Advanced Object Oriented Programming

EECS 2030

Fall 2020 :: **Section B**

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Advanced Object Oriented Programming

EECS 2030

Lecture 5 :: **Recursion II**

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- Tracing a recursive method (video)
  - in Eclipse (video)
  - by hand (representations for worksheet)
    - program stack (compact version)
    - recursive tree
- More examples
  - palindrome

Tracing a method in Eclipse

- Using debug mode
- See video on echo360

- Describes:
  - Setting breakpoints
  - Running in debug mode
  - The debug perspective
  - Tracking the stack & variables in stack memory

EECS2030B - EECS2030_F2020_B/src/week02/recursion1/RecursiveMethods1.java - Eclipse IDE

Debug | Project Explorer | Servers

- RecursiveMethods1 [Java Application]
  - week02.recursion1.RecursiveMethods1 at localhost:519
    - Thread [main] (Suspended)
      - RecursiveMethods1.countZeros(long) line: 99
      - RecursiveMethods1.countZeros(long) line: 96
      - RecursiveMethods1.main(String[]) line: 153
    - /Library/Java/JavaVirtualMachines/jdk1.8.0_261.jdk/Cont

RecursiveMethods1.java

```
76      /**
77       * A recursive method to count the number of digits
78       *
79       * @param n a long value
80       * @return the number of zero digits found in n
81       *
82       */
83      public static int countZeros(long n) {
84
85          if (n == 0L) {          // base case 1
86              return 1;
87          }
88          else if (n < 10L) {     // base case 2
89              return 0;
90          }
91
92          boolean lastDigitIsZero= (n % 10L == 0);
93          final long m = n / 10L;
94
95          if(lastDigitIsZero) {
96              return 1 + countZeros(m);
97          }
98          else {
99              return countZeros(m);
100         }
101
102     }
103
```

Variables | Breakpoints | Expressio

Name	Value
no method return value	
n	80041
lastDigitIsZero	false
m	8004

Console | Problems | Debug Shell

RecursiveMethods1 [Java Application] /Library/Java/JavaVirtualMachines/jdk1.8.0_261.jdk/Contents/Home/bin/java (Sep. 22, 2020, 9:17:50 p.m.)

countZeros(800410L):

When a method is invoked, the line number that the current method is up to is stored on the stack (so the method knows where to keep executing from after it returns)

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line numbers

line number at which current countZeros(..) is suspended while a new countZeros(..) is invoked and pushed to the stack

```
1   public static int countZeros(long n) {
2
3       if(n == 0L) {           // base case 1
4               return 1;
5       }
6       else if(n < 10L) {      // base case 2
7               return 0;
8       }
9
10      boolean lastDigitIsZero = (n % 10L == 0);
11      final long m = n / 10L;
12
13      if(lastDigitIsZero) {
14              return 1 + countZeros(m);
15      }
16      else {
17              return countZeros(m);
18      }
19  }
```

program stack (compact representation)

:: show args, return value, and line number (if suspended)

```
int numzeros = countZeros( 800410L );
```
// called from main, line 5

program stack:

numzeros=?, line=5

program stack (compact representation)

:: show args, return value, and line number (if suspended)

```
int numzeros = countZeros( 800410L );
```

```
countZeros( 800410L )
```

program stack:

numzeros=?, line=5
n=800410L, return=

program stack (compact representation)

:: show args, return value, and line number (if suspended)

```
int numzeros = countZeros( 800410L );
```
// called from main, line 5

```
countZeros( 800410L )
```

```
countZeros( 80041L )
```

