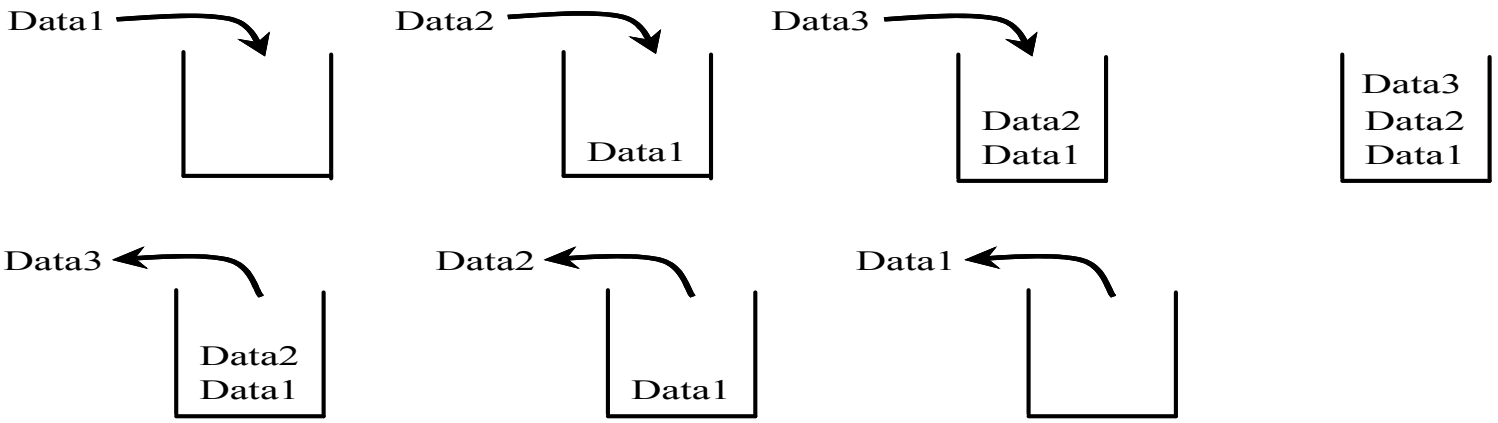
Stack

WIA1002/WIB1002 :
Data Structure

Stack

- A stack can be viewed as a special type of **list**, where the elements are accessed, inserted, and deleted only from the end, called the top, of the stack.



- It is a data structure that holds data in a last-in, first-out (LIFO) fashion.
- Stack - an adapter which defines a **restricted set of *list* methods**.

