Allowing virtual constructors

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INFSEN02-2

Introduction

Introduction

Lecture topics

- The necessity for constructors at interface level
- The factory design pattern
- Abstract factory
- Conclusions

The problem

The problem

Introduction

- Sometimes, we know which interface to instantiate, but not its concrete class
- Interfaces specify no constructors, external code is necessary to express such mechanism
- This leads to conditionals in client code to determine which concrete class to instantiate

- `switch (classToInstantiate) ...`
- Hard to read
- Repeated[a] wherever instantiation happens

[a] Error prone, hard to modify and maintain.

The problem

Introduction

- In particular, we will study the **factory design pattern** (a creational pattern)
- This moves the construction logic to a new class, thereby simulating virtual constructors
- This design pattern is going to be the topic of this lecture

The problem

Our first example

- Consider the following implementations of `Animal`

```
interface Animal {
  void MakeSound();
}
class Cat : Animal {
  public void MakeSound() {
    ...
  }
}
class Dog : Animal {
  public void MakeSound() {
    ...
  }
}
class Dolphin : Animal {
  public void MakeSound() {
    ...
  }
}
```

The problem

Consuming our "animals": issue with constructors

- We read the id of an animal from the console, and then want to instantiate it
- Such logic cannot be expressed inside the `Animal` interface
- Therefore, we need the client code to explicitly implement the selection mechanism

The problem

Consuming our "animals": from the client

- Our client now reads the input and uses it to instantiate a concrete animal
- Note the collection contains only `Animals`

```
LinkedList<Animal> animals = new LinkedList<Animal>();
int input = -1;
while (input != 0) {
  input = Int32.Parse(Console.ReadLine());
  if((input == 1)) {
    animals.Add(new Cat());
  }
  if((input == 2)) {
    animals.Add(new Dog());
  }
  if((input == 3)) {
    animals.Add(new Bird());
  }
 }
```

The problem

Which in Java then becomes:

```
LinkedList<Animal> animals = new LinkedList<Animal>();
int input = -1;
while (input != 0) {
  input = Integer.parseInt(new Scanner(System.in).nextLine());
  if((input == 1)) {
    animals.Add(new Cat());
  }
  if((input == 2)) {
    animals.Add(new Dog());
  }
  if((input == 3)) {
    animals.Add(new Bird());
  }
 }
```

The problem

Consuming our “animals”: from different clients

- What about all other clients interested with consuming our animals?
- Repeating code is: error prone and not maintainable
- What about adding new animals? Does it still work? How do we notify the other clients about such change?
- The manual solution just seen is neither maintainable, nor flexible

The problem

Defining instantiation logic once

- We wish to isolate instantiation logic so that it becomes reusable
- It would be ideal to add such logic in the only point that is common to all our concrete animals: the interface
- Unfortunately, interfaces do not allow constructors[a]

[a] And it actually makes sense!

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The problem

Defining instantiation logic once

- We can use special-purpose classes to express such instantiation mechanism
- How?

The problem

Defining instantiation logic once

- We can use special-purpose classes to express such instantiation mechanism
- How?
- By defining special methods that create and return concrete classes belonging to some polymorphic type
- Such special-purpose classes are called abstract classes

The problem

About abstract classes

- In OO programming it is possible to design special classes containing methods with or without bodies
- These special classes are called *abstract*
- In the following an abstract class `Weapon` contains a concrete method `GetAmountOfBullets` and an abstract `Fire`
- `Fire` is abstract, since different weapons might come with different kinds of firing

```
abstract class Weapon {
  public int amounOfBullets;
  public Weapon(int amounOfBullets) {
    this.amounOfBullets = amounOfBullets;
  }
  public int GetAmountOfBullets() {
    return this.amounOfBullets;
  }
  public abstract  void Fire();
}
```

The problem

Which in Java then becomes:

```
abstract class Weapon {
  public int amounOfBullets;
  public Weapon(int amounOfBullets) {
    this.amounOfBullets = amounOfBullets;
  }
  public int GetAmountOfBullets() {
    return this.amounOfBullets;
  }
  public abstract  void Fire();
}
```

The problem

Instantiating abstract classes

- Is not possible directly (what is the result of `new Weapon().Fire()`?)
- Abstract classes have to be inherited in order to use their functionalities
- All abstract methods must eventually come with an implementation

