Recursion

You will learn the definition of recursion as well as seeing how simple recursive programs work

What Is Recursion?

"*the determination of a succession of elements by operation on one or more preceding elements according to a rule or formula involving a finite number of steps*" (Merriam-Webster online)

What This Really Means

Breaking a problem down into a series of steps. The final step is reached when some basic condition is satisfied. The solution for each step is used to solve the previous step. The solution for all the steps together form the solution to the whole problem.

(The "Tam" translation)

Definition For Philosophy

"*...state of mind of the wise man; practical wisdom...*" [1]

See Metaphysics

1 The New Webster Encyclopedic Dictionary of the English Language

Metaphysics

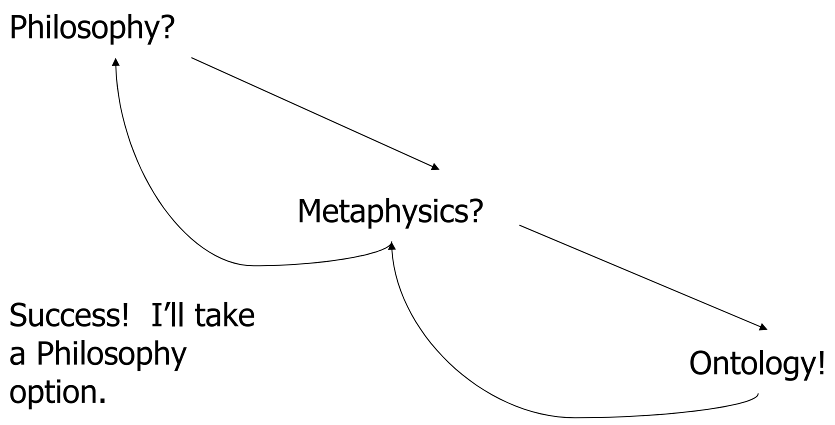
"...know the ultimate grounds of being or what it is that really exists, embracing both psychology and ***ontology*****."** [2]

2 The New Webster Encyclopedic Dictionary of the English Language

Result Of Lookup , Possibility One: Success

•I know what Ontology means!

Result Of Lookup, Possibility One

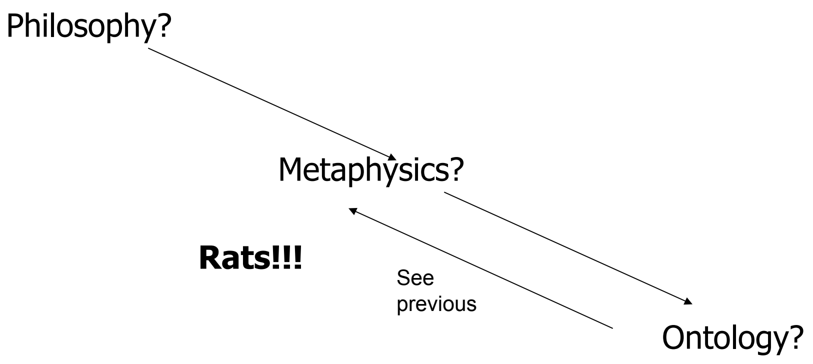


Success! I'll take a Philosophy option.

Result Of Lookup, Possibility Two: Failure

•Lookups loop back.

Result Of Lookup, Possibility Two



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Ontology

"*...equivalent to metaphysics.*"[3]

3 The New Webster Encyclopedic Dictionary of the English Language

Wav file from "The Simpsons"

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Result Of Lookup, Possibility Three: Failure

- You've looked up everything and still don't know the definition!

