Data Structures

Stacks

CS284

Structure of this week's classes

Stacks

Applications

Implementing a Stack

Stack

- A stack is one of the most commonly used data structures in computer science
- A stack can be compared to a Pez dispenser
  - Only the top item can be accessed
  - You can extract only one item at a time
- The top element in the stack is the one added to the stack most recently
- The stack's storage policy is Last-In, First-Out, or LIFO

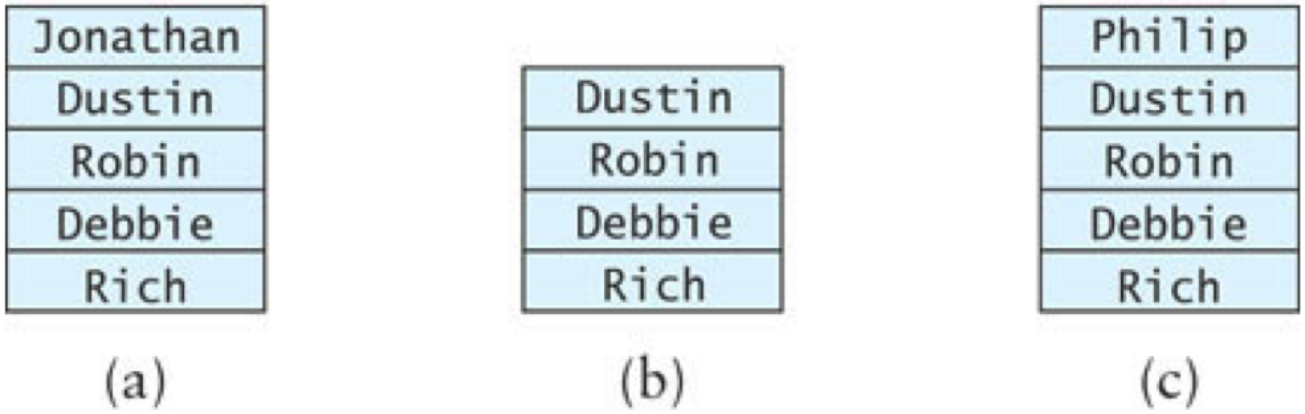
Operations on Stacks

- Only the top element of a stack is visible; therefore the number of operations performed by a stack are few
- We need the ability to
  - test for an empty stack (`boolean empty()`)
  - inspect the top element (`E peek()`)
  - retrieve the top element (`E pop()`)
  - put a new element on the stack (`E push(E obj)`)

StackInt<E> interface

```
public interface StackInt<E> {

    E push(E obj);

    E peek();

    E pop();

    boolean empty();
}
```

An example: a stack of strings `java.util.List` interface



- "Rich" is oldest element on stack; "Jonathan" is youngest (Figure a)
- `String last = names.peek();`
  stores a reference to "Jonathan" in last
- `String temp = names.pop();`
  removes "Jonathan" and stores a reference to it in temp (Figure b)
- `names.push("Philip");`
  pushes "Philip" onto the stack (Figure c)

Stacks

Applications

Implementing a Stack

Finding Palindromes

- Palindrome: a string that reads identically in either direction, letter by letter
  - "kayak"
  - "I saw I was I"
  - "Able was I ere I saw Elba"
  - "Level, madam, level"
- We ignore case and whitespace
- Problem: Write a program that reads a string and determines whether it is a palindrome

`PalindromeChecker` class

PalindromeChecker
private String inputString private Stack<Character> charStack
public PalindromeChecker(String str) // Stores str and pushes onto stack private void fillStack() private String buildReverse() public boolean isPalindrome()

`PalindromeChecker` class

```
import java.util.*;

public class PalindromeChecker {
  private String inputString;
  private Stack<Character> charStack = new Stack<Character>();

 public PalindromeChecker(String str) {
   inputString = str;
   fillStack();
 }
 ...
}
```

