

Inventory Management System

Making Renting and Charching effortless

**Felix Huther, Jingya Zhao, Kandaker Majharul
Islam, Philipp Becker, Sven Lepper**

A collaborative project involving
Hochschule Darmstadt (Germany)
& Centria University of Applied Sciences (Finnland)



Spring/Summer Term 2024

Contents

1	Quote example	4
2	Content page Ifdi	5
3	Introduction Philipp	6
4	Research / State of the Art / alternatively: Motivation (Ting)	7
5	Methodology (Felix)	8
6	Software Design	9
6.1	Introduction	9
6.2	Architectural Approach	10
6.3	Frontend Technologies	10
6.4	Google Maps Integration	11
6.5	Backend Technologies	11
6.6	Database Management	11
6.7	Database Choice	12
6.8	Locker Controls	12
6.9	Charging Data Management	12
6.10	Hosting and Deployment	13
6.10.1	Frontend Deployment	13
6.10.2	Backend Deployment	14
6.10.3	Database Hosting	14
6.10.4	Sensor Data Management	15
6.11	Conclusion	15
7	Implementation	17
7.1	Frontend	17

7.2	Backend	18
7.3	Backend Implementation	18
7.3.1	Project Setup	18
7.3.2	List of Important Libraries and Versions	19
7.3.3	Request Handling in FastAPI and SQLAlchemy	19
7.3.4	Project Structure	20
7.3.5	API Design	26
7.3.6	Database Schema Design	29
7.3.7	Logging	30
7.3.8	Areas for Improvement	31
7.4	Arduino	33
7.5	Arduino Implementation	33
7.5.1	Arduino Setup	33
7.5.2	List of Important Libraries and Versions	35
7.5.3	Flow Chart	37
7.5.4	Sensors Overview	38
7.5.5	Fritzing	43
7.5.6	Areas for Improvement	44
8	Testing / Evaluation (Ting)	46
9	Reflection and Lessons Learned	47
9.1	Successes and Effective Practices	47
9.1.1	Successes and Effective Practices	47
9.2	Areas for Improvement and Lessons Learned	48
10	Next steps / Outlook	50
10.1	Expanding from One Locker Prototype to Locker Systems . . .	50
10.2	Real-time Charging Level Monitoring	51

10.3 Implementation of QR Codes for Streamlined Inventory Man- agement	51
10.4 Scheduled Maintenance Protocol	52
10.5 Automated Reservation System	52
11 Summary Ifdi	54
12 Append	55

1 Quote example

According to (author?) [1], ...

2 Content page Ifdi

3 Introduction Philipp

1. goal / problem that should be solved
2. how did we divide up the members of the class into teams; introduce the teams (tasks, people, tasks of individuals)- keep this short

4 Research / State of the Art / alternatively: Motivation (Ting)

(keep this short and possibly replace it by a motivation why you chose this topic)

5 Methodology (Felix)

1. which are the steps that are taken in which order to reach the result
2. which steps are taken
3. which tools were used (keep this short)
4. always give reasons for WHY you chose certain steps
5. always give reasons for WHY you chose certain tools

6 Software Design

Written by: Sven

6.1 Introduction

This chapter delves into the intricate details of the software design employed in the development of the locker system for university environments. A robust and efficient software architecture is pivotal in ensuring the seamless functioning and user satisfaction of the system. In this section, we provide an overview of the architectural approach, technologies, and frameworks chosen for the implementation of the locker system software, highlighting their significance and relevance to the project objectives.

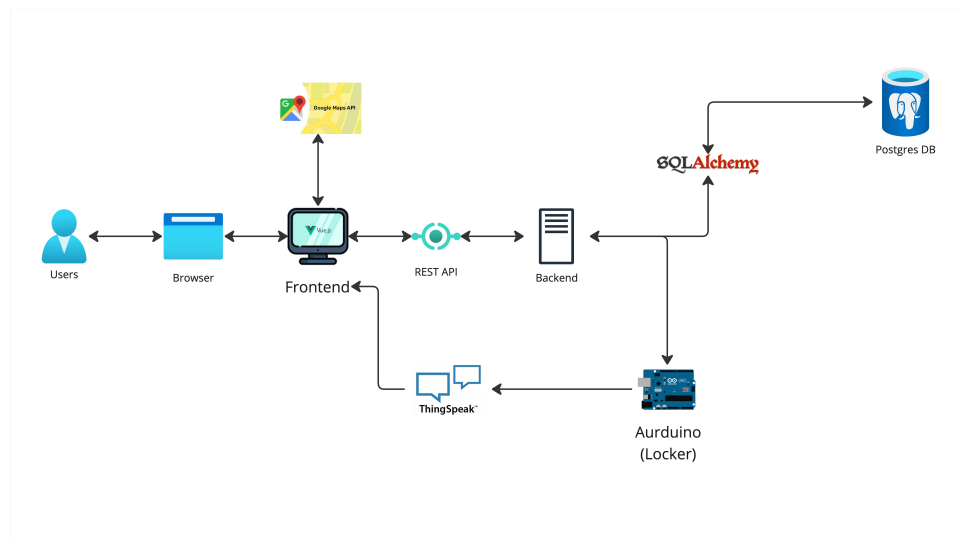


Figure 1: Software Design Diagram

The image above depicts a high-level overview of the software design architecture, illustrating the interaction between various components and their roles within the system. Throughout this chapter, we elucidate the rationale behind each architectural decision and technology selection, elucidating

their benefits and contributions to the overall functionality and performance of the locker system.

Now, let's delve into the intricacies of the software design, beginning with an exploration of the architectural approach adopted for the project.

6.2 Architectural Approach

The adoption of a modern microservices architecture, with clear separation between frontend and backend components, offers several advantages for the locker system project. By decoupling these layers and enabling communication via a RESTful API, we achieve enhanced modularity, scalability, and flexibility. This modular approach facilitates independent development and deployment of frontend and backend services, enabling rapid iteration and evolution of the system. Moreover, the RESTful API design simplifies integration with third-party services and future expansion of functionality, ensuring adaptability to changing requirements and technological advancements.

6.3 Frontend Technologies

Vue.js was selected as the frontend framework due to its lightweight nature, simplicity, and extensive ecosystem of plugins and libraries. Its reactive data binding and component-based architecture enable the creation of dynamic and interactive user interfaces, enhancing the user experience. Additionally, the integration of Tailwind CSS and Bootstrap provides a comprehensive set of styling utilities and pre-designed components, enabling rapid prototyping and ensuring consistent design across different devices and screen sizes. The use of these frontend technologies not only accelerates development but also enhances maintainability and scalability, making them well-suited for a complex application like the locker system.

