

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Introduction

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Hogeschool Rotterdam
Rotterdam, Netherlands

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Introduction

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Lecture topics

- Intro to DEV4
- Design patterns introduction
- The visitor design pattern
- Course agenda
- Conclusions

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Options

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

What you have done so far?

- Encapsulation, polymorphism, subtyping, generics, etc.;
- Powerful ways to express interactions among objects.

What we have not told you?

- Interactions between program modules affect maintainability
- The higher the interactions, the higher is the chance of having bugs
- This phenomenon is known as coupling

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Options's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

What is coupling?

- If changing one module in a program requires changing another module, then we have coupling.

High-coupling

- As the amount of interaction between two classes **A** and **B** increases, the coupling between them increases as well;
- This translates into: whenever **A** changes, the chance to erroneously change **B** is “high”;
- More bugs

High-coupling

- The class Driver contains a field of type Car
- The class Driver has visibility of all Car public methods and fields
- The interaction between Driver and Car should be limited to the Move method

```
1  class Driver {  
2      private Car car;  
3      void Drive() {  
4          public this.car.Move();  
5      }  
6  }  
7  class Car {  
8      public void Move() {  
9          ...  
10     }  
11 }
```


Low-coupling

- The amount of interaction between two classes **A** and **B** is limited to a series of methods provided by an interface;
- This translates into: whenever **A** changes, the chance to erroneously change **B** is “low”, since **A** know little about **B**.

Low-coupling

- The class Driver contains a polymorphic type Vehicle
- The interaction between Driver and Car is restricted to the interface method Move

```
1  class Driver {  
2      private Vehicle vehicle;  
3      void Drive() {  
4          public this.vehicle.Move();  
5      }  
6  }  
7  interface Vehicle {  
8      void Move();  
9  }  
10 class Car : Vehicle {  
11     public void Move() {  
12         ...  
13     }  
14 }
```

Low vs High coupling

- As the amount of entities increases, the of amount of interactions increases (especially if the interfaces are not clear or not used at all);
- It is a very big number (we are talking about a factorial function) depending on the amount of interacting objects
- More precisely, given C classes, it is:

$$I \sim \left(\sum_{k=2}^C \frac{C!}{2(C-k)!} \right)$$

Low vs High coupling

- Consider a very simple program with only 4 classes
- This amount is given by

$$I \sim \frac{4!}{2(4-2)!} + \frac{4!}{2(4-3)!} + \frac{4!}{2(4-4)!} = 30$$

Finding the right amount of coupling

- One could argue that: to avoid coupling we can put everything in one big class;
- Unfortunately this does not solve the problem, since we can have coupling also within a single class.
- Parts of the class `Driver` still have complete visibility on the rest of the class

```
1 class Driver {  
2     private Vehicle vehicle;  
3     void Drive() {  
4         public this.vehicle.Move();  
5     }  
6     public void Move() {  
7         ...  
8     }  
9 }
```

Achieving low-coupling

- Maintaining code is hard and expensive
- Low coupling = easily maintainable code
- What seems desirable when dealing with software development is to keep coupling (our interactions) among entities as low as possible

Maintainability in code

- Is an important aspect in development;
- It affects costs, code customization, bug fixing, etc.
- Maintainable code = low chance of bugs and smaller effort in making changes

Polymorphism for taming coupling in programs

- We can control interactions by means of an interface that hides the specifics of some classes
- Every entity interacts with another only through small “windows” (defined as interfaces), each exposing specific and controlled behavior.

Low-coupling a general view

- Given two classes A and B;
- A interacts with an I_B interface, whenever A needs to interact with an instance of type B;
- B interacts with an I_A interface, whenever B needs to interact with an instance of type A.

Introduction

The INFDEV team

Introduction

Our first design pattern

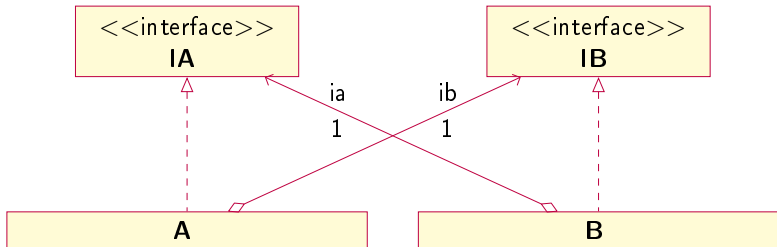
Visiting Option's

Visiting Options without lambdas

Visiting Options lambdas

The visitor design pattern

Course structure



```
1 class Driver {  
2     private Vehicle vehicle;  
3     void Drive() {  
4         public this.vehicle.Move();  
5     }  
6 }  
7 interface Vehicle {  
8     void Move();  
9 }  
10 class Car : Vehicle {  
11     private Engine engine;  
12     public void Move() {  
13         ...  
14     }  
15 }
```

- The driver can yes interact with a vehicle, but only with its public Move method;
- The engine, which should not be accessible outside the car, is not mentioned in the interface, so the driver cannot interact with it.

