Software Design Patterns

Code Refactoring for Carrot Defense

Group T02

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1. Project Introduction

1.1 Project Background

Carrot Defense is a classic tower defense game where players build different types of towers on a map to stop the invasion of enemies and protect the carrot from being destroyed. In the game, players must strategically place towers to counter increasingly difficult waves of enemies. By defeating enemies, players earn coins which they can use to build or upgrade towers, gradually enhancing their defense capabilities.

However, as the project progressed and more features were added, several issues emerged in the initial version of the project , which made the project difficult to maintain and expand. The main problems include:

1. **Code Structure Chaos:** The initial implementation was relatively simple, but as more features were added, the code became cluttered and hard to understand. Various modules were tightly coupled, which led to redundant code and made debugging and modification difficult.

2. **Poor Scalability**: While the existing code handles basic functionality, it lacks the flexibility to easily extend with new features, such as adding new turret types, monsters, or levels. Expanding functionality often requires significant changes to existing code, which increases development and maintenance costs.

3. **Performance Bottlenecks:** As the game scales with more monsters and complex maps, the existing code fails to optimize critical parts, such as collision detection and attack logic. This can cause the game to slow down or experience lag, affecting the user experience.

To address these issues, we decided to refactor the existing code. The goal of the refactor is to improve the maintainability, scalability, performance, and overall user experience of the game. The specific objectives include:

1. **Improve Code Maintainability and Readability**: The existing code has redundant and non-standard parts, making it difficult to understand and modify. By refactoring, we will modularize and decouple the code to reduce redundancy and make each module's functionality clearer and more independent. This will enhance code

readability and ease of maintenance, allowing for easier debugging and modification.

2. **Optimize Performance**: As the game grows, performance bottlenecks, especially in collision detection and attack logic, become more noticeable. We will optimize these critical areas by reducing unnecessary calculations, improving data structures, and using techniques like spatial partitioning to boost the game's efficiency and ensure smooth gameplay, even with larger numbers of monsters and more complex maps.

3. **Enhance Flexibility and Scalability**: To accommodate future feature expansions—such as adding new turret types, monsters, or levels—we will redesign the code to make it more flexible and modular. This will allow new features to be added easily without requiring large-scale changes to the existing code. By using interfaces and abstract classes, we will ensure that new functionality can be integrated smoothly with the existing system, reducing the cost of future development and maintenance.

4. Improve User Experience: The refactor will also focus on enhancing the visual effects, interactions, and overall game experience. We will add more advanced turret attack effects, monster hit animations, and improve the user interface to make the game more immersive and enjoyable. Additionally, we will ensure that the game is responsive and intuitive for players, leading to a better overall experience.

In conclusion, the refactor of Carrot Defense aims to address the key issues encountered in the initial implementation, ensuring that the game is not only easier to maintain and expand but also laying a solid foundation for future feature extensions. This will allow the game to efficiently handle new gameplay elements and features while continuously enhancing the player experience.

1.2 Project Features

After the refactor, the Carrot Defense game system has seen significant improvements in structure, performance, scalability, and user experience. The core goal of the refactor was to optimize the implementation of existing features and provide more flexible support for potential future expansions. By modularizing and decoupling the code, we have added more depth and strategic elements to the game, while also enhancing its smoothness and maintainability. Below are the **main features** of the system after the refactor:

Table 1 Implemented Features

Feature Module	**Subfeatures**	**Feature Module**	**Subfeatures**
Basic Functions		**Advanced Features**	
Diverse Tower Functions	Build Tower, Delete Tower, Two-level Tower Upgrades	Special Attack Mode	Turret Special Abilities, Activate Special Abilities
Special Effects Display	Tower Attack Effects, Monster Hit Effects	Upgrade Effect Enhancement	Unlock New Effects on Upgrade
Economy System	Earn Gold by Defeating Monsters, Spend Gold to Build and Upgrade Turrets	Flexible Game Flow	Restart During Gameplay, Exit and Select Level
Monsters and Maps	Three Types of Monsters, Two Maps		
Health and Background Music	Display Carrot Health, Background Music		
Save Function	Save Game Progress		

2. Project Refactoring Overview

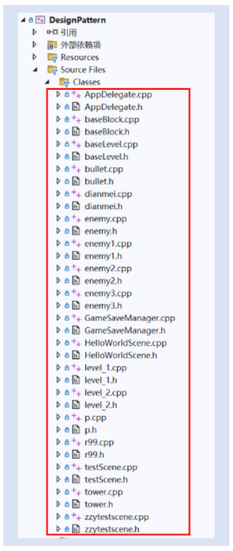
In this section, we will compare the overall structure of the project before and after the refactor, and provide an overview of the design patterns used. Through this comparative analysis, we will clearly demonstrate the architectural optimizations brought by the refactor and how the selected design patterns help improve the maintainability, scalability, and performance of the code. Next, we will present the project structure before and after the refactor, and briefly introduce the design patterns chosen.

2.1 Project Structure

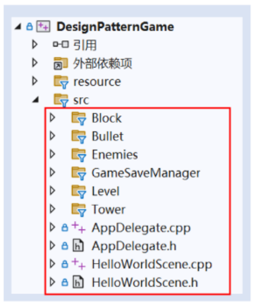
In this section, we will compare the changes in the project's structure before and after the refactor. The diagram below provides a clear visualization of the code organization before and after the refactor.

Before the refactor (left), the code structure was relatively chaotic, with files for various functional modules scattered and lacking effective categorization. This made code maintenance and feature expansion more challenging.

