CSE 1322 Module 4 – Part 1

Recursion: The Function Stack



Function Stack - What is it?

- Also known as Call Stack.
- It is a special region in memory that we use to temporarily store the information of active functions (methods) calls during the execution of the program.



Function Stack – Stack

- We are going to cover this later in the semester.
- A stack is a Last-In, First-Out (LIFO) data structure.
- This means that the last item added, is the first one removed.
- Think of a stack of pancakes, most likely you start eating from the pancake at the top.



Function Stack – Stack

- We are going to cover this later in the semester.
- A stack is a Last-In, First-Out (LIFO) data structure.
- This means that the last item added, is the first one removed.
- Think of a stack of pancakes, most likely you start eating from the pancake at the top.
- Meaning that the one of the top pancake was placed last in the plate,
 while the bottom pancake was the first one placed in the plate.



- The Function Stack behaves the same.
- The first function added into the stack will usually always be the first item in the stack.
- While the main method is still active, our program is still active.
- Whenever we do a method call, we add another function into the stack.
- When the method call is resolved, we delete it from the stack.



- The running function will always be at the "top" of the stack.
- Any functions below the top stack, is "waiting" for the top stack to resolve.



```
public class Main {
    public static void method2(){
        System.out.println("Method 2 was called");
    }

    public static void method1(){
        System.out.println("Method 1 was called");
        method2();
        System.out.println("Method 1 still alive");
    }

    public static void main(String[] args) {
        method2();
        method1();
        System.out.println("Finished!");
    }
}
```



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    public static void main(String[] args) {
        method2();
        method1();
        System.out.println("Finished!");
    }
}
```

Week-8/Function-Stack/Main.java

main()

- 1. Call method2()
- 2. Call method1()
- 3. Print "Finished!"



```
public class Main {
    public static void method2(){
        System.out.println("Method 2 was called");
    }

    public static void method1(){
        System.out.println("Method 1 was called");
        method2();
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    }

    public static void main(String[] args) {
        method2();
        method2();
        method1();
        System.out.println("Finished!");
    }
}
```

method2()
1. Print '

1. Print "Method 2 was called"

main()

- 1. Call method2()
- 2. Call method1()
- 3. Print "Finished!"



```
public class Main {
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       System.out.println("Method 1 was called");
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   public static void main(String[] args) {
       method2();
       method1();
       System.out.println("Finished!");
   }
}
```

method2() 1. Print

1. Print "Method 2 was called"

main()

- 1. Call method2()
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```
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        method2();
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    }

    public static void main(String[] args) {
        method2();
        method1();
        System.out.println("Finished!");
    }
}
```

method2()

1. Print "Method 2 was called"

main()

- 1. Call method2()
- 2. Call method1()
- 3. Print "Finished!"



```
public class Main {
    public static void method2(){
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        System.out.println("Method 1 still alive");
    }

    public static void main(String[] args) {
        method2();
        method1();
        System.out.println("Finished!");
    }
}
```

main()

- 1. Call method1()
- 2. Print "Finished!"



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public class Main {
    public static void method2(){
        System.out.println("Method 2 was called");
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    public static void method1(){
        System.out.println("Method 1 was called");
        method2();
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    public static void main(String[] args) {
        method2();
        method1();
        System.out.println("Finished!");
    }
}
```

method1()

- 1. Print "Method 1 was called"
- 2. Call method2()
- 3. Print "Method 1 still alive"

main()

- 1. Call method1()
- 2. Print "Finished!"



```
public class Main {
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        System.out.println("Method 1 was called");
        method2();
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    }

public static void main(String[] args) {
        method2();
        method1();
        System.out.println("Finished!");
    }
}

Method 2 was called
```

method1()

- 1. Print "Method 1 was called"
- 2. Call method2()
- 3. Print "Method 1 still alive"

main()

- 1. Call method1()
- 2. Print "Finished!"



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public class Main {
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        method2();
        System.out.println("Method 1 still alive");
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public static void main(String[] args) {
        method2();
        method2();
        System.out.println("Finished!");
}

Method 2 was called

Method 1 was called
```

method1()

- 1. Print "Method 1 was called"
- 2. Call method2()
- 3. Print "Method 1 still alive"

main()

- 1. Call method1()
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public static void main(String[] args) {
        method2();
        method1();
        System.out.println("Finished!");
}

Method 2 was called

Method 1 was called
```

method2()

1. Print "Method 2 was called"

method1()

- 1. Call method2()
- 2. Print "Method 1 still alive"

main()

- 1. Call method1()
- 2. Print "Finished!"



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public class Main {
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    public static void method1(){
        System.out.println("Method 1 was called");
        method2();
        System.out.println("Method 1 still alive");
    }

    public static void main(String[] args) {
        method2();
        method1();
        System.out.println("Finished!");
    }
}

Method 2 was called

Method 1 was called

Method 1 was called

Method 1 was called

Method 1 was called

Method 2 was called

Method 1 was called

Method 2 was called

Method 1 was called

Method 2 was called

Method 1 was called

Method 2 was called

Method 1 was called

Method 2 was called

Method 3 was called

Method 2 was called

Method 2 was called

Method 3 was called

Method 3 was called

Method 3 was called

Method 4 was called

Method 4 was called

Method 5 was called

Method 1 was called

Method 2 was called

Method 1 was called

Method 2 was called

Method 3 was called

Method 4 was called

Method 4 was called

Metho
```

method2()

