ULIB: Library Management System with Data Analytics

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ABSTRACT

University libraries play a critical role in supporting students' academic growth by offering access to a wide range of academic materials. The adoption of Library Management Systems (LMS) also revolutionises the way they operate, from relying on index cards and handwritten logs to using a platform that support various functionalities including cataloguing, storing and managing resources. Despite these advancements, university libraries still face challenges such as declining usage of printed books as students struggle to navigate large collections and remain unaware of the valuable materials. Librarians also lack analytical insights to align book collections with students' needs. Therefore, this project aims to develop an LMS that employs descriptive data analytics to enhance access to library resources and promote student engagement with printed materials. The methodology implemented in this project is Feature-Driven Development (FDD), an iterative and feature-focused approach while technologies used are PHP for the backend and HTML, CSS, and JavaScript for the frontend. Chart.js is used for data visualization while MySQL is for database management. Key features include book recommendations, analytics dashboards, and reservation module. All testing showed positive results, confirming the system is working and user-friendly.

Keywords: Library Management System (LMS), Data Analytics, Descriptive Analytics, Feature Driven Development (FDD), Chart.js

INTRODUCTION

University library is widely recognized as the 'brain' of organization that plays a major role in developing and maintaining growth of knowledge [1]. It serves as a vital function for students by providing a variety of materials such as books, newspapers, magazines, and other academic related materials [2]. The rapid advancement of technology has led to the development of Library Management System (LMS), revolutionizing the way library operates from relying on manual system with index cards and handwritten logs to using a platform that automates various functionalities including cataloguing, storing and managing resources [3]. This transformation enables libraries to operate efficiently while reducing manual works for librarians.

However, despite the widespread use of LMS, university libraries still face the challenges of declining rate in the use of printed book resources[2]. The physical book collections in libraries are continuously increasing in numbers but remain unutilized [2]. Students also have a problem when navigating the huge collection in libraries as they have limited knowledge and awareness of available materials [4]. Moreover, library still struggles to properly manage resources to meet the growing needs of students [5]. These problems create a mismatch between the library's offerings and students' needs, limiting access to essential academic materials that could support their success.

Therefore, to address the challenges, emerging technology like Data Analytic can be implemented in LMS. It is defined as the process of analysing raw data sets to discover meaningful information and insights [6]. Hence,

data analytics plays a key role in enhancing operations, decision-making, and promoting the growth of organizations [7]. However, the majority of current LMS do not offer features related to data analytics and visualization, leaving librarians to perform it manually which is inefficient and takes time to be done [8]. This contributes to the rising issues of inefficient services since data management in library now requires academic librarians to collect and utilize data from various sources to make informed decisions [9]. This creates a gap between what the system could offer and the expectations of users in today's digital age.

The gaps identified highlight the need for a library management system that utilize data analytics. Therefore, the study aims to develop a library management system that integrates descriptive data analytic to track and analyse borrowing trends, enabling informed decisions regarding resource acquisition. The system also enables student to reserve books for over-the-counter pick-up, addressing the problem of navigating huge collections and underutilization of printed materials. Ultimately, the addition of simple recommender system provides a new channel for student to discover new materials when choosing what books to be borrowed from the library.

LITERATURE REVIEW

This section covers the importance of libraries in higher education, elaborates on related issues, and defines the data analytic used as well as its relevancy in library setting.

Libraries play an important role in assisting students to find appropriate information and prepare them for learning and research [10], [11]. They provide students with the means to locate and access the right information for their academic needs including materials for writing assignments, conducting research, or gaining deeper understanding in a particular field of study. In short, library is the heart of researching in educational institutes as they contain the books and scientific resources that are needed by university community [12].

However, despite their importance, there are three main issues that contribute to the underwhelming usage from students. The first one is inefficient accessibility for printed resources. There is a noticeable decline in the use of printed book resources all around the world and this claim is supported by an article from New Straits Time in 2019, reporting that the percentage of physical book borrowing at University of Nottingham Malaysia has decreased over the last three years [2], [13]. It is believed that the decrease is driven by students' increasing preference for digital alternatives. This is because online platform like Google, provide instant access to various learning resources making it appear more relevant to users. Compared to the manual borrowing process in library, with just a few clicks, students can access articles, books, journals, and other educational materials without having to leave their homes. As a result, many libraries face the challenge of underutilized printed collections despite the continuous growth in their book inventories [2]. This situation highlights the inefficiencies in printed resource accessibility and prompts a critical need for libraries to meet the evolving demands of users effectively.

The next issue is limited insights for decision-making. Tracking the popularity or underutilization of resources in a library can be a challenging task, especially in traditional Library Management Systems (LMS). The majority of LMS only feature basic functionalities, such as borrowing and returning books, which significantly limits their ability to track the usage of resources. These basic systems are not equipped with advanced features for tracking real-time data or generating insights on resource usage which creates challenges in identifying what books are in high demand and what are rarely borrowed [8]. Without automated tracking, admin and librarian struggle to gain an accurate understanding of resource popularity, which can result in inefficiencies such as overstocking underused books while overlooking those with higher demand [2].

Another main issue is the difficulties in discovering relevant academic materials. Many traditional Library Management Systems (LMS) fail to provide features that allow students to easily identify popular or in-demand resources. The majority of current LMS do not offer features related to data analytics and visualization which results in students often left unaware of which resources are currently popular or highly recommended by their peers [8]. The lack of visibility into on demand items means that students may miss out on valuable resources that could be highly relevant to their academic work. They can only rely solely on manual searches or word-of-

mouth to discover books which not only limits resource exploration but can also result in inefficiencies where popular books are over-requested, leaving students with fewer choices.