After the refactor (right), we implemented a modular design for the project structure, grouping related functional files into their respective directories, such as Block, Bullet, Enemies, and others. This clear separation of responsibilities among different functional modules makes the code easier to maintain and extend while also improving its overall readability.



```
DesignPattern
    引用
    外部依赖项
    Resources
    Source Files
        Classes
            AppDelegate.cpp
            AppDelegate.h
            baseBlock.cpp
            baseBlock.h
            baseLevel.cpp
            baseLevel.h
            bullet.cpp
            bullet.h
            dianmei.cpp
            dianmei.h
            enemy.cpp
            enemy.h
            enemy1.cpp
            enemy1.h
            enemy2.cpp
            enemy2.h
            enemy3.cpp
            enemy3.h
            GameSaveManager.cpp
            GameSaveManager.h
            HelloWorldScene.cpp
            HelloWorldScene.h
            level_1.cpp
            level_1.h
            level_2.cpp
            level_2.h
            p.cpp
            p.h
            r99.cpp
            r99.h
            testScene.cpp
            testScene.h
            tower.cpp
            tower.h
            zzytestscene.cpp
            zzytestscene.h
```



```
DesignPatternGame
    引用
    外部依赖项
    resource
    src
        Block
        Bullet
        Enemies
        GameSaveManager
        Level
        Tower
        AppDelegate.cpp
        AppDelegate.h
        HelloWorldScene.cpp
        HelloWorldScene.h
```

2.2 Design Patterns Summary Table

During the process of code refactoring, we introduced various classic design patterns to enhance the system's maintainability and scalability. The application of these patterns not only optimized the code structure but also significantly improved code reusability and readability. Below is an overview and analysis of the design patterns utilized:

Number	Name	Type	Brief Description
1	Factory Method	Creational Patterns	Enemy Creation
2	Singleton	Creational Patterns	Singleton of EnemyNotifyManager
3	Flyweight	Structural Patterns	Bullet Texture Sharing
4	Decorator	Structural Patterns	Bullet attack mode expansion
5	Observer	Behavioral Patterns	Enemies' subscription and tower's update
6	Template Method	Behavioral Patterns	Level Initialization Process
7	Object Pool	Others	Bullet Object Pool

3. Design Patterns Details

3.1 Factory Method

3.1.1 Pattern Introduction

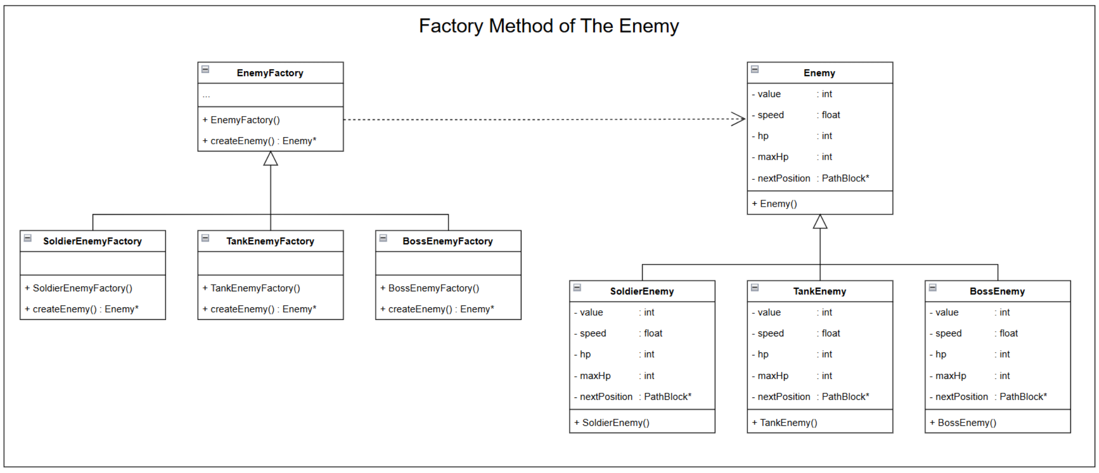
The Factory Method is a creational design pattern that defines an interface for creating objects but allows subclasses to alter the type of objects that will be created. Instead of directly instantiating objects using the new keyword, this pattern provides a flexible approach to encapsulate the creation logic within a factory method, thereby promoting loose coupling and scalability.

In the context of game development, particularly for creating Enemy objects, the Factory Method ensures that the creation logic for enemies is centralized and consistent, which facilitates future modifications and enhances code reusability.

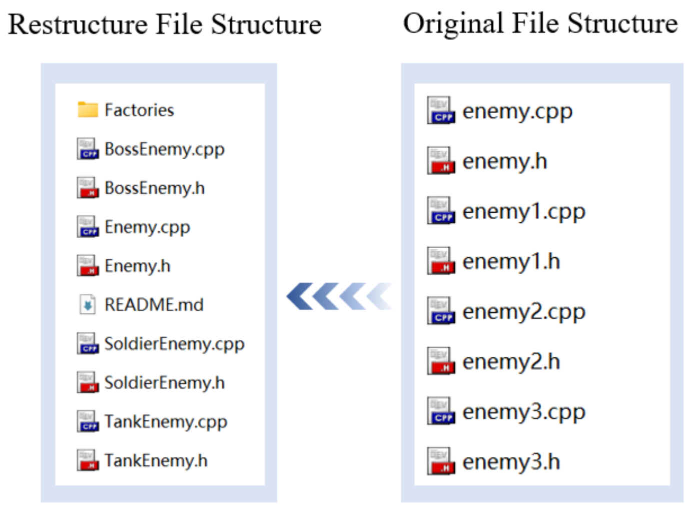
3.1.2 Application Scenarios

Before implementing the Factory Method, the creation of the Enemy objects was scattered across multiple parts of the code and was done through direct instantiation. This approach resulted in duplicated logic, poor scalability, and made it difficult to manage changes to the Enemy creation process. After the refactor, the creation of all Enemy objects was centralized in a factory class, which not only facilitates future modifications but also improves the reusability of the code.

3.1.3 Code Refactoring



This class diagram illustrates a design based on the Factory Method Pattern. The core idea is that the abstract factory class EnemyFactory defines an interface for creating enemies. Different subclasses, such as SoldierEnemyFactory, TankEnemyFactory, and BossEnemyFactory, implement this interface to create corresponding enemy objects (SoldierEnemy, TankEnemy, and BossEnemy). All specific enemy classes inherit from the abstract base class Enemy, providing a unified abstraction for enemy objects.



Factories
BossEnemy.cpp
BossEnemy.h
Enemy.cpp
Enemy.h
README.md
SoldierEnemy.cpp
SoldierEnemy.h
TankEnemy.cpp
TankEnemy.h

enemy.cpp
enemy.h
enemy1.cpp
enemy1.h
enemy2.cpp
enemy2.h
enemy3.cpp
enemy3.h

This design separates the logic of object creation from its usage, offering the following **advantages**:

Flexibility: Adding new enemy types only requires creating new factory classes and corresponding enemy classes without modifying existing code, adhering to the Open-Closed Principle.

Scalability: New features or types can be easily expanded by extending the abstract factory and base class.

Code Reusability: The unified creation interface and base class structure improve code reusability and consistency.