Recurrent patterns in objects interactions

- Disciplined interactions such as the one above tend to exhibit some recurring high level structures;
- Such recurrent structures are known under the umbrella term of **design patterns**.

Design Patterns

- Design patterns in short are: ways to capture recurrent patterns for expressing controlled interactions between objects;
- We will now see a specific example of such a pattern.

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Our first design pattern

Our first design pattern

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Choosing in the presence of polymorphism

- As you already know polymorphism is a powerful mechanism that allows decomposition and code reuse;
- However, polymorphism becomes dangerous when given a general^a instance we have to choose what its specific shape is.

^aCat is Animal. Cat is specific. Animal is general.

Our first design pattern

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Why is choosing concrete types so dangerous?

- Mainly because a general type has no information about what classes are implementing it.

```
1 interface Vehicle {  
2     void Move();  
3 }  
4 class Car : Vehicle {  
5     ...  
6 }  
7 class Bike : Vehicle {  
8     ...  
9 }
```

- Given an instance *v* of type *Vehicle*, what can we say about the concrete type of *v*?
- Is it a *Car* or a *Bike*?
- What if we want to turn on the lights of the car of *v*?

Our first design pattern

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Safe choice in the presence of polymorphism

- We need a mechanism that allows us to manipulate polymorphic instances as if they were concrete;
- Concrete instances are the only ones who know their identity, so we allow them to choose from a series of given “options”.

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Visiting Option's

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

The Option data structure

- Is used when an actual value might not exist for a named value or variable;
- An option has an underlying type and can hold a value of that type, or it might not have a value.

Example of usage

- The following code illustrates the use of the option type;
- In this case we are capturing the number 5 within a `Some<int>` object;

```
1 Option<int> a_number = new Some<int>(5);
```

Example of usage

- In this case we capturing the “nothing” common to all values of type `int` withing a `None<int>` object;

```
1 Option<int> another_number = new None<int>();
```

Some<T> and None<T>

- Both types implement the Option<T> data structure;

```
1 class Some<T> : Option<T> {  
2   ...  
3 }
```

```
1 class None<T> : Option<T> {  
2   ...  
3 }
```

- Some<T> is a container of data, of type T, which is ready to get consumed; and
- None<T> is a container of data, of type T, which is not ready to get consumed yet.

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Option<T>

- Is an interface that represents both the absence and presence of data of type T

```
1 interface Option<T> {  
2   ...  
3 }
```

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Options's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Visiting Options without lambdas

Visiting an Option<T>

- As an option represents a generic container for any type of objects, we need a mechanism that allows us to manipulate its concrete content;
- To do so, we add a method `Visit` to the interface that accepts as input a “Visitor” (an `IOptionVisitor<T, U>`) and returns a generic result;
- The visitor object is able to identify the type of the concrete option (`Some` or `None`) and manipulate it;
- **Note**, in many literature this `Visit` method is generally called `Accept`.

```
1 interface Option<T> {  
2     U Visit<U>(IOptionVisitor<T, U> visitor);  
3 }
```


What is an IOptionVisitor<T, U>

- Is an interface that provides a series of method overloads (methods sharing the same name but different arguments) each per concrete class;
- In our case we have two signatures one for visiting a concrete Some instance and one for the None.

```
1 interface IOptionVisitor<T, U> {  
2     U Visit<U>(Some<T> option);  
3     U Visit<U>(None<T> option);  
4 }
```

Visiting Options without lambdas

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

A concrete visitor - LambdaOptionVisitor<T, U>

- Is able to perform operations on polymorphic data structures (our case on objects of type Some and None);
- Such operations (used within the Visit's) are assigned during initialization and are stored as attributes of this class;

```
1 class LambdaOptionVisitor<T, U> : Option<T> {  
2     private Func<T, U> onSome;  
3     private Func<U> onNone;  
4     public LambdaOptionVisitor(Func<T, U> onSome, Func<U> onNone) {  
5         this.onNone = onNone;  
6         this.onSome = onSome;  
7     }  
8     public U Visit<U>(Some<T> option) {  
9         return onSome(option.value);  
10    }  
11    public U Visit<U>(None<T> option) {  
12        return onNone();  
13    }  
14 }
```

