IFLA WLIC 2019 Athens

Submitted on: 13.09.2019

Information Technology *Satellite Meeting*
"Robots in libraries: challenge or opportunity?"
21-22 August 2019
Technical University of Applied Sciences Wildau, Germany

A Post-implementation Review Analysis for an Autonomous RFID Inventory Project: A Qualitative Study

Zhengwei Xia
Library, Wuhan University, Wuhan, China.
E-mail address: zwxia@lib.whu.edu.cn

Quan Li
Library, Wuhan University, Wuhan, China.
E-mail address: liquan@lib.whu.edu.cn

Wenhui Duan
Library, Wuhan University, Wuhan, China.
E-mail address: whduan@lib.whu.edu.cn

Ping Fu
Brooks Library, Central Washington University, Ellensburg, United States.
E-mail address: ping.fu@cwu.edu

Abstract:

The purpose of the study is to use the results of a post-implementation review analysis for an autonomous RFID inventory project in Wuhan University Library to examine three hypotheses: the RFID locating function can help end users to find books more quickly (Hypothesis 1); the RFID robot system improves inventory work efficiency (Hypothesis 2), and; the RFID robot system improves inventory accuracy (Hypothesis 3), and make recommendations to areas for improvement identified through the review. A qualitative research method is primarily employed for the study. Two surveys are designed for collecting data and gaining information and insights from a predefined group of respondents. A research interview is also conducted with the library dean and associate dean for technology for seeking feedback and insights from library administrators. Additionally, two experiments are designed for measuring inventory accuracy and scanning and locating accuracy. The results of the analysis and experiments positively supported the three hypotheses. Finally, the study proposed some recommendations to areas for improvement such as enhancing locating

algorithm; ensuring network connected; migrating location calculation to a local server; providing more training to library staff and patrons, and; promoting the locating function to patrons.

Keywords: RFID inventory, Robot, post-implementation review, locating accuracy

1. Introduction

Libraries conduct inventories for some reasons such as ensuring the accuracy of their catalogs records, identifying missing items, making changes accordingly in the catalogs to alert the patron, finding misplaced materials on the shelves and analyzing a collection's strengths and weaknesses (Greenwood, 2013). There are many automated systems and tools available in the market. Librarians are no longer required to take an inventory by hand. However, not all library inventory systems are created equal. One innovative way is to use RFID (Radio Frequency Identification) technology (Butters, 2008). The library staff uses an RFID inventory cart to conduct an inventory task. Another revolutionary way is to use a robot. Some researchers (Ramos-Garijo et al, 2003; Thirumurugan et al., 2010; Pathak et al., 2016; Sundara et al., 2017; Calvert, 2017) proposed and /or made an experiment approach to use RFID technology to create a robot to do shelf reading, retrieve items, and report the results back to human staff. A real robot was reported in 2016 to be used by Singapore National Library for navigating and scanning library shelves and for detecting misplaced books. In 2017, Wuhan University Library (WUL) implemented an automatic RFID inventory robot developed by a research team from Nanjing University. WUL became the first user in China since the new RFID inventory robot had been put into production.

1.1 Project Background

WUL is one of the largest university libraries in China, serving more than a total of 80,000 faculty, staff and students. WUL has about 6 million physical items, thousands of e-books, thousands of electronic databases and e-journals, and a vast array of digital resources. WUL consists of the main library and three branch libraries. The Main Library currently has 722,371 physical books for circulation and the three branch libraries have a total of 595,249 physical books for circulation, a total of 1,317,620 physical books for circulation for the entire library. In 2017, to improve work efficiency and users borrowing experiences, an autonomous RFID inventory robot project was kicked off for the Main Library. During the implementation, the vendor and the WUL worked together to establish a joint implementation team. The joint implementation team conducted numerous testing and made several enhancements during the implementation. The improved automated RFID inventory robot now can automatically turn on from its charging station, move forward and backward with a pre-configured routine and bypass obstacles to complete an inventory task. The robot runs a well-designed locating algorithm to find and scan books on shelves and generating detailed location information. The robot can return to the charging station by itself under the circumstance of low battery power. After the battery is fully recharged, the robot can automatically return to the location where the previous inventory was stopped and continue performing the inventory task. After the task is completed, the robot can return to the charging station and automatically shut down. The automated inventory robot work in an environment without human supervision. It starts to work immediately after the library is closed at night and completes work just right before the library's opening on the second day. The robot collects all inventory data such as item barcode, call