Decoupling: The caller does not need to worry about the specific enemy creation process, as it can generate objects by using the abstract factory interface, reducing coupling between modules.

3.1.4 Key Code Demonstration

```
#include "BossEnemyFactory.h"
Enemy* BossEnemyFactory::createEnemy() {
	return BossEnemy::create();
}

#include "SoldierEnemyFactory.h"
Enemy* SoldierEnemyFactory::createEnemy() {
	return SoldierEnemy::create();
}

#include "TankEnemyFactory.h"
Enemy* TankEnemyFactory::createEnemy() {
	return TankEnemy::create();
}
```

3.2 Singleton

3.2.1 Pattern Introduction

The Singleton Pattern is a design pattern that restricts the instantiation of a class to a single object and provides a global point of access to that object. It ensures that only one instance of the class exists throughout the application's lifecycle, which is particularly useful for managing shared resources or controlling access to a specific component, such as logging, database connections, or in this case, managing the state of game enemies.

The Singleton Pattern generally involves:

1. **Private constructor:** To prevent external instantiation of the class.

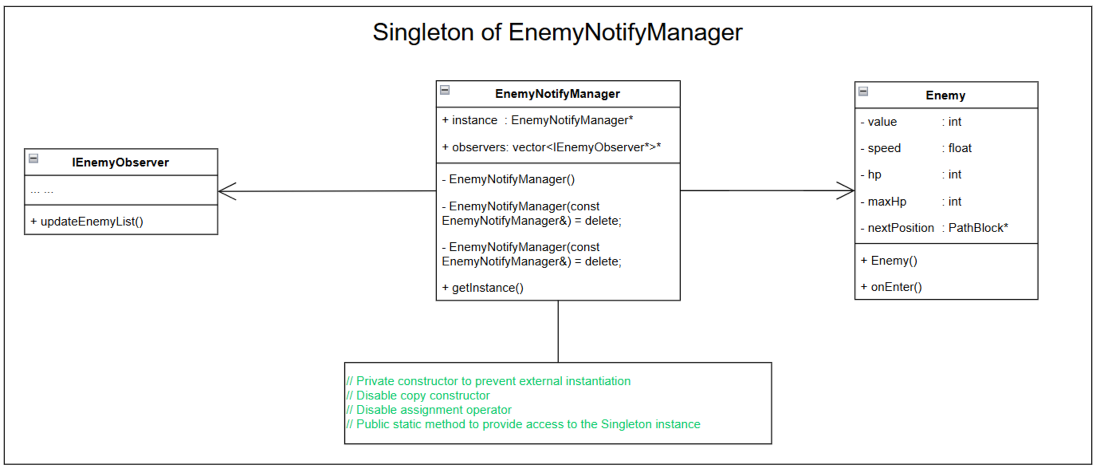
2. **Static instance variable:** To hold the single instance of the class.

3. **Public static method:** To provide access to the instance, ensuring that it is created only once.

3.2.2 Application Scenarios

In our code, the EnemyNotifyManager uses the Singleton Pattern to manage the list of enemy observers. It ensures that there is only one manager responsible for notifying observers when an enemy is created or removed. This centralization makes the notification process more efficient and prevents potential conflicts between multiple instances.

3.2.3 Code Refactoring


Singleton of EnemyNotifyManager
IEnemyObserver
... ...
+ updateEnemyList()
EnemyNotifyManager
+ instance : EnemyNotifyManager*
+ observers: vector<IEnemyObserver*>*
- EnemyNotifyManager()
- EnemyNotifyManager(const EnemyNotifyManager&) = delete;
- EnemyNotifyManager(const EnemyNotifyManager&) = delete;
+ getInstance()
Enemy
- value : int
- speed : float
- hp : int
- maxHp : int
- nextPosition : PathBlock*
+ Enemy()
+ onEnter()
// Private constructor to prevent external instantiation
// Disable copy constructor
// Disable assignment operator
// Public static method to provide access to the Singleton instance

The class implements the singleton pattern to ensure the uniqueness of EnemyNotifyManager: the constructor is made private to prevent external instantiation, and the copy constructor and assignment operator are deleted to avoid duplication or reassignment. A static pointer is used to store the single instance of the class, and a static method getInstance() is provided to access this instance. If the instance has not been created, it is initialized when the method is called. This design guarantees that only one instance of EnemyNotifyManager exists throughout the program.

The **advantages** of implementing the Singleton pattern include:

Global Unique Instance: The Singleton pattern ensures that there is only one instance of EnemyNotifyManager throughout the entire program, which is useful for classes that need to share resources or control access. In this case, EnemyNotifyManager is used to manage all observers (e.g., tower defense objects), ensuring that all observers receive the same state updates.

Lazy Initialization: The Singleton pattern can use lazy initialization, meaning the instance is created only when it is first accessed, reducing unnecessary resource overhead.

3.2.4 Key Code Demonstration

```
class EnemyNotifyManager {
private:
        static EnemyNotifyManager* instance;
        std::vector<IEnemyObserver*> observers;

        // Private constructor to prevent external instantiation
        EnemyNotifyManager() {}
        // Disable copy constructor
        EnemyNotifyManager(const EnemyNotifyManager&) = delete;
        // Disable assignment operator
        EnemyNotifyManager& operator=(const EnemyNotifyManager&) = delete;
}
```

