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Introduction

This document describes a library system architecture designed to automate operations and enhance the user experience. The system is divided into several core modules, each with distinct functionalities:

- **Data Types**: Defines various data categories within the system, including users, media, metadata, transactions, and notifications;
- **Authentication/Card Module**: Manages user identification and access control through physical or virtual library cards;
- **Return Media Module**: Handles the return process for both physical and virtual media, offering automated and semi-automated options for physical media returns;
- **Library Stations**: Provides patrons and staff with self-service terminals for browsing and searching the library catalogue;
- **Checkout Module**: Facilitates the checkout process for different media types, enabling borrowing of available physical items, reservations for unavailable items, and instant access to digital media;
- **Inventory Management Module**: Grants authorized staff exclusive access to manage media inventory, monitoring checkout and reservation statuses;
- **Mobile App**: Serves as a user-friendly interface for patrons and staff to interact with the library system. It enables functionalities like searching for media, checking availability, reserving items, managing checkouts and returns, viewing due dates and fines, and receiving notifications;

These modules operate cohesively, connected through the library's data system and the mobile app.

Data Types

Users

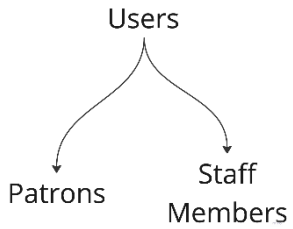

Fig. 1 – Types of Users

There are two types of users: Patrons and Staff members. There is a necessity to divide into two types of the users because the Staff members will have more responsibilities and different permissions regarding the library system.

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Media

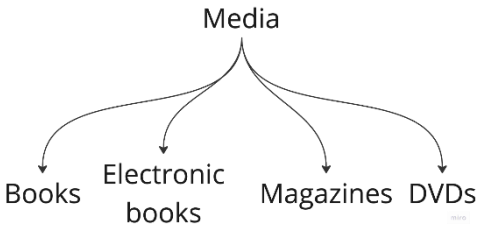

Fig. 2 – Types of Media

Besides the books, the library offers to loan different types of media like electronic books, magazines, DVDs, etc.

Metadata

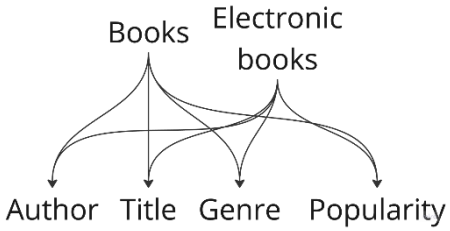

Fig. 3 – Types of Metadata

Associated with each type of media there is the metadata. A book or e-book has associated with it its author, title, genre, popularity, topic, etc. A magazine has associated with it its publisher, title, genre, popularity, target audience, issue frequency, etc. While a DVD has associated with it its director, title, genre, popularity, actors, release date, etc.

Transactions

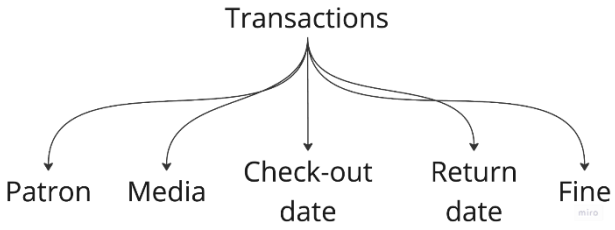

Fig. 4 – Types of Transactions

Between the users and the library, there are the following types of transactions: check-outs and returns. Also, these transactions can be associated with a fine if the patron fails to meet the return date of the media that he had checked out.

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Notifications

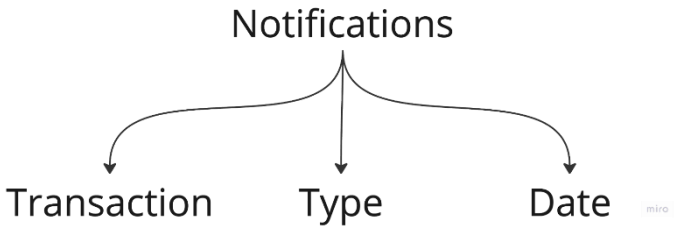

Fig. 5 – Types of Notifications

Between the patron and the library, communication is done via notifications. There are primarily two types of notifications: Reservation Notifications, where the patron is notified 3 to 5 days before and on the day of the return date, and Fine Notifications, where the patron is notified that he needs to pay a fine because he failed to return a media that he had reserved.

