Scala project

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Introduction

This project was developed as part of the *Functional Programming with Scala* course and consists in building a fully functional **Library Management System**, combining the power of Scala 3's functional programming features with a clean and interactive web interface.

The goal of this system is to simulate the real-life operations of a library: managing a catalog of books, allowing users to search for and borrow books, tracking loans and returns, and offering personalized recommendations based on user history. Users are identified by a unique ID and can interact with the system through an intuitive interface that provides access to book search, availability status, and suggested titles.

From a technical perspective, the backend logic is written in **Scala 3**, following a pure functional programming approach. It makes use of:

- **Algebraic Data Types** (e.g., sealed traits for users),
- **Opaque and union types** for domain modeling (ISBNs, User IDs),
- **Functional error handling** with Either, Try, and Option,
- And **ScalaTest/ScalaCheck** for unit and property-based testing.

Library data is persisted in a structured JSON file (Library.json), and the system ensures data integrity through validation mechanisms. The web front-end, built separately, connects to the core logic to provide a seamless user experience, showing key stats such as total books, current users, and ongoing transactions.

This report details the architecture, key implementation decisions and development process behind the system.

Link of the demo video of our application

demo video link

Remark : examples of system usage are shown on the demo video as well on the link above

Link to github repository of the project :

Project github repository

System Architecture

The Library Management System is composed of two main layers: a functional backend written in Scala 3, and a web-based frontend implemented in HTML/CSS/JavaScript. The architecture follows a modular, type-safe, and layered design, enabling maintainability, extensibility, and testability.

Overview of Project Structure

```
project-root/
├── public/                    # Web interface (HTML + JS)
│   ├── index.html             # UI layout and search bar
│   └── app.js                 # Frontend logic (fetch, DOM updates)
├── src/
│   ├── main/scala/
│   │   ├── api/               # DTOs for REST API (ApiModels.scala)
│   │   ├── models/            # Domain models (Book, User, Transaction)
│   │   ├── services/          # Business logic (LibraryCatalog, Codec)
│   │   ├── utils/             # JSON I/O + Scala 3 extensions
│   │   ├── LibraryApp.scala       # Optional CLI-based app (legacy)
│   │   ├── LibraryServer.scala    # Akka HTTP server for REST API
│   │   └── Test.scala             # Experimental / dev script
│   └── test/scala/
│       ├── api/               # API model tests
│       ├── models/            # Domain model tests
│       ├── services/          # Logic, codec, and integration tests
│       ├── utils/             # File I/O, error handling, coverage tests
```

```
│   └── FinalCoverageBoostTest.scala      # High-coverage test file
├── Data/                                 # Persistent JSON data (Library.json)
├── build.sbt                             # Build configuration (SBT)
└── README.md                             # Project documentation
```

Main Source Code Structure (`src/main/scala`)

The main Scala source code is organized into modular packages, each serving a specific responsibility:

Path	Purpose
api/ApiModels.scala	API layer DTOs: defines case classes like LoanRequest, ApiResponse.
models/Book.scala	Defines the Book case class and ISBN type alias.
models/User.scala	User models with sealed trait User and its subtypes (Student, etc.).
models/Transaction.scala	Transaction trait and subtypes: Loan, Return, Reservation.
services/LibraryCatalog.scala	Functional core of the app: search, loan, return, recommend, stats, etc.
services/LibraryCatalogCodec.scala	Circe JSON codecs for all domain models.

utils/JsonIO.scala	File I/O helpers for saving and loading the full catalog as JSON.
utils/UnionAndExtensionExamples.scala	Demonstrates advanced Scala 3 features like union types and extensions.
LibraryApp.scala	Legacy command-line interface (CLI), now superseded by the REST server.
LibraryServer.scala	Akka HTTP-based REST API server.
Test.scala	Exploratory or debug utility file (not used in production flow).

This modular structure follows the separation of concerns principle, ensuring clarity and scalability in code organization.

Backend – Functional Core in Scala 3

The backend uses modern functional programming paradigms and Scala 3 features such as:

- Algebraic Data Types (sealed trait, case class) for modeling,
- Immutable state (catalog updates produce new instances),
- Safe error handling using Either and Option,
- Functional I/O using Circe for JSON encoding/decoding.

Domain Layer (models/)

- Book, User, and Transaction are modeled as immutable case classes and sealed traits.
- Uses **type aliases** like `ISBN`, `UserID` for improved clarity.
- `Transaction` types (`Loan`, `Return`, `Reservation`) carry timestamps and user associations.

Service Layer (services/)

- `LibraryCatalog` is the **pure functional core**, supporting:

    - Searching books by title/author
    - Borrowing/returning/reserving
    - Recommending books based on user history
    - Statistics (top genres/authors)
- All methods are **pure**, deterministic, and testable.
- `synchronizeBookAvailability` ensures internal state matches transaction history.