Methods in stack

- Pop() = removes item on top

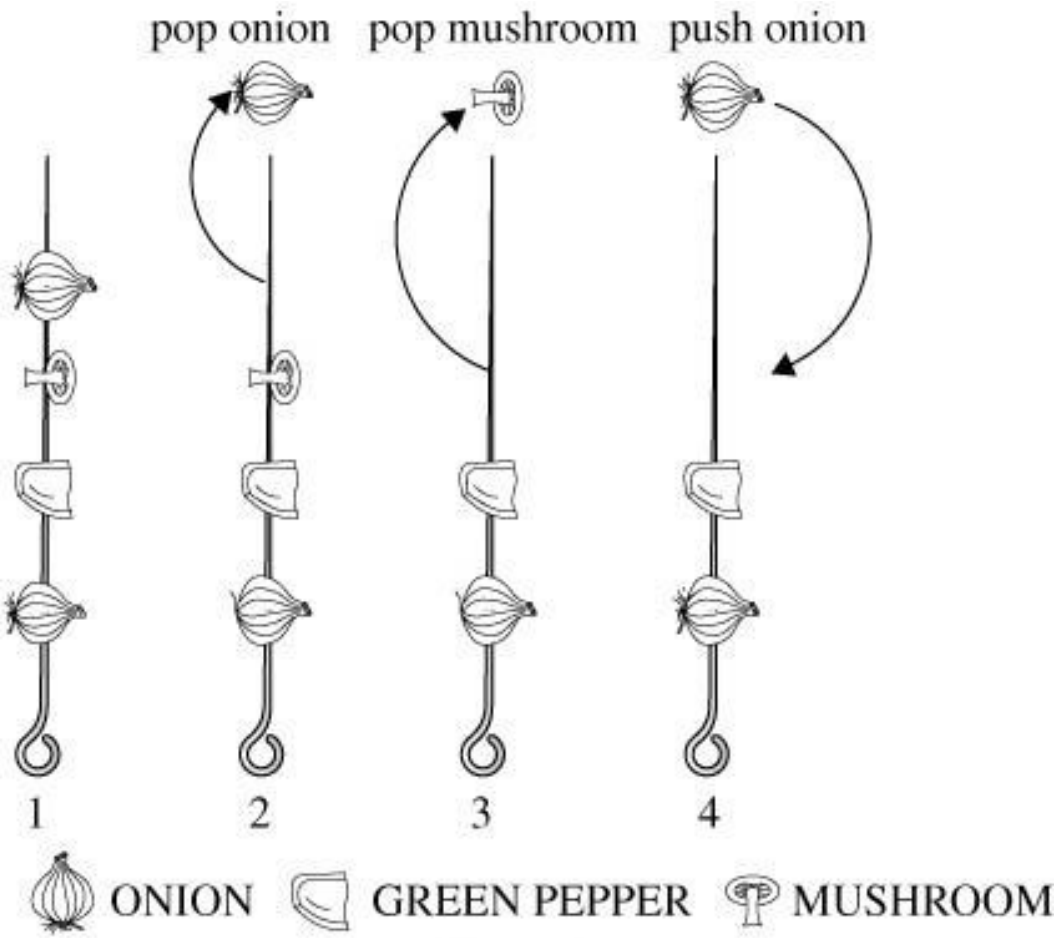
removeLast();

- Push() = adds item at the top

addLast();

