Storage Strategies: Static Arrays

- StackADT Interface
- ArrayStack Implementation
- ArrayStack Methods with Big-O analysis
- StackIterator Class
- StackIterator Methods
- StackIterator Summary
- Reading: L&C 3.6-3.8, 7.3

Stack Abstract Data Type

- A *stack* is a linear collection where the elements are added or removed from the same end
- The processing is *last in, first out (LIFO)*
- The last element put on the stack is the first element removed from the stack
- Think of a stack of cafeteria trays

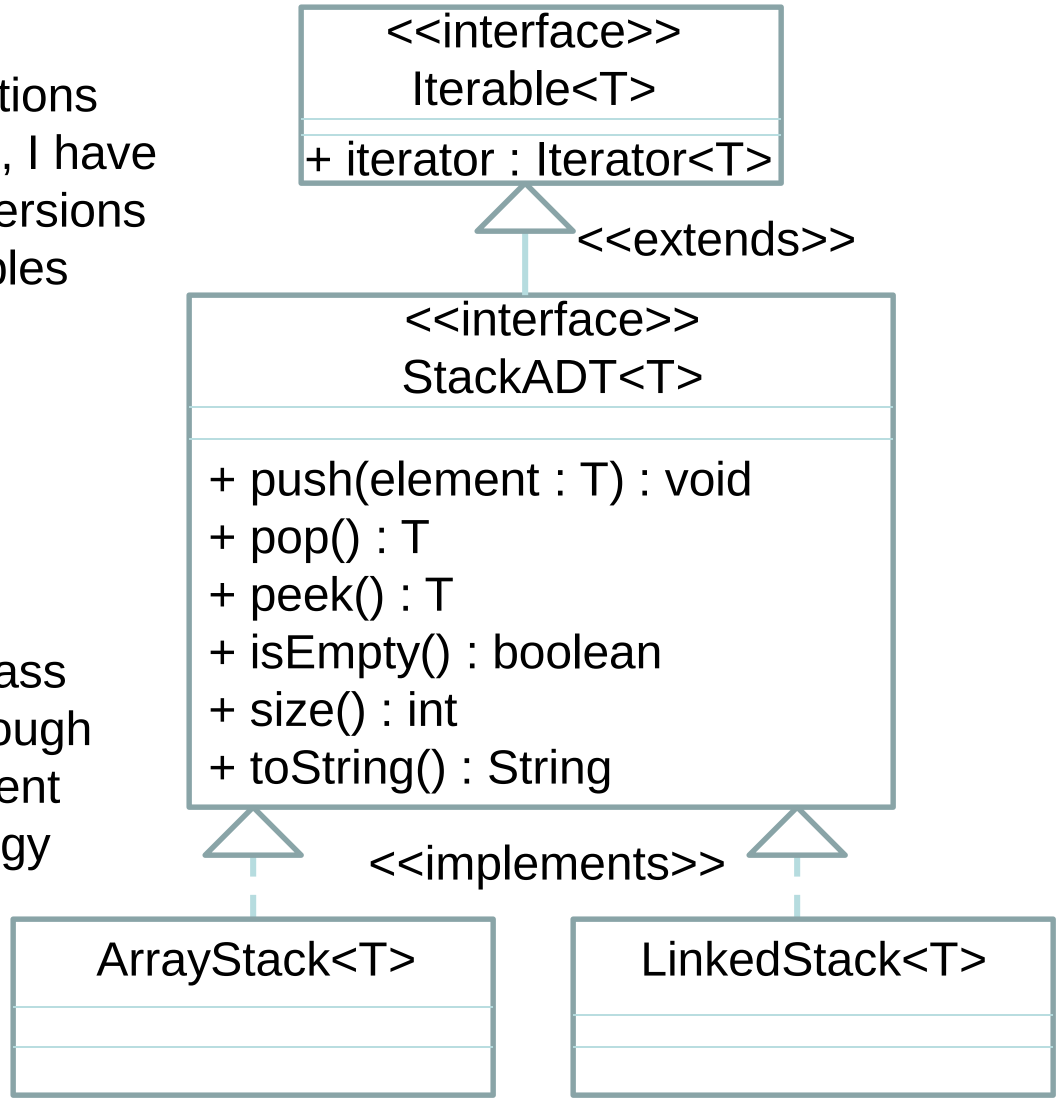
Stack Terminology

- We *push* an element on a stack to add one
- We *pop* an element off a stack to remove one
- We can also *peek* at the top element without removing it
- We can determine if a stack is *empty* or not and how many elements it contains (its *size*)
- The StackADT interface supports the above operations and some typical class operations such as `toString()`

