TASK

Software Design

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Introduction

WELCOME TO THE SOFTWARE DESIGN TASK!

In this task we are going to introduce you to some of the most useful techniques used for designing object-oriented software systems and reducing the complexity of the process. We are going to work through the following diagrams and techniques:

- Class diagrams
- Sequence diagrams
- Separation of concerns
- Use case analysis
- CRUD matrices

Let’s dive in!

MODULARISATION

Modularisation involves breaking down complex systems into independent, interchangeable, and self-contained modules. These modules, or components, can function autonomously, contributing to the overall system's functionality. One of the key advantages of modularisation is its ability to enhance development efficiency, code reusability, and collaboration among developers.

In the realm of applications, this modular approach becomes especially valuable. Applications often undergo rapid changes, updates, and improvements to meet evolving user needs and take advantage of technological advancements. Modularisation allows for the swift removal and replacement of specific modules without disrupting the entire system. This adaptability is crucial in dynamic environments where quick adjustments are required to keep pace with market demands or to address emerging issues.

Furthermore, the ability to reuse modules across different applications can significantly streamline the development process. Developers can leverage existing, well-tested modules, saving time and effort by avoiding the need to recreate functionality from scratch. This not only accelerates development timelines but also contributes to a more consistent and reliable codebase.

In summary, modularisation's strength lies not only in its ability to decompose complexity and enhance collaboration but also in its support for the agile development of applications. The rapid removal, replacement, and reuse of modules empower developers to respond swiftly to changing requirements, ensuring that applications remain adaptable and resilient in a dynamic technological landscape.

KEY PRINCIPLES OF MODULARISATION

Independence: Modules (self-contained units such as functions or classes) should operate independently, minimising dependencies on other components. This independence facilitates easier testing, maintenance, and updates.

Interchangeability: Modules should be interchangeable (such as a Database Connector Module) allowing developers to replace or upgrade one module without affecting the entire system. This flexibility is crucial for system evolution.

Reusability: Design modules with a focus on reusability. A well-designed module (such as the print function) can be applied in different parts of a system or even in entirely different projects, saving development time and effort.

Encapsulation: Each module should encapsulate a specific functionality, (such as user authentication) hiding its internal workings. This encapsulation promotes a clear understanding of each module's purpose without delving into the intricacies of its implementation.

Scalability: Modular design supports scalability by enabling the addition or removal of modules to accommodate changes in system requirements (consider a web server). This adaptability is essential for systems that may evolve.

WHAT DOES MODULARISED SOFTWARE DESIGN LOOK LIKE?

In practical terms, modular design involves creating distinct, independent components within a system. These components communicate through well-defined interfaces (think of an interface as a socket through which your program can plug into), allowing seamless interaction. Let's explore a generic example.

Example: A building automation system

Consider a building automation system that controls heating, ventilation, air conditioning (HVAC), and lighting. In a modular design approach, we would have a module for each aspect:

Temperature control module:

- Responsible for monitoring and controlling the HVAC system
- Independent functionalities include temperature sensing, fan control, and temperature adjustment

Lighting control module:

- Manages the lighting system based on occupancy and time of day
- Independent functionalities include occupancy sensing, light intensity adjustment, and scheduling

Security module:

- Deals with security aspects such as access control and surveillance
- Independent functionalities include door access management, camera control, and alarm systems

Communication interface:

- Acts as a central communication hub
- Independent functionalities include data transmission between modules, error handling, and system-wide notifications

Each module operates independently, focusing on a specific aspect of the building automation system. This modular approach enhances the system's maintainability, flexibility, and overall robustness.

ADVANTAGES OF MODULAR DESIGN

Ease of maintenance: Isolating functionalities into modules makes it easier to locate, fix, or update specific parts of the system without affecting the entire codebase. This modularity not only streamlines the debugging process but also facilitates collaboration among developers, as each module can be assigned to different team members for efficient maintenance. Additionally, modular code promotes code reusability, reducing the need for redundant coding efforts and ensuring that updates or fixes applied to one module can be easily propagated throughout the system, enhancing the overall maintainability of the software.