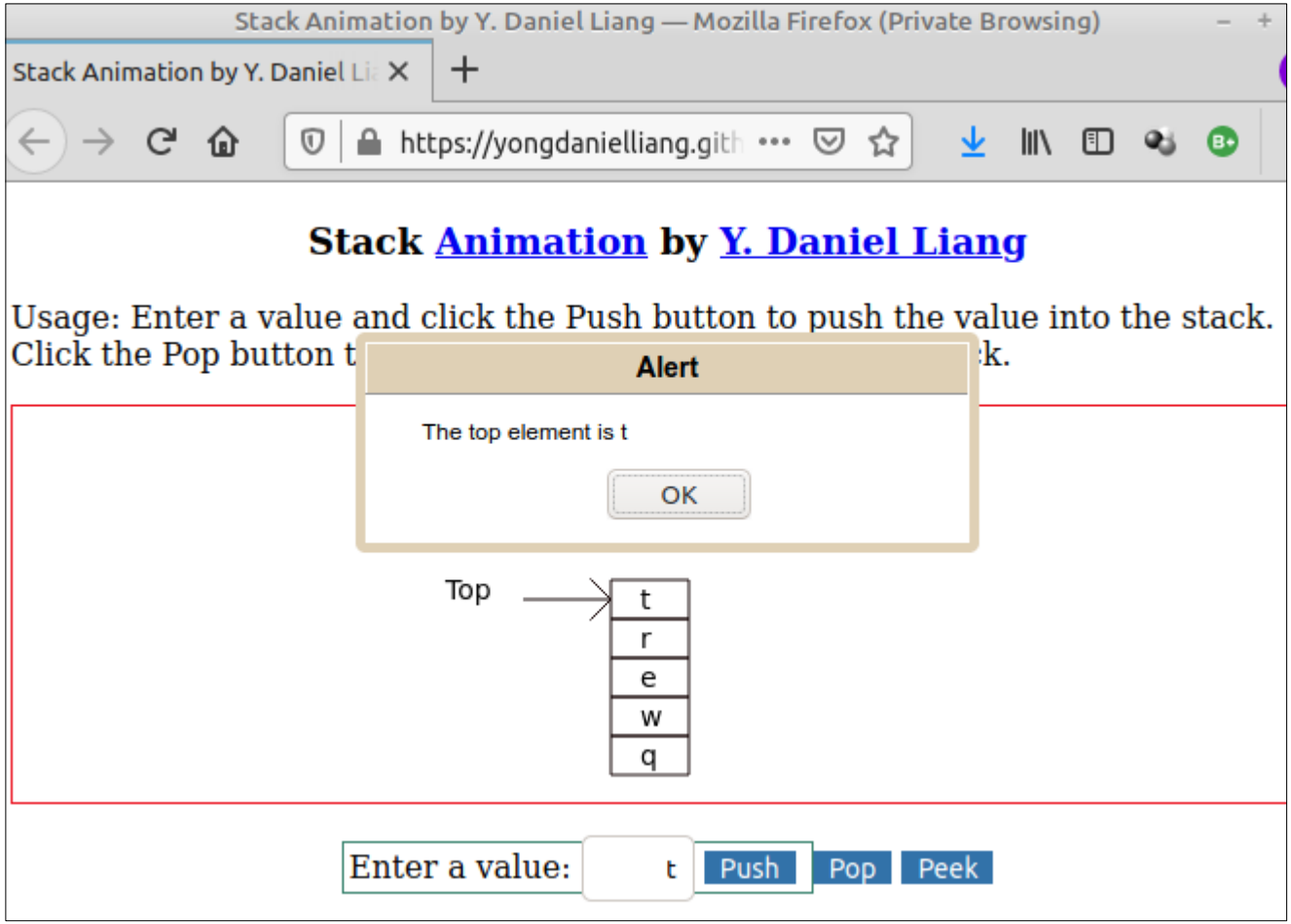
- Peek() or Top() = access value on top

getLast();



vegetable stack

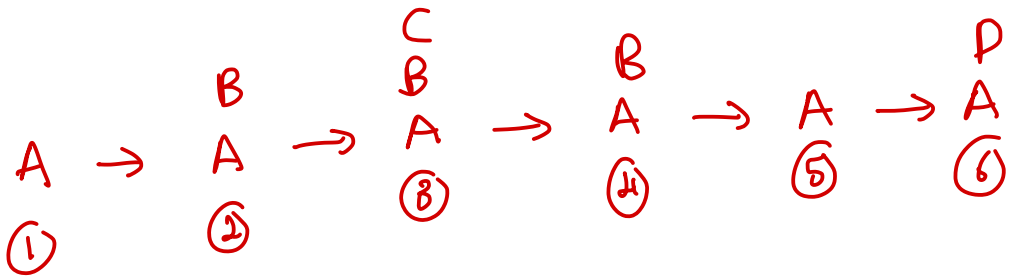
Stack Animation



https://yongdanielliang.github.io/animation/web/Stack.html

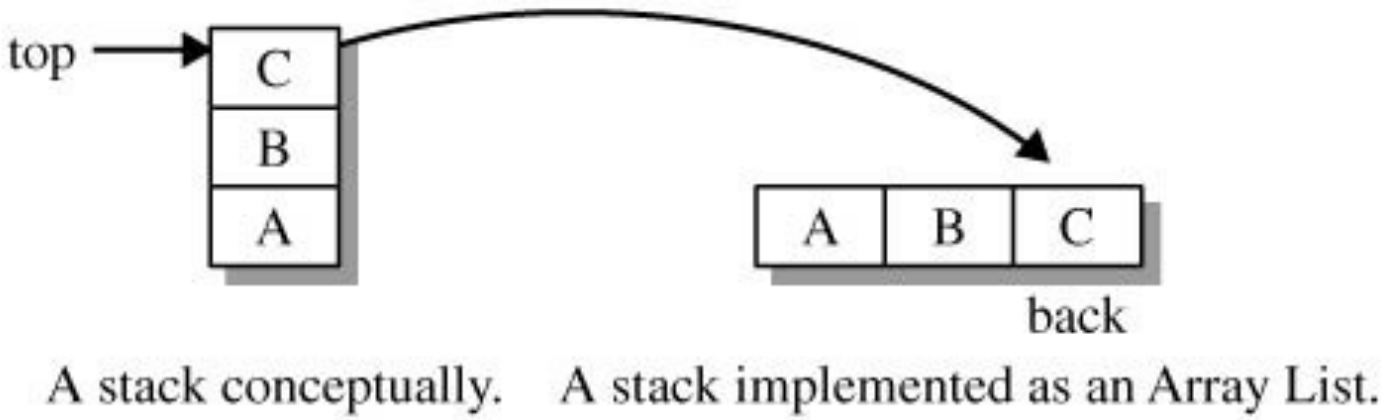
Check Point

- Draw a stack for the following :
  1. Push A
  2. Push B
  3. Push C
  4. Pop C
  5. Pop B
  6. Push D