Persistence Layer

- Implemented with LibraryCatalogCodec.scala using Circe's Encoder/Decoder typeclasses.
- Supports custom JSON handling for User, Transaction, and LocalDateTime.
- File I/O is encapsulated and tested to ensure data integrity with Library.json.

Data Flow and Interaction

- **Input/Output**: All library data is persisted in a single Library.json file, which stores:
    - the complete book catalog (books),
    - user data (users),
    - transaction history (transactions, including Loan and Return types).
- **Interaction Loop**:
    - On application start, the system loads Library.json into immutable Scala data structures.
    - Users interact with the frontend (search, borrow, get recommendations).
    - The Scala backend processes requests, updates in-memory structures, and writes changes back to Library.json.

Web Interface Overview (/public)

The public folder of the project contains the **entire web interface** of the Library Management System. It includes two key files:

- index.html – the static HTML layout and styling of the user interface,
- app.js – the dynamic behavior and frontend logic written in JavaScript.

Together, they create a responsive, single-page application (SPA) that allows users to interact with the library system in real time.

Structure and Components

index.html

This file defines the **static skeleton** of the interface, composed of the following sections:

- **Header**: Displays the title and tagline of the application.

- **Statistics Area** (#stats): Populated dynamically to show real-time counts of books, users, and transactions.

- **Sidebar**:
    - **User Identification**: Input for user ID.
    - **Search Interface**: Input field to search books by title.
    - **Action Buttons**:
        - Show available books,
        - Show personal recommendations,
        - Show all books.
- **Main Content**:
    - Book list display area,
    - Section title and dynamic updates via JavaScript,
    - Support for alerts and loading spinners.

It includes embedded CSS styles for:

- Aesthetic design (gradients, shadows, responsive layout),
- Highlighting book availability (green/red tags),
- Clean mobile adaptability (using media queries).

app.js

This script handles **all user interactions** and **data communication** with the backend API (/api/...), including:

- **Fetching data**:
    - /api/books, /api/users, /api/transactions for stats.
    - /api/books/available to show borrowable books.
    - /api/books/search for keyword searches.
    - /api/users/:id/recommendations for book suggestions.
- **User actions**:
    - Borrowing a book: /api/books/loan
    - Returning a book: /api/books/return
- **Real-time DOM updates**:

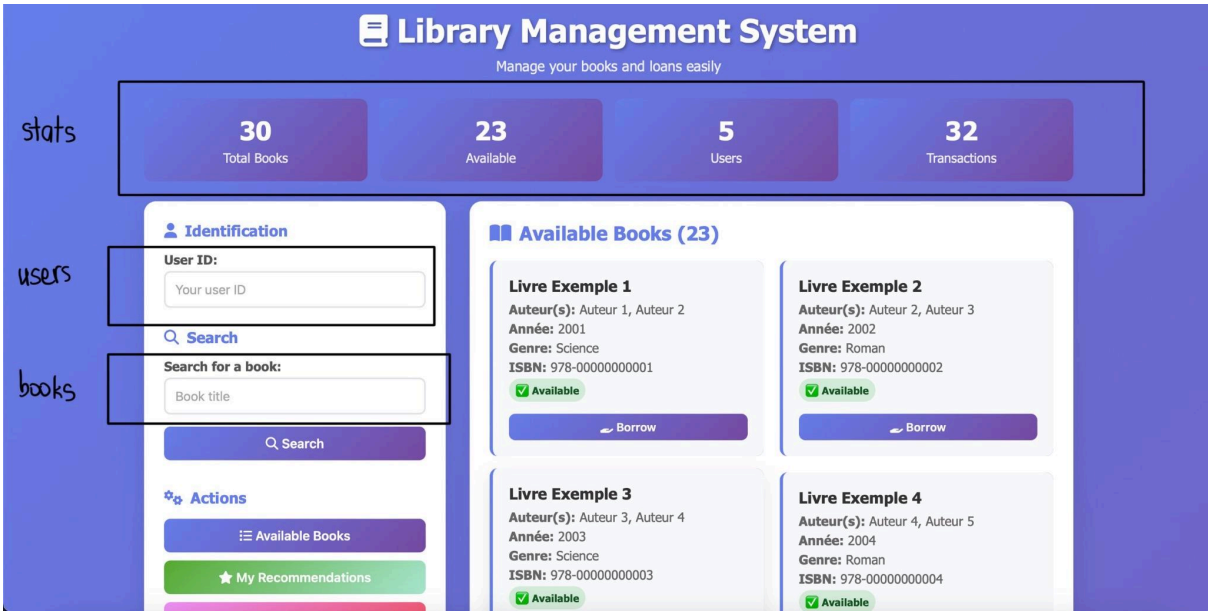
    - Displaying books as cards (createBookCard()),
    - Updating section titles and counts,
    - Showing visual alerts and loaders.
- **User feedback**:
    - Success and error alerts using showAlert(),
    - Inline loading animations during asynchronous calls.