6.4 Google Maps Integration

The integration of the Google Maps API enriches the user experience by providing visual representation of locker locations. This feature enhances user convenience and navigation, particularly in large university campuses where locker locations may not be readily apparent. By leveraging the Google Maps API, users can easily locate their rented devices, thereby reducing frustration and improving overall satisfaction with the service.

6.5 Backend Technologies

FastAPI was chosen as the backend framework due to its high performance, asynchronous capabilities, and intuitive API design. Its built-in support for asynchronous programming enables efficient handling of concurrent requests, ensuring optimal responsiveness and scalability, especially under heavy loads. Additionally, FastAPI's automatic generation of OpenAPI documentation simplifies API documentation and client integration, enhancing developer productivity and collaboration. The use of FastAPI aligns with industry best practices and standards, ensuring the reliability, security, and maintainability of the locker system backend.

6.6 Database Management

The utilization of SQLAlchemy as the ORM tool offers numerous benefits for database management within the locker system project. By abstracting away the complexities of database interaction, SQLAlchemy enhances developer productivity and code maintainability, while also mitigating the risk of SQL injection vulnerabilities. Furthermore, Alembic provides seamless database schema versioning and migration capabilities, facilitating continuous evolution and refinement of the database schema over time. These features ensure data integrity, consistency, and scalability, making

SQLAlchemy and Alembic well-suited for managing the relational database backend of the locker system.

6.7 Database Choice

PostgreSQL was selected as the underlying database management system for its robustness, reliability, and advanced feature set. Its support for ACID transactions, data integrity constraints, and extensible data types ensures the consistency and integrity of stored data, critical for a mission-critical application like the locker system. Additionally, PostgreSQL’s scalability and performance optimizations make it capable of handling large volumes of concurrent transactions and complex queries, making it an ideal choice for the storage and retrieval of locker rental and user data.

6.8 Locker Controls

The integration of Arduino-based locker controls provides a cost-effective and customizable solution for managing locker access and device rentals. Arduino’s open-source hardware platform, coupled with its rich ecosystem of sensors and actuators, enables the implementation of tailored locker control mechanisms suited to the specific requirements of the locker system. By exposing REST APIs for communication with the backend, Arduino controllers facilitate real-time updates and authentication checks, ensuring secure and reliable access to rented devices.

6.9 Charging Data Management

ThingSpeak serves as an IoT analytics platform for collecting, storing, and visualizing charging data generated by the Arduino controllers. Its cloud-based infrastructure and user-friendly interface simplify data management and analysis, enabling administrators to monitor charging activities and

usage patterns in real-time. The integration of ThingSpeak with the frontend enables the seamless transmission of processed data for visualization, empowering administrators to make informed decisions regarding resource allocation and system optimization.

6.10 Hosting and Deployment

The successful deployment and hosting of the locker system components are crucial for ensuring accessibility, scalability, and reliability. In this section, we elucidate the deployment strategies employed for the frontend, backend, and database components, leveraging cloud-based solutions and containerization technologies for seamless deployment and management.

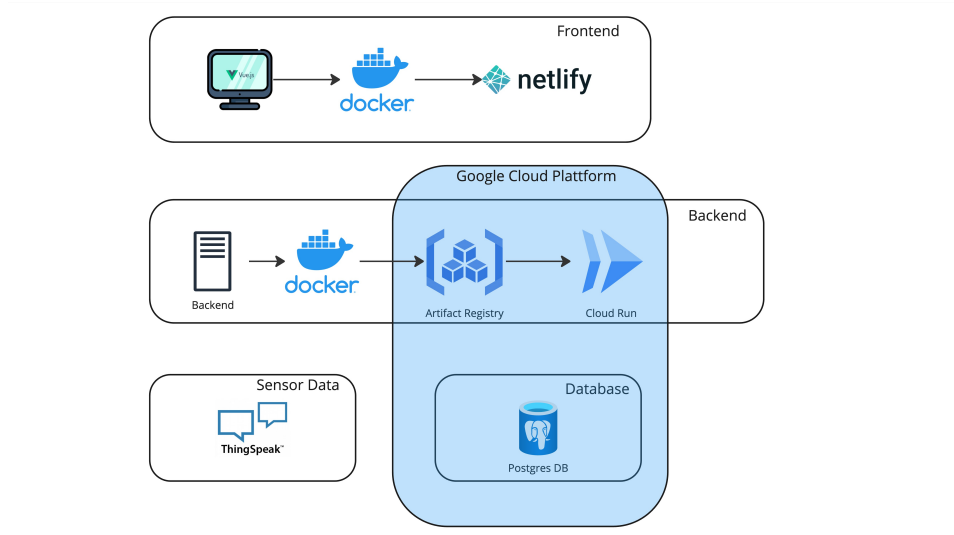


Figure 2: Overview of Deployment Processes

6.10.1 Frontend Deployment

The frontend of the locker system is packaged into a Docker container to encapsulate its dependencies and environment. This containerized approach

ensures consistency and portability across different environments, mitigating potential compatibility issues. Subsequently, the Docker container is deployed to Netlify, a popular platform for hosting static websites and web applications. Netlify provides a straightforward deployment process, seamless integration with Git repositories, and automatic build and deployment pipelines. Additionally, Netlify assigns a public address to the deployed frontend, enabling users to access the locker system via the internet with ease.

6.10.2 Backend Deployment

Similar to the frontend, the backend services are containerized using Docker to streamline deployment and management. Once the backend Docker image is built, it is pushed to Google Cloud's Artifact Registry, a managed service for storing container images securely. Artifact Registry ensures version control, access control, and image vulnerability scanning, enhancing the security and reliability of the deployment process. Subsequently, the containerized backend services are deployed to Google Cloud Run, a fully managed serverless platform for running containerized applications. Google Cloud Run automatically scales the backend services based on demand, ensuring optimal performance and cost-efficiency. Furthermore, Google Cloud Run assigns a public address to the deployed backend services, facilitating seamless communication with the frontend and other system components over the internet.

6.10.3 Database Hosting

The PostgreSQL database used by the locker system is hosted on Google Cloud SQL, a fully managed relational database service. Google Cloud SQL offers automatic backups, high availability, and scalability, relieving the

burden of database administration and maintenance. By leveraging Google Cloud SQL, we ensure data durability, reliability, and performance, critical for the storage and retrieval of locker rental and user data. Additionally, Google Cloud SQL provides seamless integration with other Google Cloud services, simplifying data management and access control.

6.10.4 Sensor Data Management

The sensor data collected by the Arduino controllers is transmitted to ThingSpeak, a cloud-based IoT analytics platform. ThingSpeak provides a scalable and reliable infrastructure for storing, analyzing, and visualizing sensor data in real-time. As a Software as a Service (SaaS) solution, ThingSpeak eliminates the need for hosting and infrastructure management, allowing developers to focus on application logic and data analysis. By leveraging ThingSpeak, we ensure efficient management and utilization of the sensor data.