3.3 Flyweight

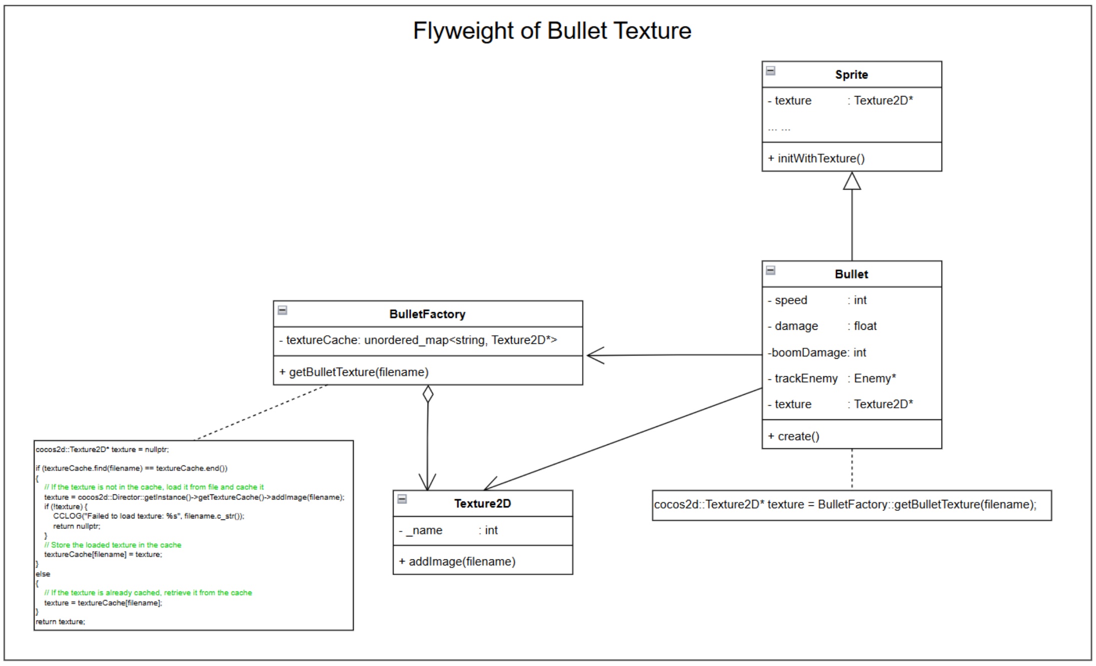
3.3.1 Pattern Introduction

The Flyweight Pattern is a structural design pattern that minimizes memory usage by sharing as much data as possible with similar objects. It is particularly useful when there are many objects that share common properties, as it avoids the need to duplicate shared data across all objects. This is achieved by using a centralized pool of shared objects and referencing these objects where needed.

3.3.2 Application Scenarios

The Flyweight Pattern is ideal for scenarios where a large number of objects share common attributes, significantly optimizing memory usage and improving performance. In the bullet system's texture management, it addresses the problem of excessive memory consumption by storing Texture2D objects in a centralized mapping table (e.g., unordered_map) with filenames as keys, allowing textures to be reused if they already exist or newly created only when necessary. It also reduces memory usage and loading times during dynamic loading by ensuring each texture is loaded only once and reused across objects, such as bullets, particle effects, or UI elements. Furthermore, this pattern is particularly effective for low-memory devices, where shared textures minimize resource usage and enhance the game's efficiency and smoothness on resource-constrained platforms.

3.3.3 Code Refactoring



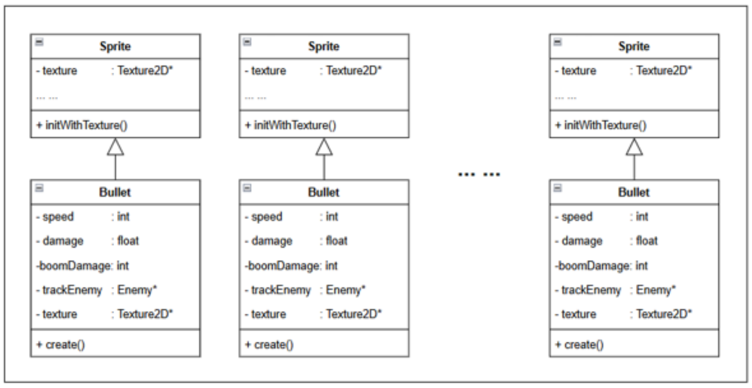
```
cocos2d::Texture2D* texture = nullptr;

if (textureCache.find(filename) == textureCache.end())
{
    // If the texture is not in the cache, load it from file and cache it
    texture = cocos2d::Director::getInstance()->getTextureCache()->addImage(filename);
    if (!texture) {
        CCLOG("Failed to load texture: %s", filename.c_str());
        return nullptr;
    }
    // Store the loaded texture in the cache
    textureCache[filename] = texture;
}
else
{
    // If the texture is already cached, retrieve it from the cache
    texture = textureCache[filename];
}
return texture;
```

```
cocos2d::Texture2D* texture = BulletFactory::getBulletTexture(filename);
```

This class diagram demonstrates the use of the Flyweight Pattern to optimize memory usage for bullet textures. The BulletFactory class employs a caching mechanism (e.g., unordered_map) to centrally manage Texture2D objects, ensuring that the same texture file is loaded only once and shared across multiple bullet objects. The Bullet class retrieves the required texture by calling methods provided by the BulletFactory, then passes the texture to the Sprite class for initialization. Texture2D represents the actual texture data, while BulletFactory serves as the core factory class responsible for creating or retrieving texture objects.

Original Structure

Each time a bullet is created, a texture image that takes up a large amount of space is saved.



The **advantages** of implementing the Flyweight pattern include:

Reduced Memory Overhead: By sharing texture objects, it avoids loading textures separately for each bullet object, significantly reducing redundant storage of texture data and lowering overall memory usage.

Optimized Performance: The number of texture loads is minimized, avoiding repetitive I/O operations and memory allocations, which improves the performance of the game, especially in resource-intensive scenarios.

3.3.4 Key Code Demonstration

```
// Static function to get a texture for a bullet by filename
static cocos2d::Texture2D* getBulletTexture(const std::string& filename) {
        cocos2d::Texture2D* texture = nullptr;
        if (textureCache.find(filename) == textureCache.end())
        {
                // If the texture is not in the cache, load it from file and cache it
                texture =
cocos2d::Director::getInstance()->getTextureCache()->addImage(filename);
                        if (!texture) {
                                CCLOG("Failed to load texture: %s", filename.c_str());
                                return nullptr;
                        }
                        // Store the loaded texture in the cache
                        textureCache[filename] = texture;
                }
                else
                {
                        // If the texture is already cached, retrieve it from the cache
                        texture = textureCache[filename];
                }
                return texture;
        }
```

