ESTRUCTURA DE DATOS

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22P

PYTHON PROGRAMMING EXPRESS

MATERIAL BASADO EN CURSO DE JOHN ZELLE

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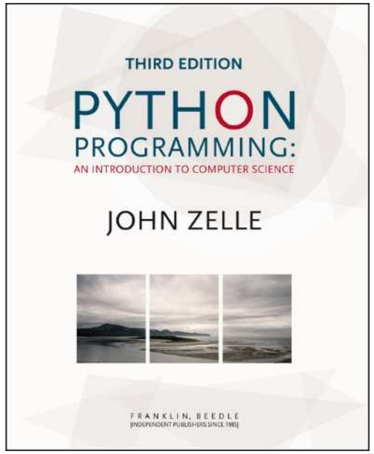
Introduction

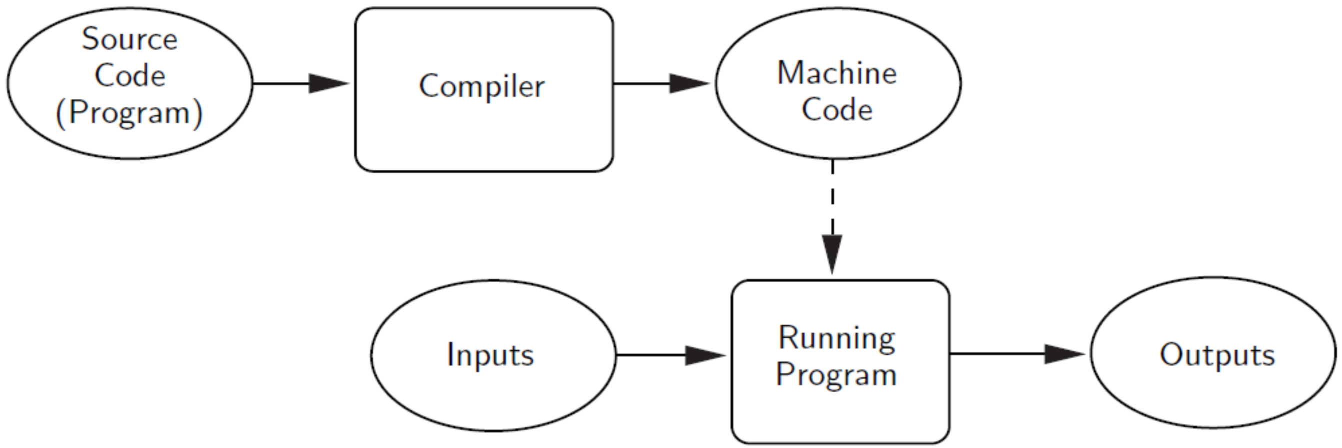
Homepage

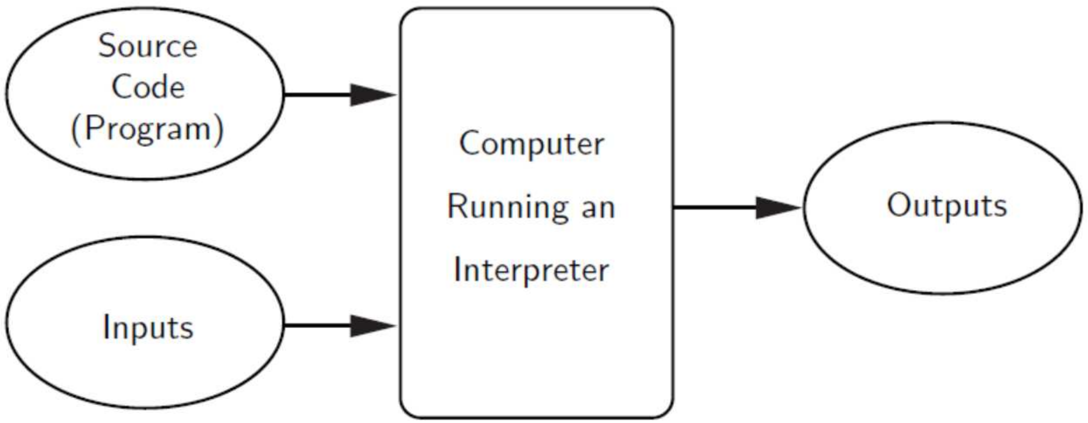
Books



The Magic of Python

Compiled vs Interpreted Programming Languages





The Magic of Python

- The “>>>” is a Python *prompt* indicating that Python is ready for us to give it a command. These commands are called *statements*.

```
>>> print("Hello, world")
Hello, world
>>> print(2+3)
5
>>> print("2+3=", 2+3)
2+3= 5
>>>
```

- Usually we want to execute several statements together that solve a common problem. One way to do this is to use a function.

```
>>> def hello():
        print("Hello")
        print("Computers are Fun")

>>>
```

The Magic of Python

```
# File: chaos.py
# A simple program illustrating chaotic behavior

def main():
    print("This program illustrates a chaotic function")
    x = eval(input("Enter a number between 0 and 1: "))
    for i in range(10):
        x = 3.9 * x * (1 - x)
        print(x)

main()
```

- We'll use *filename.py* when we save our work to indicate it's a Python program.
- In this code we're defining a new function called **main**.
- The main() at the end tells Python to run the code.

