Topic 15
Implementing and Using Stacks

"stack n.
The set of things a person has to do in the future. "I haven't done it yet because every time I pop my stack something new gets pushed." If you are interrupted several times in the middle of a conversation, "My stack overflowed" means "I forget what we were talking about."

-The Hacker's Dictionary

Friedrich L. Bauer
German computer scientist who proposed "stack method of expression evaluation" in 1955.

Stack Overflow

Sharper Tools

Lists

Stacks

Stacks

- Access is allowed only at one point of the structure, normally termed the *top* of the stack
  - access to the most recently added item only
- Operations are limited:
  - push (add item to stack)
  - pop (remove top item from stack)
  - top (get top item without removing it)
  - clear
  - isEmpty
  - size?
- Described as a "Last In First Out" (LIFO) data structure

Stack Operations

Assume a simple stack for integers.

Stack s = new Stack();

s.push(12);

s.push(4);

s.push(s.top() + 2);

s.pop()

s.push(s.top());

//what are contents of stack?

Stack Operations

Write a method to print out contents of stack in reverse order.

Common Stack Error

```
Stack s = new Stack();
// put stuff in stack
for(int i = 0; i < 5; i++)
     s.push( i );
// print out contents of stack
// while emptying it. (??)
for(int i = 0; i < s.size(); i++)
     System.out.print( s.pop() + “ “);

// What is output?
```

Attendance Question 1

- What is output of code on previous slide?

A 0 1 2 3 4

B 4 3 2 1 0

C 4 3 2

D 2 3 4

E No output due to runtime error.

Corrected Version

```
Stack s = new Stack();
// put stuff in stack
for(int i = 0; i < 5; i++)
    s.push( i );
// print out contents of stack
// while emptying it
int limit = s.size();
for(int i = 0; i < limit; i++)
    System.out.print( s.pop() + “ “);
//or
//  while( !s.isEmpty() )
//      System.out.println( s.pop() );
```

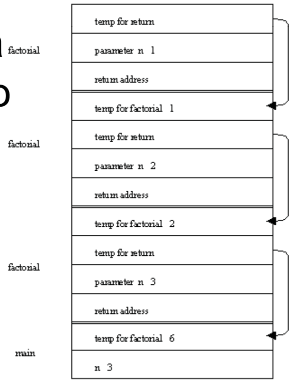
Implementing a stack

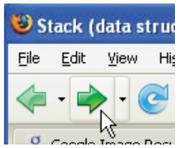
- need an underlying collection to hold the elements of the stack
- 2 basic choices
  - array (native or ArrayList)
  - linked list
- array implementation
- linked list implementation
- Some of the uses for a stack are much more interesting than the implementation of a stack

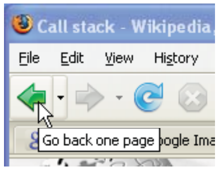
Applications of Stacks

Problems that Use Stacks

- The runtime stack used by a process (running program) to keep track of methods in progress
- Search problems
- Undo, redo, back, forward







Mathematical Calculations

What is 3 + 2 * 4?   2 * 4 + 3?   3 * 2 + 4?

The precedence of operators affects the order of operations. A mathematical expression cannot simply be evaluated left to right.

A challenge when evaluating a program.

Lexical analysis is the process of interpreting a program.

Involves Tokenization

What about 1 - 2 - 4 ^ 5 * 3 * 6 / 7 ^ 2 ^ 3

Infix and Postfix Expressions

- The way we are use to writing expressions is known as infix notation
- Postfix expression does not
- require any precedence rules
- 3 2 * 1 + is postfix of 3 * 2 + 1
- evaluate the following postfix expressions and write out a corresponding infix expression:

  2 3 2 4 * + *   1 2 3 4 ^ * +

  1 2 - 3 2 ^ 3 * 6 / +   2 5 ^ 1 -

Attendance Question 2

- What does the following postfix expression evaluate to?

