A Self-service System Using RFID

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ABSTRACT

This paper discusses the design and implementation of a self-service library management system using Radio Frequency Identification (RFID). RFID is a combination of radio frequency-based technology and microchip technology. It is slated to replace barcodes in library applications to provide a faster and more efficient way to manage library materials and perform check-in and out. The self-service system allows users to checkout and check in items by themselves without the need for a library patron. The library management system will be placed at Hopper lab in the Center for Science and Technology at Earlham College. Currently, there is no management system in place, and students and faculty in the department have a difficult time managing devices. The self-service system uses a UHF RFID reader and tags, and is designed to improve student access to the lab as well as making inventory and user monitoring easier for the Computer Science department. This paper introduces the different components of the system, design plan, implementation, and testing.

KEYWORDS

RFID, Library Management System, Self Service System, Library Security

1 INTRODUCTION

Libraries across the world are adopting new technology to better serve customers and make the process of check-in/out and inventory more efficient. One solution for a more time efficient and secure library management system is radio frequency identification (RFID)[13]. RFID is a radio frequency and microchip-based technology and can be used for tracking, identifying, sorting and detecting of library holdings. It can be used to implement a self-service system where patrons can check in/out items by their-selves, and the libraries can inventory and keep track of items in a more efficient way.

The first use of RFID technology can be traced back to World War II, where British armed forces used a crude version of it to identify friendly and enemy planes [12]. Later in 1973. Mario W. Carulla recorded a patent for his passive read and write tag [9]. This invention led to the use of RFID tags, which embedded chips and memory, in a variety of roles in the civilian sector. Today RFID technology has applications in supply chain management, libraries and many more. Ford Motors, for instance, uses RFID technology to manage its parts replenishment system in its factories as well as to track vehicles in the distribution network [7]. Wal-Mart uses RFID to manage items in its warehouses.

In libraries, RFID technology has started to replace the barcoding system. RFID tags are placed in books or other materials, and RFID reader and antenna are integrated into self-checkout machines. RFID was first implemented in a library at the University of Guelph in Canada in 1991 [2]. However, its application in libraries has not been very comprehensive, with only 3000 libraries using the technology in 2012 [5].

The resource management system will be placed in the Hopper lab in the Center for Science and Technology. Currently, there is no system in place that tracks students use or facilitates the process of check in and out. Additionally, there is no inventory system, and the computer science department does not keep a current record of its holdings, or monitor student usage. This discourages students from using the materials, as it is difficult to search for devices or have them checked out on time. The resource management system described in this paper addresses these issues, and places in an efficient system both for students and the department. Students can search for items from their personnel computers, check for their availability, and check out items without the need of a faculty approval. The RFID reader allows multiple items to be scanned at once. The system allows the administrator to keep track of the devices and student use. Additionally, the department can inventory items and store their information in the system.

Students and objects are assigned individual tags, and their information is saved in a database. In a check in or check out operation the RFID reader reads the tags and communicates them to the database, where it distinguishes between person and object tags. The system then checks if the user is allowed to checkout the item based on the measurements set by the department. Following this, the objects are checked if they are available, and then the operation is recorded. The resource management system provides an easy to use user interface that enables the administrator to see a record of the operations, and add/edit information regarding students or objects.

Section two of this paper discusses the existing literature on RFID, comparing barcode and RFID systems in the context of libraries. This section also discusses the use of self-service systems before RFID technology came into place and how the integration of RFID into the library management systems has led to improvements in efficiency and organization. Section three discusses the design of the system and the requirements guiding the design decisions. This section explains the requirements universal to all library management systems as well as specific to the Hopper lab. Section four discusses implementation, and how the system is meeting the requirements mentioned in section three. The next section talks about the evaluation of the system. Section 6 provides future directions in which the system can be further improved. Finally, section 7 concludes the paper by summarizing the core contributions of the paper.

2 RELATED WORK

Self-service technology was utilized in libraries before the introduction of RFID and often using a barcode system. This section compares the RFID and conventional barcodes system. It begins by comparing the technical specifications of the two technologies, followed by a holistic review of the literature on the pre-RFID, and post-RFID self-service systems.