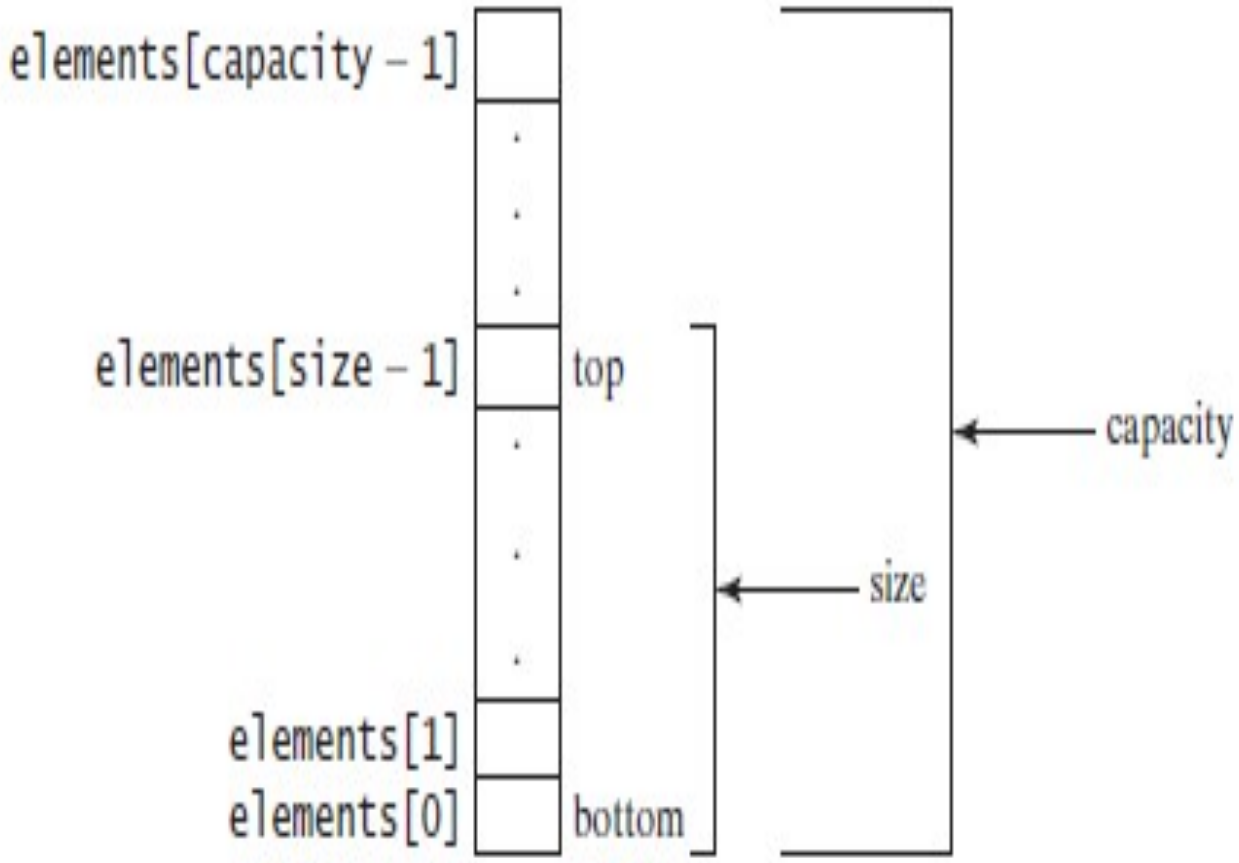


Implementing Stack

- using an array list to implement a stack is more efficient than a linked list since the insertion and deletion operations on a stack are made only at the end of the stack.



