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An Internet of Things-Based System for Book Shelving Accuracy Improvement in Libraries

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Abstract
The Internet of Things serves as a crucial hub for the advancement of several types of systems. Despite the development and numerous advancements that have been observed in traditional library management systems as a result of technological progresses, the system still faces the persistent problem associated with book misplacement, wrong shelving, and resource management. This research reviewed approaches proposed by researchers in the following areas: Radio Frequency Identification (RFID), Near Field Communication (NFC), and Wireless Sensor Networks (WSN). It presents a four-tier design architecture which includes the following sections: human and resource identification, a cyber-physical system, an application programming interface (API), and a Web-based Library Management System (WLMS). The Cyber-physical systems block includes the input, the output, and the processing module that simulates the RFID reader functionality using PHP and MySQL Web Technology. The cyber-physical system communicates with the WLMS through an API, using LEDs for display feedback. The system sends upon detection of a library resource about to be placed in a wrong shelf does not open the shelf's door, and at the same time sends a signal to the user via the interfaced LEDs. The system's evaluation of the time it takes to respond from the point of trigger averages to 5 seconds. The internet connection was provided through an MTN Nigeria Mifi device. The results indicate an acceptable improvement in the library incorporating this technology.

Keywords: Internet of Things, Library Management, RFID-Technology, NFC, Wireless Sensor Network, Book Shelving Accuracy, Smart Libraries

1. Introduction

The library is undoubtedly, a crucial hub for research and learning. It offers a wealth of valuable resources and cultivates an environment conducive for scholarly pursuits. This dedicated space is purposefully designed to house an array of materials, including books, periodicals, and various reference materials. The concept of the library as a platform for distributing information, rather than the traditional notion of collecting and preserving data and information, emerged during the transition phase in human civilization (Gleason, 2018). Credit is due to the advancement of technology and infrastructure development, which has made books more accessible and encouraged exploration of the open access system. Beyond traditional offerings, libraries have grown to encompass an array of advanced electronic resources, encompassing the vast space of the Internet, digital collections, and remote technological access, effectively bridging the gap between technology and instruction.

Distinctive in their purpose and scope, five major library types cater to diverse communities(Barus, Simanjuntak and Resmayasari, 2021). Among these are: Academic libraries extend support to institutions of higher learning, while public libraries serve as community-wide information centers. School libraries cater to the educational needs of students from kindergarten to grade 12 (Senior secondary school), and special libraries fulfill unique requirements within specialized contexts such as healthcare, corporations, museums, military facilities, businesses, and governmental institutions. The use of libraries cannot be over emphasized.

Library as an electronic information space offers a diverse array of resources, encompassing services for document delivery, websites, electronic books, periodicals, electronic databases offered by information aggregators, and indexing as well as abstracting services(Hanelt *et al.*, 2021). Despite the spread and the use of libraries amidst all the benefits lie the limitations posed by the traditional library systems. These challenges range from the problem of book misplacement and inventory management to resource accessibility. Others are security and loss prevention, environmental control, space utilization, user engagement and interaction, resource tracking and maintenance, personalized services, data driven decision making, remote access and services. While traditional library approach has measures in place to manage some of these problems, there are yet issues to solve due to limitations of the human users because of their human make-up.

The advent of the Internet of Things (IoT) technology has ushered in a new era in smart libraries' development. By integrating IoT into library systems, accessibility of materials for both users and librarians has been dramatically enhanced, facilitating streamlined management. The IoT, characterized by interconnected computing devices transmitting data wirelessly has significantly reduced the workload for librarians and users alike. This technological evolution guards against book loss while enabling efficient management of the library's resources. The use of technology in libraries starts with a good inventory system using a technology like electromagnetic identification (EMID) technology (Cheng *et al.*, 2017). Several works implemented the use of RFIDs, NFCs, WSN, Blockchain technology and so on. Some researchers have also developed robotic systems to help human librarians in the libraries using RFID technology for path-finding (Krishnan, Singh and Yadav, 2020). RFID antennas has also been employed alongside the readers to provide effective wireless communication with the readers during the inventory process (Cheng *et al.*, 2017). However, the use of RFID raises some significant security and privacy concerns in library management(Olaniran, Akinola and David, 2020). Hence, its use requires a proper authentication algorithm to ensure safety especially in autonomous libraries. Some online security techniques in cloud-based infrastructures for online libraries include multi password generation technique, Serpentine Multifactor Authentication Technique and dual combat technique (Erike, Inyiama and Nwalozie, 2015; Erike *et al.*, 2023; Erike, Azubogu and Mshelia, 2023).

This study introduces an algorithm leveraging Internet of Things (IoT) technology to address the persistent problem of book misplacement within traditional libraries. The primary aim of this research is to create a system with the capacity to identify instances of incorrect book placement in libraries by harnessing the widespread Internet of Things technology. This innovative approach seeks to alleviate the challenges arising from the continuous misplacement of books on library shelves, ultimately enhancing the organization and user-friendliness of libraries, particularly in the context of user self-serviced library environments. (Kassab, DeFranco and Laplante, 2020). The rest of the articles is organized as follows: section two presents a review of literatures. Section three presents the methodology of implementation while section four discusses the outcome of the research implementation followed by a conclusion and recommendation.

