CS3300 Introduction to Software Engineering

Lecture 05: Tools of the Trade #4

Spring, Spring Boot

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Frameworks

- Framework is a predefined set of tools, libraries, best practices, and conventions that helps developers create applications more efficiently and effectively.

- Provides a foundation on which developers can build programs for a specific platform.

Provides a consistent structure for collaboration	Reusable Code	Includes Best practices for foundational elements
Extensions and Plugins	Inversion of Control	Learning Curve

Java Frameworks

- Java framework is a body of reusable prewritten code acting as templates used by developers to create apps using the Java programming language

Web frameworks

- SpringBoot, Vaadin, JavaServer Faces, JHipster

Data Access frameworks

- Hibernate, Java Persistence API, MyBatis

Microservices

- Spring Cloud, MicroProfile, Quarkus

Big Data

- Apache Kafka, Apache Spark, Apache Hadoop

Testing

- Junit, TestNG, Mockito, Spring Test

Security

- Spring Security

Framework *vs.* API

- Framework serves as a foundation for programming, while an API provides access to the elements supported by the framework.
- Framework includes an API
- Will also include code libraries, compiler and other programs needed for software development

Spring

- Most popular, powerful, lightweight and open-source application development framework used for Java Enterprise Edition (JEE). Other frameworks include Hibernate, JSF, Struts etc.
    - JEE is built upon Java SE (Standard Edition) . Provides functionalities like web application development, servlets etc.
    - JEE provides APIs for running large scale applications

Advantages of Spring

- MVC architecture. Distinct division between models (data), controllers (application logic) and views(user interface).
- Framework of frameworks. Can easily integrate with other frameworks like Struts, Hibernate etc.
- Flexibility
- One stop-shop for all enterprise applications. But modular, allows you to pick which modules you need.
- Allows loose coupling among modules
- Easier to test
- Increases efficiency due to reduction in application development time

Inversion of Control (IoC)

- Principle in software engineering which transfers the control of objects or portions of a program to a container or framework. Most often used in the context of object-oriented programming. The architecture helps in decoupling the execution of a task from its implementation.

- Instead of your code explicitly instantiating, configuring, and managing the lifecycle of its dependencies, you delegate that responsibility to an external framework or container.

- In Spring, objects configured in XML file and Spring container is responsible for creation and deletion of objects by parsing XML file.

Inversion of Control (IoC)

Example of highly coupled classes

```
public class DataAccess
{
    public DataAccess()
    {
    }

    public string GetCustomerName(int id) {
        return "Dummy Customer Name"; // get it
    }
}
```

```
public class CustomerBusinessLogic
{
    DataAccess _dataAccess;

    public CustomerBusinessLogic()
    {
        _dataAccess = new DataAccess();
    }

    public string GetCustomerName(int id)
    {
        return _dataAccess.GetCustomerName(id);
    }
}
```

- *CustomerBusinessLogic* and *DataAccess* classes are tightly coupled. Changes in the *DataAccess* class will lead to changes in the *CustomerBusinessLogic* class. For example, if we add, remove or rename any method in the DataAccess class then we need to change the CustomerBusinessLogic class accordingly.

- The *CustomerBusinessLogic* class creates an object of the *DataAccess* class using the **new** keyword. There may be multiple classes which use the *DataAccess* class and create its objects. So, if you change the name of the class, then you need to find all the places in your source code where you created objects of *DataAccess* and make the changes throughout the code.

- Because the *CustomerBusinessLogic* class creates an object of the concrete *DataAccess* class, it cannot be tested independently (TDD). The DataAccess class cannot be replaced with a mock class.

