"NEORA"
LIBRARY AT YOUR FINGER TIPS

IN PARTIAL FULFILLMENT OF THE REQUIRMENT FOR THE DEGREE OF

B.Sc. MATHEMATICS

Mahatma Gandhi University, Kottayam

Submitted By;

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[AB23AMAT009]

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ST. TERESA'S COLLEGE
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ESTD 1925

2023-2026

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SEPTEMBER 2025

ST. TERESA`S COLLEGE (AUTONOMOUS), ERNAKULAM
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CERTIFICATE

This is to certify that the dissertation entitled, **"NEORA-THE LIBRARY AT YOUR FINGER TIPS"**, is a bona fide record of the work carried out by **ARYA V K** under my guidance as partial fulfilment of the requirements for the award of the degree of **Bachelor of Science in Mathematics** at St. Teresa`s College (Autonomous), Ernakulam affiliated to Mahatma Gandhi University, Kottayam.

No part of this work has been submitted for any other degree or diploma.

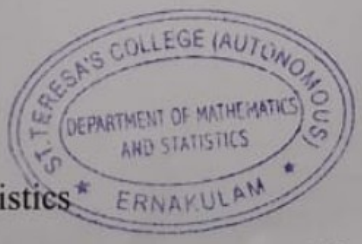
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DECLARATION

I hereby declare that the work presented in this project is based on the original work done by us under the guidance of **Ms. Sreelakshmi K Anil**, Assistant professor, Department of Mathematics and Statistics, St. Teresa's College (Autonomous), Ernakulam, and that it has not been included in any other project submitted previously for the award of any degree.

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ACKNOWLEDGEMENT

I take this opportunity to express our sincere gratitude towards **Ms. Sreelakshmi K Anil,** Department of Mathematics and Statistics, St. Teresa's College (Autonomous), Ernakulam, for encouraging and guiding us to carry out this work.

Her continuous, valuable, and knowledgeable guidance throughout this study helped us complete the work up to this stage.

We will always be thankful for her support and kind assistance.

We also express our thanks to all those who have indirectly guided and helped us in the completion of this project.

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Chapter 1

INTRODUCTION

1.1 Need for a Library Chatbot

Libraries play a crucial role in academic and research institutions, serving as the backbone of knowledge dissemination. However, in the modern digital era, students and researchers often face challenges in locating required resources quickly and efficiently. Traditional methods of searching—such as manually browsing shelves, depending on librarians, or referring to lengthy catalogues—are both time-consuming and inefficient.

A Library Chatbot acts as an automated conversational agent that resolves these issues by providing instant access to book-related data. By simply entering a query, users can immediately obtain details such as the title, author, edition, publisher, or shelf number of the desired book.

The need for such a system is further emphasized by the following factors:

- **Automation of Queries:** Reduces the burden on library staff by answering frequently asked questions and providing data instantly.
- **Instant Access:** Ensures students can retrieve information without delays.
- **Reduced Dependency on Manual Searching**: Saves time by eliminating physical browsing or repeated enquiries.
- **Increased Productivity:** Enhances both the user experience and the overall efficiency of academic activities.

1.2 Objectives

The development of a Library Chatbot is driven by the need to create a smarter, faster, and more accessible solution for handling academic resources. In a student-centred learning environment, time and accuracy are crucial. The objectives of this system have been carefully designed to address these requirements:

- **Instant Access to Library Data**
  One of the primary objectives is to provide users with quick and easy access to library resources. Instead of searching through catalogues or physically browsing shelves, students can interact with the chatbot to obtain relevant information instantly. This eliminates unnecessary delays and improves the overall learning process.
- **Complete Book Information Retrieval**
  The chatbot is capable of displaying detailed information about each book, including:
  - Title
  - Author
  - Edition
  - Publisher
  - Shelf number / Book number

By offering all essential details in one place, students can save time and ensure they are accessing the correct edition or publication needed for their coursework or research.

- **Ensuring Time Efficiency**

Libraries often contain thousands of books, making manual search processes inefficient. The chatbot minimizes the time required to locate resources by replacing traditional searching methods with AI-powered instant responses. This allows students and researchers to focus more on their academic tasks rather than the search process itself.

- **Improved Accessibility for All Students**

Accessibility is another core objective. The chatbot is designed with a user-friendly interface, ensuring that students from various academic and technical backgrounds can operate it without difficulty. The conversational style of the

chatbot makes it feel natural and approachable, similar to interacting with a librarian.

- **Reduction of Human Dependency**

While librarians play an essential role, repeated manual queries can consume their time and reduce efficiency. By automating common queries, the chatbot reduces dependency on library staff for routine information, allowing them to focus on more complex tasks.

- **Enhancement of Learning and Productivity**

Ultimately, the chatbot contributes to academic growth by supporting a more efficient library experience. Students can devote more time to reading, researching, and learning instead of wasting time searching for resources. This improves both individual productivity and the overall academic output of the institution.

1.3 Overview

The proposed system is designed as a comprehensive digital solution that integrates mathematical concepts, computer science principles, and user-centric design. The chatbot not only assists in searching for books but also provides availability checks and recommendations. By combining artificial intelligence with structured mathematical systems, the chatbot ensures reliable and fast responses to user queries.

The following components highlight the core of the system:

- **Spatial Organization**: *Grid Mapping*

  Helps in representing the physical layout of the library in a systematic grid, allowing books to be located based on shelf and row numbers.

- **Graph Theory**: *Classification Tree*

  Implements decision-tree like structures for efficient searching and categorization of books.

- **Classification System**: *Hierarchical Tree Structure*

  Supports systematic storage and retrieval of data, similar to how libraries categorize resources.

- **Backend**: *Python*

  The backend logic, chatbot intelligence, and data processing are implemented using Python, known for its versatility and AI/ML support.

- **Frontend**: *HTML, CSS, JavaScript*

  Ensures that the system is user-friendly and visually interactive.

- **Data Storage**: *Excel and JSON*

  Library book data is stored in Excel and converted into JSON format for fast retrieval and integration with the chatbot system.