Authentication / Card Module

A person is a patron of the library if they have a card. A card is a physical or virtual way of identifying a patron. The card has on the front the name and ID of the patron and on the back has a QR code.

If a person wants to be a patron, they can sign up via the Library App or with a staff in person. The card is available virtually immediately after the signup, but the physical needs to be asked for and it's delivered to the patron's home or in the library where they signed up.

The patron can identify itself in three ways:

- Entering their credentials
- Scanning the QR code
- Using the contactless functionality of the card (NFC, if the card is virtual)

The patron needs to present their card to enter the library, by scanning it in the card validator, following the next flowchart image:

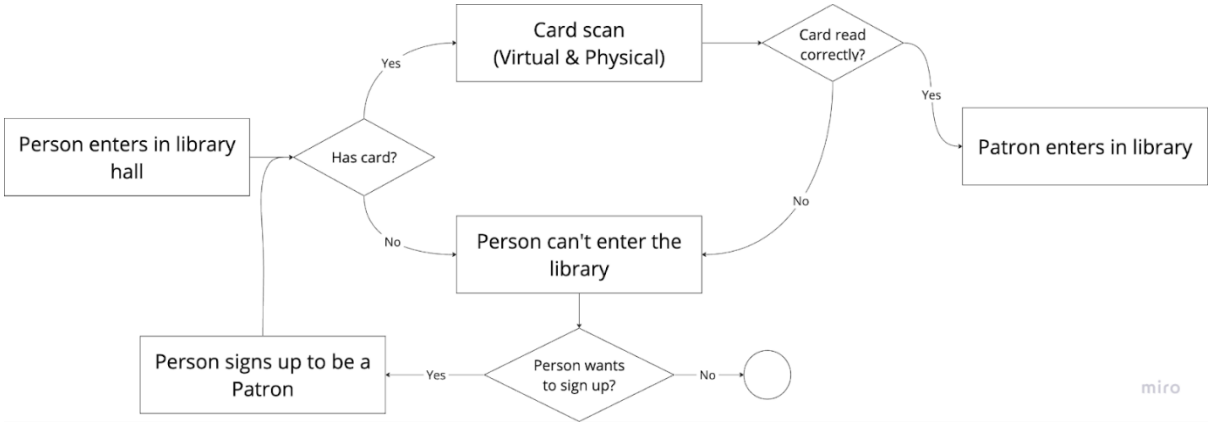

Fig. 6 – Flowchart authentication / card logic

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The decision to mandate library card presentation upon entry enhances security and ensures that library services and privileges are reserved for registered members (patrons). The option for a physical card accommodates those more comfortable with tangible materials, but the virtual card also aids the ones who don't carry a wallet regularly. Incorporating multiple identification methods, mentioned above, addresses various user preferences, ensuring inclusivity and convenience.

Return Media Module

When the patron makes a return, independent of the type of media, he selects, if not predefined, the return date of the media. This action needs to be divided into two because there are two types of media: physical and virtual.

With virtual media, like e-books, there is no need to return the media because multiple people can read the same book if it is available online. The physical media, like books, magazines, and DVDs, need to be returned in person at the library where the user checked out.

There is two ways of returning the physical media, one fully automated, with no staff involved, and one semi-automated:

Fully automated solution

For this solution, when the patron receives the notification that he needs to return the media, he also receives information as to where to place the book to return. Each book has a place in the library, a certain space, on a certain shelf, on a certain bookcase, on a certain aisle. The patron to return the media needs to place it in this place, which is the same as it was before. With this solution, the library always has its media ordered and correctly placed.

Semi-automated solution

In this solution, each type of media needs to have an RFID tag associated with it and the library needs to have a special bookcase for the patrons to return their checked out media. The patron to return the media just needs to place it in this special bookcase. At the end of the day, a staff member scans all the media in the bookcase, to mark as returned, and correctly places the media in the library.