Inversion of Control (IoC)

Using Factory pattern of the IoC principle => Loosely coupled design

```
public class CustomerBusinessLogic
{

    public CustomerBusinessLogic()
    {
    }

    public string GetCustomerName(int id)
    {
        DataAccess _dataAccess =  DataAccessFactory.GetDataAccessObj();

        return _dataAccess.GetCustomerName(id);
    }
}
```

```
public class DataAccessFactory
{
    public static DataAccess GetDataAccessObj()
    {
        return new DataAccess();
    }
}
```

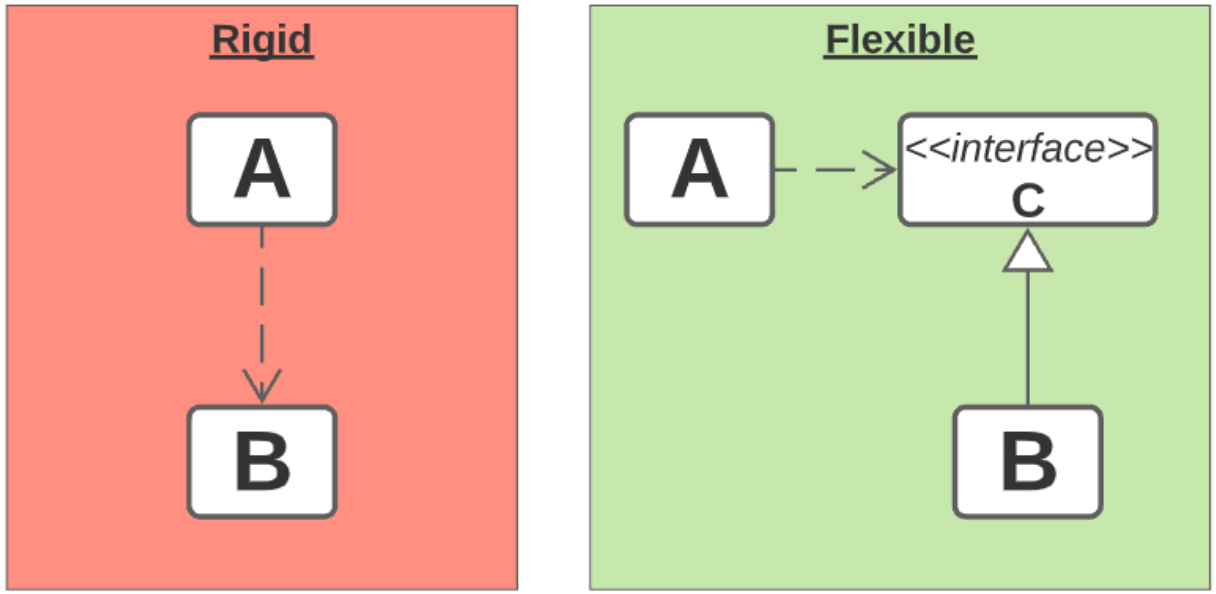
```
public class DataAccess
{
    public DataAccess()
    {
    }

    public string GetCustomerName(int id) {
        return "Dummy Customer Name"; // get it
    }
}
```

The *CustomerBusinessLogic* class uses the *DataAccessFactory*.*GetCustomerDataAccessObj*() method to get an object of the *DataAccess* class instead of creating it using the new keyword. Thus, we have inverted the control of creating an object of a dependent class from the *CustomerBusinessLogic* class to the *DataAccessFactory* class.

first step towards achieving fully loose coupled design.

Dependency Inversion Principle (DIP)