How the Frontend Works

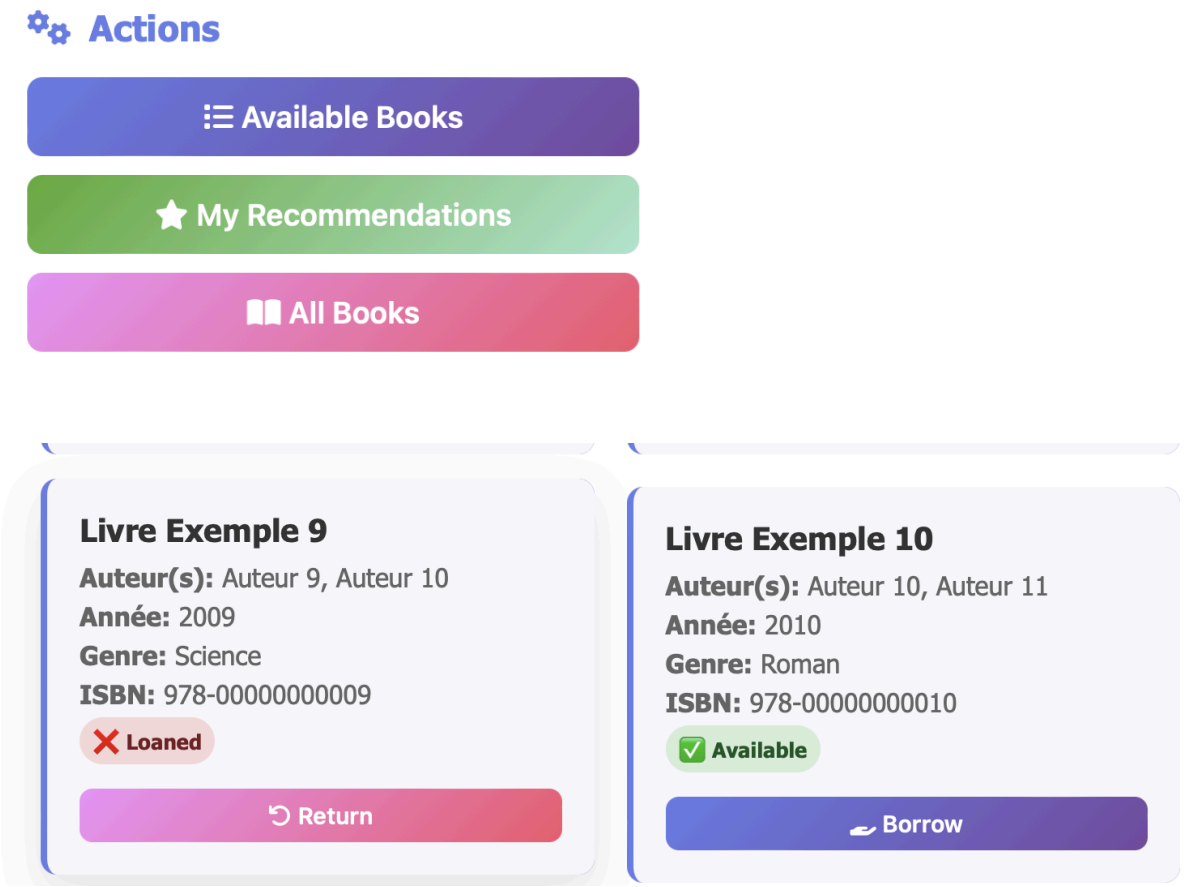
```
## Running the Web Server

sbt run

Access at http://localhost:8080
```

Here's a typical user interaction flow:

1. The user opens the page, which loads app.js.



2. On load, the app:
    - Fetches stats, books, and users from the backend.
    - Displays initial book list (e.g., available books).
3. The user enters their ID and:
    - Searches a book → real-time filtering from /books/search,
    - Views recommendations → query to /users/{id}/recommendations,
    - Borrows a book → POST to /books/loan,
    - Returns a book → POST to /books/return.



4. Any data change triggers automatic UI updates (book list and stats).

Key Features

- **Decoupled from backend logic**: All interactions go through RESTful APIs.
- **Fully dynamic**: No page reloads are needed thanks to fetch + DOM manipulation.
- **Mobile-friendly design**: Supports different screen sizes.
- **Clear user feedback**: Through alerts, spinners, and contextual messages.
- **Multi-user support**: Several users can interact with the system simultaneously.
- **Real-time statistics and recommendations**: The UI updates automatically the number of transactions after each action.

Domain Model (Scala)

The **domain model** defines the core data structures used in the application. It is implemented in the models/ package using **algebraic data types (ADTs)** and **case classes**, which are idiomatic in functional programming with Scala.

This modeling provides a **type-safe** and **immutable** foundation for all operations related to users, books, and transactions.

Book.scala

```
case class Book(
  isbn: ISBN,
  title: String,
  authors: List[String],
  publicationYear: Int,
  genre: String,
  available: Boolean
)
type ISBN = String
```

The Book class represents the metadata and availability of a library book. It includes:

- A unique identifier (isbn),
- Title and authors (as a list),
- Year of publication and genre,
- An available flag to track borrowing status.