2. Review of Literatures

A lot of scholarly articles have been published in the domain of library management, all geared towards making a library experience a more scintillating one. In their research, Eiriemiokhale and Olutola explored the application of Internet of Things - IoT technology to enhance the quality service in Nigerian universities' libraries with the aim of identifying important areas of application, functions, and benefits within these libraries (Eiriemiokhale and Olutola, 2023). The research adopted a descriptive survey research method, employing a self-designed questionnaire for data collection and descriptive statistics (which involves frequency counts and percentages) for data analysis. Their findings revealed that IoT technologies such as Wireless Sensor Networks, Cloud Computing, Smoke or Heat sensors, and RFID may be employed in technical and reader services, theft management, and alerting services to improve library services in university libraries. The researchers recommended increasing awareness about available IoT technologies, implementation of suitable strategies for applying these technologies across different library functions and leveraging IoT to modernize libraries, turning them into centers for innovative purposes.

In view of this research report by Kennedy and Olutola, this section reviews basically different technologies that has been engaged by researchers to implement a tech-based library and the problem each tool was meant to solve. This review however comes under the following technologies:

i. Radio Frequency Identification

ii. Near Field Communication

iii. Wireless Sensor Networks

2.1 Radio Frequency Identification - RFID

RFID simply stands for Radio Frequency Identification. An RFID system usually would consist of a small radio tranceiver. When activated by an electromagnetic pulse from a nearby RFID reader device, the tag transmits the data it contains digitally. The data may be an identifying inventory number which is being communicated back to the reader. This number can then be used to track inventory goods such as books, DVDs or other library materials. The RFID works over a range of frequencies. Coyle and Chandrakar explored the multiple applications of the RFID technology in securing library items including DVDs, books, and other retail items. RFID systems most times are embedded with the capacity to read multiple tags simultaneously, allowing a check out of a stack of books in a single. By this, according to Coyle, the RFID technology has capacity to be used to gather statistics on the re-shelving of books in the stacks area.

Grover & Ahuja, and Addepalli & Addepalli implemented RFID-Based Library Management System (LMS). The research aims to develop a system that fast-tracks the flow of transaction and makes it easy to solve the issue of returning of books to the physical library without much need of manual book keeping practice (Addepalli and Addepalli, 2014). The system relied on RFID readers and passive RFID tags that are capable of electronically storing data, which could be retrieved using the RFID reader. The developed system can facilitate book check-out and return by utilizing RFID tags affixed to the books and readers strategically positioned throughout the library. In addition, it calculates fines based on the duration a book is absent from the library database.

A smart library system that uses uses RFID tags, RFID tag readers, ESP8266 microcontrollers, and a backend database to automate book issuing and returning processes with minimal human intervention. The system also provides a user-friendly library portal for students and staff to access information about library resources and book transactions was developed by (Phani Gannamraju, Yarramsetti and Kumar, 2021). The study results demonstrated the successful implementation of the outlined design particularly focused on the area of borrowing and returning of books

In a separate study, Srujana and colleagues designed a library management system that uses the RFID technology, with MATLAB playing a pivotal role in the development process. This system leveraged a high-frequency DLP RFID Reader/Writer that operates within the 13.56 MHz frequency range, capable of simultaneously scanning up to 15 RFID tags. MATLAB was employed to craft an intuitive Graphical User Interface (GUI) tailored for librarians. To enhance system performance, a MySQL database was integrated for efficient data management. In addition, web technologies were harnessed to provide users with advanced search capabilities for locating books within the library's collection (Srujana *et al.*, 2013). In summary, this work can make for the simultaneous operation and management of library resources. However, the study did not delve into solving the problem wrong shelving of books in the library.

Bhure implemented the Internet of Things in management of library system. The Internet of things technology provides patrons with the ability to check a book's information about a required book at any time. In addition to this, face recognition feature is introduced to ensure a more secured access to the resources of library (Bhure, 2018). For automation, the RFID tags are used for issuing processes and allow identification of large number of tagged objects like books. The developed system was built around Raspberry Pi as the processing unit and RFID tag for library resource identification. In another research endeavor, a work by Singh focused on the use of Quick Response (QR) code technology for quick issuance, return, and management of library resources. The technology provides end to end solution for easy library book management and a patron's interaction and operation with the library management software solution (Singh, 2019).

Kanoba and team conducted research on an RFID-based library management system, investigating the potential of Radio Frequency Identification and Detection (RFID) technology for developing an efficient library management solution. The research developed a system utilizing RFID for tracking book information and monitoring library access. Key components of this library management solution included RFID readers, a Bluetooth module, a microcontroller, and RFID transponders for tracking library items. Each item received a unique ID, which was stored in a desktop application alongside relevant information, aiding in cataloguing processes within the library.

The development of the system was done using the C and Visual Basic programming languages. The system incorporated RFID and Bluetooth technologies, and a centralized database. User identification was done through RFID tags, and security features like password-protected logins was included both for both librarians and patrons (Kanoba *et al.*, 2022).