Using Array list as the storage structure for Stack


elements[capacity – 1]
elements[size – 1]
top
capacity
size
elements[1]
elements[0]
bottom

Implementing Stack

- two ways to design the stack class using ArrayList:
  - Using inheritance: You can define a stack (GenericStack) class by extending ArrayList class
  - Using composition: You can define an array list as a data field in the stack (GenericStack) class

it is a linkedlist/arraylist

it has a linkedlist/arraylist

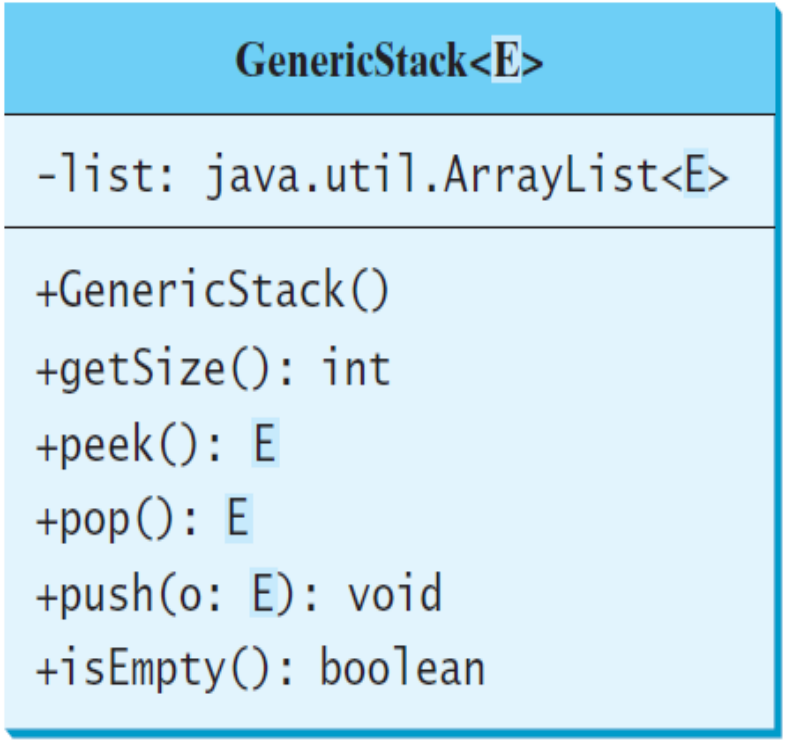
(a) Using inheritance

(b) Using composition

GenericStack

GenericStack class using an ArrayList & composition approach.

HAS A



-list: java.util.ArrayList<E>	An array list to store elements.
+GenericStack()	Creates an empty stack.
+getSize(): int	Returns the number of elements in this stack.
+peek(): E	Returns the top element in this stack.
+pop(): E	Returns and removes the top element in this stack.
+push(o: E): void	Adds a new element to the top of this stack.
+isEmpty(): boolean	Returns true if the stack is empty.

* The peek() and pop() require that the stack contains at least one element.

GenericStack

The peek() and pop() require that the stack contains at least one element.
If condition is not satisfied, the methods should throw an EmptyStackException.

```
if(isEmpty()) {
      throw new EmptyStackException();
}
```

GenericStack class

```
1  public class GenericStack<E> {
2    private java.util.ArrayList<E> list = new java.util.ArrayList<>();
3
4    public int getSize() {
5      return list.size();   }
6
7    public E peek() {
8      return list.get(getSize() - 1);   }
9
10   public void push(E o) {
11     list.add(o);   }
12
13   public E pop() {
14     E o = list.get(getSize() - 1);
15     list.remove(getSize() - 1);
16     return o;
17   }
18
19   public boolean isEmpty() {
20     return list.isEmpty();   }
21
22   @Override
23   public String toString() {
24     return "stack: " + list.toString();
25   }
26 }
```