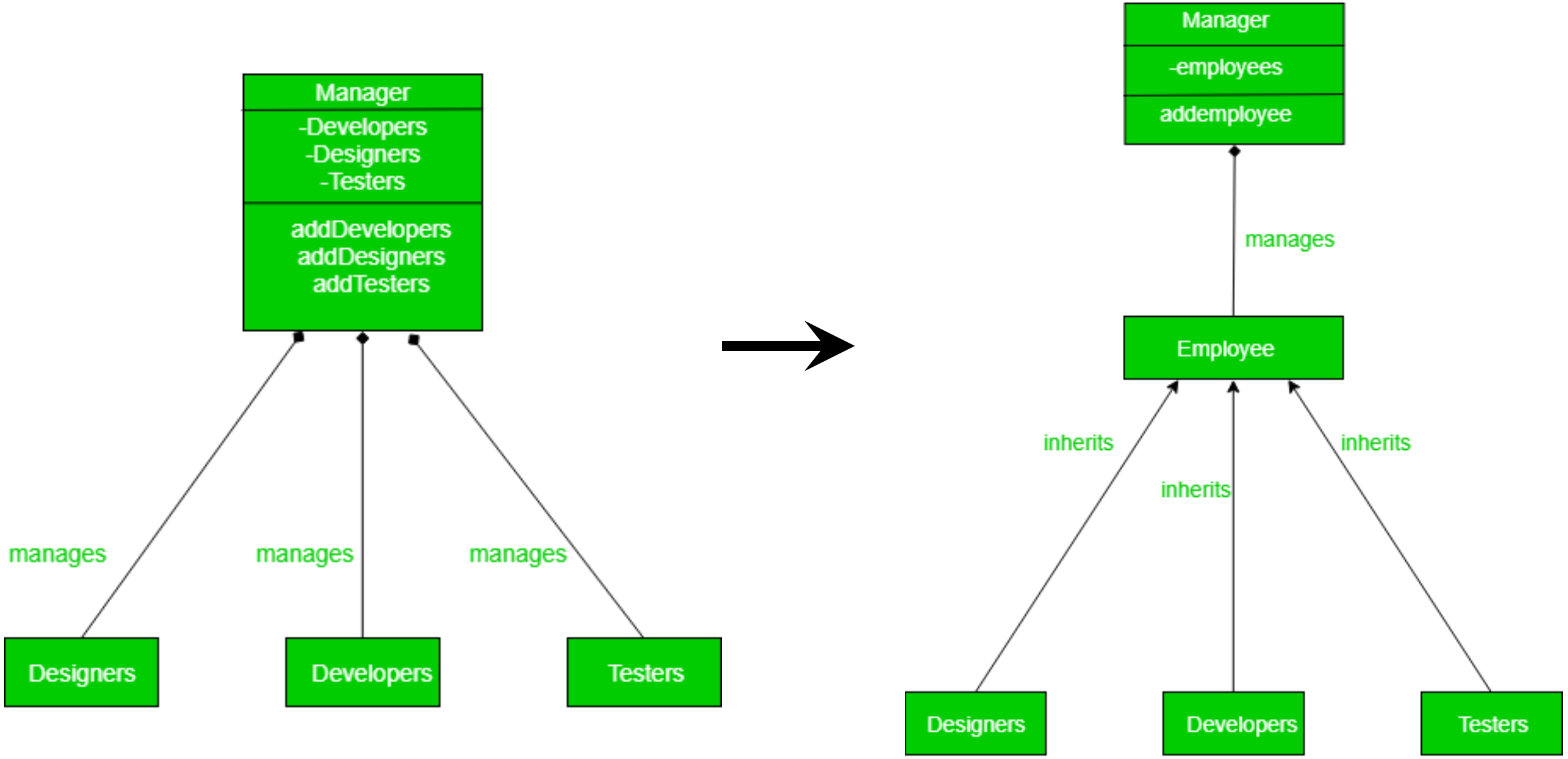
- A high-level module (depends on other modules) should not depend on low-level modules (*DataAccess* Class). Both should depend on abstraction.



- Abstractions should not depend on details. Details should depend on abstractions

