P4 Sec 19.2) Recursion

Syllabus Content:

19.2 Recursion

- show understanding of recursion

Notes and guidance

  - Essential features of recursion.
  - How recursion is expressed in a programming Language.
  - Write and trace recursive algorithms

- Show awareness of what a compiler has to do to translate recursive program code.

Notes and guidance

  - Use of stacks and unwinding

Have you ever seen a set of Russian dolls? At first, you see just one figurine, usually painted wood, that looks something like this:

When we open the doll, we find another in it little smaller than the first one, then another one in it and so on. We started with one big Russian doll, and we saw smaller and smaller Russian dolls, until we saw one that was so small that it could not contain another.

What do Russian dolls have to do with algorithms? Just as one Russian doll has within it a smaller Russian doll, which has an even smaller Russian doll within it, all the way down to a tiny Russian doll that is too small to contain another, we'll see how to design an algorithm to solve a problem by solving a smaller instance of the same problem, unless the problem is so small that we can just solve it directly. We call this technique **recursion**.

Recursion

A very efficient way of programming is to make the same function work over and over again in order to complete a task.

One way of doing this is to use 'Recursion'.

Recursion is where a function or sub-routine calls itself as part of the overall process. Some kind of limit is built in to the function so that recursion ends when a certain condition is met.

Example

A *recursive* procedure is one that calls itself. In general, this is not the most effective way to write Visual Basic code.
The following procedure uses recursion to calculate the factorial of its original argument.

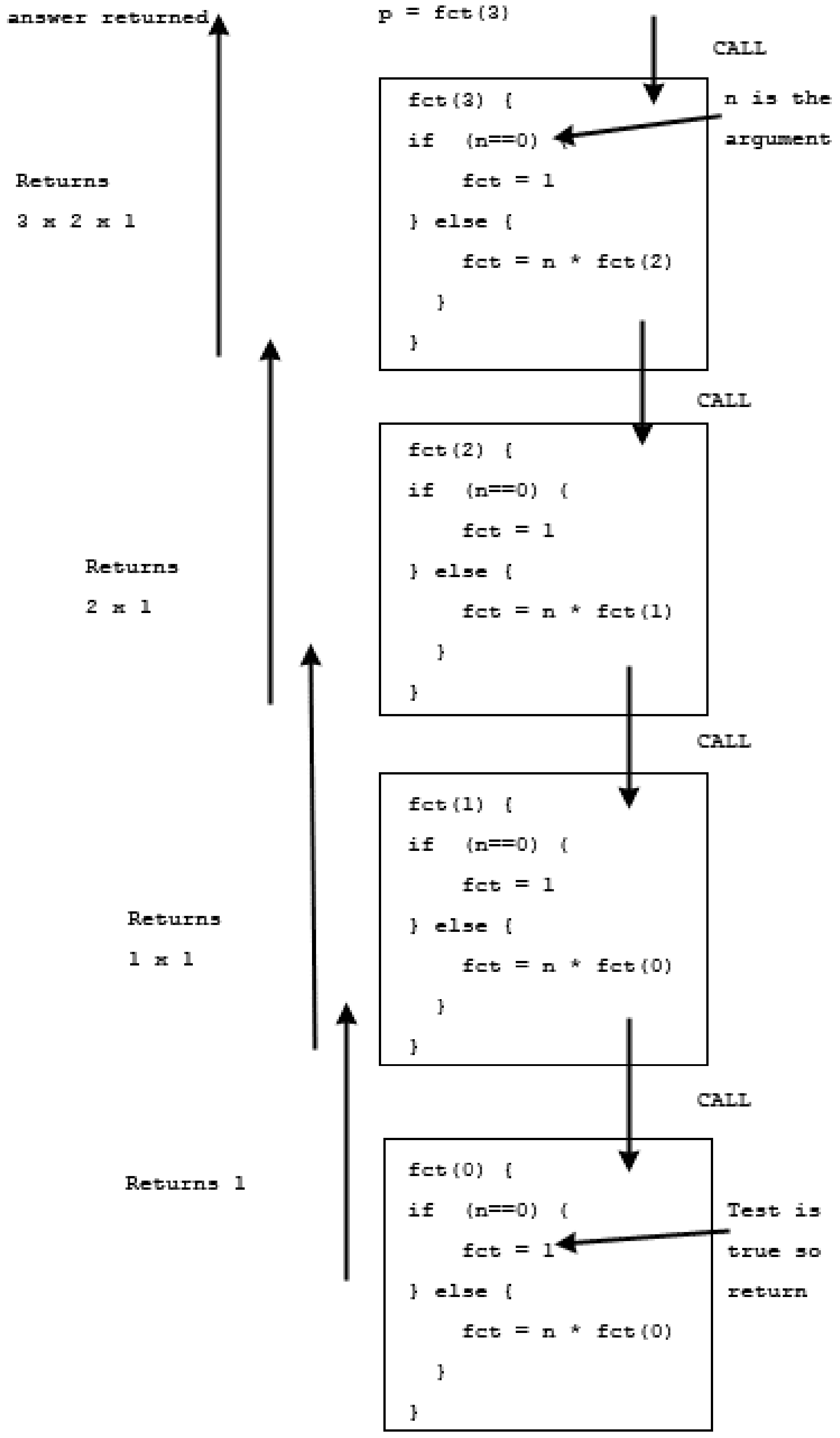
```
VB

Function Factorial(n As Integer) As Integer
    If n <= 1 Then
        Return 1
    End If
    Return Factorial(n - 1) * n
End Function
```