6.11 Conclusion

In summary, the deployment and hosting of the locker system components leverage cloud-based solutions and containerization technologies to ensure accessibility, scalability, and reliability. By utilizing platforms such as Netlify, Google Cloud, and ThingSpeak, we streamline the deployment process, enhance security and performance, and enable seamless integration between different system components. This comprehensive approach to hosting and deployment underscores the importance of utilizing cloud-native technologies and services for building robust and scalable applications in modern computing environments.

The software design of the locker system incorporates a carefully selected set of technologies and architectural principles tailored to the specific

requirements and challenges of managing locker rentals and device access in university environments. Many of these technologies were introduced in lectures at our university, and while there may be other options available, we opted for those recommended by the university and with which we had prior experience. By leveraging modern frameworks, platforms, and best practices, the system delivers enhanced functionality, scalability, and user experience, ensuring its effectiveness and viability in real-world deployments.

7 Implementation

1. how did we reach the result / coding (snippets)
2. screen shots

7.1 Frontend

Written by: Philipp

7.2 Backend

Written by: Sven

7.3 Backend Implementation

This subsection provides an overview of the implementation details for the backend of the locker system. It covers the technologies, frameworks, and development environment used in the development process.

7.3.1 Project Setup

The backend part of the locker system project is developed using FastAPI and SQLAlchemy/alembic. These technologies were chosen for their robustness, scalability, and ease of use in building web APIs and managing database migrations.

The development environment setup involves several steps to ensure a smooth workflow. Firstly, it requires a local Postgres database instance to be running, with specific configuration settings provided via environment variables. These variables include the database username, password, host, port, and name.

The project setup also involves cloning the backend repository and configuring the environment variables as necessary. A virtual environment is then created to isolate dependencies, followed by the installation of required packages specified in the ‘requirements.txt’ file using pip.

Once the development environment is set up, the application can be run locally by activating the virtual environment and starting the application. Additionally, database migrations can be managed using alembic, with commands provided to generate and apply migration scripts.

7.3.2 List of Important Libraries and Versions

The following list includes the most important libraries used in the backend implementation along with their versions:

- **FastAPI** (`fastapi==0.110.2`): FastAPI is a modern, fast (high-performance) web framework for building APIs with Python 3.7+ based on standard Python type hints.
- **SQLAlchemy** (`SQLAlchemy==2.0.29`): SQLAlchemy is the Python SQL toolkit and Object-Relational Mapper that gives application developers the full power and flexibility of SQL.
- **Alembic** (`alembic==1.13.1`): Alembic is a lightweight database migration tool for usage with the SQLAlchemy Database Toolkit for Python.
- **Pydantic** (`pydantic==2.7.1`): Pydantic is a data validation and settings management using Python type annotations.
- **uvicorn** (`uvicorn==0.29.0`): Uvicorn is a lightning-fast ASGI server implementation, using uvloop and httptools.
- **psycopg2-binary**: Psycopg is the most popular PostgreSQL database adapter for the Python programming language.

7.3.3 Request Handling in FastAPI and SQLAlchemy

A crucial aspect of understanding the backend implementation is to grasp how FastAPI and SQLAlchemy handle incoming requests and interact with the database. The following diagram illustrates the request handling process:

This diagram visually depicts the sequence of steps involved in processing a client request, starting from the client making an HTTP request to the

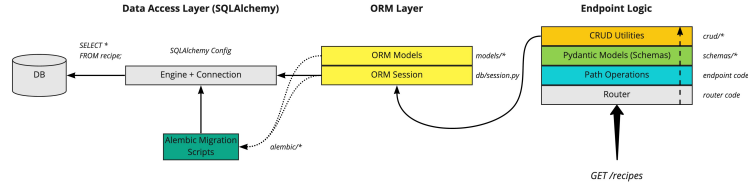


Figure 3: Request Handling in FastAPI and SQLAlchemy (author?) [2]

backend API. FastAPI routes the request to the appropriate endpoint, where it is processed by the corresponding router function. The router function interacts with the database through SQLAlchemy ORM, executing CRUD operations as necessary to fulfill the request. Once the database operations are complete, a response is generated and returned to the client.

Understanding this request handling flow is essential for developers to comprehend the inner workings of the backend system and troubleshoot any issues that may arise during development or deployment.

7.3.4 Project Structure

The backend part of the locker system project adheres to a well-organized structure, following best practices to ensure clarity, modularity, and maintainability. Below is an overview of the project structure and the rationale behind each component:

- **README.md:** This file serves as the project's main documentation hub, containing comprehensive information on setup instructions, deployment steps, and other essential details. A well-written README enhances project understanding and facilitates collaboration among team members.
- **requirements.txt:** This file enumerates all Python packages required by the project, making it easy for developers to install dependencies

using pip. Managing dependencies in a centralized file promotes consistency and reproducibility across different environments.

- **.env:** Environment variables play a crucial role in configuring the application, especially sensitive information like database credentials. Utilizing a separate .env file allows for easy management of configuration settings across various deployment environments.
- **venv:** The virtual environment isolates project dependencies, ensuring compatibility and preventing conflicts with other Python projects. By encapsulating dependencies within a dedicated environment, developers can maintain a clean and reproducible development setup.
- **alembic/versions:** This directory houses database migration files managed by Alembic, a lightweight migration tool for SQLAlchemy. Organizing migrations in a structured manner facilitates version control and systematic evolution of the database schema over time.
- **images:** Images used in the project documentation, such as the README file, are stored in this directory. Including visual aids enhances readability and comprehension of project-related instructions and guidelines.
- **Dockerfile:** Docker simplifies application deployment by encapsulating the application and its dependencies into portable containers. The Dockerfile specifies the steps to build a Docker image, promoting consistency and reproducibility across different deployment environments.

The **app** folder encapsulates the core components of the backend application. It is further divided into the following subdirectories and files (examples are used from the Category class, but the structure is the same for all classes):

- **api** folder: This folder contains endpoint-specific modules responsible for handling HTTP requests and responses. Each endpoint module typically consists of three main components:

- **CRUD operations (Create, Read, Update, Delete)**: These operations define the basic functionalities for interacting with database entities. For example, the `crud.py` files contain functions for creating, retrieving, updating, and deleting records from the database.

The following code snippet demonstrates the `delete_category_by_id` function, which is responsible for deleting a category from the database by its ID:

```
1         def delete_category_by_id(category_id:
2             int, db: Session):
3                 category = get_category_by_id(
4                     category_id, db)
5                 if category:
6                     db.delete(category)
7                     db.commit()
```

This function first retrieves the category with the specified ID using the `get_category_by_id` function. If the category exists, it is deleted from the database using the SQLAlchemy `delete` method, followed by a commit to persist the changes.