Enhanced reusability: Enhanced reusability: Well-designed modules can be reused in different projects, promoting efficiency and consistency in software development. This not only accelerates the development process but also ensures that proven and reliable components are employed across various applications. The ability to reuse modules fosters a standardised approach to coding, leading to a more cohesive and maintainable codebase. Moreover, developers can leverage existing modules, saving time and effort, while also minimising the risk of introducing new bugs, as the reused components have already undergone testing and validation in previous projects.

Improved collaboration: Developers can work on different modules concurrently, fostering collaboration and accelerating the development process. This concurrent development approach allows teams to divide the workload efficiently, with each member focusing on specific modules. Regular communication and integration of individual modules ensure that the overall project progresses smoothly. Additionally, improved collaboration is not limited to just the development phase; it extends to maintenance and updates as well. Teams can independently address issues in their assigned modules, enhancing agility and responsiveness to evolving project requirements. This collaborative model promotes a more dynamic and efficient software development lifecycle.

Scalability: As system requirements evolve, additional modules can be integrated or existing ones replaced, ensuring the system remains adaptable. This adaptability is a cornerstone of scalability, allowing the software to grow efficiently in response to increased demand or expanded functionalities. The modular design facilitates the seamless integration of new modules to handle increased workloads or expanded user bases. Whether it's accommodating a growing number of users, handling increased data volumes, or supporting additional features, the scalability inherent in modular systems ensures that the software can scale up or down as needed without a complete overhaul. This ability to scale is essential for both current and future requirements, providing a robust foundation for the long-term viability of the system.

Simplified testing: Testing individual modules in isolation simplifies the debugging and testing process, ensuring each component functions as intended. This focused testing approach allows developers to identify and address issues within specific modules without the complexity of testing the entire system at once. It not only streamlines the debugging process but also enhances the overall reliability of the software by enabling thorough testing of each module's functionality independently. Additionally, simplified testing accelerates the development lifecycle, as developers can quickly identify and rectify issues within specific modules before integration. This modular testing strategy contributes to a more robust and error-resistant software system, ultimately improving the quality of the final product.

Summary

By adhering to modular design principles, software engineers create systems that are robust, adaptable, and conducive to collaborative development. This design philosophy promotes the creation of independent and reusable modules, each responsible for a specific functionality. The modularity enhances the system's robustness by containing errors within isolated modules, preventing them from affecting the entire system. Moreover, adaptability stems from the ease with which new modules can be added or existing ones replaced, ensuring the software can evolve to meet changing requirements.

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WHAT IS USE CASE ANALYSIS?

Use case analysis is a vital software engineering technique aimed at comprehensively defining and explaining how users interact with a system to accomplish specific objectives. This method captures real-world workflows and requirements, employing use case analysis diagrams to visually map plausible user-system interactions. These diagrams offer a high-level overview illustration of the functionalities users can engage within the system.

The significance of use case analysis lies in its role as a valuable tool for discussions about stakeholder needs, identification of edge cases, and planning rigorous tests to ensure that the coded system delivers the required behaviours. In essence, use case analysis serves as a facilitative tool, guiding us in exploring how users will utilise a system. The resulting use case analysis diagrams provide a visual model that aids in aligning and planning the development process effectively.

USE CASE ANALYSIS DIAGRAM COMPONENTS

A use case analysis diagram represents the interactions between **actors** (**users** or **external systems**) and the web application. It helps us to visualise and understand how different actors interact with the system through various use cases. Let's look at some of the components used to construct use case diagrams.

Actors:

- **Users:** Actors represent entities outside the system that interact with it. Actors can be categorised into different roles, each having distinct interactions with the application. For instance, administrators, registered users, and anonymous visitors are common actor types.

- **External systems:** Other systems or services that interact with the application, such as third-party APIs or databases.

Use cases: Use cases describe specific functionalities or tasks that actors can perform within the system. Each use case should be focused on a single action. Use cases often align with specific views or functions, such as user authentication or data manipulation. Examples of use cases in an application could include user authentication, data submission, and content retrieval.

System boundary: The system boundary defines the scope of the application, encapsulating all actors and use cases. It helps establish a clear delineation between the internal components of the application and external entities.

