

The decorator design pattern

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Lecture topics

- Adding responsibilities dynamically
- Possible solutions and pitfalls
- The decorator design pattern
- Conclusions

Introduction

- Today we are going to study a behavioral pattern: the decorator design pattern
- Sometimes, we need to modify behaviors (or to add responsibilities) of an object dynamically

Introduction

- Hand made combinations could be a solution, but excessive inheritance is a pitfall, since the amount of combinations could be huge
- Examples:
 - Add a turbo to a Car
 - Add a truck to a Car
 - Add an extra seat to a Car
 - Add a turbo and an extra seat to a Car
 - etc.

Introduction

- The decorator pattern (also known as wrapper) solves this issue
- How? By emulating polymorphism through composition

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Case study

- Consider again the iterator interface

```
1 interface Iterator<T> {  
2     IOption<T> GetNext();  
3 }
```

Case study

- Consider again the natural numbers implementation

```
1  class Naturals : Iterator<int> {  
2      private int current;  
3      public Naturals() {  
4          current = 1;  
5      }  
6      IOption<int> GetNext() {  
7          current = (current + 1);  
8          return new Some<int>(current);  
9      }  
10 }
```

First task: selecting only natural even numbers

- We wish now to iterate only the even numbers of our natural number list

```
1 class Evens : Iterator<int> {  
2     private int current;  
3     public Evens() {  
4         current = -1;  
5     }  
6     IOption<int> GetNext() {  
7         current = (current + 1);  
8         if(((current % 2) == 0)) {  
9             return new Some<int>(current);  
10        }  
11        else{  
12            return this.GetNext();  
13        }  
14    }  
15 }
```

Another task: iteration with offset

- We wish now to iterate our natural number list and while iterating it add an offset to each element

```
1 class Offset : Iterator<int> {  
2     private int current;  
3     private int offset;  
4     public Offset(int offset) {  
5         current = -1;  
6         this.offset = offset;  
7     }  
8     IOption<int> GetNext() {  
9         current = (current + 1);  
10        return new Some<int>((current + offset));  
11    }  
12 }
```

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UML

- Lets give a look to the UML of our classes made so far..

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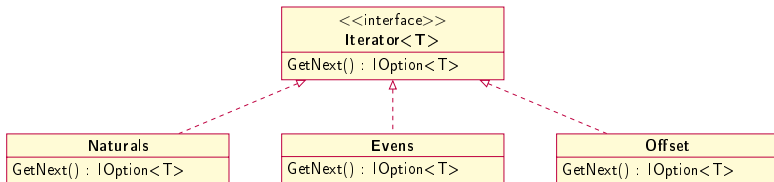
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A new task: iteration over evens with offset

- We wish now to iterate only even numbers of our natural number list and for each number add an offset
- Yes, we need another class...

```
1 class EvensFrom : Iterator<int> {  
2     private int current;  
3     private int offset;  
4     public EvensFrom(Offset offset) {  
5         current = -1;  
6         this.offset = offset;  
7     }  
8     IOption<int> GetNext() {  
9         current = (current + 1);  
10        if(((current % 2) == 0)) {  
11            return new Some<int>((current + offset));  
12        }  
13        else{  
14            return this.GetNext();  
15        }  
16    }  
17 }
```

UML discussion

- As we can see our class hierarchy is growing “horizontally”, because of lacks of reuse
- Let us see the UML again

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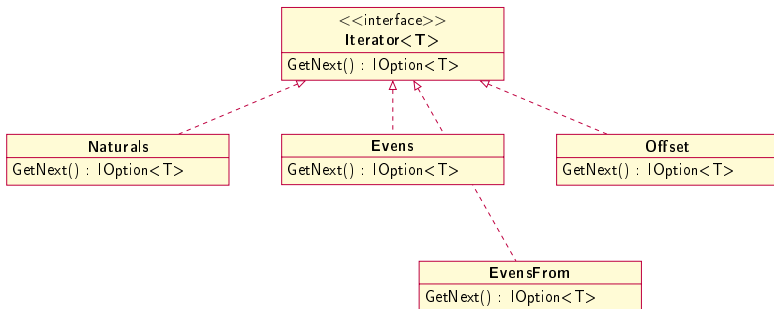
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Iterating a range between two integers