number, item status, RFID tag EPC (Electronic Product Code), item permanent location, item temporary location, and last checkout timestamp and stores such data in an RFID inventory database. The joint implementation team also developed a synchronization program to automatically synchronize daily borrowing and returning data between the library management system Aleph and the RFID inventory database. If an item is checked out, theoretically it should not be scanned during the inventory process, vice versa, if an item is returned, it should be scanned for verifying whether it is placed in the right place and good order or not. The inventory process also tracks item statuses such as filtered, searched, missing, lost, on-reserve, and in process. After an inventory task is completed, custom reports are generated and sent to the library staff who are responsible for library shelving. The custom reports include shelved items list, error collection list, abnormal status list, abnormal TAG list, loan list, book on reserve list, and lost items list. Currently, three robots are employed in the Main Library while the other three branch libraries are still using traditional RFID inventory and tracking cart.

1.2 Problems Statement and Hypotheses

This study uses post-implementation review principles and methods to conduct a post-implementation review and evaluation for the RFID automated inventory project at the WUL Main Library. A post-implementation review is a process of assessing whether project objectives are met. Project managers can use it to review the management effects of the project. This helps avoid making similar mistakes in future projects and learning how to run the project better. The purposes of this study to adopt the post-implementation review are to:

(1) Evaluate whether the objectives of the RFID automated inventory were met successfully or not, discuss the advantages, disadvantages, and benefits of the project and/or experiences and lessons learned from the project;
(2) Examine three hypotheses:
    Hypothesis 1 – the RFID locating function helps end users to find books more quickly,
    Hypothesis 2 – the RFID robot improves inventory work efficiency,
    Hypothesis 3 – the RFID robot improves inventory accuracy, and
(3) Make recommendations for improvement in the areas identified through the review.

2. Literature Review

RFID technology has been widely used in libraries. There were works of literature about RFID self-check machines, identification and security, and material tracking systems. However, there were few kinds of literature focused on the RFID inventory robot. A chronological literature review is adopted by this study.

Thirumurugan J. et al. (2010) demonstrated an application of Line Following Robot for library inventory. The robot was able to automatically reach a book and send the book's location information back to library staff or patron who requested the book. Greenwood (2013) examined multiple inventory methods at the University of Mississippi Libraries and proposed a way to reduce user frustration from not being able to locate materials. Sun (2013) described a locating book visualization system designed and implemented by Flash, ASP and database technology. Jiang and Wu (2015) analyzed and compared the principles, advantages, disadvantages of the manual positioning method, the first book intelligent positioning method, the virtual first and last book positioning method and the surrounding book positioning method. Shen et al. (2016) reported their study of a book inventory robot designed and produced by

ultra-high frequency (UHF) RFID technology. Pathak et al (2016), Sundara et al (2017), proposed a library management robot by using RFID, Line following, kinematics of robotic arm and other related technologies to improve book shelving work and eliminate problems like misplacing of books. Calvert (2017) reviewed the applications of robots used in libraries such as shelf reading, reporting the results to human staff, retrieving large items such as boxes, but identifying and picking up small and varied objects such as books. Pradosh et al. (2017) suggested inventing a robot by using RFID technology to help and simplify book finding and picking process and reduce manual routine work done by staff and users. Yuet al. (2019) proposed a technique to improve the accuracy of robot positioning and navigation and that of book accessing and returning operations.

