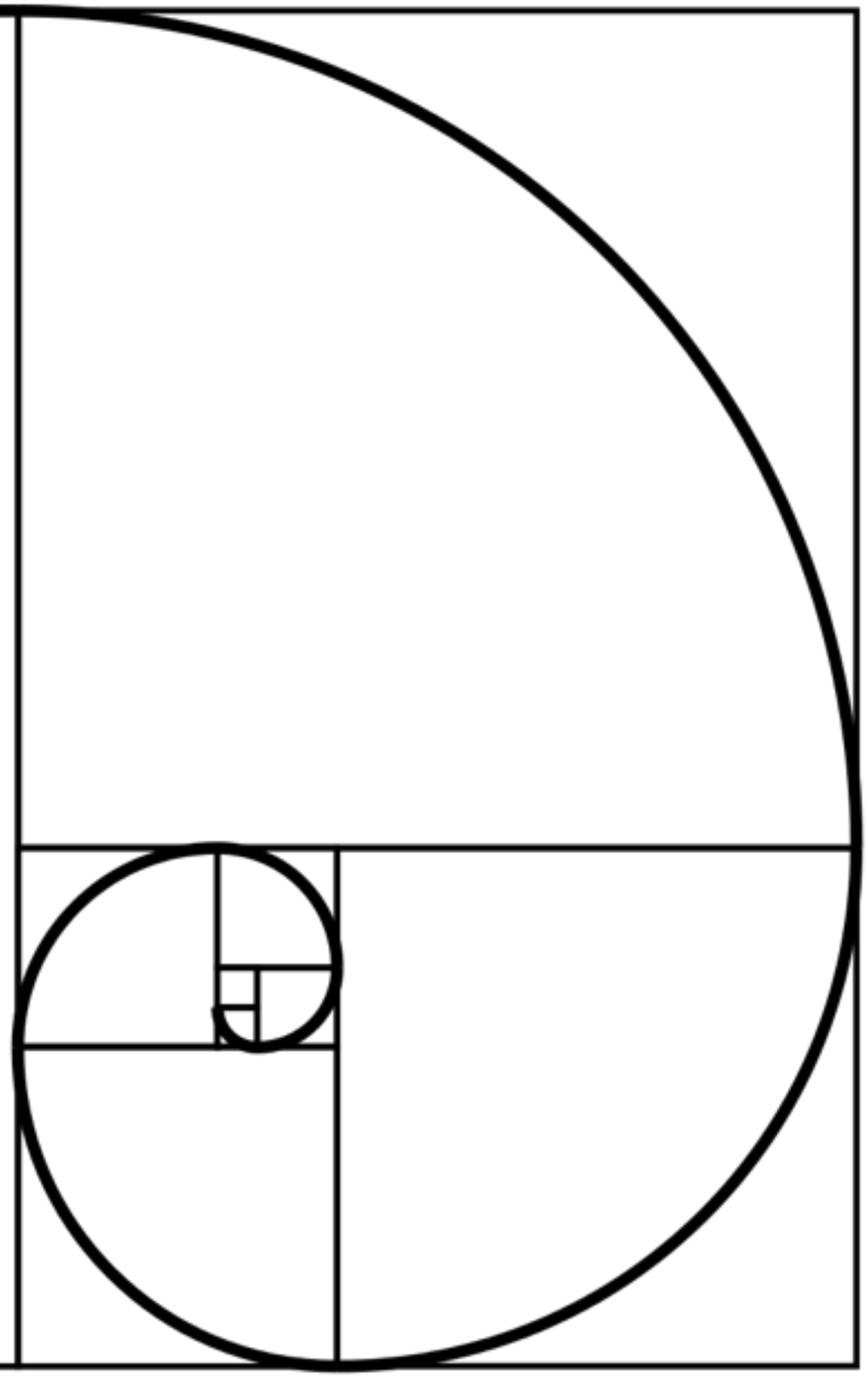
Functions



Gordon Erlebacher and Peter Beerli

Function Tutorials

- Intro to functions
  - http://anh.cs.luc.edu/python/hands-on/3.1/handsonHtml/functions.html
- More on functions
  - http://www.tutorialspoint.com/python/python_functions.htm

What is a Function

- In math: a function is a mapping:
  - input ==> unique output
- In Python:
  - input ==> unique (or no) output
  - However, something must happen
    - change a global variable
    - output to a file, a pipe, to the web

Kinds of Functions

- Simplest regular function
  - def funct(args):
    pass
- Simplest nontrivial Lambda function
  - a = lambda x: x+2
    a(5) # ==> 7

Python supports the creation of anonymous functions (i.e. functions that are not bound to a name) at runtime, using a construct called **lambda**.