Each approach presented above is designed to optimize the user experience while maintaining accuracy and efficiency in inventory management. The first one, while being more expensive in the beginning, will pay for itself with the shortage of staff needed at the library. The second one provides a more friendly interaction for the user when returning the media that they have checked out before.

Library Stations

Once inside the library, the users - patrons or staff - can use the library stations freely to browse and search in the media catalogue. To perform this task the library station will be connected to the library database and fetch the results according to the user input.

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Search Flow

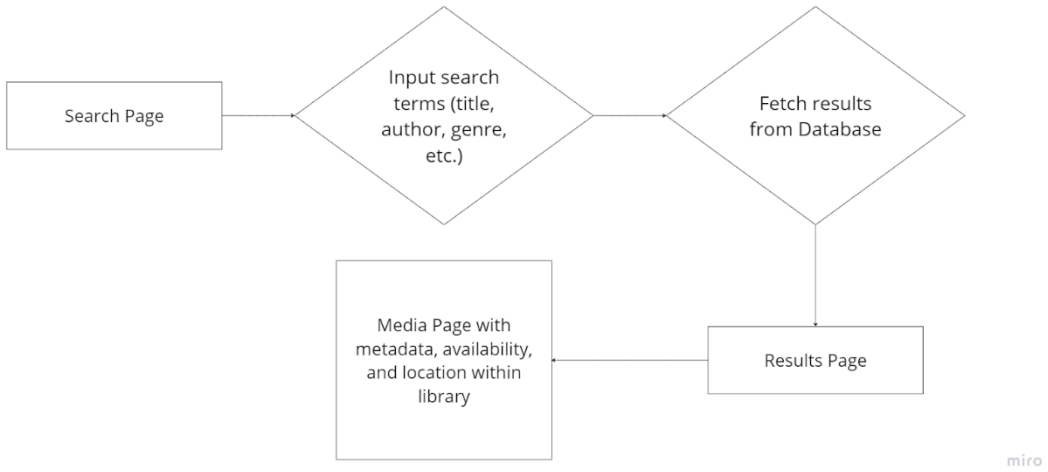

Fig. 7 – Flowchart of searching in the library system

Checkout Module

Fig. 8 – Flowchart of the checkout process

The checkout flow can be divided into 3 classes of items:

- **Available physical items**: to check out this type of media the user will need to scan the barcode associated with it using the mobile app.
- **Unavailable physical items**: this type of media cannot be checked out but can be reserved, and to do so the user will need to search for this item in the mobile app and then reserve it.
- **Digital items (like e-books)**: to check out this type of media the user will need to search for it in the mobile app, without even needing to be inside the library. Considering this type has no stock limits, there can be multiple instances of it checked out simultaneously.

Inventory Management Module

The Inventory Management Module is responsible for controlling all aspects related to media inventory. This module is exclusively accessible and manageable by authorized staff members, who are responsible for maintaining the system's integrity and overseeing media-related activities.

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Staff responsibilities involve integrating new media into the system, requiring the entry of specific details such as id, title, author, ISBN, available stock, and more. Additionally, staff members can modify existing information related to media of any type, making sure the system remains up-to-date and accurate. All these interactions with the system trigger communications with a database, where information about the entire library system is stored.

Staff members also hold the capability to view detailed information about checked-out and reserved media. This includes specifics such as expiration dates, reservation dates, and other pertinent details. The checkout component of the system automatically updates the status of the media in the database upon completion of the checkout process. In the case of check-ins, two distinct types exist, although the final state of the media will be either available or reserved, particularly if another patron has already placed a reservation.