3. Methods

This study uses a qualitative research method. We used post-implementation review methods such as stakeholder surveys and in-person interviews to conduct a review and collect data and information. Additionally, we used data generated by the RFID reporting systems and Aleph ILS to help identify problems and areas we need to improve. We also designed two experiments to help examine our hypotheses.

To collect information and insights from stakeholders such as librarians and staff, students, and library administrators and managers, we designed two surveys and one set of interview questions. One survey is designed for collecting information and feedback from library staff regarding RFID project including the use of self-check machines and inventory robots. It contains ten multiple choices questions and one opinion question. Example questions are as follows: How difficult do you operate the following devices? Do you think the following devices have a reasonable design and user interface? Do you think the features of the following devices are consistent with the features you expect? Have you seen other devices/technologies besides the RFID devices used in the library? What equipment/technologies do you want the libraries to implement? These questions will help us to have a big picture and get insights from librarians and staff. The details of the questionnaire see Appendix I — Questions of Survey for Librarians and staff in the Dataset about the Review of Autonomous RFID Inventory Project in Wuhan University Library (http://hdl.handle.net/20.500.12304/10196).

Similarly, another survey is designed for collecting information from end users. It contains thirteen multiple choice questions and one opinion question. Example questions include: Have you used the RFID locating function for the print books on the OPAC? What is the reason you don't use the RFID locating function? (If you have used RFID locating function, you can skip this question)? Do you think that the RFID locating function improves the efficiency of your finding print books? (If you never used this function, you can skip this question). These questions will help us to get a sense of the research problems such as how our patrons are aware of the robot implemented in the library and if the robot can help our end users to find a book more quickly. The details of the questionnaire see Appendix II — Questions of Survey for Students in the Dataset about the Review of Autonomous RFID Inventory Project in Wuhan University Library (http://hdl.handle.net/20.500.12304/10196).

Furthermore, a set of interview questions are designed for collecting information and opinions from the library administrators and managers. Here are some examples of questions: what are the main purposes of implementing RFID projects in the libraries from your perspective? Has the project been implemented as scheduled? What functions have been used since the implementation of the project? What features help the library administrators and/or

managers make appropriate decisions? The details of the interview questions please refer to Appendix III – Interview with Administrators in the Dataset about the Review of Autonomous RFID Inventory Project in Wuhan University Library (http://hdl.handle.net/20.500.12304/10196).

One online survey tool called WJX (问卷星) is used for surveys. All the survey and interview questions were created in Chinese. For this article, we translated all the questions into English. The Survey I was distributed by email to 50 library staff selected from the Main Library and three branch libraries based on their job categories. All of these 50 library staff are involved in circulation and shelving. Among the 50 staff, 7 staff are from the Main Library who have real experience with robots. 50 valid responses were received. We post Survey II online and set the opening time for two weeks. A total of 301 students responded. However, the number of responses for each question was different. Some participants just answered part of the questions of the survey. Regarding the use of the RFID locating function, we received 100 answers. 23 participants responded that they had experience with the function while 77 participants responded they never used the function yet. The responses were automatically encoded and processed by the survey tool WJX. Furthermore, an in-person interview was conducted with the library administrators to seek feedback and insights from the angles of the administrators.

Additionally, two experiments, Experiment A and Experiment B, are designed for better understanding whether the locating algorithm and locating function of the automated inventory robot can effectively help students to find a book and improve work efficiency and inventory accuracy.

The principle of Experiment A is to compare the effectiveness and efficiency of finding books between the method by using call numbers only and the method by using call numbers plus the location information provided by the RFID locating function such as row number, column number, shelf number, floor number, and library name. The experimental scheme is as follows. First, we prepare two rounds testing: Round A and Round B. Round A contains 20 book lists coded as A1-A20, each of which contains 50 books' barcode, call number, and title. Round B first duplicates Round A; however, the information generated by the RFID locating function is added to each B list for each book. Make sure the only difference between Round A and Round B is Round B contains detailed location information. That means, A1 and B1 contain the same 50 books but B1 has additional detailed location information for books. Secondly, invite 20 volunteers to participate in the experiment. Each volunteer will be given a code, for example, the first volunteer is given a code called V1, and so forth. In Round A, each participant will be issued an A-list. For example, the V1 participant will be given the list of A1, the V2 participant will be given the list of A2, and so forth. Then we record the time spent on finding books and the number of books correctly found for each participant in Round A. In Round B, the same 20 volunteers are issued a B-list; however, to get a better accurate measurement, we use this way: the V1 participant will be given the B2 list, and so on, the V20 participant will be given the B1 list. This way ensures each participant uses two different A list and B list. It also eliminated the potential measurement errors caused by participants' memory abilities. Then we record the time spent on finding books and the number of books correctly found for each participant in Round B.

