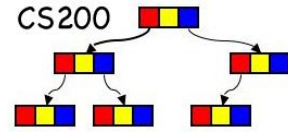


CS200: Stacks

- Prichard Ch. 7

Linear, time-ordered structures

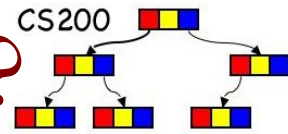


- Data structures that reflect a *temporal* relationship
 - order of removal based on order of insertion
- We will consider:
 - “first come, first serve”
 - first in first out - FIFO (queue)
 - “take from the top of the pile”
 - last in first out - LIFO (stack)

Stacks or queues?

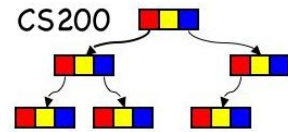


What can we do with coin dispenser?

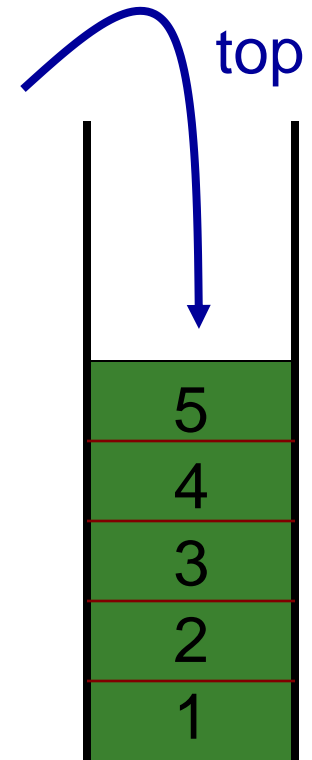


- “**push**” a coin into the dispenser.
- “**pop**” a coin from the dispenser.
- “**peek**” at the coin on top, but don’t pop it.
- “**isEmpty**” check whether this dispenser is empty or not.

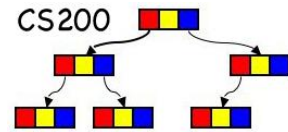
Stacks



- Last In First Out (LIFO) structure
 - A stack of dishes in a cafe
- Add/Remove done from same end: the top

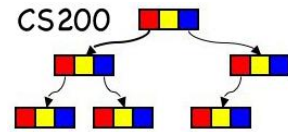


Possible Stack Operations



- **isEmpty():** determine whether stack is empty
- **push():** add a new item to the stack
- **pop():** remove the item added most recently
- **peek():** retrieve the item added most recently

Checking for balanced braces

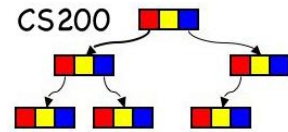


- How can we use a stack to determine whether the braces in a string are balanced?

abc{defg{ijk}{l{mn}}op}qr

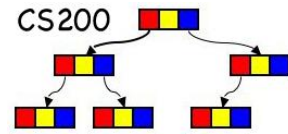
abc{def}}{ghij{kl}m

Pseudocode



```
while ( not at the end of the string){  
    if (the next character is a "{") {  
        aStack.push("{")  
    }  
    else if (the character is a "}") {  
        if(aStack.isEmpty()) ERROR!!!  
        else aStack.pop()  
    }  
}  
if (!aStack.isEmpty()) ERROR!!!
```


question



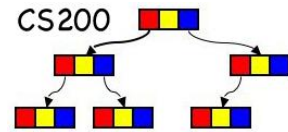
- Could you use a single int to do the same job?
- How?

Try it on

`abc{defg{ijk}{l{mn}}op}qr {st{uvw}xyz}`

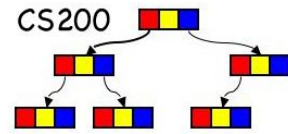
`abc{def}}{ghij{kl}m`

Expressions



- Types of Algebraic Expressions
 - Prefix
 - Postfix
 - Infix
- Prefix and postfix are easier to parse. No ambiguity. Infix requires extra rules: precedence and associativity.
- Postfix: operator applies to the operands that immediately precede it.
- Examples:
 1. $- 5 * 4 3$
 2. $5 - 4 * 3$
 3. $5 4 3 * -$

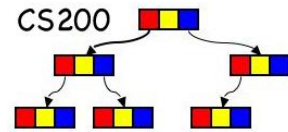




What type of expression is “5 * 4 3 -”?