3.4 Decorator

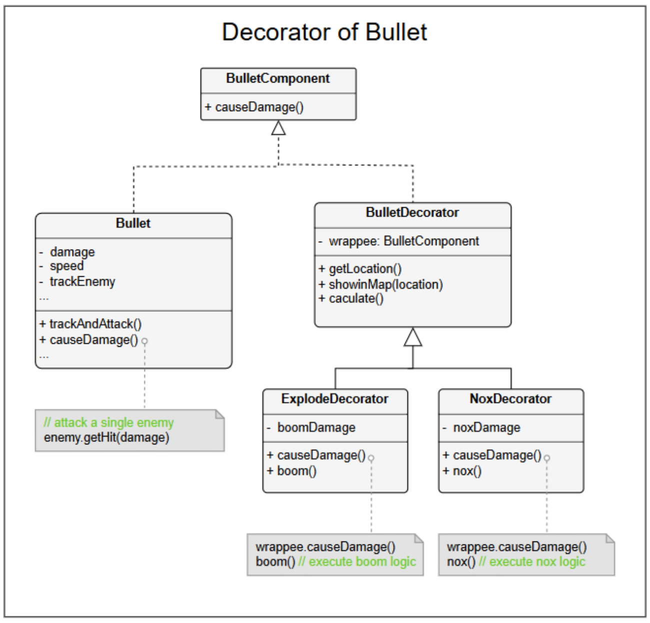
3.4.1 Pattern Introduction

The Decorator Pattern is a structural design pattern that allows functionality to be dynamically added to a single object without affecting the behavior of other objects of the same class. It provides a flexible alternative to subclassing for extending functionality. The Decorator Pattern is typically used in scenarios where an object needs to have multiple features added, and these features can exist independently or in different combinations.

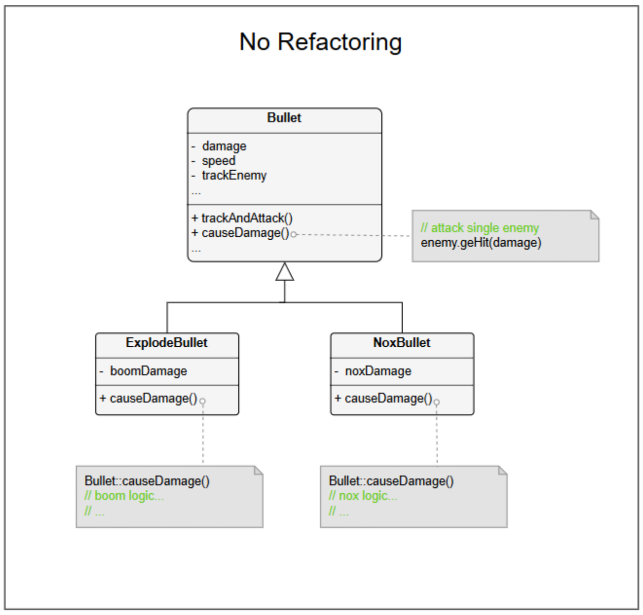
3.4.2 Application Scenarios

In a game, for example, bullets may have different attack types, such as poison or explosive attacks. To extend the attack modes of the base bullet class without modifying it, the Decorator Pattern is an ideal choice. It enables dynamic addition of attack modes to bullets while maintaining modular and maintainable code.

3.4.3 Code Refactoring



This class diagram illustrates the Decorator Pattern, where BulletDecorator extends the functionality of a Bullet without altering its structure. ExplodeDecorator and NoxDecorator add specific effects, such as explosion or toxic damage, by wrapping the original Bullet and enhancing its causeDamage() method with additional logic. This design ensures flexibility and modularity in extending bullet behaviors.



The unrefactored code class diagram is as above, so the **advantages** of implementing the Decorator pattern include:

Flexibility and scalability: The Decorator pattern allows for **the dynamic combination of different features** (such as explosion or toxic damage), enabling the addition or removal of functionalities for each Bullet instance as needed. It provides flexible combinations of behaviors without modifying the existing code.

Enhancing functionality without changing the original structure: By using the Decorator pattern, functionality can be extended without modifying the Bullet class itself. Each decorator only adds specific functionality without affecting the base Bullet implementation, making the code easier to maintain and extend.

Adhering to the Open/Closed Principle: This design follows the Open/Closed Principle, which states that classes should be open for extension but closed for modification. New decorators can be created to add functionality without changing the Bullet class or existing decorators.

Code reuse: The Decorator pattern encapsulates different behaviors in separate decorator classes, avoiding code duplication. It increases code reuse by allowing decorators to be shared across multiple bullet types or behaviors.

3.4.4 Key Code Demonstration

```
void FrostTower::shootBoomBullet() {
        auto attack_enemy = atk_eny.front();
        Bullet* bullet = Bullet::create("nox.png");
        bullet->setScale(1);
        bullet->setTrack(attack_enemy);
        bullet->setSpeed(1000);
        bullet->setDamage(damage);
        // Added an explosive decorator to the base bullet
        ExplodeDecorator* Explodebullet= new ExplodeDecorator(bullet, booomDamage);
        Explodebullet->setPosition(Vec2(this->getPosition().x, this->getPosition().y));
        this->getParent()->addChild(Explodebullet, 1); // Bullets join the scene
        Explodebullet->scheduleUpdate(); // Bullets begin to track the enemy
}
void FrostTower::shootNoxBullet() {
        auto attack_enemy = atk_eny.front();
        auto bullet = Bullet::create("nox.png");
        bullet->setScale(1);
        bullet->setTrack(attack_enemy);
        bullet->setSpeed(1000);
        bullet->setDamage(damage);
        // Added an nox decorator to the base bullet
        NoxDecorator* Noxbullet= new NoxDecorator(bullet, noxDamage);
        Noxbullet->setPosition(Vec2(this->getPosition().x, this->getPosition().y));
        this->getParent()->addChild(Noxbullet, 1); // Bullets join the scene
        Noxbullet->scheduleUpdate(); // Bullets begin to track the enemy
}
void FrostTower::shootNoxAndBoomBullet() {
        auto attack_enemy = atk_eny.front();
        Bullet* bullet = Bullet::create("nox.png");
        bullet->setScale(1);
        bullet->setTrack(attack_enemy);
        bullet->setSpeed(1000);
        bullet->setDamage(damage);
        // Added an explosive decorator to the base bullet
        ExplodeDecorator* Explodebullet= new ExplodeDecorator(bullet, booomDamage);
        // Added an nox decorator to the base bullet
        NoxDecorator* Noxbullet= new NoxDecorator(Explodebullet, noxDamage);
        // Now the bullet can simultaniously cause boom and nox damage
        Noxbullet->setPosition(Vec2(this->getPosition().x, this->getPosition().y));
        this->getParent()->addChild(Noxbullet, 1); // Bullets join the scene
        Noxbullet->scheduleUpdate(); // Bullets begin to track the enemy
}
```