2.2 Near Field Communication – NFC

An NFC tag is designed to send radio waves which in turn activates the antenna in a receiving device. The receiving device is expected to verify the information to complete data exchange. The technology operates over a very short range of approximately four inches. NFC tags work without a battery and draws power from another device, e.g., a smartphone, which is the thing that sets it apart from other technologies.

In separate conceptual studies, Brian *et al.* and Patil *et al* proposed an IoT-based Smart Library System that could provide users with the privilege of fetching a book from the placed location with the help of an IoT-based interconnected devices that uses a Wi-Fi based Local Positioning System (LPS) and NFC tags in the library. The purpose of the concept is to build a Smart Library System with facilities to seamlessly issue, return, and even locate the book using any authenticated smart phone in the library. The system proposed does not provide any help to the user to be able to track the book right to its rack (Brian, Arockiam and Malarchelvi, 2014; Patil *et al.*, 2017). This work however was not developed. So the challenges associated with the proposal has not been established yet. The work by Patil *et al.* directly provides the book information from the library management system(Patil *et al.*, 2017). The system interfaces with the user's smart phone alongside a separate handheld reader to view the entire book information available on a PC and the major goal is for the user's task of searching for the books and then issuing books.

In the study by Siddharth and team, they explored the use of Near Field Communication (NFC) technology to enhance library services. The study implemented Mifare tags with unique identification numbers (UIN) on both user identity cards and books. When a user selects a book for borrowing, their IDs are verified at the entrance reader and transmitted to a coordinating server for authentication. The server cross-checks the user's details, and if the authentication is successful, the user can then proceed with the borrowing process. The system also includes the feature for sending SMS notification to users after the book(s) have been issued and returned, providing transaction details at both ends. The researchers suggest that this system could be further enhanced by incorporating additional security measures (Jagtap *et al.*, 2015).

Bhandari introduced a system incorporating smart-card technology and electromagnetic waves, with the smart card utilizing Near Field Communication Technology (NFC). The author's concept aims to enhance efficiency in library operations by reducing labour costs, improving time management, and minimizing paper usage through the integration of IoT sensors (Bhandari, 2021). This system employs NFC and magnetic sensors for library transactions, utilizing magnetic waves to activate the chip on smartcards required for transactions. Additionally, NFC tags automatically store data in a computer when within range of electromagnetic waves, ultimately reducing the need for human intervention in library transactions and decreasing paper consumption.

In addition to the foregoing, a work by I. Gede and team revealed a loophole in the use of the NFC and QR Code technology for their ability to read at a maximum of about 7cm from the object being red (Sujana *et al.*, 2022). Their research implemented automatic identification of library resources using NFC card for library procedure implementation – borrowing and returning.

2.3 Wireless Sensor Network – WSN

A wireless sensor network comprises of a multitude of small sensor nodes that are scattered, either within the system environment to be monitored or in its immediate vicinity. These sensor nodes comprise of the sensory components, data processing units, and communication modules. However, the placement of these sensor nodes does not necessary require meticulous engineering or predefinition. In discussing the applications of internet of things in academic libraries, Nag and Nikam particularly deliberated on the usage of IoT with particular recourse to cloud computing, magic mirror technology, and pressure pad sensors using, WSN (Nag and Nikam, 2016). The adoption of the IoT technologies aims to enhance resource optimization and the provision of better managerial services in academic libraries. The main characteristics of the method include self-healing, multi-tenancy and service-oriented, service level agreement (SLA) Driven, Virtuality, and Flexibility.

The system proposed by Gupta comprised of a display device, cameras that are connected to a server, and a processor. The aim of the work is to provide IoT concepts to academic libraries in order to improve their services in an efficient way (Gupta, 2020). The utilization of some innovative technologies such as cloud computing, Magic Mirror, and wireless sensor networks that are equipped with pressure sensor pads was implemented to enhance user convenience in the library system while at the same time boosting profitability.

In summary, while ubiquitous technology holds the potential to revolutionize library management and reduce human errors, implementing a completely human-independent system presents a significant challenge. This challenge revolves around achieving high shelving accuracy, a problem that even traditional libraries managed by physical librarians have encountered. This research aims to address and resolve this shelving accuracy issue.

3. Methodology

The research uses a four-tier architecture as shown in figure 1 for implementation, comprising blocks labelled A to D. Block A represents the human and resource identification system, Block B shows the Cyber-physical system, Block C denotes the Application Programming Interface Block, and Block D stands for the Web-based Library Management System. The user at block A interacts with the cyber-physical system of block B. The Cyber-physical system links up with the API block powered by Thingspeak server depicted by block C to make changes to the Web-based LMS represented by block D. The operation of the W-LMS also activates some actuators – like library doors, shelf doors and so on in the Cyber-physical system through the instrumentality of the API block.

Further elaboration on each block is provided in subsequent sections. The composition of materials utilized for each block is detailed within their respective sections. Notably, the developed system employed a semi-simulation approach, wherein some parts of the system were simulated, while others were not.

