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LATESS: Library Anti-Theft Electronic Surveillance System Case Study: KNUST Prempeh II Library

Benjamin Kommey [a, *], Emma Naa Kai Odametey [a], Yoocee Direntwi Ansah [a], Valdo Ato Kekeli Abruquah [a]

[a] *Dept. of Computer Engineering, Kwame Nkrumah University of Science and Technology, Kumasi - Ghana*

bkommey.coe@knust.edu.gh, naa.kai.odametey@gmail.com, yooceeansah@gmail.com, valdoato@gmail.com

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ABSTRACT

The Kwame Nkrumah University of Science and Technology (KNUST) Library is one of the most important services on the school's campus. It provides a serene atmosphere for studies as well as a multitude of resources for research and learning. Unfortunately, this opportunity is abused by some individuals who steal books, causing others who need them to be found wanting and incurs unnecessary costs on the school to replace those materials. In this project, we propose the use of an Electronic Article Surveillance (EAS) system to identify and keep track of books in the library. The proposed system would use Radio Frequency Identification (RFID) to raise an alarm when a book is being taken out of the library without having gone through the required procedures put in place for the borrowing of books. An alarm serves to notify the security guards and library staff stationed for quick alert and response to the book theft as well as to deter individuals from attempting to do so. If implemented correctly, a very high accuracy of detection can be achieved. The proposed system is limited in that it cannot prevent a student from borrowing a book without return, and some individuals may find a way to tamper with the tags to avoid being detected by the EAS system.

* Corresponding author at:
Department of Computer Engineering, Kwame Nkrumah University of Science and Technology
PMB UPO, Kumasi, 00233
Ghana
E-mail address: bkommey.coe@knust.edu.gh

ORCID ID:
First Author: 0000-0003-3145-0066

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1. Introduction

The KNUST Library, also called the Main Prempeh II Library, is a very important service to the populace of the university. The library provides a peaceful environment for students to engage in studies, as well as a plethora of learning resources to make studies easier and more effective for all its patrons. In the digital age, libraries have adapted to also provide internet access to users as well as digital learning resources to keep up with modern times. The digitization of books and learning resources does not imply that they can be obtained for free. Most of the time, obtaining a personal copy of an e-book requires one to make a purchase for it, as is done with hardcopy books. This necessitates the need for libraries to provide these resources to the public, who usually do not need to or cannot afford to buy a personal copy for themselves. This shows that the services provided by libraries are still indispensable in the modern world. Regardless of this changing dynamic, physical books in libraries are still very essential to their operation since, a vast number of books are only available in hardcopy format, with no plans put in place to make the transition over to digital for most of them.

Although borrowing library books is permitted, some individuals nefariously decide to take books away with the intention of not returning them, which causes other students who need information from those sources to be left stranded and incurs an extra cost on the university to replace the stolen materials. To limit the possibility of books being stolen, patrons of the KNUST Library are required to leave their bags in lockers situated in front of the various library sections. This has caused a new problem to arise from this situation, in that, some individuals steal from the bags in the lockers or even go as far as to take the whole bag away. Although there are security guards stationed around, there is no real way to confirm which bag belongs to which individual and is based largely on the honesty of its patrons. This leads to there being a lingering feeling of unease in students, especially during periods when the library is especially busy, such as during examination periods and revision weeks.

This project implementation will have a significant impact on the library and its operations. It will lead to a larger sense of security on the library premises, as library books and especially the personal belongings of patrons are protected. This results in a substantial reduction in the need to replace lost or stolen items. Implementing the book database system revolutionizes the current inventory management system in place, which is currently done manually. The proposed system enables accurate tracking and organization of books, ensuring that the library maintains a comprehensive and accurate catalogue of its holdings. These two combined provide a vastly improved user experience for the patrons and ease of management for the staff. One of the key contributions of the designed system is the introduction of data-driven decision-making to the library management practices. By analysis of the transaction logs, library management can gain valuable insights to make proactive decisions regarding book acquisition and resource allocation, leading to the overall improvement of library services.

2. Related Works

To determine what identification technology would be most effective in solving the problem, a literature review was conducted to analyze the various technologies that are used in common practice. The technologies highlighted are namely, EM (electromagnetic), RF (radio frequency), RFID (radio frequency identification) and RuBee.

Othman [1] designed an anti-theft system with a library as his area of study at Universiti Malaysia Pahang (UMP). His project was aimed at designing and developing an antitheft system used in libraries to detect thefts of library books, using the concept of a magnetic field. A magnetic element would be placed in each book and at least a pair of hall cells placed adjacent to the exit so that anyone leaving the library would go in between the hall cells, and if a book tagged with a magnet is within possession, an indicator such as an alarm or LED would operate to indicate a possible theft. The whole concept is based on the principle of electromagnetism where magnetic sensors detecting the fields associated with magnetic objects would induce current in the coils to operate the indicators. The downside of the methodology adopted in this case is that the system would prove unstable and as such is expected to be ineffective since the magnetization weakens over time. [2] conducted a study and compared EM to RF and RFID. This study gathered that EM systems eventually become unstable because magnetization weakens over time. Therefore, although they pose a cheaper alternative, they would not be an ideal choice with longevity in mind. In comparing RF to RFID, the latter is preferred because its tags uniquely identify whatever article they are attached to, as opposed to the former which only tells the receiver that an article is present. Thus, RFID will be of use not only for anti-theft alerts but also to aid in the identification of the item in question. [3] delves into RF and RFID technology and differentiates between their modes of operation. It states that while both RF and RFID are used as Electronic Article Surveillance, there is some distinction between their operation. Acousto-Magnetic (AM) is cited as one of the most popular versions of RF technology. It sets off an alarm when the receiver picks up a signal from a tag. Its biggest advantage is that it can be scanned at quite a distance with remarkable speed. RFID tags, however, are more advanced than RF tags in the sense that they are capable of uniquely identifying the article they are attached to. The radio signal sent from the tag on an article contains a digitally encoded identifier, which allows the receiver to decode and identify the item. This technology is rather popular in libraries that allow people to self-check out books and other media. RFID tends to work over shorter distances though. Passive RFID tags work entirely by responding to incoming radio waves from a transmitter. As such, they have no batteries. An alternate version, active tags, contains more advanced technology and batteries and can work over greater distances.