Example Program: Temperature Converter

```
#convert.py
# A program to convert Celsius temps to Fahrenheit
# by: Susan Computewell

def main():
    celsius = eval(input("What is the Celsius
  temperature? "))
    fahrenheit = (9/5) * celsius + 32
    print("The temperature is ",fahrenheit," degrees
  Fahrenheit.")

main()
```

Simultaneous Assignment

We can swap the values of two variables quite easily in Python! `x, y = y, x`

```
>>> x = 3
>>> y = 4
>>> print(x, y)
3 4
>>> x, y = y, x
>>> print(x, y)
4 3
```

Definite Loops

```
for <var> in <sequence>:
      <body>
```

The beginning and end of the body are indicated by indentation.

```
>>> for i in [0,1,2,3]:
            print (i)
>>> for odd in [1, 3, 5, 7]:
            print(odd*odd)
>>>
```

Example Program: Future Value

```
# futval.py
#    A program to compute the value of an investment
#    carried 10 years into the future


def main():
    print("This program calculates the future value of a 10-year investment.")


    principal = eval(input("Enter the initial principal: "))
    apr = eval(input("Enter the annual interest rate: "))


    for i in range(10):
        principal = principal * (1 + apr)


    print ("The value in 10 years is:", principal)


main()
```

Numeric Data Types

- Python has a special function to tell us the data type of any value.
- Operations on ints produce ints, operations on floats produce floats (except for /).

```
>>> type(3)
<class 'int'>
>>> type(3.1)
<class 'float'>
>>> type(3.0)
<class 'float'>
>>> myInt = 32
>>> type(myInt)
<class 'int'>
>>>
```

```
>>> 3.0+4.0
7.0
>>> 3+4
7
>>> 3.0*4.0
12.0
>>> 3*4
12
>>> 10.0/3.0
3.3333333333333335
>>> 10/3
3.3333333333333335
>>> 10 // 3
3
>>> 10.0 // 3.0
3.0
```

```
>>> float(22//5)
4.0
>>> int(4.5)
4
>>> int(3.9)
3
>>> round(3.9)
4
>>> round(3)
3
>>> round(3.1415926,
   2)
3.14
```

Type Conversions & Rounding

```
# change.py
#   A program to calculate the value of some change in dollars

def main():
    print("Change Counter")
    print()
    print("Please enter the count of each coin type.")
    quarters = int(input("Quarters: "))
    dimes = int(input("Dimes: "))
    nickels = int(input("Nickels: "))
    pennies = int(input("Pennies: "))
    total = quarters * .25 + dimes * .10 + nickels * .05 + pennies * .01
    print()
    print("The total value of your change is", total)
```

Using the Math Library

```
# quadratic.py
#    A program that computes the real roots of a quadratic equation.
#    Illustrates use of the math library.
#    Note: This program crashes if the equation has no real roots.

import math  # Makes the math library available.

def main():
    print("This program finds the real solutions to a quadratic")
    print()

    a, b, c = eval(input("Please enter the coefficients (a, b, c): "))

    discRoot = math.sqrt(b * b - 4 * a * c)
    root1 = (-b + discRoot) / (2 * a)
    root2 = (-b - discRoot) / (2 * a)

    print()
    print("The solutions are:", root1, root2 )
```

Using the Math Library

Python	Mathematics	English
pi	π	An approximation of pi
e	e	An approximation of e
sqrt(x)	$\sqrt{x}$	The square root of x
sin(x)	$\sin x$	The sine of x
cos(x)	$\cos x$	The cosine of x
tan(x)	$\tan x$	The tangent of x
asin(x)	$\arcsin x$	The inverse of sine x
acos(x)	$\arccos x$	The inverse of cosine x
atan(x)	$\arctan x$	The inverse of tangent x

Python	Mathematics	English
log(x)	$\ln x$	The natural (base *e*) logarithm of *x*
log10(x)	$\log_{10} x$	The common (base 10) logarithm of *x*
exp(x)	e^x	The exponential of x
ceil(x)	$\lceil x \rceil$	The smallest whole number >= *x*
floor(x)	$\lfloor x \rfloor$	The largest whole number <= *x*

Accumulating Results: Factorial

```
# factorial.py
#    Program to compute the factorial of a number
#    Illustrates for loop with an accumulator

def main():
    n = eval(input("Please enter a whole number: "))
    fact = 1
    for factor in range(n,1,-1):
       fact = fact * factor
    print("The factorial of", n, "is", fact)

main()
```

The Limits of Int

- What is 100!?

```
>>> main()
Please enter a whole
   number: 100
The factorial of 100 is
   9332621544394415268169923
   8856266700490715968264381
   6214685929638952175999932
   2991560894146397615651828
   6253697920827223758251185
   2109168640000000000000000
   00000000
```

- Wow! That’s a pretty big number!

- Floats are approximations
- Floats allow us to represent a larger range of values, but with fixed precision.
- Python has a solution, expanding ints!
- Python ints are not a fixed size and expand to handle whatever value it holds.

The String Data Type

```
>>> str1="Hello"
>>> str2='spam'
>>> print(str1, str2)
Hello spam
>>> type(str1)
<class 'str'>
>>> type(str2)
<class 'str'>
```

The String Data Type

Getting a string as input

```
>>> firstName = input("Please enter your name: ")
Please enter your name: John
>>> print("Hello", firstName)
Hello John
```

Notice that the input is not `eval`uated. We want to store the typed characters, not to evaluate them as a Python expression.

The String Data Type

H	e	l	l	o		B	o	b
0	1	2	3	4	5	6	7	8

```
>>> greet = "Hello Bob"
>>> greet[0]
'H'
>>> print(greet[0], greet[2], greet[4])
H l o
>>> x = 8
>>> print(greet[x - 2])
B
```

The String Data Type

H	e	l	l	o		B	o	b
0	1	2	3	4	5	6	7	8

In a string of *n* characters, the last character is at position *n-1* since we start counting with 0.

We can index from the right side using negative indexes.

```
>>> greet[-1]
'b'
>>> greet[-3]
'B'
```

The String Data Type

Slicing:

`<string>[<start>:<end>]`

- `start` and `end` should both be ints
- The slice contains the substring beginning at position `start` and runs up to **but doesn't include** the position `end`.