Function Arguments

- def add(x,y):
    return x+y

- def add(a,b,*lst):
    return a + b + sum(lst)

  add(5,3,7,8,9)   # ==> 32

Keyword arguments

- def return_args(a,b,c):
  return a,b,c # also return (a,b,c)
- add(b=27,a=2,c=10) # ==> (2, 27, 10)
- add(2,c=5,b=3) # ==> (2 ,3, 5)
- add(2,c=5,a=3) # error
  - b not defined
- add(b=3,a=2,3) # error
  - keywords must come first

Default Arguments

- def add(x,y=3):
  return x+y
- add(5) # returns 8
- add(5,8) # returns 13

- if less arguments are specified than the number of arguments, the missing arguments take default values
- missing arguments can take default values *if all* given arguments use keywords
- cannot have default arguments and at the same time have arbitrary number of arguments! Why?
- useful for very long argument lists

Variable Number of Arguments

- A function as 2 arguments, but 4 arguments are passed
- def add(x,y,*kw): # add all arguments
  return x+y+sum(kw)
- add(3,4,5,6) # returns 18
- add(3,4,5,6,7) # returns 25
- Cannot use keyword arguments if there are more than 2 arguments since kw is a list of non-keyword arguments, and keywords come after non-keyword arguments

Dictionary argument

- def add(a,b,**kww):
  try:
  print "N:", kww['N']
  except:
  print "no keyword N"
  return a+b
- kww returns all excess key-value pairs
- add(3,5,N=35,h=2)
  - returns ==> N: 35
- add(3,5,NN=35,h=2)
  - returns ==> 'no keyword N'
  - type of NN is a string

Functions are references

- def add(a,b):
    return a+b
  def sub(a,b):
    return a-b

- v = add
  v(3,4)   # ==> 7
  v = sub
  v(3,4)   # ==> -1

- v = [sub, add]
  for i in v:
    print i(5,9)   # returns -4 and 14

Functions are references

- def calc(fct, a, b):
    return fct(a,b)
- v = [add, sub]
  for i in v:
      calc(i,5,8)
- returns 13 and -3

Callbacks

- A reference can be used like any variable
- A variable can be a function argument
  - therefore, a function argument can be a function
- Callback: use functions as arguments

First order Differential Equation

```
""" Solve an ODE via a first order Euler method.
    Compute the error as a function of time as:

    We solve dy/dt = rhs(y,t)  for x in [a,b]

    rhs(y,t): right hand side

"""
from pprint import pprint
#-------------------------------------------------------
def ode(interv, sol0, max_iter, rhs, dt):
    y = [sol0]
    a = interv[0]
    b = interv[1]
    t = 0.
    iter = 0

    while t < b and iter < max_iter:
        ynew = y[-1] + dt * rhs(y[-1],t)
        y.append(ynew)
        iter += 1
        t += dt
    return y
```

```
def rhs1(y,t):
    return(-y)

def rhs2(y,t):
    return(-3.*y)

def rhs3(y,t):
    return(-15.*y)
#-------------------------------------------------------
if __name__ == "__main__":
    interv, sol0, max_iter, rhs , dt =  \
            ([1,5], 1., 1000, rhs3, .2)

    tests = [rhs1, rhs2, rhs3]
    for rhs in tests:
        sol = ode(interv, sol0, max_iter, rhs, dt)
        ti = [ dt*i for i in range(0,len(sol)) ]
        sol = [[t,s] for t,s in zip(ti,sol)]
        pprint(sol)
        print "======================"
```

Three different ODEs

Lambda expressions

- useful to define functions directly in arguments
- elegant, but not necessary
- lambda x,y : body of function
- fct = lambda x,y : x+y
  fct(3,4) # returns 7
- fct is used like any other function

Flexibility of functions

- Can use functions like any other reference
- Functions can be "transported" from place to place
- Functions can be stored in files
  - use eval or exec to evaluate them
  - (EXAMPLE)

