CS2010: ALGORITHMS AND DATA STRUCTURES

Lecture 7: Java Generics & Iterators

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Java Generics

http://algs4.cs.princeton.edu

1.3 Bags, Queues, and Stacks

Parameterized stack

We implemented: `StackOfStrings`.

We also want: `StackOfURLs`, `StackOfInts`, `StackOfVans`, ...

Attempt 1. Implement a separate stack class for each type.

- Rewriting code is tedious and error-prone.
- Maintaining cut-and-pasted code is tedious and error-prone.

@#$*! most reasonable approach until Java 1.5.

(Java 1.5 released Sep 2004)

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Parameterized stack

We implemented: `StackOfStrings`.

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Attempt 2. Implement a stack with items of type `Object`.

- Casting is required in client.
- Casting is error-prone: run-time error if types mismatch.

```
StackOfObjects s = new StackOfObjects();
Apple  a = new Apple();
Orange b = new Orange();
s.push(a);
s.push(b);
a = (Apple) (s.pop());
```

run-time error

Parameterized stack

We implemented: `StackOfStrings`.

We also want: `StackOfURLs`, `StackOfInts`, `StackOfVans`, ...

Attempt 3. Java generics.

- Avoid casting in client.
- Discover type mismatch errors at compile-time instead of run-time.

type parameter

```
Stack<Apple> s = new Stack<Apple>();
Apple  a = new Apple();
Orange b = new Orange();
s.push(a);
s.push(b);
a = s.pop();
```

compile-time error

Guiding principles. Welcome compile-time errors; avoid run-time errors.

Generic stack: linked-list implementation

```
public class LinkedStackOfStrings
{
   private Node first = null;

   private class Node
   {
      String item;
      Node next;
   }

   public boolean isEmpty()
   {  return first == null;  }

   public void push(String item)
   {
      Node oldfirst = first;
      first = new Node();
      first.item = item;
      first.next = oldfirst;
   }

   public String pop()
   {
      String item = first.item;
      first = first.next;
      return item;
   }
}
```

```
public class Stack<Item>
{
   private Node first = null;

   private class Node
   {
      Item item;
      Node next;
   }

   public boolean isEmpty()
   {  return first == null;  }

   public void push(Item item)
   {
      Node oldfirst = first;
      first = new Node();
      first.item = item;
      first.next = oldfirst;
   }

   public Item pop()
   {
      Item item = first.item;
      first = first.next;
      return item;
   }
}
```

generic type name

Generic stack: array implementation

```
public class FixedCapacityStackOfStrings
{
   private String[] s;
   private int N = 0;

   public ..StackOfStrings(int capacity)
   {  s = new String[capacity];  }

   public boolean isEmpty()
   {  return N == 0;  }

   public void push(String item)
   {  s[N++] = item;  }

   public String pop()
   {  return s[--N];  }
}
```

the way it should be

```
public class FixedCapacityStack<Item>
{
   private Item[] s;
   private int N = 0;

   public FixedCapacityStack(int capacity)
   {  s = new Item[capacity];  }

   public boolean isEmpty()
   {  return N == 0;  }

   public void push(Item item)
   {  s[N++] = item;  }

   public Item pop()
   {  return s[--N];  }
}
```

@#$*! generic array creation not allowed in Java

Generic stack: array implementation

```
public class FixedCapacityStackOfStrings
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   private String[] s;
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   public ..StackOfStrings(int capacity)
   {  s = new String[capacity];  }

   public boolean isEmpty()
   {  return N == 0;  }

   public void push(String item)
   {  s[N++] = item;  }

   public String pop()
   {  return s[--N];  }
}
```

the way it is

```
public class FixedCapacityStack<Item>
{
   private Item[] s;
   private int N = 0;

   public FixedCapacityStack(int capacity)
   {  s = (Item[]) new Object[capacity]; }

   public boolean isEmpty()
   {  return N == 0;  }

   public void push(Item item)
   {  s[N++] = item;  }

   public Item pop()
   {  return s[--N];  }
}
```

the ugly cast

Unchecked cast

```
% javac FixedCapacityStack.java
Note: FixedCapacityStack.java uses unchecked or unsafe operations.
Note: Recompile with -Xlint:unchecked for details.

% javac -Xlint:unchecked FixedCapacityStack.java
FixedCapacityStack.java:26: warning: [unchecked] unchecked cast
found   : java.lang.Object[]
required: Item[]
        a = (Item[]) new Object[capacity];
                     ^
1 warning
```

Q. Why does Java make me cast (or use reflection)?

Short answer. Backward compatibility.

Long answer. Need to learn about type erasure and covariant arrays.

Generic data types: autoboxing

Q. What to do about primitive types?

Wrapper type.

- Each primitive type has a wrapper object type.
- Ex: `Integer` is wrapper type for `int`.

Autoboxing. Automatic cast between a primitive type and its wrapper.

```
Stack<Integer> s = new Stack<Integer>();
s.push(17);         // s.push(Integer.valueOf(17));
int a = s.pop();    // int a = s.pop().intValue();
```

Bottom line. Client code can use generic stack for any type of data.