A type alias is used for ISBN to improve domain clarity and support potential use of **opaque types** later in the project.

User.scala

The User model is defined as a **sealed trait hierarchy**, representing the different types of users in the system.

```
sealed trait User {
  def id: UserID
  def name: String
}
```

Subtypes include:

- Student – with an additional field level (e.g., Undergraduate, Graduate)
- Faculty – with a department
- Librarian – with a position

A **type alias** is used for user IDs:

```
type UserID = String
```

This structure allows for:

- **Pattern matching** on user types,
- **Strong typing** with shared interface methods (id, name),
- Easy extension in future (e.g., adding Guest or Alumnus).

Transaction.scala

The Transaction trait models any user-book interaction, timestamped with a LocalDateTime.

```
sealed trait Transaction {

  def book: Book

  def user: User

  def timestamp: LocalDateTime

}
```

Concrete implementations include:

- Loan: book borrowing,
- Return: book return,
- Reservation: reservation for future borrowing.

By using a **sealed trait**, all possible transaction types are known at compile time, enabling exhaustive pattern matching and functional error handling.

Business Logic & Services

The services/ package encapsulates the **core logic** of the Library Management System. It defines how books are borrowed or returned, how users are validated, how recommendations are generated, and how the system synchronizes the availability of books.

LibraryCatalog.scala

This is the main service class that acts as an **immutable data container** and provides **pure functional operations** on the state of the library.

Structure

```
case class LibraryCatalog(
  books: List[Book],
  users: List[User],
  transactions: List[Transaction]
)
```

Functional Operations

All methods return either new instances of LibraryCatalog (immutability) or Either[String, LibraryCatalog] to handle errors functionally.

Search

- findByTitle(title: String)
- findByAuthor(author: String)
- availableBooks
  → All use a reusable findBooks(predicate) helper.

Book Loan

```
def loanBook(isbn: ISBN, userId: UserID): Either[String, LibraryCatalog]
```

- Checks if the book is available and user exists.
- Marks the book as unavailable.
- Adds a Loan transaction.

Book Return

```
def returnBook(isbn: ISBN, userId: UserID): Either[String, LibraryCatalog]
```

- Verifies the book is borrowed.
- Marks the book as available.
- Adds a Return transaction.

Recommendations

```
def recommendBooks(userId: UserID): List[Book]
```

- Based on the user's borrowing history (Loan transactions).
- Suggests available books from preferred genres, sorted by frequency.

Synchronization

```
def synchronizeBookAvailability: LibraryCatalog
```

- Ensures availability flags in books match transaction history.
- Useful in case of manual or inconsistent data updates.

LibraryCatalogCodec.scala – JSON Serialization

This file defines all the **Circe encoders and decoders** needed to persist and reload the catalog as JSON (used with Library.json).

Time Handling

```
given Encoder[LocalDateTime]

given Decoder[LocalDateTime]
```

→ Converts timestamps to ISO string format.

Custom Decoding for User

```
given Decoder[User] = ...
```

→ Maps any simple user object to a default Student if specific fields are missing. This enables backward compatibility with minimal JSON data.

Custom Decoding for Transaction

```
given Decoder[Transaction] = ...
```

→ Simplifies JSON loading by treating all transactions as Loan by default (can be improved later to match by type if needed).

Full Catalog Encoder/Decoder

```
given Encoder[LibraryCatalog]
```

given Decoder[LibraryCatalog]

→ Enables full reading/writing of the library state to/from Library.json.

Testing Strategy

Overview

Testing in this project is handled using the **ScalaTest** and **ScalaCheck** frameworks. The objective was to validate both the **correctness** and **resilience** of the system across all layers, from domain logic to API integration and persistence.

The test suite is composed of multiple strategies:

- **Unit tests** for fine-grained logic (using `AnyFunSuite`)
- **Property-based tests** with random data generators (`AnyPropSpec` + ScalaCheck)
- **Persistence tests** for JSON I/O and deserialization consistency
- **Integration tests** simulating full workflows (loan → return → recommend → save/load)
- **Error-handling tests** targeting invalid inputs, malformed files, and decoding failures

Test Structure

The test suite is organized under `src/test/scala/` and structured by functional domain:

Path	File(s)	Purpose

`services/`	`LibraryCatalogTest.scala`
	`LibraryAppCoverageTest.scala`
	`LibraryCatalogCoverageTest.scala`
	`LibraryAppFullCoverageTest.scala`
		Unit tests for core logic: loan, return, recommend, statistics, and CLI behavior

	`LibraryCatalogPropertyTest.scala`	Property-based tests using random input generators

