Basic Data Structures

Outline

Generics in Java

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Generics (aka parametrized types) enable us to implement collection ADTs that can store any type of data

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Generics (aka parametrized types) enable us to implement collection ADTs that can store any type of data

Example

```
LinkedStack<String> s1 = new LinkedStack<String>();
LinkedStack<Date> s2 = new LinkedStack<Date>();
s1.push("03/14/1879");
s2.push(new Date(3, 14, 1879));
String s = s1.pop();
Date d = s2.pop();
```

Generics in Java

Java automatically converts a primitive type to the corresponding reference type (auto boxing) and vice versa (auto unboxing)

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Java automatically converts a primitive type to the corresponding reference type (auto boxing) and vice versa (auto unboxing)

Example

```
LinkedStack<Integer> stack = new LinkedStack<Integer>();
stack.push(42);      // auto boxing (int -> Integer)
int i = stack.pop(); // auto unboxing (Integer -> int)
```

Generics in Java

Java automatically converts a primitive type to the corresponding reference type (auto boxing) and vice versa (auto unboxing)

Example

```
LinkedStack<Integer> stack = new LinkedStack<Integer>();
stack.push(42);      // auto boxing (int -> Integer)
int i = stack.pop(); // auto unboxing (Integer -> int)
```

Wrapper types

boolean	Boolean
byte	Byte
char	Character
short	Short
int	Integer
float	Float
long	Long
double	Double

Linked List

Linked List

A linked list is a data structure that is either empty (`null`) or a reference to a node having a generic item and a reference to the rest of the linked list

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Example

Linked List

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Example

Linked list ADT

```
private class Node {
    private Item item;
    private Node next;
}
```

Linked List

Traverse a linked list

Linked List

Traverse a linked list

Linked List

Traverse a linked list


```
for (Node x = first; x != null; x = x.next) {
    StdOut.print(x.item + " ");
}
```

Linked List

Traverse a linked list


```
for (Node x = first; x != null; x = x.next) {
    StdOut.print(x.item + " ");
}
```

```
to be or not to be
```

Linked List

Linked List

Build a linked list

Linked List

Build a linked list

```
Node first = new Node();
first.item = "be";
```

Build a linked list

```
Node first = new Node();
first.item = "be";
```

Linked List

Insert at the beginning

Insert at the beginning

Linked List

Insert at the beginning


```
Node oldfirst = first;
first = new Node();
first.item = "to";
first.next = oldfirst;
```

Linked List

Insert at the beginning


```
Node oldfirst = first;
first = new Node();
first.item = "to";
first.next = oldfirst;
```

Linked List

Insert at the end

Linked List

Insert at the end

Linked List

Insert at the end


```
Node oldlast = last;
last = new Node();
last.item = "or";
oldlast.next = last;
```

Linked List

Insert at the end


```
Node oldlast = last;
last = new Node();
last.item = "or";
oldlast.next = last;
```

Linked List

Remove from the beginning

Remove from the beginning

Linked List

Remove from the beginning


```
first = first.next;
```

Linked List

Remove from the beginning


```
first = first.next;
```

Linked List

Operation	$T(n)$
Insert at the beginning	1
Insert at the end	1
Remove from the beginning	1

Bag

Bag

A `Bag` is an iterable collection that stores generic items

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dsa.Bag<Item> extends java.lang.Iterable<Item>

`boolean isEmpty()`	returns `true` if this bag is empty, and `false` otherwise
`int size()`	returns the number of items in this bag
`void add(Item item)`	adds `item` to this bag
`Iterator<Item> iterator()`	returns an iterator to iterate over the items in this bag

Bag

Bag

Program: `Stats.java`

Bag

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- Standard input: a sequence of doubles

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- Standard input: a sequence of doubles
- Standard output: their mean and standard deviation

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```
>_ ~/workspace/dsaj/programs
$ _
```

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```
>_ ~/workspace/dsaj/programs
$ java Stats
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```
>_ ~/workspace/dsaj/programs

$ java Stats
1 3 5 7 9
```