The String Data Type

H	e	l	l	o		B	o	b
0	1	2	3	4	5	6	7	8

```
>>> greet[0:3]
'Hel'
>>> greet[5:9]
' Bob'
>>> greet[:5]
'Hello'
>>> greet[5:]
' Bob'
>>> greet[:]
'Hello Bob'
```

The String Data Type

- The function *len* will return the length of a string.

```
>>> "spam" + "eggs"
'spameggs'
>>> "Spam" + "And" + "Eggs"
'SpamAndEggs'
>>> 3 * "spam"
'spamspamspam'
>>> "spam" * 5
'spamspamspamspamspam'
>>> (3 * "spam") + ("eggs" * 5)
'spamspamspameggseggseggseggseggs'
```

```
>>> len("spam")
4
>>> for ch in "Spam!":
            print (ch, end=" ")

S p a m !
```

The String Data Type

Operator	Meaning
+	Concatenation
*	Repetition
<string>[]	Indexing
<string>[:]	Slicing
len(<string>)	Length
for <var> in <string>	Iteration through characters

Simple String Processing

Usernames on a computer system

- First initial, first seven characters of last name

```
# get user’s first and last names
first = input("Please enter your first name (all lowercase): ")
last = input("Please enter your last name (all lowercase): ")

# concatenate first initial with 7 chars of last name
uname = first[0] + last[:7]
```

Simple String Processing

```
# month.py
#  A program to print the abbreviation of a month, given its number

def main():

    # months is used as a lookup table
    months = "JanFebMarAprMayJunJulAugSepOctNovDec"

    n = int(input("Enter a month number (1-12): "))

    # compute starting position of month n in months
    pos = (n-1) * 3

    # Grab the appropriate slice from months
    monthAbbrev = months[pos:pos+3]

    # print the result
    print ("The month abbreviation is", monthAbbrev + ".")
```

Lists as Sequences

- Strings are always sequences of characters, but *lists* can be sequences of arbitrary values.
- Lists can have numbers, strings, or both!

```
myList = [1, "Spam ", 4, "U"]
```

Lists as Sequences

```
# month2.py
#  A program to print the month name, given it's number.
#  This version uses a list as a lookup table.

def main():

    # months is a list used as a lookup table
    months = ["Jan", "Feb", "Mar", "Apr", "May", "Jun",
              "Jul", "Aug", "Sep", "Oct", "Nov", "Dec"]

    n = int(input("Enter a month number (1-12): "))

    print ("The month abbreviation is", months[n-1] + ".")
```

- Note that the months line overlaps a line. Python knows that the expression isn't complete until the closing ']' is encountered.

Lists as Sequences

```
# month2.py
#  A program to print the month name, given it's number.
#  This version uses a list as a lookup table.

def main():
    # months is a list used as a lookup table
    months = ["Jan", "Feb", "Mar", "Apr", "May", "Jun",
              "Jul", "Aug", "Sep", "Oct", "Nov", "Dec"]
    n = int(input("Enter a month number (1-12): "))

    print ("The month abbreviation is", months[n-1] + ".")
```

- Since the list is indexed starting from 0, the *n-1* calculation is straight-forward enough to put in the print statement without needing a separate step.

Lists as Sequences

This version of the program is easy to extend to print out the whole month name rather than an abbreviation!

```
months = ["January", "February", "March",
          "April", "May", "June", "July",
          "August", "September", "October",
          "November", "December"]
```

Lists as Sequences

- Lists are *mutable*, meaning they can be changed. Strings can **not** be changed.

```
>>> myList = [34, 26, 15, 10]
>>> myList[2]
15
>>> myList[2] = 0
>>> myList
[34, 26, 0, 10]
>>> myString = "Hello World"
>>> myString[2]
'l'
>>> myString[2] = "p"

Traceback (most recent call last):
  File "<pyshell#16>", line 1, in -toplevel-
    myString[2] = "p"
TypeError: object doesn't support item assignment
```

More String Methods

- `s.capitalize()`

– Copy of s with only the first character capitalized

- `s.title()`

– Copy of s; first character of each word capitalized

- `s.center(width)`

– Center s in a field of given width

- `s.count(sub)`

– Count the number of occurrences of sub in s

- `s.find(sub)`

– Find the first position where sub occurs in s

- `s.join(list)`

– Concatenate list of strings into one large string using s as separator.

- `s.ljust(width)`

– Like center, but s is left-justified

More String Methods

- `s.lower()`
  – Copy of s in all lowercase letters
- `s.lstrip()`
  – Copy of s with leading whitespace removed
- `s.replace(oldsub, newsub)`
  – Replace occurrences of oldsub in s with newsub
- `s.rfind(sub)`
  – Like find, but returns the right-most position
- `s.rjust(width)`
  – Like center, but s is right-justified
- `s.rstrip()`
  – Copy of s with trailing whitespace removed
- `s.split()`
  – Split s into a list of substrings
- `s.upper()`
  – Copy of s; all characters converted to uppercase

Lists Have Methods, Too

- The `append` method can be used to add an item at the end of a list.
- `squares = []`
- `for x in range(1,101):`
```
  squares.append(x*x)
```

We start with an empty list ([]) and each number from 1 to 100 is squared and appended to it (`[1, 4, 9, …, 10000]`).

Lists Have Methods, Too

```
# numbers2text2.py
#     A program to convert a sequence of Unicode numbers into
#         a string of text. Efficient version using a list accumulator.

def main():
    print("This program converts a sequence of Unicode numbers into")
    print("the string of text that it represents.\n")

    # Get the message to encode
    inString = input("Please enter the Unicode-encoded message: ")

    # Loop through each substring and build Unicode message
    chars = []
    for numStr in inString.split():
        codeNum = int(numStr)             # convert digits to a number
        chars.append(chr(codeNum))         # accumulate new character

    message = "".join(chars)
    print("\nThe decoded message is:", message)
```

Input/Output as String Manipulation

We now have a complete set of type conversion operations:

Function	Meaning
float(<expr>)	Convert expr to a floating point value
int(<expr>)	Convert expr to an integer value
str(<expr>)	Return a string representation of expr
eval(<string>)	Evaluate string as an expression

