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The INFDEV team

Hogeschool Rotterdam
Rotterdam, Netherlands

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Lecture topics

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

What you have done so far?

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

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What we have not told you?

- Maybe you have already noticed it;
- Interactions affect coupling.

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What is coupling?

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

High-coupling

- As the interaction surface 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”;
- Thus, the amount of bugs.

```
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 interaction surface 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**.

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

$$O \left(\sum_{1 \leq k \leq C} \frac{C!}{2(C-k)!} \right)$$

Finding the right amount of coupling

- One could argue that: to avoid coupling we can put everything in one big class;
- Unfortunately this is completely true, since we can have coupling also within a single class.

Achieving low-coupling

- What seems desirable when dealing with software development is to keep coupling (our interactions) among entities as low as possible;
- Why?
- To mainly keep code maintainable.

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Maintainability in code

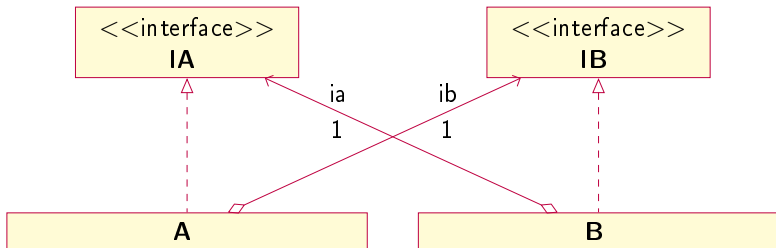
- Is an important aspect in development;
- It affects costs, code customization, bug fixing, etc.

Achieving low-coupling

- How how can we reduce the interaction surface among objects??
- We can use polymorphism, as seen in the last example, as a tool for specifying interaction surfaces.

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.



Polymorphism for taming coupling in programs

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


```
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.

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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.

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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*?

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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”.

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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.

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

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

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 }
```

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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 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 }
```

- 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));
```

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More sample

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

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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 actual 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.

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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 $f_i^1, \dots, f_i^{m_i}$

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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

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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     }
```

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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     }
```


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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.

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Visitor

<<interface>>
M<FieldsC1, FieldsCN>

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

C1

Visit<U>(onC1 : FieldsC1 →
U, ...) : U

CN

Visit<U>(..., onCN : FieldsCN
→ U) : U

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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.

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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.

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Conclusions

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

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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.

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The best of luck, and thanks for the
attention!