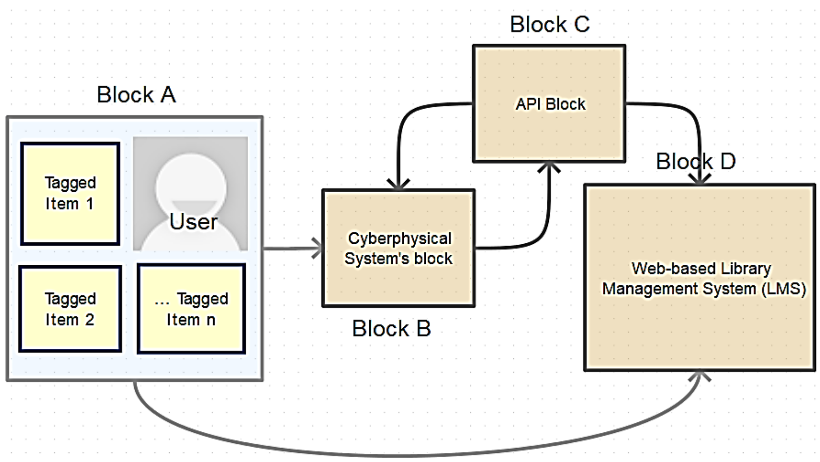

Figure 1. The four-tier architecture of the IoT-based library management system.

3.1 Human and Resource Identification Block

The system implemented an automatic generation of unique RFID tag numbers for a library user as well as for any library resource at the point of registration. A university library complex is simulated such that student’s registration numbers alongside their departments were used to uniquely identify each student at the point of registration. This particular block A interacts with block D at the point of registration of individuals and library resources (in this case books). Each unique Id generated for the book differs from the Id generated for a patron so as to aid in evaluation of the logical performance of the system. While student’s Ids were generated to reflect their enrolment date, book_ids were generated following a pre-assigned departmental code.

3.2 The Cyber-physical System

The cyber-physical system acts as an intermediary between the user and the web-based LMS, establishing communication with the latter via an API. In practicality, the cyber-physical system encompasses three core components: the input module, the output module, and the processing module, as illustrated in Figure 2. The IoT demonstration's web interface, showcased in Figures 3, 4, and 5, simulates the functionality of RFID readers positioned at the entrance door, bookshelves, and exit door, each capable of simultaneously reading multiple tags. The system receives RFID tag numbers via a form field, undergoes logical processing in the backend, and subsequently conveys the results to the API block. The API block, in turn, relays this data to the non-simulated physical system, representing actuators (buzzers, lights, motors) responsible for actions such as opening entrance, exit, and shelf doors as well as triggering wrong shelving alerts. These actions are visually represented by red, yellow, and green light emitting diodes, LEDs.

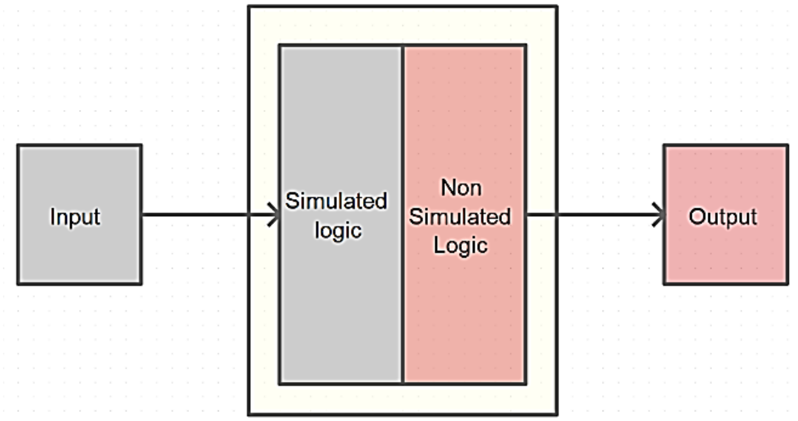

Figure 2. The hybrid cyber-physical system model for the IoT-based Library Management System