Defining Functions

Functions and Parameters: The Details

- A function definition looks like this:

```
def <name>(<formal-parameters>):
    <body>
```

- The name of the function must be an identifier
- Formal-parameters is a (possibly empty) list of variable names
- A function is called by using its name followed by a list of *actual parameters* or *arguments*.

```
<name>(<actual-parameters>)
```

Functions That Return Values

- This function returns the square of a number:

```
def square(x):
   return x*x
```

- When Python encounters `return`, it exits the function and returns control to the point where the function was called.
- In addition, the value(s) provided in the `return` statement are sent back to the caller as an expression result.
- We can use the square function to write a routine to calculate the distance between (x_1,y_1) and (x_2,y_2).

```
def distance(p1, p2):
    dist = math.sqrt(square(p2.getX() - p1.getX()) +
                     square(p2.getY() - p1.getY()))
    return dist
```

Functions That Return Values

- Sometimes a function needs to return more than one value.
- To do this, simply list more than one expression in the `return` statement.

```
def sumDiff(x, y):
    sum = x + y
    diff = x – y
    return sum, diff
```

- When calling this function, use simultaneous assignment.

```
num1, num2 = eval(input("Enter two numbers (num1, num2) "))
s, d = sumDiff(num1, num2)
print("The sum is", s, "and the difference is", d)
```

- As before, the values are assigned based on position, so s gets the first value returned (the sum), and d gets the second (the difference).

Functions That Return Values

- One "gotcha" – all Python functions return a value, whether they contain a `return` statement or not. Functions without a `return` hand back a special object, denoted `None`.
  - A common problem is writing a value-returning function and omitting the `return`!
- The formal parameters of a function only receive the *values* of the actual parameters. The function does not have access to the variable that holds the actual parameter.
  - Python is said to pass all parameters *by value*.
- Some programming languages (C++, Ada, and many more) do allow variables themselves to be sent as parameters to a function. This mechanism is said to pass parameters *by reference*.
  - When a new value is assigned to the formal parameter, the value of the variable in the calling program actually changes.

Functions that Modify Parameters

- Since Python doesn't have this capability, we can program the `addInterest` function so that it returns the `newBalance`.
- When `addInterest` terminates, the list stored in `amounts` now contains the new values.
- The variable `amounts` wasn't changed (it's still a list), but the state of that list has changed, and this change is visible to the calling program.

```
# addinterest3.py
#    Illustrates modification of a mutable parameter (a list).

def addInterest(balances, rate):
    for i in range(len(balances)):
        balances[i] = balances[i] * (1+rate)

def test():
    amounts = [1000, 2200, 800, 360]
    rate = 0.05
    addInterest(amounts, 0.05)
    print(amounts)

test()
```

Decision Structures

Decisions & Loops

- The `if` statement is used to implement the decision.

```
if <condition>:
      <body>
```

- The body is a sequence of one or more statements indented under the `if` heading.

- The `if-else` statement implements two-way decision:

```
if <condition>:
    <statements>
else:
    <statements>
```

- The `if-elif-else` statement implements multiway decision :

```
if <condition1>:
   <case1 statements>
elif <condition2>:
   <case2 statements>
elif <condition3>:
   <case3 statements>
…
else:
   <default statements>
```

Forming Simple Conditions

Python	Mathematics	Meaning
<	$<$	Less than
<=	$\leq$	Less than or equal to
==	$=$	Equal to
>=	$\geq$	Greater than or equal to
>	$>$	Greater than
!=	$\neq$	Not equal to

Multi-Way Decisions

```
# quadratic4.py
import math

def main():
    print("This program finds the real solutions to a quadratic\n")

    a = float(input("Enter coefficient a: "))
    b = float(input("Enter coefficient b: "))
    c = float(input("Enter coefficient c: "))

    discrim = b * b - 4 * a * c
    if discrim < 0:
        print("\nThe equation has no real roots!")
    elif discrim == 0:
        root = -b / (2 * a)
        print("\nThere is a double root at", root)
    else:
        discRoot = math.sqrt(b * b - 4 * a * c)
        root1 = (-b + discRoot) / (2 * a)
        root2 = (-b - discRoot) / (2 * a)
        print("\nThe solutions are:", root1, root2 )
```

Exception Handling

- The `try` statement has the following form:

```
try:
   <body>
except <ErrorType>:
   <handler>
```

- When Python encounters a `try` statement, it attempts to execute the statements inside the body.
- If there is no error, control passes to the next statement after the `try`…`except`.

Exception Handling

```
# quadratic5.py
import math

def main():
    print ("This program finds the real solutions to a quadratic\n")

    try:
        a = float(input("Enter coefficient a: "))
        b = float(input("Enter coefficient b: "))
        c = float(input("Enter coefficient c: "))
        discRoot = math.sqrt(b * b - 4 * a * c)
        root1 = (-b + discRoot) / (2 * a)
        root2 = (-b - discRoot) / (2 * a)
        print("\nThe solutions are:", root1, root2)
    except ValueError:
        print("\nNo real roots")
```

Exception Handling

```
# quadratic6.py
import math

def main():
    print("This program finds the real solutions to a quadratic\n")

    try:
        a = float(input("Enter coefficient a: "))
        b = float(input("Enter coefficient b: "))
        c = float(input("Enter coefficient c: "))
        discRoot = math.sqrt(b * b - 4 * a * c)
        root1 = (-b + discRoot) / (2 * a)
        root2 = (-b - discRoot) / (2 * a)
        print("\nThe solutions are:", root1, root2 )
    except ValueError as excObj:
        if str(excObj) == "math domain error":
            print("No Real Roots")
        else:
            print("Invalid coefficient given.")
    except:
        print("\nSomething went wrong, sorry!")
```

MAXN

```
# program: maxn.py
#   Finds the maximum of a series of numbers

def main():
    n = int(input("How many numbers are there? "))

    # Set max to be the first value
    max = float(input("Enter a number >> "))

    # Now compare the n-1 successive values
    for i in range(n-1):
        x = float(input("Enter a number >> "))
        if x > max:
            max = x

    print("The largest value is", max)
```

- Or use Python's built-in function called `max` that returns the largest of its parameters.

- ```
  def main():
      x1, x2, x3 = eval(input("Please enter three values: "))
      print("The largest value is", max(x1, x2, x3))
  ```
  ```

For Loops

- The `for` statement allows us to iterate through a sequence of values.