Step by step, this is what happens. Recursion winds and then unwinds.

A classic computer programming problem that make clever use of recursion is to find the factorial of a number. i.e. 4 factorial is

4! = 4 x 3 x 2 x 1
Lets see how **Recursion winds and unwinds** in program given below:



```
fct(3) {
if  (n==0) {
    fct = 1
} else {
    fct = n * fct(2)
  }
}
```

```
fct(2) {
if  (n==0) {
    fct = 1
} else {
    fct = n * fct(1)
  }
}
```

```
fct(1) {
if  (n==0) {
    fct = 1
} else {
    fct = n * fct(0)
  }
}
```

```
fct(0) {
if  (n==0) {
    fct = 1
} else {
    fct = n * fct(0)
  }
}
```

RECURSION EXAMPLE

The factorial function is called with argument 3

- 3 is passed as an argument to the factorial function 'fct'
- the test (if n==0) is false and so the else statement is executed
- the statement fct = n * fct(n-1) becomes
- fct = 3 * fct(2)
- In order to resolve this another call is made to factorial with argument 2 this time
- **RECURSION** happens i.e. the function is calling itself as fct(2)
- 2 is passed as an argument to the factorial function 'fct'
- the test (if n==0) is false and so the else statement is executed
- the statement fct = n * fct(2-1) becomes
- fct = 2 * fctl(1)
- In order to resolve this another call is made to factorial with argument 1 this time
- **RECURSION** happens i.e. the function is calling itself as fct(1)
- 1 is passed as an argument to the factorial function 'fct'
- the test (if n==0) is false and so the else statement is executed
- the statement fct = n * factorial(1-1) becomes
- fct = 1 * fct(0)
- In order to resolve this another call is made to factorial with argument 0 this time
- **RECURSION** happens i.e. the function is calling itself as fctl(0)
- the test (if n==0) is TRUE and so the value 1 is returned to the calling function
- now each function call returns a value to the previous one, until the first function called returns a value to 'p'.

Programming a recursive subroutine

We can program the function factorial iteratively using a loop:

```
FUNCTION Fictorial : INTEGER:  RETURS  INTEGER
      Result ←  1
      FOR i ←       1 to n
            Result←       Result  *  i
      NEXT
      RETURN Result
END FUNCTION
```

Or

```
FUNCTION Fictorial ( n : INTEGER)  RETURS  INTEGER
      IF n = 0
            THEN
                  Result ←       1
            ELSE
                  Result ←       n * Fictorial (n-1)

      END IF
RETURN Result
END FUNCTION
```