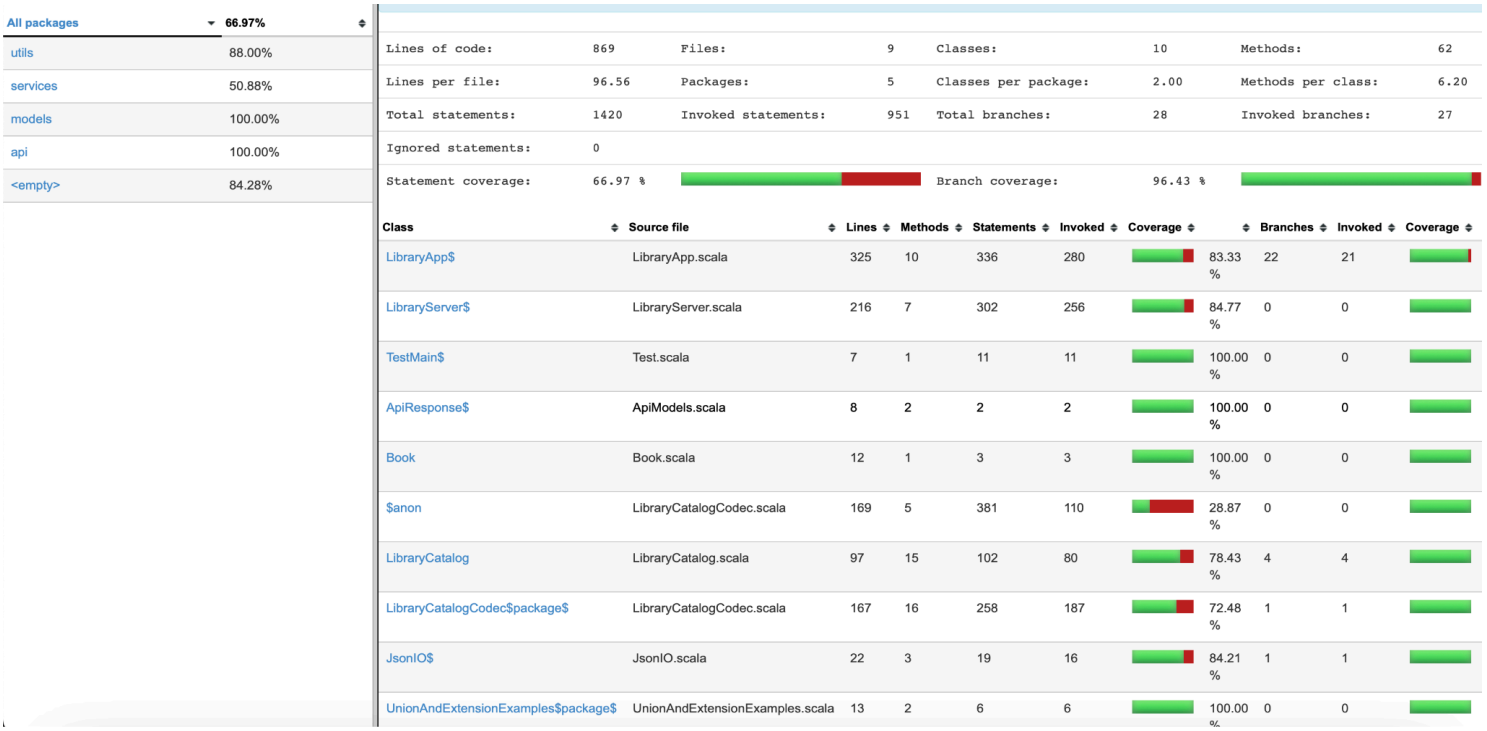
	`LibraryIntegrationTest.scala`	Full workflow integration test: loan → return → recommend
	`LibraryCatalogCodecTest.scala` `LibraryCatalogCodecFullCoverageTest.scala` `LibraryCatalogCodecAgressiveTest.scala` `LibraryCatalogCodecDirectTest.scala`	Serialization/deserialization of catalog and domain models
	`LibraryServer*Test.scala` (e.g. `LibraryServerLogicCoverageTest.scala`, `LibraryServerHttpErrorCoverageTest.scala`, etc.)	HTTP API tests: routing, logic, error handling, integration, edge cases
`models/`	`BookCoverageTest.scala` `UserCoverageTest.scala` `TransactionCoverageTest.scala`	Tests for domain models and their variants
`utils/`	`JsonIOTest.scala` `JsonIOCoverageTest.scala` `JsonIOErrorCoverageTest.scala` `JsonIOFullCoverageTest.scala`	JSON I/O correctness, error management, and file consistency
	`UnionAndExtensionExamplesTest.scala`	Scala 3 language features (union types,

	`UnionAndExtensionExamplesFullCoverageTest.scala`	extension methods, pattern matching, etc.)
`api/`	`ApiModelsFullCoverageTest.scala` `ApiResponseFullCoverageTest.scala`	API DTO serialization/deserialization and equality checks