Relationships between use cases:

- **Association:** Associations represent relationships between actors and use cases. They show which actors are involved in each use case. This might indicate which types of users are associated with specific actions, such as administrators managing user accounts.
- **Dependency:** Dependencies show the relationships between different use cases. For instance, one use case may depend on the successful completion of another. This could represent dependencies between user authentication and access to specific features.
- **Generalisation:** Generalisation represents inheritance relationships between use cases. It's particularly relevant when different types of users share common functionalities. For example, both administrators and regular users might share the use case of adding tasks to a to-do list.

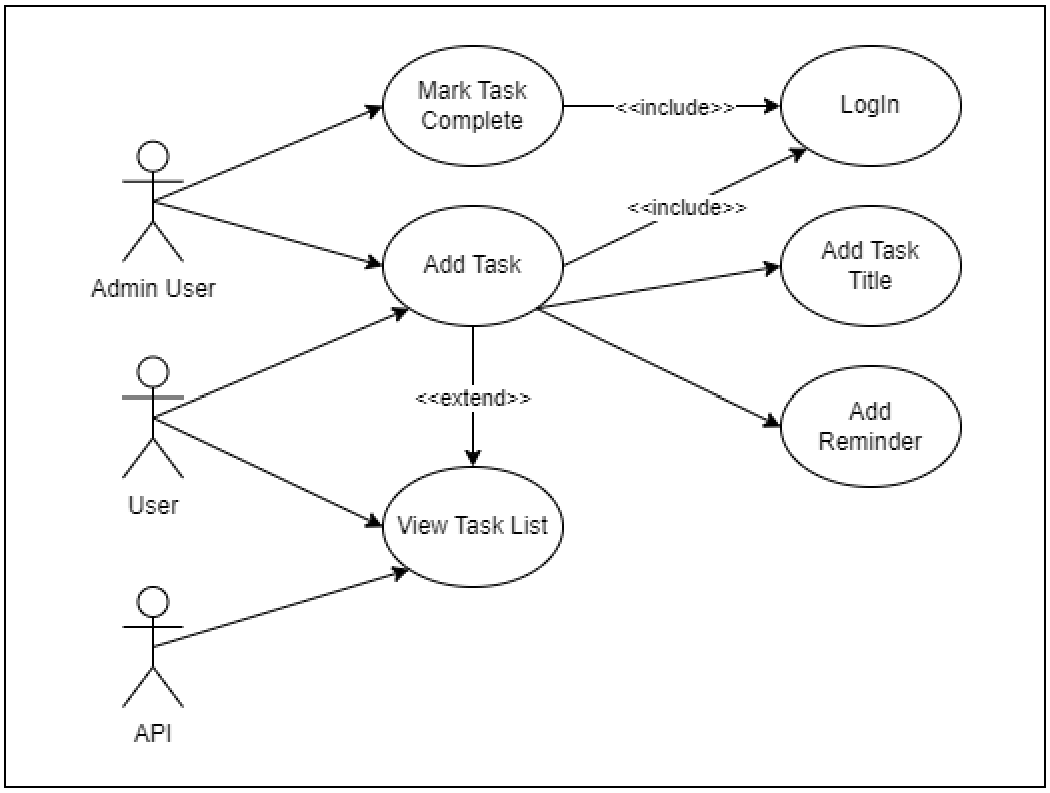
Include and extend relationships:

- **Include relationship:** "Include" relationships indicate that one use case includes the functionality of another. This could be seen when a higher-level use case, like "Manage Tasks," includes lower-level functionalities like "Add Task" and "Mark Task as Completed."

- **Extend relationship:** "Extend" relationships represent optional or conditional behaviour. This might be illustrated when a use case for adding a task can be extended with optional features like setting reminders or attaching files.

- **System controller (optional):** The system controller represents the mechanism or component responsible for coordinating the flow of information between actors and the application. This often corresponds to views (components within a system that are responsible for specific functions related to user interaction and application functionality), which handle user requests, process data, and manage the application's response.

Here's a simplified example:



In this diagram, you would further detail each use case with specific actions and interactions within the application. The relationships and actors would depend on the specific functionalities and requirements of your project.

WHAT IS A SEQUENCE DIAGRAM?