1. Print "Method 2 was called"

method1()

- 1. Call method2()
- 2. Print "Method 1 still alive"

main()

- 1. Call method1()
- 2. Print "Finished!"



```
public class Main {
    public static void method2(){
        System.out.println("Method 2 was called");
    }

    public static void method1(){
        System.out.println("Method 1 was called");
        method2();
        System.out.println("Method 1 still alive");
    }

    public static void main(String[] args) {
        method2();
        method2();
        system.out.println("Finished!");
    }
}

Method 2 was called

Method 3 was called

Method 2 was called

Method 3 was called

Method 2 was called

Method 3 was called

Method 3 was called

Method 4 was called

Method 5 was called

Method 6 was called

Method 7 was called

Method 8 was called

Method 9 was called

Metho
```

method2()

1. Print "Method 2 was called"

method1()

- 1. Call method2()
- 2. Print "Method 1 still alive"

main()

- 1. Call method1()
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```
public class Main {
    public static void method2(){
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        System.out.println("Method 1 was called");
        method2();
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    public static void main(String[] args) {
        method2();
        method2();
        method1();
        System.out.println("Finished!");
    }
}

Method 2 was called

Method 2 was called

Method 1 still alive
```

method1()

Print "Method 1 still alive"

main()

- 1. Call method1()
- 2. Print "Finished!"



```
public class Main {
   public static void method2(){
       System.out.println("Method 2 was called");
   public static void method1(){
       System.out.println("Method 1 was called");
                                                   Method 2 was called
       method2();
       System.out.println("Method 1 still alive");
                                                   Method 1 was called
                                                   Method 2 was called
   public static void main(String[] args) {
       method2();
                                                   Method 1 still alive
       method1();
       System.out.println("Finished!");
                                                   Finished!
```

main()
1. Print "Finished!"



```
public class Main {
   public static void method2(){
       System.out.println("Method 2 was called");
   public static void method1(){
       System.out.println("Method 1 was called");
                                                   Method 2 was called
       method2();
       System.out.println("Method 1 still alive");
                                                   Method 1 was called
                                                   Method 2 was called
   public static void main(String[] args) {
       method2();
                                                   Method 1 still alive
       method1();
       System.out.println("Finished!");
                                                   Finished!
```

Program terminated



Repetition Structures

- Loops/Iterative:
 - Also called Explicit Repetition.
 - State is maintained by value.
 - Examples:
 - For Loop
 - Foreach Loop
 - While Loop
 - Do While Loop



Repetition Structures

- Recursion or Implicit Repetition:
 - A function calling itself.
 - State is maintained in the call stack.



Recursion

- Recursion is a programming concept that involves a function calling itself.
- Recursion is used to reduce complex problems into smaller subproblems.
- Code-wise, recursion solutions looks simpler and shorter than its iterative counterpart.



Recursion

- A recursive method consists of two essential components:
- Base Case We define the stopping point of the recursion.
- Recursive Call We define the part where the function calls itself.



In-Class Example 1

- Create a Recursive Method that prints a counter.
- It should take in one integer value, which is the starting number for the counter.
- The counter should count down to 0.



```
public class Counter {
    public static void counter(int number){
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0){
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}</pre>
```



```
public class Counter {
    public static void counter(int number) {
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0) {
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter(5);
    }
}</pre>
```

main()
1. Call counter(5)



main()
1. Call counter(5)



counter(5)

- 1. ls 5 < 0?
- 2. Print "Counter: 5"
- 3. Call counter(4)

main()

Call counter(5)



counter(5)

- 1. ls 5 < 0?
- 2. Print "Counter: 5"
- 3. Call counter(4)

main()

Call counter(5)



counter(5)

- 1. Print "Counter: 5"
- 2. Call counter(4)

main()

1. Call counter(5)



counter(5)1. Call counter(4)

main()

1. Call counter(5)