```
for <var> in <sequence>:
   <body>
```

- The loop index variable `var` takes on each successive value in the sequence, and the statements in the body of the loop are executed once for each value.

```
# average1.py
#    A program to average a set of numbers
#    Illustrates counted loop with accumulator

def main():
    n = int(input("How many numbers do you have? "))
    sum = 0.0
    for i in range(n):
        x = float(input("Enter a number >> "))
        sum = sum + x
    print("\nThe average of the numbers is", sum / n)
```

Indefinite Loops

- ```
  while <condition>:
      <body>
  ```
- `condition` is a Boolean expression, just like in `if` statements. The body is a sequence of one or more statements.
- Semantically, the body of the loop executes repeatedly as long as the condition remains true. When the condition is false, the loop terminates.
  ```

Sentinel Loops

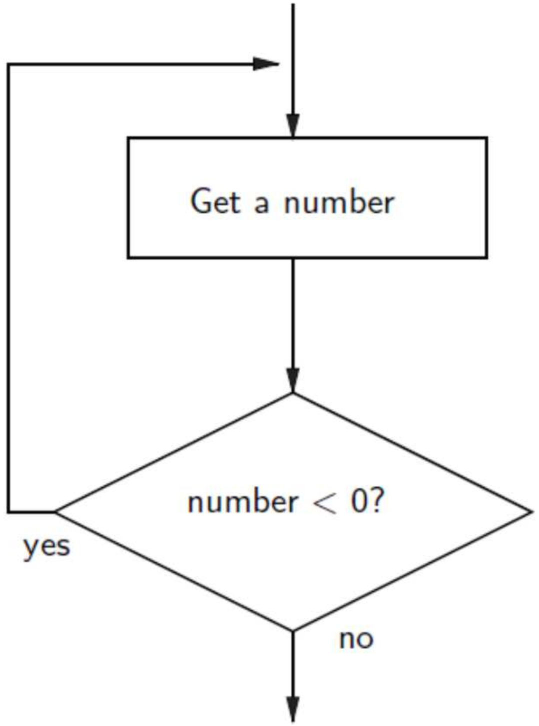
```
# average4.py
#    A program to average a set of numbers
#    Illustrates sentinel loop using empty string as sentinel

def main():
    sum = 0.0
    count = 0
    xStr = input("Enter a number (<Enter> to quit) >> ")
    while xStr != "":
        x = float(xStr)
        sum = sum + x
        count = count + 1
        xStr = input("Enter a number (<Enter> to quit) >> ")
    print("\nThe average of the numbers is", sum / count)
```

Boolean Operators

- The Boolean operators `and` and `or` are used to combine two Boolean expressions and produce a Boolean result.
- `<expr> and <expr>`
- `<expr> or <expr>`

Post-Test Loop

```
repeat
    get a number from the user
until number is >= 0
```



- When the condition test comes after the body of the loop it's called a *post-test loop*.
- A post-test loop always executes the body of the code at least once.
- Python doesn't have a built-in statement to do this, but we can do it with a slightly modified `while` loop.

Post-Test Loop

- We seed the loop condition so we're guaranteed to execute the loop once.

```
number = -1        # start with an illegal value
while number < 0: # to get into the loop
    number = float(input("Enter a positive number: "))
```

- By setting `number` to –1, we force the loop body to execute at least once.

- The same algorithm implemented with a `break`:

```
while True:
    number = float(input("Enter a positive number: "))
    if x >= 0: break # Exit loop if number is valid
```

- A while loop continues as long as the expression evaluates to true. Since `True` *always* evaluates to true, it looks like an infinite loop!

Post-Test Loop

- In the `while` loop version, this is awkward:

```
number = -1
while number < 0:
    number = float(input("Enter a positive number: "))
    if number < 0:
        print("The number you entered was not positive")
```

- We're doing the validity check in two places!

- Adding the warning to the `break` version only adds an `else` statement:

```
while True:
    number = float(input("Enter a positive number: "))
    if x >= 0:
        break # Exit loop if number is valid
    else:
        print("The number you entered was not positive.")
```

Loop and a Half

- Stylistically, some programmers prefer the following approach:

```
while True:
    number = float(input("Enter a positive number: "))
    if x >= 0: break # Loop exit
    print("The number you entered was not positive")
```

- Here the loop exit is in the middle of the loop body. This is what we mean by a *loop and a half*.

- The loop and a half is an elegant way to avoid the priming read in a sentinel loop.

```
while True:
     get next data item
     if the item is the sentinel: break
     process the item
```

- This method is faithful to the idea of the sentinel loop, the sentinel value is not processed!

Data Collections

Lists and Arrays

- A list or array is a sequence of items where the entire sequence is referred to by a single name (i.e. `s`) and individual items can be selected by indexing (i.e. `s[i]`).
  - In other programming languages, arrays are generally a fixed size, meaning that when you create the array, you have to specify how many items it can hold.
  - Arrays are generally also *homogeneous*, meaning they can hold only one data type.
- Python lists are dynamic. They can grow and shrink on demand.
  - Python lists are also *heterogeneous*, a single list can hold arbitrary data types.
  - Python lists are mutable sequences of arbitrary objects.