- **Router functions**: The `router.py` files define FastAPI router instances responsible for routing HTTP requests to the appropriate endpoint functions. Routers enhance code organization and modularity by grouping related endpoint operations together. The following code snippet illustrates a router function responsible for handling HTTP DELETE requests to delete a category:

```

1      @router.delete('/categories/{category_id}
2      ', response_model=None, tags=['category'])
3      def delete_category(
4          category_id: int,
5          db: Session = Depends(get_db)):
6          category_crud.delete_category_by_id(
7              category_id, db)
8
9          return Response(status_code=status.
10                          HTTP_204_NO_CONTENT)

```

In this function, the route decorator specifies the HTTP method (DELETE) and the endpoint URL pattern ("/categories/category_id"). The function parameters include the category ID to be deleted and a database session dependency obtained through the `get_db` function. Inside the function, the `delete_category_by_id` function from the CRUD module (`category_crud`) is called to delete the category from the database. Finally, a 204 No Content response is returned to indicate successful deletion.

- **Schema definitions:** Schemas define the structure and validation rules for request and response payloads exchanged between the client and server. The `schemas.py` files contain Pydantic models representing data schemas for serialization and validation purposes.

The following code snippet presents a Pydantic model (`CategoryBaseSchema`) defined in a schema file:

```

1      class CategoryBaseSchema(BaseModel):
2          name: str
3

```

In this schema definition, `CategoryBaseSchema` inherits from `BaseModel`,

a Pydantic base class used for defining data models. The schema consists of a single field (**name**) with a data type of **str**, representing the name of a category. Pydantic models provide automatic data validation based on the specified field types, enabling robust input validation and serialization/deserialization of data between client and server components.

- **db** folder: This folder contains modules related to database management and configuration. Key components include:
 - **Configuration module (config.py)**: This module defines database connection settings using environment variables and provides functions for establishing database connections and checking connectivity status. Centralizing database configuration facilitates easy maintenance and deployment across different environments.

The following code snippet illustrates the `config.py` module, which manages database configuration:

```
1      from sqlalchemy import create_engine
2      from sqlalchemy.orm import sessionmaker
3      from sqlalchemy.exc import
      OperationalError
4      from dotenv import load_dotenv
5      import os
6
7      load_dotenv()
8
9      DB_USERNAME = os.getenv("
DATABASE_USERNAME")
10     DB_PASSWORD = os.getenv("
DATABASE_PASSWORD")
11     DB_HOST = os.getenv("DATABASE_HOST")
```

```

12     DB_PORT = os.getenv("DATABASE_PORT")
13     DB_NAME = os.getenv("DATABASE_NAME")
14     DB_URL = f"postgresql://{DB_USERNAME}:{DB_PASSWORD}@{DB_HOST}:{DB_PORT}/{DB_NAME}"
15
16     def get_database_url():
17         return DB_URL
18
19     engine = create_engine(DB_URL)
20     SessionLocal = sessionmaker(autocommit=False, autoflush=False, bind=engine)
21
22     def check_database_connection():
23         try:
24             engine = create_engine(DB_URL)
25             with engine.connect():
26                 return True
27         except OperationalError:
28             return False
29

```

This module loads database connection settings from environment variables using the `dotenv` library. It defines functions for retrieving the database URL, establishing a database engine, and checking database connectivity. By encapsulating database configuration in a single module, the codebase becomes more modular and maintainable, enabling seamless deployment across various environments.

- **Model definitions** (`models.py`): Models define the structure of database tables and their relationships using SQLAlchemy declarative base. Models encapsulate business logic and data integrity constraints, promoting code organization and reusability.

The following code snippet demonstrates a model definition (`Category`) in the `models.py` module:

```
1      from sqlalchemy import Column, Integer,
      String
2      from db.config import Base
3
4      class Category(Base):
5          __tablename__ = 'categories'
6
7          id = Column(Integer, primary_key=
      True)
8          name = Column(String, nullable=False
      )
9
```

In this model definition, `Category` is a SQLAlchemy model representing the `categories` table in the database. It inherits from `Base`, the declarative base provided by SQLAlchemy. The `__tablename__` attribute specifies the table name, while `id` and `name` represent the table columns. By encapsulating database schema in model classes, the codebase becomes more organized and maintainable, facilitating data manipulation and ensuring data integrity.

- **main.py:** The main entry point of the backend application, responsible for initializing the FastAPI application instance and configuring middleware, routers, and other application-level settings.

7.3.5 API Design

The backend API is documented using the OpenAPI Specification (OAS) format, commonly known as Swagger. Swagger provides a standardized,

machine-readable representation of the API, detailing its endpoints, request/response formats, and data models.

What is Swagger?: Swagger is an open-source framework that enables the design, documentation, and testing of RESTful APIs. It defines a structured format for describing API endpoints, parameters, responses, and authentication mechanisms, facilitating seamless integration and collaboration among developers.

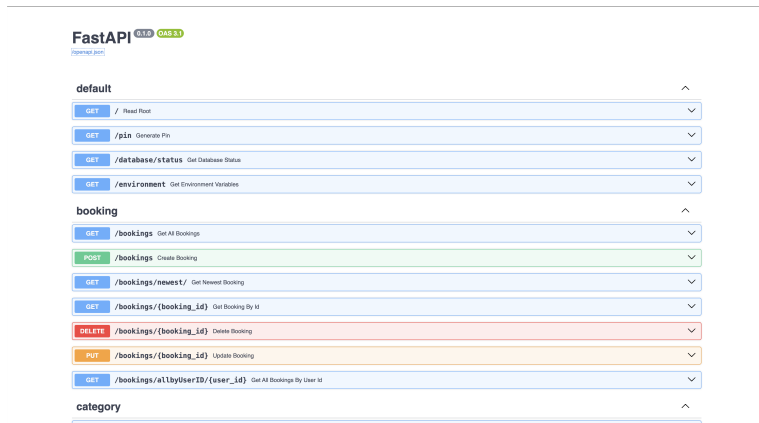


Figure 4: FastAPI Swagger UI

Why is Swagger Useful?: Swagger simplifies API development by offering a centralized platform for describing and visualizing API specifications. It enhances communication between frontend and backend developers, accelerates client-side integration, and fosters interoperability across diverse programming languages and frameworks.

FastAPI and Swagger: FastAPI, a modern web framework for building APIs with Python, integrates seamlessly with Swagger to automate API documentation. FastAPI generates Swagger UI out of the box, allowing developers to interactively explore and test API endpoints. By leveraging FastAPI's native support for Swagger, developers can focus on implementing business logic without worrying about manual documentation efforts.