2.1 RFID vs Conventional Barcodes System

RFID delivers advanced capabilities compared to barcodes in terms of functionality and implementation. Bar-coding uses a line of sight technology and scanning a printed label with an optical laser to identify the object[18]. RFID is more time efficient and easier to operate since it uses radio-frequency signals and there is no need for line of sight scanning. RFID readers have different ranges from a few centimeters to a few meters and can read multiple tags at the same time.

Another difference between RFID and barcoding is in implementation. RFID technology requires careful stage-based planning, while RFID reader and security checks can also cost hundreds of thousands of dollars to put together [6]. On the other hand, basic barcoding can be used by simply plugging the scanner into the computer [17]. The cost of barcode reader is also relatively less than RFID.

There are two common problems with the use of RFID technology: the possibility of an invasion of privacy and lack of universal standards. Since RFID tags can be read with any readers that are at the required range, it raises a risk to a possible breach. Muir outlines a scenario where agents of governments or other organizations could create a scanner which reads the contents of the RFID tag in a book. In most cases, item tags store information of the user that checked them out. This creates a possible breach of information [2].The second problem is that since RFID is not globally utilized, there are not many suppliers of the technology and thus there is not one single data model. For years, each RFID supplier used their own model for transferring data. Libraries had to pick and choose which parts of the systems that these companies developed, they would purchase [2].

The self-service system introduced in this paper addresses the above problems: It reduces the possibility of invasion by storing only the unique IDs of the users in the tags. All the personal information of the users will be stored in the database and be only accessible to the administrator. The administrator's and the user's features and requirements are kept separate, which helps make the system modular such that it will be compatible with different products. Additionally, the system uses cost-effective tags and readers, and the software is built from scratch to make the system affordable.

2.2 Pre RFID Self-service System

Until the 20th century, most libraries' collections could only be accessed by request, and the librarian would bring the stock to the user. Later, with the opening of library stock to users, and the development of e-journals and databases, users were able to locate and use the library stock themselves [14]. Self-service systems were another important development in this process.

Early self-service systems were based on barcodes. Papers analyzing the self-service systems reported improvement in efficiency and productivity. An early case of self-service was in Shropshire Public Libraries in the United Kingdom [16]. The library was equipped with a system where users were able to issue their books at terminals using a scanner. Morris found that queues are reduced with the implementation of the self-service system [13]. Smart found evidence that productivity is increased by 85% with the implementation of self-service systems [14]. Gollin shows that self-service systems allow for redeployment of staff from routine circulation roles to more customer-focused roles. He found that 22% of library staff had changed their role after self-service implementation [4].

However, barcode-based systems have several short-comings. Snelling found that most libraries that used barcode-based systems achieved self-service levels below 10%, with self-return not utilized at all [15]. These were due inherent problems with barcode-based self-services systems. For barcoding to work effectively, the barcodes needed to be in a standard position on each book for the user to process them. As a result, libraries had to re-barcode all their stock [10]. Additionally, the barcodes system needs to be accompanied by EM tag technology for anti-theft. EM technology is based around a magnetic pulse to sensitize and desensitize the EM tag when scanned at the door; thus it wasn't possible to issue AV material on self-service units such as videos and DVDs, as it wiped their content when being processed.

2.3 Post RFID Self-service System

The problems with the early barcode-based self-service systems were solved by the introduction of RFID technology, as it is not a line of sight technology, and the tag can be placed anywhere in the materials [1]. RFID uses radio waves instead of magnetic pulses and thereby makes the process easy for all stock.

In 1998, Bukit Batok public library in Singapore implemented an RFID based resource management system. With 200,000 items and 28,000 members, the new technology was successful in reducing queuing from 90 minutes to 15 minutes and could cope with increasing transactions without having to increase staff. It was later rolled out to all 212 libraries in the authority by 2002. Around the same time, Rockefeller University Library in Manhattan installed their RFID based system for self-service, security and stock control. Another major adopter of the technology was the University of Nevada in Las Vegas who beta tested the 3M's Library Systems Digital Identification System. Birgit Lindl of Bibliotheca estimated that in 2005 the number of libraries using RFID had increased to over 300 worldwide with approximately 120 million tagged items [8]. The number of libraries using RFID was about 600 to 900 between 2007 and 2009 and reached approximately 3000 in 2012 [5].