- A. Prefix
- B. Infix
- C. Postfix
- D. None of the above (i.e., illegal)

Evaluating a Postfix Expression



while there are input tokens left

 read the next token

 if the token is a value

 push it onto the stack.

 else

 //the token is a operator taking n arguments

 pop the top n values from the stack and perform the operation

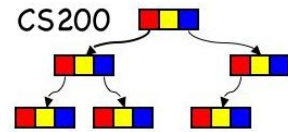
 push the result on the stack

If there is only one value in the stack return it as the result

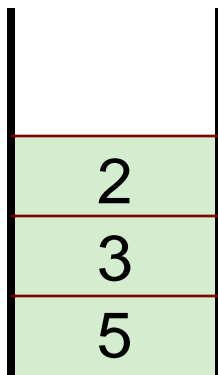
else

 throw an exception

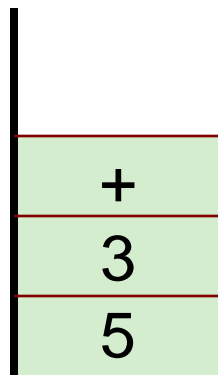
Quick check



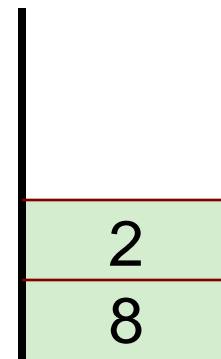
- If the input string is “5 3 + 2 *”, which of the following could be what the stack looks like when trying to parse it?



A

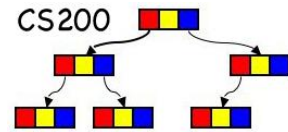


B



C

Stack Interface



`push(StackItemType newItem)`

- adds a new item to the top of the stack

`StackItemType pop()` throws `StackException`

- deletes the item at the top of the stack and returns it
- Exception when deletion fails

`StackItemType peek()` throws `StackException`

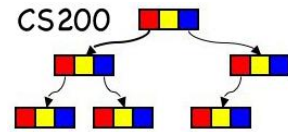
- returns the top item from the stack, but does not remove it
- Exception when retrieval fails

`boolean isEmpty()`

- returns true if stack empty, false otherwise

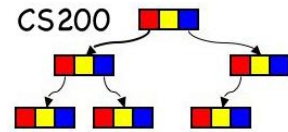
Preconditions? Postconditions?

Comparison of Implementations



- Options for Implementation:
 - Array based implementation
 - Array List based implementation
 - Reference based implementation
- What are the advantages and disadvantages of each implementation?
- Let's look at a Linked List based implementation
- In P1 you program an Array List based implementation

Stack API in Java

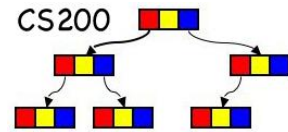


public class **Stack**<E> extends Vector<E>

Implemented Interfaces: Iterable<E>, Collection<E>, List<E>, RandomAccess

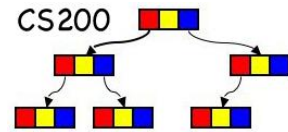
- Stack extends Vector with operations that allow a vector to be treated as a stack (push, pop, peek, empty, search)

Stacks and Recursion

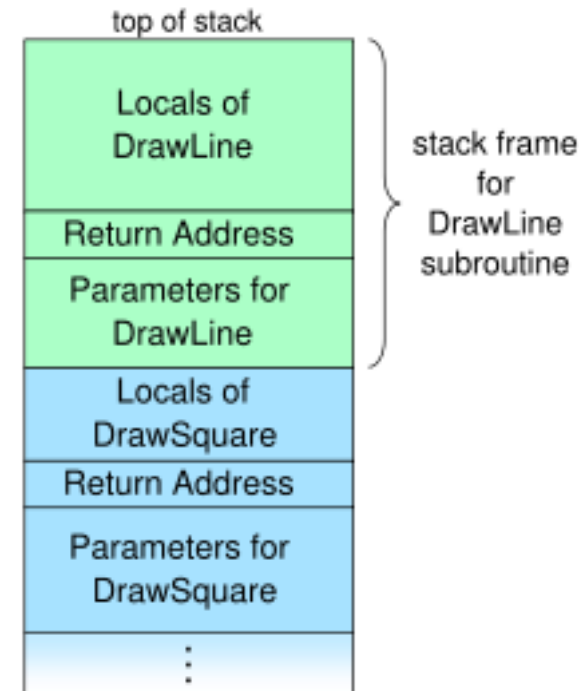


- Most implementations of recursion maintain a stack of activation records.
- Within recursive calls, the most recently executed activation record is stored at the top of the stack.