RuBee is a relatively new technology that is used in high-security applications. [4] compared RuBee to RFID. This study found that RuBee provides superior reading capabilities against RFID in environments involving metal and water. However, the downside to using RuBee is that it is now emerging, and thus more work must be done to find out how to apply it in suitable and cost-effective ways. After studying the various technologies, RFID was found to be the superior choice for this project. [5] spoke about the benefits of RFID tags in multiple areas like retail and pointed out some challenges concerning the use of RFID tags. These included the design of tags being able to cover the whole RFID-regulated bands, providing appropriate read performance. [6] emphasized the need to use RFID tags in libraries. The author also divulged some points to consider if the custodians of a library were looking to invest in RFID technology. These included finding a supplier with some longevity and paying particular attention to system design. [7] discussed RFID management and highlighted the history of RFID technology. The RFID kit was selected based on frequency, capability of near reading and many more. [8] gave extensive advice on mistakes to avoid making when working on an RFID project. The document had a compiled list of the most fatal mistakes people make when embarking on an RFID project. The first mistake was skipping the site survey. It was stated clearly that failed projects often had their site survey step poorly done. If done properly, the resulting Site Survey Report will outline the specific RFID components and services necessary to satisfy the requirements. Further, being on-site with customer personnel allows for accurate measurement of the location of fixed readers and general discussions about customer processes and RFID expectations. [9] released a journal which remarked on the development of an RFID-based management system using MATLAB. RFID technology was selected for their project because it does not require a line of sight to the tag to retrieve its data. The library management system consisted of a library PC, a DLP RFID1 reader, an RFID tag, and a USB-to-serial converter. An optimal position of the tag on library books was also heavily debated. It was discovered that, when tagging placement in one item directly overlays another placement and both items are in very close proximity, readability is compromised.

Adak [10] published a journal centered around an RFID-based security system using the Arduino module and developing a secure system that would be dependable and respond quickly to security breaches for industries and companies. [11] presents the concept of an innovative electronic system for managing confidential document tracking to be used in government institutions. The objectives included developing a real-time remote identification system for RFID-tagged sensitive and no-sensitive media in both the workplace and storage facilities and developing an automatic inventory system for classified and unclassified documents arranged in stacks and contained in binders, along with automatic detection of changes in their positions. [12] made public a proposal for an RFID data model for a certain Libraries Working Group in Denmark. The purpose was to establish an RFID Data Model for the Danish market with a view to providing the background for international initiatives in standardization for libraries. The data model proposal consisted of three main parts. The first part consisted of background information, formalities, and the progress of the work. The second part outlined the main demands for the data model and presented a discussion of options to consider. The third part consisted of detailed data model defining elements, the structure of these elements, encoding and value range. [13] cited reasons why RFID technology would be perfect for libraries. It would replace both electromagnetic security strips and barcodes on books. It also mentioned that RFID technology would be able to handle all library assets including documents, video, and audio tapes, but it would also allow for high-speed inventory and identify items which are out of order. [14] conducted an analysis of the implementation of RFID technology within the North Canton, Ohio Public Library. The primary outcome of this study was to advance professional practice and knowledge in public library applications of RFID technology. The solution to this was to replace foil covers with paper copies of the original covers. Asset tracking was successful. Patrons of the library were even able to self-checkout library materials. Evidence revealed that maintenance of patron records was more efficient because staff members did not have to perform most checkouts any longer. Now, patron records are automatically updated when items were borrowed. [15] discussed the implementation of a “location-aware Library RFID service employing RFID as a communication technology”. The study implemented a simulation of the system with randomly distributed tags and spatially distributed antennas. In the study, the librarians in charge of the Auckland University of Technology (AUT), New Zealand, Library were interviewed, and it was found that the AUT library system utilizes both RFID and the barcode system. The existing barcode system was used to regulate the borrow & return process and identification of books in the library management software. The RFID system was used solely in the anti-theft system. [16] in a collaboration between the University of Nicosia, Cyprus and the Aristotle University of Thessaloniki, Greece, worked on the topic an RFID-Based Library Management System Using Smart Cabinets and later worked on another article titled “An RFID-enabled library management system using low-SAR smart bookshelves” [17]. The idea of this project was to design and deploy an intelligent Library Management System (LMS) for the university library to replace the existing barcode system to improve productivity and reduce labor costs. [18] worked on an “RFID Based Library Management System” (LMS) and proposed a system based on UHF RFID readers, supported with antennas at the gate and transaction sections, and library cards containing RFID transponders to electronically store information that can be read/written without physical contact. The Monitoring System was to be installed at the library’s gates to monitor the incoming/outgoing bags continuously. The reader scans the RFID tags attached to the books and library member cards and sends the tag IDs to the monitoring system, which saves the information in a database with a timestamp. The system alarms the librarians whenever there is a movement at the gates concerning an un-borrowed book. [19] worked on the topic “The University Library Management System Based on Radio Frequency Identification”. The paper concentrated on the design plan of an RFID-based university library management system and focused on the general structure of its design, including system hardware and software. In this report, a label conversion subsystem was utilized to achieve the rapid conversion of the book from the barcode to the RFID tag. The system consists mainly of RFID tag conversion hardware equipment and the conversion software system. The label conversion system equipment is seamlessly integrated with the existing management software of the library and then the relevant information in the book bar code is quickly written on the label.