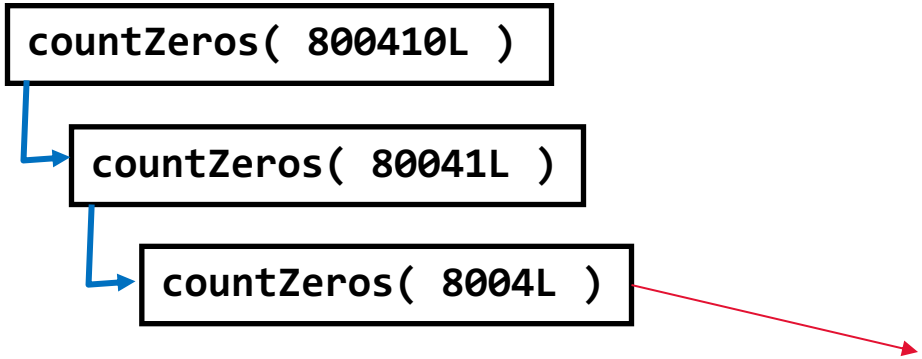
program stack:

numzeros=?, line=5
n=800410L, return=1+?, line=14
n=80041L, return=

program stack (compact representation)

:: show args, return value, and line number (if suspended)

```
int numzeros = countZeros( 800410L ); // called from main
```



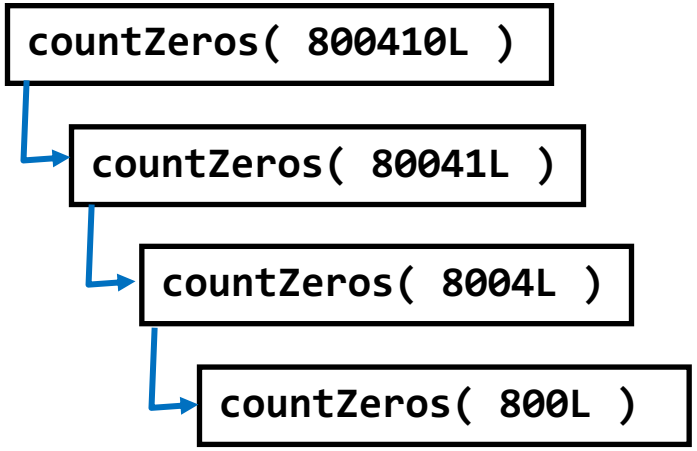
program stack:

numzeros=?, line=5
n=800410L, return=1+?, line=14
n=80041L, return=?, line=17
n=8004L, return=

program stack (compact representation)

:: show args, return value, and line number (if suspended)

```
int numzeros = countZeros( 800410L ); // called from main
```



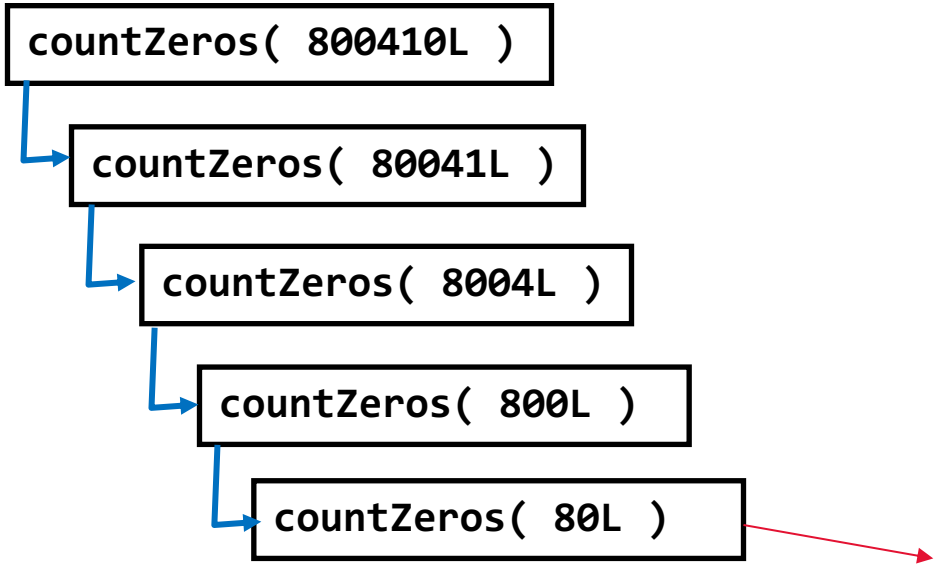
program stack:

numzeros=?, line=5
n=800410L, return=1+?, line=14
n=80041L, return=?, line=17
n=8004L, return=?, line=17
n=800L, return=

program stack (compact representation)