String to Stack

```
private void fillStack() {
  for(int i = 0; i < inputString.length(); i++) {
    if (inputString.charAt(i) != ' ')
        charStack.push(inputString.charAt(i));
  }
}
```

Stack to String

```
private String buildReverse(){
  StringBuilder result = new StringBuilder();
  while(!charStack.empty()) {
    result.append(charStack.pop());
  }
  return result.toString();
}
```

Compare original string with reversed one

```
public boolean isPalindrome() {
   return inputString.equalsIgnoreCase(buildReverse());
}
```

Testing

We can test this class using the following inputs:

- a single character (always a palindrome)
- multiple characters in a word
- multiple words
- different cases
- even-length strings
- odd-length strings
- the empty string (considered a palindrome)

Balanced Parenthesis

- When analyzing arithmetic expressions, it is important to determine whether an expression is balanced with respect to parentheses

$$(a + b * (c/(d - e))) + (d/e)$$

- The problem is further complicated if braces or brackets are used in conjunction with parentheses
- The solution is to use stacks!

Principal operations we shall implement

```
public static boolean isBalanced(String expression)
```

- Returns true if the expression is balanced w.r.t. parenthesis and false otherwise

```
private static boolean isOpen(char ch)
```

- Returns true if ch is an opening parenthesis

```
private static boolean isClose(char ch)
```

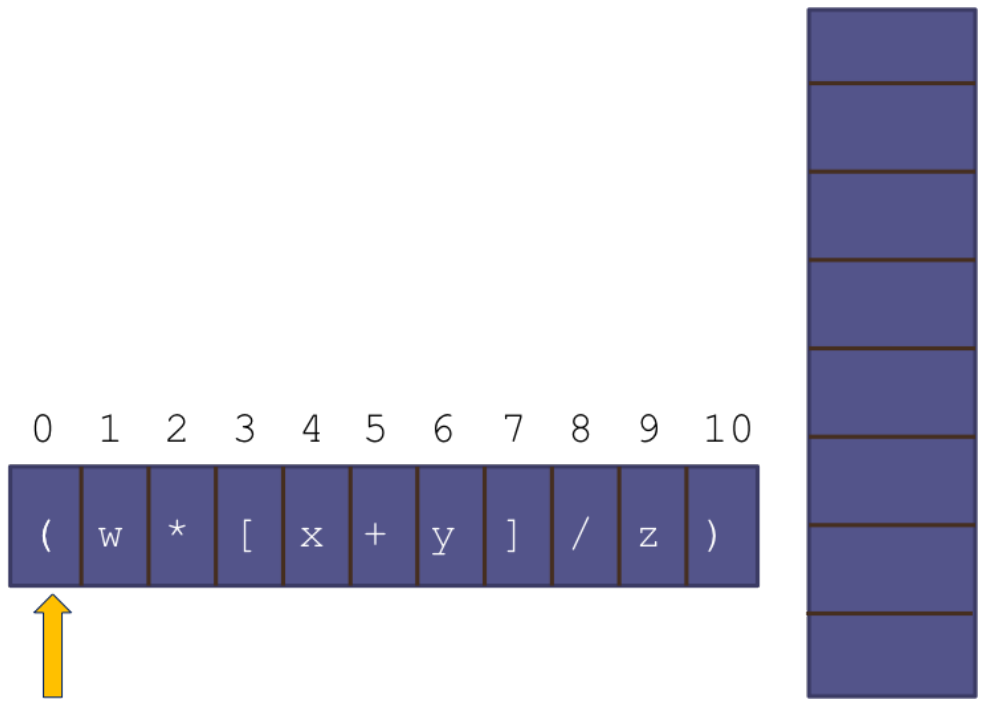
- Returns true if ch is a closing parenthesis