3.5 Observer

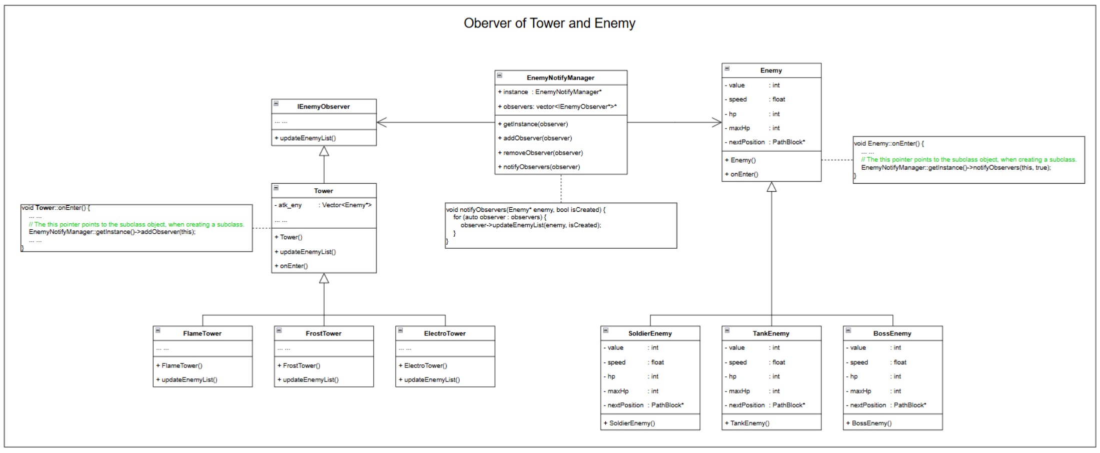
3.5.1 Pattern Introduction

The Observer Pattern is a behavioral design pattern that establishes a one-to-many dependency relationship between objects. When the state of one object (the "subject") changes, it notifies all its dependent objects (the "observers") to update themselves automatically. This pattern promotes loose coupling between the subject and its observers, as the subject does not need to know the exact implementation details of the observers. Instead, observers adhere to a common interface for receiving notifications, making the system flexible and extensible.

3.5.2 Application Scenarios

In the original design, all enemies were stored in the level, and towers attacked by iterating through the enemy list and calculating the relative positions of each enemy. This approach led to performance bottlenecks as the number of enemies increased. To optimize this, the observer pattern was introduced. Now, when an enemy is created, it notifies all relevant towers to add themselves as observers. When the enemy dies, it notifies the towers to remove itself. This way, towers no longer need to iterate through all enemies every frame. Instead, they perform attacks based on notifications from the enemies, significantly reducing unnecessary iteration and calculations. The coupling between enemies and towers is reduced, improving system performance, especially when there are many enemies. Overall, the architecture becomes more modular, easier to maintain, and more extensible.

3.5.3 Code Refactoring

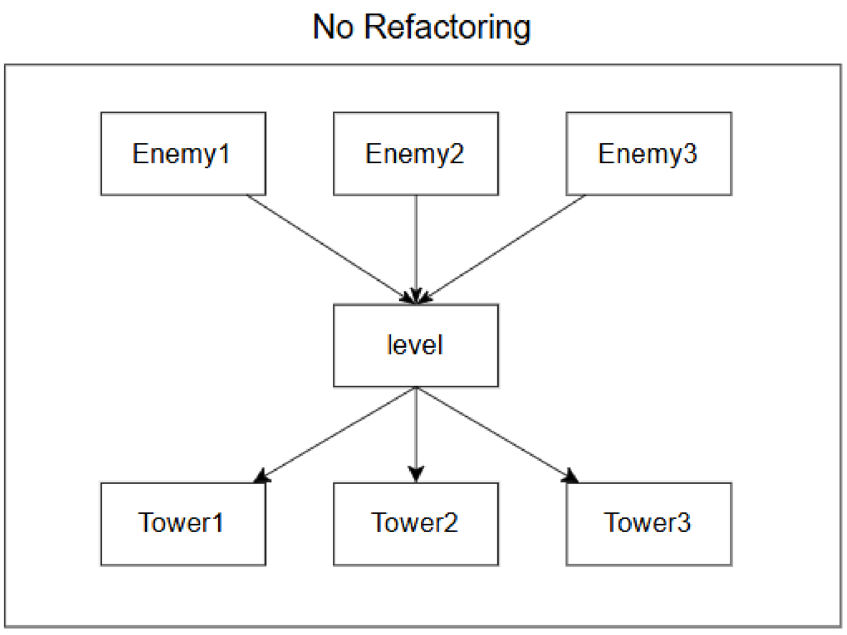


```
void Tower::onEnter() {
    ... ...
    // The this pointer points to the subclass object, when creating a subclass.
    EnemyNotifyManager::getInstance()->addObserver(this);
    ... ...
}
```

```
void notifyObservers(Enemy* enemy, bool isCreated) {
    for (auto observer : observers) {
        observer->updateEnemyList(enemy, isCreated);
    }
}
```

```
void Enemy::onEnter() {
    ... ...
    // The this pointer points to the subclass object, when creating a subclass.
    EnemyNotifyManager::getInstance()->notifyObservers(this, true);
}
```

This class diagram shows the relationship between Towers and Enemies using the Observer Pattern. The EnemyNotifyManager, a singleton, manages observers (e.g., Towers) that implement the IEnemyObserver interface. When an enemy appears or dies, it notifies all observers. The Tower class registers with the EnemyNotifyManager using addObserver() and updates its status via updateEnemyList().Specific tower types, like FlameTower or FrostTower, extend Tower for extra functionality.



The **advantages** of implementing the Observer pattern include:

Dynamic Updates and Optimization: Real-time updates on live enemies avoid redundant calculations, improving efficiency.

Performance and Decoupling: Eliminating unnecessary checks reduces system load, while decoupling towers and enemies enhances maintainability.

Flexibility and Extensibility: Centralized enemy management makes adding new enemies or events easier, boosting scalability.

Maintenance and Expansion: Interface-based interaction allows easy tower addition/removal without affecting other components, ensuring flexibility and quick expansion.