:: show args, return value, and line number (if suspended)

```
int numzeros = countZeros( 800410L ); // called from main
```



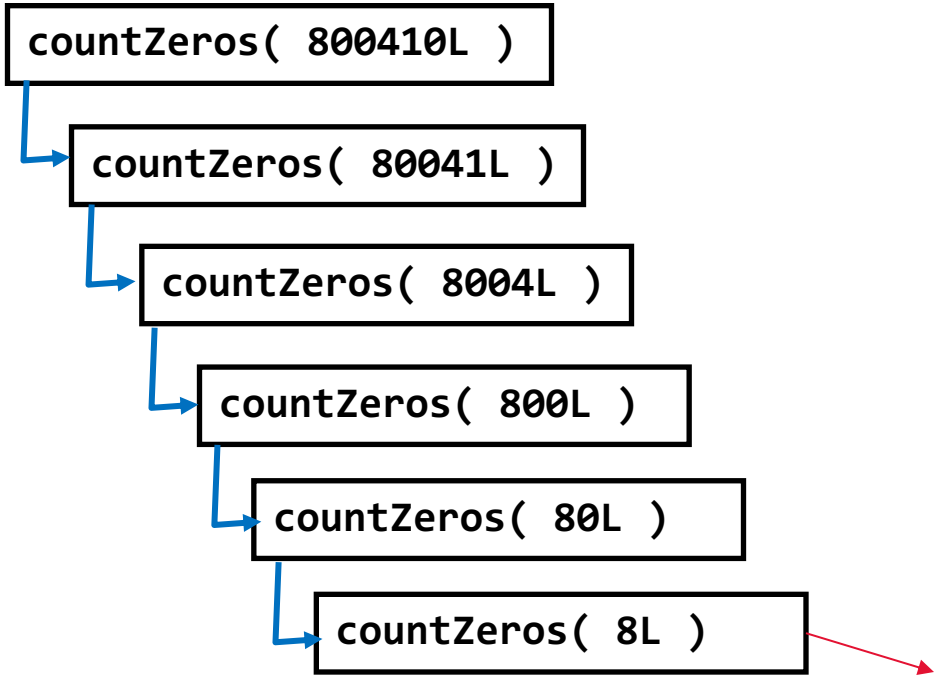
program stack:

numzeros=?, line=5
n=800410L, return=1+?, line=14
n=80041L, return=?, line=17
n=8004L, return=?, line=17
n=800L, return=1+?, line=14
n=80L, return=

program stack (compact representation)

:: show args, return value, and line number (if suspended)

```
int numzeros = countZeros( 800410L );  // called from main, line 5
```



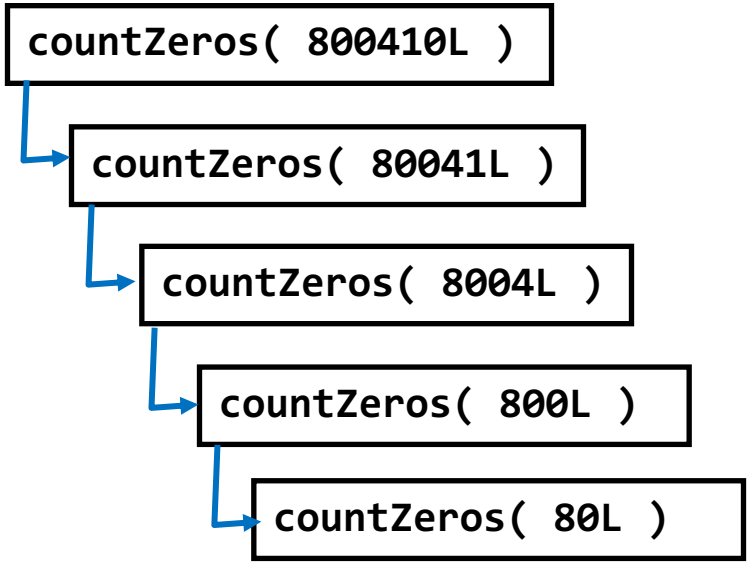
program stack:

numzeros=?, line=5
n=800410L, return=1+?, line=14
n=80041L, return=?, line=17
n=8004L, return=?, line=17
n=800L, return=1+?, line=14
n=80L, return=1+?, line=14
n=8L, return=0

program stack (compact representation)