The algorithm for `isBalanced`

```
Create an empty stack of characters
balanced = true
Set index to 0
while (balanced and index < expression's length) {
  Get the next character in the data string
  if (the next character is an opening parenthesis)
     { Push it onto the stack }
  else if (the next character is a closing parenthesis)
     { Pop the top of the stack
       If (the stack was empty or its top does not match the c
         { balanced = false }
     }
  Increment index
}
Return true if balanced is true and the stack is empty
```

A Sample Execution

$$(w * [x + y])/z)$$



ParenChecker Class

```
public class ParenChecker {

    private static final String OPEN = "([{";
    private static final String CLOSE = ")]}";

    public static boolean isBalanced(String expression) {
    ...
    }

    private static boolean isOpen(char ch) {
        return OPEN.indexOf(ch) > -1;
    }

    private static boolean isClose(char ch) {
        return CLOSE.indexOf(ch) > -1;
    }
```

ParenChecker Class (cont.)

```
public static boolean isBalanced(String expression) {
    Stack<Character> s = new Stack<Character>();
    boolean balanced = true;
    try {
      int index = 0;
      while (balanced && index < expression.length()) {
            char nextCh = expression.charAt(index);
            if (isOpen(nextCh)) {
                s.push(nextCh);
            } else if (isClose(nextCh)) {
                 char topCh = s.pop();
                 balanced = OPEN.indexOf(topCh) == CLOSE.index
            }
            index++;
            }
     } catch (EmptyStackException ex) {
        balanced = false;
     }
    return (balanced && s.empty());
}
```

Stacks

Applications

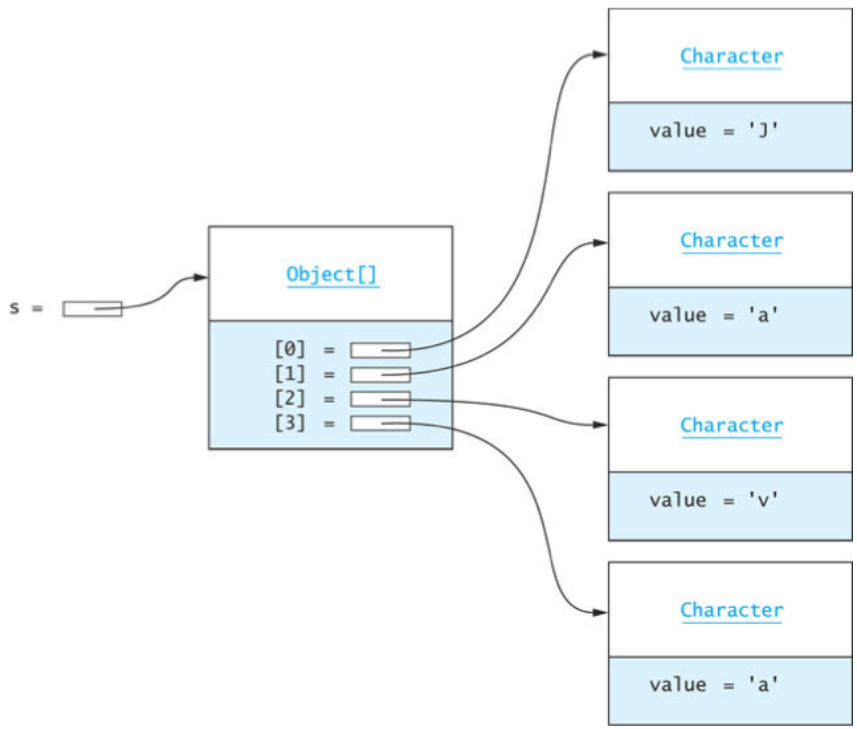
Implementing a Stack

A Stack as an Extension of Vector

- Java API includes Stack class as part of package `java.util`:

```
public class Stack<E> extends Vector<E>
```

- Elements of a Vector can be accessed using an integer index and the size can grow or shrink as needed to accommodate the insertion and removal of elements



Implementing a Stack as an Extension of Vector (cont.)