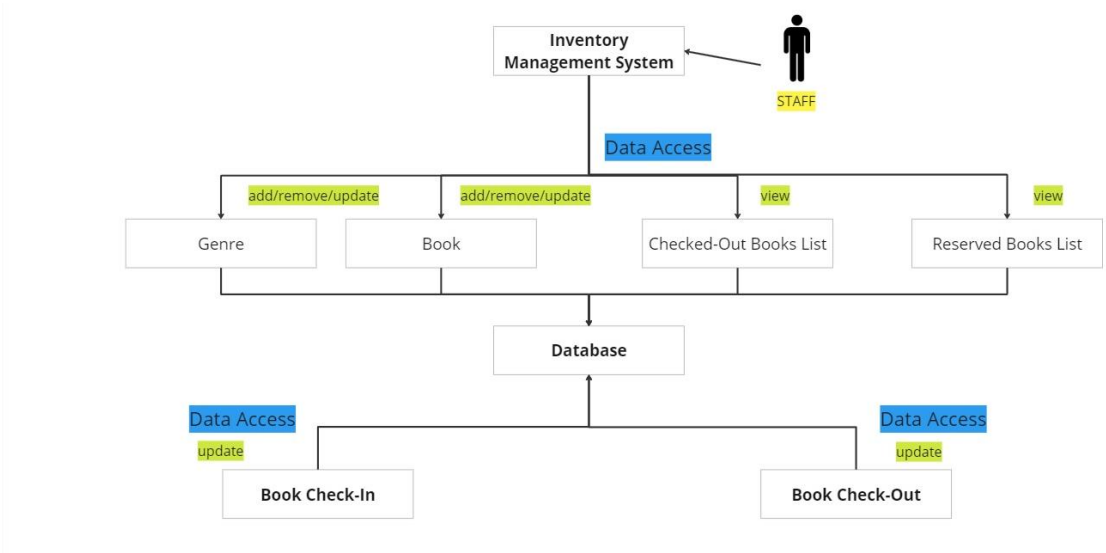

Fig. 9 – Flowchart of inventory management system

Mobile App Flow

When a user first enters the app, whether as a customer or a member of staff, they must enter their authentication credentials. If the correct credentials are entered, the user is directed to the homepage. From here, the user can look for specific media. If they find what they're looking for, they can access more information about it.

The user can view a piece of media via the media details page. Furthermore, they may decide to check it out. However, the outcome of this action is contingent on the type of the media. If the piece of media is electronic, the process is complete. If it's physical, they should check its availability. If it's available, the user is redirected to a scanner, where they can examine the media with their phone camera. If the scan was successful, the check-out process is complete. If it is not available, the user navigates to the reservation page.

The user can also see a list of media that they have checked out but need to return. This return list page indicates whether it is late or not. If it is, then the user must pay a late fee.

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To return a piece of media, they are directed to the instructions page, which tells them what to do based on whether they are dealing with physical or electronic media. When it comes to physical media, they must return it to the library. Otherwise, the media will return itself.

Staff can also manage inventory through the inventory management page.

Finally, the user receives app notifications informing them of the return date of the checked-out media, and proximity to it. Some notifications alert the users to the tardiness of a piece of media.