Sequence diagrams are a type of interaction diagram in **UML** (**unified modeling language**) that visually represents the chronological flow of messages and interactions among different components or objects in a system. These diagrams are particularly useful for illustrating the dynamic aspects of a system, showcasing how various entities collaborate over time to achieve a specific functionality or respond to an event.

In a sequence diagram, the participants, which can be objects or components, are depicted as vertical lifelines. The timeline runs horizontally, representing the progression of time from top to bottom. Arrows and messages between the lifelines illustrate the order and nature of interactions, showcasing the exchange of information or calls between different parts of the system.

Key elements of sequence diagrams include:

- **Lifelines:** Vertical lines representing the entities involved in the sequence. Each lifeline corresponds to an object or component *(user, view, database)*.
- **Messages:** Arrows indicating the flow of communication between lifelines. Messages can be synchronous *(denoted by solid arrows)* or asynchronous *(denoted by dashed arrows)*, depending on whether they occur in a blocking or non-blocking manner.
- **Activation bars:** Rectangular vertical boxes along a lifeline that represent the duration of time during which an object is active or performing a task.

Sequence diagrams are valuable tools for understanding and documenting the dynamic behaviour of a system. They aid in visualising the order of interactions, identifying potential bottlenecks, and ensuring that the system behaves as intended during different scenarios. These diagrams are particularly helpful in the design and communication phases of software development, providing a clear and concise way to illustrate the flow of control and communication between system components.

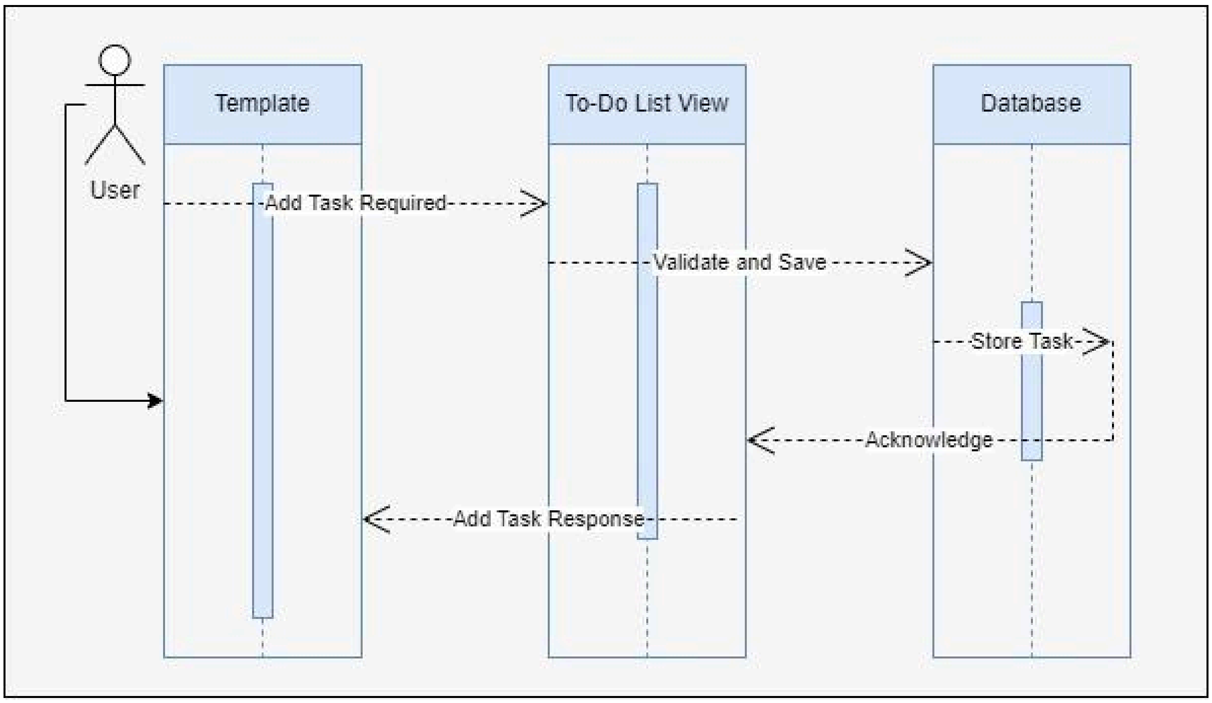
SEQUENCE DIAGRAM COMPONENTS

A **sequence diagram** represents the flow of interactions between different components or objects over time. It is particularly useful for illustrating the chronological order of messages exchanged between different parts of an application during a specific process or scenario.