A complete case study of the implementation of RFID in the Pilkington Library revealed that the success of the system exceeded in the initial expectations [2]. In the first year, about 91% of library users successfully used the system, and the required efficiency saving was also met with staff reductions within the first 12 months of implementation. In the second year, the average usage was 93%, 13% higher than the original target [11].

In a library sitting, the RFID unit is a normal PC which communicates the data to another software such as library management

system (LMS) or a database [3]. In general, the introduction of RFID to the self-service system had solved some of the issues with the existing pre-RFID systems and increased efficiency of self-service systems. The system introduced in this proposal differs from the existing work as it utilizes simple, cost-effective tools to provide the same capabilities. Although RFID technology has its own shortcomings such as privacy issues and high costs, the system explained in this seeks to tackle those challenges.

3 DESIGN AND REQUIREMENTS

This section provides the fundamental design concepts and requirements of the library management system. These requirements emerge from needs global to all the libraries, as well as those specific to the computer science lab where the system will be placed in at Earlham College.

3.1 Efficiency

An important aspect of RFID technology is a proven increase in efficiency [13]. In libraries, RFID technology brings efficiency both to the administrator and the users. The reader allows read of multiple items at the same time. For an inventory, the administrator can scan rows of items by walking through them producing a current record of the items. Users, on the other hand, can self-check in/out multiple items at the same time without needing for a patron.

Currently, at the computer science lab, the administrator doesn't have an inventory of what items are available for checkout, or record of student use. This condition makes the administrator's work in-efficient and hinders proper student use. The second major in-efficiency is in the process of check-in/out. Students can only check out an item after getting permission from the faculty. This process takes a lot of time, as the faculty are not available at all times, especially after 5 pm. Additionally, when checking in items, students need to notify the faculty personally, on the return of items. The implementation of the library management system will address these shortcomings.

3.2 Accessibility

Currently, at the computer lab in Earlham College, the only way for students to know the availability of a certain item is to ask a faculty or search the lab. The implementation of the library management system will enable students to always have access to a complete record of the items in the lab and check their availability.

3.3 Accountability

In the libraries, it is important to monitor usage. For instance, how many people are using objects and how many objects are checked out regularly. Currently, in the computer lab, it is almost impossible to keep track student usage.

Additionally, it is difficult for the administrator to find out if lab items are returned on time. If there are any damaged or missing items it is difficult to track who last checked them out of the lab. With the implementation of this system the administrator will have access to a complete record of check-ins and outs, as well as frequency of student use.

3.4 Security

Libraries often store valuable items, textbooks or computers that are not suitable to be checked out for an extended amount of time or taken out of the facility. Currently, there is no system in place to make sure this is applied. With the implementation of the library management system, the administrator can put in place different measures and restrictions on the items such maximum length of checkout, and they will be easily communicated to the user.

3.5 Scalability

Scalability is an important requirement for library management systems since the number of items in the library or users constantly grow over time. This project is designed such that it will be easier to add more features or have the system manage a larger amount of objects and users.

4 IMPLEMENTATION AND ARCHITECTURE

This section explains the implementation and architecture of the system for the design and requirement explained in Section Three. The first part of this section explains the architecture framework, followed by specification of the tools used in the system. The second part discusses the two main use cases, and the features developed to address the project requirements.