  6 3 2 + *

A. 18

B. 36

C. 24

D. 11

E. 30

Evaluation of Postfix Expressions

- Easy to do with a stack
- given a proper postfix expression:
  - get the next token
  - if it is an operand push it onto the stack
  - else if it is an operator
    - pop the stack for the right hand operand
    - pop the stack for the left hand operand
    - apply the operator to the two operands
    - push the result onto the stack
  - when the expression has been exhausted the result is the top (and only element) of the stack

Infix to Postfix

- Convert the following equations from infix to postfix:

  2 ^ 3 ^ 3 + 5 * 1

  11 + 2 - 1 * 3 / 3 + 2 ^ 2 / 3

  Problems:

  Negative numbers?

  parentheses in expression

Infix to Postfix Conversion

- Requires operator precedence parsing algorithm
  - parse v. To determine the syntactic structure of a sentence or other utterance

Operands: add to expression

Close parenthesis: pop stack symbols until an open parenthesis appears

Operators:

Have an on stack and off stack precedence

Pop all stack symbols until a symbol of lower precedence appears. Then push the operator

End of input: Pop all remaining stack symbols and add to the expression

Simple Example

Infix Expression: 3 + 2 * 4

PostFix Expression:

Operator Stack:

Precedence Table

Symbol	Off Stack Precedence	On Stack Precedence
+	1	1
-	1	1
*	2	2
/	2	2
^	10	9
(	20	0

Simple Example

Infix Expression: + 2 * 4

PostFix Expression: 3

Operator Stack:

Precedence Table

Symbol	Off Stack Precedence	On Stack Precedence
+	1	1
-	1	1
*	2	2
/	2	2
^	10	9
(	20	0

Simple Example

Infix Expression: 2 * 4

PostFix Expression: 3

Operator Stack: +

Precedence Table

Symbol	Off Stack Precedence	On Stack Precedence
+	1	1
-	1	1
*	2	2
/	2	2
^	10	9
(	20	0

Simple Example

Infix Expression: * 4

PostFix Expression: 3 2

Operator Stack: +

Precedence Table

Symbol	Off Stack Precedence	On Stack Precedence
+	1	1
-	1	1
*	2	2
/	2	2
^	10	9
(	20	0

Simple Example

Infix Expression: 4

PostFix Expression: 3 2

Operator Stack: + *

Precedence Table

Symbol	Off Stack Precedence	On Stack Precedence
+	1	1
-	1	1
*	2	2
/	2	2
^	10	9
(	20	0

Simple Example

Infix Expression:

PostFix Expression: 3 2 4

Operator Stack: + *

Precedence Table

Symbol	Off Stack Precedence	On Stack Precedence
+	1	1
-	1	1
*	2	2
/	2	2
^	10	9
(	20	0

Simple Example

Infix Expression:

PostFix Expression: 3 2 4 *

Operator Stack: +

Precedence Table

Symbol	Off Stack Precedence	On Stack Precedence
+	1	1
-	1	1
*	2	2
/	2	2
^	10	9
(	20	0

Simple Example

Infix Expression:

PostFix Expression: 3 2 4 * +

Operator Stack:

Precedence Table

Symbol	Off Stack Precedence	On Stack Precedence
+	1	1
-	1	1
*	2	2
/	2	2
^	10	9
(	20	0

Example

1 - 2 ^ 3 ^ 3 - (4 + 5 * 6) * 7

Show algorithm in action on above equation

Balanced Symbol Checking

- In processing programs and working with computer languages there are many instances when symbols must be balanced
  { } , [ ] , ( )

  A stack is useful for checking symbol balance. When a closing symbol is found it must match the most recent opening symbol of the same type.

Algorithm?

Algorithm for Balanced Symbol Checking

- Make an empty stack
- read symbols until end of file
  - if the symbol is an opening symbol push it onto the stack
  - if it is a closing symbol do the following
    - if the stack is empty report an error
    - otherwise pop the stack. If the symbol popped does not match the closing symbol report an error
- At the end of the file if the stack is not empty report an error

Algorithm in practice

- list[i] = 3 * (44 - method(foo(list[2 * (i + 1) + foo(list[i - 1])) / 2 *) - list[method(list[0])];
- Complications
  - when is it not an error to have non matching symbols?
- Processing a file
  - *Tokenization*: the process of scanning an input stream. Each independent chunk is a token.
- Tokens may be made up of 1 or more characters