A solution for these problems would be the implementation of data analytics in library setting. It is defined as the process of analysing raw data sets to discover meaningful information and insights [6]. Data analytics involves organizing and processing large volumes of data to identify patterns and trends that is not immediately visible. In other words, raw data will be transformed into manageable and structured form that makes it easy to identify key information and gain a clearer understanding of the data. The conclusions derived from the findings will guide decision-making and facilitate the creation of new knowledge. This means that the outcomes or results gained from analysing the raw data will be utilized to make informed decision and facilitates the creation of new idea or strategies that will help solve current problems. Therefore, as data volume keep surging day by day, many organizations has been adopting the technology to utilize their data effectively [14]. Data analytics has become an indispensable tool that make use of advanced algorithm and methodologies to achieve the goals set by the organization.

The type of analytic used in this study was Descriptive Analytic. It is defined as the first step in data analytics framework and are the basis for other types of analytics such as diagnostic and predictive. It concentrates on historical data and analyses it to put together essential findings that form a picture of what had occurred or behaviour in the past. Descriptive analytics is a statistical method that provides summaries or descriptions of the key characteristics of a data set or database [15]. It assists in presenting data in clear and precise way by applying different statistical tests such as dispersion, central tendency and frequency distribution.

Furthermore, several research indicates that data analytics plays a major role in enhancing the effectiveness of services provided in library. This is because by utilizing data analytics, libraries now can leverage the huge amount of information collected to dive deep into visitors' need and enhance library services [14]. For example, by analysing book circulation data, library staff can see the borrowing pattern and they can make informed decision from the findings. Librarians can know what book is borrowed the most by student and what book is unutilized. This way, they can decide which book need to be removed from the shelves and which book should be acquired to ensure the library collection is curated to student's needs. Analysing library data like visitors, campus and book category can also give insightful information that will enhance visitor's experience and library services [16]. These findings highlight that data analytics is relevant to be implemented in library setting.

METHODOLOGY

The approach taken during the development was Feature driven development (FDD), an agile method that is feature-oriented and iterative in nature [17]. It was carried out by breaking down the system to a smaller and manageable set of features, which then designed and developed separately [18]. Moreover, FDD was adaptive, enabling the accommodation of software requirements changes and refinements process even at the later stage [19]. This means it was flexible enough to adapt when new features were added even when part of the system had already been built. For instance, when new requirements were identified, they were added as new features to the feature list. Then, FDD would treat it as part of the next development cycle instead of the current one. Thus, the extra functionality was seamlessly integrated into the development process without breaking the system workflow.

Develop an Overall Model

The first phase of the Feature Driven Development (FDD) is Develop an Overall Model. Information needed to fulfil the aim of implementing data analytics in library management system (LMS) was collected. For instance, information such as the functional and non-functional requirements were generated by comparing and analysing similar existing LMS. Then, the result was documented in Software Requirement Specification (SRS) and used to guide the creation of system design elements, such as use case diagrams and the hardware and software requirements of the ULib system. Fig. 1 is the use case diagram of the ULib system meanwhile Table I outlines the software tools used during the development, each playing a specific role in building the system's functionality, design, and management.

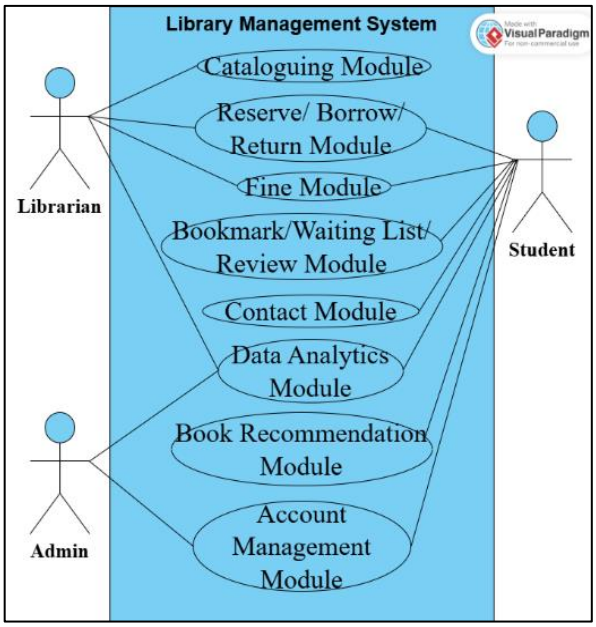


Fig. 1 Use Case Diagram

TABLE I: SOFTWARE TOOLS USED DURING THE DEVELOPMENT

No	Software	Specification
1.	Frontend Development	HTML, CSS, JavaScript
2.	Backend Development	PHP
3.	Local Server Environment	XAMPP (Apache, MySQL, PhpMyAdmin)
4.	Data Visualization	Chart.js
5.	Project Management	Gantt Chart
6.	Design tool	draw.io, Visual Paradigm

The system architecture diagram illustrated in Fig. 2 represents how users interact with the system. It starts with each of the users accessing the system through a user interface that allows them to use the system features such as accessing the cataloguing module or managing book inventories. The requests are then directed to a central server where the logic and back-end operation are processed. For example, if user wants to log in, the server will communicate with database which stores essential data like username and password for authentication. The server also communicates with third party services like SMTP or email service to send notification to users including alerts for book returns and reservation approval. This architecture separates the presentation, application, and data layers which ensures efficient data processing and smooth overall operation.