We can use Vector's add method to implement push:

```
public E push(obj E) {
  add(obj);
  return obj;
}
```

`pop` can be coded as

```
public E pop throws EmptyStackException {
  try {
    return remove(size() - 1);
  } catch (ArrayIndexOutOfBoundsException ex) {
    throw new EmptyStackException();
  }
}
```

Disadvantage of Stack as Subclass of Vector

- Because a Stack is a Vector, all of Vector operations can be applied to a Stack (such as searches and access by index)
- But, since only the top element of a stack should be accessible, this violates the principle of information hiding

```
Stack<Integer> s = new Stack<Integer>();
s.push(3);
s.push(4);
System.out.println(s.elementAt(0)); // prints 3
```

Implementing a Stack with a List Component

- Alternative: write a class, `ListStack`, that has a `List` component (in the example below, `theData`)

```
public class ListStack<E> implements StackInt<E>{
    private List<E> theData;
    public ListStack() {
        theData = new ArrayList<E>();
    }
...
}
```

Implementing a Stack with a List Component

- We can use `ArrayList`, `Vector`, or the `LinkedList` classes, as all implement the List interface.
- The `push` method, for example, can be coded as

```
public E push(E obj) {
  theData.add(obj);
  return obj;
}
```

- A class which adapts methods of another class by giving different names to essentially the same methods (push instead of add) is called an adapter class
- Writing methods in this way is called method delegation