Visiting Options without lambdas

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Visiting a None<T>

- At this point, when visiting an object of type None<T> we only implement the Visit method: we call the visitor method Visit of the visitor given as input (with this as its input, in this way we will help the system to select the method among those declared in the IOptionVisitor interface) then we return the result of its call;
- By assigning this to the Visit method we force the visitor to choose the overload expecting a None object;
- In this way we are sure that the operation performed is the one meant for this class.

```
1 class None<T> : Option<T> {  
2     public U Visit<U>(IOptionVisitor<T, U> visitor) {  
3         return visitor.Visit(this);  
4     }  
5 }
```

Visiting a Some<T>

- When instantiating a Some<T> a data of type T is passed and stored inside a field value;
- When visiting an object of type Some<T> we only implement the Visit method: we call the visitor method Visit of the visitor given as input (with this as its input, in this way we will help the system to select the method among those declared in the IOptionVisitor interface) then we return the result of its call;
- By assigning this to the Visit method we force the visitor to choose the overload expecting a Some object;
- In this way we are sure that the operation performed is the one meant for this class.

```
1 class Some<T> : Option<T> {  
2     public T value;  
3     public Some(T value) {
```

Testing out our Option<T>

- The next line shows how to use our option to capture numbers and define operations over it;
- More precisely we instantiate a `LambdaOptionVisitor`, which is then used to visit a `Some` containing the number 5.

```
1 IOptionVisitor<int, int> opt_visitor = new LambdaOptionVisitor<int, int>(()  
2     => "Throw␣exception..", x => (x + 1));  
3 Option<int> number = new Some<int>(5);  
   number.Visit(opt_visitor);
```

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Visiting Options lambdas

Visiting an Option<T>

- As option represents a generic container for any type of objects, we need a mechanism that allows us to manipulate its content regardless its concrete data type;
- We add a method to our interface called Visit that accepts as inputs a series of options (in the shape of lambdas) and a generic result;
- Each option will be selected by exactly one of the possible concrete types;
- We decided a priori that the first argument is meant for the class None<T> while the second one for the Some<T>

```
1 interface Option<T> {  
2     U Visit<U>(Func<U> onNone, Func<T, U> onSome);  
3 }
```

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Visiting a None<T>

- When visiting an object of type None<T> we first select the input reserved for it then we return the result of its call;

```
1  class None<T> : Option<T> {  
2      public U Visit<U>(Func<U> onNone, Func<T, U> onSome) {  
3          return onNone();  
4      }  
5  }
```


Visiting Options lambdas

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Visiting a Some<T>

- When instantiating a Some<T> a data of type T is passed and stored inside a field value;
- When visiting an object of type Some<T> we first select the input reserved for it then we return the result of its call with value given as input;
- We pass value to the lambda, since it might be transformed/consumed by it;

```
1 class Some<T> : Option<T> {  
2     private T value;  
3     public Some(T value) {  
4         this.value = value;  
5     }  
6     public U Visit<U>(Func<U> onNone, Func<T, U> onSome) {  
7         return onSome(value);  
8     }  
9 }
```

Testing out our Option<T>

- The next line shows how to use our option to capture numbers and define operations over it;
- More precisely we define a Some containing the number 5 with the following operations:
 - The first lambda runs an exception, since we are trying to read a data that is not ready (None represents a null object);
 - The second lambda gets as input the value stored into Some and increments it by 1.

```
1 Option<int> number = new Some<int>(5);  
2 int inc_number = number.Visit(() => "ThrowException..", x => (x + 1));
```

Testing out our Option<T>

- The next line shows an example with a None object;
- Visiting such object will indeed cause an exception;
- As we see we managed to define operations on the fly over polymorphic data types in a controlled way;
- This design will work properly (regardless the data type captured by T) as long as there are always options to choose.

```
1 Option<int> number = new None<int>();  
2 int inc_number = number.Visit(() => "ThrowException..", x => (x + 1));
```

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Options

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

More sample

- Can be found on GIT under the folder: Design Patterns Samples C.

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Options

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

The visitor design pattern

The visitor design pattern

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

The general idea

- What we have seen so far is an example implementing the *visitor* design pattern;
- It allows the recovery of “lost-type” information from a general instance back to specifics;
- The recovery is based on the actualy activation of one of the multiple “options”;
- The options can be instances of some concrete visitor interface, or (more elegantly) lambda's;
- We will for now on focus on the lambda implementation.