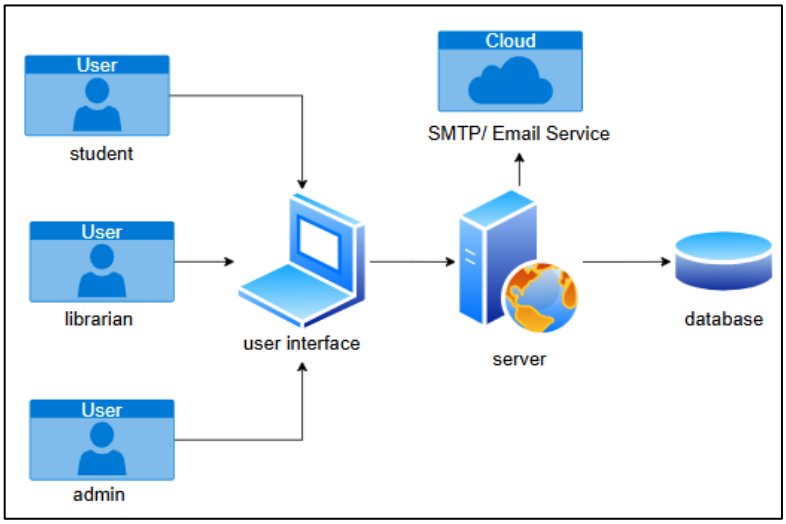


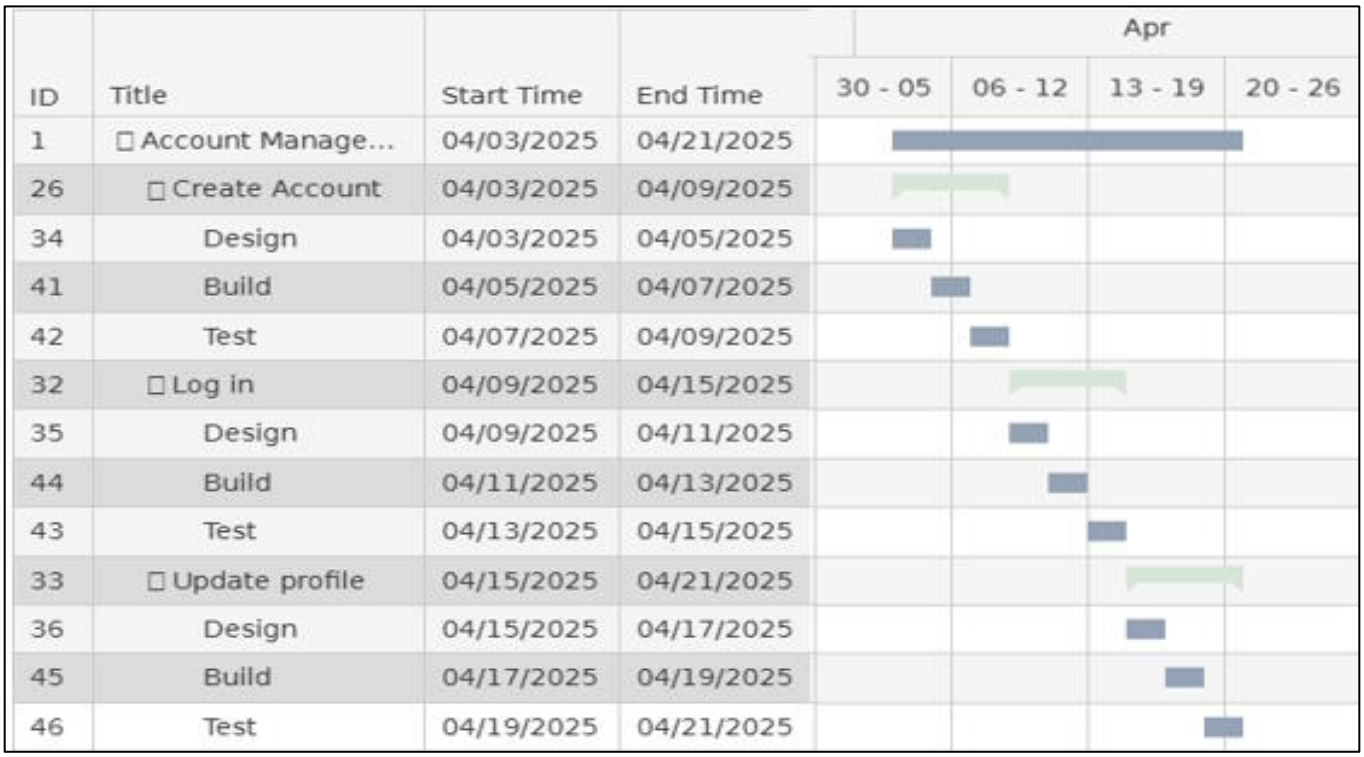
Fig. 2 System Architecture Diagram

Build a Features List

The second phase was Build a Feature list. The primary goal of this phase was to identify and organize the features or functionalities of the system that needed to be developed. This means that specific feature was identified and listed under the modules from use case diagram. Then, the features were arranged based on the priority, with the most critical feature set to be developed first and followed by the subsequent features accordingly.