Bag

Program: `Stats.java`

- Standard input: a sequence of doubles
- Standard output: their mean and standard deviation

```
>_ ~/workspace/dsaj/programs

$ java Stats
1 3 5 7 9
-
```

Bag

Program: `Stats.java`

- Standard input: a sequence of doubles
- Standard output: their mean and standard deviation

```
>_ ~/workspace/dsaj/programs

$ java Stats
1 3 5 7 9
<ctrl-d>
```

Bag

Program: `Stats.java`

- Standard input: a sequence of doubles
- Standard output: their mean and standard deviation

```
>_ ~/workspace/dsaj/programs

$ java Stats
1 3 5 7 9
<ctrl-d>
Mean:    5.00
Std dev: 3.16
$ _
```

Bag

Bag

Stats.java

```java
import dsa.LinkedBag;

import stdlib.StdIn;
import stdlib.StdOut;

public class Stats {
    public static void main(String[] args) {
        LinkedBag<Double> bag = new LinkedBag<Double>();
        while (!StdIn.isEmpty()) {
            bag.add(StdIn.readDouble());
        }
        int n = bag.size();
        double sum = 0.0;
        for (double x : bag) {
            sum += x;
        }
        double mean = sum / n;
        sum = 0.0;
        for (double x : bag) {
            sum += (x - mean) * (x - mean);
        }
        double stddev = Math.sqrt(sum / (n - 1));
        StdOut.printf("Mean:    %.2f\n", mean);
        StdOut.printf("Std dev: %.2f\n", stddev);
    }
}
```

Bag

Bag

dsa.LinkedBag<Item> implements dsa.Bag<Item>	
`LinkedBag()`	constructs an empty bag
`String toString()`	returns a string representation of this bag

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Instance variables:

- Reference to the front of the bag: `Node first`

Bag

dsa.LinkedBag<Item> implements dsa.Bag<Item>	
`LinkedBag()`	constructs an empty bag
`String toString()`	returns a string representation of this bag

Instance variables:

- Reference to the front of the bag: `Node first`

- Number of items in the bag: `int n`

Bag

Bag

LinkedBag.java

```
package dsa;

import java.util.Iterator;
import java.util.NoSuchElementException;

import stdlib.StdIn;
import stdlib.StdOut;

public class LinkedBag<Item> implements Bag<Item> {
    private Node first;
    private int n;

    public LinkedBag() {
        first = null;
        n = 0;
    }

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

    public int size() {
        return n;
    }

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

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

Bag

LinkedBag.java

```
    }

    public String toString() {
        StringBuilder sb = new StringBuilder();
        for (Item item : this) {
            sb.append(item);
            sb.append(", ");
        }
        return n > 0 ? "[" + sb.substring(0, sb.length() - 2) + "]" : "[]";
    }

    private class Node {
        private Item item;
        private Node next;
    }

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

        public ListIterator() {
            current = first;
        }

        public boolean hasNext() {
            return current != null;
        }

        public Item next() {
            if (!hasNext()) {
                throw new NoSuchElementException("Iterator is empty");
            }
            Item item = current.item;
            current = current.next;
            return item;
        }
```

Bag

LinkedBag.java

```
    }

    public static void main(String[] args) {
        LinkedBag<String> bag = new LinkedBag<String>();
        while (!StdIn.isEmpty()) {
            String item = StdIn.readString();
            bag.add(item);
        }
        StdOut.println(bag.size() + " items in the bag");
        StdOut.println(bag);
    }
}
```

Bag

Bag

Operation	$T(n)$
`LinkedBag()`	1
`boolean isEmpty()`	1
`int size()`	1
`void add(Item item)`	1
`Iterator<Item> iterator()`	1
`String toString()`	n

Bag

Bag

dsa.ResizingArrayBag<Item> implements dsa.Bag<Item>	
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Instance variables:

- Array of items in the bag: `Item a[]`

Bag

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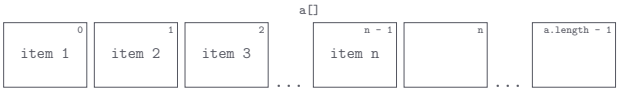

- Number of items in the bag: `int n`

Bag

Bag

ResizingArrayBag.java