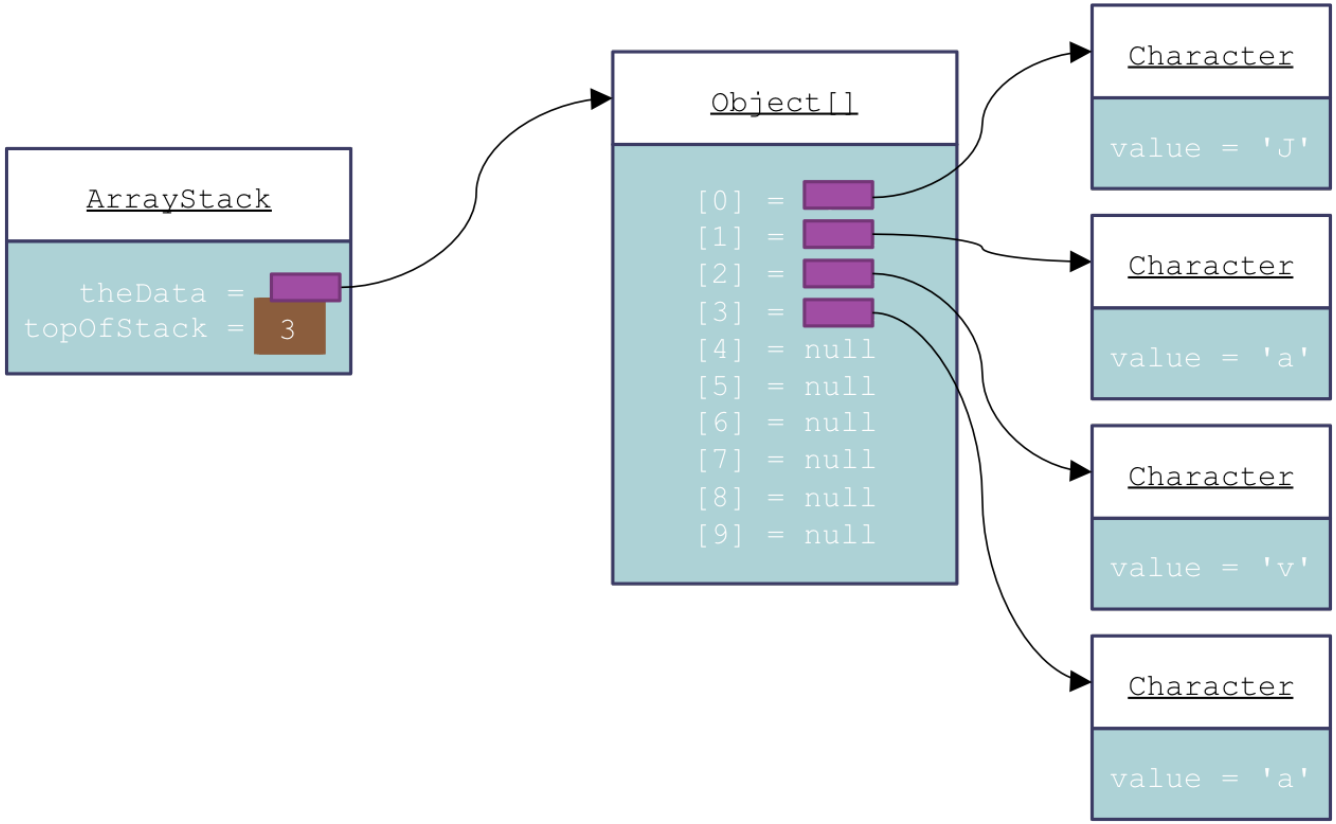
Implementing a Stack Using an Array

If we implement a stack as an array, we would need...

```
public class ArrayStack<E> implements StackInt<E> {
  private E[] theData;
  int topOfStack = -1;
  private static final int INITIAL_CAPACITY = 10;

  @SuppressWarnings("unchecked")
  public ArrayStack() {
    theData = (E[])new Object[INITIAL_CAPACITY];
  }
```

- Note: The `SuppressWarnings` annotation is just to avoid the compiler from warning: "Type safety: Unchecked cast from `Object[]` to `E[]`"

Implementing a Stack Using an Array

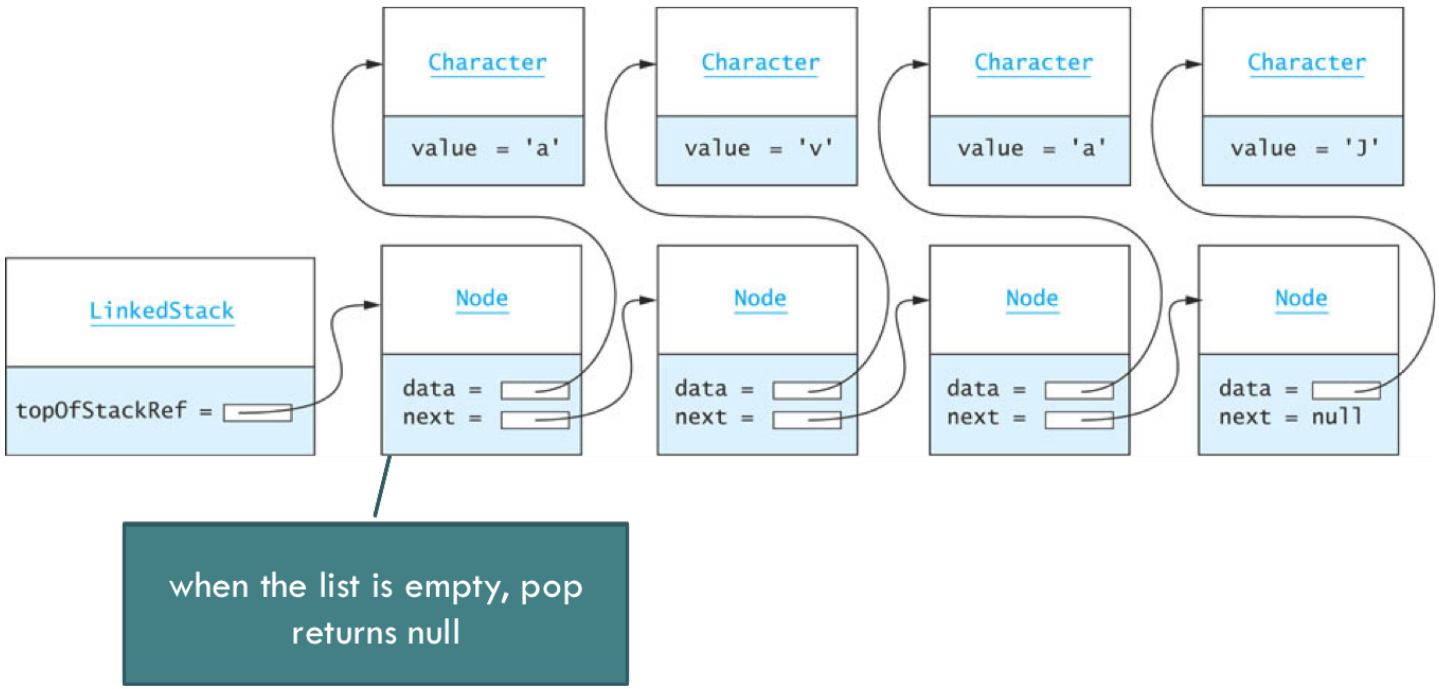



```
public E push(E obj) {
  if (topOfStack == theData.length-1) { reallocate(); }
  topOfStack++;
  theData[topOfStack] = obj;
  return obj;
}
```