Plan by Feature

The third phase was Plan by Feature. In this phase, the planning of the project was carried out by creating a schedule that outlines the timeframe for the completion of each feature or module. The maximum duration for the completion of any feature is two weeks therefore if the feature is too complex to be done in that specific timeframe, it should be broken down into smaller and manageable components [20]. This modular approach helped prevent delays in the development process. Since proper scheduling is crucial, this phase was done carefully to ensure the project progress stays on track. Fig. 3 is the schedule created using Gantt Chart.



ID	Title	Start Time	End Time
1	Account Manage...	04/03/2025	04/21/2025
26	Create Account	04/03/2025	04/09/2025
34	Design	04/03/2025	04/05/2025
41	Build	04/05/2025	04/07/2025
42	Test	04/07/2025	04/09/2025
32	Log in	04/09/2025	04/15/2025
35	Design	04/09/2025	04/11/2025
44	Build	04/11/2025	04/13/2025
43	Test	04/13/2025	04/15/2025
33	Update profile	04/15/2025	04/21/2025
36	Design	04/15/2025	04/17/2025
45	Build	04/17/2025	04/19/2025
46	Test	04/19/2025	04/21/2025

Fig. 3 Extract of the Gantt Chart (Account Management Module only for illustration purposes)

Design by Feature

The fourth phase was Design by Feature. This phase emphasized various tasks including refining the overall model and defining the classes [20]. This helped in providing clear understanding on how the system interface would be and how it would operate and communicate with database. Since the Design by Feature and Build by Feature phases of FDD are iterative, when the design for account management feature was completed, the process was followed by the build phase. Only after the build phase for that feature was completed, that the process can move on to the next feature. This continued iteratively until all features were designed and built.

In this phase, the first activity was creating user interface design and the tool used was wireframe. Wireframe served as a visual representation of website layout and structure since basic arrangement of elements like forms, buttons and content areas can be shown. This helped stakeholders understand the flow and arrangement of the system. Since wireframe did not emphasize detailed design elements like images, font and colour scheme, it reduced time spent on the activity. Fig. 4 shows the wireframe created when designing the book catalogue interface.

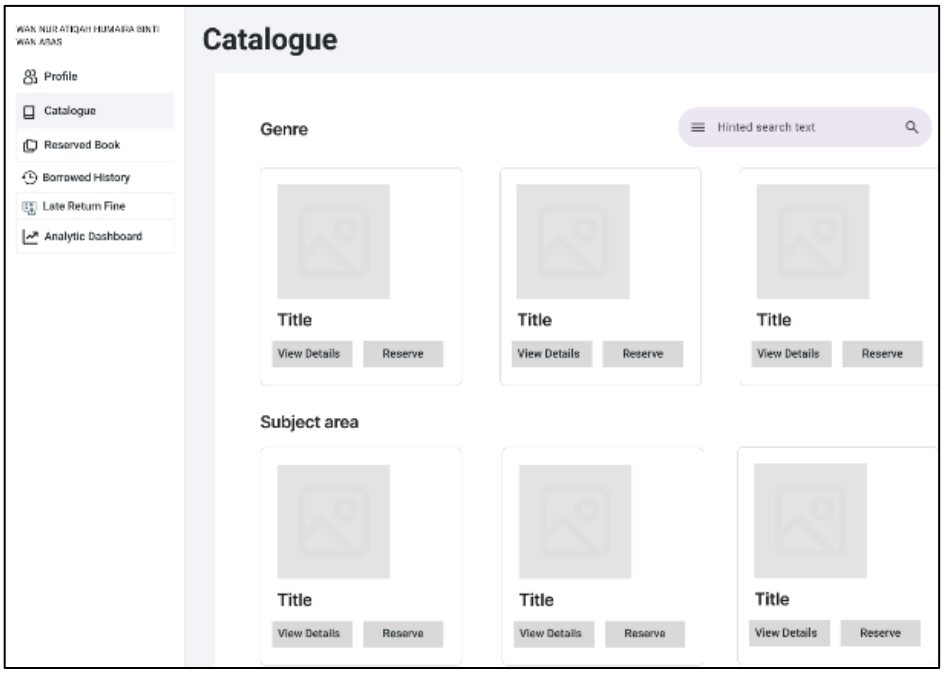


Fig. 4 Wireframe design for book catalogue interface

Build by Feature

The last phase of the feature-driven development methodology is Build by Feature. This phase is where the actual system was developed iteratively. This means that instead of building the entire system at once, the development process is focused on one feature at a time. Fig. 5 illustrates the book catalogue interface of the ULib system that was built following the design made in previous phase.

