

- intro to stacks
- function call and return example
- reversing digits example
- stack exercise

### **Next week and homework**

- next week: dynamic implementation of stack
- homework by next week:
  - download, run and understand this week's example programs
  - read Horstmann, section 16.3 on stacks; Chapter 18 Generic Classes

### **Lab**

- homework assigned this week. See Canvas for due date

### **Review last week**

- introduced the reference or pointer, so that we can build dynamic data structures
- began reading our excellent course textbook:
  - Horstmann, Cay. Big Java Early Objects, 7th edition, Wiley, 2018, ISBN 978-1-119-49909-1. (Paper or eTextbook formats are available.)
  - (note that this is the same textbook used for the CSCI 114 prereq class)
  - you were told to read section 15.5 on stacks before this week, to prepare for the new content
- reviewed BlueJ, required for writing all our Java programs this semester
  - homework on this was assigned, due by end of last week
- reviewed how to write Javadoc comments
  - an essential part of program clarity, required in all programming assignments to earn full credit

### **Introduction to this week**

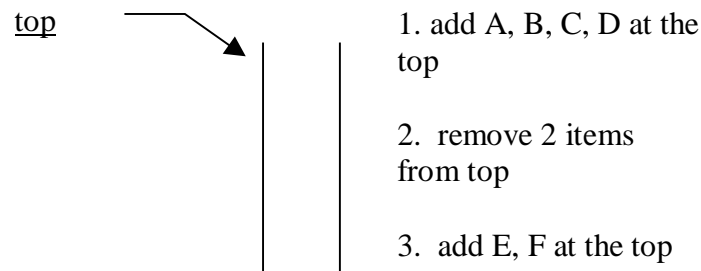
- this week we begin our tour of the standard set of data structures
- next several weeks with stacks
- start this week with stacks in abstract
- will introduce the characteristics and primitive operators for a stack
- review some example applications
- will do an array implementation of stack for homework

## Intro to stacks

Objective: introduce abstract idea of a stack and its primitive operations. Introduce implementation using an array

### Items may be pushed and popped only at the top

- "ordered collection of items such that items may be added (pushed) and removed (popped) only at the top" e.g.



*Figure 1 push and pop a stack of characters*

- Q: what will be the contents of the stack, top to bottom?
- A: F, E, B, A
- is Last In First Out (LIFO) data structure
  - very different to First In First Out – i.e. queue at the bank

### Abstract idea vs. implementation

- the abstract idea of a stack is clearly as a dynamic data structure
  - grows and shrinks over time
- implementation can be static or dynamic
  - will consider the simpler static implementation first, because it's more familiar to us
  - i.e. stack implemented as an array
  - (NOTE: assume that every stack item is of the same data type)

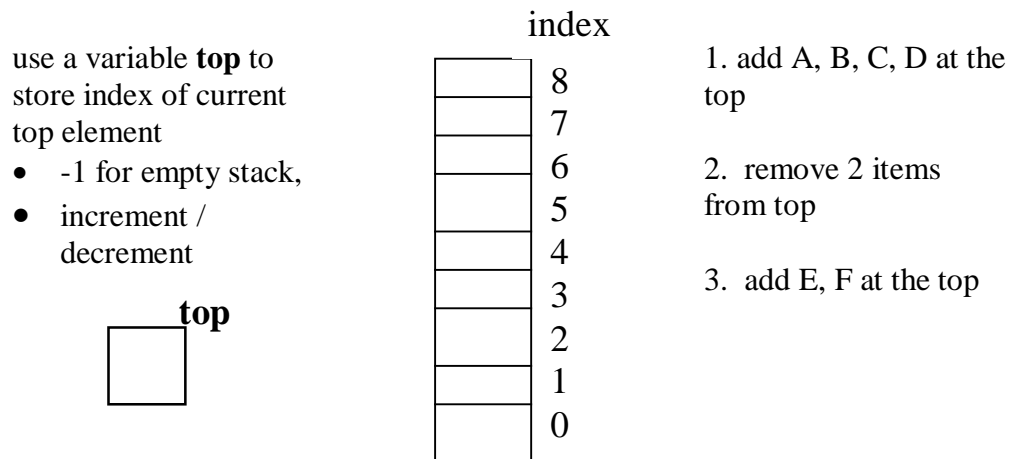


Figure 2 static implementation of the stack as an array

- (BTW, note that while the abstraction of stack can be accessed at the top only
  - the array implementation can actually be accessed at any element)

#### Begin the array implementation

- would package these together as the instance variables of a new `Stack` class e.g.

```
public class Stack {  
    public static final int MAX = 9;  
  
    private int element[];  
    private int top;  
    ...  
}
```

- notice here that the data type stored inside this stack is actually `int`

- then the constructor to initialize a new empty stack:

```
public Stack()  
{  
    element = new int[MAX];  
    top = -1; //stack starts empty  
}
```

#### Stack primitives – “the set of operations that act on a data structure”

- set of operations to act on the data structure. Here, for a `Stack` object `s`:

- `s.push(i)` – adds item `i` to top of stack `s`
- `i = s.pop()` – removes top item from stack `s`

Some problems to watch for:

- `pop()` an empty stack
  - is called underflow
  - implementation must handle this in some appropriate way
  - all we will do is output an error message to standard error
- `push()` to a full stack
  - called overflow
  - (is an implementation issue here, because the array has a fixed, limited size `MAX`)

Other useful stack primitives

- could add some other useful stack operations, e.g.
- `s.isEmpty()` – true if `s` is empty e.g. to pop everything off the stack:  

```
while (!s.empty())  
    i = s.pop()
```
- `s.isFull()` – true if `s` is full
- `i = s.top()` – returns a copy of top item on stack without modifying the stack
  - so `s.top()` could be implemented as:  

```
i = s.pop()  
s.push(i)
```
- `s.clear()` – removes all elements from stack
  - could be:  

```
while (!s.empty())  
    i = s.pop()
```

### Summary

- stack is a 'Last In First Out' (LIFO) data structure
- the most important primitive operations are:
  - push()
  - pop()
- can be implemented statically or dynamically
  - will do an array implementation for homework this week
- use a stack when a problem has 'LIFO characteristics'. This is quite common e.g.
  - to reverse something
  - whenever backtracking is required – “to return to a previously encountered state”
  - will look at some stack example applications demonstrating these...

## Function call and return example

Objective: show a LIFO kind of problem, where a stack is used to implement call and return

- a stack is used to implement function call and return in procedural programming languages e.g.

main()	foo()	bar()	wah()
{	{	{	{
~~~	~~~	~~~	~~~
~~~	~~~	~~~	~~~
@foo()	#bar()	\$wah()	~~~
~~~	~~~	~~~	~~~
~~~	~~~	~~~	}
}	}	}	

Figure 3 method calls from main(), with each return address marked

- here are some method calls from main(), with each return address marked
- when the first method call to foo() is executed, we push the return address of the instruction we come back to onto the return address stack, and so on
  - e.g. here's the stack when we're in wah():

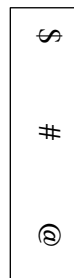


Figure 4 return addresses pushed to the stack

- then we pop the stack each time a method ends, returning correctly to the method call
- (BTW, all the other stuff local to each calling method is also pushed to the stack each method call)
- at end of main(), stack is empty...

- means that the program has ended
- neat!

### Summary

- a stack application, used in almost every programming language
- (also a good preparation for recursion, coming soon)



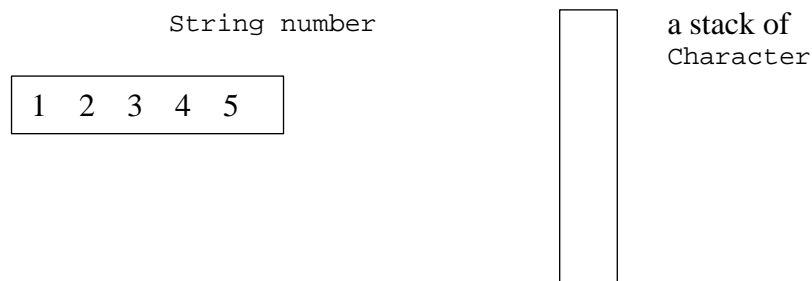
## Reversing digits example

Objective: introduce next week's stack exercise

- stacks are used when we need to reverse something. For example, reverse the order of digits in an integer
  - e.g. for the integer 12345
  - use a stack to reverse the order of digits, to give 54321

### Use a stack to reverse digits

- will actually represent the integer as a string of characters, to avoid overflow problems. So we need a stack of datatype `Character` to do the reverse:

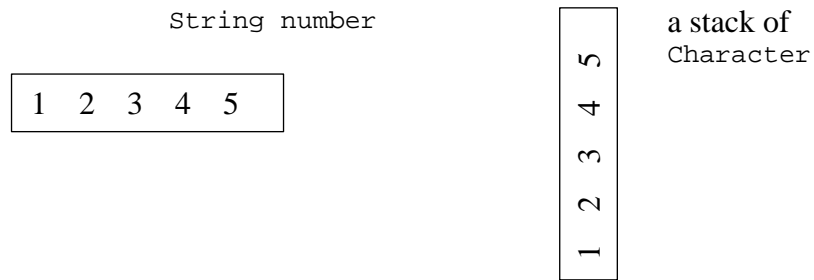


*Figure 5 use a string and a stack of characters*

- reversing algorithm in pseudocode is something like:

```
loop for the digits in the number
  push digit to stack
while (!stack is empty)
  pop stack
```

- so reversing the digits would look something like:



*Figure 6 reversing, with all the digits pushed to the stack*

- all the digits have been pushed to the stack
- now pop the stack, to get digits in reverse order

#### Summary

- you will write this reverse using a stack next week

### Stack exercise

Objective: a quick exercise to get you working with stacks

- reverse an array of 10 integers using a stack:

a

3	7	4	6	2	0	9	1	5	8
---	---	---	---	---	---	---	---	---	---

*Figure 7 example array to be reversed*

- do this now, pencil and paper, pseudocode, 10 minutes, keep it simple

### Review

- should be something like:

```
create empty stack s
for (i = 0; i < 10: ++i)
    s.push(a[i]);
for (i = 0; i < 10: ++i)
    a[i] = s.pop();
```

### Summary

- a common use of stacks is to reverse something

**Next week and homework**

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