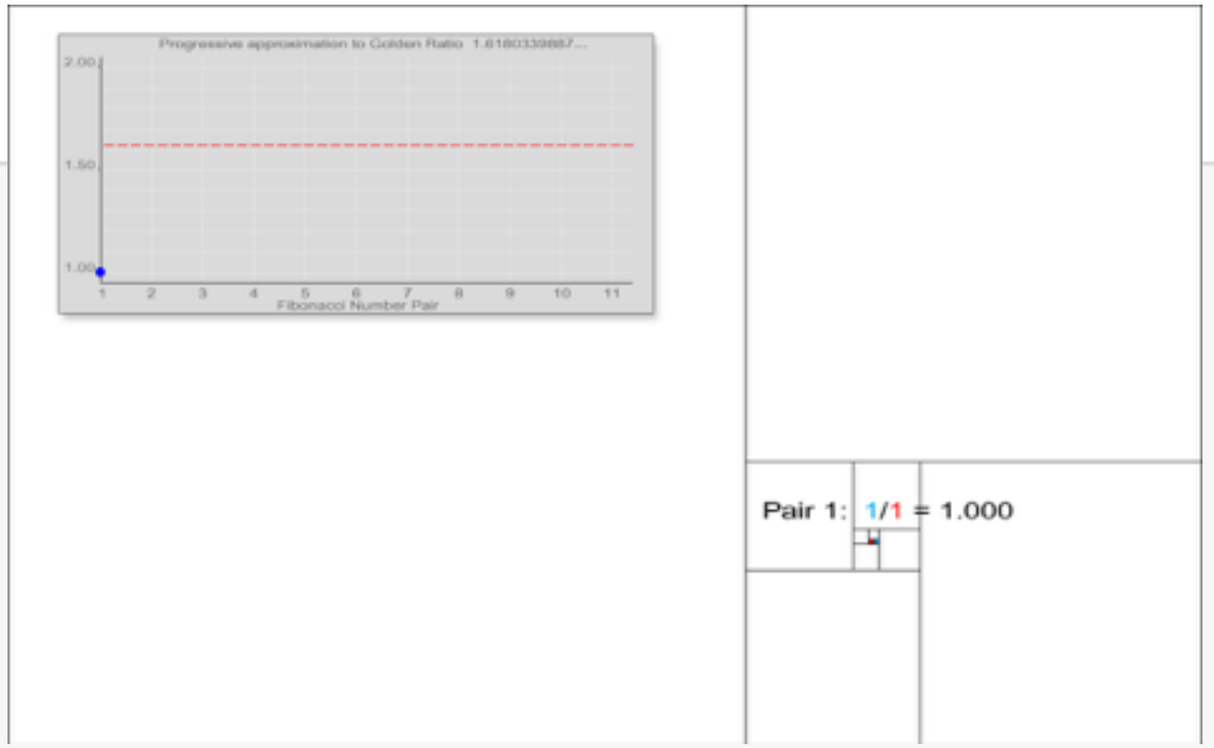
Recursive Functions

In [1]:
```
def factorial(n):
    # assume n > 0
    if (n <= 1):
        return 1
    else:
        return n*factorial(n-1)
```

Use of Recursive Functions

- Any problem where a subset has a similar structure to the whole
  - fractals
  - trees, binary trees, quad-trees, oct-trees
  - solution to recursions
    - a[n+1] = a[n] + a[n-1]
      a[0] = 0, a[1] = 1
- Harder to program without recursion, although possible
- Use recursion if easier. If too slow, remove recursion at a later stage of development.

Fibonacci sequence




```
"""
  Solve a[n+1] = a[n] + a[n-1]
        a[0] = 0
        a[1] = 1
"""

def recursion(n):
    if n == 0: return 0
    elif n == 1: return 1
    else:
        return recursion(n-1) + recursion(n-2)

#-----------------------------------------------

if __name__ == "__main__":
    for i in xrange(100):
        print recursion(i),
```

```
0 1 1 2 3 5 8 13 21 34 55 89 144 233 377 610 987 1597 2584 4181 6765 10946 17711 28657 46368 7502
832040 1346269 2178309 3524578 5702887 9227465 14930352 24157817 39088169 63245986
```

Function methods

```
a = lambda x: 1
print dir(a)
```

```
['__call__', '__class__', '__closure__', '__code__', '__defaults__', '__de
lattr__', '__dict__', '__doc__', '__format__', '__get__', '__getattribute_
_', '__globals__', '__hash__', '__init__', '__module__', '__name__', '__ne
w__', '__reduce__', '__reduce_ex__', '__repr__', '__setattr__', '__sizeof_
_', '__str__', '__subclasshook__', 'func_closure', 'func_code', 'func_defa
ults', 'func_dict', 'func_doc', 'func_globals', 'func_name']
```

```
print (dir(a.func_code))
```

```
['__class__', '__cmp__', '__delattr__', '__doc__', '__eq__', '__format__',
'__ge__', '__getattribute__', '__gt__', '__hash__', '__init__', '__le__',
'__lt__', '__ne__', '__new__', '__reduce__', '__reduce_ex__', '__repr__',
'__setattr__', '__sizeof__', '__str__', '__subclasshook__', 'co_argcount',
'co_cellvars', 'co_code', 'co_consts', 'co_filename', 'co_firstlineno', 'c
o_flags', 'co_freevars', 'co_lnotab', 'co_name', 'co_names', 'co_nlocals',
'co_stacksize', 'co_varnames']
```

One can do interesting things with all these functions!