Experiment B is designed to compare the efficiency and accuracy of the inventory work done by the robot with the efficiency and accuracy of the inventory work done by 2 skilled human staff who use a traditional RFID inventory and tracking cart. The vendor claimed that the robot

inventory locating accuracy rate was 96% but we never measured and proved it before and we never measured human locating accuracy either. The experiment is designed as follows:

(1) Randomly select one floor and two rows of shelves in the Main Library to get a book list. We begin the experiment just before the library's closing time and make sure that no books will be moved during the experiment.
(2) We use a barcode scanner to get the book list data as an experiment sample.
(3) Then 2 skilled human staff use an RFID inventory cart to locate and scan the sample books.
(4) Record the locating and scanning time needed by the 2 skilled human staff separately.
(5) The robot begins to locate and scan this floor automatically. The robot locating and scanning time is calculated automatically by the robot in this way:
The robot locating and scanning time = (number of the sample books scanned/total books scanned in the floor) * (total time robot spent for scanning the floor)
(6) Export data from the RFID inventory cart and the robot report separately.
(7) Then we use a formula to calculate the accuracy of the locating algorithm and the robot's scanning accuracy and work efficiency:
Formula 1: Scanning Accuracy Rate = ((number of books correctly located + number of books incorrectly located)/(total number of books on the selected shelves))*100%
Formula 2: Locating Accuracy Rate = (number of books correctly located/total number of books on the selected shelves)*100%
Formula 3: Scanning Efficiency Comparison Ratio = (average minutes spent on scanning by human staff)/(minutes spent on scanning by the robot)

4. Findings

Through the RFID Post-implementation review and evaluation, particularly use the survey responses, interview answers, statistical data generated from the systems, and experiment results, we have the following findings:

(1) Although the robot has been implemented and gone live more than one year, the Survey I results show most library staff, particularly for branch library staff, lack of knowledge and experience with the RFID inventory robot. Among 50 survey participants, only 7 library staff from the Main Library answered they had real experience with the robot. 11 staff from branch libraries answered that they had limited knowledge about the robot. 32 library staff, accounting for 64% of survey participants, answered they didn't know at all about the robot. The complete survey data see Appendix IV – Results of Survey for Librarians and Staff_1.xlsx in the Dataset about the Review of Autonomous RFID Inventory Project in Wuhan University Library (http://hdl.handle.net/20.500.12304/10196).

(2) Similarly, the Survey II results show most students have never used the RFID locating function yet. Among 100 valid responses, 77 students answered never used the function. Among the 77 students who never used the function, 46 students, accounting for 60% of the responses, responded they were not aware of the function and didn't know what was about and how it would work. 23 students, accounting for 30% of the responses, responded that they thought they could find a book more quickly by using call numbers only. While 8 students, accounting for 10% of responses, said they tried but it was difficult for them to understand and remember so they just gave up to use the function.

The complete survey data see Appendix V – Results of Survey for Students_2.xlsx in the Dataset about the Review of Autonomous RFID Inventory Project in Wuhan University Library (http://hdl.handle.net/20.500.12304/10196).