Younis [20] worked on a study on the topic “SLMS: A Smart Library Management System based on an RFID technology” at the University of Baghdad, Iraq. This system's features included allowing only authorized users to access the library, sounding an alert when an un-borrowed book exited, and remotely tracking the availability of books. To handle each component of library administration, this system was separated into modules: The borrowing module is used by the library operator for the process of borrowing books. The monitoring module is used to track the books at the library's exit/entrance doors. Here, the module continuously reads the book tags, queries the database, and checks the masking bits of the books. If any masking bit is active (true), then the module starts the alarming system and closes the exit door. The alert remains active until the operator eliminates it by issuing the ignore command to the book monitoring module. [21] conducted a study on “RFID Based Library Management System”. This system employed a GSM module to provide an alert message for the registered user during the return process. It is equipped with a theft detection system to detect thefts that occur in the library. To prevent theft inside the library, an alarm mechanism is provided in this system. The alert is triggered whenever a student attempts to remove a book without first registering it. RFID EAS Gate is used for anti-theft in this system. This gate tracks items with a range of 1 meter. When an un-borrowed book passes through them, the buzzer goes off and the gate lights flash to inform the security officers. [22] worked on the project “Intelligent RFID Based Library Management System” in the MS Ramaiah Institute of Technology Bangalore, India, in the year 2021. In addition to the standard library administration operations, this system employs machine learning ideas to assist in the categorization of books, as well as other analytics related to prediction and classification. The design and implementation of a general anti-theft system by [23] employed the use of RFID technology for storing and retrieving data remotely and providing identity codes to the monitored object. The system also comprised of a motion sensor which was integrated with the tag to detect tampering instantly, a PIC Microcontroller for processing and interpreting signals, memory to serve as external storage and a Chipcon Transceiver Module for transmission and reception of signals. The aim of the project was to design a security system using RFID embedded with motion sensors to serve as monitors of objects to be protected. [24] undertook a study titled “Library Management System using RFID Technology” and proposed and designed a system in which each book would be uniquely identified via the RFID tags attached to it and communication would be done wirelessly. This communication method would allow students and authorities to access information regarding a book remotely instead of the traditional way of manually searching the book. The system mainly focused on library management and automation with additional services such as a web interface and an Android app for transactions and viewing various interfaces. The type of RFID reader used was the EM-18 reader module. [25] and [26] worked on the simulation of a radio frequency identification-based library system at the Al - Mustansiriyah University using an Arduino card (UNO), RFID-RC522 Device and RFID tag chips. The read range of this RFID card was less than one meter. [27] proposed a library management system where an arm would be focused on following a white line to track and take a book from the shelf and vice versa. The book to be handled is recognized by an RFID number made possible by RFID tags placed in books. The arm would be programmed to take a book from the return box when a customer returns the book and place in the appropriate shelf. This system adopts the traditional way of bookkeeping and automates it, making it easier to maintain the library.

3. Material and Methods

The operation of the Library Anti-Theft Electronic Surveillance System (LATESS) is intended to cater for the processes of borrowing and returning library books from the university.

3.1. LATESS System Architecture

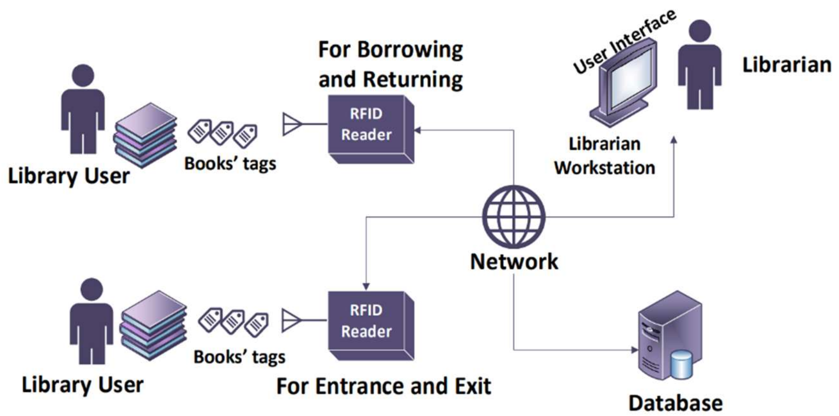


Figure 1 LATESS System Architecture

As shown in Figure 1, the LATESS system architecture comprises two main actors: **Library User** – The library user, in this context, is any individual that has the authorization to use the library’s facilities; particularly the borrowing of books. The library user can be a student, lecturer, or librarian.

Librarian – The librarian is the library staff member that is authorized to grant or deny the request of a library user to borrow a book. A borrow request is to be denied if the library user is no longer eligible to check out a book, for example, if the user has a book to be returned that is overdue.

The LATESS system architecture comprises the following units:

1. **Books and books' tags** are to be used by any library material that has an RFID tag and is allowed to be borrowed. An RFID reader for borrowing and returning, which is also a desktop RFID reader located at the librarian's workstation that is used to scan and write data onto the RFID tags of the books. The system has an RFID reader for entrance and exit, which is in this case a gate RFID reader located at the exit of the library that scans for any unauthorized book being taken out of the library. There is also a Librarian workstation, where their computer, RFID reader and all other equipment are located.
2. The **LATESS User Interface** (GUI) is a desktop software application on the librarian's computer to facilitate the borrowing or returning process. This is what the librarian interacts with to deactivate or activate the detection bit of the RFID tag of the book. 'The detection bit' in this project refers to a True or False value (e.g., 1 or 0) that is written onto the memory of the RFID tag to determine whether the book has been approved for borrowing. An integrated Database stores all information concerning the borrowing and return of books and the patrons who carry out these tasks and a Network that interconnects the other components for the transfer of information between all parts of the LATESS system.

The borrowing process starts when a library user takes the book intended to be checked out to the librarian on duty, who scans the RFID tag of that book using the desktop RFID reader at their workstation. Using the GUI, the information stored on the book tag is retrieved from the database by the RFID reader, and the detection bit of the tag is also deactivated. When this is done, the user can then pass through the RFID gate at the exit with the library books, and the alarm is not set off. Therefore, when the aforementioned procedure is not followed, the alarm is sounded at the gate upon exit with the books and the security officers will apprehend the individual responsible.

The returning process begins when the library user takes the book back into the library and presents it to the librarian on duty at their workstation. Using the GUI and the reader, the librarian scans the RFID tag of the book and reactivates the detection bit of the tag. When this is done, the book can be put back into its place on the library shelf for other users to access or borrow if need be. The RFID readers are connected to the operator workstation to communicate over a network, and the Graphical User Interface GUI is to be designed to facilitate the borrowing/returning process, including interaction with the library database.

