SMART LIBRARY INFRASTRUCTURE USING RFID FOR BOOK PLACEMENT AND RETRIEVAL

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***Abstract*—** Modern libraries are evolving rapidly to meet the demands of efficiency, accuracy, and user convenience in managing vast collections of books and resources. Traditional manual shelving and tracking systems are increasingly proving inadequate due to human error, time constraints, and inefficiencies in inventory management. This paper proposes a smart library infrastructure that leverages Radio Frequency Identification (RFID) technology for automated book placement and retrieval. By integrating RFID tags into library resources and using RFID readers at shelving units, the system enables real-time tracking, precise book location identification, and intelligent shelf management. This approach significantly reduces the time required for book searching, re-shelving, and auditing, while also enhancing user satisfaction and staff productivity. The paper discusses the system architecture, hardware components, data flow, and software logic behind the implementation. Furthermore, it evaluates the system's effectiveness through performance metrics such as retrieval time, placement accuracy, and scalability. The findings demonstrate that an RFID-based shelving system is a transformative solution for creating smart, efficient, and user-friendly library environments.

I. INTRODUCTION

Libraries have long served as vital repositories of knowledge and culture, but the growing volume of printed and digital resources poses new challenges for their effective management. One of the most time-consuming and error-prone aspects of library operations is the shelving and retrieval of books. Traditional library systems depend heavily on manual processes for sorting, placing, and locating materials, leading to inefficiencies such as misplaced books, long search times, and difficulties in maintaining accurate inventories. As academic and public libraries strive to modernize, the integration of smart technologies becomes essential in enhancing operational efficiency and improving user experience.

Radio Frequency Identification (RFID) technology has emerged as a promising solution to address these challenges. Unlike barcodes, RFID tags do not require line-of-sight scanning and can be read remotely and simultaneously in bulk, making them ideal for dynamic environments like libraries. When embedded in books and integrated with RFID-enabled shelves and readers, these tags allow for real-time tracking, accurate placement verification, and streamlined search processes.

This paper explores the development of a smart shelving system powered by RFID technology that transforms how books are managed within a library environment. The proposed system enables automatic recognition of book placements, flags misfiled items, assists users in locating desired resources, and supports efficient stock auditing. Additionally, the integration of software and hardware components—including microcontrollers, RFID readers, and user-friendly interfaces—ensures smooth functionality and scalability for libraries of various sizes.

By adopting RFID for shelving and retrieval, libraries can significantly reduce labor-intensive tasks, minimize human error, and enhance the accessibility and responsiveness of library services. This study presents the design, implementation, and evaluation of such a system, aiming to contribute to the ongoing digital transformation of library infrastructure.

Fig.1. Books arrangement in the Library

Due to the library's extensive collection of materials used for teaching, research, and community service at the university, it is crucial that all books remain in their designated spaces; otherwise, patrons may have trouble locating certain books, even though the catalogue indicates where they should be. It could be more frustrating to look for certain volumes in a large library if they aren't all in their rightful places.

II. RFID TECHNOLOGY

Radio frequency identification (RFID) consists of two main components, Transponder and Interrogator. The RFID Transponder is simply known as Tags (RFID Card, etc) which is always placed on the object or person to be located. While the Interrogator is the RFID Reader which could be of different type and design depending on the purpose for which it is to be used. It is the device that reads and locates the tagged object or person.

Radio frequency identification systems are small low cost tags on objects in order to track their positions (Andrews, & Ghosh, 2007). RFID systems are now being typically deployed at low (125kHz), medium (13.56MHz) and high frequency (869MHz, 2.5GHz) bands. At 125kHz and 13.56MHz, inductive coupling is used to communicate between readers and tags, whereas electromagnetic coupling is used at 868MHz and 2.5GHz (Bogachev, et al 2010)

An RFID transponder also known as RFID tag is a device that has an antenna and transceiver and is capable of storing and transmitting data to a reader. There are various sizes of an RFID tag. Some are seen in Figure 2 below

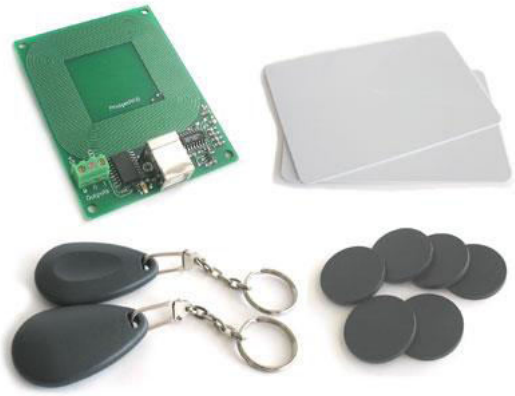


Fig.2: RFID tags

Sanghera, et al. (2011 pp. 128-131) stated that when choosing a tag, some features must be considered, and they are: The operating frequency of the RFID tag to be used, the size of the RFID tag, the range of the RFID tag, the data capacity of the RFID tag, the environmental condition (where the tag will be used) of the RFID tag, and importantly, the kind of RFID tag (passive, semi active, or active) to be used.

