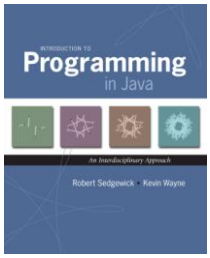
4.3 Stacks, Queues, and Linked Lists



Data Types and Data Structures

Data types. Set of values and operations on those values.
- Some are built into the Java language: `int`, `double[]`, `String`, …
- Most are not: `Complex`, `Picture`, `Stack`, `Queue`, `ST`, `Graph`, …

this lecture

Data structures.
- Represent data or relationships among data.
- Some are built into Java language: arrays.
- Most are not: linked list, circular list, tree, sparse array, graph, …

this lecture · TSP assignment

Collections

Fundamental data types.
- Set of operations (add, remove, test if empty) on generic data.
- Intent is clear when we insert.
- Which item do we remove?

Stack. [LIFO = last in first out] ← this lecture
- Remove the item most recently added.
- Ex: cafeteria trays, Web surfing.

Queue. [FIFO = first in, first out] ← Guitar Hero Assignment
- Remove the item least recently added.
- Ex: Line for help in TA office hours.

Symbol table.
- Remove the item with a given key.
- Ex: Phone book.

Stacks

Stack API

```
public class *StackOfStrings
                *StackOfStrings()   create an empty stack
        boolean isEmpty()           is the stack empty?
           void push(String item)   push a string onto the stack
         String pop()               pop the stack
```

Stack Client Example 1: Reverse

```
public class Reverse {
   public static void main(String[] args) {
      StackOfStrings stack = new StackOfStrings();
      while (!StdIn.isEmpty()) {
         String s = StdIn.readString();
         stack.push(s);
      }
      while (!stack.isEmpty()) {
         String s = stack.pop();
         StdOut.println(s);
      }
   }
}
```

```
% more tiny.txt
it was the best of times

% java Reverse < tiny.txt
times of best the was it
```

← stack contents when standard input is empty

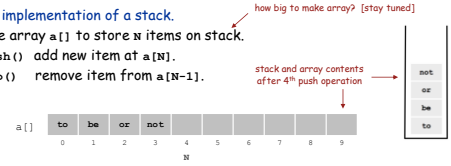
Stack: Array Implementation

Array implementation of a stack.

- Use array `a[]` to store `N` items on stack.
- `push()` add new item at `a[N]`.
- `pop()` remove item from `a[N-1]`.

how big to make array? [stay tuned]

stack and array contents after 4th push operation

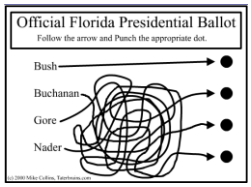



```
public class ArrayStackOfStrings {
   private String[] a;
   private int N = 0;

   public ArrayStackOfStrings(int max) { a = new String[max]; }
   public boolean isEmpty()            { return (N == 0); }
   public void push(String item)       { a[N] = item; N++; }
   public String pop()                 { N--; return a[N + 1]; }
}
```

temporary solution: make client provide capacity

8

Linked Lists



11

Sequential vs. Linked Allocation

Sequential allocation. Put items one after another.

- TOY: consecutive memory cells.
- Java: array of objects.

Linked allocation. Include in each object a link to the next one.

- TOY: link is memory address of next item.
- Java: link is reference to next item.

Key distinctions.

- Array: random access, fixed size.
- Linked list: sequential access, variable size.

get ith item

get next item

12

Linked Lists

Linked list.

- A recursive data structure.
- An item plus a pointer to another linked list (or empty list).
- Unwind recursion: linked list is a sequence of items.

Node data type.

- A reference to a `String`.
- A reference to another `Node`.

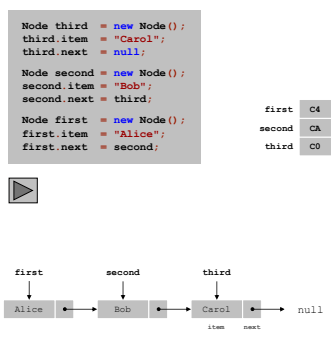
```
public class Node {
   public String item;
   public Node next;
}
```

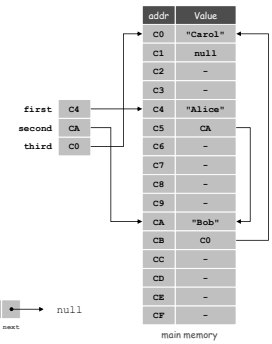
special pointer value `null` terminates list

14

Building a Linked List

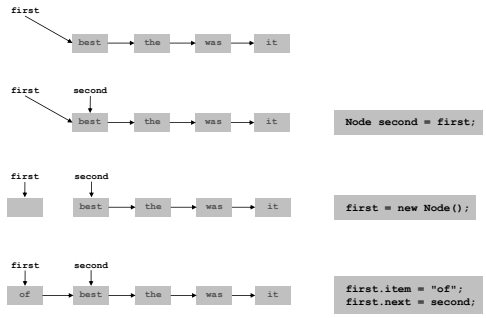
```
Node third  = new Node();
third.item  = "Carol";
third.next  = null;

Node second = new Node();
second.item = "Bob";
second.next = third;

Node first  = new Node();
first.item  = "Alice";
first.next  = second;
```





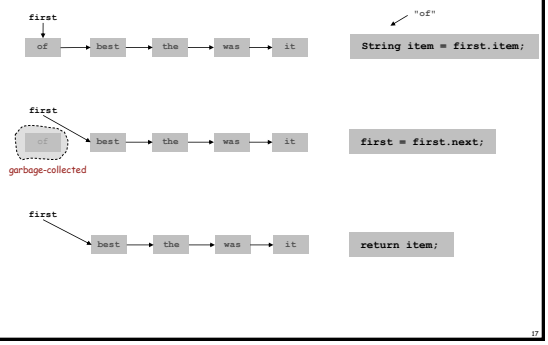
15

Stack Push: Linked List Implementation



16

Stack Pop: Linked List Implementation



17

Stack: Linked List Implementation

```
public class LinkedStackOfStrings {
   private Node first = null;

   private class Node {
      private String item;
      private Node next;
   }
                "inner class"

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

   public void push(String item) {
      Node second = first;
      first = new Node();
      first.item = item;
      first.next = second;
   }

   public String pop() {
      String item = first.item;
      first = first.next;
      return item;
   }
}
```

stack and linked list contents after 4th push operation

18

Stack Data Structures: Tradeoffs

Two data structures to implement `Stack` data type.

Array.
- Every push/pop operation take constant time.
- But… must fix maximum capacity of stack ahead of time.

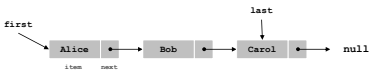
Linked list.
- Every push/pop operation takes constant time.
- Memory is proportional to number of items on stack.
- But… uses extra space and time to deal with references.

20

List Processing Challenge 2

Q. What does the following code fragment do?

```
Node last = new Node();
last.item = StdIn.readString();
last.next = null;
Node first = last;
while (!StdIn.isEmpty()) {
   last.next = new Node();
   last = last.next;
   last.item = StdIn.readString();
   last.next = null;
}
```



23