STACKS (6.1)

EECS 2011

Abstract Data Types (ADTs)

- An abstract data type (ADT) is an abstraction of a data structure
- An ADT specifies:
  - Data stored
  - Operations on the data
  - Error conditions associated with operations
- Example: ADT modeling a simple stock trading system
  - The data stored are buy/sell orders
  - The operations supported are
    - order buy(stock, shares, price)
    - order sell(stock, shares, price)
    - void cancel(order)
  - Error conditions:
    - Buy/sell a nonexistent stock
    - Cancel a nonexistent order

Stacks: LIFO

- Insertions and deletions follow the Last-In First-Out rule

- Example applications:
  - Undo operation in a text editor
  - History of visited web pages
  - Sequence of method calls in Java

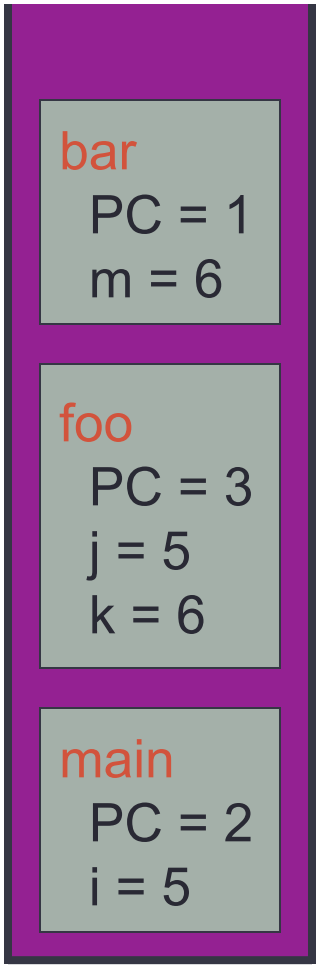
Method Stack in the JVM

- The Java Virtual Machine (JVM) keeps track of the chain of active methods with a stack
- When a method is called, the JVM pushes on the stack a frame containing
  - Local variables and return value
  - Program counter, keeping track of the statement being executed
- When a method ends, its frame is popped from the stack and control is passed to the method on top of the stack
- Allows for **recursion**

```
main() {
  int i = 5;
  foo(i);
  }

foo(int j) {
  int k;
  k = j+1;
  bar(k);
  }

bar(int m) {
  ...
  }
```



Stack ADT

- Data stored: arbitrary objects

- Operations:
  – ***push***(*e*): add *e* to the top of the stack
  – object ***pop***(): removes and returns the top element from the stack (or *null* if the stack is empty)

- Other useful operations:
  – object ***top***(): returns the top element without removing it

Error Conditions

- ***push***(*e*)
- object ***pop***()
- object ***top***()
- Exceptions are thrown when an operation cannot be executed.
- Execution of ***pop***() or ***top***() on an empty stack
  → throws *EmptyStackException.*
- Another useful operation:
  - **boolean *isEmpty***(): returns true if the stack is empty; false otherwise.

Stack Operations

- ***push***(e)
- object ***pop***()
- object ***top***()
- **boolean *isEmpty***()

- Still another useful operation:
  int *size*(): returns the number of elements in the stack

- Any others?
  Depending on implementation

Stack Interface in Java

- Java interface corresponding to our Stack ADT
- Requires the definition of class EmptyStackException
- Different from the built-in Java class java.util.Stack

```
public interface Stack {

   public int size();

   public boolean isEmpty();

   public Object top()
         throws EmptyStackException;

   public void push(Object o);

   public Object pop()
         throws EmptyStackException;
}
```

Array-based Implementation

- An array *S* of maximum size *N*
- A variable *t* that keeps track of the top element in array *S*
  - How to initialize *t*?
- Top element: *S*[*t*]
- *push*( ), *pop*( ): how to update *t*?
- Stack is empty, *isEmpty*( ): ?
- Number of elements in the stack, *size*(): ?

Class ArrayStack

```
public class ArrayStack
      implements Stack {

   // holds the stack elements
   private Object S[ ];

   // index to top element
   private int top = –1;

   // constructor
   public ArrayStack(int capacity) {
       S = new Object[capacity]);
    }
```

Pseudo-code

Algorithm ***size***():
  return (*t* + 1);

Algorithm ***isEmpty***():
  return (*t* < 0);

Algorithm ***top***():
  if (*isEmpty*())
   throw *StackEmptyException*;
  return *S*[*t*];

Algorithm ***pop***():
  if (*isEmpty*())
   throw *StackEmptyException*;
  temp = *S*[*t*];
  t = *t* – 1;
  return *temp*;

Optimization: set *S*[*t*] to *null* before decrementing *t.*

Homework: implement *pop*() without any temp variable.

