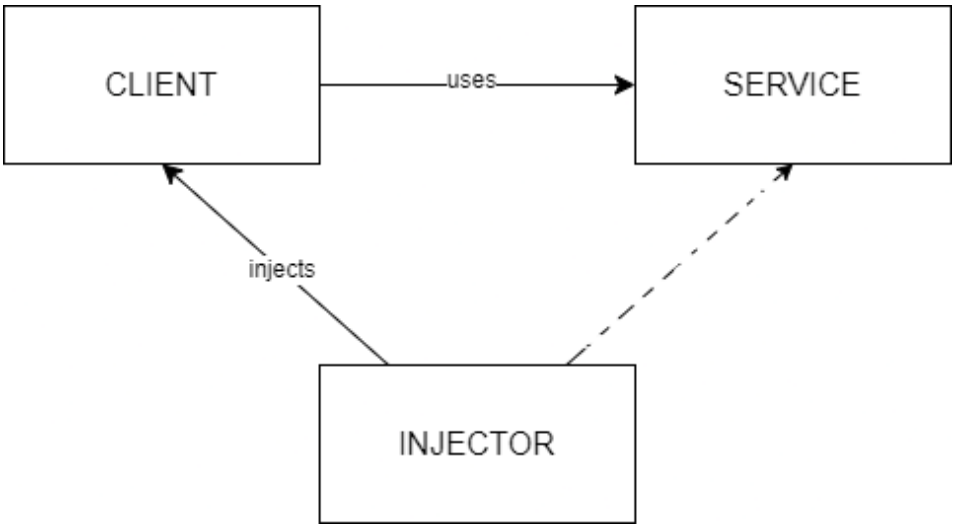
DEPENDENCY INJECTION

Introduction:

In general, when we want to develop a new application, we don't simply want to obtain working code, but we want to do it in the most effective, efficient, modular and understandable way possible. To this end, over the years, a series of rules and best practices to follow have been created, which are called "design patterns".

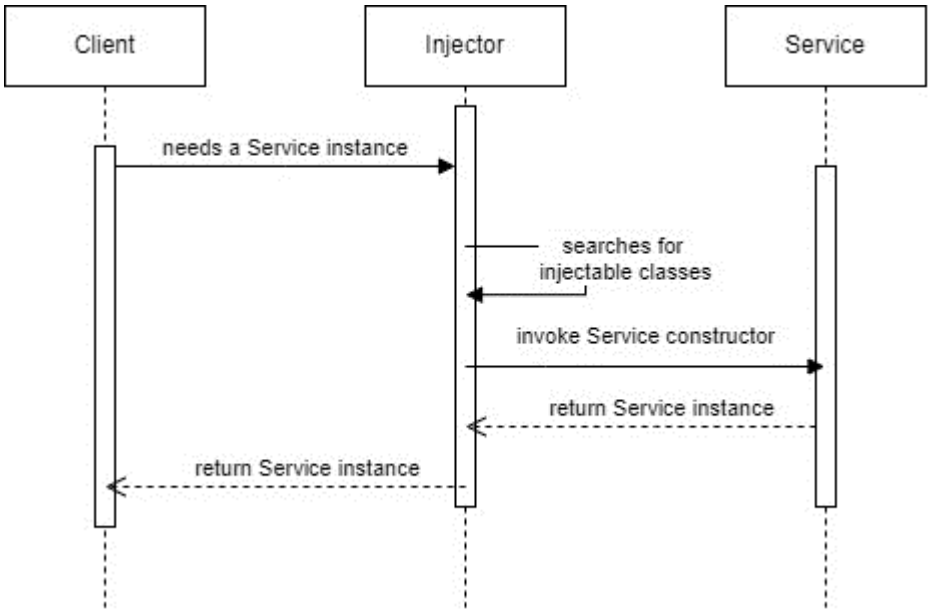
Mark Seemann has defined dependency injection as "a set of software design principles and patterns that enable us to develop loosely coupled code". The idea behind this principle is that we don't want our classes and modules to be dependent on other components by directly instantiate them, but we would like to have them "injected" by someone else. In this way, we can create non hard-coded dependencies that lead to more flexible and maintainable code.

