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Rotterdam, Netherlands

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Lecture topics

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

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Exam

- written exam
- 3 open questions
- stack/heap, type system, and design patterns
- no grade: go (score ≥ 75) or no go (otherwise)

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Exercises

- exercises to prepare step-by-step
- builds up to actual practicum
- there is no grade for this

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Congratulations

Assignments

- a connected series of programming tasks
- build a GUI framework
- **mandatory**, but with no direct grade

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Oral

- the oral is entirely based on the assignments
- we remove some pieces of code from the working solutions and you fill them back in
- the oral gives you the final grade for the course

Expected study effort

- between 10 and 20 **net**^a hours a week
- read every term on the slides and every sample
- if you do not understand it perfectly, either ask a teacher, google, or brainstorm with other students
- every sample of code on the slides you should both **understand** and **try out** on your machine

^aNo, 9gag does not count even if the slides are open on another monitor

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What you have done so far

- Encapsulation, polymorphism, subtyping, generics, etc.;
- Ways to express interactions among entities.

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Conclusions

What is coupling?

- Interactions between entities affect maintainability;
- The more the interactions, the higher the likelihood of having bugs;
- This phenomenon is known as coupling.

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Compositions

What is coupling?

- If changing something in a program requires changing something else, then we have coupling.

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Compos

Sort of coupling

- High, which is undesirable;
- Low, which is our target.

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Conclusions

High-coupling

- As the number of interaction between two classes **A** and **B** increases, the coupling between them increases as well;
- This translates into: whenever **A** changes, the likelihood to erroneously change **B** is “high”;
- Therefore, likely 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, such as the cylinders status;
- Move is really the only relevant bit here

```
1 class Driver {  
2     private Car car;  
3     void Drive() {  
4         public this.car.Move();  
5     }  
6 }  
7 class Car {  
8     public CylindersStatus cylinders;  
9     public void Move() {  
10         ...  
11     }  
12     ...  
13 }
```

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Conclusions

Low-coupling

- The number 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 likelihood to erroneously change **B** is “low”, since **A** knows 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;
- No cilinders;
- Also electric cars (no cilinders in electric cars).

```
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 number of entities increases, the number of interactions increases;
- More precisely, given N classes, it is:

$$I \simeq \left(\sum_{i=2}^N \frac{N!}{2(N-i)!} \right)$$

- It is a very big number!

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Conclusions

Low vs High coupling

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

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

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Conclusions

Achieving low-coupling

- Maintaining code is hard and expensive
- Low coupling results in easily maintainable code
- What seems desirable when dealing with software development is to keep coupling between entities as low as possible

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Conclusions

Maintainability in code

- Is an important aspect in development;
- It affects costs of fixing bugs and changing functionalities.

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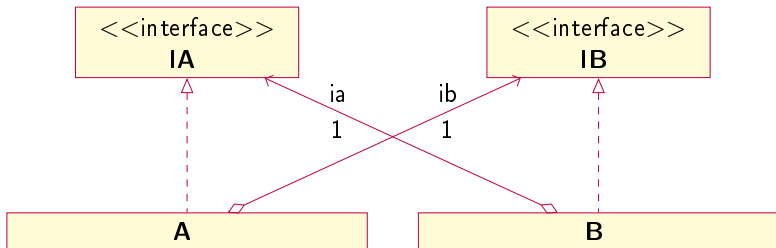
Conclusions

Polymorphism for reducing 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 a specific and controlled behavior.

A general view of low-coupling

- 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.




```
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 (class B) can interact with a vehicle (interface IA);
- The engine, which should not be accessible outside the car, is not mentioned in the interface, so the driver cannot interact with it.

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Conclusions

Recurrent patterns in objects interactions

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

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Conclusions

Design Patterns

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

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Conclusions

Choosing in the presence of polymorphism

- As you already know polymorphism is a powerful mechanism that allows decomposition and code reuse;
- Sometimes though, we need to go “back” from general instances to concrete ones^a.

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

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Conclusions

Why is choosing concrete types so problematic?

- 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 aircro of *v* if it is a *Car*?

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Conclusions

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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Conclusions

The `IOption<T>` data structure

- Is used when an actual value of type `T` might or might not be variable;
- It is also called “reified null” or “null object”.