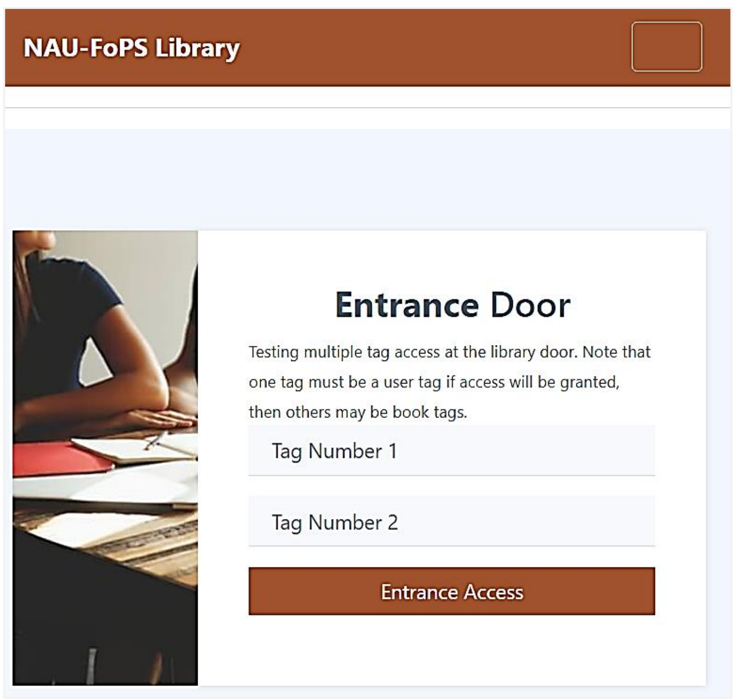

Figure 3 – Entrance door simulation point for the IoT-Based LMS

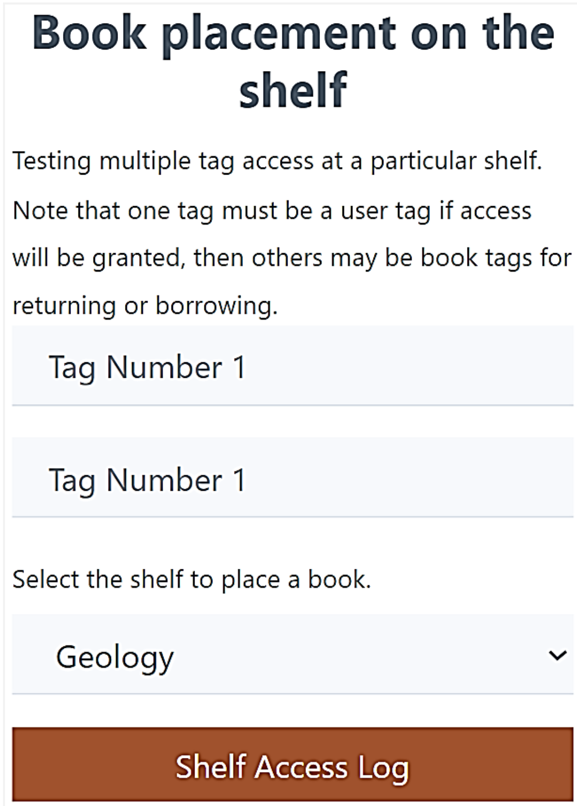

Figure 4. Book placement simulation point for the IoT-Based LMS

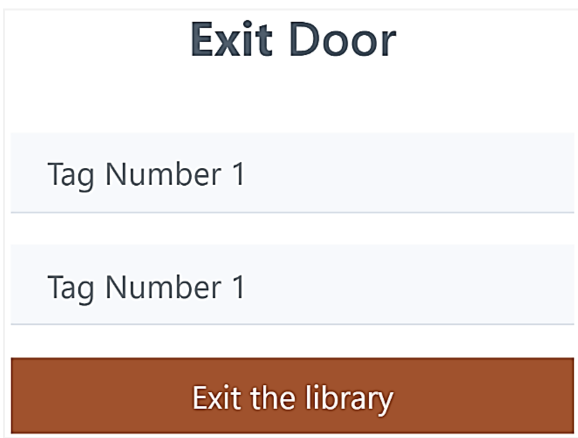

Figure 5. Exit door simulation point for the IoT-Based LMS

3.3 The Application Programming Interface

The research utilized the Thingspeak IoT platform as a Service to communicate with the non-simulated aspect of the system depicted in figure 2 on the event of a trigger from the simulated aspect of the system hosted with the web application. When the red LED is turned on, it means that the user is denied access. The yellow LED glowing indicates a warning to the user concerning the operation he is about to take. Finally, a green LED glowing shows a successful operation. Before using the Thingspeak platform, a registration protocol was undertaken for all the 'Things' that are needed to be controlled. All were registered with specified identity number which is used to send direct signal to the required actuator.

3.4 The IoT Schematic Diagram

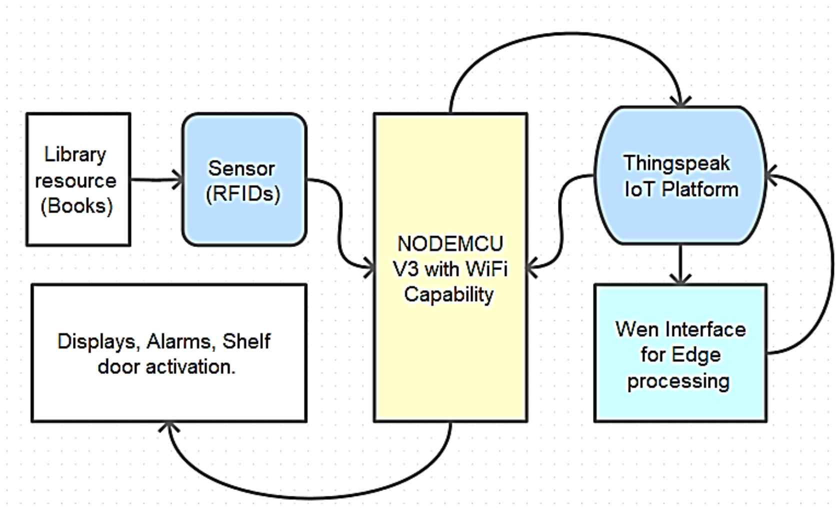

Figure 6 – The IoT architecture

Figure 6 is the IoT schematic diagram describing the interaction of the components. Firstly, the books and other library resources are tagged at the point of inventory and registration with each item having a unique ID tied to the tag ID. The RFID reader or sensor attached to the microcontroller reads the analogue signal from the book or any other resource and communicate same to the microcontroller unit. The NodeMCU block houses the microcontroller with the inherent WiFi capability for connecting to the internet. The read data is transmitted to the Thingspeak IoT platform which in turn connects to the Library management system. An edge processing is performed on the data and fed back to the Thingspeak server which in turn communicates back to the NodeMCU. The data value determines the response that is seen at the actuator section of the prototype.