Method *push*()

Algorithm ***push***(object):
  $t = t + 1$;
  $S[t]$ = object;

- The array may become full
- ***push***() method will then throw a *FullStackException*
- Limitation of array-based implementation
- One solution: extend the stack

Algorithm ***push***(object):
  if (*size*() == *N*)
    throw *FullStackException*;
  $t = t + 1$;
  $S[t]$ = object;

Array-based Stack in Java

```
public class ArrayStack
      implements Stack {

   // holds the stack elements
   private Object S[ ];

   // index to top element
   private int top = -1;

   // constructor
   public ArrayStack(int capacity) {
       S = new Object[capacity]);
    }
```

```
public Object pop()
      throws EmptyStackException {
   if isEmpty()
      throw new EmptyStackException
         ("Empty stack: cannot pop.");
   Object temp = S[top];
   // facilitates garbage collection
   S[top] = null;
   top = top – 1;
   return temp;
}
```

Performance of Array Implementation

- Space usage: O(*N*) where *N* is the array size.
- Each operation runs in *O*(1) time (no loops, no recursion)
- Array-based implementation is simple, efficient, but …
- The maximum size *N* of the stack is fixed.
- How to determine *N*? Not easy!

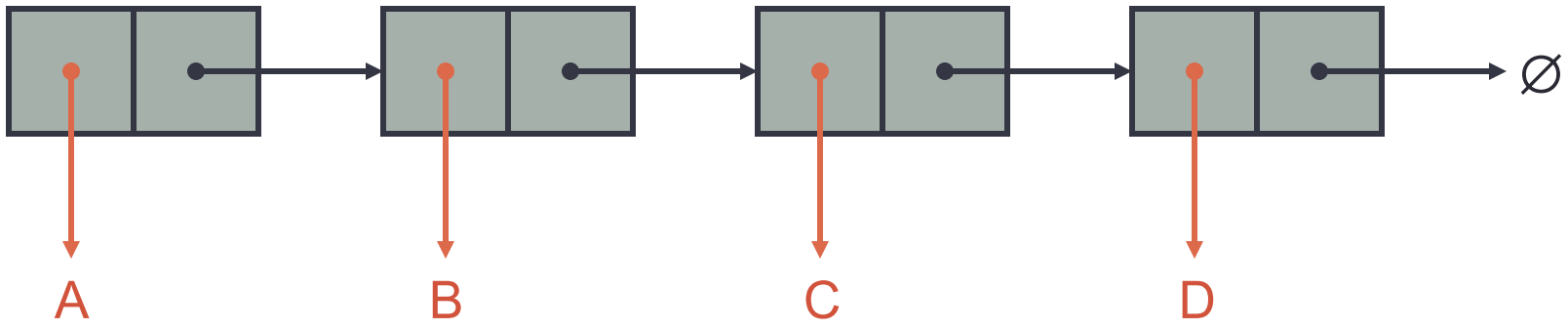
- Alternatives?
  - Extendable arrays
  - Linked lists (singly or doubly linked?)

Linked List Review

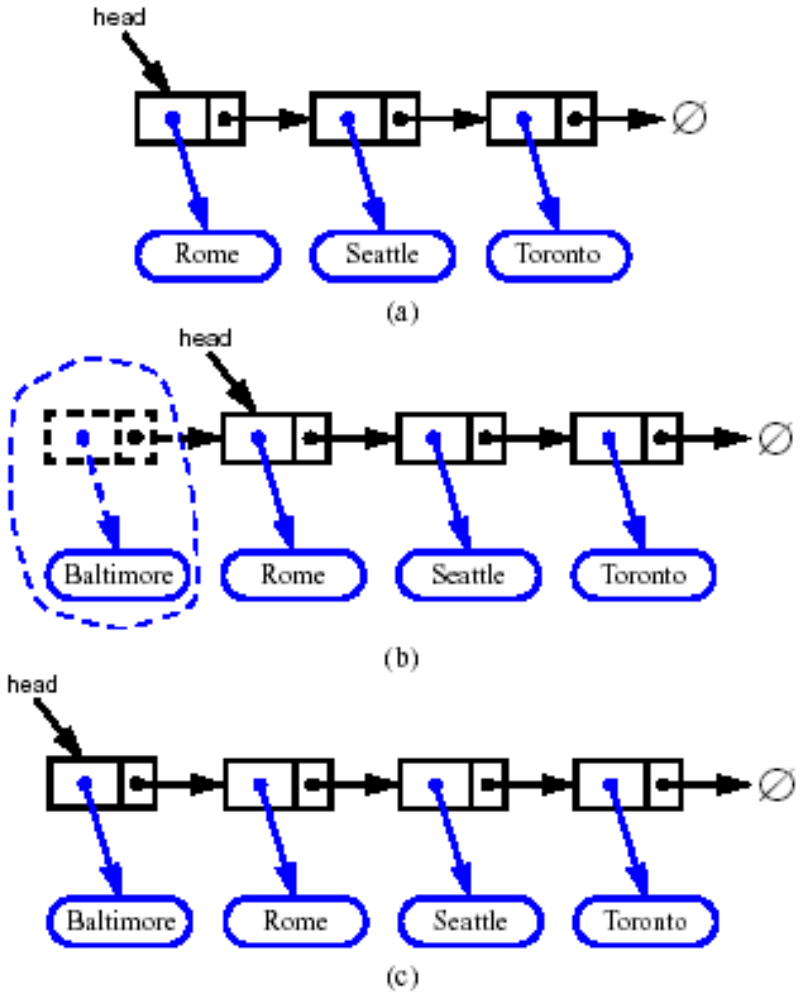
Operation	Singly linked (head, tail)	Doubly linked (header, trailer)
insert first	O( )	O( )
insert last	O( )	O( )
remove first	O( )	O( )
remove last	O( )	O( )