Endpoints Definition: The backend API comprises a set of well-defined endpoints, each catering to a specific functionality within the locker system. Endpoints such as `/bookings`, `/categories`, `/devices`, `/reports`, `/users`, among others, provide access to the corresponding resources and operations.

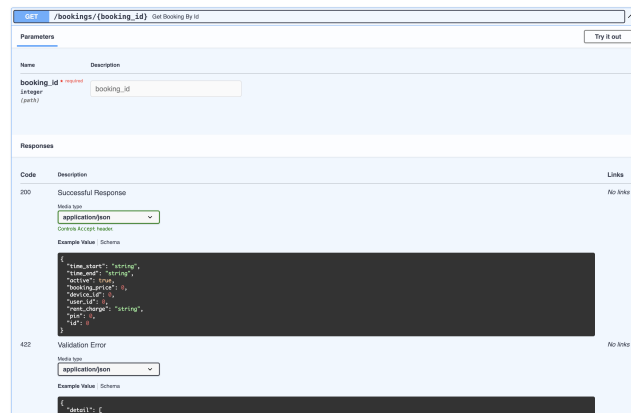


Figure 5: FastAPI Swagger UI - Bookings Endpoint

Request/Response Formats: For each endpoint, clear specifications are provided regarding the expected request formats, including request bodies, query parameters, and path parameters. Similarly, the response formats, denoted by response schemas, outline the structure of data returned by the server in response to client requests.

Data Models: The API leverages distinct data models to represent various entities and their attributes. These models, including `BookingSchema`, `CategorySchema`, `DeviceSchema`, `ReportSchema`, and `UserSchema`, encapsulate the structure of data exchanged between the client and server. Additionally, specialized schemas such as `BookingCreateSchema`, `CategoryCreateSchema`, and others are utilized for specific operations, ensuring consistency and validation of incoming data.

7.3.6 Database Schema Design

The database schema for the locker system is designed to efficiently store information related to bookings, categories, devices, reports, and users. The schema employs normalization techniques to minimize redundancy and ensure data integrity. Indexing strategies are implemented to optimize query performance, particularly for frequently accessed fields.

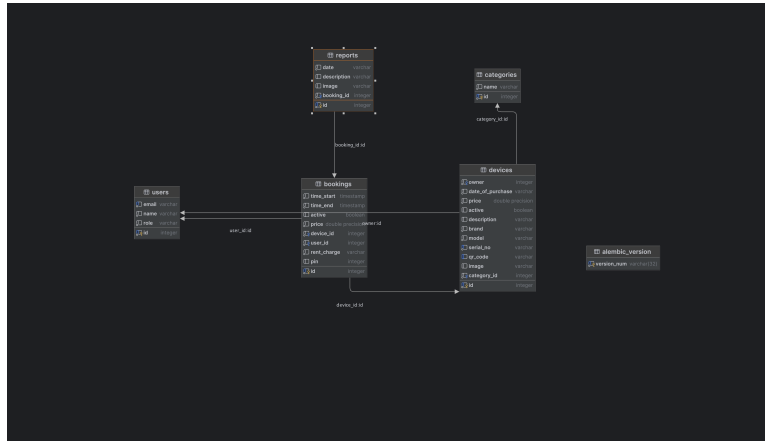


Figure 6: Database Schema Design

Normalization: The schema adheres to normalization principles to eliminate data redundancy and dependency issues. By organizing data into well-structured tables and establishing relationships between them, normalization ensures efficient data storage and maintenance.

Indexing: To enhance query performance, the database schema incorporates appropriate indexes on key fields. Indexing accelerates data retrieval operations by facilitating quick access to specific records, especially in scenarios involving large datasets.

Optimization: The schema design incorporates optimization strategies to streamline database operations and enhance overall system performance. Techniques such as query optimization, caching, and resource allocation are

employed to mitigate bottlenecks and ensure optimal resource utilization.

7.3.7 Logging

Logging plays a crucial role in monitoring and troubleshooting the backend operations of the locker system. By capturing relevant information during runtime, logging enables developers to track system behavior, identify errors, and analyze performance metrics.

Logging Implementation: The backend API incorporates logging functionality to record significant events and activities. The Python logging module provides a flexible framework for logging messages of varying severity levels to different destinations, including files, streams, or external services.

Example: Consider the following function for creating a booking within the locker system:

```
1 def create_booking(schema: BookingCreateSchema, db:
    Session):
2     entity = Booking(**schema.dict())
3     entity.pin = random.randint(1000, 9999)
4     logging.info('Booking created with id {}'.format(
        entity.id))
5     db.add(entity)
6     db.commit()
7     return entity
```

In this example, the `create_booking` function creates a new booking entity based on the provided schema. After generating a random PIN for the booking, the function logs a message indicating the successful creation of the booking along with its ID. This logging statement provides valuable insights into the system's activity and facilitates debugging and auditing processes.

7.3.8 Areas for Improvement

While the backend implementation of the locker system prototype adheres to common best practices, several areas require further attention and refinement before the system can be considered production-ready:

- **Error Handling:** The current implementation lacks comprehensive error handling mechanisms, which are essential for gracefully managing unexpected scenarios and providing informative feedback to users. For example, enhancing error responses with appropriate status codes and error messages would improve the system's robustness.
- **Infrastructure:** The prototype operates in a development environment and lacks the infrastructure necessary for deployment in a production setting. Implementing scalable infrastructure components, such as load balancers, auto-scaling groups, and fault-tolerant databases, is crucial for ensuring system reliability and performance under varying workloads.
- **Validation:** While basic input validation is incorporated into the API endpoints, there is room for strengthening validation logic to enforce data integrity and prevent malicious inputs. Implementing robust validation mechanisms, such as input sanitization and parameter validation, would enhance the security and reliability of the system.
- **Security:** Security measures, including authentication, authorization, and data encryption, are fundamental requirements for safeguarding sensitive information and protecting the system against security threats. Implementing authentication mechanisms, role-based access control (RBAC), and encryption protocols would mitigate security risks and enhance the system's trustworthiness.

Addressing these areas of improvement would contribute to the development of a robust, secure, and scalable backend system for the locker application.

7.4 Arduino

Written by: Felix

7.5 Arduino Implementation

This document presents a comprehensive overview of the Arduino implementation, encompassing essential setup instructions, required libraries, a detailed flow chart elucidating the use case, a comprehensive sensor overview, and a schematic representation using Fritzing. Through this structured presentation, readers will gain a robust understanding of the technical components and operational procedures integral to this Arduino-based project.

7.5.1 Arduino Setup

The Arduino **ARDUINO UNO WiFi REV2** [3] component of the locker system project is developed using Arduino IDE version 2.3.2 [4]. This development environment ensures a streamlined workflow, particularly when the Arduino is connected via USB, with logs displayed within the IDE's Terminal.

