
}
```

Figure 3 shows the pseudo code that indicates the sequence of steps taken by a tracker agent when it tries to locate a misplaced book within a zone. In this code, the processInformation() method corresponds to the calculation of the current book position based on the neighbourhood and the update of the database and corresponding log files.

Communication Between Agents

The agents in our system can communicate with each other using FIPA ACL messages. The following interactions can take place in our system:

a. Library service provider agent can send a request for searching a book to a tracker agent;

Figure 4. System performance where agents are not collaborating

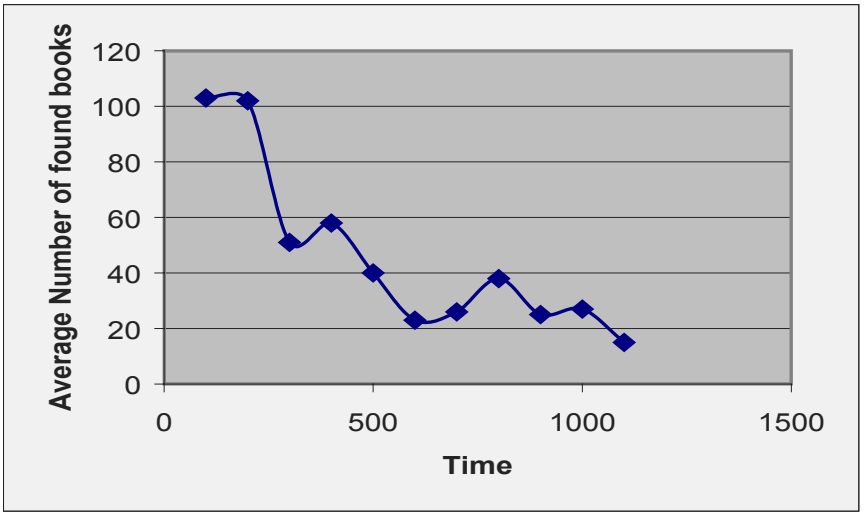
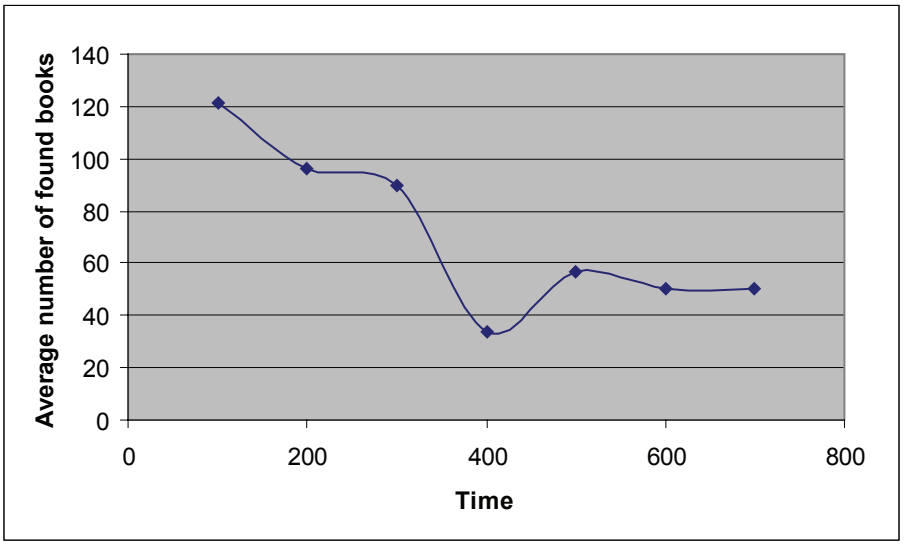


Figure 5. System performance where agents are collaborating



b. In case a particular tracker agent is not available (or busy or unavailable due to charging or maintenance), the library service provider agent will send a request to the floor agent to find a replacement;
c. When a zone agent wants to update the database, it sends all the position data to the library service provider agent, which then updates the repository. Similarly, floor agent and tracker agent send the data to the library service provider agent.