Actors/Objects:

- **Users:** Represented as the initiator of the sequence, sending a message to add a task.
- **Views/Controllers:** Components that handle incoming requests and coordinate the flow of data and logic.
- **Models:** Representations of the application's software entities and business logic.
- **Templates:** Views responsible for rendering HTML and presenting data to users.
- **External systems:** Other systems or services that the application interacts with, such as databases, external APIs, etc.
- **Lifelines:** Lifelines represent the different participants (actors, components) in the sequence diagram. Each lifeline corresponds to a participant involved in the sequence of interactions.
- **Messages:** Messages depict the communication between lifelines. Messages could be HTTP requests, function calls, or any other communication between components. Messages can be synchronous or asynchronous.
- **Activation bar:** Activation bars represent the period during which a lifeline is active or engaged in processing a message. They show the duration of the interaction for a particular lifeline.
- **Return messages:** Return messages show the response or data flow back from the recipient to the sender.
- **System boundary:** Similar to what we did with the use case analysis diagram, you might include a system boundary to illustrate the scope of the application.

- Here's a simplified example of a sequence diagram for adding a task to a web application:



In this example, the sequence diagram shows the flow of messages between the user, the view, and the database during the authentication and profile rendering process. Each arrow represents a message, and the activation bars show when each component is actively processing the message.

The "Template” lifeline has an activation bar extending from the moment it initiates the "Add Task Request" message until it receives the "Add Task Response" message.

The "To-Do List View" lifeline has an activation bar that starts when it receives the "Add Task Request" message and continues through the "Validate and Save" process, ending after it sends the "Add Task Response" message to the user.

The "Database" lifeline has an activation bar starting when it receives the "Store Task" message and ending after it sends the acknowledgement back to the To-Do List View.

SEPARATION OF CONCERNS

Creating a web application involves more than just coding features – developers also bear important responsibilities around ethical design, quality assurance, and planning for long-term sustainability. At the forefront are security and privacy considerations, ensuring user data is handled safely and only in ways they have consented to. Accessibility standards must also be upheld so those with disabilities can effectively use the app.

Performance tuning through efficient algorithms and cloud infrastructure is key for responsiveness. Architecting a clean, well-documented codebase makes adding features and fixing bugs much easier down the road. Following platform best practices helps manage issues before they snowball. While balancing all these technical and social responsibilities adds complexity, prioritising users and system health leads to more robust and equitably useful applications. By proactively addressing areas of concern, web developers can focus on innovation while creating trust. Let's consider these concepts in the context of our modular design approach to building a web app.

The responsibilities and concerns are effectively distributed across various components. Models define the software entities and encapsulate business logic and interactions with the database. Views manage presentation logic and shape the visual presentation This modular approach, following the Model-view-controller (MVC) pattern, enhances code organisation, maintainability, and collaboration.

MVC is a design pattern commonly used in software development to organise code and separate concerns within an application. It is a conceptual framework that divides the application into three interconnected components: models, views, and controllers. Let's take a closer look at these components.

Models:

- **Definition:** Models represent the application's software entities and business logic. They encapsulate the data and define the rules and operations for manipulating that data.

- **Responsibilities:**
  - Receive data from the controller, process it, and return the result.
  - Implement business logic related to the manipulation and processing of data.

- **Example (in the context of a to-do list application):**
  - Define the Task model to represent tasks with attributes such as title, description, and completion status

Views:

- **Definition:** Views are responsible for presenting the application's data to the user and receiving user input. Controllers render views using models.

- **Responsibilities:**
    - Handle user interface elements and interactions.
    - Interact with the models for data retrieval and modification.
    - Return appropriate responses, often by rendering templates.