3.5 The Web-based LMS

The web-based LMS is implemented using PHP 8 as the backend development technology. The user interface is developed with the following technologies: HTML, CSS and JavaScript, while MySQL is employed as the backend database system to manage and store data for the W-LMS.

While the registration and inventory process for users and library resources follow a normal process with validations, the system implements three profound states. In each case, one library resource and one user is considered for the purposes of the research simulation. However, since there are RFID readers that are capable of reading multi tags, the implementation of the research can further be designed to accommodate multiple library resources with one user.

In state one, the user can enter the library without any library resource. In other words, at the entrance door depicted in figure 3, at least on tag identifier must be presented. The logic is written to make sure that in a case that only one tag is presented at the entrance door, then the tag must of necessity be a user's tag. In the case that more than one tag is presented, then, only one tag must of necessity be a user's tag. The other tag or tags must be that of the library resources that a user may have borrowed and is returning same to the library.

The pseudocode for the operation is here presented:

```
FUNCTION UserEntersLibrary(tags)

  IF tags.length == 0 THEN

    PRINT "Access Denied: No tags detected."
```

```
    ELSE IF tags.length == 1 AND tags[0].isUserTag() THEN
        PRINT "Welcome, User!"
    ELSE IF tags.length > 1 AND CountUserTags(tags) == 1 THEN
        PRINT "Welcome, User!"
        FOR EACH tag IN tags DO
            IF NOT tag.isUserTag() THEN
                ProcessLibraryResource(tag)
            END IF
        END FOR
    ELSE
        PRINT "Access Denied: Incorrect tag configuration."
    END IF
END FUNCTION

FUNCTION CountUserTags(tags)
    count = 0
    FOR EACH tag IN tags DO
        IF tag.isUserTag() THEN
            count = count + 1
    IF count > 1
         PRINT "Access Denied: Two users trying to access the library at the same time"
    END IF
        END IF
    END FOR
    RETURN count
END FUNCTION

FUNCTION ProcessLibraryResource(tag)
    IF tag.isResourceTags() THEN
        Return True
```

```
    ELSE
        Return False
    END IF
END FUNCTION
```

The moment a user is authenticated, a session variable is created for the user with a duration spanning through the time allotted for the daily library operations. Every user's session is designed to expire either as the user checks out of the library or at the closure of work when everyone must of necessity be required to leave the library.

In state two, the system simulates a user's visit to the shelf. A particular **shelf_name** is associated with the category of books or other library resource the shelf houses. Just as in state one, it takes a user to pay a visit to the shelf, hence, at least one tag must be recorded at the shelf area. A user's visits to the shelf simulates either a borrow or a return of a resource to the shelf. If a resource tag is noted at the shelf area, then, the system checks the user's tag along with the resource tag. If the resource tag that the user supplies at the simulation point does not depict the **category** that the **shelf-name** represents, the system identifies it as wrong shelving. An alarm is triggered. This is depicted by red LED glowing on the cyber physical system. This is the heart of the research because it is assumed that the proposed library would not have any physical persons working on it to be arranging the resources and placing them correctly on the supposed shelfs.

It is important at this point to note that the entire state logics are interlinked. State one flows with state two, and then with state three that has to do with exit from the library. When a user pays a visit to a particular shelf in the library, the system logs the visit and holds it in a session variable waiting for the user's exit from the library.

The third state monitors when the user leaves the library. Just like in the other states mapping the user's movement in the library, a user tag variable is a constant. Therefore, unless the user tag variable is recorded at the exit door depicted in figure 5, access will not be granted to any other variable.

At check-out, the system checks to see if the tags presented at the exit door represents a user's tag. If none of the tags is a user tag, then access will be denied. If the there is a user tag and another tag, the system checks to see if the other tag is a valid resource tag. If it is not, the system raises a warning. If it is a valid resource tag, the system calls into operation the session variables established at the entrance and at the shelf area. If the resource tag variable established at the point of entry matches the same resource variable at the exit from the library complex, then the system does not record anything, it will rather notify the user that he is leaving the library with the same resource he came in with. If the user is found not leaving the library with the same resource he came in with, the system checks the session variable recorded at the shelf area. If there exists a variable at the shelf area, it means that the user actually shelved the book. However, if no recorded session variable was established at the shelf area for the user, this means that the user actually did not return the book to the shelf. Hence access will be denied the user, otherwise, the system marks the resource as 'returned' and notifies the user. In another case, a user may enter the library with a resource variable and leaves with a different resource variable. In this case, the first resource variable will be marked as returned while the new resource variable will be marked as borrowed after considering the aforementioned logics, and the user notified accordingly.