```
package dsa;

import java.util.Iterator;
import java.util.NoSuchElementException;

import stdlib.StdIn;
import stdlib.StdOut;

public class ResizingArrayBag<Item> implements Bag<Item> {
    private Item[] a;
    private int n;

    public ResizingArrayBag() {
        a = (Item[]) new Object[2];
        n = 0;
    }

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

    public int size() {
        return n;
    }

    public void add(Item item) {
        if (n == a.length) {
            resize(2 * a.length);
        }
        a[n++] = item;
    }

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

Bag

ResizingArrayBag.java

```
    public String toString() {
        StringBuilder sb = new StringBuilder();
        for (Item item : this) {
            sb.append(item);
            sb.append(", ");
        }
        return n > 0 ? "[" + sb.substring(0, sb.length() - 2) + "]" : "[]";
    }

    private void resize(int capacity) {
        Item[] temp = (Item[]) new Object[capacity];
        for (int i = 0; i < n; i++) {
            temp[i] = a[i];
        }
        a = temp;
    }

    private class ArrayIterator implements Iterator<Item> {
        private int i;

        public ArrayIterator() {
            i = 0;
        }

        public boolean hasNext() {
            return i < n;
        }

        public Item next() {
            if (!hasNext()) {
                throw new NoSuchElementException("Iterator is empty");
            }
            return a[i++];
        }
```

Bag

ResizingArrayBag.java

```
    }

    public static void main(String[] args) {
        ResizingArrayBag<String> bag = new ResizingArrayBag<String>();
        while (!StdIn.isEmpty()) {
            String item = StdIn.readString();
            bag.add(item);
        }
        StdOut.println(bag.size() + " items in the bag");
        StdOut.println(bag);
    }
}
```

Bag

Bag

Operation	$T(n)$
`ResizingArrayBag()`	1
`boolean isEmpty()`	1
`int size()`	1
`void add(Item item)`	1 (amortized)
`Iterator<Item> iterator()`	1
`String toString()`	n

Queue

Queue

A `Queue` is an iterable collection that stores generic items in first-in-first-out (FIFO) order

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dsa.Queue<Item> extends java.lang.Iterable<Item>

`boolean isEmpty()`	returns `true` if this queue is empty, and `false` otherwise
`int size()`	returns the number of items in this queue
`void enqueue(Item item)`	adds `item` to the end of this queue
`Item peek()`	returns the item at the front of this queue
`Item dequeue()`	removes and returns the item at the front of this queue
`Iterator<Item> iterator()`	returns an iterator to iterate over the items in this queue in FIFO order

Queue

Queue

Program: `KthFromLast.java`

Queue

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- Command-line input: k (int)

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- Command-line input: k (int)
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- Standard output: the kth integer from the end

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>_ ~/workspace/dsaj/programs
$ _
```

Program: `KthFromLast.java`

- Command-line input: k (int)
- Standard input: a sequence of integers
- Standard output: the kth integer from the end

```
>_ ~/workspace/dsaj/programs

$ java KthFromLast 4
```

Program: `KthFromLast.java`

- Command-line input: k (int)
- Standard input: a sequence of integers
- Standard output: the kth integer from the end

```
>_ ~/workspace/dsaj/programs

$ java KthFromLast 4
-
```

Program: `KthFromLast.java`

- Command-line input: k (int)
- Standard input: a sequence of integers
- Standard output: the kth integer from the end

```
>_ ~/workspace/dsaj/programs

$ java KthFromLast 4
1 2 3 4 5 6 7 8 9 10
```

Program: `KthFromLast.java`

- Command-line input: k (int)
- Standard input: a sequence of integers
- Standard output: the kth integer from the end

```
>_ ~/workspace/dsaj/programs

$ java KthFromLast 4
1 2 3 4 5 6 7 8 9 10
-
```

Program: `KthFromLast.java`

- Command-line input: k (int)
- Standard input: a sequence of integers
- Standard output: the kth integer from the end