Chapter 2

DATA ORGANIZATION AND ENCODING

Data collection is the foundation of any software development project because the performance of the system is directly linked to the quality of the data it uses. For a library chatbot, the entire system's accuracy, reliability, and usefulness depend on the richness, correctness, and organization of the data stored in its database. A chatbot cannot think or generate new answers on its own. Instead, it relies on the information that has been previously collected and stored. When a user asks a question, the chatbot searches through its organized dataset and selects the most relevant and accurate piece of information to display. This process ensures that users receive quick, clear, and meaningful responses. Proper data collection involves several steps:

- **Identifying the required information**: Deciding what type of data is essential for the chatbot, such as book details, author names, availability, due dates, or library rules.
- **Gathering data from reliable sources**: Collecting accurate data from authentic and verified sources, like library records, academic databases, or official catalogues.
- **Cleaning and filtering the data**: Removing errors, duplicates, or irrelevant details to avoid confusion during retrieval.
- **Organizing the data in a structured format**: Storing it in a database where information is easy to access, search, and update.

If the data is incomplete, outdated, or unorganized, the chatbot will fail to perform effectively. Users may receive wrong answers, outdated details, or conflicting responses, which reduces the credibility of the system. On the other hand, well-collected and structured data ensures reliability, consistency, and trustworthiness. Therefore, in this project, data collection and organization were considered the most important initial steps. Without a strong and structured dataset, even the most advanced chatbot technology or programming would not be able to produce

useful results. This makes data collection not just a background process, but the backbone of the entire system.

2.1 Source of Data

The primary source of data for this project was the Maths Library, which serves as a central hub of academic resources for students and faculty members. The maths library houses an extensive collection of mathematics textbooks, reference materials, research journals, and other scholarly publications that cover topics such as algebra, calculus, statistics, geometry, and applied mathematics. These resources provide reliable and authentic information, making the maths library an ideal source for gathering structured data for the development of the chatbot. For the purpose of building the chatbot, it was necessary to extract key bibliographic information from the available books in the maths library. This data was gathered systematically with the assistance of the librarian, ensuring accuracy and consistency across the dataset. The essential details that were collected included the following:

- **Book Title:** The official name of the book, which serves as the primary identifier.
- **Author Name:** The individual(s) or editor(s) responsible for writing or compiling the book.
- **Edition:** The version or updated print of the book, which is important since academic books are frequently revised.
- **Publisher:** The company or organization that published the book.
- **Shelf Number:** The unique code or classification number assigned to the book in the maths library, which indicates its physical location.

By organizing and digitizing these details, the project aimed to create a structured dataset that could be integrated into the chatbot system. This would allow students to interact with the chatbot to search for books more efficiently, saving time and reducing dependency on manual catalogue searches.

2.2 Storage of Data

Once the data was collected, the next crucial step was to store it in a format that was both user-friendly and machine-readable. The storage method needed to be simple enough for manual handling, while also structured enough for the chatbot system to retrieve information efficiently. For this purpose, Microsoft Excel was chosen. Excel provides a powerful tabular structure that supports easy data entry, editing, and updating. Each piece of information can be organized systematically into rows and columns, making the dataset clear, searchable, and manageable.

- **Rows and Columns Representation:** In the Excel sheet, each row represented a single book, while each column represented one attribute of that book, such as Title, Author, Edition, Publisher, or Shelf Number.

- **Ease of Updating and Maintenance:** If a new book was added to the library, it could be entered as a new row without disturbing the existing structure. Similarly, if details such as a new edition, a change in publisher, or an updated shelf number were required, they could be modified quickly. This flexibility ensured that the dataset remained up-to-date and accurate at all times**.**

- **User-Friendly Features:** Excel also provides built-in features like sorting, filtering, and searching, which made it easy to locate a specific book or group of books.

- **Scalability:** Another advantage of Excel is that it can store large volumes of data in a compact manner. As the number of books in the library grows, the same format can be expanded without major adjustments.

This scalability is essential for long-term sustainability of the chatbot project.

TITLE	AUTHOR	SHELF/BOOK NO:	EDITION	PUBLICATION
A First Course in Abstract Algebra	John B. Fraleigh	MAT 512/FRA (a)	7th Edition	Pearson
Modern Algebra	B.S. Vatsa, Suchi Vatsa	MAT 512/VAT	2nd Edition	New Age International Pvt. Ltd
Higher Algebra	Barnald Child	512/BER MAT	Enlarged Edition	A.I.T.B Publisher's India

3.2 Conversion for Chatbot Use

Although Microsoft Excel is highly effective for human use because of its tabular and visual structure, it is not the most efficient format for software operations. Computers and chatbots process data more effectively in structured formats that are machine-readable and lightweight. Therefore, before integrating the dataset with the chatbot, the Excel sheet was converted into JSON (JavaScript Object Notation).

JSON is a widely used data-interchange format that is:

- **Lightweight**: The file size is smaller compared to spreadsheets, making it quick to load.
- **Human-readable:** The structure is simple and resembles everyday text formatting.
- **Machine-friendly:** JSON is natively supported by most programming languages.
- **Flexible:** Data can be stored as key–value pairs, arrays, or nested objects.

Conversion Example:

{

"Title": " A First Course in Abstract Algebra "

"Author": " John B. Fraleigh "

"Edition": "7th"

"Publisher": "Pearson"

"Shelf No": " MAT 512/FRA (a)"

}

2.4 Importance of Organized Data

Organized data is the foundation of any efficient system, especially in applications like chatbots, where accuracy and reliability are crucial.

- **The chatbot provides accurate results*:*** When data is structured and well-organized, the chatbot can quickly retrieve the most relevant information.
- **Information is updated easily in case of new arrivals:** Organized data allows updates to be made without disturbing the structure.
- **Duplicate or missing entries can be minimized:** Properly managed datasets eliminate redundancy and missing data issues.
- **Students receive the same reliable information every time:** Organized data promotes consistency and builds confidence in the system.
- **Broader Impact of Organized Data*:*** Organized data not only improves chatbot accuracy but also saves time, enhances user experience, enables analytics, and ensures scalability.