4.1 Framework

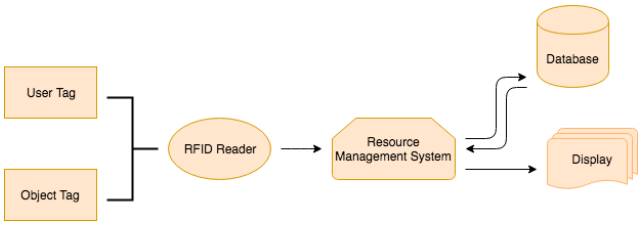


Figure 1: System architecture

The system is composed of a RFID reader, RFID tags, a database unit, and a management software providing an easy to use interface for the student users and the administrator. All the components, except the tags, are connected to the management system. Users and objects are given unique tag IDs, which are stored in the database and associated with the respective person or object. Users need to have their tags when checking items. In each operation, when the reader scans a number of object tags and one-person tag, it will send the tag information to the resource management system where the user and object tags will be distinguished. The user and the objects will be checked against certain measures to make sure the items are available and ready to be checked out by the specific person. A record of the operation will then be saved in the database, and the system will display a confirmation message to the user.

4.1.1 RFID Tags. There are two types of RFID tags: active and passive. Active tags have their own power source and can transmit over a long distance. Passive tags have no internal power source and rely on an external source to supply data. This project uses Ultra High-Frequency, ISO18000-6C Long Range passive tags. These tags have a longer life than active tags and cost relatively less.

4.1.2 RFID Reader or Interrogator. A RFID reader is composed of a radio frequency module and an antenna to interrogate the tags. It provides the power source for passive tags by sending radio waves. The reader works as the link between the RFID tags and the resource management system; it gets the information from an individual tag and sends it to the management system. The system uses ISO 18000-6C UHF Reader/Writer with 860-960 mhz frequency. It can read tags within 1m and more.

4.1.3 Technical Details. The project is built using the Django-a Python programming language-based framework. On the backend, PostgreSQL is used, and on the frontend HTML, CSS, JavaScript, JQuery, and Bootstrap are used.

4.2 Overview of two use cases

The library management system is designed with two different users in mind: student users and the administrator. There are different features and options for each type of user, which all emerge from the design decision and requirements explained in Section Three. This subsection explains technical details of the different features, referencing how they solve the aforementioned requirements.

4.3 User's Features

4.3.1 Search. The system allows the users to search for items in the library from their personal computers, addressing accessibility requirement [Section 3.2]. When the user enters the name of the object, shown in figure 2, the system queries the Object table in the database for any items that contain the specific name. For instance, if the user searches for "Macbook," the system will return all instances of "MacBook Pro" or "MacBook Air." If the user doesn't enter a specific name, the system returns all the objects stored in the Object table. The result has the name of the object, availability, maximum number of days the object is allowed to get checked out for and the location. The location can be Hopper or Turing labs, both in the Center for Science and Technology.

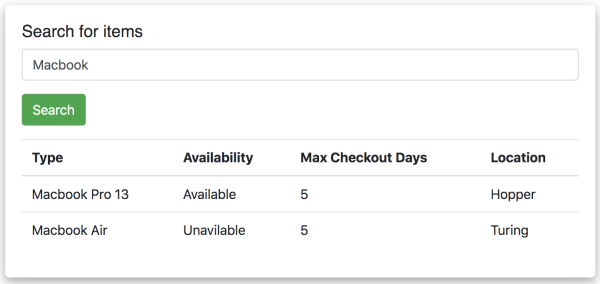


Figure 2: Student user search bar

4.3.2 Self Check-out. The library management system allows the user to check out items by themselves addressing efficiency requirement [Section 3.1]. The user can select "Check-out" on the main page of the interface demonstrated in Figure 3. As the user approaches the RFID reader, it will scan all the tags, and fill in the fields on the form. The system distinguishes between the user and object IDs after the form is submitted. After that the following steps take place:

(1) The system checks if the user is registered in the system by querying the User table
(2) If the user exists, then the system will query the Record table to see if the user has previously checked out items that have not been returned. If there have been five or more objects already checked out, the system will not allow any more check out and will send a message to the user. This solves the security requirement [Section 3.4]
(3) If the user has checked out fewer than five items, than the system allows only a few checkouts, depending on how many are allowed before reaching five checkouts. The user will be notified of the objects that haven't been checked out
(4) The system will then check if the objects are registered in the system by querying the Object table. If the IDs are registered, then the system will check if the items are available for checkout
(5) If all the measures are passed, then the system will create a separate record for each item in the Record table storing the following information: user ID, object ID, date, time, type which is "check-out," and status which is "Active."
(6) The system will then query the Object table, and make the items unavailable