There are three types of dependency injection that differ from the point in which they apply the injection, but, in general, there are always the following elements:



- Client: the class that needs the dependency.
- Service: the class that is needed. It is often the implementation of a more general interface to satisfy the dependency inversion principle. In this way, the client won't have an explicit dependency on the service class.
- Injector: the class that creates the service and injects it into the client. It can be implemented in many languages thanks to the mechanisms they offer, such as reflection and annotations. Other solutions are ready-to-use frameworks and containers.

So, to achieve dependency injection, we need to add an indirection layer between the client and its dependencies. This layer is responsible for retrieving service instances and injecting them into the client. The general workflow is showed in the following image:



There are many ways to achieve this type of behavior and there are just as many ways to optimize the process. Before we discuss all the problems and variants, let's see the main types of dependency injection and an example of implementation.

Constructor injection:

This type of injection uses the constructor to pass in the dependencies of a service. In this way, we are saying that, if you want to use the client, you need to provide certain classes before. Otherwise, you won't be able to use it.

```
public class MyClass {

    private Dependency dependency;

    public MyClass (Dependency dep){
        this.dependency = dep;
    }
}
```

The class that needs the dependency must expose a public constructor that takes an instance of the required dependency as a constructor argument. A better solution can also prevent null parameters by throwing an exception (guard pattern):

```
public class MyClass {

    private Dependency dependency;

    public MyClass (Dependency dep) throws Exception {
        if (dep == null) {
            throw new Exception("cannot pass a null parameter!");
        } else {
            this.dependency = dep;
        }
    }
}
```

Constructor injection should be used every time the client requires the service in order to work properly and when the dependency in question has a lifetime longer than a single method.

Property injection (or setter injection):

In this case, dependencies are set using setter methods:

```
public class MyClass {

    private Dependency dependency;

    public void setDependency(Dependency dep) throws Exception {
        if (dep == null) {
            throw new Exception("cannot pass a null argument!");
        } else {
            this.dependency = dep;
        }
    }
}
```

The class that needs the dependency must expose a public setter method that takes an instance of the required dependency as an argument. This approach allows for flexibility in setting dependencies after the client class instance has been created. Property injection is mostly used when we want to use different implementations of the service during the client lifecycle or when the dependency is optional. In these cases, we usually instantiate a default service implementation for the client during its creation. At a later stage, we can switch the dependency implementation by using the setter method or decide to maintain the default configuration.

```
public class MyClass {
    private Dependency dependency;

    public MyClass(){
        this.dependency = new DefaultDependency();
    }

    public void setDependency(Dependency dep) throws Exception {
        if (dep == null) {
            throw new Exception("cannot pass a null argument!");
        } else {
            this.dependency = dep;
        }
    }
}
```

```java
public class App {
    public static void main(){
        MyClass c = new MyClass();
        /*
         *   Using MyClass with default dependency
         */
        try {
            c.setDependency(new SpecializedDependency());
        } catch (Exception e) {
            throw new RuntimeException(e);
        }
        /*
         *   Using MyClass with new dependency injected
         */
    }
}
```

Method injection:

Similarly to property injection, dependencies are injected via methods, but they can be different from setters.

```java
public class MyClass {

    public void myMethod(Dependency dep) throws Exception {
        if (dep == null) {
            throw new Exception("cannot pass a null argument!");
        } else {
            /*
                Using dependency...
             */
        }
    }

}
```

Method injection is best used when the dependency can vary with each method call. This can be the case when the DEPENDENCY itself represents a value, but it is often seen when the caller wishes to provide the consumer with information about the context in which the operation is being invoked. This is often the case in add-in scenarios where an add-in is provided with information about the runtime context via a method parameter. In such cases, the add-in is required to implement an interface that defines the injecting method(s).