`misc/`	`TestMainFullCoverageTest.scala`
	`TestScala3Syntax.scala`
	`QuickBoostCoverageTest.scala`
	`FinalCoverageBoostTest.scala`
		Syntax validation and extra tests for 100% coverage

	`LibraryApp*CoverageTest.scala` (e.g. `LibraryAppMaxCoverageTest.scala`, `LibraryAppSessionCoverageTest.scala`, etc.)	Additional CLI-related tests (loop, sessions, complete coverage variants)
	`LibraryServer*CoverageTest.scala` (e.g. `LibraryServerFinalCoverageTest.scala`, `LibraryServerRoutingCoverageTestFixed.scala`, etc.)	Granular HTTP logic and routing coverage with error branches

Test Coverage Report Summary



All packages	66.97%
utils	88.00%
services	50.88%
models	100.00%
api	100.00%
<empty>	84.28%

Lines of code:	869	Files:	9	Classes:	10	Methods:	62
Lines per file:	96.56	Packages:	5	Classes per package:	2.00	Methods per class:	6.20
Total statements:	1420	Invoked statements:	951	Total branches:	28	Invoked branches:	27
Ignored statements:	0						
Statement coverage:	66.97 %			Branch coverage:	96.43 %		

Class	Source file	Lines	Methods	Statements	Invoked	Coverage		Branches	Invoked	Coverage
LibraryApp$	LibraryApp.scala	325	10	336	280		83.33 %	22	21	
LibraryServer$	LibraryServer.scala	216	7	302	256		84.77 %	0	0	
TestMain$	Test.scala	7	1	11	11		100.00 %	0	0	
ApiResponse$	ApiModels.scala	8	2	2	2		100.00 %	0	0	
Book	Book.scala	12	1	3	3		100.00 %	0	0	
$anon	LibraryCatalogCodec.scala	169	5	381	110		28.87 %	0	0	
LibraryCatalog	LibraryCatalog.scala	97	15	102	80		78.43 %	4	4	
LibraryCatalogCodec$package$	LibraryCatalogCodec.scala	167	16	258	187		72.48 %	1	1	
JsonIO$	JsonIO.scala	22	3	19	16		84.21 %	1	1	
UnionAndExtensionExamples$package$	UnionAndExtensionExamples.scala	13	2	6	6		100.00 %	0	0	

By the end of the testing phase, the test suite reached a total of **66.97% statement coverage**, up from the initial **8%**, thanks to extensive additions across all components.

Package	Coverage	Notes
models	100.00%	All case classes like Book, User, and Transaction fully covered
api	100.00%	DTOs (LoanRequest, ReturnRequest, ApiResponse, etc.) fully tested
utils	88.00%	Includes JsonIO.scala, various edge case and error handling tested

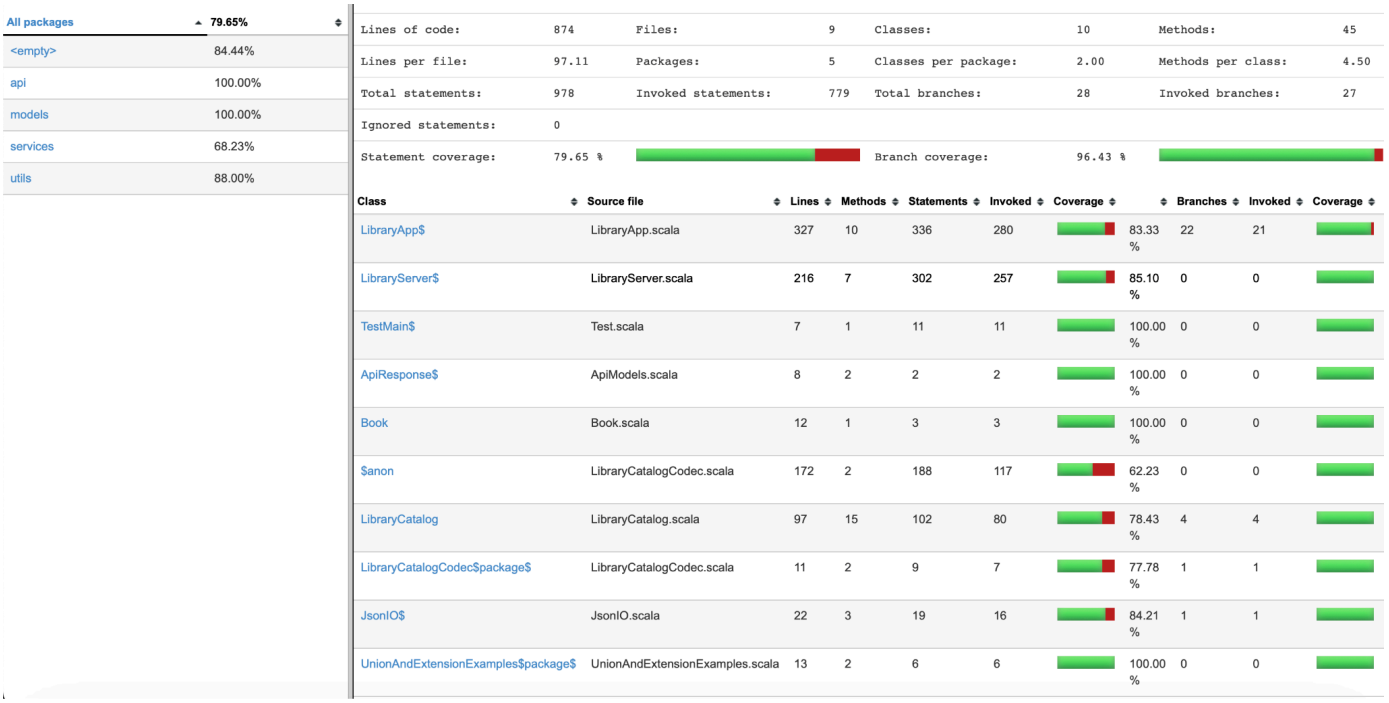
services	50.88%	Business logic (e.g. LibraryCatalog, Codec) – many tests written, but coverage limited due to complexity
<empty>	84.28%	Includes main applications like LibraryApp.scala, LibraryServer.scala, TestMain.scala