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Looking Up A Word

```
if (you completely understand a definition) then
    return to previous definition (using the definition that's understood)
else
   lookup (unknown word(s))
```

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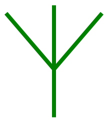
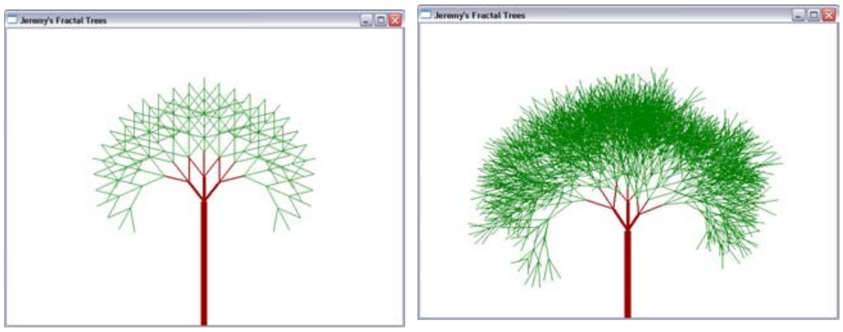
Recursion: Can Be Used To Produce Graphics

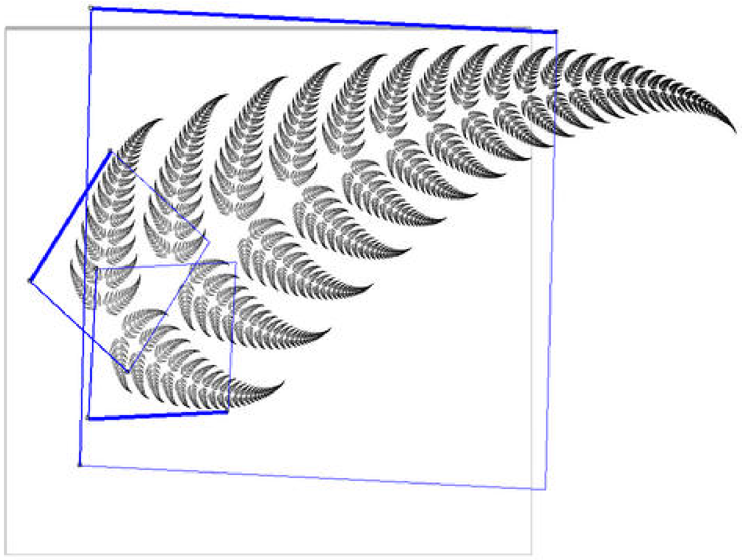


Produce a picture by repeating a pattern



Images from http://www.csis.gvsu.edu/~marzkaj/CS367/project1.htm

Recursion: Can Be Used To Produce Graphics (2)

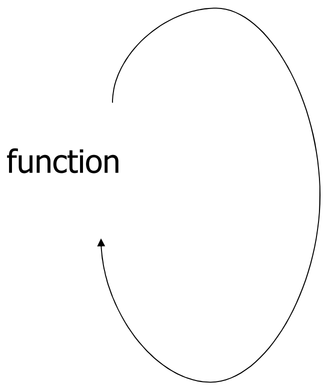


http://charm.cs.uiuc.edu/users/olawlor

Recursion In Programming

"*A programming technique whereby a function calls itself either directly or indirectly*."

Direct Call



```
def fun ():
     :
   fun ()
     :
```

Indirect Call

$$\begin{tikzcd}
f^1 \arrow[dr, bend left] & \\
& f^2 \arrow[ul, bend left]
\end{tikzcd}$$

Indirect Call

$$\begin{tikzcd}
f^1 \arrow[dr, bend left] &&&& \\
& f^2 \arrow[dr, bend left] &&& \\
&& f^3 \arrow[dr, bend left] && \\
&&& \cdots \arrow[dr, bend left] & \\
&&&& f^n \arrow[uuuullll, bend left]
\end{tikzcd}$$

Indirect Call (2)

Name of the example program: recursive.1py

```
def fun1 ():
  fun2 ()

def fun2 ():
  fun1 ()

fun1 ()
```