3.2. LATESS System Block Diagram

The block diagram of the system is illustrated in Figure 2. A prototype was designed to demonstrate the system functionalities. The prototype consists of Passive RFID tags (13.56MHz frequency). The memory of the RFID tag stores the information about the tagged item such as the detection bit, which is used to trigger the alarm, and other information about the book such as its title and author name. A passive tag does not have an energy source of its own; it is activated by the RFID reader which sends out energy waves to it. The tag stores this power across its capacitor and is used to send a feedback signal to the RFID reader containing the information stored in memory. 13.56MHz RFID tags are selected as this is the same frequency that the chosen RFID reader for this project operates on. There are two RFID readers (MFRC522 RFID reader) for the LATESS system, one as the desktop reader located at the librarian's workstation and the other as the RFID gate placed at the exit of the library. The reader sends the signal to activate the RFID tag and reads the feedback signal (response) received from it containing the information which is to be processed. MFRC522 RFID readers are selected as they are the preferred choice for working with the chosen microcontrollers for this project. A microcontroller with serial peripheral for serial communication. The two RFID reader modules are each connected to the embedded microcontrollers which are responsible for handling the processing of data concerning the RFID tags. The desktop reader connects to the librarian's computer via the USB port to receive input for the activation and deactivation of the detection bit of the RFID tag in the borrowing and or returning process. The Arduino Uno Board was used for the prototype as the embedded board selected for the desktop reader. A microcontroller (Wi-Fi Module), for this prototype is the NodeMCU, an Arduino Uno, which has an ESP8266 Wi-Fi module embedded onto it. The ESP8266 is a recognized module for integration with Arduino boards. This microcontroller will be used for wireless communication between the RFID reader at the gate and the librarian/security personnel's computer.

A desktop application software provides an interface for the librarian to interact with the microcontroller, enabling them to perform the processes involved in the borrowing/returning process, that is, logging a borrowed/returned book in the database and the activation/deactivation of the tag's detection bit and an integrated database (MySQL) that contains all the information concerning the books and their tags; keeping record of books that are in the library and their borrowed/returned status.

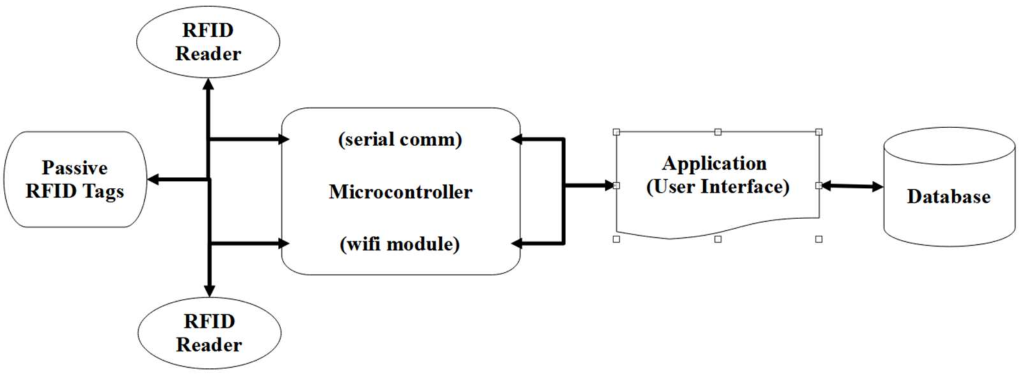


Figure 2 LATESS Block Diagram

3.3. LATESS Workflow Diagram

The diagram in Figure 3 shows the full operation of the system from when a book is picked up by a library user to the end of each possible outcome:

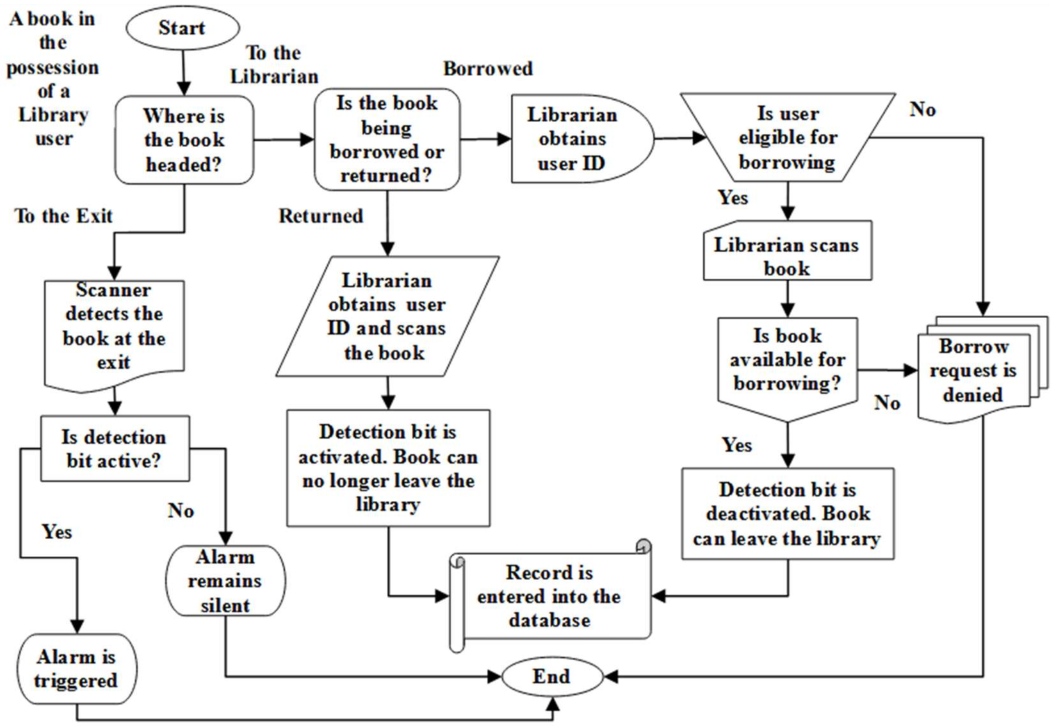


Figure 3 LATESS Workflow Diagram

A book taken by the library user may be moved to any location within the library at their discretion, but once they want to take the book out of the library, they must present it to the on-duty librarian for approval. The librarian then finds out if the book being presented to them is being borrowed or returned and, based on that information, uses the system to either deactivate or reactivate the detection bit of the RFID tag after confirming that the operation is valid. If a user requests to borrow a book that is not available for borrowing, or the user is not eligible for borrowing, their request will be denied, and if they try to take the book out of the library, an alarm will sound at the exit. The alarm is set off at the exit and the book is taken from the user if they try to remove the book from the library without following the procedure depicted in the diagram.