List Operations

Operator	Meaning
<seq> + <seq>	Concatenation
<seq> * <int-expr>	Repetition
<seq>[]	Indexing
len(<seq>)	Length
<seq>[:]	Slicing
for <var> in <seq>:	Iteration
<expr> in <seq>	Membership (Boolean)

List Operations

- Except for the membership check, we've used these operations before on strings.
- The membership operation can be used to see if a certain value appears anywhere in a sequence.

```
>>> lst = [1,2,3,4]
>>> 3 in lst
True
```

- The summing example from earlier can be written like this:

```
sum = 0
for x in s:
    sum = sum + x
```

- Unlike strings, lists are mutable:

```
>>> lst = [1,2,3,4]
>>> lst[3]
4
>>> lst[3] = "Hello“
>>> lst
[1, 2, 3, 'Hello']
>>> lst[2] = 7
>>> lst
[1, 2, 7, 'Hello']
```

List Operations

- A list of identical items can be created using the repetition operator. This command produces a list containing 50 zeroes:

```
zeroes = [0] * 50
```

- Lists are often built up one piece at a time using append.

```
nums = []
x = float(input('Enter a number: '))
while x >= 0:
    nums.append(x)
    x = float(input('Enter a number: '))
```

- Here, `nums` is being used as an accumulator, starting out empty, and each time through the loop a new value is tacked on.

List Operations

Method	Meaning
<list>.append(x)	Add element x to end of list.
<list>.sort()	Sort (order) the list. A comparison function may be passed as a parameter.
<list>.reverse()	Reverse the list.
<list>.index(x)	Returns index of first occurrence of x.
<list>.insert(i, x)	Insert x into list at index i.
<list>.count(x)	Returns the number of occurrences of x in list.
<list>.remove(x)	Deletes the first occurrence of x in list.
<list>.pop(i)	Deletes the i^{th} element of the list and returns its value.

List Operations

- Most of these methods don't return a value – they change the contents of the list in some way.
- Lists can grow by appending new items, and shrink when items are deleted. Individual items or entire slices can be removed from a list using the `del` operator.
- ```
  >>> myList=[34, 26, 0, 10]
  >>> del myList[1]
  >>> myList
  [34, 0, 10]
  >>> del myList[1:3]
  >>> myList
  [34]
  ```
- `del` isn't a list method, but a built-in operation that can be used on list items.
  ```

List Operations

- Basic list principles
  - A list is a sequence of items stored as a single object.
  - Items in a list can be accessed by indexing, and sublists can be accessed by slicing.
  - Lists are mutable; individual items or entire slices can be replaced through assignment statements.
  - Lists support a number of convenient and frequently used methods.
  - Lists will grow and shrink as needed.

Non-sequential Collections

- After lists, a *dictionary* is probably the most widely used collection data type.
  - Dictionaries are not as common in other languages as lists (arrays).
  - Lists allow us to store and retrieve items from sequential collections.
  - When we want to access an item, we look it up by index – its position in the collection.
- What if we wanted to look students up by student id number? In programming, this is called a *key-value pair*
  - We access the value (the student information) associated with a particular key (student id)

Dictionary Basics

- Three are lots of examples!: Names and phone numbers, Usernames and passwords, State names and capitals
  - A collection that allows us to look up information associated with arbitrary keys is called a *mapping*.
  - Python dictionaries are *mapping*s. Other languages call them *hashes* or *associative arrays*.
- Dictionaries can be created in Python by listing key-value pairs inside of curly braces.
- Keys and values are joined by ":" and are separated with commas.

```
>>>passwd ={"guido":"superprogrammer","turing":"genius","bill":"monopoly"}
```

- We use an indexing notation to do lookups

```
>>> passwd["guido"]
'superprogrammer'
```

Dictionary Basics

- `<dictionary>[<key>]` returns the object with the associated key.
- Dictionaries are mutable.

```
>>> passwd["bill"] = "bluescreen"
>>> passwd
{'guido': 'superprogrammer', 'bill':
'bluescreen', 'turing': 'genius'}
```

- Did you notice the dictionary printed out in a different order than it was created?

Dictionary Basics

- Mappings are inherently unordered.
  - Internally, Python stores dictionaries in a way that makes key lookup very efficient.
- When a dictionary is printed out, the order of keys will look essentially random.
  - If you want to keep a collection in a certain order, you need a sequence, not a mapping!
- Keys can be any immutable type, values can be any type, including programmer-defined.

Dictionary Operations

- Like lists, Python dictionaries support a number of handy built-in operations.
- A common method for building dictionaries is to start with an empty collection and add the key-value pairs one at a time.

```
passwd = {}
for line in open('passwords', 'r'):
    user, pass = line.split()
    passwd[user] = pass
```

Dictionary Operations

Method	Meaning
<key> in <dict>	Returns true if dictionary contains the specified key, false if it doesn't.
<dict>.keys()	Returns a sequence of keys.
<dict>.values()	Returns a sequence of values.
<dict>.items()	Returns a sequence of tuples (key, value) representing the key-value pairs.
del <dict>[<key>]	Deletes the specified entry.
<dict>.clear()	Deletes all entries.
for <var> in <dict>:	Loop over the keys.
<dict>.get(<key>, <default>)	If dictionary has key returns its value; otherwise returns default.

Dictionary Operations

```
>>> list(passwd.keys())
['guido', 'turing', 'bill']
>>> list(passwd.values())
['superprogrammer', 'genius', 'bluescreen']
>>> list(passwd.items())
[('guido', 'superprogrammer'), ('turing', 'genius'), ('bill', 'bluescreen')]
>>> "bill" in passwd
True
>>> "fred" in passwd
False
>>> passwd.get('bill','unknown')
'bluescreen'
>>> passwd.get('fred','unknown')
'unknown'
>>> passwd.clear()
>>> passwd
{}
```

Algorithms

Strategy 1: Linear Search

- This strategy is called a *linear search*, where you search through the list of items one by one until the target value is found.