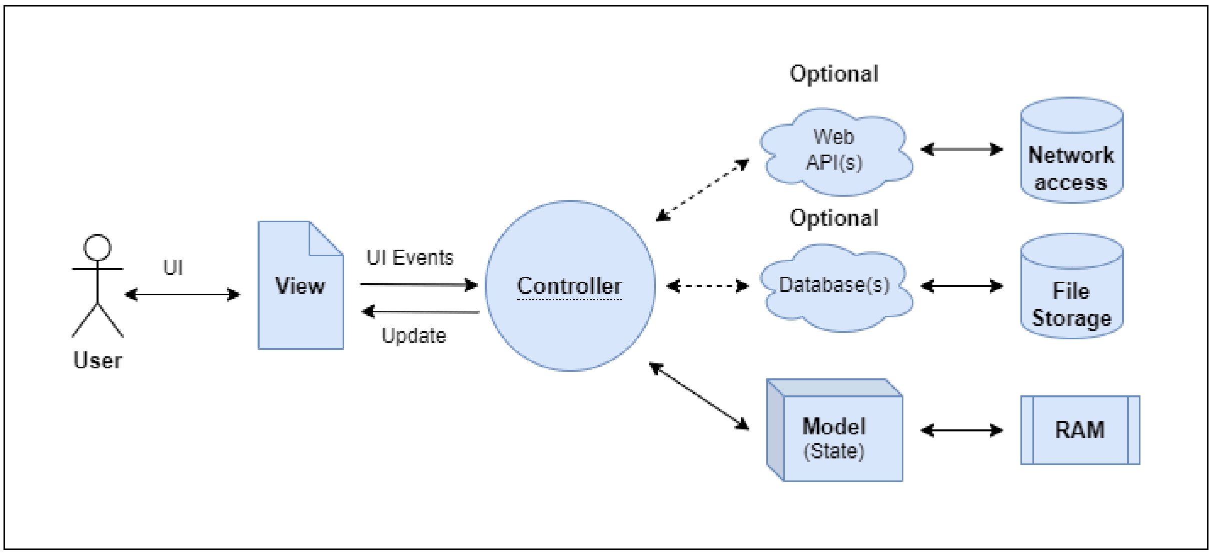
- **Example (in the context of a to-do list application):**
    - Displaying a task list
    - Accepting commands from the user to add tasks to the task list..

Controllers:

- **Definition:** Controllers act as intermediaries between the models and views. They receive user input from the views, interact with the models to process that input, and update the views accordingly.

- **Responsibilities:**
    - Handle user input and invoke corresponding actions on the models.
    - Update views based on changes in the models.

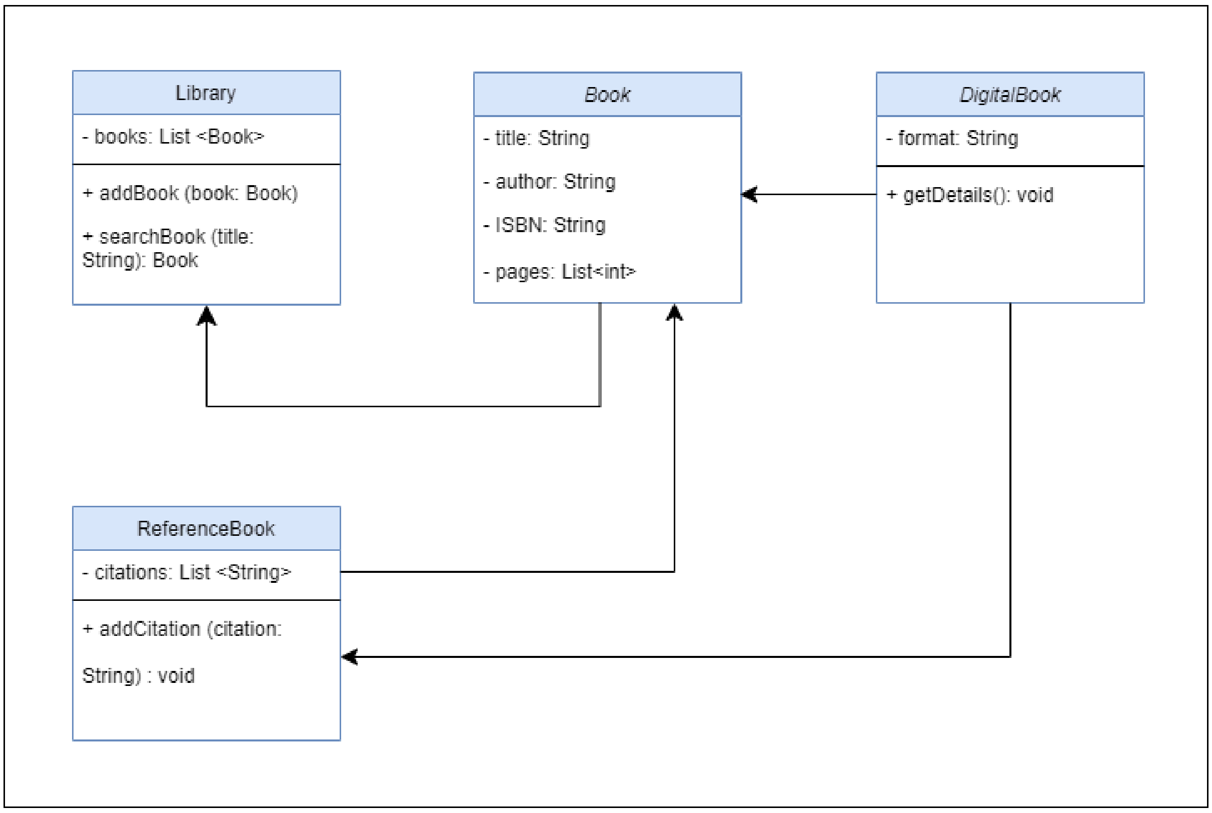
- **Example (in the context of a to-do list application):**
    - Handle user requests to add or delete tasks, and update the task list accordingly.