The visitor design pattern

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

How do we define it (lambda version)? (Step 1)

- Given: C_1, \dots, C_n classes implementing a common interface I ;
- Every class C_i has fields $f_i^1, \dots, f_i^{m_i}$

The visitor design pattern

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

How do we define it (lambda version)? (Step 2)

- We now add to I a method `Visit` that returns an result of type U ;
- `Visit`, which is method common to all classes implementing I , picks the right option based on its concrete shape;
- And since we do not know the visit result it returns a result of type generic sU

The visitor design pattern

Introduction

The INFDEF team

Introduction

Our first design pattern

Visiting Options

Visiting Options without lambdas

Visiting Options lambdas

The visitor design pattern

Course structure

How do we define it (lambda version)? (Step 2)

- The Visit method accepts as input arguments as many as the possible concrete classes;
- Every argument is a function that depends on the fields of the concrete instance and produces a result of type U.

```
1 interface I<FieldsC1, FieldsC2, ..., FieldsCN>
2 {
3     U Visit<U>(Func<FieldsC1, U> onC1,
4               ...,
5               Func<FieldsCN, U> onCN);
6 }
```

The visitor design pattern

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

How do we implement it (lambda version)? (Step 3)

- Every class implementing the interface `I` has the task now to implement the `Visit` method, by selecting and calling the appropriate argument.

```
1  class C1<FieldsC1, FieldsC2, ..., FieldsCN>
2      : I<FieldsC1, FieldsC2, ..., FieldsCN>
3      {
4          Input_1 value;
5          U Visit<U>(Func<FieldsC1, U> onC1,
6                      ...,
7                      Func<FieldsCN, U> onCN){
8              onC1(this.value);
9          }
10     }
```

The visitor design pattern

Introduction

The INFDEV team

Introduction

Our first design pattern

Visiting Option's

Visiting Options without lambdas

Visiting Options lambdas

The visitor design pattern

Course structure

How do we use it (lambda version)? (Step 4)

- Every time we want to consume an instance of type M we have to Visit it.

```
1  I<FieldsC1, FieldsC2, ..., FieldsCN> i;  
2  ...  
3  m.Visit(  
4    i_1 => b1,  
5    ...,  
6    i_N => bn);
```

- Every argment of the visit becomes a function that is triggered depending on the concrete type of i ;
- i_i are the fields of a concrete class C_i ;
- b_i is the block of to run when a visit on an instance of a concrete type C_i is needed.

The visitor design pattern

Introduction

The INFDEV team

Introduction

Our first design pattern

Visiting Option's

Visiting Options without lambdas

Visiting Options lambdas

The visitor design pattern

Course structure

Visitor

<<interface>>

M<FieldsC1, FieldsCN>

Visit<U>(onC1 : FieldsC1 \rightarrow U, ..., onCN : FieldsCN \rightarrow U) :
U

C1

Visit<U>(onC1 : FieldsC1 \rightarrow
U, ...) : U

CN

Visit<U>(..., onCN : FieldsCN
 \rightarrow U) : U

The visitor design pattern

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Final considerations

- The visitor patterns provides us with a mechanism to safely manipulate polymorphic instances;
- From the interface point of view: this mechanism is transparent and safe, as there always will be an appropriate function to call;
- From the concrete class point of view: the instance itself is able to select the proper implementation among the input arguments of the visitor method without any complexity or risks.

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Course structure

Introduction

The INFDEV team

Introduction

Our first design pattern

Visiting Option's

Visiting Options without lambdas

Visiting Options lambdas

The visitor design pattern

Course structure

Final considerations

- Lectures

- Intro to design patterns (1 lecture) TODAY
- Entities construction - Factory (1 lecture)
- Generalizing behaviors - Adapter (1 lecture)
- Extending/Composing behaviors - Decorator (1 lecture)
- Composing patterns - MVC, MVVM (1 lecture)
- Live coding class (1 lecture)

- Assignment

- Build a GUI application containing interactive buttons.

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Options

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Conclusions

- Coupling in code is dangerous;
- Unmanaged interactions might introduce bugs;
- Interfaces are powerful means to control interactions.

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Option's

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

Conclusions

- Software engineering techniques (called design patterns) have been developed to achieve low-coupling by effectively using interfaces;
- This is going to be the topic for this course;
- We will study a series of basic design patterns, used in many applications.

Introduction

The INFDEV
team

Introduction

Our first
design
pattern

Visiting
Options

Visiting
Options
without
lambdas

Visiting
Options
lambdas

The visitor
design
pattern

Course
structure

The best of luck, and thanks for the
attention!