Implementing a Stack Using an Array

```
public E pop() {
  if (empty()) {
    throw new EmptyStackException();
  }
  return theData[topOfStack--];
}
```

Implementing a Stack as a Linked List



Implementing a Stack as a Linked List

```
import java.util.EmptyStackException;

public class LinkedStack<E> implements StackInt<E> {

  private static class Node<E> {
    private E data;
    private Node next;
```

Implementing a Stack as a Linked List

```
// Constructors
  private Node(E dataItem) {
    data = dataItem;
    next = null;
  }

  private Node(E dataItem, Node<E> nodeRef) {
    data = dataItem;
    next = nodeRef;
  }
} //end class Node
```

Implementing a Stack as a Linked List

```
// Data Fields
  /** The reference to the first stack node. */
  private Node<E> topOfStackRef = null;

  /** Insert a new item on top of the stack.
      post: The new item is the top item on the stack.
            All other items are one position lower.
      @param obj The item to be inserted
      @return The item that was inserted
   */
  public E push(E obj) {
    topOfStackRef = new Node<E>(obj, topOfStackRef);
    return obj;
  }
```

Implementing a Stack as a Linked List

```
/** Remove and return the top item on the stack.
      pre: The stack is not empty.
      post: The top item on the stack has been
        removed and the stack is one item smaller.
      @return The top item on the stack
      @throws EmptyStackException if stack is empty
   */
  public E pop() {
    if (empty()) {
      throw new EmptyStackException();
    }
    else {
      E result = topOfStackRef.data;
      topOfStackRef = topOfStackRef.next;
      return result;
    }
  }
```

Implementing a Stack as a Linked List

```
/** Return the top item on the stack.
     pre: The stack is not empty.
     post: The stack remains unchanged.
     @return The top item on the stack
     @throws EmptyStackException if stack is empty
  */
 public E peek() {
   if (empty()) {
     throw new EmptyStackException();
   }
   else {
     return topOfStackRef.data;
   }
 }
```

Implementing a Stack as a Linked List

```
 /** See whether the stack is empty.
      @return true if the stack is empty
   */
  public boolean empty() {
    return topOfStackRef == null;
  }
}
```

Comparison of Implementations

- Extending a `Vector` (as is done by Java) is a poor choice for stack implementation, since all `Vector` methods are accessible
- The easiest implementation uses a `List` component (`ArrayList` is the simplest) for storing data
  - An underlying array requires reallocation of space when the array becomes full, and
  - An underlying linked data structure requires allocating storage for links
  - As all insertions and deletions occur at one end, they are constant time, $\mathcal{O}(1)$, regardless of the type of implementation used

More Applications

- Evaluating postfix expressions
- Converting postfix to infix expressions