- Imagine if we now wish to implement a new data structure `Range` that takes two integers `A` and `B` (where $A \leq B$)
- We want `Range` to support the `Offset` and `Even` behaviors
- We have to literally duplicate everything and to implement all possible combinations

Considerations

- Polymorphism solves our problem, but adds another one.
Too many combinations
- Every change/add requires lots of work
- Behavioral commonalities are not taken into consideration

Considerations

- How can we group such behaviors (offset and even) to define them once and use them everywhere?
- A possible solution would see our natural number implementing offset and even

```
1 class EvensFrom : Naturals, Offset, Evens {  
2     ...  
3 }
```

- This solution is not good, since the responsibilities are now not clear, see SOLID

Considerations

- Abstract classes with a series of booleans, which we can use as “switchers” to select the appropriate algorithm, could be another solution
- But fields do not force appropriate behavior for each of the roles

```
1  class Naturals : Iterator<int> {  
2      private bool isEven;  
3      private bool isOffset;  
4      ...  
5  }
```

- This solution is not good, since the responsibilities are now not clear, see SOLID

Considerations

- We need a better mechanism. Ideally we wish:
 - To define once our naturals
 - To define once our even behavior
 - To define once our offset behavior
 - To apply the above behaviors “on demand”, and not to all instances of natural lists
 - To combine the above behaviors without defining new behaviors

Idea

- A interesting solution could be to built a *proxy*, like adapter, but with the possibility to add semantics!

Idea

- We define an intermediate entity `Decorator`, which inherits our iterator and also contains an instance of it (`decorated_item`)
- Note `GetNext` acts as a proxy by simply calling `decorated_item.GetNext()` and returning its result
- `Decorator` is abstract, so you cannot create it without a “concrete” behavior

```
1 abstract class Decorator : Iterator<int> {  
2     protected Iterator<int> decorated_item;  
3     public Decorator(Iterator<int> decorated_item) {  
4         this.decorated_item = decorated_item;  
5     }  
6     protected abstract IOption<int> GetNext();  
7 }
```


Idea

- We can think of the decorator as an iterator containing elements, but which does not know how to iterate them
- A concrete decorator needs a specification of how to iterate

Idea

- We now declare concrete two decorators `Even` and `Offset` that extend our `Decorator`
- `Even` and `Offset` are unaware (and they do not need to be) of whether they are going to deal with all natural numbers, just a range of them, or something else

Idea: even class

- In the following you find the code for Even

```
1 class Even : Decorator {
2     public Even(Iterator<int> collection) : base(collection) {
3     }
4     public override IOption<int> GetNext() {
5         Option<int> current = base.decorated_item.GetNext();
6         if(current.IsNone()) {
7             return new None<int>();
8         }
9         else{
10             if(((current.GetValue() % 2) == 0)) {
11                 return new Some<int>(current.GetValue());
12             }
13             else{
14                 return this.GetNext();
15             }
16         }
17     }
18 }
```

Idea: even class, with lambdas

- In the following you find the code for Even, with lambdas

```
1 class Even : Decorator {
2     public Even(Iterator<int> collection) : base(collection) {
3     }
4     public override IOption<int> GetNext() {
5         Option<int> current = base.decorated_item.GetNext();
6         current.Visit(() => new None<int>(), current =>
7         { if(((current % 2) == 0)) {
8             return new Some<int>(current);
9         }
10        else{
11            return this.GetNext();
12        }
13    });
14    }
15 }
```