In short, organized data acts like a strong foundation of a building—without it, no matter how advanced the chatbot technology is, it will collapse under pressure.

Chapter 3

MATHEMATICAL CONCEPTS

3.1 Set Theory in Chatbot

Set theory is one of the most fundamental areas of mathematics, dealing with the study of collections of objects. It provides a structured and precise way to represent and manipulate groups of elements, making it particularly suitable for applications where classification and filtering are required. In the context of library management, set theory plays an essential role in designing intelligent chatbot systems. These chatbots serve as virtual assistants that help users locate, retrieve, and filter information from vast digital collections. In such a system, every book can be considered as an element belonging to a larger set, and subsets are created according to attributes such as subject, author, or publication. When users pose queries to the chatbot, these are interpreted as set operations like union, intersection, or complement. By relying on these operations, the chatbot ensures that the responses are mathematically sound, logically consistent, and efficient. Thus, set theory forms the logical backbone of library chatbots, making them reliable tools for digital information retrieval.

- **Universal Set and Subsets in the Library**

In any library database, the collection of all available books can be thought of as the universal set.

Symbolically, this may be expressed as: $U = \{b1, b2, b3, \ldots, bn\}$

- **User Queries as Set Operations**

One of the most powerful applications of set theory in a library chatbot is its ability to transform user queries into mathematical operations. Consider a user who types, “Show me Mathematics books written by Stewart and published by XYZ Publications.” The chatbot interprets this query by mapping keywords into sets: for Mathematics books, for books authored by Stewart, and for books published by XYZ Publications. The chatbot then applies the intersection

operation, computing. The result of this operation is the set of books that belong to all three categories simultaneously. In practice, this might return Calculus by Stewart, published by XYZ, if it exists in the database. Similarly, if the user asks for "Mathematics or Physics books," the chatbot applies a union operation to combine the subsets. A request such as "Mathematics books but not by Stewart" is processed using the difference operation. These examples illustrate how the chatbot makes direct use of set operations to provide accurate responses to even complex queries.

- **Relation of Set Theory with the Chatbot**

The close relationship between set theory and the chatbot lies in the way information is structured and retrieved. Every book is treated as an element of the universal set, while categories such as subject, author, or publication are defined as subsets. When a query is received, the chatbot does not search the entire database blindly; instead, it applies set operations to narrow down the possibilities and focus only on relevant subsets. For example, a request for "Find Mathematics books by Stewart" is reduced to the operation. The chatbot then returns only the books that fall under both conditions. In this way, set theory serves as the logical engine of the chatbot, providing a mathematically precise method for query resolution. This avoids confusion, eliminates redundancy, and ensures that the chatbot produces consistent results every time.

- **Implementation of Set Theory in the Library Chatbot**

The implementation of set theory in a library chatbot can be described in four major steps. First, the universal set of books is represented in the database. Each book is entered with attributes such as title, subject, author, year of publication, and publisher. These attributes form the basis for generating subsets such as Mathematics books, books authored by Stewart, or books published by XYZ Publications. Second, the chatbot makes use of natural language processing (NLP) to interpret user input. Phrases such as "Math books" are mapped to subset, "by Stewart" is mapped to subset, and "published by XYZ Publications" is mapped to subset. Third, the chatbot applies the appropriate set operations. For example, if the user asks for "Math or Physics books," the chatbot computes. If the query is "Math books but not by Stewart," it computes. Finally, once the correct set operation is applied, the chatbot extracts the relevant book entries from

the database and presents them to the user. This step-by-step implementation ensures both logical rigor and user satisfaction.

- **Why Set Theory is Useful in Chatbots**

The usefulness of set theory in library chatbots lies in its ability to simplify, scale, and enhance the accuracy of query handling. Every user request, no matter how complex, can be expressed as a combination of basic set operations. This makes the system easy to design and maintain. Set theory also offers scalability, since the library collection is not static. New books, authors, or publishers can be added seamlessly by simply expanding the subsets without altering the overall structure. Accuracy is another major benefit, as queries are defined in strict mathematical terms, leaving little room for ambiguity. For example, the difference operation will always yield "Mathematics books excluding those by Stewart." Furthermore, efficiency is greatly improved because instead of scanning the entire database, the chatbot only focuses on subsets relevant to the query. This not only saves computational resources but also provides users with faster responses.

- **Advantages of Using Set Theory in Library Chatbots**

The integration of set theory in library chatbots offers several distinct advantages. It enables efficient classification of books, as titles can be logically grouped by subject, author, or publication. For instance, all Mathematics books published by XYZ Publications can be grouped into one easily retrievable subset. Set theory also ensures accurate query resolution, even for complex queries involving multiple conditions. For example, a query such as "Find all Mathematics books written by Stewart and published by XYZ Publications" translates directly to the operation, leaving no ambiguity. Another advantage is scalability; as new authors or publishers are introduced, they can be included as new subsets without disturbing the existing system. Finally, set theory guarantees mathematical precision. The outcome of each set operation is predictable and repeatable, which means the chatbot's responses are not only fast but also logically sound.

- **Future Scope of Set Theory in Library Chatbots**

The role of set theory in library chatbots is likely to grow further as technology advances. Future systems can integrate set theory with machine learning techniques to automatically refine subsets based on user preferences and reading patterns. For example, if a user frequently requests books from a specific publisher, the chatbot could prioritize this subset in future searches. Visualization tools such as Venn diagrams could also be integrated into chatbot responses, helping users better understand the filtering process. Another exciting direction is the combination of set theory with graph theory, allowing chatbots not only to classify books into subsets but also to analyse relationships between them, such as similar subjects or shared publishers. This hybrid approach could transform library chatbots into intelligent systems capable of offering recommendations rather than just search results. Thus, set theory, while already foundational, has significant potential to evolve and contribute further to the development of smarter library systems.