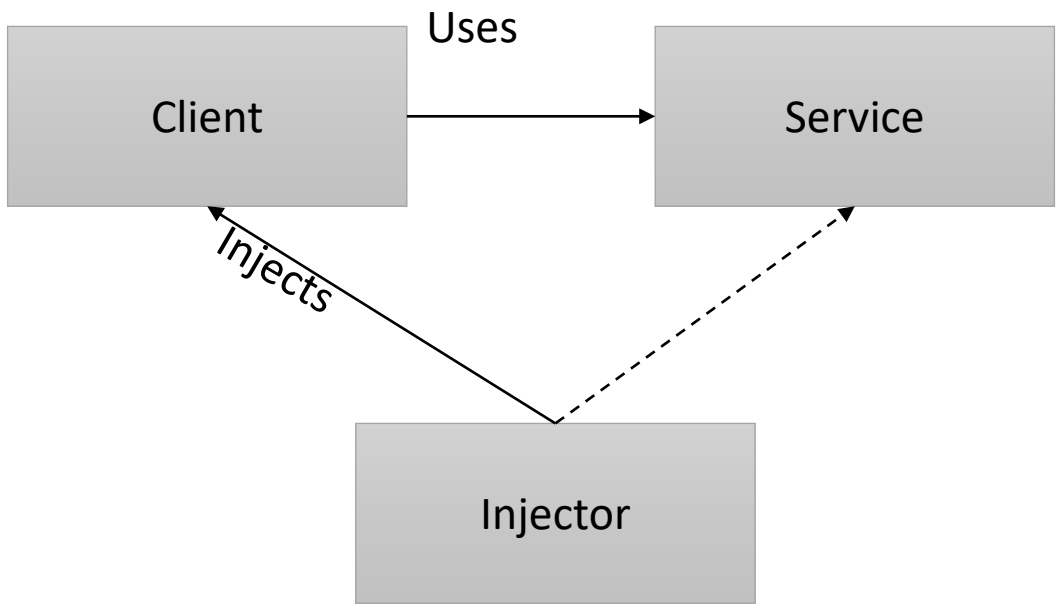
Abstraction in OOPS means to create an interface or an abstract class which is non-concrete. This means we cannot create an object of an interface or an abstract class.

Dependency Inversion Principle (DIP)



Dependency Injection (DI)

- Dependency Injection (DI) is a design pattern used to implement IoC. It allows the creation of dependent objects outside of a class and provides those objects to a class through different ways.
- Increases possibility to reuse classes and test independently of other classes while unit testing
- DI pattern includes 3 class types:



Injector class creates an object of service class, injects it to a client object. Hence, separates the responsibility of creating an object of service class out of the client class.

Benefits of using DI

- Helps in Unit testing.
- Boiler plate code is reduced, as initializing of dependencies is done by the injector component.
- Extending the application becomes easier.
- Helps to enable loose coupling, which is important in application programming.

Without DI example

```java
// Engine class
class Engine {
    public void start() {
        System.out.println("Engine started.");
    }
}
```

Problems with This Approach:

- **Tight Coupling**: The Car class is tightly coupled with the Engine class. If you want to change the engine type (e.g., to a DieselEngine), you must modify the Car class code.
- **Difficult to Test**: You cannot easily replace the Engine with a mock or stub for testing purposes.
- **Low Flexibility**: Every change in the Engine class or its behavior requires changes in the Car class.

```java
// Car class without Dependency Injection
class Car {
    private Engine engine;

    public Car() {
        // The Car class creates its own Engine instance
        this.engine = new Engine();
    }

    public void start() {
        engine.start();
        System.out.println("Car started.");
    }
}

// Usage
public class Main {
    public static void main(String[] args) {
        Car car = new Car(); // Car creates its own dependencies
        car.start();
    }
}
```

With DI example

```java
// Service class
class Engine {
    public void start() {
        System.out.println("Engine started.");
    }
}
```

```java
// Client class
class Car {
    private Engine engine; // Dependency

    // Constructor Injection: The Engine is injected via the constructor
    public Car(Engine engine) {
        this.engine = engine;
    }

    public void start() {
        engine.start(); // Using the injected dependency
        System.out.println("Car started.");
    }
}
```

```java
// Injector class
class CarInjector {
    public static Car getCar() {
        // Create the service instance (Engine)
        Engine engine = new Engine();

        // Inject the service into the client and return the client
        return new Car(engine);
    }
}
```