```
>_ ~/workspace/dsaj/programs

$ java KthFromLast 4
1 2 3 4 5 6 7 8 9 10
<ctrl-d>
```

Program: `KthFromLast.java`

- Command-line input: k (int)
- Standard input: a sequence of integers
- Standard output: the kth integer from the end

```
>_ ~/workspace/dsaj/programs

$ java KthFromLast 4
1 2 3 4 5 6 7 8 9 10
<ctrl-d>
7
$ _
```

Queue

Queue

KthFromLast.java

```java
import dsa.LinkedQueue;

import stdlib.StdIn;
import stdlib.StdOut;

public class KthFromLast {
    public static void main(String[] args) {
        int k = Integer.parseInt(args[0]);
        LinkedQueue<Integer> queue = new LinkedQueue<Integer>();
        while (!StdIn.isEmpty()) {
            queue.enqueue(StdIn.readInt());
        }
        int n = queue.size();
        for (int i = 1; i <= n - k; i++) {
            queue.dequeue();
        }
        StdOut.println(queue.peek());
    }
}
```

Queue

Queue

dsa.LinkedQueue<Item> implements dsa.Queue<Item>	
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- References to the front and back of the queue: `Node first` and `Node last`

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Instance variables:

- References to the front and back of the queue: `Node first` and `Node last`

- Number of items in the queue: `int n`

Queue

Queue

LinkedQueue.java

```
package dsa;

import java.util.Iterator;
import java.util.NoSuchElementException;

import stdlib.StdIn;
import stdlib.StdOut;

public class LinkedQueue<Item> implements Queue<Item> {
    private Node first;
    private Node last;
    private int n;

    public LinkedQueue() {
        first = null;
        last = null;
        n = 0;
    }

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

    public int size() {
        return n;
    }

    public void enqueue(Item item) {
        Node oldlast = last;
        last = new Node();
        last.item = item;
        last.next = null;
        if (isEmpty()) {
            first = last;
        } else {
```

Queue

LinkedQueue.java

```
            oldlast.next = last;
        }
        n++;
    }

    public Item peek() {
        if (isEmpty()) {
            throw new NoSuchElementException("Queue is empty");
        }
        return first.item;
    }

    public Item dequeue() {
        if (isEmpty()) {
            throw new NoSuchElementException("Queue is empty");
        }
        Item item = first.item;
        first = first.next;
        n--;
        if (isEmpty()) {
            last = null;
        }
        return item;
    }

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

    public String toString() {
        StringBuilder sb = new StringBuilder();
        for (Item item : this) {
            sb.append(item);
            sb.append(", ");
        }
```

Queue

LinkedQueue.java

```
        return n > 0 ? "[" + sb.substring(0, sb.length() - 2) + "]" : "[]";
    }

    private class Node {
        private Item item;
        private Node next;
    }

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

        public ListIterator() {
            current = first;
        }

        public boolean hasNext() {
            return current != null;
        }

        public Item next() {
            if (!hasNext()) {
                throw new NoSuchElementException("Iterator is empty");
            }
            Item item = current.item;
            current = current.next;
            return item;
        }
    }

    public static void main(String[] args) {
        LinkedQueue<String> queue = new LinkedQueue<String>();
        while (!StdIn.isEmpty()) {
            String item = StdIn.readString();
            if (!item.equals("-")) {
                queue.enqueue(item);
```

Queue

LinkedQueue.java