4. Results

The research implemented an IoT-Based System for library management. The Cyber physical system is implemented in two sections – the input section which simulates the operations of multiple RFIDs read operations using PHP and MySQL for the backend logics, and HTML, CSS, and JavaScript for the front-end design. The input simulation points are represented in figures 3, 4 and 5. The output section is implemented using NodeMCU ESP8266 and some LEDs (red, green, and yellow) to represent the workings of the actuators. Figures 7a, 7b, 7c are snapshot of the device in different states. At the start of the system, the first green LED glows depicting that the system has connected to the WiFi network programmed for its operation.

Compared to prior research efforts that focused on tasks such as book and shelf localization within a library and mapping robotic paths in library environments, this study distinguishes itself by its capacity to identify instances of incorrect book placement in libraries that operate without human librarians.

4.1 System's Logical Test

To test the correctness of the different algorithms used in the development of the IoT-based system, several combinations of user tags and resource tags were used to test the operation and logical correctness of the system. The operations were tested on the simulated IoT platform developed to mimic the operation of multi-reader RFID. At first, a correct user tag and a resource tag which had been borrowed was used to access the entrance door. Figure 6a shows a successful state of the system when a user tag and a resource tag was used to access the system.

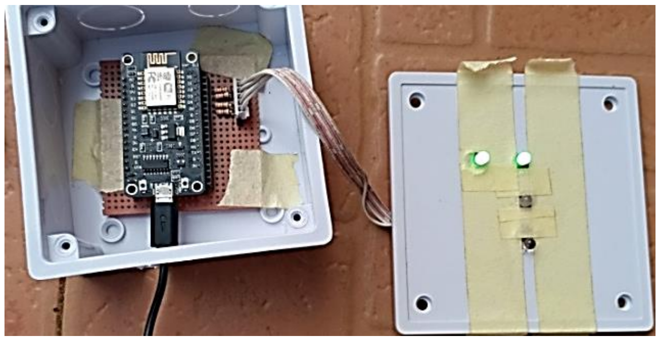

Figure 7a. Hardware access indicator light showing access granted state

At some point, the researchers deliberately did not access any shelf's door before accessing the exit door of the IoT demo operation (meaning that the borrowed book was no returned to any shelf). The system activates a yellow LED to glow, notifying that the resource that the user entered the library with was never taken to the required shelf. In another instance, the resource was taken deliberately to a different shelf – depicting a wrong shelving operation. These operations triggered the actuator warning and denial state depicted in figure 7b.

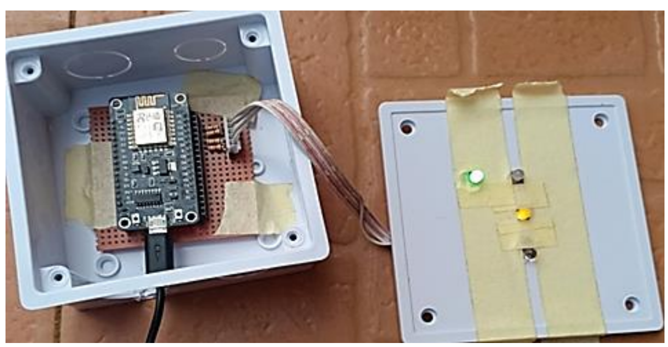

Figure 7b. Hardware access indicator light showing access warning state

Finally tried leaving the exit door with only the resource tag. In another instance, the researchers tried accessing the exit door without first of all accessing the entrance door. In both of these trials, the system denied such accesses. The snapshot of the operation is depicted in figure 7c.

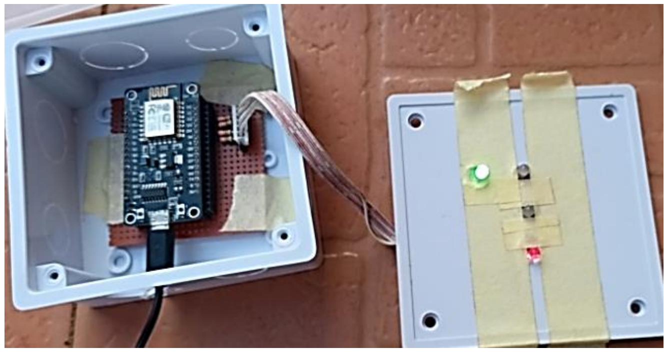

Figure 7c. Hardware access indicator light showing access denial state

Hence, the logical performance of the of the algorithm developed for the IoT-based system proves to be effective at every point of testing both for borrowing, returning, and correct shelving of books in a completely humanless library management system.

As previous studies have not addressed the topic of addressing improper book shelving, there is no established benchmark for evaluating this work concerning existing literature. Consequently, this research stands as a distinct and well-prepared proposal, uniquely addressing this issue.

4.2 System Speed Response Test

A deliberate speed-response test was carried out on the system to determine how the response of the system will impact its use if adopted. The system was tested on an HP Spectre 360 laptop with the following specifications: 500SSD storage, 16GB of RAM, Intel Core i7-7500U processor and CPU operating at 2.7GHz 2.9GHz. The internet connection was through MTN Nigeria customized 4G Mifi. The internet speed was significantly high. The time it took to get the response of the server on the physical device was measured in milliseconds. This experiment was taken at different positions – the entry door, the shelf door and at the exit door. Table below presents the recordings for fifteen (15) trials at entry, visit to the entrance door, shelf door and the exit door of the library. Table 1 is a table of response time recorded at the various simulated points.