→ check top element

→ add element at stack

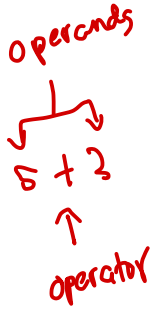
→ remove top element

Test GenericStack

```java
public class TestGenericStack {
  public static void main(String[] args) {
    // Create a stack
    GenericStack<String> stack = new GenericStack<>();

    // Add elements to the stack
    stack.push("Tom"); // Push it to the stack
    System.out.println("(1) " + stack);

    stack.push("Susan"); // Push it to the the stack
    System.out.println("(2) " + stack);

    stack.push("Kim"); // Push it to the stack
    stack.push("Michael"); // Push it to the stack
    System.out.println("(3) " + stack);

    // Remove elements from the stack
    System.out.println("(4) " + stack.pop());
    System.out.println("(5) " + stack.pop());
    System.out.println("(6) " + stack);
  }
}
```

```
(1) stack: [Tom]
(2) stack: [Tom, Susan]
(3) stack: [Tom, Susan, Kim, Michael]
(4) Michael
(5) Kim
(6) stack: [Tom, Susan]
```

Postfix Expressions



- Can be implemented using stacks
- Also called Reverse Polish Notation, is an alternative way of representing mathematics expressions
- In a postfix evaluation format for an arithmetic expression, an operator comes after its operands.
- Advantages:
  - Do not need precedence rules
  - Do not need parentheses
  - Reduce computer memory access

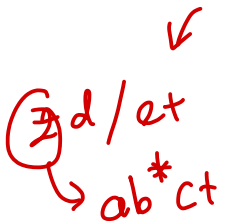
Postfix Expressions

- If there are multiple operations, operators are given immediately after their second operands
- Examples:
- a + b * c RPN: a b c * +

  Operator * has higher precedence than +.
- (a + b) * c RPN: a b + c *

  The parenthesis creates subexpression a b +
- (a*b + c) / d + e RPN: a b * c + d/ e +

  The subexpression is a b * c +. Division is the next operator followed by addition.