:: show args, return value, and line number (if suspended)

```
int numzeros = countZeros( 800410L ); // called from main
```



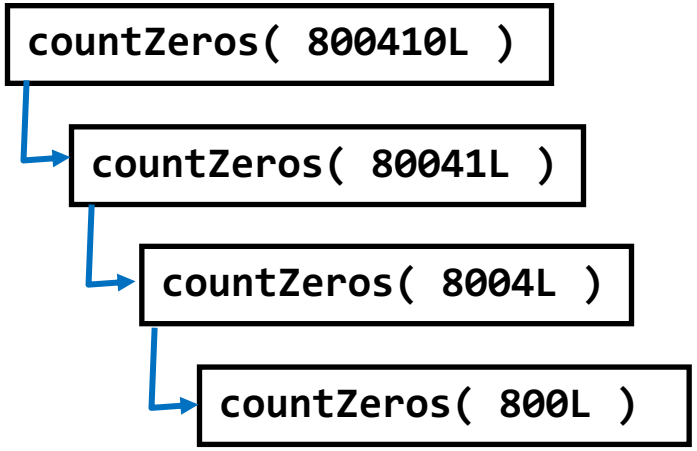
program stack:

numzeros=?, line=5
n=800410L, return=1+?, line=14
n=80041L, return=?, line=17
n=8004L, return=?, line=17
n=800L, return=1+?, line=14
n=80L, return=1+0, line=14

program stack (compact representation)

:: show args, return value, and line number (if suspended)

```
int numzeros = countZeros( 800410L ); // called from main
```



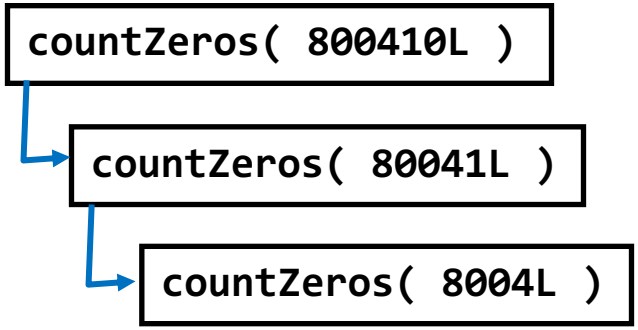
program stack:

numzeros=?, line=5
n=800410L, return=1+?, line=14
n=80041L, return=?, line=17
n=8004L, return=?, line=17
n=800L, return=1+1, line=14

program stack (compact representation)

:: show args, return value, and line number (if suspended)

```
int numzeros = countZeros( 800410L ); // called from main
```



program stack:

numzeros=?, line=5
n=800410L, return=1+?, line=14
n=80041L, return=?, line=17
n=8004L, return=2, line=17

program stack (compact representation)

:: show args, return value, and line number (if suspended)

```
int numzeros = countZeros( 800410L ); // called from main
```

```
countZeros( 800410L )
    countZeros( 80041L )
```

program stack:

numzeros=?, line=5
n=800410L, return=1+?, line=14
n=80041L, return=2, line=17

program stack (compact representation)

:: show args, return value, and line number (if suspended)

```
int numzeros = countZeros( 800410L ); // called from main
```

```
countZeros( 800410L )
```

program stack:

numzeros=?, line=5
n=800410L, return=1+2, line=14

program stack (compact representation)