To set up the Arduino for this project, follow these steps:

1. **Cloning the Arduino Repository:** Begin by cloning the Arduino repository referenced in the project documentation [5].
2. **Wiring the Cables:** Refer to the Fritzing diagram provided in Section 7.5.5 Figure 13 to correctly wire the components for the Arduino setup.
3. **Downloading Required Libraries:** Utilize the Arduino IDE specified in Section 7.5.2 to download and integrate the necessary libraries into your project.

4. **Configuring WiFi Connection:** Update the WiFi credentials within the Arduino sketch as illustrated below:

```
1 // WiFi Configuration
2 #include <WiFiNINA.h>
3 char ssid[] = "YOUR_SSID";
4 char wifi_password[] = "YOUR_PASSWORD";
5
```

Listing 1: WiFi Configuration in Arduino Sketch

Replace `YOUR_SSID` and `YOUR_PASSWORD` with your WiFi network name (SSID) and password.

5. **Creating a ThingSpeak Channel for Data Monitoring:** To monitor the wattage data from the sensors, you need to create a ThingSpeak channel online. This channel will serve as a platform to collect and visualize the sensor data in real-time. Obtain the Channel ID and Write API Key for your ThingSpeak channel.

Include the following code snippet in your Arduino sketch to interface with ThingSpeak:

```
1 // ThingSpeak Configuration
2 #include "ThingSpeak.h"
3 unsigned long smart_room_channel_number =
YOUR_CHANNEL_NUMBER; // ThingSpeak Channel
Number
4 const char* write_API_KEY = "YOUR_WRITE_API_KEY"
; // ThingSpeak Write API Key
5
```

Listing 2: ThingSpeak Configuration in Arduino Sketch

Replace `smart_room_channel_number` and `write_API_KEY` with your specific ThingSpeak channel number and Write API Key.

6. **Setting up your Voltage:** Ensuring the correct voltage configuration is essential for accurate wattage measurements, as it directly impacts the output of electrical equations.

To determine the appropriate voltage settings for your Arduino project, consult international standards or local electrical regulations to identify the correct voltage rating for your power grid, which can be found here [\[6\]](#)

```
1 // Setting up Voltage for Power Grid
2 int voltage = 220; // Default Voltage for Power
  Grid (in volts)
3
```

Listing 3: Setting Voltage in Arduino Sketch

In the provided Arduino sketch code snippet, the ‘voltage’ variable is initialized with a default value of 220 volts, which is commonly used in many regions. Modify this value according to the specific voltage rating of your local power grid to ensure accurate readings and safe operation of your voltage monitoring system.

After setting up the development environment and configuring the Arduino, proceed with starting the Arduino. The LCD display will provide real-time status updates or prompts, such as commands to close the door. The Arduino initializes in a consistent state upon startup.

Ensure adherence to this structured approach to establish a reliable and functional Arduino setup for the locker system project.

7.5.2 List of Important Libraries and Versions

The following list includes the most important libraries used in the Arduino implementation along with their versions:

- **Servo** by Michael Margolis, Arduino 1.2.1 (Servo Motor)
Controls the movement of servos for locking and unlocking the locker door.
- **Grove - LCD RGB Backlight** by Seeed Studio 1.0.0 (Display LCD)
Displays information and status messages on the locker system interface.
- **ArduinoJson** by Benoit Blanchon 7.0.4
Parses and manipulates JSON data for communication and data exchange.
- **WifiNINA** by Arduino 1.8.14
Enables Wi-Fi connectivity for accessing online services (FastAPI) and remote monitoring (ThingSpeak).
- **Keypad** by Mark Stanley, Alexander Brevig 3.1.1 (Keypad)
Allows user input for password authentication and interaction with the locker system.
- **ThingSpeak** by MathWorks 2.0.1
Sends sensor data to ThingSpeak for real-time monitoring and visualization.

7.5.3 Flow Chart

In this section, we provide a detailed flow chart illustrating the step-by-step process of utilizing our locker system for charging or renting items. The flow chart serves as a visual guide to clarify the functionality of our product, outlining the precise sequence of actions required to either charge your item securely within our lockers or efficiently rent an item from our locker device. This visual representation will enhance your understanding of how our innovative locker system operates, ensuring a seamless and user-friendly experience for our customers. Let's delve into the flow chart to explore the intricacies of our product functionality.

Figure 7: Flow chart for charging or renting items

7.5.4 Sensors Overview

1. Keypad

Reference: Tutorial available at [\[7\]](#)

Purpose: The keypad allows user input for controlling and interacting with the Arduino locker system. It enables entering the PIN code or commands like # for starting to enter the password or * for confirming the password, to operate the system securely.

Functionality: The Arduino interprets the key presses from the keypad matrix and executes corresponding actions based on the input received.

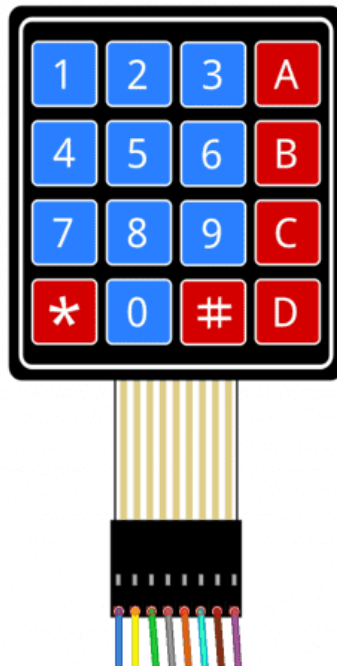


Figure 8: Keypad

2. LCD-Screen

Reference: Details available at [\[8\]](#)

Purpose: The LCD screen displays real-time information and system status to users, providing visual feedback about the locker system's operation.

Functionality: The Arduino sends commands to the LCD screen to display text and graphics, enhancing user interaction and system monitoring capabilities.



Figure 9: LCD Screen

3. Current Sensor

Reference: Follow this [\[9\]](#) for implementation details

Purpose: The current sensor measures electrical current flowing through a circuit, enabling monitoring of power consumption and detecting anomalies.

Functionality: The Arduino reads analog voltage signals from the current sensor to calculate current values, which can be used for power management and safety monitoring.



Figure 10: Current Sensor

4. Door Sensor

Reference: Learn more about Arduino door sensors from this [\[10\]](#)

Purpose: The door sensor detects the state (open or closed) of the locker door, providing security and triggering actions based on door status changes.

Functionality: The Arduino reads digital signals from the door sensor to determine the door's position and reacts accordingly, such as activating the locking mechanism.