Understanding and appropriately managing these responsibilities and concerns in their respective components helps in building a well-organised, modular, and maintainable application. This separation of concerns is a fundamental principle in software design and contributes to the overall robustness and scalability of the application.

CLASS DIAGRAMS

A class diagram serves as a visual representation of the static structure within an application, illustrating classes, their attributes, and the relationships existing among them. To enhance the illustrative depth of the diagram, we aim to incorporate elements and details, such as relationships between classes, Inheritance hierarchies, and attributes.



Here's a breakdown of the classes:

Book class

Attributes:

- title: String (private)
- author: String (private)
- ISBN: String (private)

Methods:

- getDetails(): void (public)

<u>Library class</u>

Attributes:

- books: List<Book> (private)

Methods:

- addBook(book: Book): void (public)
- searchBook(title: String): Book (public)

<u>DigitalBook class</u>

Attributes:

- title: String (inherited)
- author: String (inherited)
- ISBN: String (inherited)
- format: String

Methods:

- getDetails(): void (inherited from Book)

<u>ReferenceBook class</u>

Attributes:

- title: String (inherited)
- author: String (inherited)
- ISBN: String (inherited)
- citations: List<String>

Methods:

- getDetails(): void (inherited from Book)
- addCitation(citation: String): void

In this simple representation:

- The arrows indicate the direction of associations.
- The solid arrow from Book to Library represents the Library having a list of books.
- The solid arrow from subclasses (DigitalBook and ReferenceBook) to Book indicates inheritance.
- The DigitalBook class has an additional method, getDetails.
- The ReferenceBook class has an association with Book, indicating it inherits and has an "is-a" relationship; in other words, a ReferenceBook *is a* Book.

The “+” indicates public access, and “-” indicates private access. The lines connecting the classes represent associations.

To learn more about class diagrams, take a look at **this article**.

CRUD MATRIX

A **CRUD** Matrix is a tool used to document the relationships between different entities (usually database tables) and the **CRUD** (**Create**, **Read**, **Update**, **Delete**) operations that can be performed on them. These entities are often represented by models. Here's how you might create a CRUD Matrix for a simple application:

Example CRUD matrix:

Let's consider a library application with a model: **Task**.

Entity	Create	Read	Update	Delete
Task	X	X	X	X

Task entity:

Create (C): Creating a new task instance.
Read (R): Retrieving information about a task.
Update (U): Modifying information of an existing task.
Delete (D): Removing a task from the system.