```
            } else if (!queue.isEmpty()) {
                StdOut.print(queue.dequeue() + " ");
            }
        }
        StdOut.println();
        StdOut.println(queue.size() + " items left in the queue");
        StdOut.println(queue);
    }
}
```

Queue

Operation	$T(n)$
`LinkedQueue()`	1
`boolean isEmpty()`	1
`int size()`	1
`void enqueue(Item item)`	1
`Item peek()`	1
`Item dequeue()`	1
`Iterator<Item> iterator()`	1
`String toString()`	n

Queue

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dsa.ResizingArrayQueue<Item> implements dsa.Queue<Item>	
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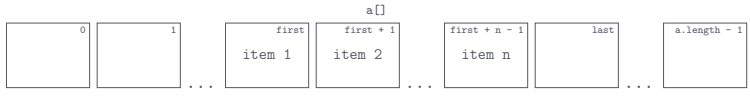
Instance variables:

- Array of items in the queue: `Item a[]`



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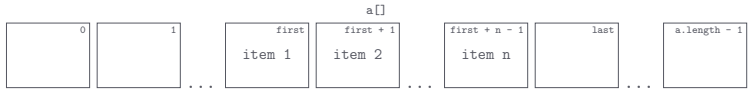

- Index of the first item: `int first`

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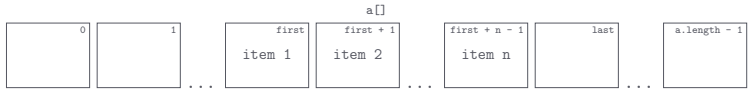

- Index of the first item: `int first`
- Index of the next new item: `int last`

Queue

dsa.ResizingArrayQueue<Item> implements dsa.Queue<Item>	
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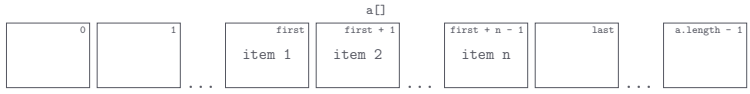

- Index of the first item: `int first`
- Index of the next new item: `int last`
- Number of items in the queue: `int n`

Queue

Queue

ResizingArrayQueue.java

```
package dsa;

import java.util.Iterator;
import java.util.NoSuchElementException;

import stdlib.StdIn;
import stdlib.StdOut;

public class ResizingArrayQueue<Item> implements Queue<Item> {
    private Item[] a;
    private int first;
    private int last;
    private int n;

    public ResizingArrayQueue() {
        a = (Item[]) new Object[2];
        n = 0;
        first = 0;
        last = 0;
    }

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

    public int size() {
        return n;
    }

    public void enqueue(Item item) {
        if (n == a.length) {
            resize(2 * a.length);
        }
        a[last++] = item;
        if (last == a.length) {
```

Queue

ResizingArrayQueue.java

```
            last = 0;
        }
        n++;
    }

    public Item peek() {
        if (isEmpty()) {
            throw new NoSuchElementException("Queue is empty");
        }
        return a[first];
    }

    public Item dequeue() {
        if (isEmpty()) {
            throw new NoSuchElementException("Queue is empty");
        }
        Item item = a[first];
        a[first] = null;
        n--;
        first++;
        if (first == a.length) {
            first = 0;
        }
        if (n > 0 && n == a.length / 4) {
            resize(a.length / 2);
        }
        return item;
    }

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

    public String toString() {
        StringBuilder sb = new StringBuilder();
```

Queue

ResizingArrayQueue.java

```
        for (Item item : this) {
            sb.append(item);
            sb.append(", ");
        }
        return n > 0 ? "[" + sb.substring(0, sb.length() - 2) + "]" : "[]";
    }

    private void resize(int capacity) {
        Item[] temp = (Item[]) new Object[capacity];
        for (int i = 0; i < n; i++) {
            temp[i] = a[(first + i) % a.length];
        }
        a = temp;
        first = 0;
        last = n;
    }

    private class ArrayIterator implements Iterator<Item> {
        private int i;

        public ArrayIterator() {
            i = 0;
        }

        public boolean hasNext() {
            return i < n;
        }

        public Item next() {
            if (!hasNext()) {
                throw new NoSuchElementException("Iterator is empty");
            }
            Item item = a[(i + first) % a.length];
            i++;
            return item;
```

Queue

ResizingArrayQueue.java