3.2 Graph Theory in Library Chatbot

Graph theory is a branch of mathematics that studies relationships between objects using nodes (vertices) and connections (edges). In the context of a library, nodes can represent books, authors, subjects, or even users, while edges show relationships such as written by, similar subject, recommended with, or stored nearby. Graph theory is useful because a library is not just a collection of isolated books—it is a network of knowledge. The chatbot can use graph models to navigate this network, helping users find books faster, discover related material, and receive intelligent recommendations.

- **Mathematical Modelling of Graph Theory in Library Chatbot**

We can mathematically represent the library as a graph G = (V, E), where V (Vertices) represents entities such as books, authors, subjects, or shelves, and E (Edges) represents relationships between them. For example, in a Book–Author Graph, an edge exists between a book and its author. In a Book–Subject Graph, books are connected to subjects. In a Shelf Navigation Graph, books and shelves form nodes, and edges show adjacency, allowing shortest path algorithms to guide a student physically or virtually.

- **Applications of Graph Theory in Library Chatbot**

Graph theory finds multiple applications in a library chatbot. In book search and retrieval, a user query like "Find books by J.K. Rowling" becomes a graph traversal problem. Recommendation systems use shared edges between books to suggest related titles. Pathfinding algorithms such as Dijkstra's can be applied to library layouts, guiding students to book locations. Centrality measures can detect popular books, and clustering algorithms can group related subjects together, enabling advanced recommendation features.

- **Advantages in Library Chatbot**

The use of graph theory offers multiple advantages. Retrieval is faster since traversal is efficient. Recommendations are smarter as relationships are automatically detected. Navigation becomes optimized as shortest paths guide users to physical bookshelves. Graphs also highlight hidden knowledge relationships, making it possible to explore connections across subjects. Moreover, graphs are scalable, as they can grow with new books, and flexible, since they represent diverse relationships between entities in the library system.

- **Mathematical Benefits and Applications**

Several mathematical algorithms in graph theory enhance the chatbot. Graph traversal algorithms such as BFS and DFS enable systematic searching of books and authors. Shortest path algorithms like Dijkstra's and A* are useful for navigation. Centrality measures identify the most borrowed or influential books in the network. Graph colouring helps in classification of books under different subjects. Bipartite graphs, which connect users and books, help predict borrowing patterns and recommend new books to readers based on history.

- **Example Graph Representation**

For example, consider the Dewey Decimal classification of Mathematics. The subject "Mathematics" is represented by the code 515. This node branches into subcategories such as 515.3 (Algebra), 515.8 (Geometry), and 515.9 (Calculus). Each of these subcategories forms a child node connected to Mathematics. If a user queries, "Show me Algebra books," the chatbot identifies node 515.3 and traverses its subtree to retrieve all Algebra-related books, along with books under

further subdivisions. Similarly, if the user asks for Calculus books (515.9), the chatbot can also recommend related areas like Algebra (515.3) or Geometry (515.8) because they are connected under the mathematics category (515). This hierarchical graph structure makes the chatbot efficient in retrieving books, suggesting related subjects, and guiding users step by step from a broad topic like science → Mathematics → Algebra.

For another example, consider four books and two authors: B1 "Graph Theory Basics" and B2 "Discrete Mathematics" by Author A1, and B3 "Algorithms" and B4 "Data Structures" by Author A2. Edges connect authors to books and also relate books under similar subjects. The chatbot can answer queries such as "Books by Author A1" or "Related to Graph Theory Basics." This graph-based model helps in quick responses and better book discovery.

- **Future Enhancements**

Graph theory in library chatbots can be enhanced further by using weighted graphs, where weights represent popularity or borrow counts. Dynamic graph updates can track borrowing in real-time. Graph Neural Networks (GNNs) can provide advanced AI-driven recommendations. 3D graph visualization may allow interactive exploration of relationships, while augmented reality can guide students through physical shelves. Hybrid graphs combining both digital and physical library elements can deliver a seamless experience.

3.3 Formal Logic in Library Chatbot

It provides a precise mathematical framework to represent knowledge, reason about it, and generate correct answers. In the context of a Library Chatbot, formal logic ensures that user queries about books, authors, availability, and shelf numbers are interpreted consistently and answered correctly.

- **Knowledge Representation The first step is to represent library information logically.**

  Predicates: - Book(x) → x is a book - Author (x, y) → book x is written by author y - Shelf (x, s) → book x is on shelf s → book x is published in year y Rules (Axioms):

- ∀x (Book(x) → ∃! y book no(x)=y) → Every book has a unique book number.
- ∀x (Available(x) → ¬Borrowed(x)) → If a book is available, it cannot be borrowed.
- ∀x ∀y (Author (x, y) → Book(x)) → If x has an author, then x must be a book.
- ∀x (Borrowed(x) → ¬Available(x)) → Borrowed books are not available.

- **User Query Understanding When a student types a query, the chatbot converts it into logical form.**

- *Example 1*:

  User Query: "*Find books by JK Rowling published after 2010"*

  - *Logical Expression*: Book(x) ∧ Author (x, "JK Rowling") ∧ Year (x, y) ∧ y > 2010

- *Example 2*:

  User Query: "*Where is book no. 515 ALG?"*

  Logical Expression: Book(x) ∧ book no(x)="515 ALG" ∧ Shelf (x, s) ∧ Row (x, r)

- **Reasoning and Inference The chatbot applies logical rules to derive answers**.

- *Case A*: Availability Check Rule: ∀x (Available(x) → ¬Borrowed(x)) If Borrowed ("515 ITL") is true → infer ¬Available ("515 ITL").
- *Case B:* Shelf Location Shelf ("515 ALG", 2) ∧ Row ("515 ALG", 3) Response: "Book 515 ALG is located in Shelf 2, Row 3."