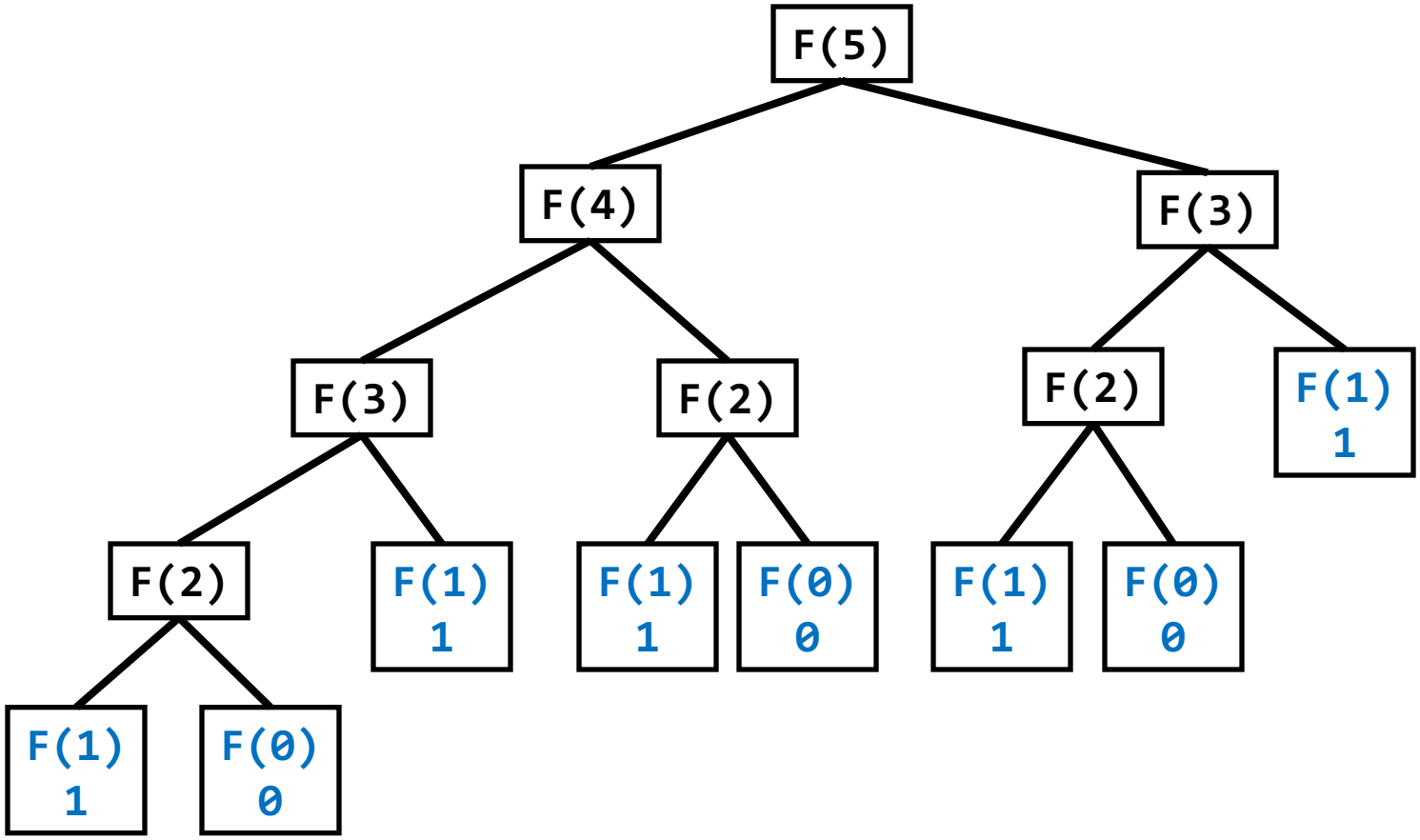
:: show args, return value, and line number (if suspended)

```
int numzeros = countZeros( 800410L ); // called from main
```

program stack:

numzeros=3

recursive tree (e.g. Fibonacci)



recursive tree (alternative manual trace)

