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Smart Library with Automatic Book Management

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***Abstract*—Libraries are indispensable for books and reading, as well as an abundant source of information. The majority of the current conventional libraries employ labor-intensive, time-consuming processes that result in long lines for borrowing and returning materials. In this paper, we propose a smart library system built on the Internet of Things that addresses these issues. The proposed system involves using books that have RFID tags attached to them and a camera at the borrowing counter. The RFID readers on the bookshelves and at the borrowing counter can read the book information stored electronically on the RFID tags and the camera verifies the user by scanning their face using a face recognition model. As a result of the combination of Face recognition and RFID Technology, the system automates the processes of borrowing, returning, and sorting the books by enabling the self-borrow and self-return process along with the ability to track each book's location on the bookshelf. An e-mail will be sent to the user acknowledging both the transactions. The proposed system remarkably quickens the process of borrowing, returning and sorting thus reducing long queues at the librarian's desk and lesser human intervention for the management.**

Index Terms—Radio Frequency Identification, Device-to-Device Communication, Cloud Services, User experience

I. INTRODUCTION

A library management system is designed to monitor all the library activities and maintain a database of all books with their issue, return details as well as the due dates. The main aim of a library management system is to provide accurate data regarding any type of book and easy user interaction with the system therefore saving a lot of time and effort. The major problem faced by the current system is the improper management of books, misplacement and slow check in/check out for the user. The conventional methods use bar code scanning, magnetic stripe reading and other methods to prevent these problems but they are often error prone. The existing system is semi-automated meaning it requires additional efforts for the librarian for borrowing the books, sorting it and observing the misplacement of the books in the bookshelves. The users often experience long delays while borrowing or returning the books which leads to spending unnecessary time in queue. Hence, there is a need for an automated library management system and a solution for updating the location of the library books in a central database efficiently.

The proposed system is to be deployed in public libraries which currently uses a manual system consisting of bar-code technology for accessing the book and requires a dedicated person to scan the books and place them returned in the designated shelf. It replaces the existing traditional library management system with a combination of RFID and Face Recognition mechanism thus allowing a very effective level of automation in the various processes of the library. The proposed system is based on the technologies of RFID, Face Recognition and Cloud computing. The bookshelves which will be equipped with RFID readers will enable the user to return the borrowed book with a single tap before putting it back in the designated shelf. The data will be sent to the central database on the cloud. At the borrowing counter, the registered user will be identified using the camera and Face recognition. The book to be issued will be identified using RFID and the combination of this data will be sent to the central database thus completing the process of issuing the book faster. An e-mail receipt of both these transaction will be sent to the user automatically.

The terms RFID Reader and Tags refer to Radio Frequency Identification technology. RFID automatically identifies and collects data from objects by attaching RFID tags to them using electromagnetic fields and radio waves. In this case, the RFID Tag has a microchip that saves data. Radio waves are used by RFID tags to transfer data. They normally don't have batteries; instead, they get their power from the radio waves the reader produces.The energy travels through the internal antenna of the tag to the tag's chip after the transmission is received from the reader/antenna. This chip gets turned on and starts modulating the energy with the information that is stored inside it. The signal is then sent back to the RFID Reader. RFID reader is a device that can receive and transmit a radio signal.

Face recognition is a frequently used biometric technology in access control and authentication. It makes use of automated techniques to confirm or identify the identity of a living individual on the basis of their physiological features. People can be recognized using facial recognition technology in real-time or in still images and videos. The computer reads the person's face's geometry. The separation of the eyes, the depth of eye sockets, the space between forehead and chin, the form of cheekbones and the shape of lips, ears, and chin are all important aspects taken into consideration. The objective is to

discover the distinctive facial features that make a person's face unique.

Cloud Computing is a method of accessing and using computing resources like data storage, processing power, and software packages via the internet. Cloud computing enables users to store and process data remotely in sizable data centers owned and operated by third-party companies rather than depending on local servers or personal computers. Customers get on-demand access to these resources, typically via a subscription-based approach, and can adjust their usage as necessary. It provides tw0o of the key aspects i.e flexibility and scalability which are important for large scale applications. Customers don't need to make expensive hardware updates because they can quickly modify their computing capacity to suit their changing needs. This makes it possible for people and enterprises to be more adaptable and receptive to market needs.The proposed system utilizes Cloud Database based on the Cloud Computing technology to store the necessary library information.