Idea: offset class

- In the following you find the code for Offset

```
1 class Offset : Decorator {  
2     private int offset;  
3     public Offset(int offset, Iterator<int> collection) : base(collection) {  
4         this.offset = offset;  
5     }  
6     public override IOption<int> GetNext() {  
7         Option<int> current = base.decorated_item.GetNext();  
8         if (current.IsNone()) {  
9             return new None<int>();  
10        }  
11        else {  
12            return new Some<int>((current.GetValue() + offset));  
13        }  
14    }  
15 }
```

Idea: offset class, with lambdas

- In the following you find the code for Offset, with lambdas

```
1 class Offset : Decorator {  
2     private int offset;  
3     public Offset(int offset, Iterator<int> collection) : base(collection) {  
4         this.offset = offset;  
5     }  
6     public override IOption<int> GetNext() {  
7         Option<int> current = base.decorated_item.GetNext();  
8         current.Visit(() => new None<int>(), current => new Some<int>((current +  
9             offset)));  
10    }
```

Idea

- With Even and Offset we managed to capture a reusable behavior that works with any collection made of numbers
 - They work on Range and Numbers
 - They work on any other collection of ints, even with those built with decorators
- Naturals → Evens → Offset
 - etc.

Idea

- The following are all examples of how to use our new data structures:
- `Iterator<int> ns1 = new Even(new Naturals())`
- `Iterator<int> ns2 = new Offset(new Naturals())`
- `Iterator<int> ns2 = new Offset(new Even(new Naturals()))`
- `Iterator<int> ns3 = new Offset(new Even(new Range(5, 10)))`

Idea

- Note how decomposability helps to keep the interaction surface clean and reusable and the implementation compact
- We now show the UML of our code

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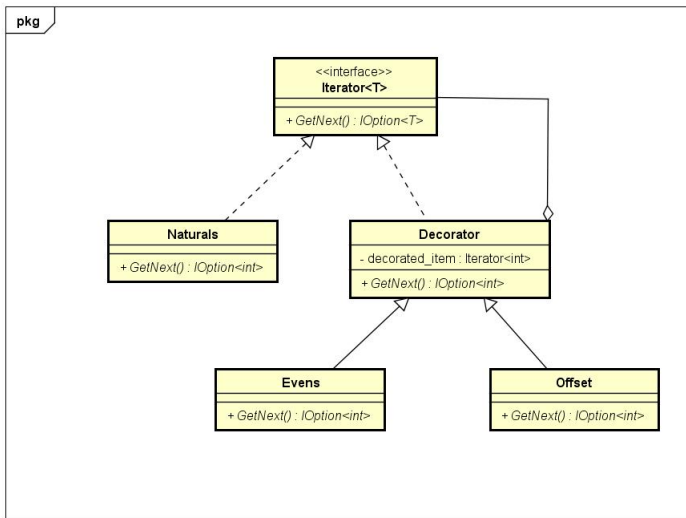
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Idea



Considerations

- The pattern seen so far follows a specific design pattern that is called the **Decorator design pattern** (a behavioral design pattern)
- We now study its formalization and add some final considerations

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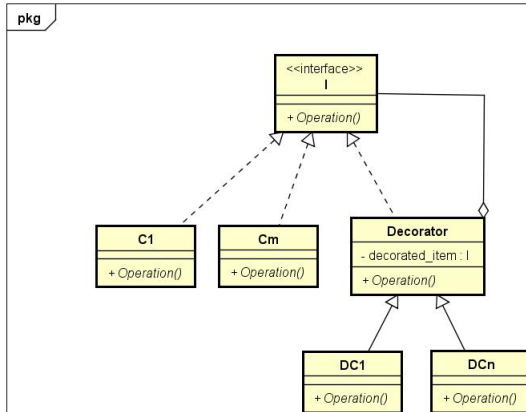
Conclusions