(3) While for 23 students who answered the question positively about the use of the RFID locating function, 15 students, accounting for about 65% of the responses, agreed the function was able to help them to find a book more quickly that supported the Hypothesis 1. While 8 students reported they were not so familiar with the function so they felt no big difference from the way of using call numbers only. The complete survey data see Appendix V – Results of Survey for Students_2.xlsx in the Dataset about the Review of Autonomous RFID Inventory Project in Wuhan University Library (http://hdl.handle.net/20.500.12304/10196).

(4) However, Experiment A demonstrated Hypothesis 1 is positive. As described in the Methods, we invited 20 volunteers to participate in the testing of finding 50 books. Since the record of finding books shows, for 20 participants, the average error rate of accidentally finding wrong books is lower than 1%, to simplifying comparison, we ignored the factor of the error rate of finding wrong books. Here is the simplified result.

Table 1: Experiment A Results

Volunteer Number	Time Spent on Finding 50 Books in Round B (Minutes)	Time Spent on Finding 50 Books in Round A (Minutes)	The Efficiency of Round B increased
v1	23:53:06	39:26:46	39.45%
v2	24:00:00	44:16:00	45.78%
v3	40:00:00	51:00:00	21.57%
v4	33:00:00	47:00:00	29.79%
v5	36:43:00	52:21:00	29.86%
v6	34:40:00	44:50:00	22.68%
v7	32:18:00	48:35:00	33.52%
v8	30:03:00	44:34:53	32.60%
v9	33:43:00	37:14:00	9.44%
v10	39:00:00	41:00:00	4.88%
v11	22:35:22	40:12:00	43.81%
v12	25:40:00	49:25:00	48.06%
v13	33:27:00	35:33:00	5.91%
v14	31:00:00	41:00:00	24.39%
v15	23:20:00	40:46:00	42.76%
v16	22:24:05	44:10:00	49.28%
v17	25:18:00	38:42:00	34.63%

v18	19:00:00	34:00:00	44.12%
v19	20:00:00	40:00:00	50.00%
v20	24:00:00	35:00:00	31.43%
Average	28:70:22	42:27:17	32.20%

As Table 1 shows, with more valid location information, for the same group of participants, the average time of finding 50 books in Round B is around 29 minutes while in Round A the average time of finding 50 books is about 42 minutes. Participants can save approximate 13.5 minutes in Round B. And the results show that compared to Round A, averagely, the efficiency of Round B increased 32% from 42 to 29 minutes per 50 books. The experiment results are consistent with the feedback from those 15 students in finding 3 who reported that they were familiar with the function and used the function frequently and support Hypothesis 1.

(5) The analysis results support Hypothesis 2 too. That is, the FRID inventory robot can make inventory work more efficient and flexible. As Experiment B described, we selected 567 books on the shelves from the location WLA3F2040101 to WLA3F2040106 and from WLA3F2040201 to WLA3F2040206. The complete data see Appendix VI – Experiment B Results.xlsx in the Dataset about the Review of Autonomous RFID Inventory Project in Wuhan University Library (http://hdl.handle.net/20.500.12304/10196).

Table 2: Experiment B Statistical Results

	Total books on the selected shelves	Correct located	Incorrect located	Scanning accuracy	Locating accuracy	Time spent (seconds)
Robot	567	549	6	97.88%	96.83%	104
Staff 1	567	535	11	96.30%	94.36%	696
Staff 2	567	542	3	96.12%	95.59%	450
Staff Manual Average	567	538.5	7	96.21%	94.97%	573

(6) As shown in Table 2, the robot takes 104 seconds for scanning 555 books and missed 12 books. While using traditional RFID Inventory cart, two skilled library staff need an average of 573 seconds for scanning 546 books and missed 21 books on average.

Use the formula 1 defined in the chapter of Methods:

Robot Scanning Accuracy Rate = ((549+6)/ 567)*100% = 97.88%
Average Human Scanning Accuracy Rate = ((538.5+7)/567)*100% = 96.21%
Difference of the two scanning accuracy rate = 97.88% - 96.21% = 1.67%

That means the robot scanning accuracy rate is higher than the average human scanning accuracy rate by 1.67%.