II. RELATED WORK

Some of the related work in this area includes RFID Based Library Management System [1]. It uses RFID for borrow and return as well as for authentication of the user. Every user is given an Identity Card with RFID tag embedded in it. The system authenticates when the user scans this Identity Card against the RFID Reader to gain access to the library. It follow the same procedure to borrow and return the book by scanning the book which is embedded with RFID tag, against the RFID Reader. The returned books after scanning are placed in a return tray. It also implements a security mechanism which involves the entry/exit gate which is equipped with RFID Reader, detect unborrowed book going out of the library and raises an alarm.

Face recognition based Attendance Monitoring System [2] identifies the person using a Face Recognition algorithm and marks its attendance record in the database. The algorithm used in this system involves steps; Image acquisition, Histogram normalization, Noise removal, Skin classification and Face Detection. After the Face detection, the face image is cropped covering the detected face and is compared with the database. This is how the student is verified and then the data is sent to the database to mark the their attendance. The system results into more accurate and faster method of authentication thereby saving time and efforts and enabling convenience for the user.

Face Recognition based on ESP32Cam [3] uses the micro-controller to stream the camera vision on a web server and recognize the person in real-time. The systems consists of a OV2640 camera having 2MP resolution and an Arduino Uno board as a communication interface to upload program to the ESP32Cam micro-controller unit. The ESP32Cam connects to a WiFi network and displays the IP address where the camera interface is setup to activate the camera. A database is created using python script consisting of 100 images each for a person recording the different grimaces. The camera after detecting the person's face, compares it with the database and displays the name of the person in an event of successful verification. The results are saved in an excel file containing the name of the person, date and time o2308650_523343_463_467 verification.

The system suggested in [4] makes use of the Near Field Communication technique for book tracking. There is a NFC tag on each book. The user places their NFC-enabled phone on the NFC reader at the entrance. The user is connected to the LAN if their fingerprint and user ID have been recorded in the database. The user uses his phone to send a request to the system for a book search, and the server responds with information about the book rack. The user sends this request to the local positioning system, which then directs him further to the selected rack. A new book is initially registered in a rack by scanning its NFC tag against the monitor of that specific rack. The entry/exit includes NFC scanners to carry out the borrow procedure. In order to return the book, the user has to just drop the book in the designated drop box.

Another technology used to enable Smart Library is a QR Code based Library Management System [5]. It involves an android application which carries out the various services in the library such as book borrow, book return, browsing the collection, checking availability of a book and a managing function for the librarian to observe the movement of books and prevent thefts. The user is authenticated by the app using an User ID and password. In order to borrow a book, the user has to click on the borrow button in the application which opens the camera on the phone to scan the QR Code. After scanning the QR Code on the book, the relevant details are gathered, return date is calculated and the process is completed by sending all the details to the database. Similarly, to return a book, the user scans the QR Code on the book and places the book in a designated shelf near the librarian. The system checks whether the book is returned in time and charges a fine if returned after the due date.

III. PROPOSED SYSTEM

The proposed system consists of 3 elements namely the borrow device, return device and Cloud database. The borrow device is placed at the borrowing counter and the return device is placed on a bookshelf each. The database is hosted on Cloud is provided by Google Firebase. Each book is embedded with a RFID Tag containing all the necessary details about the book. The processes involved are explained as follows.

A. Registration

The user while registering for the library service will be asked by the librarian to capture their face via the camera on the borrowing device and the face recognition system will store the identification data. The other details about the user such as User Name, User ID will be added to the database. The user will now be ready to use the library service. The information about each book including Author, Book ID, User ID, Edition, Location, Publication and Availability Status will be entered into the database by the library. The books will be embedded with RFID Tags and the librarian will write the tags with the Name and Book ID of the book using an additional RFID reader/writer module.