```
        }
    }

    public static void main(String[] args) {
        ResizingArrayQueue<String> queue = new ResizingArrayQueue<String>();
        while (!StdIn.isEmpty()) {
            String item = StdIn.readString();
            if (!item.equals("-")) {
                queue.enqueue(item);
            } else if (!queue.isEmpty()) {
                StdOut.print(queue.dequeue() + " ");
            }
        }
        StdOut.println();
        StdOut.println(queue.size() + " items left in the queue");
        StdOut.println(queue);
    }
}
```

Queue

Operation	$T(n)$
`ResizingArrayQueue()`	1
`boolean isEmpty()`	1
`int size()`	1
`void enqueue(Item item)`	1 (amortized)
`Item peek()`	1
`Item dequeue()`	1 (amortized)
`Iterator<Item> iterator()`	1
`String toString()`	n

Stack

Stack

A `Stack` is an iterable collection that stores generic items in last-in-first-out (LIFO) order

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dsa.Stack<Item> extends java.lang.Iterable<Item>

`boolean isEmpty()`	returns `true` if this stack is empty, and `false` otherwise
`int size()`	returns the number of items in this stack
`void push(Item item)`	adds `item` to the top of this stack
`Item peek()`	returns the item at the top of this stack
`Item pop()`	removes and returns the item at the top of this stack
`Iterator<Item> iterator()`	returns an iterator to iterate over the items in this stack in LIFO order

Stack

Stack

Program: `Reverse.java`

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- Standard input: a sequence of strings

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```
>_ ~/workspace/dsaj/programs
$ _
```

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- Standard output: the strings in reverse order

```
>_ ~/workspace/dsaj/programs
$ java Reverse
```

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-
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```
>_ ~/workspace/dsaj/programs

$ java Reverse
b o l t o n
```

Program: `Reverse.java`

- Standard input: a sequence of strings
- Standard output: the strings in reverse order

```
>_ ~/workspace/dsaj/programs

$ java Reverse
b o l t o n
-
```

Program: `Reverse.java`

- Standard input: a sequence of strings
- Standard output: the strings in reverse order

```
>_ ~/workspace/dsaj/programs

$ java Reverse
b o l t o n
<ctrl-d>
```

Program: `Reverse.java`

- Standard input: a sequence of strings
- Standard output: the strings in reverse order

```
>_ ~/workspace/dsaj/programs

$ java Reverse
b o l t o n
<ctrl-d>
n o t l o b
$ _
```

Stack

Stack

Reverse.java

```java
import dsa.LinkedStack;

import stdlib.StdIn;
import stdlib.StdOut;

public class Reverse {
    public static void main(String[] args) {
        LinkedStack<String> stack = new LinkedStack<String>();
        while (!StdIn.isEmpty()) {
            String s = StdIn.readString();
            stack.push(s);
        }
        for (String s : stack) {
            StdOut.print(s + " ");
        }
        StdOut.println();
    }
}
```

Stack

Stack

dsa.LinkedStack<Item> implements dsa.Stack<Item>	
`LinkedStack()`	constructs an empty stack
`String toString()`	returns a string representation of this stack

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Instance variables:

- Reference to the top of the stack: `Node first`

- Number of items in the stack: `int n`

Stack

Stack

LinkedStack.java

```
package dsa;

import java.util.Iterator;
import java.util.NoSuchElementException;

import stdlib.StdIn;
import stdlib.StdOut;

public class LinkedStack<Item> implements Stack<Item> {
    private Node first;
    private int n;

    public LinkedStack() {
        first = null;
        n = 0;
    }

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

    public int size() {
        return n;
    }

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

    public Item peek() {
        if (isEmpty()) {
```

Stack

LinkedStack.java

```
            throw new NoSuchElementException("Stack is empty");
        }
        return first.item;
    }

    public Item pop() {
        if (isEmpty()) {
            throw new NoSuchElementException("Stack is empty");
        }
        Item item = first.item;
        first = first.next;
        n--;
        return item;
    }