- **Worked-Out Mathematical Examples**

  - ***Example 1***: Counting Books by Predicate Logic Suppose Shelf 1, Row 2 has books: {"515 ITL", "515 BAR", "515 CHO"}

    Predicates: Book ("515 ITL"), Book ("515 BAR"), Book ("515 CHO")

    Query: *How many books are on Shelf 1, Row 2?*

    Logical Expression: | {x | Book(x) ∧ Shelf(x,1) ∧ Row(x,2)} | = 3
  - ***Example 2****:* Union of Sets with Logic Shelf 1, Row 2: {"515 ITL", "515 BAR"} Shelf 1, Row 3: {"515 ALG", "515 ITL"}

    Query: Find distinct books in Shelf 1, Rows 2 and 3

    Logical Expression: L (1,2) ∪ L (1,3) = {"515 ITL", "515 BAR", "515 ALG"}

    Result: 3 books.
  - ***Example 3***: Negation Queries

    Query: "Find books on AI but not on Machine Learning"

    Logical Expression: Book(x) ∧ Topic(x,"AI") ∧ ¬Topic (x,"Machine Learning")

- **Response Generation Once logical inference gives results, the chatbot converts them into natural English**.

*Example****:*** "Here are 3 books by JK Rowling published after 2010."

Example: "Book 515 ITL is on Shelf 1, Row 2, and is available."

- **Error Handling If no result matches the query, logic detects unsatisfiable conditions.**

  Query: "Books by Ramanujan in 1800"

  Logical Check: No Book(x) ∧ Author(x,"Ramanujan") ∧ Year(x)=1800

  Response*: "Sorry, no books found for that condition."*

- **Advanced Features**

Recommendations: Genre(x)=Genre(y) → Recommend(y)

Negations: Handling "NOT"

conditions. - Data Integrity: Verifying no duplicate book numbers exist.

- **Step-by-Step Flow 1.**

***User asks*:** *"Where is book no. 515 ITL?"*

- Chatbot parses: book no(x)=515ITL
- Logic Engine applies: Shelf(x,1) ∧ Row(x,2) ∧ Available(x)
- Inference confirms: Available ("515 ITL") =True
- Response*: "Book 515 ITL is on Shelf 1, Row 2, and is available."*

- **Conclusion Formal logic transforms a chatbot into a reasoning engine.25**

By using predicates, axioms, inference rules, and mathematical reasoning, the chatbot can:

- Accurately interpret complex queries
- Handle negations and conditions
- Ensure correctness and data integrity

Future enhancements may include integrating fuzzy logic, temporal logic, and probabilistic reasoning for even more intelligent responses

3.4 Spatial Organization in Library Chatbot

Introduction to Spatial Organization Spatial organization is a mathematical concept that deals with the arrangement of objects in a structured space. It explains how elements are positioned, grouped, and accessed in terms of their location. In mathematics, this is seen in:

Geometry → points, lines, and shapes in 2D or 3D space. –

Set Theory → arranging elements in subsets based on spatial positions.

Matrices & Grids → elements arranged in rows and columns for indexing.

In the context of a Library Chatbot, spatial organization plays a crucial role. A library is physically arranged in shelves, rows, and columns. Similarly, the chatbot stores and retrieves book data using a grid mapping model, where each book is assigned a spatial coordinate (shelf number, row number).

- **Mathematical Modelling of Spatial Organization to model spatial data**

  Mathematically, we consider the library shelves as a grid system: -
  Let S = {S1, S2, …, Sn} represent the set of shelves.
  Let R = {R1, R2, …, Rm} represent the set of rows in each shelf.
  The function L (s, r) gives the set of books in Shelf s and Row r.
  Example: L (1,2) = {“515 ITL”, “515 BAR”, “515 CHO”} L (1,3) = {“512 ALG”, “515 ITL”}
  Here, |L (1,2) | = 3 (3 books in shelf 1, row 2).
  L (1,2) ∪ L (1,3) = {“515 ITL”, “515 BAR”, “515 CHO”, “512 ALG”}. The union removes duplicates, so |L (1,2) ∪ L (1,3) | = 4. This shows how set theory combines with spatial organization to manage books efficiently.

- Data Representation The physical position of each book can be stored digitally using JSON format: {“Book": "Linear Algebra", "Author": "Gilbert Strang", "Shelf": 2, "Row": 3, "Column": 5}

- This representation helps the chatbot not only return book details but also guide the user to its exact location.

- **Advantages in Chatbot**
  - Fast Retrieval: The chatbot uses the spatial index to quickly locate a book instead of scanning all records.
  - Accurate Results: Avoids confusion when books have similar titles but are in different locations.
  - Organized Structure: Books are grouped by subject or category in specific shelves and rows.

- Scalability: As more books are added, the grid expands naturally without disturbing the existing structure.

➢ **Mathematical Benefits and Applications**:

- Grid Mapping & Matrices - The library can be represented as a matrix where rows = shelves and columns = positions.
  - *Example:* A 5×10 matrix for 5 shelves and 10 rows each.
- Set Theory Applications - Unions, intersections, and subsets help check availability across multiple shelves.
  - *Example:* L (2,4) ∩ L (3,4) → books common in two different rows.
- Graph Theory Combination - The chatbot can model shelves and pathways as a graph, where nodes = shelves and edges = pathways.
  - Helps in suggesting the shortest route to reach a physical book location.
- Optimization - Spatial indexing reduces time complexity of search from O(n) to O (1) when positions are mapped.
  - *Example:* Instead of searching 1000 books, chatbot directly jumps to Shelf 2, Row 3, Column 5.
- Conclusion & Future Scope Spatial organization provides a strong mathematical backbone for structuring, storing, and retrieving library data.

- By modelling shelves and rows as grids and using set theory, matrix representation, and graph connections, the chatbot becomes: -

- Faster in book searching. - More reliable with accurate spatial information.
- User-friendly, as it provides both book details and its exact shelf location.
- 3D Spatial Mapping: Virtual representation of the library for users.
- AR Integration: Mobile app guiding students to shelves using augmented reality.
- Advanced Clustering: AI models to group related books spatially for better recommendations.