Using the Formula 3 we defined in the chapter of the Methods:

The Scanning Efficiency Comparison Ratio = 573/104 ≈ 5.5

That means, from the angle of the scanning efficiency, one robot equals approximately 5.5 skilled library staff.

In particular, the robot works at night without human supervision. It can be configured to perform a full or a partial inventory at any time, greatly shortening the inventory cycle and providing library staff with rich custom reports so that library staff can get real-time information to better manage collections and bookshelves and correct information promptly.

(7) The analysis results and Experiment B in Table 2 also support Hypothesis 3. That is, the RFID inventory robot improves inventory accuracy. The robot can find misplaced books automatically and correctly determine the order of the books on the shelves.

By using formula 2 we defined in the chapter of the Methods:

Robot Locating Accuracy Rate = (549/567) * 100% = 96.83%
Average Human Locating Accuracy Rate = (538.5/567)*100% = 94.97%
Difference of the two locating accuracy rate = 96.83% - 94.97% = 1.86%

That means the robot locating accuracy rate is higher than the average human locating accuracy rate by 1.86%. The result also shows that the robot locating accuracy rate is a little bit higher than the locating accuracy the vendor claimed which was 96%. Also, the average human locating accuracy rate gives us a sense of how accurate that skilled human staff can make with an RFID inventory cart.

(8) The RFID inventory robot reporting system is very helpful for troubleshooting and correcting errors in the systems. The robot can automatically generate custom inventory reports to help track items so that librarians can correct information in the system promptly. Typical problems identified by the robot include shelf and location error and a circulation status error. For example, the report generated on December 20, 2018, showed that there were a total of 705 books with shelf and location error. Among them, 533 books were found by the robot from the Main Library. There were a total of 207 books loaned. A total of 412 books had a circulation status error. All of the information was reported by the robot and very helpful for troubleshooting so that librarians can take actions accordingly to correct errors timely.

5. Discussions and Recommendations

The implementation of the automated inventory robot in the library fundamentally solves the inventory problem of the libraries. It provides useful and comprehensive information to support collection development. It helps the patron to find a book more quickly. However, through this post-implementation review and analysis, we identified the following problems and/or areas need to be improved:

(1) The locating algorithm could be optimized. The locating accuracy claimed by the vendor is about 96% which is proved by the Experiment B. However, the robot locates a few books incorrectly. That's because the robot sometimes accidentally reads books surrounding the books it is supposed to read such as accidentally scanning the books on the upper row or the back row. The library should work with the research team from

Nanjing University and the vendor to identify a solution to improve the locating accuracy.

(2) The current location calculation is performed in a cloud computing environment and completely relies on the reliability of network connectivity. Once a network outage occurs, the inventory data will be lost, which will impact the calculation and report generation. We recommend we should migrate the data calculation to a local server to reduce the impact of network outages.

(3) The library should provide more guidelines and training opportunities such as creating a research guide, conducting workshops and providing in-person or online training classes for students to be familiar with the RFID locating function. The library should encourage librarians and staff to learn more knowledge about the robot so they can promote the RFID robot locating function to patrons so that more patrons know how to use the function embedded in the OPAC to assist them in finding a book more quickly.

6. Conclusions

The study presented results of the post-implementation review analysis for the autonomous RFID inventory project in WUL and made recommendations to areas for improvement identified through the review. We used a qualitative research method including conducting surveys and interviews to collect data and gain insights and information from various stakeholders such as the administrators of the libraries, librarians and staff, and students. We also analyzed statistical reports and conducting experiments to help examine our hypotheses. The results of the analysis and experimental results positively supported the three hypotheses we assumed in the chapter of the Introduction. That is, the RFID locating function can help end users to find books more quickly (Hypothesis 1); the RFID robot system makes inventory work more efficiency (Hypothesis 2), and; the RFID robot system improves inventory accuracy (Hypothesis 3). We also found the reporting system is very helpful for troubleshooting and correcting information in the systems. Finally, the study proposed some recommendations to areas for improvement such as enhancing locating algorithm; ensuring network connected; migrating location calculation to a local server; providing more training to library staff and patrons, and; promoting RFID locating function to patrons.