RFID Operation

A structure showing the operation of RFID is seen below

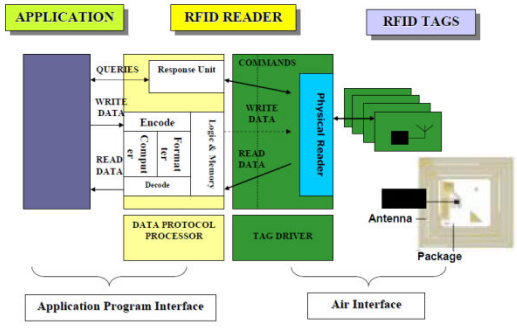


Fig.3: RFID structure

As seen in Figure 3, the RFID structure consists of three layers: RFID tag, RFID reader and application.

The RFID tags consist of coils which make up the antenna. The package is a material used to firmly hold the coils. There is no voltage source in the RFID tag. The voltage source is depends on the RF signal transmitted from the RFID reader. The interfacing between RFID tag and the RFID reader is through the air. The distance of interfacing should be around 0cm to 50cm. Depends on the product of the RFID readers, some RFID readers allow more than 50cm of communication with the tags but about 6cm is used for this project. In the RFID reader, there will be a command to write and read data. The writing and reading of data are interfaced with a data processor. In the data processor, one can see the memory, encoder and decoder. The memory is used to store the information of the RFID tag. When transmitting the information, the information will be encoded. When receive the incoming information, the information will be decoded. Hence, the RFID reader works as a two ways communication (transceiver).

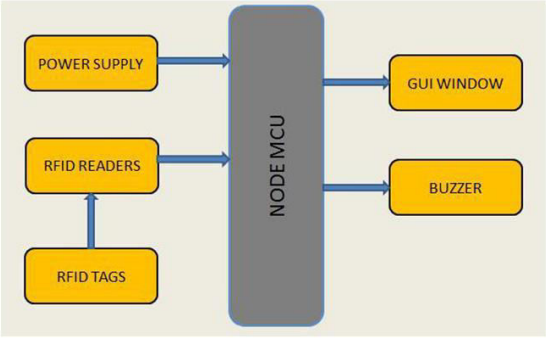
CIRCUIT DIAGRAM

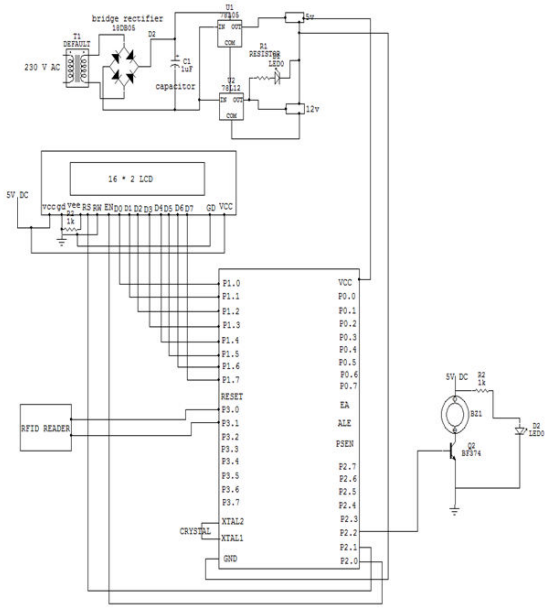
The RFID Transponder is simply known as Tags (RFID Card, etc) which is always placed on the object or person to be located. While the Interrogator is the RFID Reader which could be of different type and design depending on the purpose for which it is to be used. It is the device that reads and locates the tagged object or person. Radio frequency identification systems are small low cost tags on objects in order to track their positions RFID Technologies in Libraries. RFID systems are now being typically deployed at low (125kHz), medium (13.56MHz) and high frequency (869MHz, 2.5GHz) bands. At 125kHz and 13.56MHz, inductive coupling is used to communicate between readers and tags, whereas electromagnetic coupling is used at 868MHz and 2.5GHz. RFID devices can be divided into two categories:

1) RFID devices with power supply (battery)
2) RFID devices without power supply.