3.4. LATESS System Use Cases

There are two use cases for the application that will be installed on the librarian's computer, which are: 1. Librarian grants borrow request 2. Librarian records the return of the book. The actors for this application are the Librarian and the Library User. The use cases are depicted in Table 1 and Table 2.

Table 1 LATESS Software Application Use Case I

Use Case 1	Librarian Grants Borrow Request
Dependencies	There is a maximum number of books that can be borrowed at a time by a Library User. There is an expected return date for books that are borrowed
Description	The Librarian uses the application to determine if the library user is authorized to borrow a book, and then deactivates the detection bit of the book tag and grants the request if so.
Precondition	The Library User has been identified by their reference number from their ID card, has not reached the maximum number of books that can be borrowed simultaneously and has no outstanding penalty to pay for overdue books.
Trigger	The Library User submits a book to the librarian at their desk.
	Step Action

Use Case 1		Librarian Grants Borrow Request
Ordinary sequence	1	The Librarian logs in to the system using their username and password.
	2	The Librarian inputs the command for the book borrowing process.
	3	The system requests the reference number of the Library User requesting to borrow the book.
	4	The Librarian provides the reference number of the Library User to the system.
	5	The system requests for the identification of the books to be borrowed.
	6	The Librarian provides the data by scanning the RFID tags of the books using the desktop RFID reader.
	7	The system displays the return date for each of the books to be borrowed and requests confirmation for each of them.
	8	The Library User confirms to the Librarian which books they want to borrow after being informed of the return dates.
	9	The Librarian confirms the Library User's decision and enters it into the system.
	10	The detection bits of the books to be borrowed are deactivated and the system informs the Librarian that the operation has been successfully registered.
Post-condition	The Library User can take the borrowed books out of the library without setting off the alarm at the RFID gate at the exit.	
Exceptions	Step	Action
	3	If the library user has reached the maximum number of simultaneous books borrowable or has an overdue penalty, the system informs the Librarian of the situation, and the request is denied.
Comments	The maximum number of simultaneous books borrowable and the length of the return period depends on the category of the Library User i.e., whether it is a student, lecturer, or non-teaching staff member.	

Table 2 LATESS Software Application Use Case II

Use Case 2		Librarian Records Return of Book
Dependencies	There is a penalty on books that are returned past their due date	
Description	The Librarian uses the application to record the return of the book to the library so others can access it.	
Precondition	The Library User has been identified by their reference number from their ID card.	
Trigger	The Library User submits a book to the librarian at their desk.	
Ordinary sequence	Step	Action
	1	The Librarian logs in to the system using their username and password.
	2	The Librarian inputs the command for the book-returning process.
	3	The system requests the reference number of the Library User returning the book.
	4	The Librarian provides the reference number of the Library User to the system.
	5	The system requests the identification of the books being returned.
	6	The Librarian provides the data by scanning the RFID tags of the books using the desktop RFID reader.
	7	The system determines if the books scanned have been presented before or on the due date for return.
	8	The Librarian confirms the return of the books and enters them into the system.

Use Case 2	Librarian Records Return of Book	
	9	The detection bits of the returned books are reactivated, and the system informs the Librarian that the operation has been successfully registered.
Post-condition	The books can now be shelved again and, if taken out of the library, will set off the alarm at the RFID gate at the exit.	
Exceptions	Step	Action
	7	If the books are submitted past the due date, the system informs the Librarian, and the Library User is required to pay a specified penalty to the Librarian before they will be allowed to borrow any books subsequently.
Comments	The penalty is calculated on a per-day basis for each of the books that are kept by the Library User past the date of expected return.	

3.5. LATESS Hardware Prototype and System Design

A hardware prototype was built to demonstrate the functionality of the proposed system. This was done using Arduino (C++) for the RFID system and the Flutter framework was used to build the librarian's user interface. The Flask framework was also used to create and manage the database. An Arduino Uno microcontroller paired with an MFRC522 RFID reader was programmed to obtain the Unique Identifier (UID) of the RFID tags as well as to write data onto the memory block of the tags (this was achieved by the desktop RFID reader in Figure 4). The second microcontroller (NodeMCU) and RFID reader pair were programmed to be able to detect RFID tags of books that are not allowed for borrowing (see the RFID gate reader in Figure 5). The MFRC522 RFID reader has a read range of ~3cm, which is adequate for the desktop RFID reader at the librarian's workstation. However, this range will be by far insufficient for that of the RFID gate at the exit, thus a model will be made of it for purely demonstrative purposes. A buzzer was used as an alarm system to provide an alert for un-borrowed books exiting the library. Arduino C++ was used to create the functions to program the 'detection bit' of the RFID tag, and to scan for the information that was written. The 'detection bit' concept was implemented in this project by writing the value 'True' or 'False' into a specific memory block of the RFID tag. If 'True' is written, it means that the RFID tag for that book is included in the library database and the book is available for borrowing. If 'False' is written, it means the tag for that book is included in the library database and the book is not available for borrowing. The RFID gate will continuously scan all RFID tags moving through the exit of the library, looking for the 'False' value written in that block of the tag's memory. Therefore, when this value is detected, the alarm system is triggered. Flask, a Python framework based on MySQL, was used to create the database. The database was filled with mock information to represent the patrons table (i.e., patron's name, reference number, etc.) and the books table (i.e., book and author's name, RFID tag UID, etc.). Flutter was used to build the UI for the library anti-theft system. This UI enables the librarian to search for a patron from the database and borrow books into and/or return books from the account of the patron. The GUI also integrates with the microcontroller to access the functions that are used to toggle the detection bit of the RFID tags for the borrowing and returning process. The Wi-Fi module on the NodeMCU was used to enable the librarian's computer to communicate wirelessly with it at the RFID gate. The microcontroller sends information on the tags of books moving through the gate for a form of extra surveillance and monitoring.