StackADT and Stack Classes

Since the Java Collections all extend Iterable<T>, I have added that to all my versions of the textbook examples

Each implementing class satisfies the ADT although they each use a different internal storage strategy

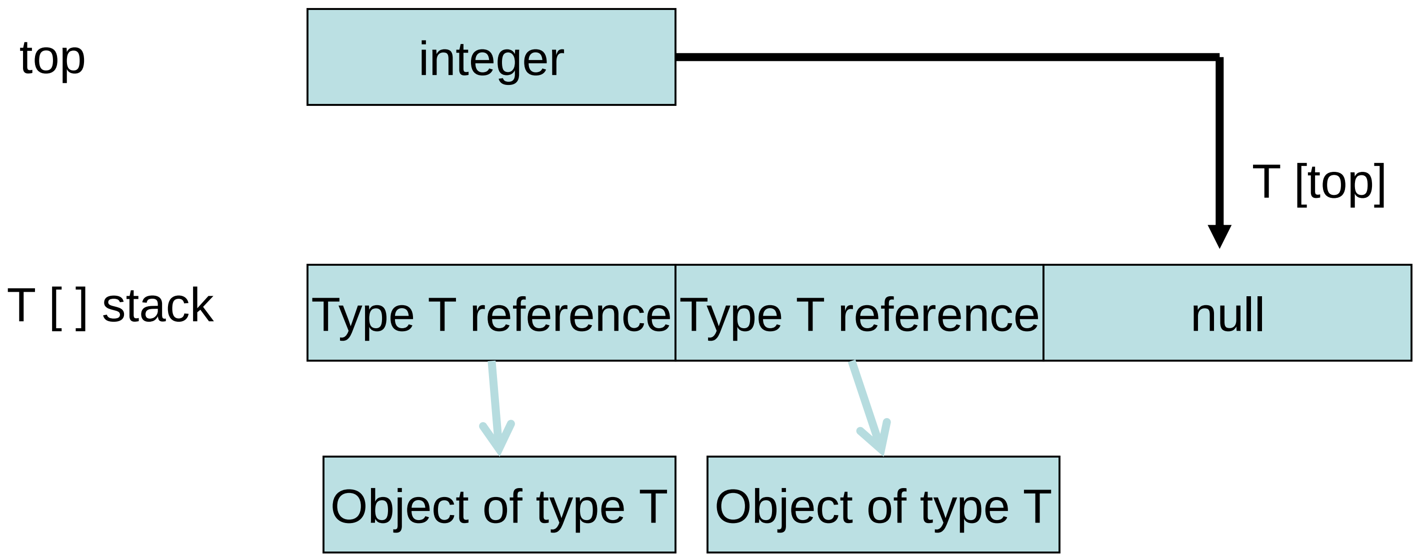


Stack Design Considerations

- Although a stack can be empty, there is no concept for it being full. An implementation must be designed to manage storage space
- For peek and pop operation on an empty stack, the implementation would throw an exception. There is no other return value that is equivalent to “nothing to return”
- A *drop-out stack* is a variation of the stack design where there is a limit to the number of elements that are retained

ArrayStack Implementation

- We can use an array of elements as a stack
- The top is the index of the next available element in the array



ArrayStack Methods

- An interface can't define any constructor methods, but any implementing class needs to have one or more of them (maybe overloading the constructor)
- Default Contructor:

```
public ArrayStack()
{                                // must be 1st statement
  this(DEFAULT_CAPACITY);        // call other constructor
}                                // with default capacity
```

- Constructor with a specified initial capacity:

```
public ArrayStack(int initialCapacity)
{
  top = 0;
  stack = (T[]) new Object[initialCapacity];
}
```