The Python script below showcases the fundamental principles of CRUD operations within a simplified task management system. The script defines a Task class representing tasks with attributes such as task `ID`, `title`, and `description`. A sample set of tasks is created, and various functions are implemented to perform CRUD operations on this data. The script then demonstrates the execution of these operations, offering a hands-on example of how to create, read, update, and delete tasks within a Python context.

```
class Task:
    """ Class representing a Task entity with attributes: task_id,
title, and description. """

    def __init__(self, task_id, title, description):
        """ Initialize a new Task instance. """
        self.task_id = task_id
        self.title = title
        self.description = description
```

Explanation:

- The Task class is a blueprint for creating instances representing tasks.
- Each task has attributes: `task_id`, `title`, and `description`.
- The __init__ method is a special method that gets called when a new Task instance is created. It initialises the attributes of the task.

```
# Sample data
tasks_data = [
    Task(1, "Task 1", "Description for Task 1"),
    Task(2, "Task 2", "Description for Task 2"),
    Task(3, "Task 3", "Description for Task 3"),
]
```

Explanation:

- `tasks_data` is a list containing three sample tasks, each represented by a Task instance.
- These instances have different `task_id`, `title`, and `description values`.

CRUD functions:

Display tasks:

```
def display_tasks():
    """ Display information for all tasks. """
    print("Tasks:")
    for task in tasks_data:
        print(f"ID: {task.task_id}, Title: {task.title}, Description:
{task.description}")
    print()
```

Create tasks:

```
def create_task(title, description):
    """ Create a new task and add it to the tasks_data list. """
    new_id = len(tasks_data) + 1
    new_task = Task(new_id, title, description)
    tasks_data.append(new_task)
    print(f"Task '{title}' created successfully!\n")
```

Read tasks:

```
def read_task(task_id):
    """ Read and display information for a task based on its ID. """
    for task in tasks_data:
        if task.task_id == task_id:
            print(f"Task found - ID: {task.task_id}, Title:
{task.title}, Description: {task.description}\n")
            return
    print(f"Task with ID {task_id} not found.\n")
```

Update tasks:

```
def update_task(task_id, new_title, new_description):
    """ Update the title and description of a task based on its ID. """
    for task in tasks_data:
        if task.task_id == task_id:
            task.title = new_title
            task.description = new_description
            print(f"Task updated successfully!\n")
            return
    print(f"Task with ID {task_id} not found.\n")
```

Delete tasks:

```
def delete_task(task_id):
    """ Delete a task based on its ID. """
    for i, task in enumerate(tasks_data):
        if task.task_id == task_id:
            del tasks_data[i]
            print(f"Task deleted successfully!\n")
            return
    print(f"Task with ID {task_id} not found.\n")
```

Explanation:

- `display_tasks` prints information about all tasks.
- Each of the functions below corresponds to a CRUD operation.
  - `create_task` adds a new task to the `tasks_data` list.
  - `read_task` searches for a task by its `ID` and prints its information.
  - `Update_task` finds a task by its `ID` and updates its `title` and `description`.
  - `delete_task` removes a task from `tasks_data` based on its `ID`.

Demonstration of CRUD operations:

```
# Demonstrate CRUD operations
display_tasks()
```

```
create_task("New Task", "Description for the new task")
display_tasks()

read_task(2)

update_task(1, "Updated Task 1", "New description for Task 1")
display_tasks()

delete_task(3)
display_tasks()
```

This matrix offers a concise summary of the operations applicable to each entity in the script. It serves as a helpful guide for grasping the fundamental functionalities of the code, and it can be referred to when implementing and understanding various aspects of the script, such as the creation, retrieval, update, and deletion of tasks.

Practical Task

In this task, you will review the design principles you have learned and practise the skills you have been introduced to by designing a task manager application with features of your choice.

Need a quick and easy drawing tool? Check out **draw.io** for creating flowcharts, diagrams, and more. It's user-friendly and perfect for spicing up your projects visually. Give it a go and let your creativity shine!

Follow these steps:

- Create a use case diagram for your task manager application. You can decide on the use cases for your application.
- Create a sequence diagram for your task manager application. You may assume that your task manager application will utilise files to store its data.
- In a plain text file, outline the concerns of each component in your task manager application.
- Create a class diagram for your task manager application.
- Create a CRUD matrix for your task manager application.

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