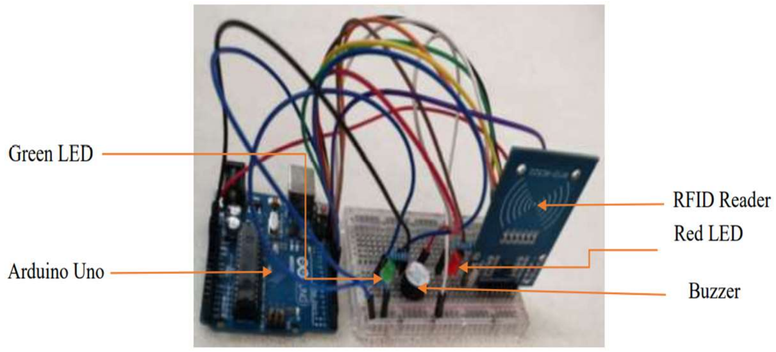


Figure 4 LATESS Desktop RFID Reader Prototype

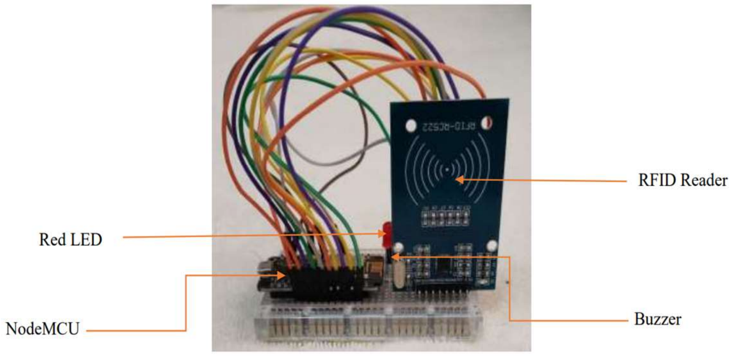


Figure 5 LATESS Gate RFID Reader

3.6. LATESS Software Design

Figure 6 depicts the graphical user interface of the LATESS desktop application. The system will be controlled and monitored on the librarian's desktop computer with the 'KNUST Library Portal' application.

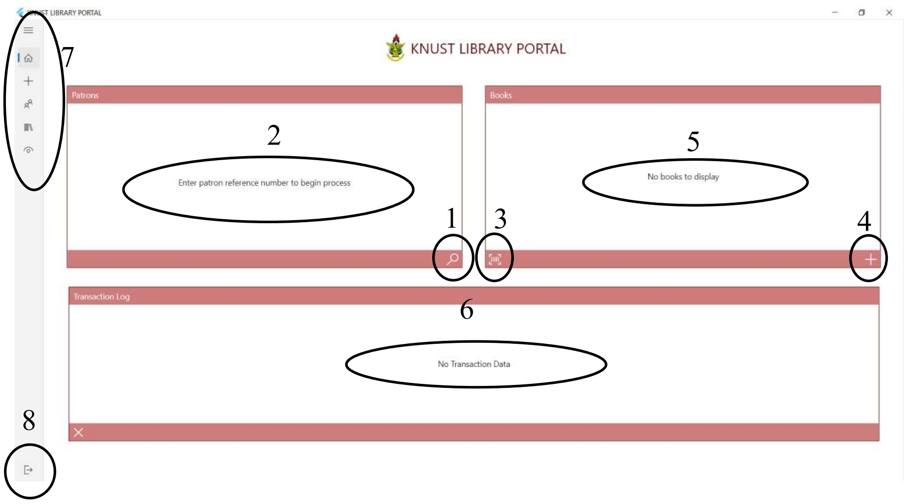
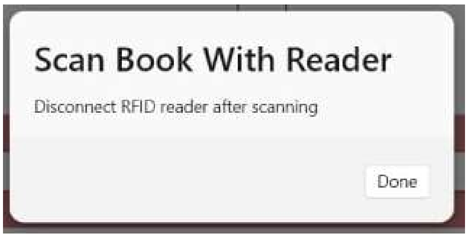
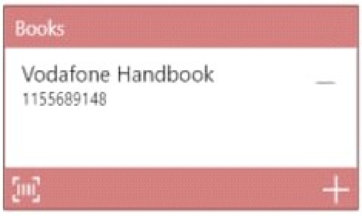
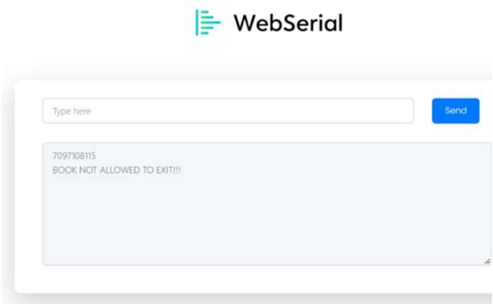


Figure 6 LATESS Software Interface

Table 3 below lists the various individual components of the LATESS user interface application and describes them as well.

Table 3 Individual Components of The LATESS User Interface Application

#	Interface	Description
Search Button		The transaction (i.e., borrow/return) process begins here. The reference number of a patron wishing to perform a transaction is entered in the dialogue box that appears upon clicking here
Patrons Box		The details of the patron appear here after they have been successfully identified via their reference number in the previous point
Scan Button		This button is used to scan the RFID tag of a book that a transaction is to be performed on. On clicking this button, a dialogue box appears asking the librarian to choose whether the book to be scanned is being borrowed or returned, and the decision is made based on the patron's request
Books Box		The details of the books borrowed into a patron's account appear here
Transaction Log Box		Operations that are performed in the transaction process are logged here.
Log Out Button		To log out of the application

The librarian is prompted to connect the USB cable of the RFID reader to the computer and clicks the appropriate button based on what transaction is to be performed. A dialogue box as depicted in Figure 7 appears and the librarian puts the RFID tag of the library book in question to the RFID reader, after which the transaction is performed and recorded in the patron's account. i.e., if the book is being borrowed, the alarm is deactivated and if it is being returned, the alarm is reactivated.