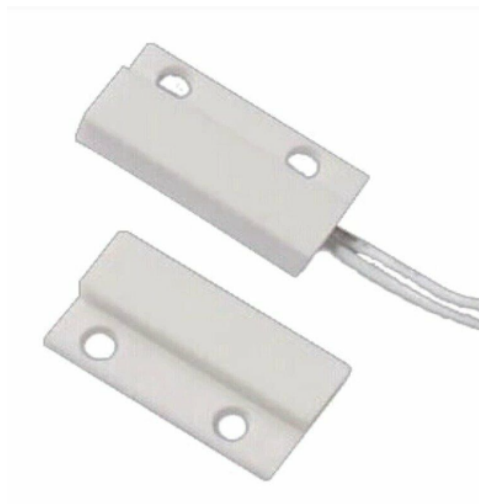


Figure 11: Door Sensor

5. Servo Motor

Reference: Tutorial available at [\[11\]](#)

Purpose: The servo motor controls the mechanical movement of the locker's locking mechanism, enabling remote operation and automation.

Functionality: The Arduino sends PWM signals to the servo motor to position it at specific angles, allowing precise control over the locking and unlocking of the locker.



Figure 12: Servo Motor

7.5.5 Fritzing

The image depicted in Figure 13 illustrates the correct arrangement and connections of cables and components required for setting up the Arduino system as described in this guide. This visual guide, created using Fritzing software, provides a clear representation of how to wire the Arduino board with various sensors and peripherals. Referencing this diagram will ensure accurate implementation of the hardware setup outlined in the instructions.

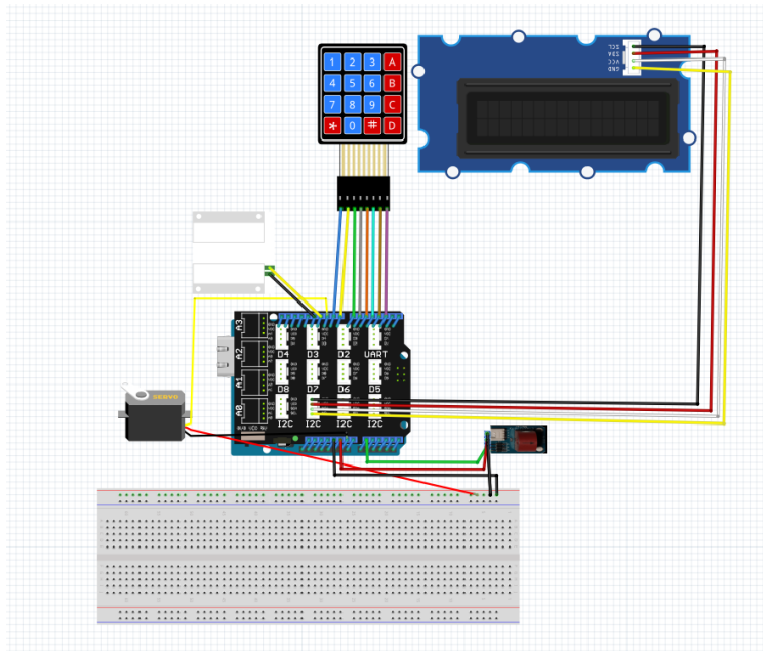


Figure 13: Arduino Fritzing setup

7.5.6 Areas for Improvement

While the backend implementation of the locker system prototype adheres to common best practices, several areas require further attention and refinement before the system can be considered production-ready:

- **Error Handling:** The current implementation lacks comprehensive error handling mechanisms, which are essential for gracefully managing unexpected scenarios and providing informative feedback to users. For example, enhancing error responses with appropriate status codes and error messages would improve the system's robustness.
- **Infrastructure:** The prototype operates in a development environment and lacks the infrastructure necessary for deployment in a production setting. Implementing scalable infrastructure components, such as load balancers, auto-scaling groups, and fault-tolerant databases, is crucial for ensuring system reliability and performance under varying workloads.
- **Validation:** While basic input validation is incorporated into the API endpoints, there is room for strengthening validation logic to enforce data integrity and prevent malicious inputs. Implementing robust validation mechanisms, such as input sanitization and parameter validation, would enhance the security and reliability of the system.
- **Security:** Security measures, including authentication, authorization, and data encryption, are fundamental requirements for safeguarding sensitive information and protecting the system against security threats. Implementing authentication mechanisms, role-based access control (RBAC), and encryption protocols would mitigate security risks and enhance the system's trustworthiness.

Addressing these areas of improvement would contribute to the development of a robust, secure, and scalable backend system for the locker application.

8 Testing / Evaluation (Ting)

1. how did we test?
2. what did we test?
3. evaluation of test results

9 Reflection and Lessons Learned

9.1 Successes and Effective Practices

Reflecting on the international project to develop a locker system for universities, several valuable lessons were learned throughout the course of the project. These reflections encompass both the successes achieved and areas for improvement, providing insights that would guide future projects.

9.1.1 Successes and Effective Practices

Overall, the project concluded with a very satisfactory outcome for us, despite the challenges posed by the tight deadline. Key factors contributing to the success of the project include:

- **Effective Communication:** Maintaining open and regular communication channels proved to be indispensable. Through platforms such as WhatsApp and Discord, along with bi-weekly meetings, team members remained well-informed about project progress and tasks.
- **Positive Team Dynamics:** The cohesive spirit within the team fostered a supportive environment where members readily assisted each other. This collaborative ethos not only enhanced productivity but also facilitated mutual learning and skill development.
- **Utilization of Kanban Board:** Adopting a Kanban board for task organization proved invaluable in visualizing workflow and tracking individual and collective progress. The transparency afforded by this tool promoted accountability and facilitated efficient task allocation.
- **Adaptability to Remote Work:** Despite a preference for face-to-face collaboration, the team demonstrated adaptability in transition-

ing to online work modes when necessary. Effective utilization of online collaboration tools enabled seamless remote teamwork.

- **Skill Integration through Pair Programming:** Pair programming is a collaborative development technique where two programmers work together at one workstation. One programmer, known as the "driver," writes the code, while the other, the "navigator," reviews each line as it's typed. This approach encourages constant communication, instant feedback, and shared problem-solving.

Pair programming was the right tool for our team for several reasons. Firstly, it facilitated knowledge sharing among team members with different expertise levels. Pairing individuals allowed for the transfer of skills and knowledge in real-time, fostering a supportive environment where team members could learn from each other's experiences.

Moreover, pair programming promoted a deeper understanding of the codebase and project requirements. The constant dialogue between the driver and navigator ensured that code was thoroughly reviewed as it was written, reducing the likelihood of errors and enhancing overall code quality. Additionally, pairing individuals with varying skill levels encouraged less experienced team members to contribute actively while receiving guidance and mentorship from more experienced team members.