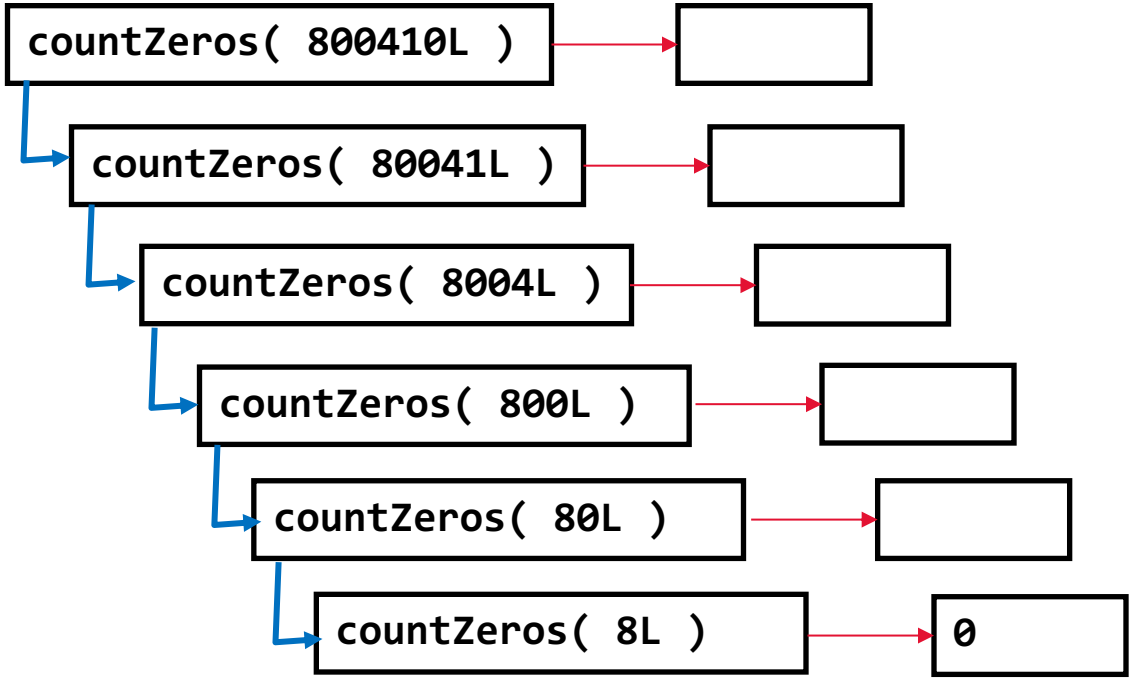
:: show method calls (indent to calling method), show return value (if appropriate)

```
int numzeros = countZeros( 800410L );
```

recursive tree (alternative manual trace)

:: show method calls (indent to calling method), show return value (if appropriate)