```
def search(x, nums):
    for i in range(len(nums)):
        if nums[i] == x: # item found, return the index value
            return i
    return -1            # loop finished, item was not in list
```

- This algorithm wasn't hard to develop, and works well for modestly-sized lists.

Strategy 2: Binary Search

```
def search(x, nums):
    low = 0
    high = len(nums) - 1
    while low <= high:          # There is still a range to search
        mid = (low + high)//2 # Position of middle item
        item = nums[mid]
        if x == item:           # Found it! Return the index
            return mid
        elif x < item:          # x is in lower half of range
            high = mid - 1      #  move top marker down
        else:                   # x is in upper half of range
            low = mid + 1       #  move bottom marker up
    return -1                   # No range left to search,
                                # x is not there
```

Recursive Problem-Solving

```
Algorithm: binarySearch – search for x in nums[low]…nums[high]

mid = (low + high)//2
if low > high
   x is not in nums
elsif x < nums[mid]
   perform binary search for x in nums[low]…nums[mid-1]
else
   perform binary search for x in nums[mid+1]…nums[high]
```

- This version has no loop, and seems to refer to itself! What’s going on??

Recursive Functions

- We’ve seen previously that factorial can be calculated using a loop accumulator.
- If factorial is written as a separate function:

```
def fact(n):
    if n == 0:
        return 1
    else:
        return n * fact(n-1)
```

Example: String Reversal

- ```
  def reverse(s):
      return reverse(s[1:]) + s[0]
  ```
- The slice `s[1:]` returns all but the first character of the string.
- We reverse this slice and then concatenate the first character (`s[0]`) onto the end.
  ```

Example: String Reversal

- ```
  def reverse(s):
      if s == "":
          return s
      else:
          return reverse(s[1:]) + s[0]
  ```
- ```
  >>> reverse("Hello")
  'olleH'
  ```

Example: Fast Exponentiation

- ```
  def recPower(a, n):
      # raises a to the int power n
      if n ==  0:
          return 1
      else:
          factor = recPower(a, n//2)
          if n%2 == 0:    # n is even
              return factor * factor
          else:           # n is odd
              return factor * factor * a
  ```
- Here, a temporary variable called *factor* is introduced so that we don't need to calculate $a^{n//2}$ more than once, simply for efficiency.
  ```

Example: Binary Search

```
def recBinSearch(x, nums, low, high):
    if low > high:              # No place left to look, return -1
        return -1
    mid = (low + high)//2
    item = nums[mid]
    if item == x:
        return mid
    elif x < item:              # Look in lower half
        return recBinSearch(x, nums, low, mid-1)
    else:                       # Look in upper half
        return recBinSearch(x, nums, mid+1, high)
```

- We can then call the binary search with a generic search wrapping function:

```
def search(x, nums):
    return recBinSearch(x, nums, 0, len(nums)-1)
```

Recursion vs. Iteration

- ```
  def loopfib(n):
      # returns the nth Fibonacci number

      curr = 1
      prev = 1
      for i in range(n-2):
          curr, prev = curr+prev, curr
      return curr
  ```
- Note the use of simultaneous assignment to calculate the new values of `curr` and `prev`.
- The loop executes only *n-2* times since the first two values have already been “determined”.
  ```

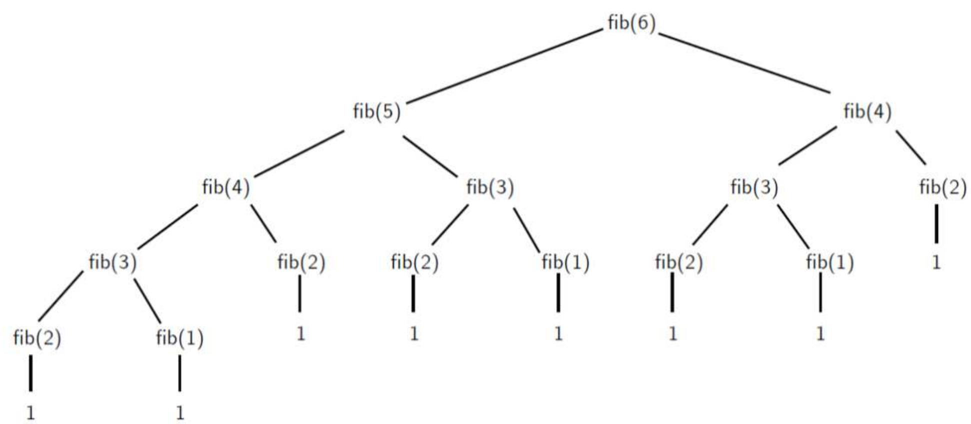
Recursion vs. Iteration

- The Fibonacci sequence also has a recursive definition:

$$fib(n) = \begin{cases} 1 & \text{if } n < 3 \\ fib(n-1) + fib(n-2) & \text{otherwise} \end{cases}$$

- This recursive definition can be directly turned into a recursive function!

```
def fib(n):
    if n < 3:
        return 1
    else:
        return fib(n-1)+fib(n-2))
```



- The recursive solution is extremely inefficient, since it performs many duplicate calculations!

Naive Sorting: Selection Sort

```
def selSort(nums):
    # sort nums into ascending order

    n = len(nums)

    # For each position in the list (except the very last)

    for bottom in range(n-1):
        # find the smallest item in nums[bottom]..nums[n-1]

        mp = bottom                         # bottom is smallest initially
        for i in range(bottom+1, n):        # look at each position
            if nums[i] < nums[mp]:          # this one is smaller
                mp = i                      # remember its index

        # swap smallest item to the bottom
        nums[bottom], nums[mp] = nums[mp], nums[bottom]
```