9.2 Areas for Improvement and Lessons Learned

While the project yielded very good results, several areas were identified for improvement, along with valuable lessons learned for future projects:

- **Investment in Quality Components:** An incident involving the malfunction of inexpensive Arduino components underscored the importance of investing in quality hardware. In future projects, buying

higher-quality components would mitigate risks of hardware failures and enhance system reliability.

- **Consideration of Hosting Platforms:** Initially opting for Amazon Web Services (AWS) for hosting, the project encountered unexpected costs associated with certain AWS components. Subsequently transitioning to Google Cloud required additional effort but provided valuable exposure to alternative cloud platforms.
- **Consolidation of API Documentation:** We generated API documentation in two separate documents, this led to discrepancies and minor bugs. Consolidating all API documentation into a single source of truth would streamline development processes and ensure consistency across the project.

In conclusion, the international project to develop a locker system for universities provided invaluable learning experiences and insights. While celebrating the successes achieved, it is important to acknowledge areas for improvement and incorporate lessons learned into future projects.

10 Next steps / Outlook

This chapter presents the next steps of our project and explores possibilities for enhancement with additional time and resources. We will outline specific options and solutions to optimize and advance project outcomes. Through this exploration, we aim to maximize the full potential of our project for maximum impact and success.

10.1 Expanding from One Locker Prototype to Locker Systems

Currently, our system features a single locker prototype designed to demonstrate the functionality and implementation of our technology. This prototype serves as a proof of concept for showcasing our capabilities.

Moving forward, our objective is to scale our system by implementing a comprehensive locker system with customizable configurations to meet diverse needs. For example:

- **Thinner Lockers for Laptops:** We plan to introduce lockers with wider compartments suitable for securely storing laptops and larger electronic devices.
- **Smaller Lockers for Phones and Small Items:** Additionally, we aim to offer compact lockers designed specifically for storing mobile phones, wallets, keys, and other smaller items.
- **Variable Compartment Sizes:** Our locker system will feature adjustable compartment sizes to accommodate various items, providing flexibility for different storage requirements.

This transition from a single prototype to a versatile locker system infrastructure represents a significant advancement in our capabilities. It enables

us to cater to a wide range of applications, including secure storage solutions tailored to specific customer needs and use cases.

10.2 Real-time Charging Level Monitoring

The current approach involves utilizing an Arduino Current Power Sensor to measure the current amperage flowing into the device, enabling determination of the charging status and current amperage. This method provides basic charging information but lacks insight into the battery's state of charge.

To enhance this system, our objective is to implement a more sophisticated feature that enables real-time monitoring of the device's charging percentage. This enhancement aims to facilitate smart and sustainable charging practices to mitigate premature battery degradation.

10.3 Implementation of QR Codes for Streamlined Inventory Management

Currently, the inventory management system relies on manual entry through an administrative interface, where item parameters must be manually inputted to add items to the system. Searching for specific items within the database requires querying by ID, name, or other attributes.

Our proposed approach involves transitioning to a QR code-based system, where each item is assigned a unique QR code identifier. This implementation aims to simplify inventory management by enabling rapid item identification through QR code scanning, streamlining the process for administrators to locate and manage items within the system.

10.4 Scheduled Maintenance Protocol

As our system continues to grow and evolve, particularly with the increasing complexity of our inventory management, we recognize the critical importance of ensuring reliability and performance. To achieve this, we are dedicated to establishing a structured and scheduled maintenance protocol. This protocol will enable us to proactively manage maintenance activities, optimize asset performance, and minimize unplanned downtime, specifically targeting our inventory items. By implementing this approach, we aim to enhance overall system reliability, support scalability, and ensure the continuous functionality and efficiency of our inventory management processes as we expand.

10.5 Automated Reservation System

Currently, our system allows users to book available items for immediate pickup. However, as we look to enhance and optimize our project outcomes, we are planning to implement an automated reservation system.

The objective of this enhancement is to enable users to reserve specific items in advance for a designated time slot. This functionality will provide users with greater flexibility and convenience, allowing them to plan ahead and secure items for their desired usage window.

Key features of the automated reservation system will include:

- **Advanced Booking:** Users will be able to browse available inventory and reserve items for future pickup, specifying the desired date and time for collection.
- **Real-time Availability:** The system will display real-time availability status, indicating whether an item is currently reserved or available for booking.

- **Notification System:** Users will receive automated notifications confirming their reservation and reminding them of the pickup time.
- **Cancellation and Modification:** Users will have the ability to modify or cancel reservations within a specified timeframe, ensuring flexibility and efficient management of resources.

Implementing an automated reservation system aligns with our goal to maximize the full potential of our project. It will enhance user experience, optimize resource allocation, and streamline operational efficiency by enabling structured and pre-planned item pickups. This evolution will contribute significantly to the scalability and effectiveness of our inventory management solutions.

11 Summary Ifdi

12 Append

Appendix

References

- [1] A. Einstein, “On the electrodynamics of moving bodies,” *Annalen der Physik*, vol. 17, no. 10, pp. 891–921, 1905.
- [2] C. Samiullah, “Ultimate fastapi tutorial pt.7: Sqlalchemy database setup.” <https://christophergs.com/tutorials/ultimate-fastapi-tutorial-pt-7-sqlalchemy-database-setup/>, 2022. Accessed: 2024-05-09.
- [3] Arduino, “Arduino uno wifi rev2.” <https://store.arduino.cc/products/arduino-uno-wifi-rev2>, 2024. Accessed on May 10, 2024.
- [4] A. Software, “Arduino software.” <https://www.arduino.cc/en/software>. Accessed: May 10, 2024.
- [5] F. Huther, “Arduino inventory database project.” https://github.com/slepp22/inventory_database_arduino, 2024.
- [6] Recreational Equipment, Inc., “World electricity guide.” <https://www.rei.com/learn/expert-advice/world-electricity-guide.html>, Accessed in 2024. Accessed on May 10, 2024.
- [7] “Keypad library tutorial.” <https://www.circuitbasics.com/how-to-set-up-a-keypad-on-an-arduino/>. Accessed on May 10, 2024.
- [8] Seeed Studio, “Grove - lcd rgb backlight.” https://wiki.seeedstudio.com/Grove-LCD_RGB_Backlight/, Accessed in 2024. Accessed on May 10, 2024.
- [9] “Arduino current sensor tutorial.” <https://www.aeq-web.com/arduino-current-sensor-power-electricity-meter/>. Accessed on May 10, 2024.

- [10] “Arduino door sensor tutorial.” <https://arduinogetstarted.com/tutorials/arduino-door-sensor>. Accessed on May 10, 2024.
- [11] Arduino Uno Guy, “The beginner’s guide to micro servos.” https://projecthub.arduino.cc/arduino_uno_guy/the-beginners-guide-to-micro-servos-ae2a30, Accessed in 2024. Accessed on May 10, 2024.