

Iterating collections

The INFDEV team

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Dev 4 - Lecture topics

Iterating
collections

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Lecture topics

- Breaking down design patterns, an introduction
- Iterating collections
- Concrete examples of the iterator design pattern
- Conclusions

Breaking down design patterns

Introduction

- After having seen the 1st design pattern, we can add some depth to the discussion
- Design patterns have been grouped in several specific categories:
 - Behavioral
 - Structural
 - Creational
- In this course we will always try, when introducing a design pattern, to picture it with respect to such categories

Behavioral patterns

- design patterns for identifying the fundamental communication behavior between entities
- Among such pattern we find:

- **Visitor pattern**
- State pattern
- Strategy pattern
- **Null Object pattern**
- Iterator pattern
- etc..

Structural patterns

- Are design patterns that ease the design of an application by identifying a simple way to implement relationships between entities
- Among such pattern we find:
 - Adapter pattern
 - Decorator pattern
 - Proxy pattern
 - etc..

Creational patterns

- Are design patterns that deal with entities creation mechanisms, trying to create entities in a manner suitable to the situation
- They make it possible to have “virtual” constructors
- Among such pattern we find:
 - Factory method pattern
 - Lazy initialization pattern
 - Singleton pattern
 - etc..

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Software development principles

- Even more abstractly, design patterns are all rooted in the same principles
- These principles make it possible to derive old and new patterns

Software development principles

- Such principles are:

DRY : Is an acronym for the design principle “Don’t Repeat Yourself”

KISS : Is an acronym for the design principle “Keep it simple, Stupid!”

SOLID : Is an acronym for Single responsibility, Open-closed, Liskov substitution, Interface segregation, and Dependency inversion

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Software development principles

- In this course we will always try, when introducing a design pattern, to present it along with its principles

Iterating collections

Introduction

- Today we are going to study collections
- In particular, we are going to study how to access the elements of a collection without exposing its underlying representation (methods and fields)
- How? By means of a design pattern: the iterator (a behavioral design pattern)
- We will see how the iterator provides a clean, almost trivial, general way representation for iterating collections

About collections

- They come in different shapes and implementations:
- Option (an option essentially is a “one-element” collections”)
- Stream of data
- Records of a database
- List of cars
- Array of numbers
- Array of Array of pixels (a matrix)
- etc..

What do we do with collections?

- However, all collections, from options to arrays, exhibit similarities
- The, *general* idea is going through all its elements one by one until there are no more to see

What do we do with collections?

- Unfortunately, every collection has its own different implementation
- This is an issue
- Why?

What do we do with collections?

- Unfortunately, every collection has its own different implementation
- This is an issue
- Why?
- Because we would have to write specific code for each collection

Similar collections, but with different implementation

- Take for example a linked list and an array:
- The former is a dynamic data structure made of linked nodes. A linked list potentially might contain infinite nodes
- The latter is a static compact data structure. In an array the maximum number of elements is fixed

Iterating lists

- Iterating a list requires a variable that references the current node in the list
- To move to the next node we need to manually update such variable, by assigning to it a reference to the next node

```
1 ...  
2 LinkedList<int> list_of_numbers = new LinkedList<int>();  
3 while (list_of_numbers.Tail != null) {  
4     ...  
5     list_of_numbers = list_of_numbers.Tail;  
6 }  
7 ...
```

Iterating array

- Iterating an array requires a variable (an index) containing a number representing the position of the current visited element
- To move to the next element we need to manually update the variable, increasing it by one.

```
1 ...  
2 int[] array_of_numbers = new int[5];  
3 int index;  
4 for(index = 0; (index <= array_of_numbers.Length); index = (index + 1)){  
5     ...  
6 }  
7 ...
```

The need for different collections

- A collection has its own use: for example arrays are very performant in retrieving data at specific positions, linked lists allow fast insertions, etc..
- But then how can we hide the implementation details so that iterating collections becomes trivial if the specifics are not relevant?

Issues

- Repeating code is problematic (DRY: do not repeat iteration logic)
- Knowing too much about a data structure increases coupling make code more complex (KISS: keep iteration simple)

Our goal

- We try to achieve a mechanism that abstracts our concrete collections from their iteration algorithms
- Iteration is a behavior common to all collections: only its implementation changes

How do we achieve it?

- We wish to delegate the implementation of such algorithms to each concrete collection
- We control such algorithms by means of a common/shared interface

What follows?