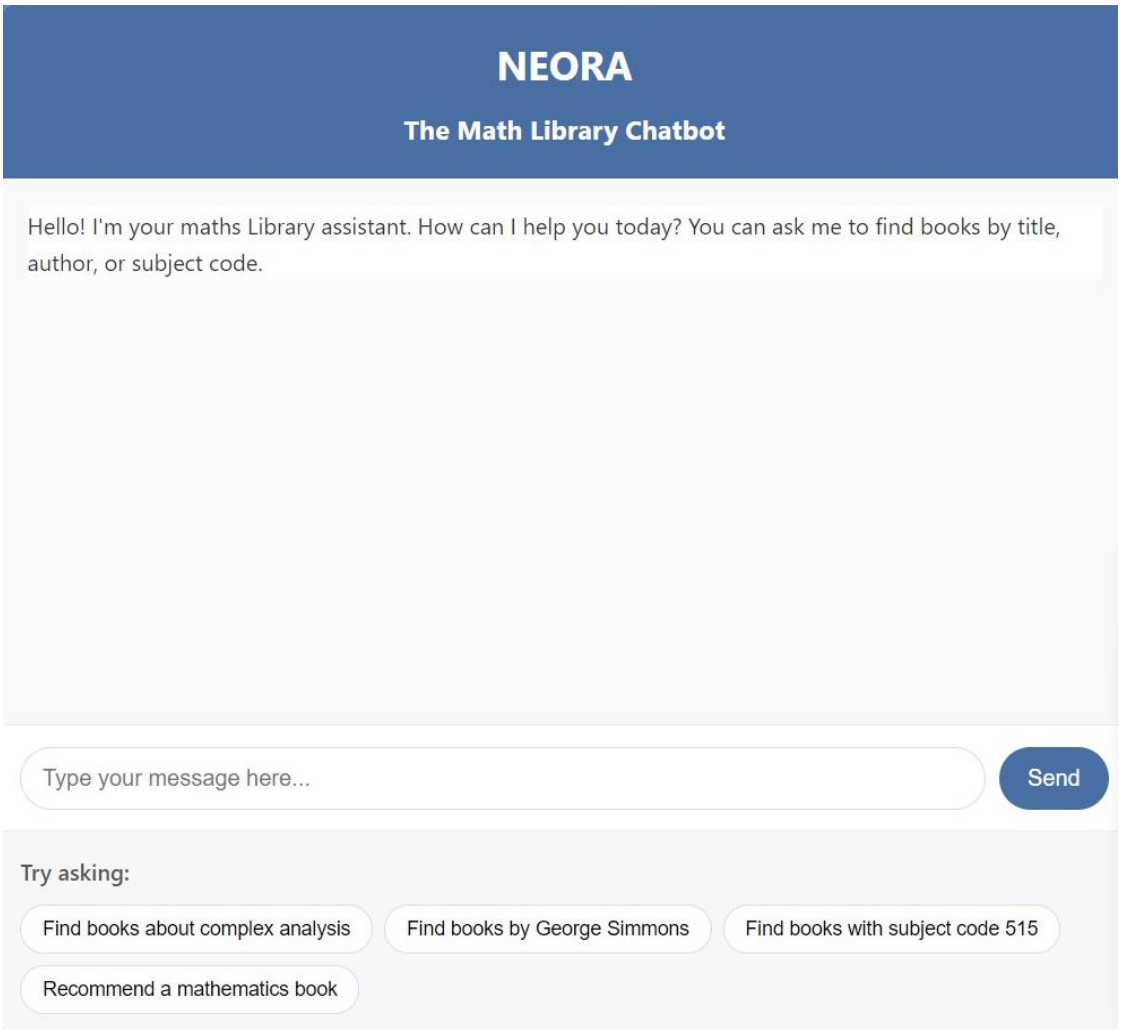
Chapter 4

CHATBOT DEVELOPMENT

4.1 Tools and Technology

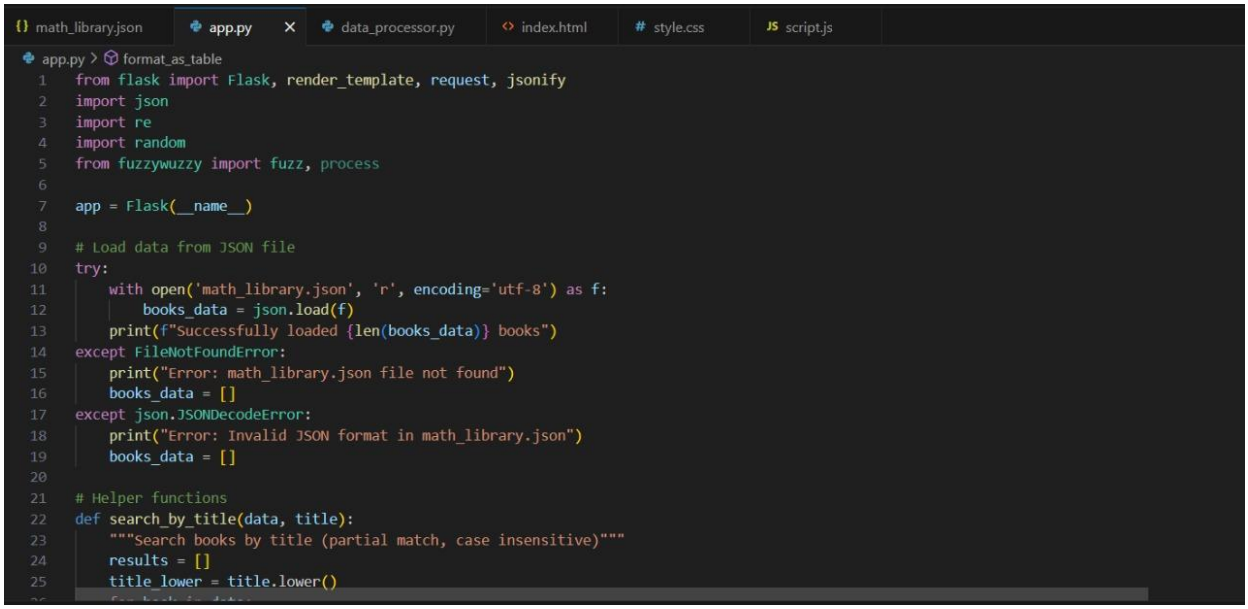
The Library Chatbot was built with a combination of web and programming technologies to provide a smooth, interactive experience:

- **Frontend:** HTML, CSS, and JavaScript create the visible interface where students type their queries.
  - HTML defines page structure.
  - CSS provides layout and design.
  - JavaScript enables real-time interaction such as showing search suggestions while the user is typing.