B. Book Borrow

The borrow device is built using an RFID Reader and an OLED Display along with two microcontrollers; ESP32Cam and ESP8266 Node MCU which are connected to WiFi and communicate with each other using a cloud platform through MQTT protocol. The RFID reader and OLED Display is connected to the Node MCU whereas the ESP32Cam handles the camera function using an interface on a web server as shown in Fig. 1 In order to borrow the book, the user scans the book by placing it near the scanning area of the borrow device.The device then reads the RFID tag in the book using the RFID reader and captures the book details. The device then scans the user's face using the camera on the ESP32Cam. Upon successful verification, the microcontroller sends the user details to the Node MCU through MQTT protocol. The NodeMCU sends the combination of book and user data to the relevant fields in the cloud database through the internet therefore completing the borrow process. It sends an email to the user acknowledging the borrow process using SMTP. All steps initiated during the process are displayed to the user on the OLED display.

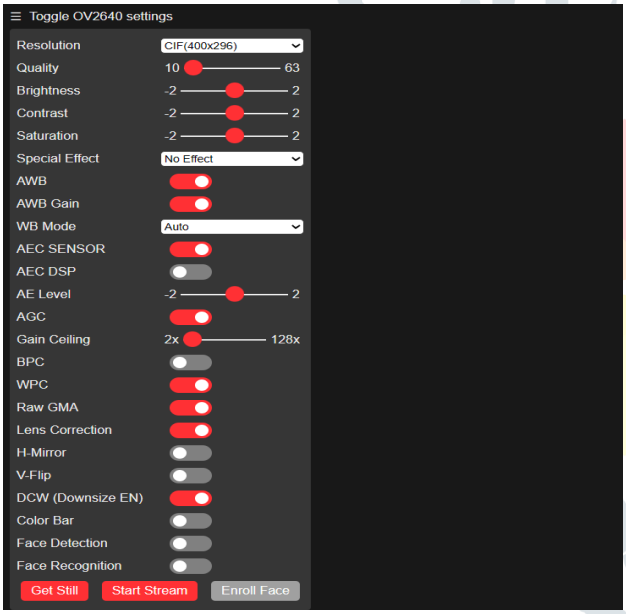

Fig. 1. Camera interface on web server

C. Book Return

The return device as shown in Fig.2 is built using a ESP32 microcontroller as its central processing unit, multiple RFID readers placed at each end of a row and an active buzzer. The user when returning the book has to make a single tap on the sensor area of the designated row of the bookshelf according to the category of the book. The return device of the bookshelf will extract the book details through the RFID reader. It will initiate a search query to the database to identify the user who has borrowed the book. Once the identification is done, it will make the necessary changes to the data in the database thereby completing the return procedure. The user will then place the book in the designated location. All the steps in this process will be notified to the user through different types of beeps by the active buzzer. An email receipt will be sent to the user automatically after the return process is finished.

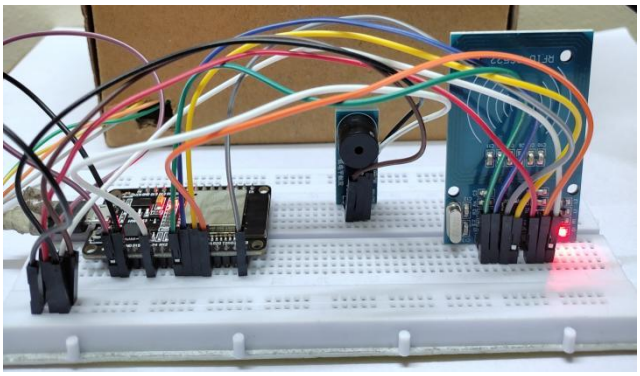

Fig. 2. Return device with a single RFID reader for one row

D. Sorting

In an event where a user tries to return the book and place it in the incorrect location, the return device compares the category of the book obtained by through the RFID reader to the category of the row of the particular bookshelf and sends an alert beep to notify the user of the incorrect location of the book. It stops the return procedure and the book is not returned to the library thereby avoiding the incorrect placing of the books in the bookshelves and reducing the need to sort the books by the librarian.