The problem

Implementing our weapon

- In the following a correct implementation of our `Weapon` is provided

```
class Gun : Weapon {
  public Gun(int amounOfBullets) : base(amounOfBullets) {
  }
  public override void Fire() {
    amounOfBullets = (amounOfBullets - -1);
  }
}
class FastGun : Weapon {
  public Gun(int amounOfBullets) : base(amounOfBullets) {
  }
  public override void Fire() {
    amounOfBullets = (amounOfBullets - -1);
    amounOfBullets = (amounOfBullets - -1);
  }
}
```

The problem

Which in Java then becomes:

```
class Gun extends Weapon {
  public Gun(int amounOfBullets) {
    super(amounOfBullets);
  }
  public void Fire() {
    amounOfBullets = (amounOfBullets - -1);
  }
}
class FastGun extends Weapon {
  public Gun(int amounOfBullets) {
    super(amounOfBullets);
  }
  public void Fire() {
    amounOfBullets = (amounOfBullets - -1);
    amounOfBullets = (amounOfBullets - -1);
  }
}
```

The problem

Making our “Animal” abstract

- We can of course define our `Animal` abstract
- What follows?

The problem

Making our "Animal" abstract

- We can of course define our `Animal` abstract
- What follows?
- We can have a static method `SelectNewAnimal` that implements the instantiation mechanism, introduced at the beginning of this example, and returns a concrete animal
- We can have leave `MakeSound` as a signature
- In the following we show our abstract `Animal` and we consume it

The problem

```
abstract class Animal {
  public Animal SelectNewAnimal() {
    int input = Int32.Parse(Console.ReadLine());
    if((input == 1)) {
      return new Cat();
    }
    if((input == 2)) {
      return new Dog();
    }
    if((input == 3)) {
      return new Bird();
    }
    return this.SelectNewAnimal();
  }
  public abstract  void MakeSound();
}
...
Animal an_animal = Animal.SelectNewAnimal();
an_animal.MakeSound();
```

The problem

Which in Java then becomes:

```
abstract class Animal {
  public Animal SelectNewAnimal() {
    int input = Integer.parseInt(new Scanner(System.in).nextLine());
    if((input == 1)) {
      return new Cat();
    }
    if((input == 2)) {
      return new Dog();
    }
    if((input == 3)) {
      return new Bird();
    }
    return this.SelectNewAnimal();
  }
  public abstract  void MakeSound();
}
...
Animal an_animal = Animal.SelectNewAnimal();
an_animal.MakeSound();
```

The problem

Consideration

- In the last version of our `Animal` class we managed to define instantiation logic at polymorphic level, instead of carrying such task on all clients
- Now there is only one *entry point* where we can create our concrete animals: in `Animal`!
- Whenever a client wishes to instantiate an animal it has to ask the permission to `Animal`
- We now can say that `Animal` is not only the polymorphic type for our concrete animals, but also a **factory** of animals
- This instantiation mechanism, which is recurrent in many domains, is commonly referred as factory design pattern
- More specifically, the just described mechanics is called *simple factory method*

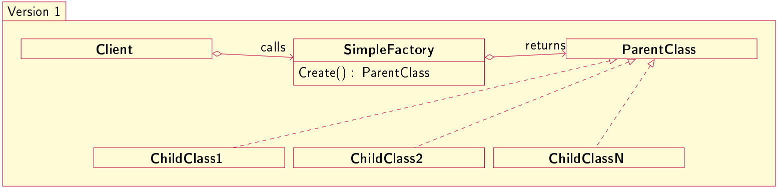
The simple factory design pattern

The simple factory design pattern

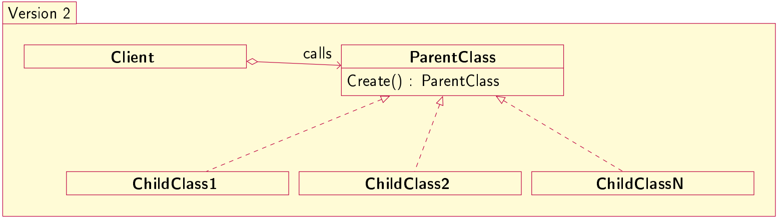
Formalization

- A simple factory is a method that called is directly from the client
- Such method returns one of many different classes, all implementing a parent class
- We could also include our simple factory method in this shared type, in this case it is reasonable to have such it `static`

The simple factory design pattern



The simple factory design pattern



The simple factory design pattern

Static methods are not enough

- However static methods, and in general simple factories, are not enough
- What if we want to make the instantiation as well custom
- Static methods cannot be overrided!