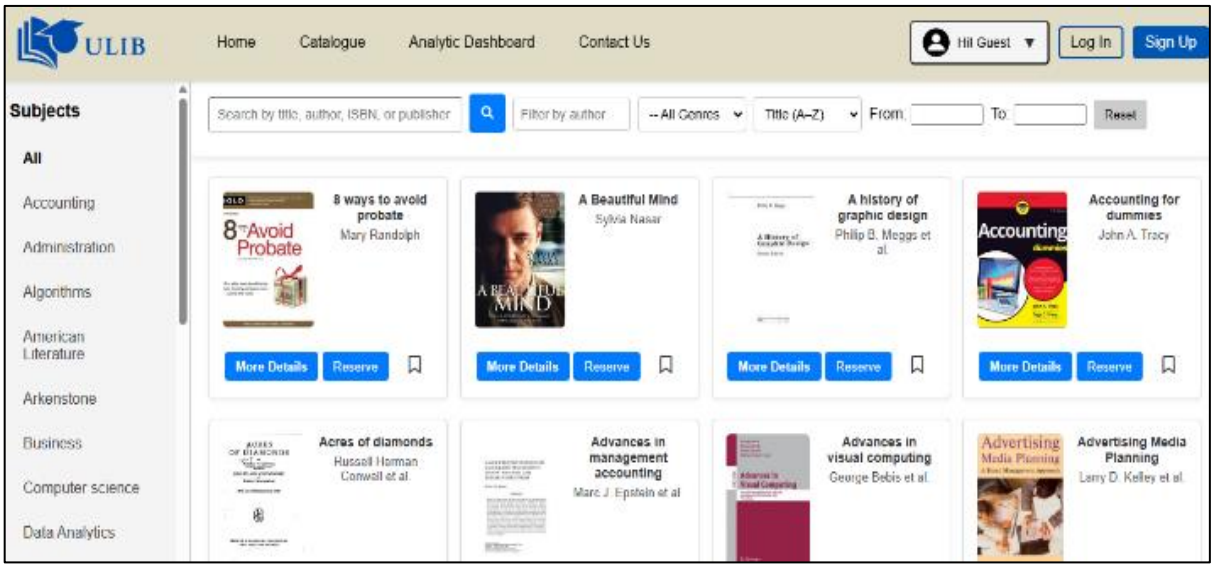


Fig. 5 Book catalogue interface

For data analytic dashboards, Fetch API were used to call functions to collect JSON data and update charts asynchronously. The backend PHP then queries the database and returns the processed data to the frontend where visualization was done via Chart.js library. Furthermore, there are two types of book recommendation engine used in ULib system. The first one is a personalized book recommendation system with user-based collaborative filtering algorithm that suggests books based on similar students' borrowing patterns. The system uses Jaccard Similarity formula as shown in Fig. 6 to compare two users and get their similarity score by checking how many books borrowed by both then divide with the total number of unique books borrowed by them. Once similarities are calculated, the system scores books that the target student has not borrowed but similar users have. Then, the scored books are sorted from highest to lowest and sent back to the front end for display.

$$Sim(u,v)^{Jaccard} = \frac{(I_u \cap I_v)}{(I_u \cup I_v)}$$

Fig. 6 Jaccard Similarity Formula

The next one is a simple AI-based book recommendation system that adopts the collaborative filtering idea. It is trained on historical borrowing records of students where borrowed books are labelled with 1, while books students have not borrowed yet labelled as 0. This mapping aids the model in learning patterns of which books are most likely to be checked out together. Once training data is ready, it was fed directly into the Brain.js model which gives scores to all possible books, ranks and filters them to get meaningful insights and displayed at front end.

After all features have been integrated, system testing was carried out using Functional Testing. The step involved preparing a test plan that list the features or functional modules of ULib system, the expected result, actual result and feedback of the test. Furthermore, to know whether the book recommender features successfully suggest relevant books, a HitRate@k accuracy test was done. This test check whether among the top 5 books recommended, at least one was borrowed by users. If there is none, the result would be a miss but if the suggestion is correct, then it is a hit. The higher the HitRate value is then the probability that the suggestion is relevant is greater [21]. The formula to do the accuracy test is shown in Fig. 7.

- u is a user identifier
- $rel(u)$ is a list of relevant items for user u from the test set
- $rec_k(u)$ the list of top-K items recommended to user u

$$HitRate@k(u) = \mathbb{I}[|rel(u) \cap rec_k(u)| > 0]$$

Fig. 7 Hit Rate (HR) Formula (Source: [21])

Lastly, the ULib system was tested using real users via System Usability Scale. Only 5 participants were needed for the SUS since the sample size is sufficient to discover 85% of the system's usability issues [22]. When the SUS was conducted, Fig. 8 was used as reference. The SUS questionnaire was distributed via Google Form and respondents were required to answer them using a five-point Likert scale.

Code	Question	Answer				
		1	2	3	4	5
Q1	I think that I would like to use this system frequently					
Q2	I found the system unnecessarily complex.					
Q3	I thought the system was easy to use.					
Q4	I think that I would need the support of a technical person to be able to use this system.					
Q5	I found the various functions in this system were well integrated.					
Q6	I thought there was too much inconsistency in this system.					
Q7	I would imagine that most people would learn to use this system very quickly.					
Q8	I found the system very cumbersome to use.					
Q9	I felt very confident using the system.					
Q10	I need to learn a lot of things before I could get going with the system.					

Fig. 8 System Usability Scale questionnaire (SUS) (Source: [23]).

RESULT AND DISCUSSION

This section presents the results of system development along with its discussion. It highlights the main features of ULib system and the outcome of testing phases which work as expected. The homepage of the ULib system is shown in Fig. 9, which was integrated with book recommendation engine powered by Brain.js and showcasing books that are recently added to the library collection. Next is Fig. 10 which is the data analytic dashboard for library administrators which includes various type of chart based on data collected.