- **Backend:** Python is used as the server-side language.

Python's simplicity and rich library support (Flask for routing, JSON handling libraries for data search) make it ideal for fast development.



- **Data Layer:**

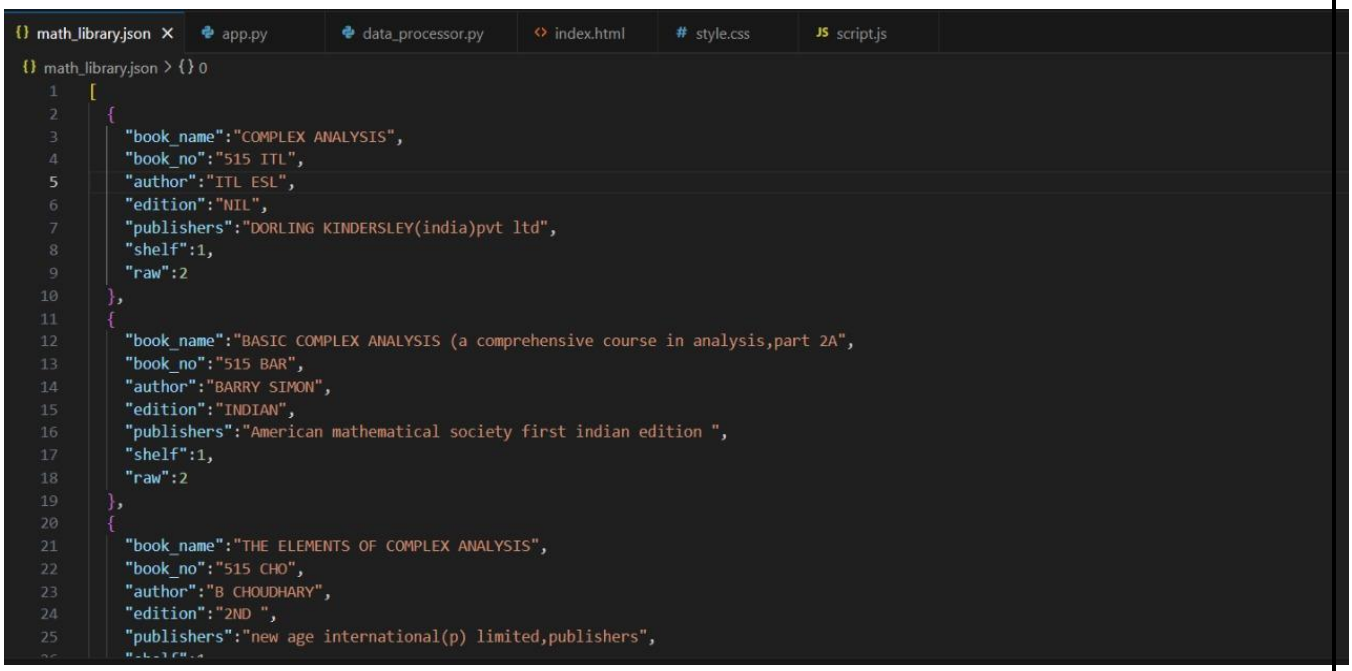
The original library catalogue was maintained in Microsoft Excel

.

- For the chatbot, this dataset was converted to JSON (JavaScript Object Notation).
- JSON provides a lightweight, hierarchical format that is easy for Python to read and for JavaScript to display.
- Development Tools – Visual Studio Code for coding, Git/GitHub for version control, and a local web server for testing.

Example: A book record in JSON format


```
{
 "BookID": "MATH-112",
 "Title": "Abstract Algebra",
 "Author": "Dr. Bijumon",
 "Publisher": "ABC Publications",
 "Edition": "3rd",
 "Location": "Section B – Row 3"
}
```

These technologies together allow the chatbot to run on any modern browser without special installation.

4.2 Working Mechanism

The overall process can be described in four main stages:

- **User Input**

A student or librarian enters a question such *as "Find Abstract Algebra by Dr. Bijoumon"* or "*Books of Real analysis*" through the web interface.

- **Data Access**

- The chatbot sends the query to the Python backend.
- Python reads the structured JSON database of books.

- **Processing & Matching**

- The backend applies string-matching and filtering rules:
- Exact title/author matching for precise requests.
- Partial or keyword matching for general queries.
- Logic operators (AND/OR) when multiple conditions are supplied.

- **Response & Display**

- Matching records are converted into a user-friendly table and returned to the browser.
- The frontend displays details such as Title, Author, Shelf Location, Book Number, Publisher, and Edition.

Example Workflow:

User types: *"Books by R. K. Narayan"*

→ Python filters all records where Author == "R. K. Narayan"

→ Browser displays a table of matching books with their shelf locations.

This mechanism ensures instant retrieval without manual catalogue searches.

4.3 Key Features

- **Instant Search**:

Results appear in less than a second for hundreds or even thousands of records.

- **Complete Details**:

Each result includes title, author, publisher, edition, book ID, and shelf location.

- **Exact Author/Title Matching**:

Enhanced filtering ensures that a query such as *"Dr. Bijoumon Abstract Algebra"* returns only that specific book.

- **24×7 Availability**:
  The chatbot is web-based and can be accessed from computers or mobile devices at any time.

- **Scalability and Future Scope**:
  The system can later integrate natural language processing (NLP) for conversational queries or expand to include book-borrowing status and user login.