```
public class Counter {
   public static void counter(int number){// counter(4)
       if(number < 0){</pre>
           return;
                                                        Counter: 5
       System.out.println("Counter: " + number);
       counter(number - 1);
    public static void main(String[] args) {
        counter(5);
```

counter(4) 1. Is 4 < 0?

2. Print "Counter: 4"

3. Call counter(3)

counter(5)

1. Call counter(4)

main()

1. Call counter(5)



counter(4)

- 1. Is 4 < 0?
- 2. Print "Counter: 4"
- 3. Call counter(3)

counter(5)

1. Call counter(4)

main()

1. Call counter(5)



counter(4)

- 1. Print "Counter: 4"
- 2. Call counter(3)

counter(5)

1. Call counter(4)

main()

1. Call counter(5)



counter(4)

1. Call counter(3)

counter(5)

1. Call counter(4)

main()

1. Call counter(5)



counter(3)1. Call counter(2)

counter(4)

1. Call counter(3)

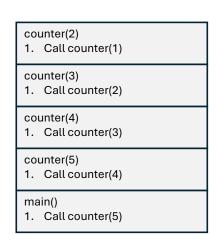
counter(5)

1. Call counter(4)

main()

1. Call counter(5)





1. Call counter(0)

counter(2)
1. Call counter(1)

counter(3)
1. Call counter(2)

counter(4)
1. Call counter(3)

counter(5)
1. Call counter(4)

main()
1. Call counter(5)

counter(1)



Week-8/Function-Stack/Counter.java

counter(0)

- 1. Is 0 < 0?
- 2. Print "Counter: 0"
- 3. Call counter(-1)

counter(1)

1. Call counter(0)

counter(2)

1. Call counter(1)

counter(3)

1. Call counter(2)

counter(4)

1. Call counter(3)

counter(5)

1. Call counter(4)

main()

1. Call counter(5)



Week-8/Function-Stack/Counter.java

counter(0) 1. Is 0 < 0?

- 2. Print "Counter: 0"
- 3. Call counter(-1)

counter(1)

1. Call counter(0)

counter(2)

1. Call counter(1)

counter(3)

1. Call counter(2)

counter(4)

1. Call counter(3)

counter(5)

1. Call counter(4)

main()

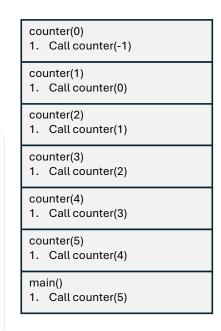
1. Call counter(5)



Week-8/Function-Stack/Counter.java

counter(0) 1. Print "Counter: 0" 2. Call counter(-1) counter(1) 1. Call counter(0) counter(2) 1. Call counter(1) counter(3) 1. Call counter(2) counter(4) 1. Call counter(3) counter(5) 1. Call counter(4) main() 1. Call counter(5)







Week-8/Function-Stack/Counter.java

counter(-1) 1. Is -1 < 0? 2. Print "Counter: -1" 3. Call counter(-2) counter(0) 1. Call counter(-1) counter(1) 1. Call counter(0) counter(2) 1. Call counter(1) counter(3) 1. Call counter(2) counter(4) 1. Call counter(3) counter(5) 1. Call counter(4) main()



1. Call counter(5)

Week-8/Function-Stack/Counter.java

counter(-1) 1. Is -1 < 0? 2. Print "Counter: -1" 3. Call counter(-2) counter(0) 1. Call counter(-1) counter(1) 1. Call counter(0) counter(2) 1. Call counter(1) counter(3) 1. Call counter(2) counter(4) 1. Call counter(3) counter(5) 1. Call counter(4) main()



1. Call counter(5)

Week-8/Function-Stack/Counter.java

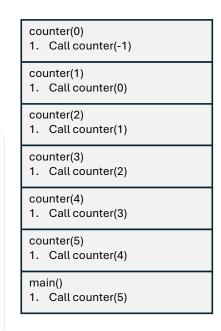
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Week-8/Function-Stack/Counter.java

counter(-1) 1. Is -1 < 0? 2. return counter(0) 1. Call counter(-1) counter(1) 1. Call counter(0) counter(2) 1. Call counter(1) counter(3) 1. Call counter(2) counter(4) 1. Call counter(3) counter(5) 1. Call counter(4) main() 1. Call counter(5)







counter(1)
1. Call counter(0)

counter(2)
1. Call counter(1)

counter(3)
1. Call counter(2)

counter(4)
1. Call counter(3)

counter(5)
1. Call counter(4)

main()
1. Call counter(5)



1. Call counter(4)

counter(2)

counter(3)
1. Call counter(2)

counter(4)1. Call counter(3)

counter(5)

1. Call counter(1)

1. Call counter(5)



counter(3)

1. Call counter(2)

counter(4)

1. Call counter(3)

counter(5)

1. Call counter(4)

main()

1. Call counter(5)



counter(4)

1. Call counter(3)

counter(5)

1. Call counter(4)

main()

1. Call counter(5)



counter(5)

1. Call counter(4)

main()

1. Call counter(5)



```
public class Counter {
    public static void counter(int number) {
        // Base case: Since we count from number to
        // 0, we should stop at -1
        if(number < 0) {
            return;
        }
        System.out.println("Counter: " + number);

        // Recursive Call: Since we count from number
        // to 0, each call should decrease number by 1
        counter(number - 1);
    }

    public static void main(String[] args) {
        counter: 2
        Counter: 1
    }
}</pre>
```

main() 1. Call counter(5)



```
public class Counter {
    public static void counter(int number){
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main()



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        System.out.println("Counter: " + number);
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    }
    public static void main(String[] args) {
        counter: 2
        Counter: 1
    }
}</pre>
```

Program terminated



In-Class Example 2

• Let's try the opposite, the method should now count up, starting from 0 until we reach the input number.

