Introduction

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Dev 4

Lecture topics

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

Intro to DEV4

Intro to DEV4

Exam

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

Exercises

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

Intro to DEV4

Assignments

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

Intro to DEV4

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

[a]No, 9gag does not count even if the slides are open on another monitor

Intro to DEV4

What you have done so far

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

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.

Intro to DEV4

What is coupling?

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

Sort of coupling

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

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";
- Threfore, 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 cilinders status;
- Move is really the only relevant bit here

```
class Driver {
  private Car car;
  void Drive() {
    public this.car.Move();
  }
}
class Car {
  public CilindersStatus cilinders;
  public void Move() {
    ...
  }
  ...
}
```

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).

```
class Driver {
  private Vehicle vehicle;
  void Drive() {
    public this.vehicle.Move();
  }
}
interface Vehicle {
  void Move();
}
class Car : Vehicle {
  public void Move() {
    ...
  }
}
```

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!

Low vs High coupling

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

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

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

Intro to DEV4

Maintainability in code

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

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`.

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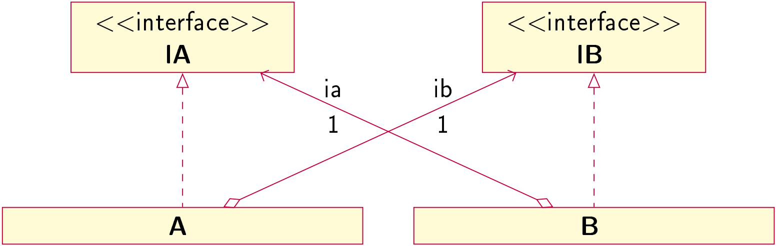


Intro to DEV4


```
class Driver {
  private Vehicle vehicle;
  void Drive() {
    public this.vehicle.Move();
  }
}
interface Vehicle {
  void Move();
}
class Car : Vehicle {
  private Engine engine;
  public void Move() {
    ...
  }
}
```

- 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.

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**.

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.

Our first design pattern

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].

[a] Cat is Animal. Cat is specific. Animal is general.

Our first design pattern

Why is choosing concrete types so problematic?

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

```
interface Vehicle {
  void Move();
}
class Car : Vehicle {
  ...
}
class Bike : Vehicle {
  ...
}
```

- 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 airco of `v` if it is a `Car`?

Our first design pattern

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".

Visiting Option's

Visiting Option's

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".

Visiting Option's

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;

```
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;

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

Visiting Option's

Some<T> and None<T>

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

```
class Some<T> : IOption<T> {
  public T value;
  public Some(T value) {
    this.value = value;
  }
  ...
}
```

```
class None<T> : IOption<T> {
  public None() {
  }
  ...
}
```

Visiting Option's

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!

```
interface IOption<T> {
  ...
}
```

Visiting Options without lambdas

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 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`

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

Visiting Options without lambdas

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`.

```
interface IOptionVisitor<T, U> {
  U onSome<U>(T value);
  U onNone<U>();
}
```

Visiting Options without lambdas

A concrete visitor - PrettyPrinterIOptionVisitor<int, string>

- Provides a pretty printer for options containing integers.

```
class PrettyPrinterOptionVisitor : IOptionVisitor<int, string> {
  public string onSome<string>(int value) {
    return value.ToString();
  }
  public string onNone<string>() {
    return "I'm␣none..";
  }
}
```

Visiting Options without lambdas

Visiting a None<T>

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

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

Visiting a Some<T>

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

```
class Some<T> : IOption<T> {
  public T value;
  public Some(T value) {
    this.value = value;
  }
  public U Visit<U>(IOptionVisitor<T, U> visitor) {
    return visitor.onSome(this.value);
  }
}
```

Visiting Options without lambdas

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.

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

Visiting Options lambdas

Visiting an IOption<T>

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

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

Visiting a None<T>

- None simply selects onNone.

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

Visiting Options lambdas

Visiting a Some<T>

- Some simply selects onSome.

```
class Some<T> : IOption<T> {
  private T value;
  public Some(T value) {
    this.value = value;
  }
  public U Visit<U>(Func<U> onNone,Func<T, U> onSome) {
    return onSome(value);
  }
}
```

Visiting Options lambdas

Testing out our IOption<T>

- String conversion is now very streamlined.

```
IOption<int> number = new Some<int>(5);
int inc_number = number.Visit(() => "I am None...",x => x.toString());
```

Visiting Options lambdas

A concrete visitor - LambdaIOptionVisitor<T, U>

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

```
class LambdaOptionVisitor<T, U> : IOption<T> {
  private Func<T, U> oneSome;
  private Func<U> onNone;
  public LambdaOptionVisitor(Func<T, U> onSome,Func<U> onNone) {
    this.onNone = onNone;
    this.onSome = onSome;
  }
  public U onSome<U>(T value) {
    return onSome(value);
  }
  public U onNone<U>() {
    return onNone();
  }
}
```

Visiting Options lambdas

More sample

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

The visitor design pattern

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.

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

- Given: $C_1, ..., C_n$ classes implementing a common interface I;
- Every class C_i has fields $f^i_1, .., f^i_{m_i}$

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`

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`.

```
interface I
  {
    U Visit<U>(Func<FieldsC_1, U> onC_1,
                  ...,
                  Func<FieldsC_N, U> onC_N);
  }
```

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.

```
class C1
      : I
  {
    F_1 f1;
    ...
    F_m fm;
    U Visit<U>(Func<FieldsC1, U> onC1,
                   ...,
                   Func<FieldsCN, U> onCN){
      onC1(f1,...,fm);
    }
  }
```

The visitor design pattern

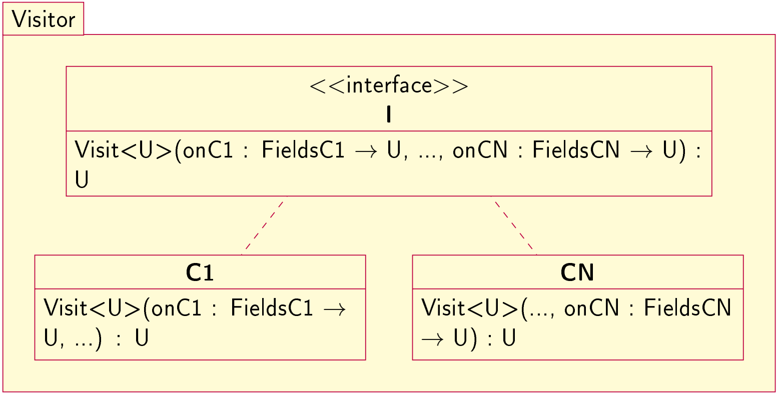
How do we use it (lambda version)? (Step 4)

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

```
I i = ...;
...
U result =
  m.Visit(
   i_1 => b_1,
   ...,
   i_N => b_n);
```

- 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.

The visitor design pattern



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.

Course structure

Course structure

Final considerations

- Lectures
  - Intro to design patterns - Visiting polymorphic instances (1 lecture) TODAY
  - Iterating collections - Iterator (1 lecture)
  - Entities construction and event management - Factory + Observer (1 lecture)
  - Building state machines - Strategy (1 lecture)
  - Extending behaviors - Decorator over Strategy (1 lecture)
  - Composing behaviours - Adapter over Strategy and input (1 lecture)
  - Live coding class (1 optional lecture)
- Assignment

Course structure

Conclusions

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

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 of this course;
- We will study a series of basic design patterns, used in many applications.

This is it!

The best of luck, and thanks for the attention!