Examples 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 IOption<int> a_number = new Some<int>(5);
```

Examples of usage

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

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

Some<T> and None<T>

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

```
1 class Some<T> : IOption<T> {  
2     public T value;  
3     public Some(T value) {  
4         this.value = value;  
5     }  
6     ...  
7 }
```

```
1 class None<T> : IOption<T> {  
2     public None() {  
3     }  
4     ...  
5 }
```

IOption<T>

- Is an interface that represents both absence and presence of data of type T;
- We cannot give direct access to the T value here as None could not implement it!

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

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Conclusions

Visiting Options without lambdas

Visiting an IOption<T>

- 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 will be able to identify the concrete type of the option (Some or None) and manipulate it accordingly^a.

^a**Note**, in many literature this `Visit` method is generally called `Accept`

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

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Conclusions

What is an IOptionVisitor<T, U>?

- An interface that provides a series of methods, one for each 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 onSome<U>(T value);  
3     U onNone<U>();  
4 }
```

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Conclusions

A concrete visitor - `PrettyPrinterOptionVisitor<int, string>`

- Provides a pretty printer for options containing integers.

```
1 class PrettyPrinterOptionVisitor : IOptionVisitor<int, string> {  
2     public string onSome<string>(int value) {  
3         return value.ToString();  
4     }  
5     public string onNone<string>() {  
6         return "I'm None..";  
7     }  
8 }
```


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Conclusions

Visiting a None<T>

- When visited, None informs its visitor of its identity by calling onNone.

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

Visiting a Some<T>

- When visited, Some informs its visitor of its identity by calling on onSome.

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

Testing out our IOption<T>

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

```
1 IOptionVisitor<int, int> opt_visitor = new PrettyPrinterIOptionVisitor<int,  
2     string>();  
3 IOption<int> number = new Some<int>(5);  
   number.Visit(opt_visitor);
```

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Conclusions

Visiting an IOption<T>

- Visiting also can be simplified;
- We give directly the methods to choose from;
- One less interface and trivial classes.

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

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Conclusions

Visiting a None<T>

- None simply selects onNone.

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

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Compositions

Visiting a Some<T>

- Some simply selects onSome.

```
1 class Some<T> : IOption<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 }
```

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Conclusions

Testing out our IOption<T>

- String conversion is now very streamlined.

```
1 IOption<int> number = new Some<int>(5);  
2 int inc_number = number.Visit(() => "I_am_None...", x => x.toString());
```


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Conclusions

A concrete visitor - LambdaOptionVisitor<T, U>

- We can adapt the “non-lambda” visitor that we introduced earlier so that it accepts lambda's as well.

```
1  class LambdaIOptionVisitor<T, U> : IOption<T> {  
2      private Func<T, U> oneSome;  
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 onSome<U>(T value) {  
9          return onSome(value);  
10     }  
11     public U onNone<U>() {  
12         return onNone();  
13     }  
14 }
```

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More sample

- Can be found on GIT under the folder: Design Patterns Samples CSharp and also Java.

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Conclusions

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 actually activation of one of the multiple concrete options available.

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Conclusions

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 $f_1^i, \dots, f_{m_i}^i$

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Conclusions

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

- We now add to *I* a method `Visit` that returns a result of type *U*;
- `Visit`, which is the common to all classes implementing *I*, picks the right option based on its concrete shape;
- Since we do not know what the visit will result in, then we return a result of a generic type *U*

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Conclusions

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

- The Visit method accepts as input one function per concrete implementation;
- Each such function depends on the fields of the concrete instance and produces a result of type U.

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

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Conclusions

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
2      : I
3  {
4      F_1 f1;
5      ...
6      F_m fm;
7      U Visit<U>(Func<FieldsC1, U> onC1,
8                  ...,
9                  Func<FieldsCN, U> onCN){
10         onC1(f1, ..., fm);
11     }
12 }
```


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Conclusions

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 i = ...;
2 ...
3 U result =
4   m.Visit(
5     i_1 => b1,
6     ...,
7     i_N => bn);
```

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

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Visitor

<<interface>>

I

**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;
- This mechanism is transparent and safe, as there always will be an appropriate function to call;
- 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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Course structure

- Intro to design patterns - Visiting polymorphic instances
- Iterating collections - Iterator
- Extending behaviors - Decorator over Iterator
- Entities construction - Factory
- Composing behaviours - Adapter over input

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Conclusions

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 of 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!