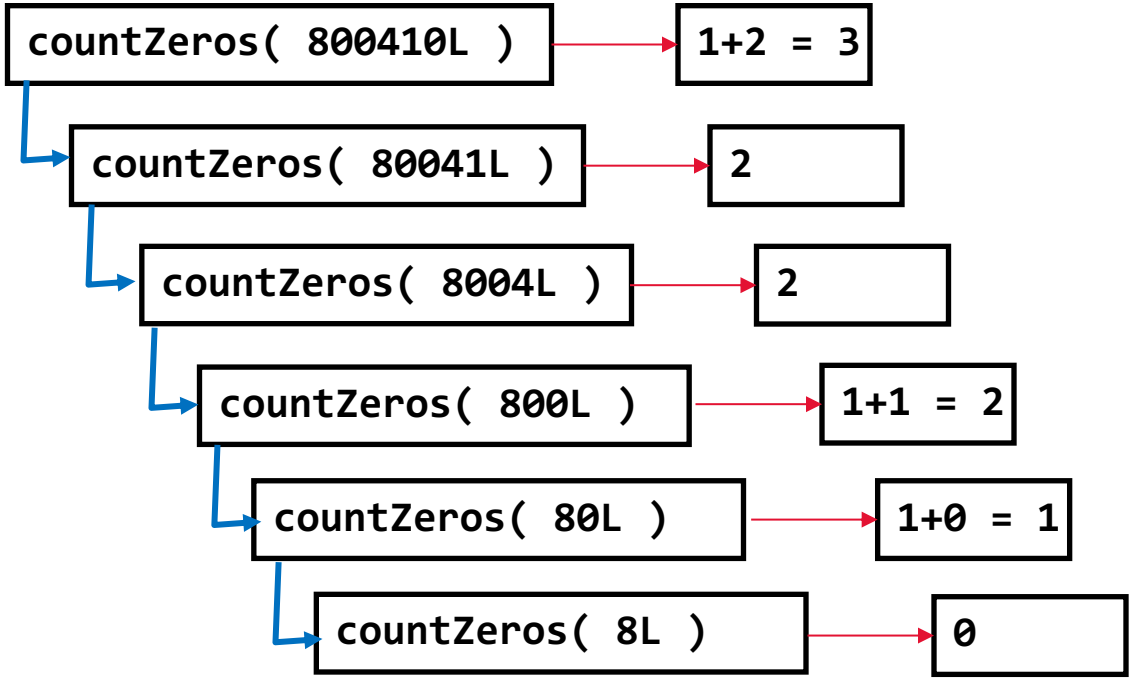
```
int numzeros = countZeros( 800410L );
```



recursive tree (alternative manual trace)

:: show method calls (indent to calling method), show return value (if appropriate)

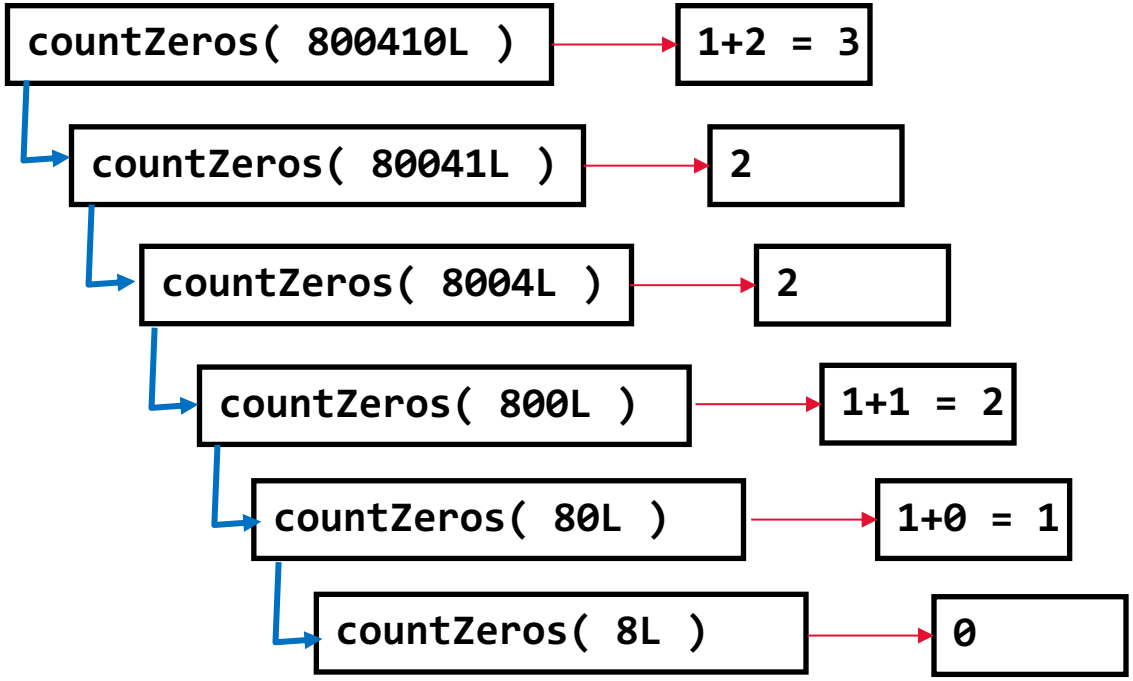
```
int numzeros = countZeros( 800410L );
```



recursive tree (alternative manual trace)