- When developers need to iterate a collection they simply use the interface provided by the chosen collection
- Such interface hides the internals of a collection and provides a clean interaction surface for iterating it

The iterator design pattern

- Is a design pattern that captures the iteration mechanism
- We will now study it in detail and provide a series of examples

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The iterator design pattern

- Is an interface `Iterator<T>` containing the following method signature

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

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Implementing the Iterator<T>

- At this point every collection that wants to provide a disciplined and controlled iteration mechanism has to implement such interface

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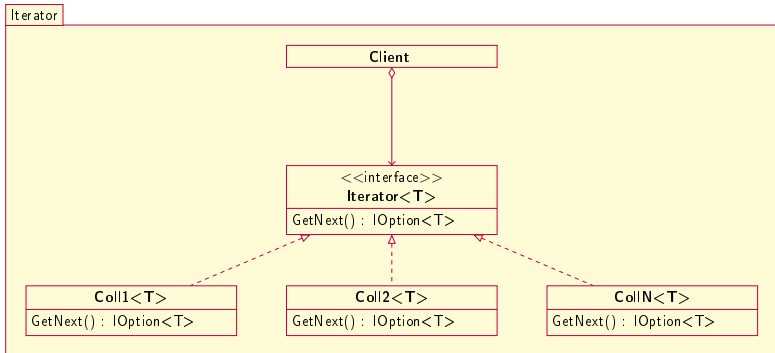
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Implementing the Iterator<T>

- We now show a series of collections implementing such our interface

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Natural numbers

- The natural numbers are all integers greater or equals to 0
- We now wish to define a collection containing all natural numbers
- To do so we define a data structure that implements our iterator
- And starting from -1 (the successor of it is 0, the first natural number), which is stored in a field called `current`, whenever we call the `GetNext` method we increase such `current` and returns its value

```
1 class NaturalList : Iterator<int> {  
2     private int current = -1;  
3     IOption<int> GetNext() {  
4         current = 1return new Some<int>(current);  
5     }  
6 }
```


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Array<T>

- Dealing with array requires to deal with its indexes
- We hide such complexity, which often is error-prone, by means of our iterator

The iterator design pattern

Array<T>

- Our “new” array takes as input an object of type array
- Aa field index keeps tracking of the current index
- Whenever the GetNext method is called we check whether we reached the end of the array: if so we return None, otherwise we increase the index and return the value of the array at position index wrapped inside a Some object

```
1 class Array<T> : Iterator<T> {  
2     private T[] array;  
3     private int index = -1;  
4     public Array(T[] array) {  
5         this.array = array;  
6     }  
7     IOption<int> GetNext() {  
8         if ((index + 1) < array.Length) {  
9             return new None<T>();  
10        }  
11        else{  
12            index = (index + 1);  
13            return new Some<int>(array[index]);  
14        }  
15    }
```

The iterator design pattern

The iterator in literature

- In literature it is often the case to see our Iterator as an interface containing the following signatures

```
1 interface UnsafeIterator<T> {  
2     void MoveNext();  
3     bool HasNext();  
4     T GetCurrent();  
5 }
```

- The main big difference now is that whenever we need to move throughout our collection we have to coordinate GetCurrent, HasNext, and MoveNext
- As we can see, this adds a layer of complexity to the iteration and is error prone, since now we have to *carefully* manipulate three methods (instead of one as for Iterator<T>)
- In what follow we show how to make UnsafeIterator

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Improving the UnsafeIterator<T> safeness

- Adapting our UnsafeIterator will require us to define an adapter AdapterIterator that implements our Iterator
- The AdapterIterator takes as input an UnsafeIterator and whenever the GetNext method is called it calls GetCurrent and MoveNext accordingly

```
1 class AdapterIterator<T> : Iterator<T> {  
2     private UnsafeIterator<T> iterator;  
3     public AdapterIterator(UnsafeIterator<T> iterator) {  
4         this.iterator = iterator;  
5     }  
6     IOption<int> GetNext() {  
7         if iterator.HasNext();  
8         {  
9             return iterator.MoveNext();  
10        new Some<int>(iterator.GetCurrent());  
11        }  
12        else{  
13            return new None<T>();  
14        }  
15    }  
16 }
```

The iterator design pattern

Adapting IOption<T>

- We could also make our IOption<T> iterable!
- To do so, we have to return Some only the first time we it and None for the successive iterations
- Note if we iterate a None we return None

```
1 class IOptionAdapter<T> : Iterator<T> {  
2     private IOption<T> option;  
3     private bool visited = false;  
4     public IOptionAdapter(IOption<T> option) {  
5         this.option = option;  
6     }  
7     IOption<int> GetNext() {  
8         if visited {  
9             return new None<T>();  
10        }  
11        else{  
12            visited = true;  
13            return option.Visit<IOption<T>>(() => new None<T>(), t => new Some<T>(t  
14                ));  
15        }  
16    }
```

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AdapterIterator examples of usage

- In what follows we show how to use our adapter
- Note in this case NaturalList is a class that implements the UnsafeIterator interface

```
1 Iterator<int> iterator = new AdapterIterator<int>(new NaturalList());
```

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Conclusions

- Iterating collections is a time consuming, error-prone, activity, since collections come with different implementations each with its own complexity
- Iterators are a mechanism that hides the complexity of a collection and provides a clean interaction surface to iterate them
- This mechanism not only reduces the amount of code to write (achieving then the DRY principle), but also reduces the amount of coupling

The best of luck, and thanks for the
attention!