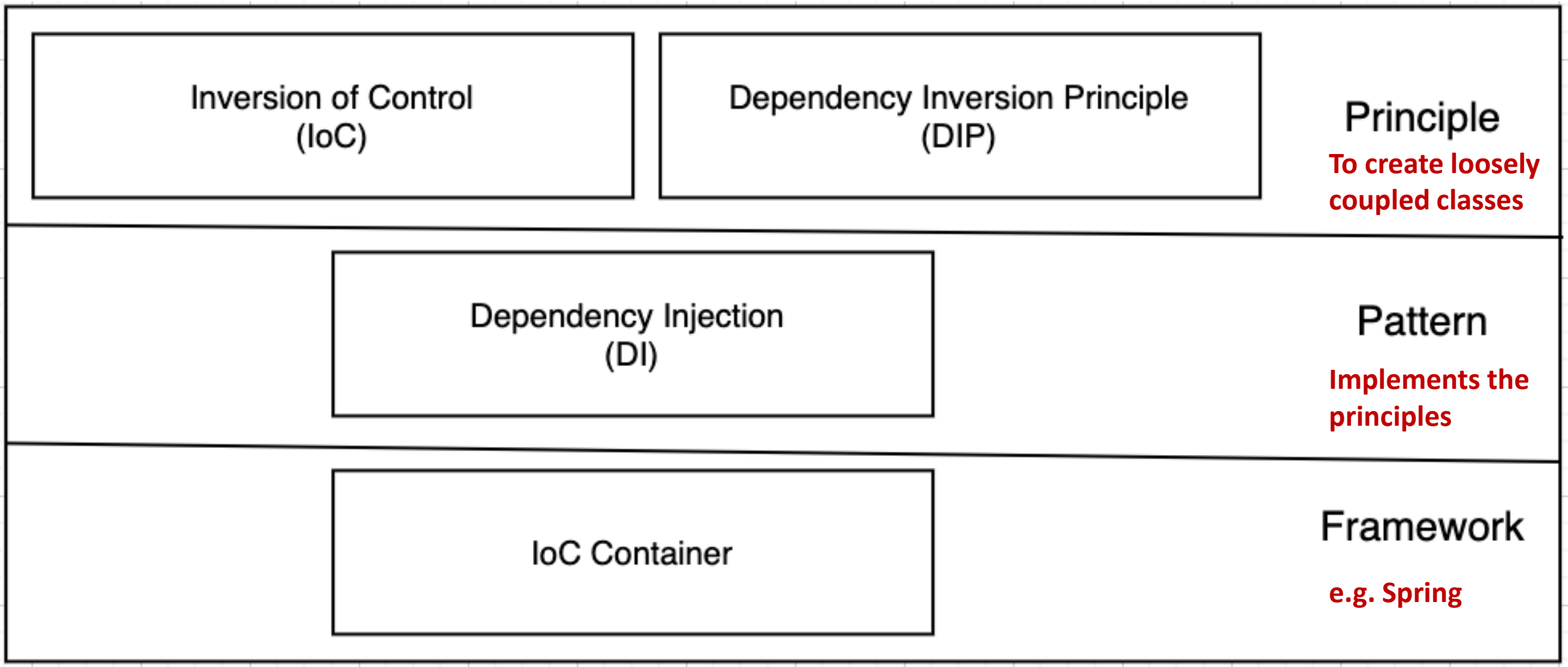
```java
public class Main {
    public static void main(String[] args) {
        // Use the injector to get the client with the service injected
        Car car = CarInjector.getCar();
        car.start();
    }
}
```

With DI example

Benefits of This Approach:

- **Loose Coupling**: The Car class is not tightly coupled to the Engine class. Any implementation of Engine (e.g., DieselEngine, ElectricEngine) can be injected.
- **Testability**: Easily test the Car class by injecting mock objects or stubs of the Engine.
- **Single Responsibility Principle**: The CarInjector class handles the creation and injection of dependencies, leaving the Car class focused on its core functionality.

IoC, DIP, DI


Inversion of Control
(IoC)
Dependency Inversion Principle
(DIP)
Principle
To create loosely coupled classes
Dependency Injection
(DI)
Pattern
Implements the principles
IoC Container
Framework
e.g. Spring

Spring Boot

- Spring Boot builds on top of Spring Framework, offering a streamlined approach to developing Spring applications with minimal boilerplate code, auto configuration, embedded servers, and other features. It means that you can **just run t**he application.

- Dependencies and configurations are managed by Spring Boot.

- Normally to run application, you need: hardware + OS + Server +Application file (.war for web applications). With Spring Boot: server embedded (Tomcat), executable files generated automatically.