Requirements For Sensible Recursion

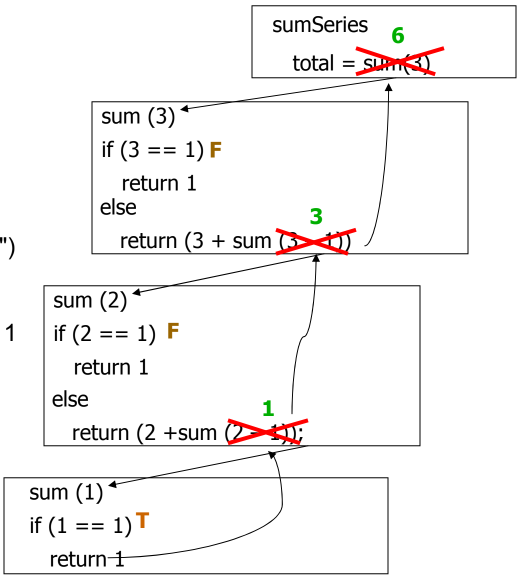
1) Base case
2) Progress is made (towards the base case)

Example Program

```
def sum (no):
   if (no == 1):
      return 1
   else:
      return (no + sum(no-1) )


def main ():
   last = input ("Enter the last
                   number in the series: ")
   last = (int) last
   total = sum (last)
   print ("The sum of the series from 1
                 to", last, "is", total)

main ()
```



When To Use Recursion

- When a problem can be divided into steps.
- The result of one step can be used in a previous step.
- There is a scenario when you can stop sub-dividing the problem into steps (recursive calls) and return to previous steps.
- All of the results together solve the problem.

When To Consider Alternatives To Recursion

- When a loop will solve the problem just as well
- Types of recursion:
  - Tail recursion
    - A recursive call is the last statement in the recursive function.
    - This form of recursion can easily be replaced with a loop.
  - Non-tail recursion
    - A statement which is not a recursive call to the function comprises the last statement in the recursive function.
    - This form of recursion is very difficult (read: impossible) to replace with a loop.

Example: Tail Recursion

- Tail recursion: A recursive call is the last statement in the recursive function.
- Name of the example program: tail.py

```
def tail (no):
  if (no <= 5):
    print (no)
    tail (no+1)

tail (5)
```

Example: Non-Tail Recursion

- Non-Tail recursion: A statement which is not a recursive call to the function comprises the last statement in the recursive function.
- Name of the example program: nontTail.py

```
def nonTail (no):
  if (no < 5):
    nonTail (no+1)
  print (no)

nonTail(1)
```

Drawbacks Of Recursion

Function calls can be costly

- Uses up memory
- Uses up time

Benefits Of Using Recursion

- Simpler solution that's more elegant (for some problems)
- Easier to visualize solutions (for some people and certain classes of problems – typically require either: non-tail recursion to be implemented or some form of "backtracking")

Common Pitfalls When Using Recursion

- These three pitfalls can result in a runtime error
  - No base case
  - No progress towards the base case
  - Using up too many resources (e.g., variable declarations) for each function call

No Base Case

```
def sum (no):
 return (no + sum (no - 1))
```

James Tam

No Base Case

```
def sum (no):
 return (no + sum (no - 1))
```

When does it stop???

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No Progress Towards The Base Case

```
def sum (no):
  if (no == 1):
    return 1
  else:
    return (no + sum (no))
```

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No Progress Towards The Base Case

```
def sum (no):
  if (no == 1):
    return 1
  else:
    return (no + sum (no))
```

The recursive case doesn't make any progress towards the base (stopping) case

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Using Up Too Many Resources

- Name of the example program: recursion2.py

```
def fun (no):
   print (no)
   aList = []
   for i in range (0, 10000000, 1):
      aList.append("*")
   no = no + 1
   fun (no)


fun(1)
```

Undergraduate Definition Of Recursion

Word: **re·cur·sion**

Pronunciation: ri-'k&r-zh&n

Definition: See recursion

Wav file from “The Simpsons”

You Should Now Know

- What is a recursive computer program
- How to write and trace simple recursive programs
- What are the requirements for recursion/What are the common pitfalls of recursion