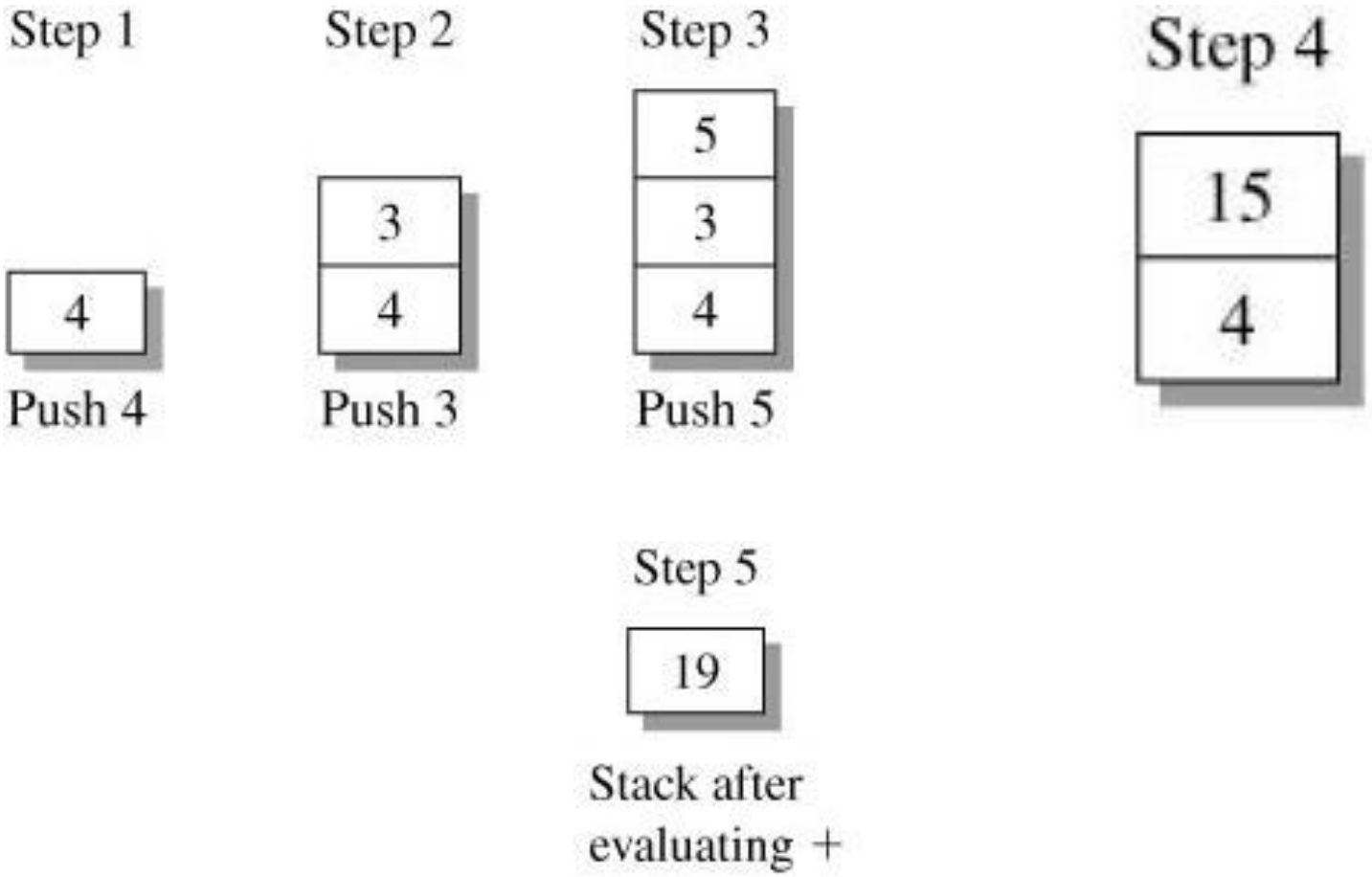


Postfix Evaluation

- To evaluate a postfix expression, execute the following steps until the end of the expression.
  1. If recognize an operand, push it on the operand stack.
  2. If recognize an operator, perform the following:
     - pop an operand as y
     - pop another operand as x
     - Perform (x operator y)
  3. Repeat step 1 and 2 until the end. Pop the step for final result.

Postfix Evaluation (continued)

- Example: evaluate "4 3 5 * +"

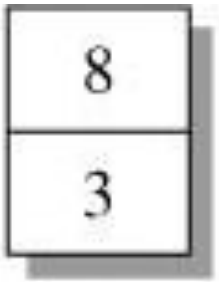


Postfix Evaluation

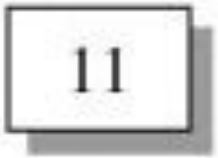
- At each step in the postfix evaluation algorithm, the state of the stack allows us to identify whether an error occurs and the cause of the error.

Postfix Evaluation - too many operators

- In the expression 3 8 + * 9 the binary operator * is missing a second operand. Identify this error when reading * with the stack containing only one element.