3.5.4 Key Code Demonstration

```
class EnemyNotifyManager {
private:
        static EnemyNotifyManager* instance;
        std::vector<IEnemyObserver*> observers;
        … …

public:
        // Public static method to provide access to the Singleton instance
        static EnemyNotifyManager* getInstance() {
                if (instance == nullptr) {
                        instance = new EnemyNotifyManager();
                }
                return instance;
        }
        void addObserver(IEnemyObserver* observer) {
                observers.push_back(observer);
                CCLOG("EnemyNotifyManager: addObserver");
        }
        void removeObserver(IEnemyObserver* observer) {
                auto it = std::find(observers.begin(), observers.end(), observer);
                if (it != observers.end()) {
                        observers.erase(it);
                }
        }
        void notifyObservers(Enemy* enemy, bool isCreated) {
                for (auto observer : observers) {
                        observer->updateEnemyList(enemy, isCreated);
                        CCLOG("EnemyNotifyManager: notifyObservers");
                }
        }
};
```

3.6 Template Method

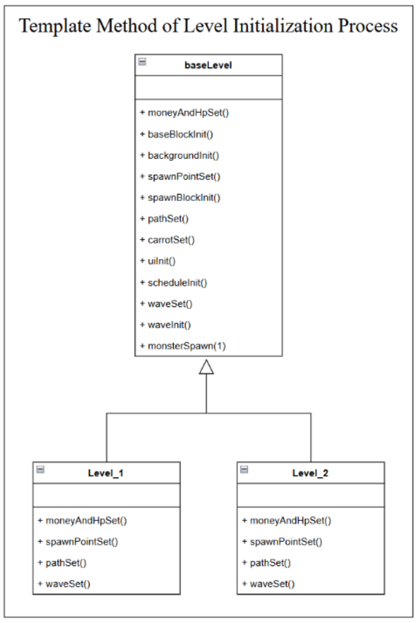
3.6.1 Pattern Introduction

The Template Method Pattern defines the skeleton of an algorithm in a base class and allows its subclasses to override specific steps of the algorithm without changing its overall structure. This pattern promotes code reuse by putting the common logic in the base class while enabling customization through subclass implementation of certain steps. The core idea is to encapsulate the invariant parts of the algorithm in the base class while leaving the variant parts to the subclasses.

3.6.2 Application Scenarios

In our game initialization process, there is a fixed sequence of operations that need to be executed, such as setting money and HP (moneyAndHpSet()), initializing base blocks (baseBlockInit()), and so on. However, for levels that are not passed, part of the initialization process is different. To handle this, we adopt the Template Method Pattern. By using the Template Method Pattern, we can standardize the game initialization process, making it easy to maintain and extend as new types of initialization are added in the future.

3.6.3 Code Refactoring



This class diagram illustrates the design of the level initialization process using the Template Method pattern. The baseLevel class serves as an abstract class that defines the template method for level initialization, including steps like moneyAndHpSet(), baseBlockInit(), and pathSet(), ensuring a fixed sequence of initialization steps. Level_1 and Level_2 inherit from baseLevel and override some of the parent class methods to implement the specific initialization logic for each level. The Template Method pattern ensures that the parent class provides a general framework, while subclasses flexibly implement specific behaviors.

The **advantages** of implementing the Template Method pattern include:

Uniformity and Consistency: The Template Method pattern ensures that the initialization process of all levels follows the same order and structure, avoiding duplicated code and maintaining consistency in the initialization process.

Code Reusability: By placing common initialization steps in the base class, subclasses can reuse the code and only focus on the specific parts for each level, enabling efficient code reuse.

Flexibility and Extensibility: Subclasses can flexibly override methods from the parent class to implement specific initialization logic for different levels, making it easy to extend functionality when adding new levels.

Simplified Maintenance: The Template Method pattern separates common workflows from specific implementations, making the code easier to maintain and extend. When adding new levels, it minimizes the impact on existing code.

3.6.4 Key Code Demonstration

```
bool baseLevel::init()
{
    moneyAndHpSet();        // Initialize money and HP
    baseBlockInit();
    backgroundInit();
    spawnPointSet();        // Initialize enemy spawn point positions
    spawnBlockInit();
    pathSet();              // Set the enemy movement path
    carrotSet();
    uiInit();
    scheduleInit();
    waveSet();              // Initialize wave information
    waveInit();
    monsterSpawn(1);

    return true;
}
```

3.7 Object Pool

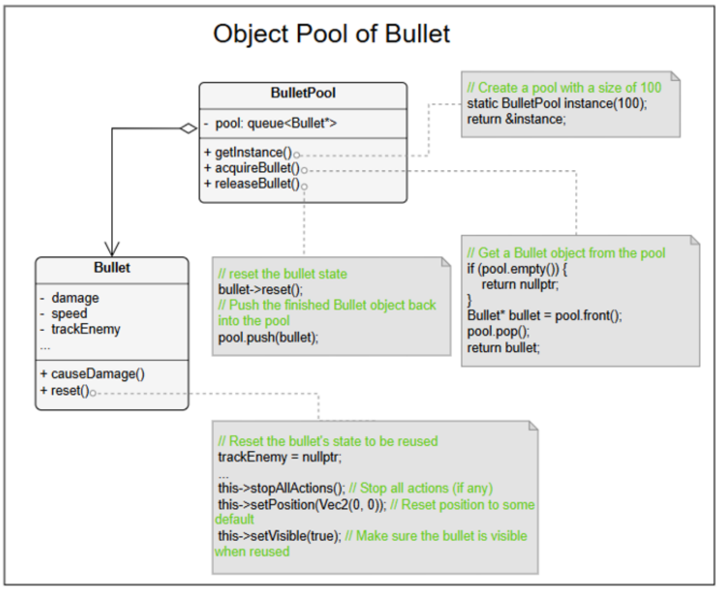
3.7.1 Pattern Introduction

The Object Pool pattern is used to manage the reuse of objects that are costly to create and destroy frequently. Instead of creating and destroying objects each time they are needed, an object pool maintains a collection of reusable instances. These objects are checked out when needed and returned when no longer in use, reducing the overhead of constant object creation and garbage collection. This pattern is beneficial in scenarios where object creation is resource-intensive, and its usage improves performance by minimizing the cost associated with object allocation and deallocation.

3.7.2 Application Scenarios

In our game project, the Object Pool pattern is primarily used to manage the creation and destruction of objects such as bullets, enemies, explosion effects, and particle effects. By pre-creating a certain number of objects and storing them in a pool, the system can retrieve objects from the pool when needed, instead of creating new ones each time. This reduces the overhead of frequent object creation and destruction, effectively lowering memory usage and garbage collection pressure, thereby improving game performance.