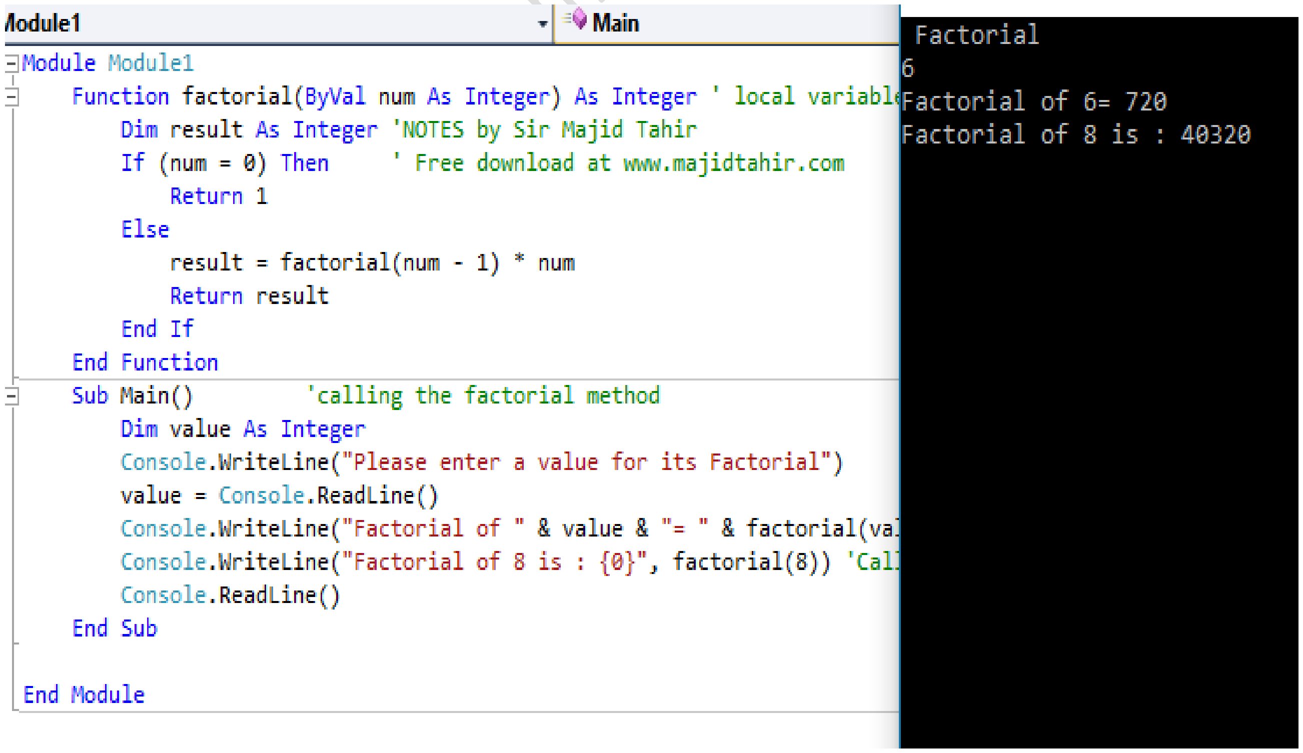
Programming a recursive subroutine in VB :

Following is an example that calculates factorial for a given number using a recursive function:

```
Module Module1
    Function factorial(ByVal num As Integer) As Integer ' local variable
declaration
        Dim result As Integer
        If (num = 0) Then
            Return 1
        Else
            result = factorial(num - 1) * num
            Return result
        End If
    End Function
    Sub Main()         'calling the factorial method

        Dim value As Integer
        Console.WriteLine("Please enter a value for its Factorial")
        value = Console.ReadLine()
        Console.WriteLine("Factorial of " & value & "= " & factorial(value))
        Console.WriteLine("Factorial of 8 is : {0}", factorial(8)) 'Calling
Factorial function with direct value
        Console.ReadLine()
    End Sub
End Module
```

When the above code is compiled and executed, it produces the following result:



```
Module Module1
    Function factorial(ByVal num As Integer) As Integer ' local variabl
        Dim result As Integer 'NOTES by Sir Majid Tahir
        If (num = 0) Then     ' Free download at www.majidtahir.com
            Return 1
        Else
            result = factorial(num - 1) * num
            Return result
        End If
    End Function
    Sub Main()         'calling the factorial method
        Dim value As Integer
        Console.WriteLine("Please enter a value for its Factorial")
        value = Console.ReadLine()
        Console.WriteLine("Factorial of " & value & "= " & factorial(va
        Console.WriteLine("Factorial of 8 is : {0}", factorial(8)) 'Cal
        Console.ReadLine()
    End Sub

End Module
```

```
 Factorial
6
Factorial of 6= 720
Factorial of 8 is : 40320
```

Advantage of recursion

- Very efficient use of code if problem is naturally recursive.

Disadvantage of recursion

- A faulty recursive function would never end and would rapidly run out of memory or result in a stack overflow thus causing the computer to freeze.
- Can be difficult to debug as it can fail many levels deep in the recursion
- Makes heavy use of the stack, which is a very limited resource compared to normal memory.

Recursion When to Use: You would process the list starting at the head or tail and then **recursively** traverse the list **using** the pointers. A tree is another case where **recursion** is often used Recursions are used when you satisfy of these conditions:

- You have a problem which is naturally recursive.
- The task must be indefinitely repetitive.
- At every round the same decision set must be applicable
- You can guarantee that you won't overflow the stack.

Function of compiler to implement recursion:

To understand this you just need to understand how a compiler interpret a function. The compiler does not need to know whether the function is recursive or not. It just make CPU jump to the address of function entry and keep on executing instructions.