Implementing dependency injection:

Dependency injection works by using reflection or annotations to inspect the components and their dependencies, and then using dynamic proxies or code generation to create and inject the dependencies at runtime. Implementation of dependency injection can be done through an injector that works in three steps:

1) Scan: the injector scans the classpath for classes decorated with predefined annotations that indicate the necessity of dependency injection
2) Wire: the injector inspects constructor and methods for annotations that indicate the points where to execute the injection of the matching dependencies from a component registry.
3) Init: the injector inspects injected components for annotations that indicate methods that must be executed before and/or after their initialization or destruction (these methods are called "lifecycle callbacks").

A practical example:

1) Define an annotation for marking the components that need dependency injection:

```java
@Retention(RetentionPolicy.RUNTIME)
@Target(ElementType.TYPE)
public @interface Injectable {
}
```

2) Define an annotation for marking the methods and constructors that need dependency injection:

```java
@Retention(RetentionPolicy.RUNTIME)
@Target(ElementType.CONSTRUCTOR)
public @interface Inject {
}
```

3) Define the injector class (full code at https://github.com/FabioGentili99/project-work-on-Distributed-Systems-M):

```java
public class Injector {

    private final Map<Class<?>, Object> instances;

    public Injector() {
        instances = new HashMap<>();
    }

    public void register(Class<?> type, Object instance) {
        instances.put(type, instance);
    }

    public Object inject(Class<?> targetClass) throws IllegalAccessException, InvocationTargetException, InstantiationException {
        /*
            scan, wire and init
         */
```

It contains a map that stores the instances of the dependencies to be used for injection (it could have been a configuration file from which to read). The inject method allows

to inject the dependencies into a target object by scanning constructors that present @Inject annotation and assigning instances that correspond to their parameter types.

4) Annotate the classes and the constructors that need dependency injection with annotation defined above:

```
@Injectable
public class Client {
    private Service service;

    public Client(){
        this.service = null;
    }

    @Inject
    public Client(Service service){
        this.service = (Service) service;
    }
```

5) Create an instance of the injector and register the dependencies. At the end, we can retrieve an instance of our client with all dependencies injected:

```
public class Main {
    public static void main(String[] args) {
        Injector injector = new Injector();
        injector.register(Service.class, new MyService());

        Client client;
        try {
            client = (Client) injector.inject(Client.class);
        } catch (IllegalAccessException | InstantiationException | InvocationTargetException e) {
            throw new RuntimeException(e);
        }
        client.start();
    }
}
```

Problems and variants:

As we can see, there are many problems with the previous simple implementation of an injector:

- The injector must be explicitly created.
- We have to manually instantiate and register the services that we want to inject.
- Injection is performed at runtime. So, the process is dynamic but non efficient as a compile-time injection.
- The injector is based on the reflection mechanism of Java. It introduces a lot of overhead during the execution of the application.

- We register only one instance for each service. So, every client will have injected the same instance of that service.

In general, it is desirable to use the best dependency injection implementation based on the needs of the applications. There are a lot of solutions available on the market, but, in some cases, we could need to build our own injector. We will see in the following chapters how to obtain dependency injection in a serverless scenario.