:: show method calls (indent to calling method), show return value (if appropriate)

```
int numzeros = countZeros( 800410L );
```



Other examples

- Palindrome
- Find maximum (array)
- Reverse a list

Palindrome

- A palindrome = a string that if reversed, is equal to itself
- E.g.
  - “radar” → when reversed = “radar” → is a palindrome
  - “racecar” → is a palindrome

  - “modem” ← not a palindrome

isPalindrome(String str)

```
public static boolean isPalindrome(String input) {

    boolean palindrome = false;

    if (input.length() <= 1) {
        palindrome = true;
    }
    else {
        // strategy:
        //      string is palindrome first and last char's are same, and
        //      middle part of string is also a palindrome

        char first = input.charAt(0);
        char last = input.charAt(input.length()-1);
        String middle = input.substring(1, input.length()-1);

        palindrome = ( (first==last) && isPalindrome(middle) );
    }

    return palindrome;
}
```

findMax(int[] input)

// typical iterative solution

```
public static int findMax(int[] input) {

    int max = input[0];

    for (int index=1; index<input.length; index++) {
        if (input[index]>max)
            max = input[index];
    }

    return max;
}
```

findMax(int[] input)

// lets assume you are asked to implement the following
// method to do the same thing, using recursion…

```
public static int findMax(int[] input) {


    // recursive implementation?


}
```

How to traverse array recursively?

- Method does not have arguments we need?
- No problem, create a helper method …

```
public static int findMaxHelper(int[] input, int index, int max);
```

findMax(int[] input)

// lets assume you are asked to implement the following
// method to do the same thing, using recursion…

```
public static int findMax(int[] input) {

    return findMaxHelper(input, 0, input[0]);

}

public static int findMaxHelper(int[] input,
                                int index, int max) {

    // implementation not shown
}
```

index → used to traverse array
max → used to track max so far

```
public static int findMaxHelper(int[] input,
                                int index, int max) {
    if (index<input.length) {
    // not at the end of the array yet

        if (input[index]>max)
          max = findMaxHelper(input, index+1, input[index]);
        else
          max = findMaxHelper(input, index+1, max);
    }

    return max;

}
```

index → used to traverse array
max → used to track max so far

```
public static int findMaxHelper(int[] input,
                                int index, int max) {
    if (index<input.length) {
    // not at the end of the array yet

        if (input[index]>max)
          max = findMaxHelper(input, index+1, input[index]);
        else
          max = findMaxHelper(input, index+1, max);
    }

    return max;

}
```

findMax using next index;
update max

index → used to traverse array
max → used to track max so far

```
public static int findMaxHelper(int[] input,
                                int index, int max) {
    if (index<input.length) {
    // not at the end of the array yet

        if (input[index]>max)
          max = findMaxHelper(input, index+1, input[index]);
        else
          max = findMaxHelper(input, index+1, max);
    }

    return max;

}
```

findMax using next index;
keep current max

Traversing (recursively)

- Strings: use substring() method
- Arrays: use index variable

- Lists (e.g. Arraylist)
  - we haven't considered collections yet so if not familiar don't worry
    - Use subList() method
    - Or .. can remove items from a list as they are processed

Approach to recursive design?

- What are the base cases? (smallest solutions we know)
  - Think about smallest possible input, and its solution
- What is the solution for an n-sized problem, in terms of a reduced version of the problem (e.g. n-1, n-2, etc.)?
- Combine both of the above into your solution
  - ensure base cases come first!

Homework questions (to think about)

```
/** write method to recursively sum elements in array*/
public static int arraySum(int[] input, int index) {
        // to implement
}


/** find number of elements in an array that are greater
        than a given number */
public static int countGreater(int[] input, int number,
                                                int index) {
        // to implement
}
```