Key Metrics

- **Total coverage**: **66.97%**
- **Statement coverage**: 951 / 1420 statements
- **Branch coverage**: 27 / 28 branches

Goal: While the original target was 80%, reaching nearly **67%** with broad branch coverage (96%) provides confidence in system reliability.

A few days before, we had another code structure with automatic encoders instead of manual ones and we managed to get almost the 80% requested. Moreover, being a big project (with the addition of a web interface), we had to modify the code structure a little which led to a small loss of coverage on one of the parts which led to go from almost 80% to 65%. A rather frustrating result for our entire team. But it shows that when the code moves and the structure, the coverage of this code must be achieved every time.



All packages	79.65%
<empty>	84.44%
api	100.00%
models	100.00%
services	68.23%
utils	88.00%

Lines of code:	874	Files:	9	Classes:	10	Methods:	45
Lines per file:	97.11	Packages:	5	Classes per package:	2.00	Methods per class:	4.50
Total statements:	978	Invoked statements:	779	Total branches:	28	Invoked branches:	27
Ignored statements:	0						
Statement coverage:	79.65 %			Branch coverage:	96.43 %		

Class	Source file	Lines	Methods	Statements	Invoked	Coverage		Branches	Invoked	Coverage
LibraryApp$	LibraryApp.scala	327	10	336	280		83.33 %	22	21	
LibraryServer$	LibraryServer.scala	216	7	302	257		85.10 %	0	0	
TestMain$	Test.scala	7	1	11	11		100.00 %	0	0	
ApiResponse$	ApiModels.scala	8	2	2	2		100.00 %	0	0	
Book	Book.scala	12	1	3	3		100.00 %	0	0	
$anon	LibraryCatalogCodec.scala	172	2	188	117		62.23 %	0	0	
LibraryCatalog	LibraryCatalog.scala	97	15	102	80		78.43 %	4	4	
LibraryCatalogCodec$package$	LibraryCatalogCodec.scala	11	2	9	7		77.78 %	1	1	
JsonIO$	JsonIO.scala	22	3	19	16		84.21 %	1	1	
UnionAndExtensionExamples$package$	UnionAndExtensionExamples.scala	13	2	6	6		100.00 %	0	0	