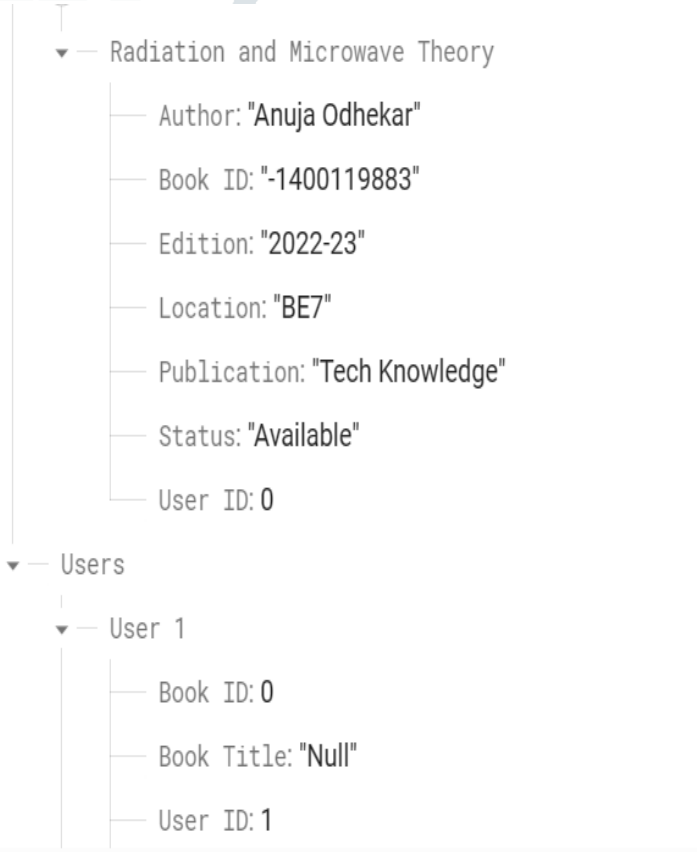

Fig. 3. Two of the fields in the Database

E. Database

The database hosted on cloud by Firebase is a real-time database. It displays all the necessary information about all the library activities in real time which is accessible to the librarian as shown in Fig.3. The database consists of two main

sections; books and users. The books section has Author, Book ID, User ID, Edition, Location, Publication and Availability Status of each book in the library. The Users section includes User Name and User ID of each user along with the Book ID and Title of the book it has borrowed. The cloud database establishes a secure connection with the borrow and return devices before carrying out the two way data transfers. The communication with the borrow and return device is carried out wirelessly using a wireless network connected to the Internet.

IV. COMPONENTS USED

A. Node MCU

NodeMCU is a development board and open-source Lua-based firmware designed primarily for Internet of Things (IoT) applications. Espressif Systems has made the firmware to run on the ESP8266 Wi-Fi SoC while the hardware is based on the ESP-12 module. The interfaces UART, SPI, and I2C are supported. In the case of a 5V supply, the USB port can be used to power Node MCU and a Vin pin can be used for input of 7–12V. This microprocessor has an adjustable clock frequency range of 80 MHz to 160 MHz and supports RTOS. To store data and programmes, Node MCU features 4MB of Flash memory and 128 KB of RAM.

B. ESP32Cam

The board is run by a Espressif ESP32-S SoC, a potent, programmable MCU with built-in WiFi and Bluetooth. It has built-in flash LED, Bluetooth 4.2 with BLE, 520 KB SRAM, 4 MB PSRAM, 9 GPIO connectors, and 802.11b/g/n Wi-Fi. The board lacks a standard USB connector, therefore to upload code to it, there is a need to use either an FTDI programmer or an Arduino UNO coupled with the Arduino IDE/ESP-IDF DEV tools. The ESP-32 CAM can do on-device machine learning tasks like picture classification, human detection, etc. using the most recent TinyML models. The ESP32Cam has two input power pins and it takes 3.3V by default. The board becomes unstable with error or images having coloured lines if the OV2640 camera is used under 3.3V supply which is why it is recommended to supply 5V.

C. ESP32

ESP32 is a microcontroller developed by Expressif that has inbuilt WiFi and Bluetooth capability. It features a dual core; Xtensa 32-bit LX6 microprocessors that have low power consumption. It has a ROM of 448KB and a 520KB SRAM. It has an operating voltage of 2.5-3.6V and can take an input voltage ranging 4.5-12V. It has 30 available pins which support various interfaces such as UART, I2C and SPI. The current drawn by each of these pins is a maximum of 40mA according to the ESP32 data sheet. With an operational temperature range of -40°C to +125°C, ESP32 can operate dependably in industrial settings.