Divide and Conquer: Merge Sort

```
def merge(lst1, lst2, lst3):
    # merge sorted lists lst1 and lst2 into lst3

    # these indexes keep track of current position in each list
    i1, i2, i3 = 0, 0, 0  # all start at the front
    n1, n2 = len(lst1), len(lst2)

    # Loop while both lst1 and lst2 have more items

    while i1 < n1 and i2 < n2:
        if lst1[i1] < lst2[i2]: # top of lst1 is smaller
            lst3[i3] = lst1[i1] #  copy it into current spot in lst3
            i1 = i1 + 1
        else:                   # top of lst2 is smaller
            lst3[i3] = lst2[i2] #  copy itinto current spot in lst3
            i2 = i2 + 1
        i3 = i3 + 1             # item added to lst3, update position
```

Divide and Conquer: Merge Sort

```
# Here either lst1 or lst2 is done. One of the following loops
# will execute to finish up the merge.

   # Copy remaining items (if any) from lst1
   while i1 < n1:
       lst3[i3] = lst1[i1]
       i1 = i1 + 1
       i3 = i3 + 1

   # Copy remaining items (if any) from lst2
   while i2 < n2:
       lst3[i3] = lst2[i2]
       i2 = i2 + 1
       i3 = i3 + 1
```

Divide and Conquer: Merge Sort

```
def mergeSort(nums):
    # Put items of nums into ascending order
    n = len(nums)
    # Do nothing if nums contains 0 or 1 items
    if n > 1:
        # split the two sublists
        m = n//2
        nums1, nums2 = nums[:m], nums[m:]
        # recursively sort each piece
        mergeSort(nums1)
        mergeSort(nums2)
        # merge the sorted pieces back into original list
        merge(nums1, nums2, nums)
```

Heap Operations

- heapq implements the priority queue algorithm. Heaps are binary trees for The interesting property of a heap is that its smallest element is always the root, heap[0].

```
from heapq import heappush, heappop
heap = []
data = [1, 3, 5, 7, 9, 2, 4, 6, 8, 0]
for item in data:
        heappush(heap, item)
sorted = []
while heap:
     sorted.append(heappop(heap))
```

Heap Operations

- We can implement short test path using a `heapq` priority queue: See irg-astar for a similar implementation of A*:

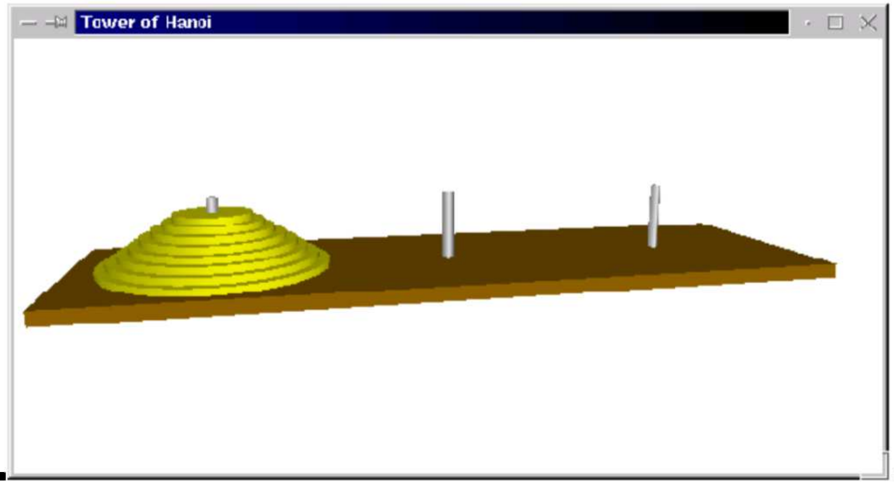
```
import heapq
import math

G = {'s':{'u':10, 'x':5},
     'u':{'v':1, 'x':2},
     'v':{'y':4},
     'x':{'u':3, 'v':9, 'y':2},
     'y':{'s':7, 'v':6}}

print ('G=', G)
def shortest_path2(G, start, end):
   def flatten(L):       # Flatten linked list of form [0,[1,[2,[]]]]
      while len(L) > 0:
         yield L[0]
         L = L[1]
```

Heap Operations

```
q = [(0, start, ())]  # Heap of (cost, path_head, path_rest).
visited = set()       # Visited vertices.
while True:
   (cost, v1, path) = heapq.heappop(q)
   if v1 not in visited:
      visited.add(v1)
      if v1 == end:
         return list(flatten(path))[::-1] + [v1]
      path = (v1, path)
      for (v2, cost2) in G[v1].items():
         if v2 not in visited:
            heapq.heappush(q, (cost + cost2, v2, path))


print ('shortest path from s to v =', shortest_path2(G,'s','v'))
```

Towers of Hanoi

– Only one disk may be moved at a time.
– A disk may not be "set aside". It may only be stacked on one of the three posts.
– A larger disk may never be placed on top of a smaller one.



Towers of Hanoi

- In `moveTower`, `n` is the size of the tower (integer), and `source`, `dest`, and `temp` are the three posts, represented by “A”, “B”, and “C”.

```
def moveTower(n, source, dest, temp):
    if n == 1:
        print("Move disk from", source, "to", dest+".")
    else:
        moveTower(n-1, source, temp, dest)
        moveTower(1, source, dest, temp)
        moveTower(n-1, temp, dest, source)
```

Towers of Hanoi

- To get things started, we need to supply parameters for the four parameters:

```
def hanoi(n):
    moveTower(n, "A", "C", "B")
```

```
>>> hanoi(3)
Move disk from A to C.
Move disk from A to B.
Move disk from C to B.
Move disk from A to C.
Move disk from B to A.
Move disk from B to C.
Move disk from A to C.
```

Towers of Hanoi

- Why is this a “hard problem”?
- How many steps in our program are required to move a tower of size n?

Number of Disks	Steps in Solution
1	1
2	3
3	7
4	15
5	31

Towers of Hanoi

- To solve a puzzle of size *n* will require $2^n - 1$ steps.
- Computer scientists refer to this as an *exponential time* algorithm.
- Exponential algorithms grow very fast.
- For 64 disks, moving one a second, round the clock, would require 580 *billion years* to complete. The current age of the universe is estimated to be about 15 billion years.