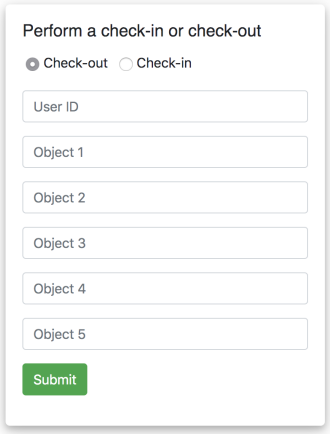


Figure 3: Checkout/check-in form

4.3.3 Self Check-in. The check-in process is kept equally simple referencing efficiency requirement [Section 3.1]. The system keeps separate records for check-in and check-out allowing the administrator to have a record of duration of use, referring to accountability requirement [Section 3.3]. After the reader scans the IDs, the system distinguishes between user and objects IDs. Following are the steps that take place afterwards:

(1) The system queries the Record table and takes all the instances with the specific user ID
(2) It then filters the query set, by those records whose status is "Active."
(3) For each object ID, it changes the status of the object in Records table to "Completed," and updates the Object table, by sitting the item to "Available."
(4) Finally, the system creates separate records for each object in the Record table, storing the following information: user

ID, object ID, date, time, type which is "Check-in," and status which is "Completed."

4.4 Administrator's Features

The system provides many features to the administrator both in the management of users and objects. On the backend features related to the administrator are kept modular and separate from the user features helping to keep the system scalable addressing scalability requirement [Section 3.5].

4.4.1 Search/Monitoring. The library management system is designed such that it is simple to use and navigate. The search bar in the main page of the administrator user-interface shown in figure 4, allows the administrator to have access to the most current record of users and records referring to the accountability and security requirements [Sections 3.1 and 3.3]. The administrator also has access to the current inventory of the item in the objects table. The administrator chooses between Records, Objects and Users options to search for a specific person or object shown in figure 4. If the title is left empty, all the instances from that table will be returned. The system allows filtering the results for the user and record tables, explained below:

Objects: the administrator can filter the results from the object table by location and availability

Record: Queries from the record table can be filtered by date, type-which is "Checkout" or "Check-in," and status which is "Active" or "Completed." This allows the user to see all checkout operations for a specific person or object, or see only active checkouts for instance.

These features allow the administrator to easily keep track of student and object use.

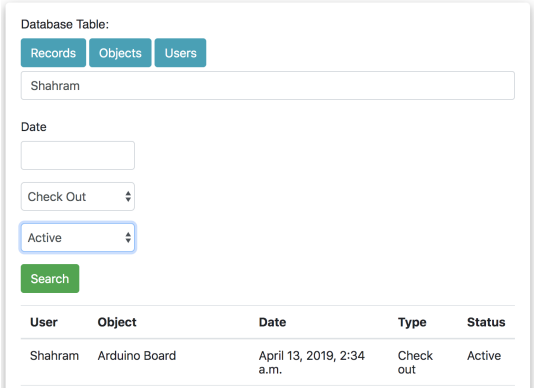


Figure 4: Administrator search bar

4.4.2 Adding objects/users. The administrator can add new items or users to the system by simply scanning the IDs and filling in the required information as shown in Figures 5 and 6. For the user, the administrator can add user ID, first name, last name, email address, and phone number. The system runs several measurements before registering the user to the system. It checks if the ID already exists in the system. The system then checks if the email address is valid through validation measurements provided by the Django framework. If any of the measures fails, the system notifies the administrator with the specific details. These measures make sure the security requirement [Section 3.4] is met.

When adding a new object to the system, the administrator can scan the object ID, and enter the name, availability, maximum check out time and the location of the object. At any time the administrator can change these details-explained in the inventory management subsection.