D. RC522 RFID Reader

The RFID reader that is going to be used is the RC522 model. It requires a power supply of 3.3V and operates on 13.56 MHz frequency. It uses the SPI protocol to communicate with the CPU board enabling a reading distance upto 60mm.The MFRC522 IC/Chip from NXP Company is the foundation of the RC522 RFID Reader Module. The chip's OSCIN and OSCOUT pins are connected to a quartz crystal with a frequency of 27.12 MHz as the internal oscillator. In the module's PCB is an embedded NFC coil. This antenna produces a high-frequency electromagnetic field with a frequency of 13.56 MHz. This module is also capable of writing to the RFID Tag.

E. SSD1306 OLED Display

It is an OLED (Organic Light Emitting Diode) monochrome display which has a size of 0.96 inches and works on the I2C or SPI interface. It is designed to work with any 3.3V-5V microcontroller. It features high brightness, high contrast ratio, wide viewing angles and very low power consumption compared to LCD displays. This display module has four pins that are Vcc, Ground, SCL and SDA. The VCC and GND pins will power the OLED display whereas the SCL is used to generate clock signal and SDA pins to transmit the data.

F. Active Buzzer Module

Active Buzzer is an audio signaling device that has a built-in oscillating source which meaning it only requires a DC power source to produce sound. The module used in the system has an operating voltage of 3.3-5V.

V. RESULTS

The system was tested on a certain size of sample consisting of students at an educational institution. The Fig. 4 shows the OLED display indicating the borrow device is ready to scan the book. When the user places the in front of the device, the device extracts the book details using RFID in 3-4 seconds time. The OLED display then indicates the user to scan their face. The figure shows the camera interface on the web server displaying the face recognition process. It is observed that the face recognition happens instantly in good lighting conditions however it took more to recognize when there was poor amount of light. Once the face recognition is done, the same is displayed on the OLED and the borrow device starts uploading the data to the cloud database. This process takes around 30-35 seconds to complete and an email is sent to the user automatically immediately after the database is updated thus completing the borrow process. The figure shows a prototype representing a row of a bookshelf which has the RFID reader placed on the side. When the user who wants to return the book places the book near the sensor, an beep sound is made instantly indicating successful return operation and the database is also updates within few seconds.The user then places the book in the bookshelf completing the return process.

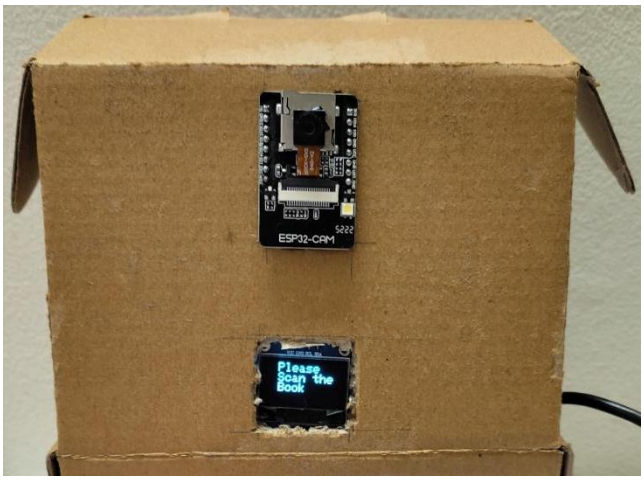

Fig. 4. Borrow device asking to scan the book

VI. CONCLUSION

The concept of Internet Of Things is executed with the system having a network of sensors, camera and processing units in system. The system automates the main library activities, makes them faster and easier for the user. The system has shown it does not require the librarian to intervene in the book borrow and return process. The return device reduces the instances of the books placed in wrong part of the bookshelf hence also reducing the need to sort the books manually. If the face recognition accuracy is improved with robust algorithms, the system can be deployed at actual libraries including public libraries and educational institutions. The system can be equipped with security by installing a gate with RFID Readers that detect the presence of unborrowed books going out of the library and raising an alarm. A mobile application can be developed for the users to browse the available books in the library along with their location.

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