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

    public String toString() {
        StringBuilder sb = new StringBuilder();
        for (Item item : this) {
            sb.append(item);
            sb.append(", ");
        }
        return n > 0 ? "[" + sb.substring(0, sb.length() - 2) + "]" : "[]";
    }

    private class Node {
        private Item item;
        private Node next;
    }

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

Stack

LinkedStack.java

```
        public ListIterator() {
            current = first;
        }

        public boolean hasNext() {
            return current != null;
        }

        public Item next() {
            if (!hasNext()) {
                throw new NoSuchElementException("Iterator is empty");
            }
            Item item = current.item;
            current = current.next;
            return item;
        }
    }

    public static void main(String[] args) {
        LinkedStack<String> stack = new LinkedStack<String>();
        while (!StdIn.isEmpty()) {
            String item = StdIn.readString();
            if (!item.equals("-")) {
                stack.push(item);
            } else if (!stack.isEmpty()) {
                StdOut.print(stack.pop() + " ");
            }
        }
        StdOut.println();
        StdOut.println(stack.size() + " items left in the stack");
        StdOut.println(stack);
    }
}
```

Stack

Operation	$T(n)$
`LinkedStack()`	1
`boolean isEmpty()`	1
`int size()`	1
`void push(Item item)`	1
`Item peek()`	1
`Item pop()`	1
`Iterator<Item> iterator()`	1
`String toString()`	n

Stack

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dsa.ResizingArrayStack<Item> implements dsa.Stack<Item>	
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- Array of items in the stack: `Item a[]`

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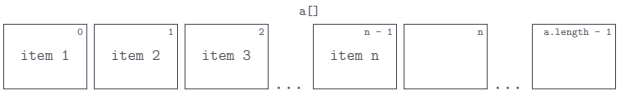

- Number of items in the stack: `int n`

Stack

Stack

ResizingArrayStack.java

```java
package dsa;

import java.util.Iterator;
import java.util.NoSuchElementException;

import stdlib.StdIn;
import stdlib.StdOut;

public class ResizingArrayStack<Item> implements Stack<Item> {
    private Item[] a;
    private int n;

    public ResizingArrayStack() {
        a = (Item[]) new Object[2];
        n = 0;
    }

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

    public int size() {
        return n;
    }

    public void push(Item item) {
        if (n == a.length) {
            resize(2 * a.length);
        }
        a[n++] = item;
    }

    public Item peek() {
        if (isEmpty()) {
            throw new NoSuchElementException("Stack is empty");
```

Stack

ResizingArrayStack.java

```
        }
        return a[n - 1];
    }

    public Item pop() {
        if (isEmpty()) {
            throw new NoSuchElementException("Stack is empty");
        }
        Item item = a[n - 1];
        a[n - 1] = null;
        n--;
        if (n > 0 && n == a.length / 4) {
            resize(a.length / 2);
        }
        return item;
    }

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

    public String toString() {
        StringBuilder sb = new StringBuilder();
        for (Item item : this) {
            sb.append(item);
            sb.append(", ");
        }
        return n > 0 ? "[" + sb.substring(0, sb.length() - 2) + "]" : "[]";
    }

    private void resize(int capacity) {
        Item[] temp = (Item[]) new Object[capacity];
        for (int i = 0; i < n; i++) {
            temp[i] = a[i];
        }
```

ResizingArrayStack.java

```
        a = temp;
    }

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

        public ReverseArrayIterator() {
            i = n - 1;
        }

        public boolean hasNext() {
            return i >= 0;
        }

        public Item next() {
            if (!hasNext()) {
                throw new NoSuchElementException("Iterator is empty");
            }
            return a[i--];
        }
    }

    public static void main(String[] args) {
        ResizingArrayStack<String> stack = new ResizingArrayStack<String>();
        while (!StdIn.isEmpty()) {
            String item = StdIn.readString();
            if (!item.equals("-")) {
                stack.push(item);
            } else if (!stack.isEmpty()) {
                StdOut.print(stack.pop() + " ");
            }
        }
        StdOut.println();
        StdOut.println(stack.size() + " items left in the stack");
        StdOut.println(stack);
```

Stack

ResizingArrayStack.java

```
    }
}
```

Stack

Operation	$T(n)$
`ResizingArrayStack()`	1
`boolean isEmpty()`	1
`int size()`	1
`void push(Item item)`	1 (amortized)
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`Iterator<Item> iterator()`	1
`String toString()`	n