Context

- All variables inside a function are local
- Global variables can be accessed but not changed except via the *global* declaration
  (the web: "If you want to simply access a global variable you just use its name. However to **change** its value you need to use the global keyword.")

- A global variable can be defined from within a function!

```
def example():
    global v
    v = 5

print v          # returns 5. Exception without global
```

```
total = 9
globvar = 11

def add(a, b):
    total = 3       # does not affect global variable
    return a+b+total+globvar

def add_glob(a, b):
    global total
    total = 3       # changes the global variable total
    return a+b+total

print add(3,5)       # returns 22 (3+5+3+11)
print total          # returns 9
print add_glob(3,5)  # returns 17
print total          # returns 3
```

Variable Types

- locals() : local variables
- globals() : global variables
- vars(obj) : object dictionary
- vars() : same as locals()

```
total, newvar = 9, 11

def add(a, b):
    total = 3
    print "locals= ", locals()
    print "globals= ", globals()
    return a+b+total+newvar

def add_glob(a, b):
    global total
    total = 3  # changes the global total
    print "locals= ", locals()
    print "globals= ", globals()
    return a+b+total

add(3,4)
print "------------------------"
add_glob(3,4)
```

Output

```
locals=  {'a': 3, 'total': 3, 'b': 4}
globals=  {'add_glob': <function
add_glob at 0x379830>, '__builtins__':
<module '__builtin__' (built-in)>,
'__file__': 'context.py', '__package__':
None, 'add': <function add at
0x379870>, '__name__': '__main__',
'total': 9, 'newvar': 11, '__doc__': None}
------------------------
locals=  {'a': 3, 'b': 4}
globals=  {'add_glob': <function
add_glob at 0x379830>, '__builtins__':
<module '__builtin__' (built-in)>,
'__file__': 'context.py', '__package__':
None, 'add': <function add at
0x379870>, '__name__': '__main__',
'total': 3, 'newvar': 11, '__doc__': None}
```

vars()

```
a = lambda x: x + 3
a.func_dict['location'] = 'scs_class'
print "\nvars= ", vars(), '\n'
print "vars(a)= ", vars(a)
```

Output

```
python vars_demo.py

vars=  {'a': <function <lambda>
at 0x379830>, '__builtins__':
<module '__builtin__' (built-
in)>, '__file__': 'vars_demo.py',
'__package__': None,
'__name__': '__main__',
'__doc__': None}

vars(a)=  {'location': 'scs_class'}
```

Returning a function

- Very straightforward
- Function is a reference variable
- Given a function, one can find out how many arguments it has and other properties

```
def add(x,y):
    return x + y

def add_more(fct, n):
    return lambda x,y: fct(x,y)+n

add_10 = add_more(add, 10)
print add_10(1,2)  # ==> 13 = 1+2-7

add_7 = add_more(add, -7)
print add_7(1,2)  # ==> -4 = 1+2-7

def add_list(fct, lst):
    def add_list(lst):
        return fct(lst[0], lst[1])
    return add_list

add_list = add_list(add, [3,5])
print add_list([5,2])  # ==> 7
```

Return function

Return function

Function Properties

```
def add(*kw, **kww):
    def newfunc(a, *lst):
        z = 3
        return a + sum(kw) + sum(lst)
    return newfunc

newfunc = add(3,5,a=10)
print newfunc(10,20,30)  # 68 = 3+5+10+20+30
print dir(newfunc)
print "name: " , newfunc.func_name
print "globals: ", newfunc.func_globals
print "freevars: ", newfunc.func_code.co_freevars
print "arg count: ", newfunc.func_code.co_argcount # ==> 1
print " etc ..."
```

```
68
['__call__', '__class__', '__closure__', '__code__', '__defaults__', '__delattr__',
'__dict__', '__doc__', '__format__', '__get__', '__getattribute__', '__globals__',
'__hash__', '__init__', '__module__', '__name__', '__new__', '__reduce__',
'__reduce_ex__', '__repr__', '__setattr__', '__sizeof__', '__str__', '__subclasshook__',
'func_closure', 'func_code', 'func_defaults', 'func_dict', 'func_doc', 'func_globals',
'func_name']
name:  newfunc
globals:  {'__builtins__': <module '__builtin__' (built-in)>, '__file__': 'temp.py',
'__package__': None, 'add': <function add at 0x1006d5848>, '__name__': '__main__',
'__doc__': None, 'newfunc': <function newfunc at 0x1006d55f0>}
freevars:  ('kw',)
arg count:  1
 etc ...
```