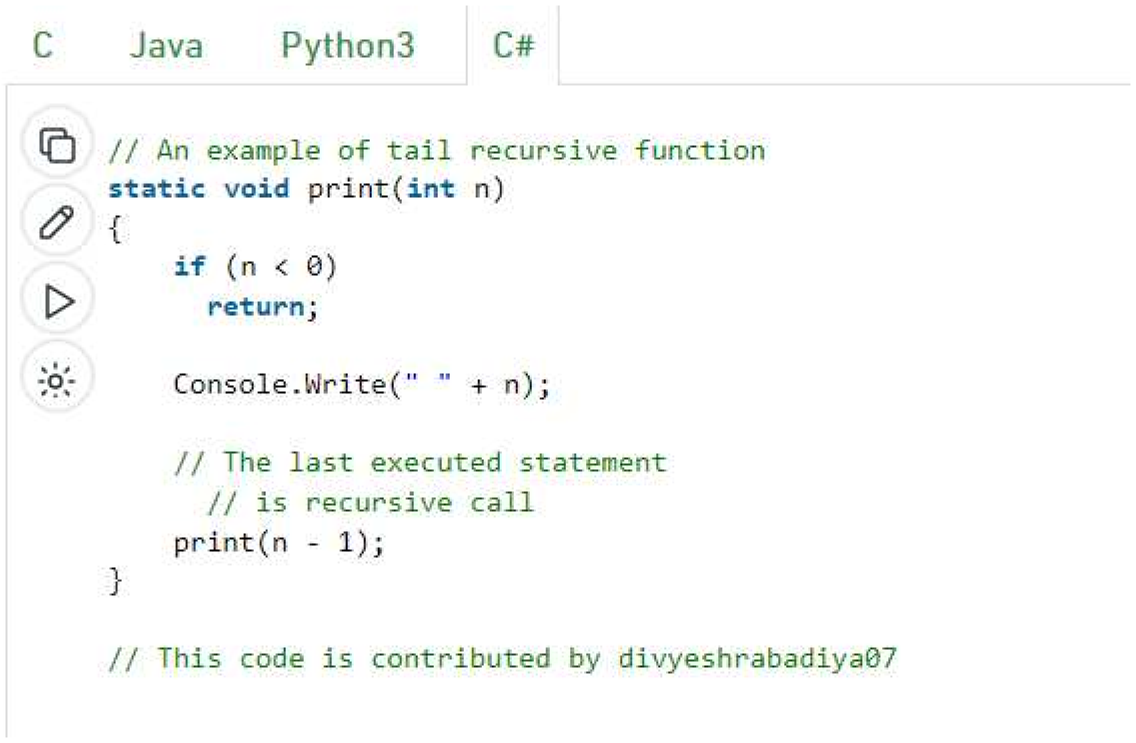
And that's why we can use that function even if its definition is not finished. The compiler just need to know a start address, or a symbol, and then it would know where to jump. The body of the function could be generated later.

However, you might want to know the **Tail Recursion**, that is a special case commonly in functional programming languages. The "tail recursion" means the recursive function call is the last statement in function definition.

What is tail recursion?

A recursive function is tail recursive when a recursive call is the last thing executed by the function.

For example the following C++ function print() is tail recursive.



```
// An example of tail recursive function
static void print(int n)
{
    if (n < 0)
      return;

    Console.Write(" " + n);

    // The last executed statement
      // is recursive call
    print(n - 1);
}

// This code is contributed by divyeshrabadiya07
```

Why do we care?

The tail recursive functions considered better than non tail recursive functions as tail-recursion can be optimized by the compiler.

- Compilers usually execute recursive procedures by using a **stack**. This stack consists of all the pertinent information, including the parameter values, for each recursive call.
- When a procedure is called, its information is **pushed** onto a stack, and when the function terminates the information is **popped** out of the stack.
- Thus for the non-tail-recursive functions, the **stack depth** (maximum amount of stack space used at any time during compilation) is more.
- The idea used by compilers to optimize tail-recursive functions is simple, since the recursive call is the last statement, there is nothing left to do in the current function, so saving the current function's stack frame is of no use.

References:
Computer Science AS & A Level Coursebook by Sylvia Langfield & Dave Duddell
https://www.geeksforgeeks.org/tail-recursion/
https://www.khanacademy.org/computing/computer-science/algorithms/recursive-algorithms/a/recursion
http://teach-ict.com/as_as_computing/ocr/H447/F453/3_3_6/defining_syntax/miniweb/pg22.htm
https://stackoverflow.com/questions/40796473/how-do-compilers-understand-recursion