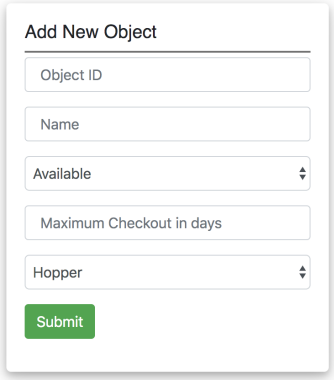


Figure 5: Add new object form

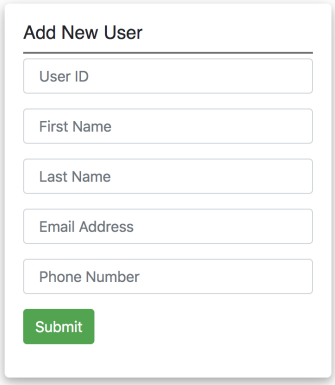


Figure 6: Add new user form

4.4.3 User Management. The system allows the administrator to manage users efficiently. In the Users page of the software, the administrator can search a user by user ID or email address. Since each student has unique email addresses, the administrator doesn't need to scan a 32 digit ID to search a specific user but can use the email address instead.

If the user ID or email address is registered in the system, the user information will be returned in a separate page. Otherwise, the system notifies that the user doesn't exist. The administrator can change the details of the user or delete the user from the system.

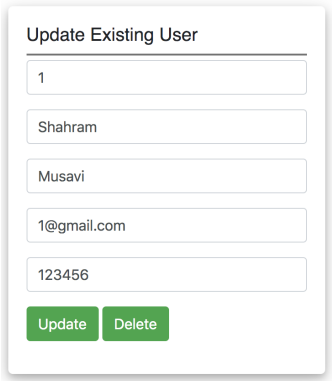


Figure 7: Manage user information

4.4.4 Inventory Management. Each item has its ID, but unlike users, several object IDs can have the same name. Thus, it is important for the administrator to be able to change details of one object, such as changing the availability of one computer, as well as to change details of all the objects with the same name. For instance, the user can change the maximum checkout time of all computers from one day to one week.

In the objects page of the administrator user interface, demonstrated in Figure 10, the administrator can search for objects by either tag ID or the object type. The object ID returns the specific object's information, and the type returns the information for the entire group of objects with the same type. If the administrator enters the object type, the returned page will have the count of objects with the same type, as well as, availability and maximum checkout time fields. The administrator can then either update this information or delete the entire group of objects.

5 RESULTS AND EVALUATION

This section provides an evaluation of the key features and security measures mentioned in the previous sections.

1. In a checkout operation, if an item is made unavailable by the administrator it won't be processed by the system and the appropriate message will be displayed to the user as shown in Figure 8.

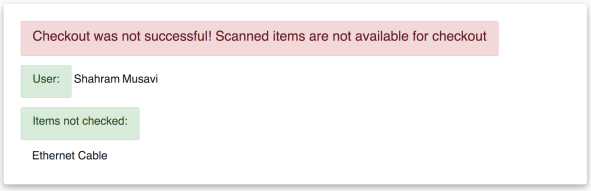


Figure 8: Unavailable item checkout

2. A student can have a maximum of five items checked out of the lab at one time. If the user tries to checkout more items, the system won't allow the operation until one or more of the checked-out items are returned as shown in Figure 9.

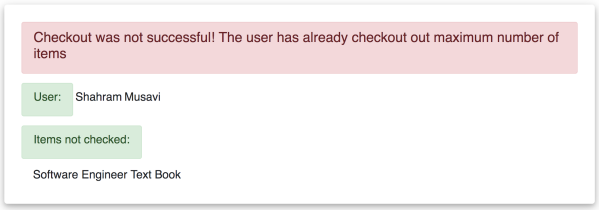
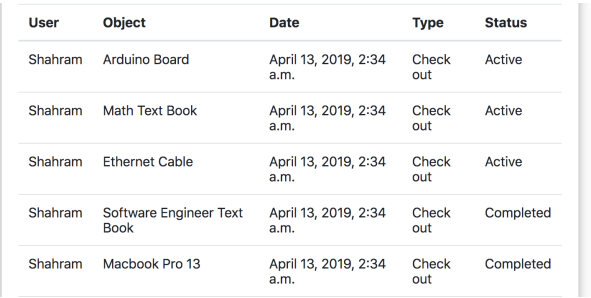