As the Dean of the Library confirmed during the in-person interview, this project “has greatly improved patrons’ borrowing efficiency and borrowing behaviors”. This is the first RFID autonomous project implemented in academic libraries in China. “The project has achieved great success and exceeded the library administration’s expectation.” However, there are also some areas to be improved, as the Associate Dean for Technology pointed out, “The dual operation and maintenance mode, which results in the complexity and uncertainty of the system, and made the implementation phase of the project longer than we expected.” Therefore, our next step is to increase the time control of the implementation of the recommendations we proposed from this study and improve communication with the vendor and the research team from Nanjing University. Overall, the RFID inventory robot project has been successful and has provided a positive example for other libraries who would like to implement an autonomous inventory robot.

Acknowledgments

This project received a grant from the Research Funding Program of Hubei Academic Library Committee (Grant Number: 2017-ZJZD-02, Research Proposal: Research on the Optimization of Library Service Based on RFID Technology). We'd like to thank all volunteers for their time and efforts who participated in the surveys and experiments. We also would like to thank the Dean of the Library, Professor Xingcai Wang, and Associate Dean for Technology, Mr. Yongkai Huang, for their time to participate in the research interview and their strong support for the study.

References

Butters, A. (2008). RFID in Australian Academic Libraries: Exploring the Barriers to Implementation. *Australian Academic & Research Libraries, 39*(3), 198-206.

Calvert, Philip. (2017). Robots, the Quiet Workers, Are You Ready to Take Over? *Public Library Quarterly*, 36.2: 167-72.

Greenwood, Judy T. (2013). Taking It to the Stacks: An Inventory Project at the University of Mississippi Libraries. *Journal of Access Services, 10*(2), 77-89.

Jiang, B., Wu, Y. (2015). A Study of RFID Book Positioning Methods in Libraries. *Journal of Modern Information, 35(5)*:131-134. 江波, 吴永祥. (2015).图书馆 RFID 系统建设中的图书定位问题研究.*现代情报, 35(5)*:131-134.

Pathak, M., Sanvaliya, R., Pandit, M., & Kanthed, S. (2016). Library Management Robot. *International Journal of Engineering Research, 5*(10): 356-364.

Ramos-Garijo, R., Prats, M., Sanz, P., & Pobil, A. D. (2003). An autonomous assistant robot for book manipulation in a library. *SMC03 Conference Proceedings. 2003 IEEE International Conference on Systems, Man and Cybernetics. Conference Theme - System Security and Assurance (Cat. No.03CH37483)*. doi:10.1109/icsmc.2003.1244499

Shen, K., Shao, B., Cheng, L., Shan G. (2016) The Design and Realization of an Inventory Robot with Ultra-high Frequency (UHF) RFID technology. *Research on Library Science, 378 (7*): 24-28. 沈奎林，邵波，陈力军, 单国锋. (2016).基于超高频 RFID 的图书盘点机器人的设计和实现.*图书馆学研究, 378（7*）：24-28.

Sun F. (2013). Design and Implementation of a Book Locating System. *Library and Information Service, 57(15)*:102-107. 孙发. (2013). 图书定位系统的设计与实现. *图书情报工作, 57(15)*:102-107.

Sundara m.V., Saravananb, Aravindb, Tharini d. R. (2017). Smart Robots in library management system. *International Journal of Innovative and Emerging Research in Engineering, 4(1), 74-79.*

Thirumurugan, J., Vinoth, M., Kartheeswaran, G., & Vishwanathan, M. (2010). Line following robot for library inventory management system. *Interact-2010*. doi:10.1109/interact.2010.5706151

Yu, X. et al. (2019). Positioning, Navigation, and Book Accessing/Returning in an Autonomous Library Robot using Integrated Binocular Vision and QR Code Identification Systems. *Sensors, 19*(4), 783.