Simulation and Testing of the Prototype System

In order to verify the operational correctness of the system, we are currently implementing a simulation system which is populated with a large

Figure 6. Agents participation where agents are not collaborating

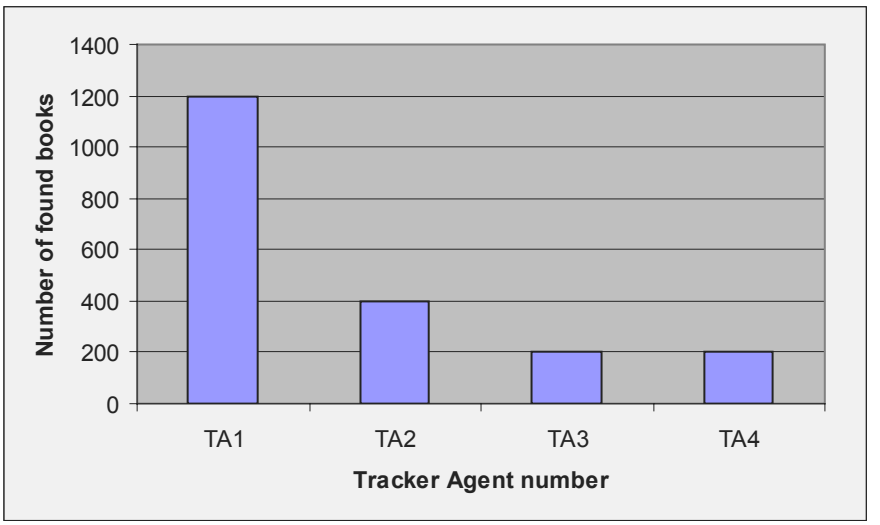
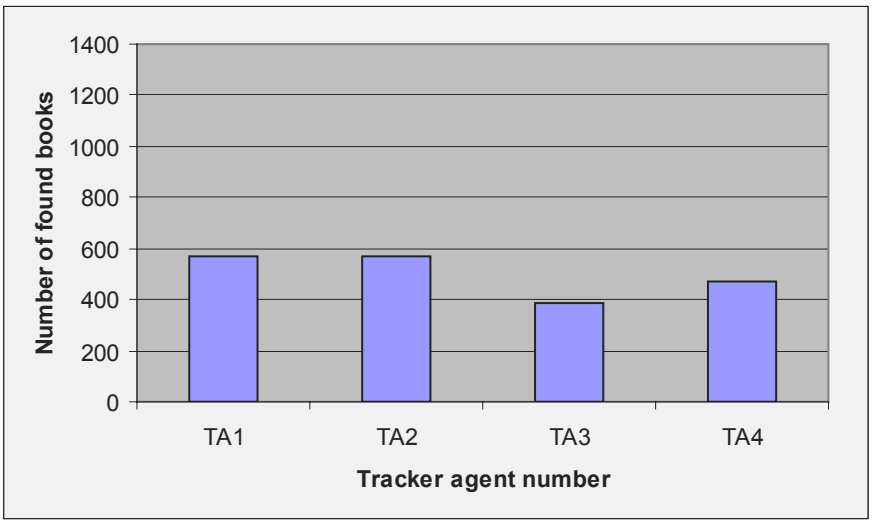


Figure 7. Agents participation where agents are collaborating



number of books. We have parameterized the number of floors, zones, shelves and racks. The user requests are modeled based on the anonymous historic data of our local library. Based on this information, we measure the performance of the system by calculating the time it takes to find the misplaced books identified by the zone agents.

In Figures 4 and 5 we show the performance of the system in finding the misplaced books in two different scenarios. Figure 4 shows the time it takes to find the misplaced books where various tracker agents are assigned to locate books in specific zones (in this example, four tracker agents are assigned respectively to four different zones). Figure 5 shows the system performance where the tracker agents cooperate with each other (an idle tracker agent may help another agent with higher work load). It is clear that when the agents work together the time that it takes to complete the same set of requests is shorter.

Figures 6 and 7 show the outcome of the same experiments from the individual tracker agent point of view. In Figure 7 the tracker agents' participations in finding the books are more evenly distributed, which resulted in a better overall system performance.

More simulation experiments will be designed to examine the system performance when different priorities are assigned for performing different tasks. In particular, we would like to explore an optimum time that has to be spent by the tracker agents to locate the misplaced books identified by the zone agents (using the long range RFID readers) as opposed to the time spent on locating the misplaced books within each zone (using the short range RFID readers by the tracker agents).

DISCUSSIONS

Issues with Use of RFID

Privacy is one of the important concerns of RFID systems. An adversary can attempt to read the library book details (such as the title, author of the book) which might reveal some personal information without the owner's consent. Molnar and Wagner discuss various methods that an adversary may use the tag information to reveal details about a person associated with certain tagged items. They describe how this can be achieved even when a unique identifier (such as barcode) is used

by the process of association (linking different people reading the same book) or book hotlisting (where the barcode of known books are identified and tracked). By using a simple mechanism of access control and encoding, the information on the tag may be better protected. It is acknowledged that with the current limitation of the RFID tags in terms of the processing capability, the more sophisticated mechanisms such as use of hash functions and symmetric encryption may not be feasible (Molnar & Wagner, 2004).

Another issue is the fact that the adversary can bypass the security system by wrapping the library items in a metallic container.

Issues with Using Robotic Agents in the Library

The use of robotic agents in a library environment can interfere with the movements of the patrons of the library. This can be addressed if the robotic tasks are performed after the closing of the library. But this will increase the latency of the information that can be made available to the users. Alternatively, the robots can be assigned to designated paths which can be made known to the patrons.

The robotic agents may run out of power to operate. A mechanism needs to be provided so that it can be recharged at appropriate time intervals.

Other Applications

Our approach can be applied to a variety of applications that have tracking and monitoring requirements. For example, our robotic agents can be used for patient monitoring in hospitals. Assume that each patient is identified using an RFID tag. A robotic agent can read a patient's RFID tag and find the appropriate information about that patient (names of possible medication and the corresponding timing information for taking the medicine). The agent can then provide specialized service (such as dialysis) based on the information obtained. The agent can then communicate this information to the server as well as other robotic agents for further treatment relevant to the patient. The agents can request for and provide help when facing a heavy load.

CONCLUSION

In this work, we have described a mechanism for locating misplaced items in a library environment where the items are tagged using RFID technology. The communication infrastructure is facilitated by software agents. We have also used robotic agents to automate the tedious task associated with locating the position of the misplaced items. Our approach is promising, as it makes the misplaced items easily known due to the continuous monitoring. The proposed architecture enables the library administrative person to make more informed decision on allocation of the library resources (staff as well as robot trackers) based on the list of misplaced books identified by the RFID readers. We are currently working on the implementation details associated with our approach.

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