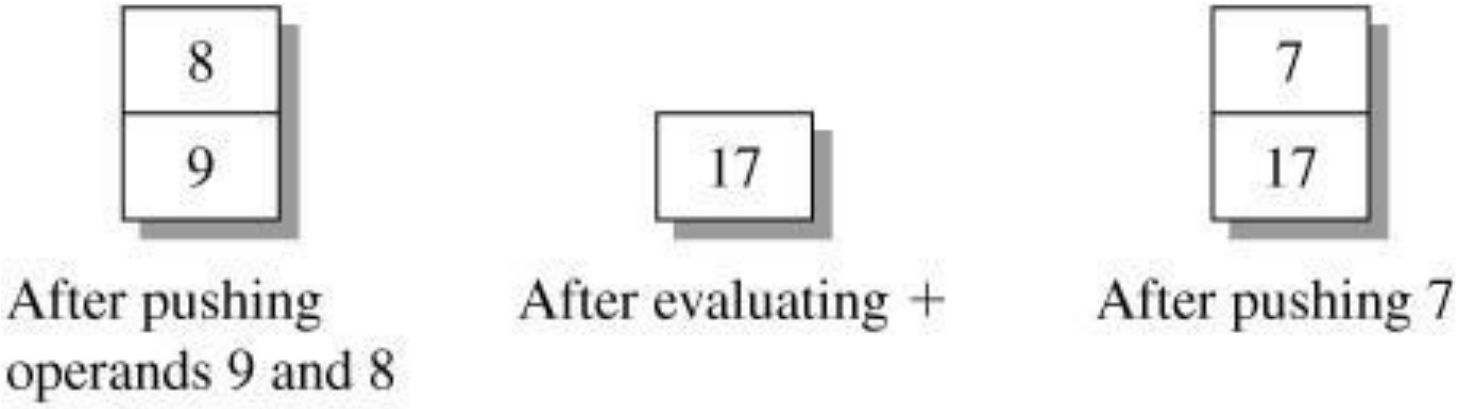
After pushing operands 3 and 8



After evaluating +

Postfix Evaluation- too many operands

- An expression may contain too many operands. Identify this error after processing the entire expression. At the conclusion of the process, the stack contains more than one element. Example: 9 8 + 7



PostfixEvaluation.java

```
 1  public class PostfixEvaluation
 2  {
 3      public static void main(String[] args)
 4      {
 5          System.out.println("Testing PostfixEvaluation:\n");
 6          System.out.println("2 3 + 4 * 5 - : "
 7           + evaluatePostfix("2 3 + 4 * 5 -") + "\n");
 8          System.out.println("2 3 * 4 2 - / 5 6 * + : "
 9           + evaluatePostfix("2 3 * 4 2 - / 5 6 * +")
10           + "\n");
11          System.out.println("2 4 - 3 ^ 5 + : "
12           + evaluatePostfix("2 4 - 3 ^ 5 +")
13           + "\n");
14          System.out.println("\n\nDone.");
15      }  // end main
16
```

```
Testing PostfixEvaluation:

2 3 + 4 * 5 - : 15.0

2 3 * 4 2 - / 5 6 * + : 33.0

2 4 - 3 ^ 5 + : -3.0



Done.
```

PostfixEvaluation.java

```
17    /** Evaluates a postfix expression.
18        @param postfix  a string that is a valid postfix expression.
19        @return  the value of the postfix expression. */
20    public static double evaluatePostfix(String postfix)   {
21       GenericStack<Double> valueStack = new GenericStack<>();
22       String[] tokens = postfix.split(" ");
23       for (String token: tokens)
24       {
25          if(isNumeric(token))
26          {
27             valueStack.push(Double.valueOf(token));
28          }
29          else if (token.equals("+") || token.equals("-") || token.equals("*")
30                  || token.equals("/") || token.equals("^"))
31          {
32                Double operandTwo = valueStack.pop();
33                Double operandOne = valueStack.pop();
34                Double result = compute(operandOne, operandTwo, token);
35                valueStack.push(result);
36          }
37       } // end for
38
39       return (valueStack.peek());
40    } // end evaluatePostfix
```

PostfixEvaluation.java

```
41
42      public static boolean isNumeric(String str)
43      {
44           try
45           {
46                double d = Double.parseDouble(str);
47           }
48           catch(NumberFormatException nfe)
49           {
50                return false;
51           }
52           return true;
53       }
54
```

PostfixEvaluation.java

```
55      private static Double compute(Double operandOne, Double operandTwo, String operator)
56      {
57         double result;
58
59         switch (operator)
60         {
61            case "+":
62               result = operandOne + operandTwo;
63               break;
64
65            case "-":
66               result = operandOne - operandTwo;
67               break;
68
69            case "*":
70               result = operandOne * operandTwo;
71                break;
72
73            case "/":
74               result = operandOne / operandTwo;
75               break;
76
77            case "^":
78               result = Math.pow(operandOne, operandTwo);
79               break;
80
81            default:    // Unexpected character
82               result = 0;
83               break;
84         } // end switch
85
86         return result;
87      } // end compute
```

Reference

- Chapter 19 and 24, Liang, Introduction to Java Programming, 10th Edition, Global Edition, Pearson, 2015
- Chapter 5, Carrano, Data Structures and Abstractions with Java, 3rd Edition, 2012