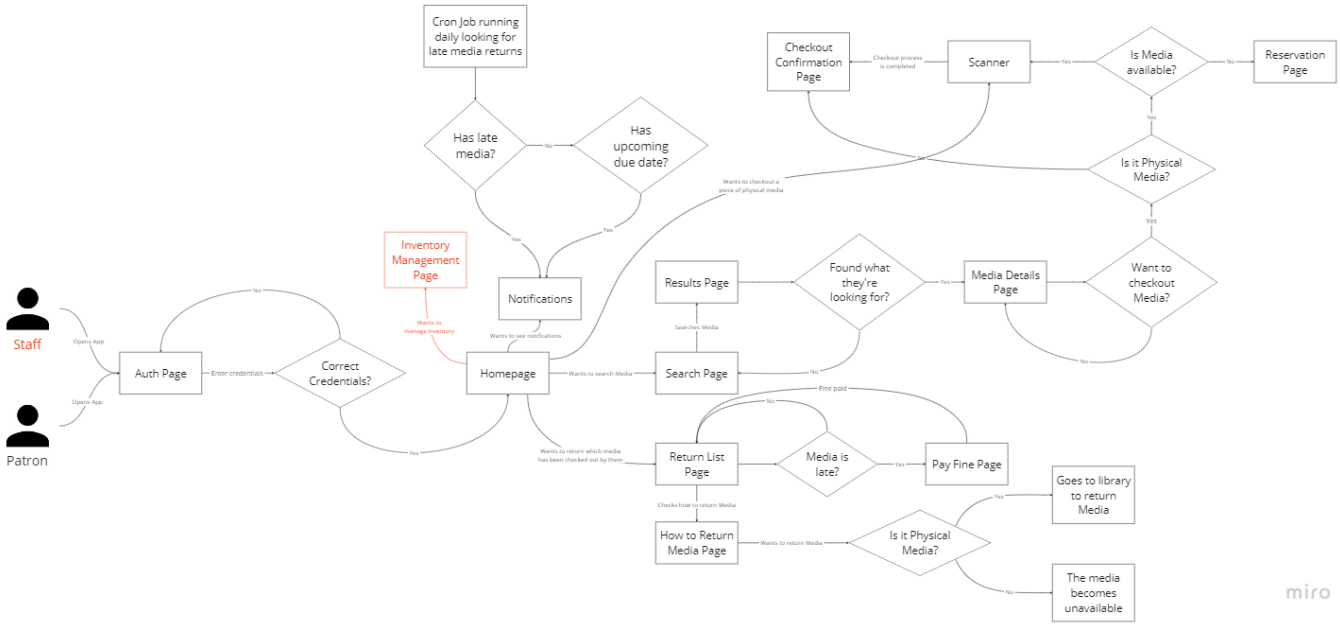

Fig. 10 – Flowchart of the mobile app

For this system, we've considered 4 main modules: Entry terminal, Library stations, Inventory management and Checkout and Return modules. These are connected through the mobile app and the data system of the library. Finally, their coupling can be observed in the following scenarios:

- A patron that wants to know if he/she has any upcoming due dates;
- A patron that wants to reserve some physical media;
- A patron needs to pay the fine for a late return;
- A patron wants to know where he/she can find a specific book.

Collaboration with other libraries

To have a more integrated and complete library system we decided that having it as a nationwide service would only benefit all users. To seamlessly integrate the described library system with other libraries or systems, several strategies can be employed. Firstly, it's crucial to standardise the card system used for patron identification, ensuring alignment with widely accepted standards. This fosters interoperability with other institutions that may employ similar card systems. Secondly, developing an API facilitates seamless interaction with external systems, enabling functions such as patron authentication, media checkout, return processing, and notification handling. Thirdly, standardizing data exchange formats for sharing

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information about patrons, media, transactions, and notifications is essential. Formats like JSON or XML ensure compatibility across systems, streamlining communication and data-sharing processes. These integrated approaches not only enhance collaboration between libraries but also optimize the overall user experience, ensuring efficient access to resources and services across diverse environments.

With this implemented we could start having users borrow a piece of physical media such as a book from a library and return it to another one, promoting greater convenience and flexibility for patrons. Additionally, we could explore the possibility of implementing a centralized catalogue system that aggregates resources from multiple libraries, enabling patrons to search and access materials from various institutions through a single interface. Furthermore, integrating real-time availability information across libraries would empower patrons to make informed borrowing decisions, reducing wait times and enhancing overall satisfaction. Moreover, implementing a unified fine management system would ensure consistency in penalty enforcement, regardless of the borrowing library. Lastly, leveraging data analytics and user feedback mechanisms could enable continuous improvement and optimization of library services, tailored to the evolving needs and preferences of patrons across the nation.

Final note

When drawing the flowcharts for the different modules, we used the following notation:

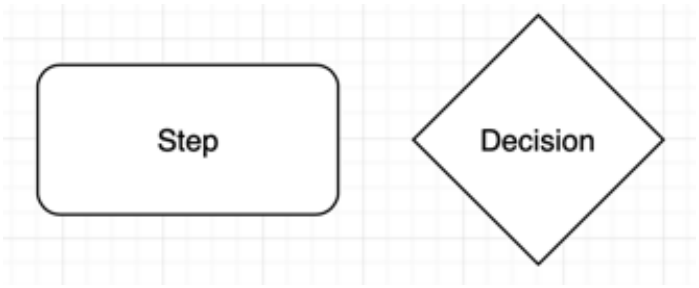

Fig. 11 – Flowchart notation