Figure 9: Maximum checkout items

3. The administrator has access to a full record of all the check-ins and check outs, and can filter results by type or status as demonstrated in figure 10



User	Object	Date	Type	Status
Shahram	Arduino Board	April 13, 2019, 2:34 a.m.	Check out	Active
Shahram	Math Text Book	April 13, 2019, 2:34 a.m.	Check out	Active
Shahram	Ethernet Cable	April 13, 2019, 2:34 a.m.	Check out	Active
Shahram	Software Engineer Text Book	April 13, 2019, 2:34 a.m.	Check out	Completed
Shahram	Macbook Pro 13	April 13, 2019, 2:34 a.m.	Check out	Completed

Figure 10: Records table result

4. The administrator can update a group of objects. For example, the administrator can make all the Ethernet cables at the lab unavailable or change their title. The system will notify the administrator about the exact number of items changed as shown in Figure 11.

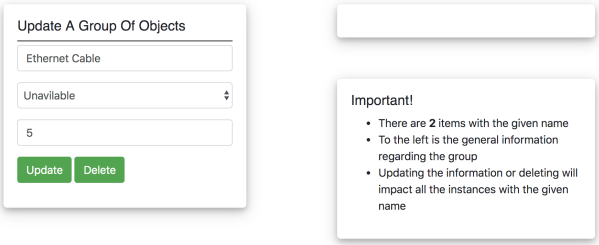


Figure 11: Update a group of objects

5. The administrator can update a specific object by scanning its tag as shown in Figure 12.

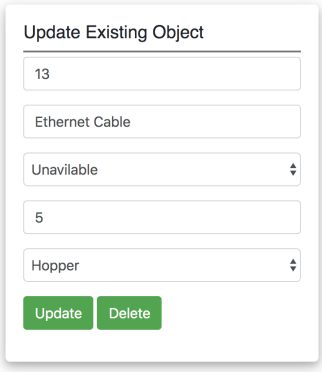


Figure 12: Update a single object

6 FUTURE WORK

This project can be further improved in future by implementing features that make the communication between the administrator and the student users more efficient. As well as help make the system more secure. Some of the features that could be implemented in the future involve:

- Reminder and confirmation emails: An important feature that could be added to the system is the ability to notify the user through email that the operation they did was successful. The email can contain the time of the check-in or check-out as well as the items involved in the operation. Additionally, the system can also send reminder emails to the users to remind them of the objects return deadline.
- Restful API: The system could be improved by implementing a Restful API. Implementing a Restful API helps data to not get tied to resources or methods since Rest can handle multiples types of calls and return different data formats.
- Instant feedback on check-in/check-out form: An interesting feature that could be added to the system is when an object or user ID is scanned the system can give instant feedback on the person or objects associated with the scanned IDs. This can be done instantly after the IDs are scanned. This feature could help make the process of check-in/check-out easier for the users. This feature can be implemented using Ajax.
- Check records table using the object ID: Future work could enhance administrator's monitoring on all operations by adding a feature, where the administrator could scan an object ID and see all the check-in or checkout operation of the object. Currently, the system only supports object names to be entered.

7 CONCLUSION

In this paper, I have compared the advantages of barcoding and RFID technologies in library management systems and how RFID has become a prominent solution. I then provide detailed information on the design and implementation of the system developed at Earlham college. The system focuses on helping students and admins to check in and check out items from Hopper and Turing labs at Earlham. For students, the system enhance accessibility to the labs as students can search for items from their personel computers, and self-check out and check-in items.

The system provides more efficient inventory to the administrator, as the administrator can oversee all the check-in and checkout operations. As well as, keep a current record of student users, and objects stored in the two labs. The administrator can also set security measures on items such as maximum number of items in each check-out, and the maximum number of days an item or group of items can be checked out for.

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