- **User-Friendly Interface**:
  Clean design with simple input box and result table so even first-time users can search easily.

Summary:

The Library Chatbot successfully combines modern web technologies (HTML/CSS/JS), a Python backend, and structured JSON data to automate routine library queries.

Its working mechanism—query input, data search, processing, and instant output—provides students and staff with fast, accurate book information while reducing manual effort for librarians.

With planned upgrades such as NLP or voice interaction, the system can evolve into a fully conversational digital library assistant.

Chapter 5

RESULTS AND CONCLUSION

5.1 Chatbot Output

After development and integration of the backend with the book-database, the Library Chatbot was deployed on a local web server for testing.

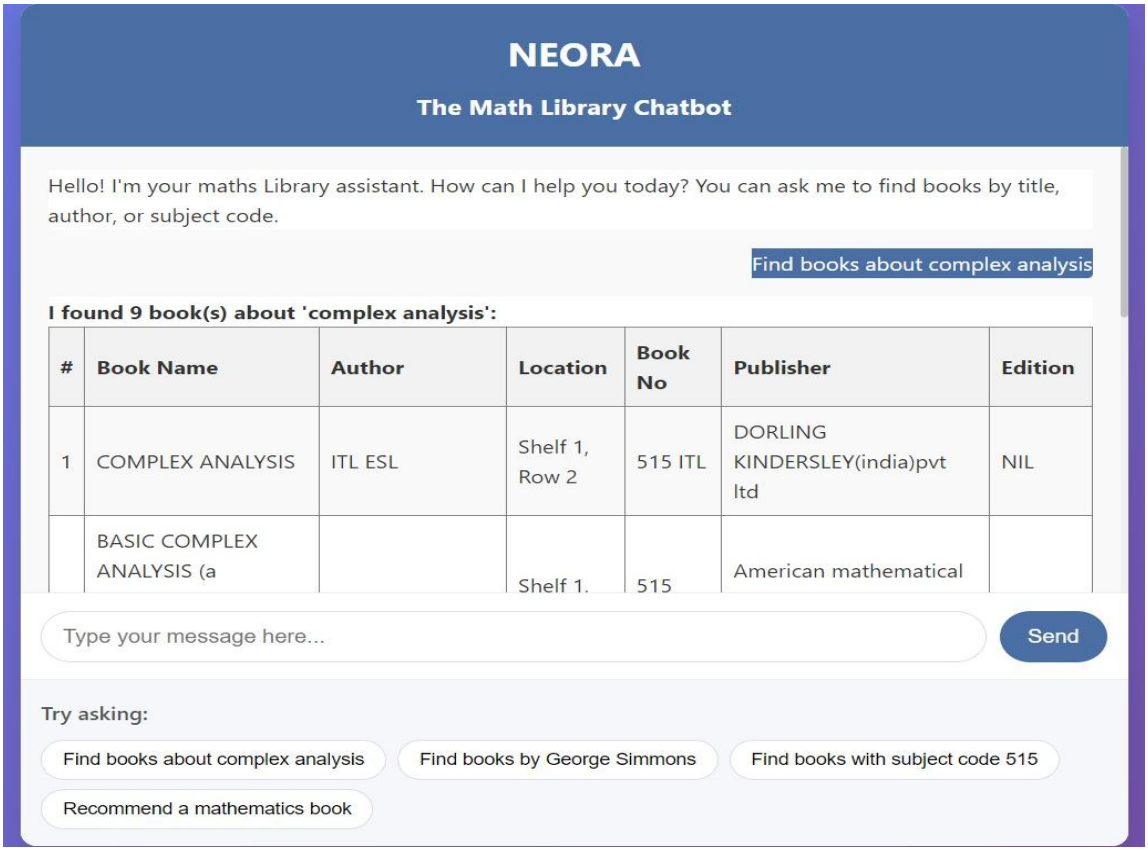
When a user enters a query—for example:

"Abstract Algebra by Dr. Bijoumon"

OR "*Books by R. K. Narayan*"

the chatbot instantly searches the JSON-formatted catalogue and displays the result table with the following details:

- Book ID / Accession Number
- Title and Author
- Publisher and Edition
- Shelf and Row



The output is delivered in less than a second, proving the system's efficiency and accuracy.

5.2 Advantages

The Library Chatbot offers several benefits to students, faculty, and librarians:

- **24×7 Availability**
  Users can search the library catalogue at any time from any device with a browser.
- **Time Saving**
  Eliminates the need to manually browse shelves or wait for a librarian to locate books.
- **User-Friendly Interface**
  Simple text box and clean results table; minimal training required.
- **Accurate and Instant Results**
  Rapid filtering of hundreds or thousands of records using keyword or exact matching.
- **Scalable Architecture**
  Database can be expanded with new titles without changing the interface.
- **Cost Effective**
  Uses open-source tools (Python, Flask, JavaScript) and free hosting options for deployment.
- **Foundation for Advanced Features**
  Can later integrate Natural Language Processing (NLP) for conversational queries or recommendation algorithms for personalized suggestions.

CONCLUSION

The Library Chatbot successfully demonstrates how an AI-powered, web-based system can automate routine library queries.

It reduces the workload of librarians, speeds up the search process for users, and lays a strong foundation for future enhancements such as speech-to-text input, recommendation engines, and integration with an online book-borrowing system.

The project proves that even with freely available technologies, an educational institution can implement an efficient digital assistant for its library, enhancing both accessibility and user satisfaction.

REFERENCES

[1] Sanji, M., Behzadi, H., & Gomroki, G. (2022). Chatbot: an intelligent tool for libraries. Library Hi Tech News, 39(3), 17-20.

[2] Khamis, I. (2023). Building a Chatbot for Libraries. In Handbook of Research on Advancements of Contactless Technology and Service Innovation in Li

[3] https://flask.palletsprojects.com

[4] https://www.json.org/

[5] https://code.visualstudio.com/docsbrary and Information Science (pp. 287-315). IGI Global.

Reshma