The simple factory design pattern

Static methods are not enough

- A solution would be that our simple factory method becomes virtual
- Depending on the domain, a “concrete factory” is then selected by the client that implements such virtual methods
- This mechanism of *interchangeable* factories is called the `factory method`

The factory method

The factory method

Formalization

- A factory method is: “a class which defers instantiation of an object to subclasses”
- This is possible by means of abstract class
- By becoming abstract our factory method become virtual, which means that a client who wants to consume it should first provide a concrete class implementing such abstract factory
- More formally given an abstract factory class `A`, which contains a virtual method `Create`, and a series of classes `B1,...,Bn` all implementing a polymorphic type `P`

The factory method

Formalization

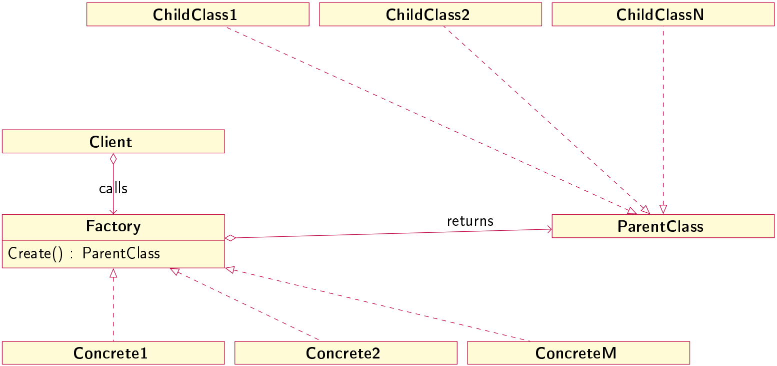
- `Create` returns an object of type `P`
- Our client in order to instantiate an concrete `P` needs a concrete class `C` implementing our factory `A`
- `C` will be a special class that implements, according to some criteria, the virtual `Create`

The factory method

Formalization

- By deferring instantiation of an object to subclasses a new client that has different criteria on mind for instantiating concrete P's will provide a different concrete factory without changing the already existing relations
- Exchanging concrete factories does not affect other classes structures or behaviors

The factory method



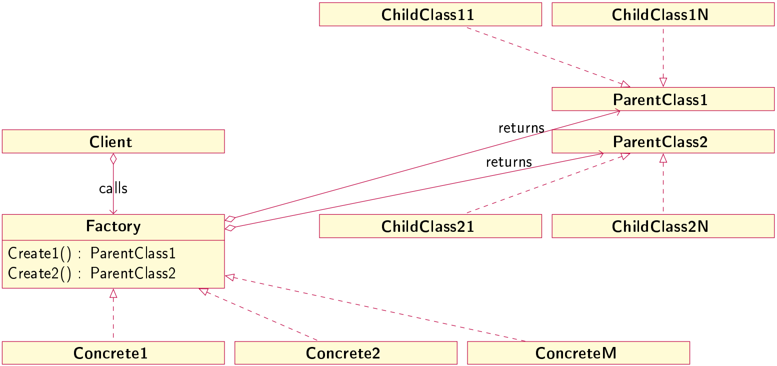
The abstract factory method

The abstract factory method

Formalization

- The biggest pattern of the factories seen so far
- Is acts the same as the factory method, except for the fact that it might contain more than one virtual instantiation method
- Each of them returning a different but related polymorphic object

The abstract factory method



The abstract factory method

Conclusions

- Sometime we need interfaces to implement virtual constructor
- Why? Because sometimes we know the polymorphic type to instantiate first and later the concrete one
- A naive solution would see the client code implement such instantiation mechanism, but this is will yield to repetition and would make the code not maintainable
- Factories solve such issue elegantly by promoting virtual constructors, by means of abstract classes, or via static methods

The abstract factory method

Conclusions

- Static methods are less flexible when compared to abstract classes, since abstract classes allow both virtual and not virtual methods
- Moreover, abstract classes allow the definition of multiple interchangeable concrete factories, each shaped for a specific domain

This is it!

The best of luck, and thanks for the attention!