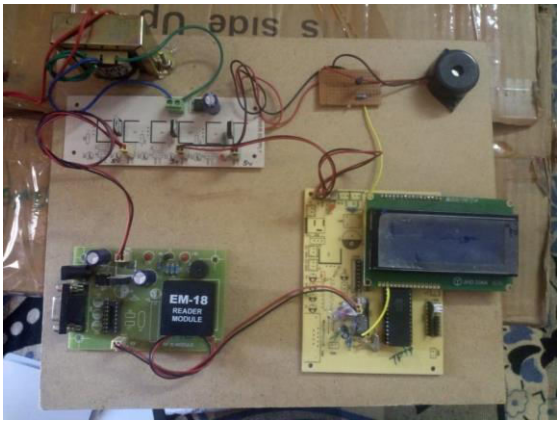
As a wireless system, the RFID tag contains a transceiver and an antenna. It can be passive, active or semi passive. A passive contain no power source, and it response only when a nearby reader power it. Passive tags have a readable distance ranging from about 10cm up to a few meters, depending on the chosen radio frequency and antenna design. Passives tags can be manufactured with a printed antenna. The semi passive and active tags contain a battery, which is used to power the circuit. This leads to a greater sensitivity than that of passive tags, typical 20dB or

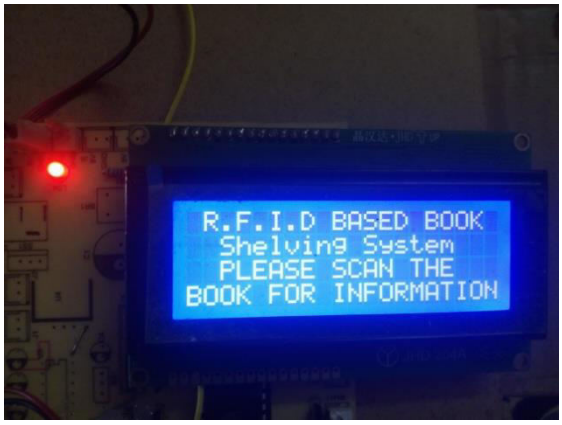
more. Thus it can reach a distance that is ten times longer, or provide a better reliability. An active tag also broadcast to the reader, thus it is much more reliable even in a very adverse RF environment, or can reach a range of 500m, but with a shorter life .Semi passive tags use the battery only to power the circuits, but not to broadcast the signal. Like a passive tag, a semi passive tag uses the RF energy received from the reader to respond.

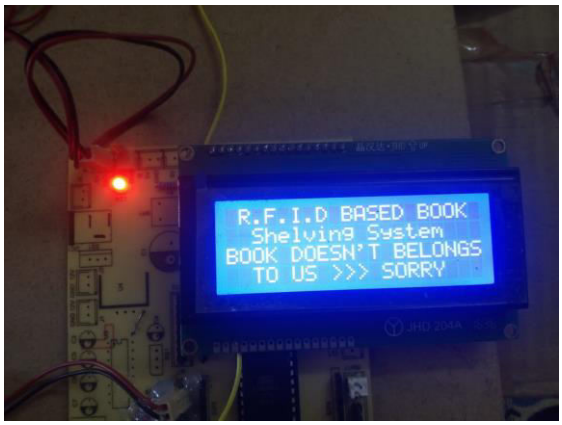


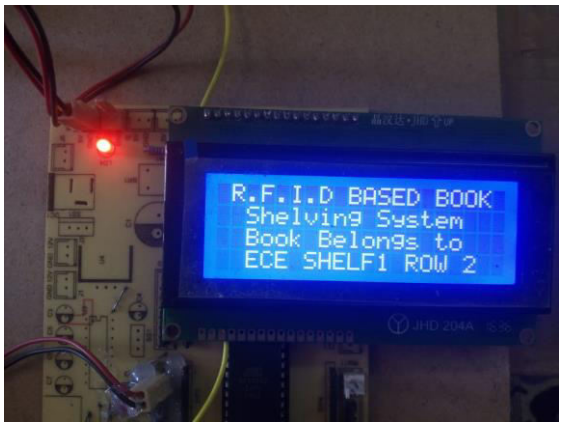


RESULTS









CONCLUSION

The integration of RFID technology into library shelving systems marks a significant advancement in the pursuit of smarter, more efficient library management. By automating the processes of book placement, tracking, and retrieval, RFID-based systems address many of the longstanding issues associated with manual library operations, such as misplaced books, inventory inaccuracies, and time-consuming searches. The proposed smart library infrastructure leverages the unique capabilities of RFID to provide real-time visibility, enhance user accessibility, and optimize staff efficiency.

This study has demonstrated how RFID can be effectively applied to develop an intelligent

shelving system that not only improves accuracy in book handling but also contributes to a seamless and modern library experience. The results indicate that such a system is scalable, cost-effective over time, and adaptable to libraries of various sizes and types. While initial implementation may require investment in infrastructure and training, the long-term benefits—ranging from operational speed to user satisfaction—make it a valuable innovation.

Moving forward, this work sets the stage for further enhancements such as robotic integration, AI-based resource prediction, and mobile app interfaces for real-time user assistance. Ultimately, RFID-based shelving systems play a key role in transforming traditional libraries into smart, automated, and user-centric knowledge environments.

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