Linked List Implementation

- Singly or doubly linked list?
- Where should the “top” be, head or tail?



push() Method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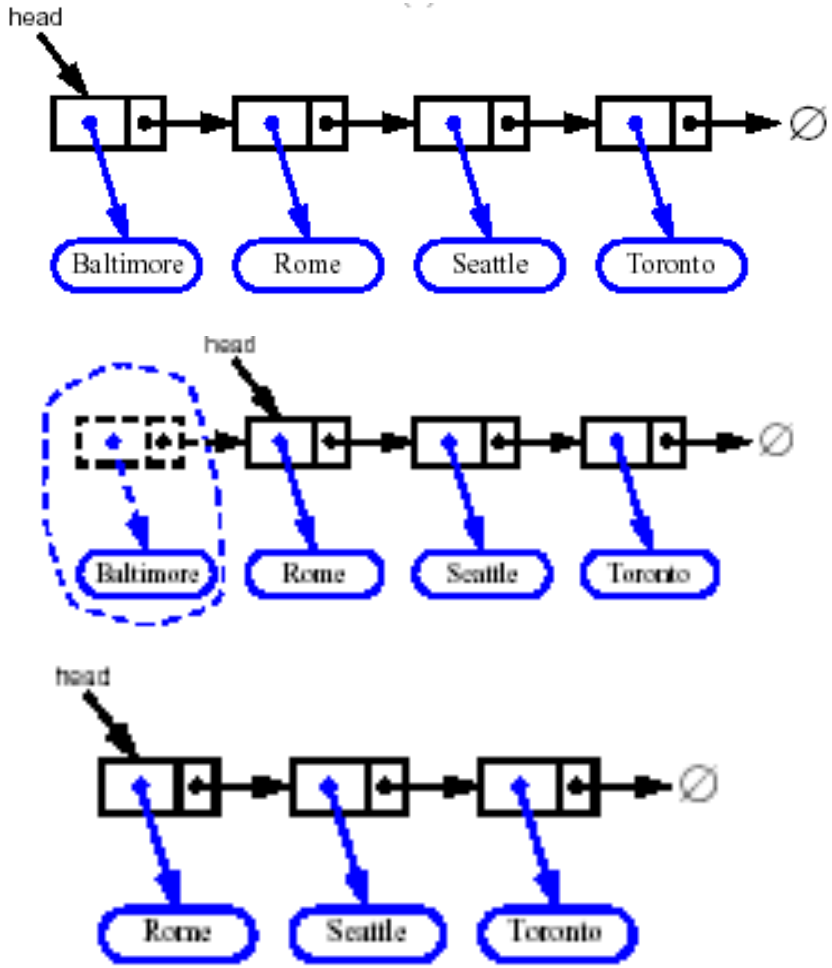
pop() Method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Analysis of Linked List Implementation

- Space usage: $O(n)$
  n = number of elements in the stack
- Each operation runs in $O(1)$ time
- No limit on the stack size, subject to available memory
  *(*run-time error *OutOfMemoryError*)
- Java code: Code Frangment 6.4

Homework

- List-based and array-based operations all run in $O(1)$ time. List-based implementation imposes no limit on the stack size, while array-based implementation does. Is list-based implementation better?

- Can we perform *push*() and *pop*() at the tail of a singly linked list? Analyze the running time in this case.

More Applications of Stacks

- Reversing an array using a stack (6.1.4)
- Matching parentheses, brackets, and quotes in Java files (6.1.5)

Next time ...

- Queues (6.2)