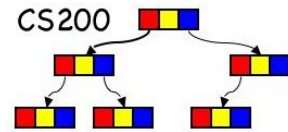
Applications - the run-time stack



- Nested method calls tracked on **call stack** (aka run-time stack)
 - First method that returns is the last one invoked
- Element of call stack - **activation record**
 - parameters
 - local variables
 - return address: pointer to next instruction to be executed in calling method

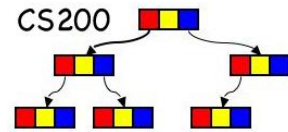


Factorial example



```
int factorial(n) {
    // pre n>=0
    // post return n!
    if (n==0)
        r=1;
    else
        r=n*factorial(n-1);
    return r;
}
```

RTS factorial(3): wind phase



only active frame: **top of the run time stack**

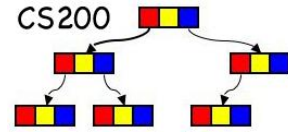
$n=3, r=?$

$n=2, r=?$
 $n=3, r=?$

$n=1, r=?$
 $n=2, r=?$
 $n=3, r=?$

$n=0, r=1$
 $n=1, r=?$
 $n=2, r=?$
 $n=3, r=?$

RTS factorial(3): unwind phase



$n=1, r=1$

$n=2, r=?$

$n=3, r=?$

$n=2, r=2$

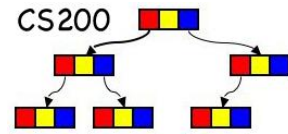
$n=3, r=?$

$n=3, r=6$

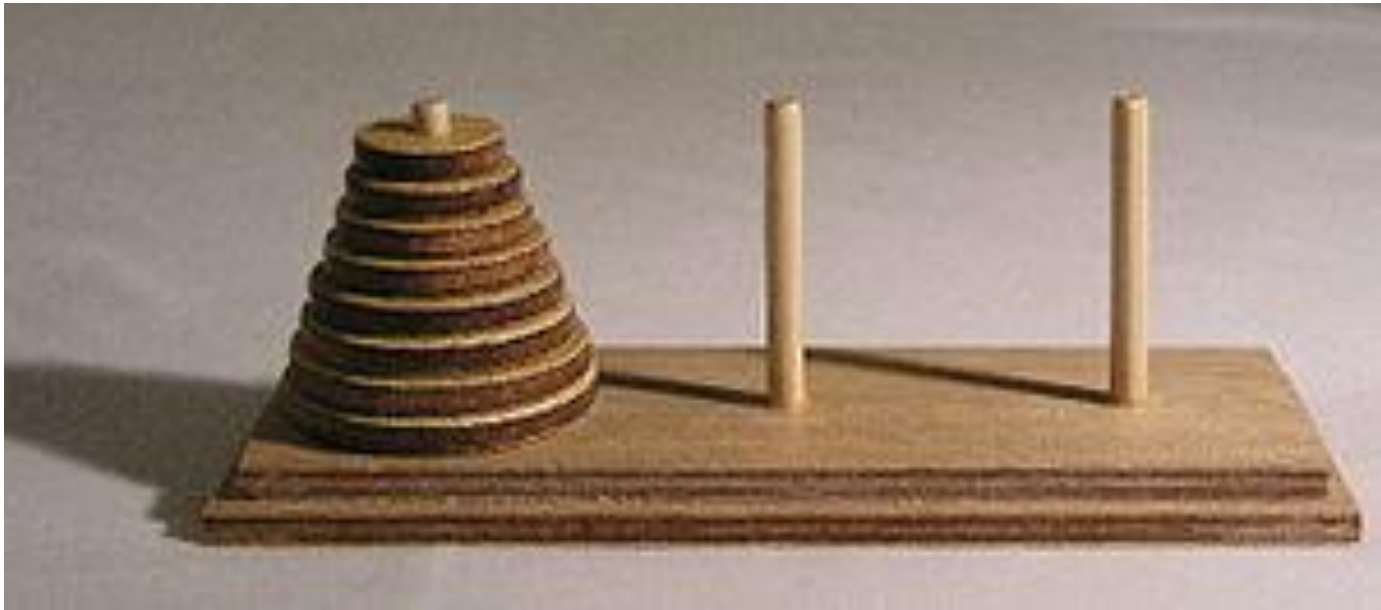
return 6

More complex example:

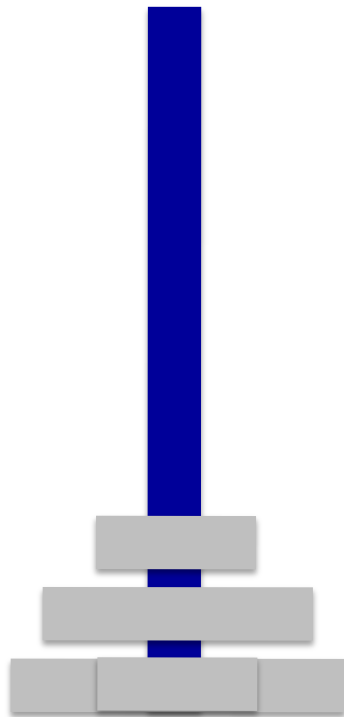
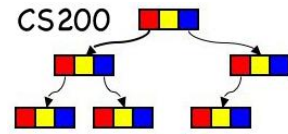
The Towers of Hanoi



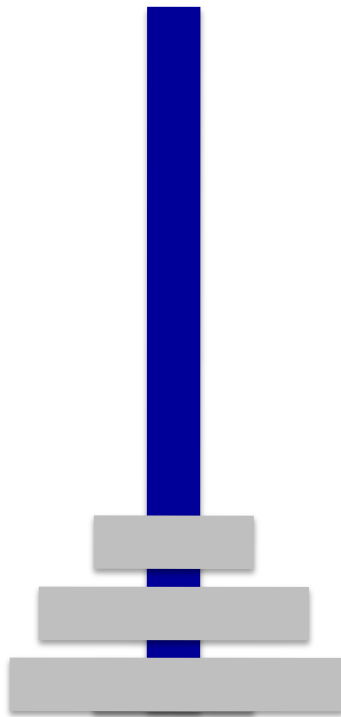
- **Move pile of disks from source to destination**
- **Only one** disk may be moved at a time.
- No disk may be placed on top of a smaller disk.