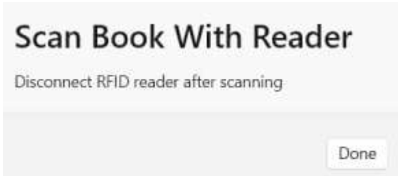


Figure 7 LATESS Book Scan Dialog Box

In the occasion that the RFID system is down or malfunctioning, there is also the option to manually input the RFID number (UID) of the library book to manually record the transaction. Figure 8 shows the dialogue box for a manual book input.

Figure 8 LATESS Book Manual Input Dialog Box

A book can also be manually returned out of the patron's account by clicking the button labelled (i) when the RFID system is unavailable. Figure 9 shows this scenario.

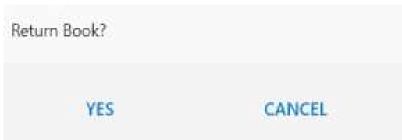
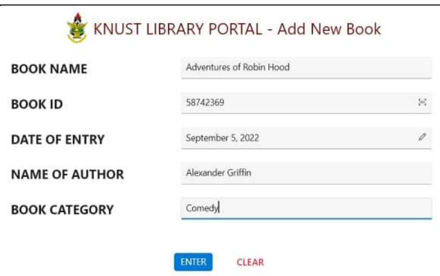
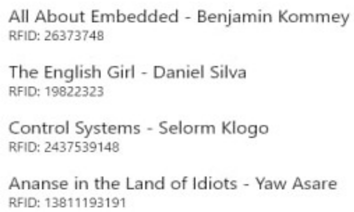


Figure 9 LATESS Book Return Dialog Box

There is a menu bar that contains menu items and buttons leading to the various screens of the application. The items are Home, Add New Book, Patrons, View Books and Monitor. Detailed descriptions of these menu items are given in Table 4.

Table 4 LATESS Menu Items

GUI screen		Description
Home		All transactions are conducted here
Add New Book		Librarian fills in the details of a new book to be added to the library database
Patrons		Librarian can view information on all the patrons in the database

GUI screen		Description
View Books		Librarian can view information on all the books in the database
Monitor		provides a link to the web serial monitor, where the librarian can monitor the operation of the RFID gate wirelessly, seeing all the books moving in and out of the library

4. Results and Discussions

A series of tests were conducted on the LATESS system after its prototyping to ensure it behaved according to specifications and objectives. The LATESS system consists of two main parts: the RFID reader at the librarian's workstation and the RFID reader at the exit of the library. While testing, care had to be taken to ensure the RFID tags were properly placed within the range of the RFID reader to obtain accurate results, as the ~3cm read range is somewhat small. The first set of tests was performed using the hardware prototype equipped with Arduino Uno microcontroller, and the second set with the NodeMCU, which provided varying results. Many different tests were conducted for each of the test cases. This section discusses in detail the test cases and results obtained.

Table 5 describes the tests the RFID reader at the desktop underwent when it was paired with the Arduino Uno board. It also outlines the expected results as well as its success rate in all test cases.

Table 5 Arduino Uno - Desktop RFID Reader

Test Case	Expected Result	Scan Success
RFID tag is placed into RFID reader range	RFID reader obtains the UID of the tag.	100% pass
The tag is placed into RFID reader range and 'True' value is written into the memory block	RFID reader obtains the UID of the tag. The buzzer short beeps (100ms) once and the green LED flashes.	100% pass 100% pass
The tag is placed into RFID reader range and 'False' value is written into the memory block	RFID reader obtains the UID of the tag. The buzzer long-beeps (1000ms) once and the red LED flashes.	100% pass 100% pass
The tag is placed into RFID reader range and value that is neither 'True' nor 'False' is written into the memory block	RFID reader obtains the UID of the tag. The alarm short beeps (100ms) three times and both LEDs flash.	100% pass 100% pass
Multiple (two) tags are placed into RFID range and 'True' value is written into their memory blocks one after the other	RFID reader can write to all the tags one after the other	0.67% fail
Multiple (two) tags are placed into RFID range and 'False' value is written into their memory blocks one after the other	RFID reader can write to all the tags one after the other	0.67% fail
Multiple (two) tags are placed into RFID range and 'True' value is written	RFID reader obtains the UIDs of the tags.	0% fail 0% fail

Test Case	Expected Result	Scan Success
into their memory blocks simultaneously	The alarm short beeps (100ms) once and the green LED flashes.	
Multiple (two) tags are placed into RFID range and 'False' value is written into their memory blocks simultaneously	RFID reader obtains the UIDs of the tags. The alarm long beeps (1000ms) once and the red LED flashes.	0% fail 0% fail
The tag was placed in a thick cloth (> 3cm) and placed within the RFID range. 'True' or 'False' value is written into the memory block of the tag.	The thickness of the cloth prevents the tag from falling within the RFID range	0% fail

Table 6 outlines the results of the test cases involving the RFID reader at the exit when it was paired with the Arduino Uno board.

Table 6 Arduino Uno - RFID Gate at Exit

Test Case	Expected Result	Scan Success
RFID tag passing through RFID reader range	RFID reader scans the memory block of the RFID tag.	100% pass
Tag concealed by a non-tag object passing through RFID reader range	RFID reader scans the memory block of the RFID tag.	100% pass
Tag approved for borrowing passing through RFID reader range	RFID reader finds the value 'True' in the memory block of the tag. The alarm is not triggered.	100% pass 100% pass
Tag not approved for borrowing passing through RFID reader range	RFID reader finds the value 'False' in the memory block of the tag. The alarm is not triggered.	100% pass 100% pass
Multiple (two) approved tags passing through RFID reader range simultaneously	RFID reader can identify the UID of both tags. The alarm is not triggered.	33% inconsistent 100% pass
Multiple (two) not approved tags passing through RFID reader range simultaneously	RFID reader can identify the UID of both tags. The alarm is triggered.	27% inconsistent 100% pass
Mixed (one approved, one not approved) tags passing through RFID reader range simultaneously	RFID reader scans the memory blocks of all the tags. The alarm is triggered.	40% inconsistent 100% pass
RFID tag not included in database passing through RFID reader range	RFID reader scans the memory block of the tag. 'True' or 'False' value found in the memory block of the tag	100% pass 0% fail
Tag placed in foil object passing through RFID reader range	RFID reader is unable to scan the tag.	0% fail
Tag passes near RFID reader but is out of range	RFID reader is unable to scan the tag.	0% fail

Table 7 contains the test results for scenarios where the NodeMCU and the desktop RFID reader being used in tandem.