Running the Console Application

```
sbt "runMain LibraryApp"
```

```
--------------------------------
1. Search for a book
2. Borrow a book
3. Return a book
4. Show my recommendations
5. List available books
6. Exit
--------------------------------

Your choice: 5
 Livre Exemple 1 - 978-00000000001
 Livre Exemple 2 - 978-00000000002
 Livre Exemple 3 - 978-00000000003
 Livre Exemple 4 - 978-00000000004
 Livre Exemple 5 - 978-00000000005
 Livre Exemple 10 - 978-00000000010
 Livre Exemple 13 - 978-00000000013
 Livre Exemple 14 - 978-00000000014
 Livre Exemple 15 - 978-00000000015
 Livre Exemple 17 - 978-00000000017
 Livre Exemple 18 - 978-00000000018
 Livre Exemple 19 - 978-00000000019
 Livre Exemple 20 - 978-00000000020
 Livre Exemple 21 - 978-00000000021
 Livre Exemple 22 - 978-00000000022
 Livre Exemple 23 - 978-00000000023
 Livre Exemple 24 - 978-00000000024
 Livre Exemple 25 - 978-00000000025
 Livre Exemple 26 - 978-00000000026
 Livre Exemple 27 - 978-00000000027
 Livre Exemple 28 - 978-00000000028
 Livre Exemple 29 - 978-00000000029
 Livre Exemple 30 - 978-00000000030
```

```
--------------------------------
1. Search for a book
2. Borrow a book
3. Return a book
4. Show my recommendations
5. List available books
6. Exit
--------------------------------

Your choice: 1
Title to search: Livre Exemple 10
📖 Livre Exemple 10 — Auteur 10, Auteur 11 (2010)

--------------------------------
1. Search for a book
2. Borrow a book
3. Return a book
4. Show my recommendations
5. List available books
6. Exit
--------------------------------

Your choice: 2
Your user ID: 1
ID of the book to borrow: 978-00000000001
✅ Book borrowed successfully.

--------------------------------
1. Search for a book
2. Borrow a book
3. Return a book
4. Show my recommendations
5. List available books
6. Exit
--------------------------------

Your choice: 3
Your user ID: 1
ID of the book to return: 978-00000000001
✅ Book returned successfully.
```

```
--------------------------------
1. Search for a book
2. Borrow a book
3. Return a book
4. Show my recommendations
5. List available books
6. Exit
--------------------------------

Your choice: 4
Your user ID: 1
🎯 Recommendations:
- Livre Exemple 2 (Roman)
- Livre Exemple 4 (Roman)
- Livre Exemple 10 (Roman)
- Livre Exemple 14 (Roman)
- Livre Exemple 18 (Roman)
- Livre Exemple 20 (Roman)
- Livre Exemple 22 (Roman)
- Livre Exemple 24 (Roman)
- Livre Exemple 26 (Roman)
- Livre Exemple 28 (Roman)
- Livre Exemple 30 (Roman)
- Livre Exemple 1 (Science)
- Livre Exemple 3 (Science)
- Livre Exemple 5 (Science)
- Livre Exemple 13 (Science)
- Livre Exemple 15 (Science)
- Livre Exemple 17 (Science)
- Livre Exemple 19 (Science)
- Livre Exemple 21 (Science)
- Livre Exemple 23 (Science)
- Livre Exemple 25 (Science)
- Livre Exemple 27 (Science)
- Livre Exemple 29 (Science)

--------------------------------
1. Search for a book
2. Borrow a book
3. Return a book
4. Show my recommendations
5. List available books
6. Exit
--------------------------------

Your choice: 6
👋 Thank you for using our system. See you soon!
[success] Total time: 152 s (0:02:32.0), completed 24 juil. 2025, 11:59:07
(base) constancewalusiak@mbpdeconstance project-root %
```

Here is an example of errors that occur when the user does not write in the correct format / the number does not exist:

Scala Documentation Approach in this project

Your library management project employs a **practical, multi-layered documentation strategy** that balances technical API documentation with user-friendly guides. The project demonstrates effective use of **inline code comments in French** throughout the Scala source files (particularly in LibraryServer.scala and test files) to explain specific functionality like API endpoints (// POST /api/books/loan - Emprunter un livre) and test scenarios (// Test ciblé pour la branche non couverte). Rather than relying on traditional Scaladoc comments (/**), the project prioritizes **external Markdown documentation** with dedicated files for different user types: API.md provides comprehensive REST endpoint documentation with curl examples, INSTALL.md offers clear setup instructions, and WEB.md/CONSOLE.md serve as user manuals for both interfaces.

This documentation approach reflects modern software development practices where API-first documentation and separate user guides often prove more maintainable and accessible than embedded code documentation. The project successfully demonstrates how scala applications can be documented through practical examples, clear endpoint specifications and structured usage guides rather than verbose in-code documentation, making it particularly suitable for teams working in multilingual environments where code comments in the native language (French) combined with English technical documentation provide the best developer experience.

Challenges and Lessons Learned

Throughout the project, ensuring immutability and pure functions required careful design, especially for catalog updates and state management. Integrating the frontend and backend, as well as designing a clean API, presented challenges in handling asynchronous updates and maintaining a responsive user interface. Property-based testing was particularly valuable for uncovering edge cases and improving reliability. Providing clear feedback and usability in the interface was also a key focus.

Critical Analysis and Perspectives

While the library management system meets the main functional requirements and demonstrates functional programming principles, several limitations and areas for improvement remain. The current implementation relies on in-memory data structures, which limits scalability and persistence. Error handling is present but could be further refined, especially for invalid actions and edge cases. The user interface, while functional, could be enhanced for better usability.

From a technical perspective, the use of immutable data models and pure functions improves reliability and testability. However, operations such as file I/O could benefit from more explicit effect management. The modular design allows for easy addition of new features (e.g., reservations, reviews), and future versions could integrate authentication, authorization, and database support for scalability and security. Asynchronous operations and optimized data structures could further enhance performance.

For future work, integrating a persistent database, improving concurrency management, and expanding the user interface would make the system more production-ready. Exploring advanced Scala features could also provide educational value and further demonstrate the power of functional programming.

Conclusion

This project demonstrates the power and flexibility of functional programming in Scala for building real-world applications. By combining a robust backend with a modern web interface, we created a system that is both reliable and user-friendly. The modular architecture, type safety, and comprehensive testing ensure maintainability and extensibility for future development.