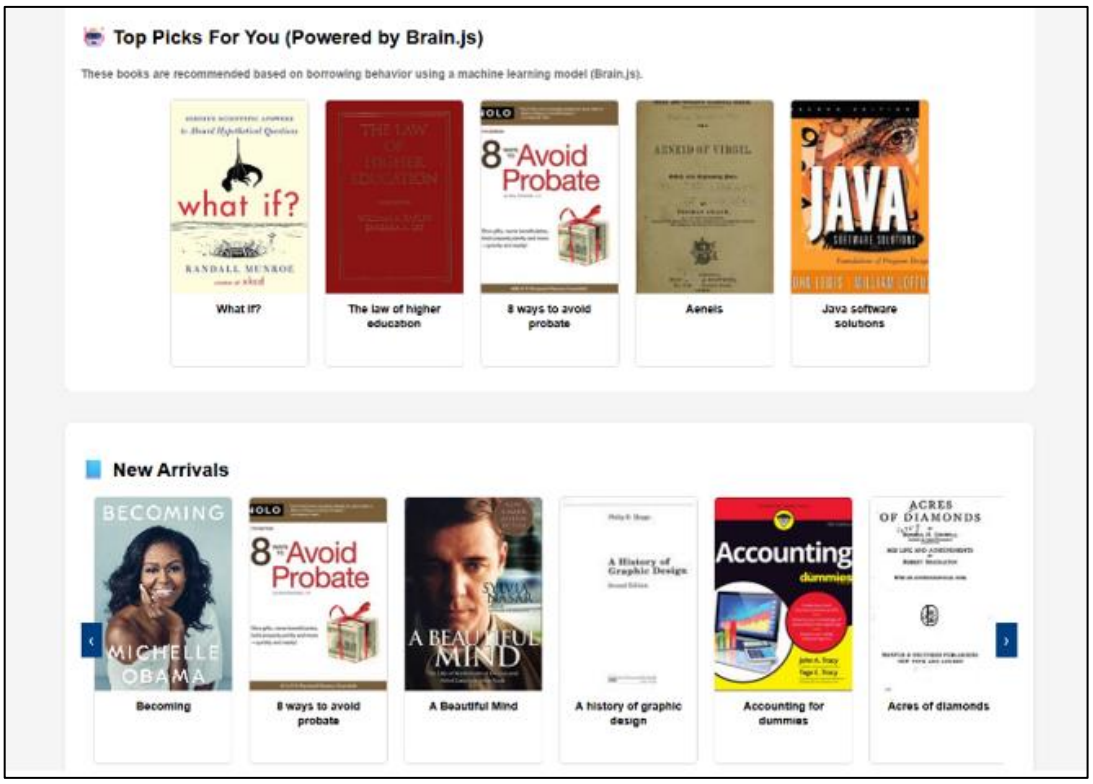


Fig. 9 Book recommendation and new arrivals section at homepage

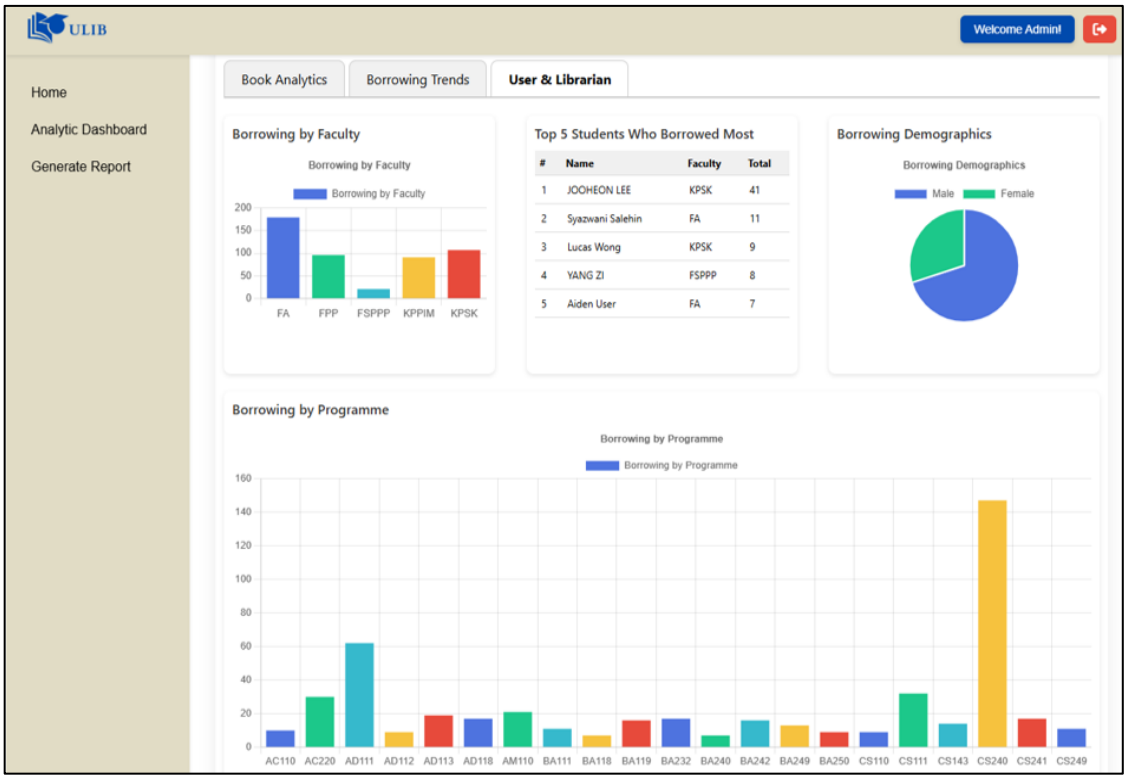


Fig. 10 Analytic dashboard for administrators

For the testing phases, Table II compares the expected result and the observed result for each module and passes or fails the test. The results are pass for all features which means the system has been completed and functional.