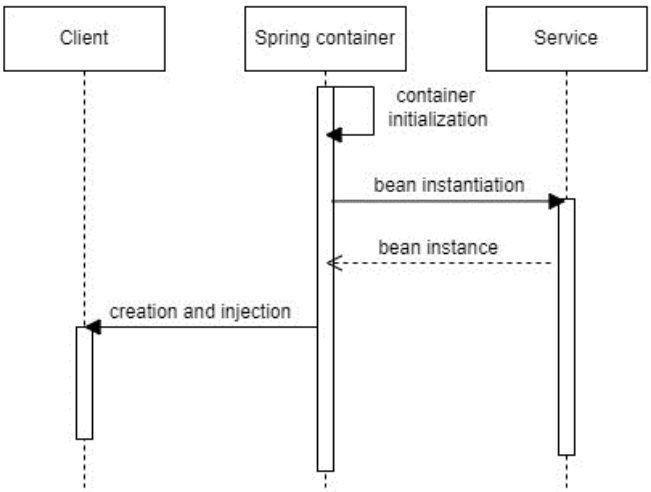
Spring IoC container:

The most used DI container in the Java environment is Spring IoC container. It is accessible via ApplicationContext interface and it uses configuration metadata to understand what objects to instantiate and assemble. The configuration metadata can be represented in XML or Java annotations. Application context exposes a getBean() method to retrieve the instances of the dependencies that we need.

The container performs dependency injection resolution as follows:

1) When the Spring application starts, the IoC container is created. It reads configuration metadata and parses it to create a representation of the bean definitions in memory
2) The container creates bean instances based on the bean definitions. It uses reflection to instantiate the objects, invoking constructors or factory methods as specified in the metadata.
3) The IoC container handles the injection of dependencies into the beans. If a bean has dependencies, the container will find them in its configuration and add them to the bean when it's created (by-need)

The container manages the beans in different ways based on their type: singleton beans are instantiated immediately when the container is created, other types only when it’s needed (lazy initialization). By default, all beans are singletons.



Dagger 2:

Usually, dependency injection is executed at run-time by using reflection mechanism. This allows our applications to be more dynamic and to start running before the dependencies are resolved, but it adds overhead during execution.

Dagger 2 is a fully static, compile-time, open-source dependency injection framework for both Java and Android. It implements dependency injection by using code generation: the annotations are translated into code at compile-time. Dagger functionalities are based on four annotations:

- @Inject: it is used to annotate classes and field that need dependency injection. So, Dagger will construct those instances.
- @Module: it is used to annotate classes whose methods provide dependencies. In this way, Dagger will know where to find the dependencies in order to satisfy them when constructing class instances.
- @Provide: inside modules we define methods containing this annotation wich tells Dagger how we want to construct and provide those dependencies.
- @Component: it is used to annotate injectors.

Obviously, the process of instantiating dependencies and injecting them is done at run-time, but dependency resolution is completed at compile-time. So, the dependency graph is calculated at compile-time. In this way, the start-up time of applications that use Dagger 2 to achieve dependency injection is reduced with respect to the ones that use traditional run-time dependency injection. On the other hand, we need to write more code and we can't obtain the flexibility of dynamic dependencies resolution.

Benefits:

It may seem that dependency injection only adds complexity to the application, without improving the performance and the quality of the code. In reality, it permits us to achieve an important objective: loose coupling between client and service implementation. This leads to many advantages that can be resumed in:

- Maintainability: simple and stand-alone classes are easier to fix than tightly coupled classes. Given that maintenance costs often exceed the cost of building the code, anything that can improve maintainability is a good thing.
- Testability: loosely coupled classes that only do one thing are more prone to unit testing. Furthermore, if we pass dependencies to classes, it's quite simple to pass-in a test double implementation. If dependencies are hard-coded, it's impossible to create test doubles and we will need to modify the code.

- Readability: code that uses dependency injection is more straightforward. Constructors aren’t cluttered and filled with logic, classes are clearly defined, smaller and more compact.
- Flexibility: loose coupled code can adapt to changes in requirements or in the execution environment.
- Extensibility: by relying on abstractions instead of implementations, code can be extended with different implementations of the service interface.
- Scalability: Dependency injection simplifies the process of scaling applications by promoting a modular and loosely coupled architecture. New components can be added or existing ones modified without impacting the overall system, making it easier to accommodate changing requirements and scale the application as needed.

References:

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https://docs.spring.io/spring-framework/reference/core.html

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