Table 1. System’s speed response table at the entrance, shelf’s and exit doors respectively

S/no	**Entry**	**Shelf**	**Exit**
1	5433	6492	6433
2	6500	5522	6492
3	6416	5402	4416
4	7375	4392	5402
5	3291	6442	4122
6	4402	5445	4452
7	2389	5399	4398
8	2400	5433	6389
9	6370	6217	5317
10	4416	5416	4566

11	3872	4399	7612
12	7812	5598	8592
13	5899	6432	6722
14	4259	7936	7647
15	5720	6647	5388
Average	**5103.6**	**5811.467**	**5863.2**

The graphical picture of the result is presented in figure 8. A noticeable time delay is recorded at most points between the time of initiating a read operation of the RFID tags from the front-end and the time the result of the operation was shown on the cyber physical system of figure 7a to figure 7c. On the average, it takes about **5.0 s**econds for a response to be seen on the physical system. This is majorly attributed to the time response system of the API block receiving an HTTP request from a requesting server, and delivering an HTTP response to the hardware. The hardware response time is also a factor factored into the response times which the research did not delve in to find out. Figure 8 is the system response chart of the different operations performed on the system.

4.3 The significance of the time response of the system

The system implemented for library management though functionally correct, its slow response to event triggers has the potential to create user frustrations and operational inefficiency within the library. The delayed system responses may result in extended wait times, potentially leading to user dissatisfaction and longer queues at the entrance and exit. This inefficiency has capacity to disrupt the flow of library operations and hinder the overall user experience with in-flux of users. Furthermore, the sluggish system may strain network bandwidth, causing further operational inefficiencies. Addressing this issue by optimizing response times is crucial to maintain the system's effectiveness, user satisfaction, and the overall efficiency of library operations, ensuring that it operates seamlessly, enhances user experiences, and prevents network congestion. This should be the future direction for the project.

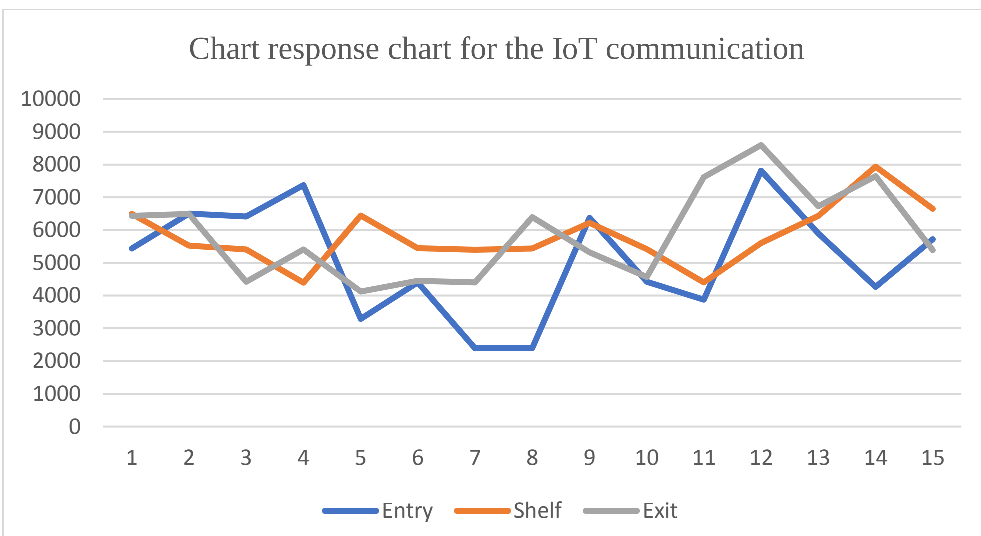

Figure 8. System speed response chart of the IoT-based LMS

5. Conclusion

In conclusion, the research developed an Internet of Things-Based System for Book Shelving Accuracy Improvement in Libraries. The system demonstrates the potential to revolutionize library management, with particular focus on addressing book shelving accuracy issues which has become a widespread issue in the traditional library management systems. Reviewed literatures show that by using technologies like RFID, NFC, and WSNs, library tasks can be automated to reduce human errors, and enhance user experiences. The research simulated the functionality of multi-reader RFID systems using some web-based technologies, and physical hardware implemented to depict the functionality of different actuators using NODEMCU ESP8266. The software system was based on the following open-source technologies – HTML, CSS, JavaScript, PHP and MySQL. The system's response time averages to 5 seconds, though with room for improvement which indicates its feasibility for real-world implementation.

While challenges remain, including security concerns and staff training, the benefits of embracing IoT in libraries are evident. This research paves the way for smarter, and more efficient libraries that bridge the gap between traditional knowledge repositories and the digital age. This research however recommends the following: that libraries should consider integrating IoT technologies using RFID, NFC, and WSN etc to enhance resource management and user experience. As IoT systems handle sensitive data, robust security measures, including encryption and user authentication, may be in place to protect user privacy. More researches are needed to explore the scalability of IoT-based library systems and their long-term impact on resource tracking and management.

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