TABLE II: FUNCTIONAL TEST PLAN FOR ULIB SYSTEM

Function Modules	Expected Result	Actual Result
Cataloguing module	Pass	Pass
Reserve/Borrow/Return module	Pass	Pass
Fine module	Pass	Pass
Bookmark module	Pass	Pass
Waiting List module	Pass	Pass
Review module	Pass	Pass
Contact module	Pass	Pass
Data Analytics module	Pass	Pass
Book Recommendation module	Pass	Pass
Account Management module	Pass	Pass

Next, since there are two types of book recommendation engine, separate HitRate@5 test were done. For Jaccard Similarity, the result is visualized using HTML and CSS for better understanding of the evaluation outcome. The test book, top 5 ISBNs and an indicator of whether the result is hit or miss is shown. Fig 11 shows the result, which is a hit indicating the system successfully recommend books that students like.

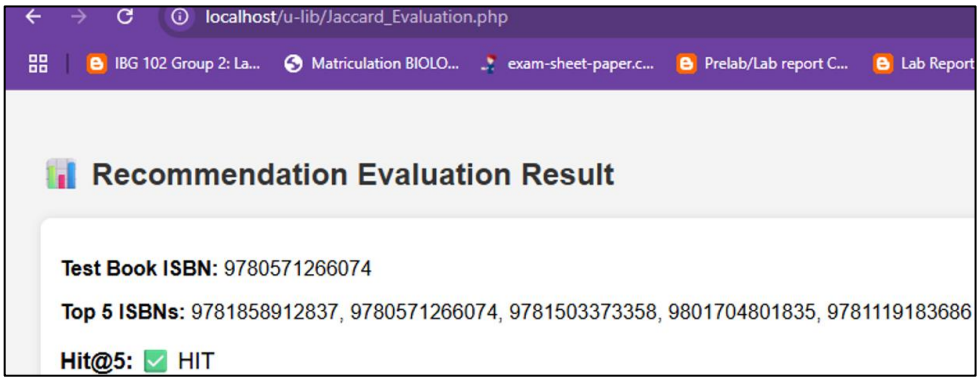


Fig. 11 Book recommendation using Jaccard Similarity test result

For the one using Brain.js model, the top 5 predicted books are compared with the actual borrowed books in the test set. If any of the real books are found in the top 5 predictions, it is counted as a hit. The result represents the percentage of correct predictions across all test cases. Fig. 12 displays the result of 76.67% which indicates that the system correctly predicted the borrowed book in the top 5 suggestions most of the time.

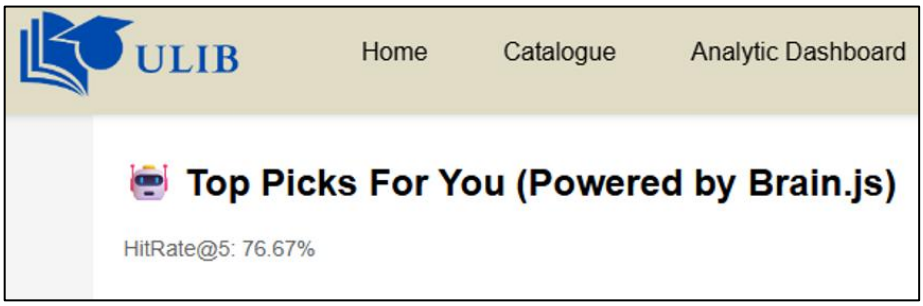


Fig. 12 Book recommendations using Brain.js test result

For SUS questionnaire, most users rated positive question with high score of 4 and 5 indicating agree and strongly agree as shown in Fig. 13. Meanwhile, for negative questions in Fig. 14 they chose strongly disagree and disagree with low score of 1 and 2. Therefore, it can be concluded that most respondents were giving positive feedback and were satisfied with the ULib system.