Generic Iterators

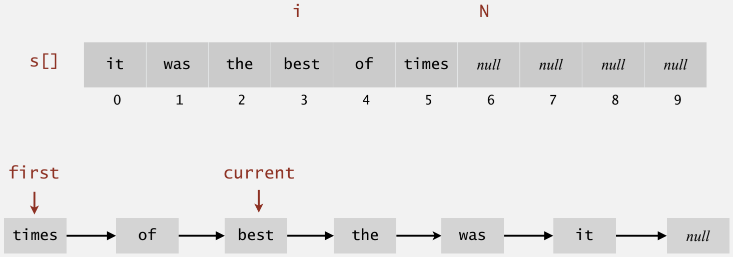
http://algs4.cs.princeton.edu

1.3 Bags, Queues, and Stacks

- *stacks*
- *resizing arrays*
- *queues*
- *generics*
- *iterators*
- *applications*

Iteration

Design challenge. Support iteration over stack items by client, without revealing the internal representation of the stack.



Java solution. Make stack implement the `java.lang.Iterable` interface.

Iterators

Q. What is an `Iterable` ?

A. Has a method that returns an `Iterator`.

java.lang.Iterable interface

```
public interface Iterable<Item>
{
   Iterator<Item> iterator();
}
```

Q. What is an `Iterator` ?

A. Has methods `hasNext()` and `next()`.

java.util.Iterator interface

```
public interface Iterator<Item>
{
   boolean hasNext();
   Item next();
   void remove();  ←  optional; use
                      at your own risk
}
```

Q. Why make data structures `Iterable` ?

A. Java supports elegant client code.

"foreach" statement (shorthand)

```
for (String s : stack)
   StdOut.println(s);
```

equivalent code (longhand)

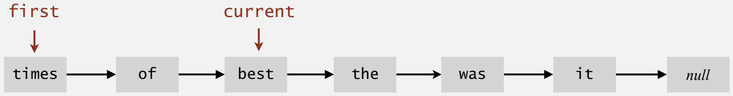
```
Iterator<String> i = stack.iterator();
while (i.hasNext())
{
   String s = i.next();
   StdOut.println(s);
}
```

Stack iterator: linked-list implementation

```
import java.util.Iterator;

public class Stack<Item> implements Iterable<Item>
{
    ...

    public Iterator<Item> iterator() { return new ListIterator(); }

    private class ListIterator implements Iterator<Item>
    {
        private Node current = first;

        public boolean hasNext() {  return current != null;  }
        public void remove()     {  /* not supported */      }
        public Item next()
        {
            Item item = current.item;
            current   = current.next;
            return item;
        }
    }
}
```

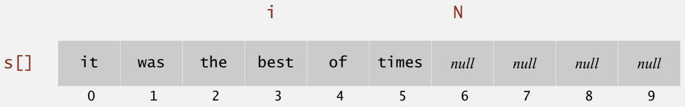
throw UnsupportedOperationException

throw NoSuchElementException
if no more items in iteration



Stack iterator: array implementation

```
import java.util.Iterator;

public class Stack<Item> implements Iterable<Item>
{
    …
    public Iterator<Item> iterator()
    { return new ReverseArrayIterator(); }

    private class ReverseArrayIterator implements Iterator<Item>
    {
        private int i = N;

        public boolean hasNext() {  return i > 0;          }
        public void remove()     {  /* not supported */  }
        public Item next()       {  return s[--i];       }
    }
}
```



Iteration: concurrent modification

Q. What if client modifies the data structure while iterating?

A. A fail-fast iterator throws a `java.util.ConcurrentModificationException`.

concurrent modification

```
for (String s : stack)
   stack.push(s);
```

Q. How to detect?

A.

- Count total number of `push()` and `pop()` operations in `Stack`.
- Save counts in `*Iterator` subclass upon creation.
- If, when calling `next()` and `hasNext()`, the current counts do not equal the saved counts, throw exception.

Generic Comparisons

COMPARISONS

Design Challenge: Add a `search` method in the Stack ADT.

```
public class Stack<Item>
{
  private Node first = null;

  private class Node
  {
    Item item;
    Node next;
  }
  ...
  boolean search(Item searchObj)
  {
    // we need to compare searchObj to other items in the Stack
    ...
  }
}
```

`Item` needs to at least implement the comparable interface.

JAVA'S COMPARABLE INTERFACE

```java
public interface Comparable<T>
{
  int compareTo(T o);
  // Compares this object with objects of class T.
}
```

`i.compareTo(o)` returns:

- 0 if `i` = `o`
- >0 if `i` > `o`
- <0 if `i` < `o`

`Comparable` is a parametric interface because it doesn't know a priori the type T.

COMPARISONS

```
public class Stack<Item extends Comparable<Item>>
{
  private Node first = null;

  private class Node
  {
    Item item;
    Node next;
  }
  ...
  boolean search(Item searchObj)
  {
    for (Item i : this)
    {
      if (i.compareTo(searchObj) == 0) return true;
    }
    return false;
  }
}
```