- Features:
  - Provides with a starter project for the application along with auto configuration
  - Does not generate XML file but configuration can be modified (using YAML files, properties or XML)

Spring Boot Starter Projects

- Goal is to help you get a project up and running quickly
  - Web application: Spring-Boot-Starter-Web
  - REST API: Spring-Boot-Starter-Web
  - Talk to database using JPA- Spring-Boot-Starter-Data-JPA
  - Talk to database using JDBC- Spring-Boot-Starter-JDBC
  - Secure web application- Spring-Boot-Starter-Security

- Manage list of maven dependencies & versions for different apps:
  - Spring-Boot-Starter-Web: Frameworks needed by typical web applications. Spring-webmvc, spring-web, spring-boot-starter-tomcat, sprint-boot-starter-json

Spring Boot Auto Configuration

- Starter defines dependencies
- Auto configurations provides basic configuration to run application using frameworks defined in your maven dependencies
- Decided based on:
  - Which frameworks are in class path?
  - What is the existing configuration? (*Maven Dependencies* – *springframework.boot.autoconfigure* – classes that will be checked)
  - Type *logging.level.org.springframework=DEBUG* in *application.properties* to see what is being auto-configured.

DEMO TIME!!

- Create a simple web app using SpringBoot
- We needed Express in Node.js to establish the server. Spring Boot has Tomcat server embedded– very convenient

WHAT IF WE HAD TO CREATE THE SAME APP WITHOUT SPRING BOOT

- We have Spring framework
- Setup and manage all maven dependencies and versions in pom.xml manually – very extensive
- Define Web.xml file to configure web related front controller (if war)
- Define a Spring context XML file to define component scans
- Install Tomcat or configure Tomcat maven plugin
- Deploy and run application IN TOMCAT

COMPARISON FROM NODE+EXPRESS

Aspect	Node + Express	Spring Boot
Server wiring	You write app.listen()	Embedded Tomcat auto-wired by Spring
Routing setup	Manual app.get()/post() calls	@RestController + @GetMapping, etc.
Middleware	You app.use() each piece	Auto-configures JSON, static, CORS, etc.
Packaging	Plain JS files + node_modules	One runnable fat-jar with embedded server
Startup	node index.js	java -jar myapp.jar or Maven plugin
Production ops	Process manager, clustering, Docker	Runs anywhere you can run a JVM

In **Express** you get a minimal, unopinionated HTTP toolkit—you choose and wire everything.
In **Spring Boot**, the framework **auto-wires** a production-ready server, so you focus almost entirely on your application's behavior rather than on plumbing.
NestJS, LoopBack 4, AdonisJS, Sails.js are Springboot equivalent frameworks

Equivalent Frameworks

Language	Framework	Highlights
JavaScript/TypeScript	**NestJS**	Built on Express or Fastify; full DI container; module system; CLI.
Python	**Django**	“Batteries included” MVC; built-in dev server; ORM; admin.
	FastAPI	ASGI-based; type-hints → auto-docs; dependency injection; async.
Ruby	**Ruby on Rails**	MVC; built-in server (WEBrick/Puma); generators; ActiveRecord.
PHP	**Laravel**	MVC; built-in server; Eloquent ORM; queues; DI container.
C#/.NET	**ASP.NET Core**	Kestrel web server; built-in DI; middleware pipeline; Razor.
Go	**Buffalo**	“Rails-like” generators; built-in dev server; migrations.
	Gin	Minimalist but with routing, middleware; less “opinionated.”
Kotlin	**Ktor**	Embedded Netty/Jetty; coroutine-friendly; minimal DSL.
Scala	**Play Framework**	Built-in Netty server; stateless MVC; hot-reload.
Elixir	**Phoenix**	Cowboy server; channels (WebSockets); MVC; generators.
Rust	**Actix-web**	Actor-model; very high performance; middleware.
	Rocket	Macro-driven routing; type-safe request guards.
Swift	**Vapor**	Async-driven; DI via service container; built-in router.
Haskell	**Yesod**	Type-safe routing; persistent ORM; built-in development server.