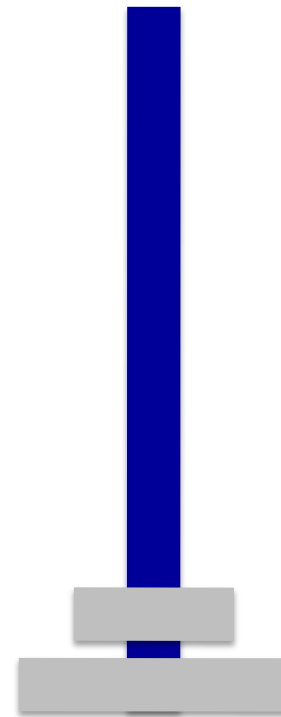
Moves in the Towers of Hanoi



Source

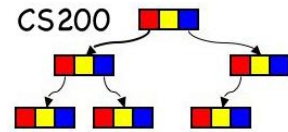


Destination



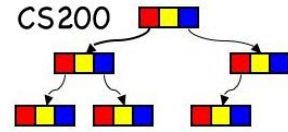
Spare

Recursive Solution



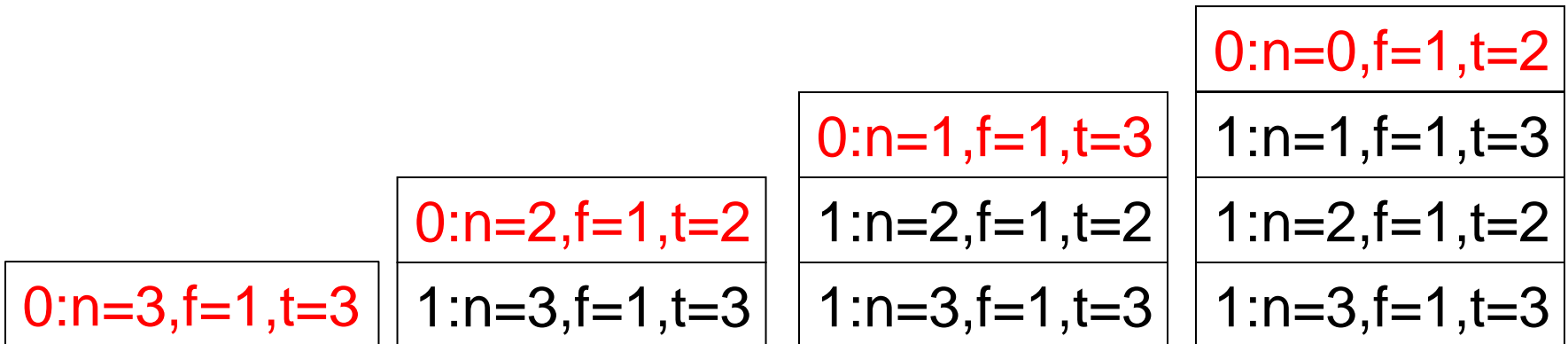
```
// pegs are numbers, via is computed
// f: source ("from") peg, t: dest ("to") peg, v: via peg
// state corresponds to return address
public void hanoi(int n, int f, int t){
    // state 0
    if (n>0) {
        int v = 6 - f - t;
        hanoi(n-1, f, v);
        // state 1
        System.out.println("move disk " + n + " from " + f + " to " + t);
        hanoi(n-1, v, t);
        // state 2
    }
}
```


Run time stack for hanoi(3,1,3)

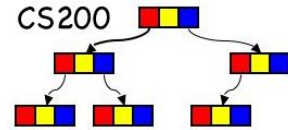


```
// state 0
if (n>0) {
    int v = 6 - f - t;
    hanoi(n-1, f, v);
    // state 1
    System.out.println("move disk " + n +
        " from" + f + " to" + t);
    hanoi(n-1, v, t);
    // state 2
}
```

only active frame:
top of the run time stack



Run time stack for hanoi(3,1,3)



```

if (n>0) {
  // state 0
  int v = 6 - f - t;
  hanoi(n-1, f, v);
  // state 1
  System.out.println("move disk " + n +
                    " from" + f + " to" + t);
  hanoi(n-1, v, t);
  // state 2
}

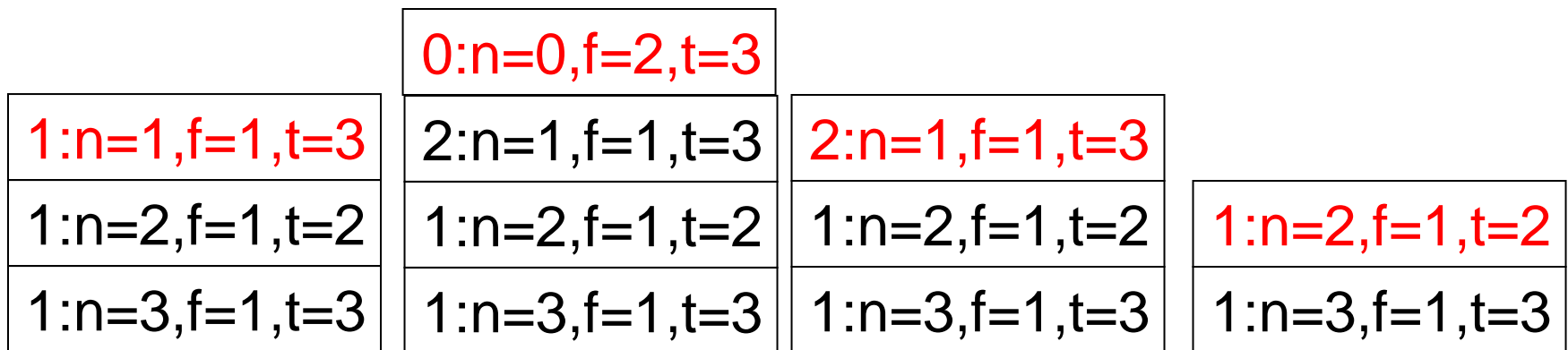
```

System.out:

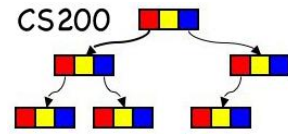
“move disk 1 from 1 to 3”

“move disk 2 from 1 to 2”

etcetera



Hanoi with explicit run time stack



- In Programming Assignment 1 you will create a Hanoi program with an explicit run time stack *rts*.
- The main loop of the program is:

```
while (rts not empty) {  
    pop frame  
    check frame state  
    perform appropriate actions, including pushing frames  
}
```