

Iterating collections

The INFDEV team

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Iterating collections

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Lecture topics

- A taxonomy of design patterns
- Iterating collections
- Concrete examples of the iterator design pattern
- Conclusions

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A taxonomy of design patterns

- After having seen the first design pattern, we can add some depth to the discussion
- Design patterns have been grouped in several specific categories (we will show at least one design pattern per category):
 - Behavioral
 - Structural
 - Creational

A taxonomy of design patterns

Behavioral patterns

- Are design patterns for identifying the fundamental communication behavior between entities
- Among such patterns we find:
 - **Visitor pattern**
 - State pattern
 - Strategy pattern
 - **Null Object pattern**
 - Iterator pattern
 - etc..

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Structural patterns

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

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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 patterns 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
- They are refinements of the broader principles of encapsulation and loose coupling

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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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DRY

- Every piece of knowledge must have a single, unambiguous, authoritative representation within a system
- Violations of DRY are typically referred to as *WET* solutions

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KISS

- It states that most systems work best if they are kept simple rather than made complicated
- Simplicity should be a key goal in design and unnecessary complexity should be avoided

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SOLID

- S** : a class should have only a single responsibility
- O** : entities should be “open” for extensions, but “closed” for modification
- L** : objects in a program should be replaceable with instances of their subtypes without altering the correctness of the program
- I** : many “specific” interfaces are better than one general-purpose interface
- D** : high-level modules should not dependent from the low-levels; both should depend on abstractions. Abstractions should not depend on details and vice-versa

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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

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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

Different implementations for different collections

- Stream of data
- Records of a database
- List of cars
- Array of numbers
- Array of Array of pixels (a matrix)
- Option (an option essentially is a “one-element’ collection”)
- 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
- The latter is a static compact data structure with a fixed number of elements

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

- What about all other collections?
- Maps, sets, trees, etc..

The need for different collections

- A collection has its own purpose: 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, making code more complex (KISS: keep iteration superficially 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

The iterator design pattern

- We will define an interface capturing the basics to all container iterations:
- get current data
- move to next item
- check if next item exists

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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 }
```

- `GetNext` returns `Some<T>` if there is data to fetch
- It moves to the next item
- It returns `None<T>` if there are no more elements to fetch

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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
- Iterating a collection with 5, 3, 2 will return: Some(5), Some(3), Some(2), None(), None(), None(), ..., None()

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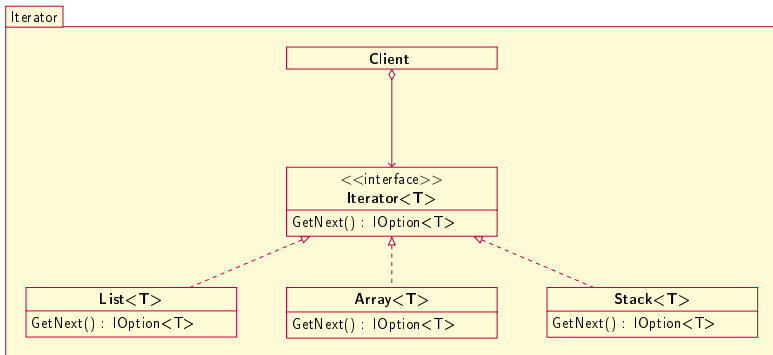
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Conclusions

Implementing the Iterator<T>

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

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Conclusions

Natural numbers

- The natural numbers are all integers greater than or equal to 0
- `GetNext` increases a counter `n` (starting from -1) and returns it within a `Some`

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

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Conclusions

List<T>

- Dealing with a list requires to deal with references
- We hide such complexity, which is error-prone, by means of our iterator

The iterator design pattern

List<T>

- Our list now takes as input an object of type list
- `GetNext` returns `None` at the end of the list (when the tail is `None`), otherwise it moves to the next node and returns its value wrapped inside a `Some`

```
1 class List<T> : Iterator<T> {  
2     private List<T> list;  
3     public List(List<T> list) {  
4         this.list = list;  
5     }  
6     IOption<int> GetNext() {  
7         if list.IsNone() {  
8             return new None<T>();  
9         }  
10        else{  
11            List<int> tmp = list;  
12            list = list.GetTail();  
13            return new Some<int>(tmp.GetValue());  
14        }  
15    }  
16 }
```


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Conclusions

Array<T>

- Dealing with an array requires to deal with its indexes
- We hide such complexity, which 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
- GetNext returns None at the end of the array, otherwise it increases the index and returns the value of the array at position index wrapped inside a Some

```
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    }  
16 }
```

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Other collections

- Each container will then store its own reference to a collection, plus the current iterated element
- The plumbing is quite obvious per container
- We obviously cannot show them all

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The iterator in literature

- In the literature we often find another formulation

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

- As we can see, this is less safe, since now we have to *carefully* manipulate three methods (instead of one as for `Iterator<T>`)

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Improving the TraditionalIterator<T> safeness

- Adapting our TraditionalIterator will require us to define an adapter MakeSafe that implements our Iterator by coordinating method calls to an underlying Iterator^a

^aAdapter allows to automatically convert back/forth between iterators

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

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- 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

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The best of luck, and thanks for the
attention!