Table 7 NodeMCU - Desktop RFID Reader

Test Case	Expected Result	Scan Success
RFID tag is placed into RFID reader range	RFID reader obtains the UID of the tag.	100% pass
The tag is placed into RFID reader range and 'True' value is written into the memory block	RFID reader obtains the UID of the tag.	100% pass 100% pass

Test Case	Expected Result	Scan Success
	The buzzer short beeps (100ms) once and the green LED flashes.	
The tag is placed into RFID reader range and 'False' value is written into the memory block	RFID reader obtains the UID of the tag. The buzzer long-beeps (1000ms) once and the red LED flashes.	100% pass 100% pass
The tag is placed into RFID reader range and value that is neither 'True' nor 'False' is written into the memory block	RFID reader obtains the UID of the tag. The alarm short beeps (100ms) three times and both LEDs flash.	100% pass 100% pass
Multiple (two) tags are placed into RFID range and 'True' value is written into their memory blocks one after the other	RFID reader can write to all the tags one after the other	0.67% fail
Multiple (two) tags are placed into RFID range and 'False' value is written into their memory blocks one after the other	RFID reader can write to all the tags one after the other	0.67% fail
Multiple (two) tags are placed into RFID range and 'True' value is written into their memory blocks simultaneously	RFID reader obtains the UIDs of the tags. The alarm short beeps (100ms) once and the green LED flashes.	0% fail 0% – fail
Multiple (two) tags are placed into RFID range and 'False' value is written into their memory blocks simultaneously	RFID reader obtains the UIDs of the tags. The alarm long beeps (1000ms) once and the red LED flashes.	0% – fail 0% – fail
The tag was placed in a thick cloth (> 3cm) and placed within the RFID range. 'True' or 'False' value is written into the memory block of the tag.	The thickness of cloth prevents the tag from falling within the RFID range	0% – fail

Table 8 depicts the test cases for the pairing of the NodeMCU and the RFID reader at the exit.

Table 8 NodeMCU - RFID Gate at Exit

Test Case	Expected Result	Scan Success
RFID tag passing through RFID reader range	RFID reader scans the memory block of the RFID tag.	100% pass
Tag concealed by a non-tag object passing through RFID reader range	The Reader scans the memory block of the RFID tag.	100% pass
Tag approved for borrowing passing through RFID reader range	RFID reader finds the value 'True' in the memory block of the tag. The alarm is not triggered.	100% pass 100% pass
Tag not approved for borrowing passing through RFID reader range	RFID reader finds the value 'False' in the memory block of the tag. The alarm is not triggered.	100% pass 100% pass
Multiple (two) approved tags passing through RFID reader range simultaneously	RFID reader can identify the UID of both tags. The alarm is not triggered.	33% inconsistent 33% inconsistent
Multiple (two) not approved tags passing through RFID reader range simultaneously	RFID reader can identify the UID of both tags. The alarm is triggered.	27% inconsistent 27% inconsistent

Test Case	Expected Result	Scan Success
Mixed (one approved, one not approved) tags passing through RFID reader range simultaneously	RFID reader scans the memory blocks of all the tags. The alarm is triggered.	40% inconsistent 40% inconsistent
RFID tag not included in database passing through RFID reader range	RFID reader scans the memory block of the tag. 'True' or 'False' value found in the memory block of the tag	100% pass 0% fail
Tag placed in foil object passing through RFID reader range	RFID reader is unable to scan the tag.	0% fail
Tag passes near RFID reader but is out of range	RFID reader is unable to scan the tag.	0% fail

The LATESS system performed as expected for most of the test cases, however, a few issues were noticed in its operation. These issues are highlighted below.

1. **Partial Scanning (All Cases).** For the RFID gate, an actual implementation would require a reader with a far greater range, so this would not be a problem as with such a range, it would be near impossible to miss the tag. For the desktop RFID reader, care should be taken when scanning a tag to ensure that it is placed well within the range of the reader. To accommodate this behavior, the desktop RFID reader has been programmed to beep and flash both LEDs three times when a value other than 'True' or 'False' is written to a tag. This notifies the librarian that an incomplete written operation was performed, and that the transaction needs to be performed again to prevent errors from occurring in the system.
2. **Continuous Scanning (Desktop RFID reader for all cases).** The program written for the desktop RFID reader prevents multiple tags from being scanned immediately one after the other. Once a tag has been scanned, no other tag can be scanned until the USB cable of the reader is disconnected and connected again. To accommodate this, the librarian is prompted in the UI on every transaction operation to unplug the USB cable after scanning and plug it back in when scanning is required.
3. **Inconsistent Results (RFID Gate for all cases**). Inconsistent results were obtained when attempting to obtain the values of the data stored in the memory blocks of multiple tags passing through simultaneously. This is likely because the read range is small and thus the reader was unable to output the information to the serial monitor before the tag moves out of range. It could also be because the RFID reader in this system not having a complex anti-collision technology, causing the multiple signals to interfere with each other.

For the Arduino Uno, the alarm was triggered in this scenario regardless, thus this does not adversely affect the performance of the system. However, for the NodeMCU the alarm was not triggered, which is an issue in the performance of the system. This could be solved by using a more sophisticated RFID reader.

5. Conclusions

In this study, research was conducted on the various types of identification technology commonly used today and the RFID technology was found the most suitable option for the implementation of the KNUST Library Anti-Theft Electronic Surveillance System (LATESS). Similar works were studied, and a hardware prototype was designed. The Flutter framework was used to design a user-friendly graphical interface desktop software application with an integrated database incorporated via the Flask framework. The LATESS system designed proved to be robust, reliable, and efficient. The system was rigorously tested with very good results and met all objectives targeted. It can, therefore, be concluded that if and after the real and proper implementation of the LATESS system at the KNUST Main Library, the number of book theft cases in the library would be reduced drastically. Future works should improve the RFID gate with a range of at least 2m and a reading rate of at least 10 tags per second at the library exit and RFID stickers with a corresponding working frequency should be used as the RFID tags for the library books.

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