3.7.3 Code Refactoring



```
// Create a pool with a size of 100
static BulletPool instance(100);
return &instance;
```

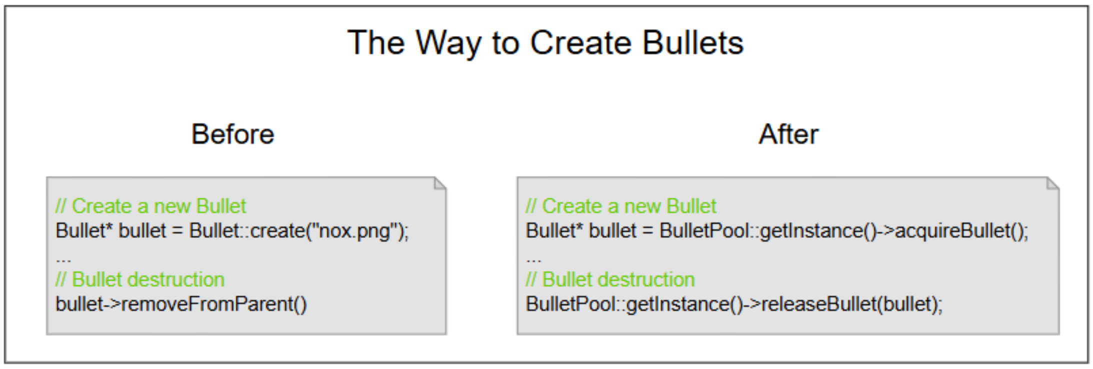
```
// reset the bullet state
bullet->reset();
// Push the finished Bullet object back into the pool
pool.push(bullet);
```

```
// Get a Bullet object from the pool
if (pool.empty()) {
    return nullptr;
}
Bullet* bullet = pool.front();
pool.pop();
return bullet;
```

```
// Reset the bullet's state to be reused
trackEnemy = nullptr;
...
this->stopAllActions(); // Stop all actions (if any)
this->setPosition(Vec2(0, 0)); // Reset position to some default
this->setVisible(true); // Make sure the bullet is visible when reused
```

This class diagram illustrates the implementation of the Object Pool for Bullets. The BulletPool class manages a queue structure (pool) to store and reuse bullet objects

(Bullet). When a bullet is needed, the acquireBullet() method retrieves a bullet object from the pool; if the pool is empty, a new bullet object can be created. Once a bullet object completes its task, it is returned to the pool using the releaseBullet() method, which calls the reset() method to reset the bullet's state for future reuse.



```
// Create a new Bullet
Bullet* bullet = Bullet::create("nox.png");
...
// Bullet destruction
bullet->removeFromParent()
```

```
// Create a new Bullet
Bullet* bullet = BulletPool::getInstance()->acquireBullet();
...
// Bullet destruction
BulletPool::getInstance()->releaseBullet(bullet);
```

The way to get bullets is as above. After reconstruction, using object pool has the following **advantages**:

Performance Boost: Reusing bullet objects instead of repeatedly creating and destroying them minimizes memory allocation and garbage collection overhead, leading to better overall performance.

Resource Efficiency: By maintaining a pool of bullet objects, the need for frequent object creation is eliminated, reducing resource consumption, particularly in cases with many short-lived bullets.

Memory Leak Prevention: The object pool ensures proper management of bullet objects, preventing potential memory leaks from continuous object creation and destruction.

Enhanced Game Efficiency: The pool allows quick retrieval of bullets when needed, and by resetting the bullet objects for reuse, it reduces the cost of object creation, improving the efficiency of the game's operations.

3.7.4 Key Code Demonstration

```
Bullet* acquireBullet() {
    if (pool.empty()) {
        CCLOG("Bullet pool is empty. Expanding pool...");
        // If the pool is empty and the size hasn't exceeded the max size,
        // create a new bullet and add it
        if (poolSize < maxPoolSize) {
            Bullet* bullet = Bullet::create("shuiguai.png");
            pool.push(bullet);
            poolSize++;
        }
        else {
            CCLOG("Error: Bullet pool has reached its maximum size.");
            return nullptr;
        }
    }
    Bullet* bullet = pool.front();
    pool.pop();
    return bullet;
}
```

4. Code Refactoring Insights

In the process of refactoring our code, we learned 22 different software design patterns, each bringing specific improvements to the architecture. During the redesign, we encountered a few key insights related to pattern usage, their dependencies, and specific nuances in implementation:

Flyweight and Singleton: When implementing the flyweight pattern, we realized that if an object is limited to a single instance (i.e. a single texture), it essentially becomes a singleton. This reflects the relationship between the two patterns. When you need to ensure that only one instance of a shared resource (such as a texture or image) exists and multiple clients can reuse it, the flyweight pattern becomes a singleton pattern.

Dependency Between Flyweight and Factory Pattern. It shows how these two patterns work together. In the Flyweight Pattern, the Factory Pattern manages object creation and reuse. The Factory checks if an object with a given configuration already exists and reuses it, reducing unnecessary object creation. This centralized management ensures efficient memory use by sharing identical objects. The Factory Pattern enables the Flyweight Pattern by handling object creation and sharing, optimizing performance and resource efficiency.

Template Method and Method Overriding. When implementing the Template Method pattern, we realized that the flexibility of the algorithm skeleton provided by the template method is achieved by allowing subclasses to override specific methods. This reflects the relationship between the two concepts. When you need to define a fixed sequence of steps in an algorithm but allow subclasses to provide their specific implementation for certain steps, the Template Method pattern essentially becomes dependent on method overriding.

5. Conclusion

This semester's "Software Design Patterns" course has provided us with an in-depth understanding of many common design patterns, including creational, structural, and behavioral patterns. Each pattern has its unique application scenarios and solutions. Through theoretical learning in the course, we have gained a more comprehensive understanding of the core concepts and principles of design patterns, particularly how they improve the maintainability, scalability, and reusability of code.

In practical projects, we applied these patterns to code refactoring and problem-solving tasks. This hands-on experience deepened our understanding of each pattern's role in real-world development. Patterns like Flyweight, Singleton, and Factory helped us save memory and optimize performance when handling large numbers of objects, further enhancing our understanding of software architecture.

We would like to express our gratitude to our teacher for their patient guidance and to our classmates for their collaborative learning. The discussions and hands-on projects in this course have been extremely beneficial and have sparked a greater interest in software engineering and design patterns. We will continue to apply, reflect on, and improve our design abilities in future projects.