Formalism

- Given a polymorphic type I (to instantiate)
- Given a series of concrete implementations of I : C_1, \dots, C_m
- A decorator D is an entity that implements I and references an instance of I
- Given a series of concrete decorators CD_1, \dots, CD_n extends D
- As concrete CD 's come with difference semantics, every CD is tasked to apply its semantics by overriding methods of the inherited D

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Formalism



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Generic decorators

- We can build generic decorators
- Genericity comes from lambdas, which act as “holes” in their behaviors
- Concrete decorators can be defined by specifying the underlying iterator + the lambdas

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Conclusions

Filter

- A Filter is a generic decorator that skips some elements
- We can use it to express our Evens, see code below

```
1 class Filter : Decorator {
2     Func<int, bool> p;
3     public Filter(Iterator<int> collection, Func<int, bool> p) : base(
4         collection) {
5         p = this.p;
6     }
7     public override IOption<int> GetNext() {
8         Option<int> current = base.decorated_item.GetNext();
9         if (current.IsNone()) {
10             return new None<int>();
11         }
12         else {
13             if (p.Invoke(current.GetValue())) {
14                 return new Some<int>(current.GetValue());
15             }
16             else {
17                 return this.GetNext();
18             }
19         }
20     }
21 }
22
23 Iterator<int> numbers = new Filter(new Range(0,5), n => ((n % 2) == 0));
```


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Conclusions

Filter, with lambdas

- A Filter is a generic decorator that skips some elements
- We can use it to express our Evens, see code below (with lambdas)

```
1 class Filter : Decorator {
2     Func<int, bool> p;
3     public Filter(Iterator<int> collection, Func<int, bool> p) : base(
4         collection) {
5         p = this.p;
6     }
7     public override IOption<int> GetNext() {
8         Option<int> current = base.decorated_item.GetNext();
9         current.Visit(() => new None<int>(), current =>
10         { if (p.Invoke(current)) {
11             return new Some<int>(current);
12         }
13         else {
14             return this.GetNext();
15         }
16     });
17 }
18 Iterator<int> numbers = new Filter(new Range(0,5), n => ((n % 2) == 0));
```

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Map

- A Map transforms all elements one after the other
- We can use it to express our Offset, see code below

```
1 class Map : Decorator {  
2     Func<int, int> t;  
3     public Map(Func<int, int> t, Iterator<int> collection) : base(collection) {  
4         this.t = t;  
5     }  
6     public override IOption<int> GetNext() {  
7         Option<int> current = base.decorated_item.GetNext();  
8         if(current.IsNone()) {  
9             return new None<int>();  
10        }  
11        else{  
12            return new Some<int>(t.Invoke(current.GetValue()));  
13        }  
14    }  
15 }  
16 Iterator<int> numbers = new Map(new Range(0,5), n => (current + 1));
```

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Map, with lambdas

- A Map transforms all elements one after the other
- We can use it to express our Offset, see code below (with lambdas)

```
1 class Map : Decorator {  
2     Func<int, int> t;  
3     public Map(Offset offset, Iterator<int> collection) : base(collection) {  
4         this.offset = offset;  
5     }  
6     public override IOption<int> GetNext() {  
7         Option<int> current = base.decorated_item.GetNext();  
8         current.Visit(() => new None<int>(), current => new Some<int>(t.Invoke(  
9             current)));  
10    }  
11    Iterator<int> numbers = new Map(new Range(0,5), n => (current + 1));
```

Map and Filter

- Of course we can combine them, so to express our EvensFrom
- `Iterator<int> numbers = new Filter(new Map(new Range(0,5), n => n + 1), n => n % 2 == 0);`

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Conclusions

- Sometimes, we need to apply behaviors instances dynamically
- Hand made combinations could be a solution, but the number of combinations is huge
- The decorator pattern solves this issue by emulating a customizable, dynamic form of polymorphism through composition
- In short, a decorator allows behavior to be added to an individual object, without affecting other objects

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The best of luck, and thanks for the
attention!