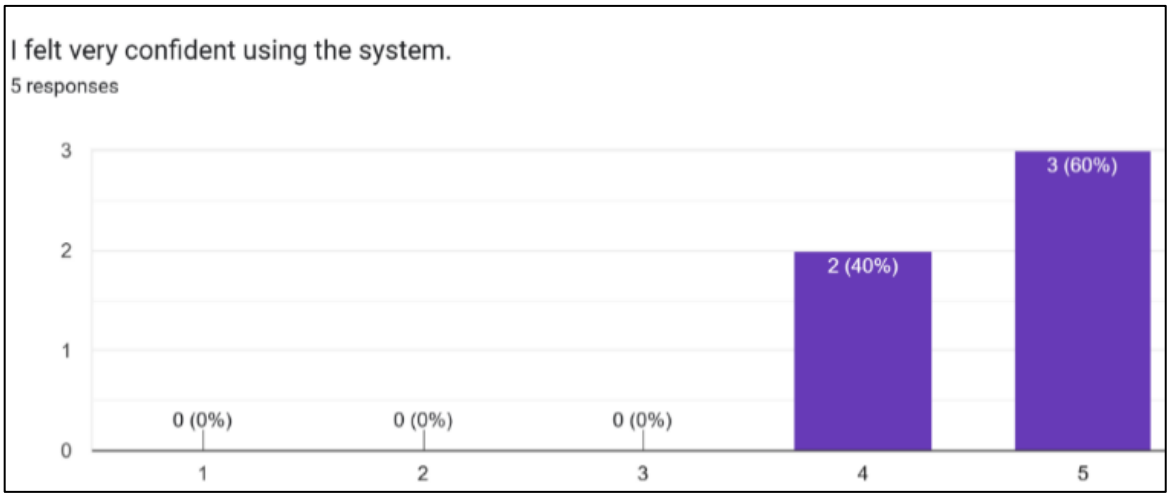


Fig. 13 Screenshot of SUS result for positive question

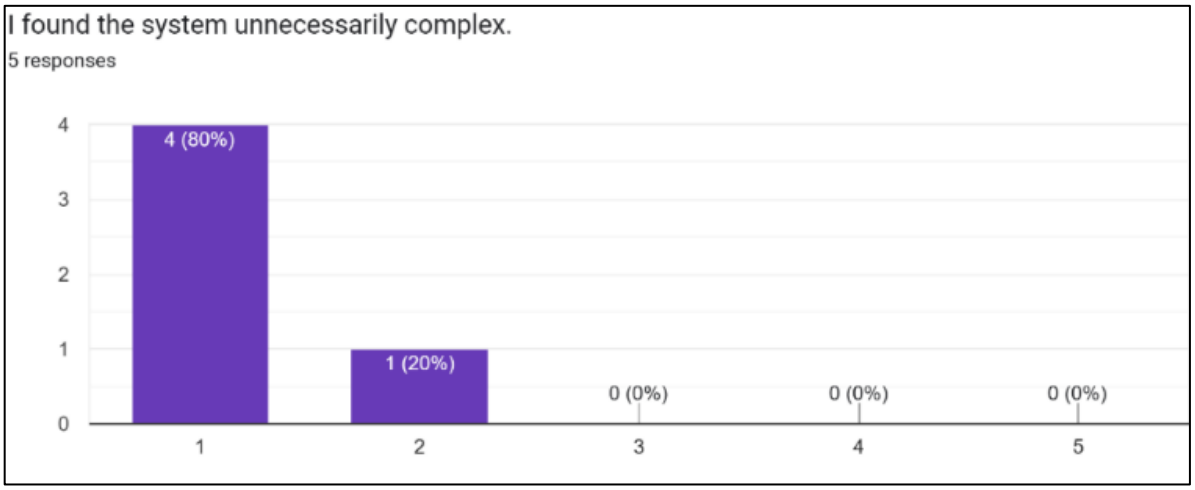


Fig. 14 Screenshot of SUS result for negative question

The comparative analysis between ULib system and existing LMS is shown in Table III. The ULib system included some enhanced features to address the shortcomings of current LMS. It consists of a reliable Online Public Access Catalogue (OPAC) for an effective search on library materials by users. For instance, for searching function, the system includes filter by title, author or even subject. This way, the search feature is more accessible and more user friendly than simple searching solution in systems like NewGenLib and OpenBiblio [24]–[26]. ULib system also supported online reservation for over the counter pick up, improving the book accessibility and user satisfaction. This feature is adapted from Alma where users can place holds or requests on printed books, whether available or currently checked out. It lets users to choose exact pick-up points and sends automated massages about the availability of the booked items.

TABLE III: COMPARATIVE ANALYSIS BETWEEN ULIB SYSTEM AND EXISTING LMS

Feature	Proposed: Ulib	Koha [27]	NewGenLib [25]	Alma [28]	Openbiblio [24]
OPAC (Online Public Access Catalog)	Yes	Yes	Yes	Yes	Yes
Book Reservation for Pickup	Yes	No	Yes	Yes	No
Integration with external visualization tool	No	Yes	Yes	No	No
Built in Data Analytics Dashboard	Yes	No	Yes	Yes	No
Role-Based Access Control	Yes	Yes	Yes	Yes	Yes
Inventory Management	Yes	Yes	Yes	Yes	Yes
Cataloguing	Yes	Yes	Yes	Yes	Yes

Next, the ULib system incorporated data analytics and visualization feature such as a built-in data analytics dashboard, offering real-time insights into library operations and usage patterns without relying on external tools. This feature enables admin and librarians to track trends, analyse usage patterns, and optimize library operations while students can interact with the analytic dashboard to explore existing materials. Also, real-time circulation insights implemented in the ULib system, allowing for dynamic monitoring of library activities such as book check-outs, returns, and overdue items. This provides greater operational oversight, derived from the live tracking capabilities of Alma [28]. The ULib system also has an interface that is modern, appealing to the user and easy to navigate, enabling easy interaction between all users and the ULib system.

Furthermore, since role-based access control, inventory tracking and cataloguing are the standard in current library management systems, they were still be implemented in the ULib system as core components. These features are crucial to properly manage a secure and organized library environment. With all these features together, the ULib system not only overcome the shortcomings of the existing LMS but also offer an easy and effective library experience.

CONCLUSION

In conclusion, the ULib system has been properly developed as a centralized web platform which supports a variety of library activities with personalized recommendation, data analytic capability and user-friendly functionality. By adding functions like using Jaccard Similarity for collaborative filtering, Brain.js for simple AI recommendation and analytics dashboards for every user, this project solved issues of traditional library systems such as the lack of personalization and poor tracking. These capabilities make tasks more streamlined for library administrators and librarians while enhancing access and user interaction through better decision-making tools.

Furthermore, based on the result of functional test, precision test and user evaluation on the System Usability Scale (SUS), the findings revealed high satisfaction and usability. This further confirmed that ULib system reliably fulfils both functional requirements and non-functional requirements, providing a robust data-centric system for better experience in academic library. Nevertheless, there are still room for further improvement particularly in user support, mobile responsiveness as well as digital resources to better accommodate student needs. For example, the improvements include mobile app development so that users can use the system on the go and chatbot integration for fast assistance and instant reply. Gamification features like digital badges or rewards for completing reading achievements will make the system more interactive and enjoyable. These future enhancements will position Ulib as a platform that is relevant and can encourage positive reading habits among users.

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