Array Stack Implementation

- push – O(1)

```
public void push (T element)
{
  if (size() == stack.length)
        expandCapacity();   // see next slide
  stack [top++] = element;
}
```

- Because a Java array's size cannot be changed after instantiation, the add method may need to allocate a larger array, copy the data to the new array, and release the memory of the old array

ArrayStack Methods

- expandCapacity – O(n)

```
private void expandCapacity()
{
   T[] larger =         // double the array size
     (T[]) new Object[2 * contents.length];
  for (int i = 0; i < contents.length; i++)
     larger[i] = stack[i];

   stack = larger;      // original array
                        // becomes garbage
}
```

Array Stack Implementation

- pop() – O(1)

```
public T pop() throws EmptyStackException
{
  if (isEmpty())
        throw new EmptyStackException();
  T result = stack[--top];
  stack[top] = null; // removes “stale” reference
  return result;
}
```

- The “stale” reference stored in stack[top] would prevent garbage collection on the object when the caller sets the returned reference value to null – ties up resources

ArrayStack Implementation

- peek() – O(1)

```
public T peek() throws EmptyStackException
{
  if (isEmpty())
        throw new EmptyStackException();
  return stack[top - 1];
  }
```

ArrayStack Methods

- size - O(1)

```
public int size()
{
  return top;
}
```

- isEmpty – O(1)

```
public boolean isEmpty()
{
  return top == 0;
}
```

ArrayStack Methods

- toString – O(n)

```
public String toString()
{
  String result = "";

  for (T obj : stack) {
    if (obj == null)  // first null is at top
      return result;
    result += obj + "\n";
  }
  return result;     // exactly full - no nulls
}
```

ArrayStack Methods

- All Java Collections API classes implement (indirectly) the Iterable interface and I add that to the definition of all textbook classes
- iterator – O(1)

```
public Iterator<T> iterator()
{
  return new StackIterator<T>();
}
```

- We need to study the StackIterator class to understand how to implement an Iterator

StackIterator Class

- The iterator method of the ArrayStack class instantiates and returns a reference to a new StackIterator object to its caller
- If an iterator class is very closely related to its collection class, it is a good candidate for implementation as an inner class
- As an inner class, the StackIterator code can access the `stack` and `top` variables of the instance of the outer class that instantiated it

StackIterator Definition/Attributes

- Class Definition/Attribute Declarations (implemented as an inner class)

```
private class StackIterator<T>
                    implements Iterator<T>
{
   private int current;
```

- Constructor:

```
public StackIterator()
{
  current = top;  // start at top for LIFO
}
```

StackIterator Methods

- hasNext – O(1)

```
public boolean hasNext()
{
  return current > 0;
}
```

- next – O(1)

```
public T next()
{
  if (!hasNext())
     throw new NoSuchElementException();
  return stack[--current]; // outer class array
}
```

StackIterator Methods

- remove – O(1)
- We may or may not implement real code for the remove method, but there is no return value that we can use to indicate that it is not implemented
- If we don’t implement it, we may indicate that it is not implemented by throwing an exception

```
public void remove() throws
                     UnsupportedOperationException
{
  throw new UnsupportedOperationException();
}
```

StackIterator Methods

- If we do implement the remove method, notice that we don’t specify the element that is to be removed and we do not return a reference to the element being removed
- It is assumed that the calling code has been iterating on condition `hasNext()` and calling `next()` and already has a reference
- The last element returned by next() is the element that will be removed

StackIterator Method Analysis

- Each of the StackIterator methods is O(1)
- However, they are usually called inside an external while loop or “for-each” loop
- Hence, the process of “iterating” through a collection using an Iterator is O(n) where n is the number of objects in the collection

ArrayListIterator Class in Textbook

- The textbook’s iterator classes detect any modification to the array and cause the iteration process to “fast-fail” with an exception
- The add and remove methods of the outer class update a variable: `modCount`
- The iterator’s constructor copies that value
- If the value of `modCount` changes during the iteration, the iterator code throws an exception
- I have not included that in my example code, but it is included in the Java Collections classes