String Formatting

Formatting Strings

- A simple way to format is the use of f-strings
  - A string preceded with an f-character
  - Can put variables into braces { }
  - Example

```
f'This is pi: {math.pi}'
```

Formatting Strings

- We really need to learn how to format strings
  - Python has made several attempts before settling on an efficient syntax.
    - You can find information on the previous solutions on the net.
  - Use the `format` function
    - Distinguish between the **blueprint**
    - and the **string to be formatted**
    - Result is the formatted string.

Formatting Strings

- Blueprint string
  - Uses `{}` to denote places for variables
  - Simple example
    - `"{} {}".format('one', ‘two')`

Blueprint

Calling format

String to be formatted

- Result `‘one two’`

Formatting Strings

- Inside the brackets, we can put indices to select variables
    - 0 means first variable, 1 second, …
    - Can reuse variables

```
>>> "{0}, {0}, {1}, just {0}".format("great", "extraordinary")
'great, great, extraordinary, just great'
```

Formatting Strings

- Additional formatting inside the bracket after a colon
- Can assign the number of characters to print out

```
>>> "{0:10}, {1:10}, {0:10}".format("funny", "nuts")
'funny     , nuts      , funny     '
```

- Default alignment is to the left

Formatting Strings

- Use ^ to center
- Use < to left-align
- Use > to right-align

```
>>> "{0:10}|{1:^10}|{0:>10}".format("sheep", "wolf")
'sheep     |   wolf   |     sheep'
```

Formatting Strings

- Numbers are handled without specifying format instructions.

```
>>> "{} divided by {} is {} modulo {}".format(143, 29, 143//29, 143%29)
'143 divided by 29 is 4 modulo 27'
```

- Or we can insist on special types
  - Use s for string
  - Use d for decimal
  - Use f for floating point
  - Use e for floating point in exponential notation

Formatting Strings

- By specifying “f” we ask for floating point format
- By specifying “e” we ask for scientific format

```
>>> "{0:f}, {0:e}".format(3.141)
'3.141000, 3.141000e+00'
>>>
```

Formatting Strings

- Padding
  - If the variable needs more space to print out, it will be provided automatically

```
>>> "{:10s}".format("Pneumonoultramicroscopicsilicovolcanoconiosis")
'Pneumonoultramicroscopicsilicovolcanoconiosis'
>>>
```

  - This is actually the longest officially recognized word in English

Formatting Strings

- Padding:
  - On the reverse, we can give the number of significant digits after a period

```
>>> "{:8.2f}".format(3.141592653589793238462643383279502884197169399375105
820974944592307816406286208998628034825342117067982148086513282306647093844
4609550582231725359408128481)
'    3.14'
```

  - We only want to keep two decimal digits after the period
  - But use a total of 8 spaces for the number.

Formatting Strings

- Escaping curly brackets:
  - If we want to write strings with format containing the curly brackets “{“ and “}”, we just have to write “{{“ and “}}”

```
>>> "{{ {}, {} }}".format(3, 4)
'{ 3, 4 }'
```

  - A single bracket is a placeholder, a double curly bracket is a single one in the resulting string.

Files

Opening and Reading Text Files

- Python follows the posix conventions:
  - You can open a file
  - You can interact with a file
  - You then close the file
- Easiest done with a **Python context**
  - The context automatically closes the file after use

```
with open(filename) as infile:
    |— statement block  —|
```

Opening and Reading Text Files

- To read from a file, we can use a for loop

```
with open(filename) as infile:
     for line in infile:
         |— do something with each line
```

  - Within the for loop, we can use strip( ) in order to break the line apart at white spaces

```
with open(filename) as infile:
     for line in infile:
         for words in line.split( )
```

Standard Example

- Use a text file from project Gutenberg
  - Gutenberg is a good source of free books, but on occasion, German characters force you to use special encodings
- Read the text line for line
- Count the number of lines and the number of symbols in a line.

```
with open('alice.txt') as inputfile:
    count_symbols = 0
    count_lines = 0
    for line in inputfile:
        count_symbols += len(line)
        count_lines += 1
print(count_symbols, count_lines)
```

Standard Example

```
with open('alice.txt') as inputfile:
    count_symbols = 0
    count_lines = 0
    for line in inputfile:
        count_symbols += len(line)
        count_lines += 1
print(count_symbols, count_lines)
```

8pen file in default mode: text, read, utf8

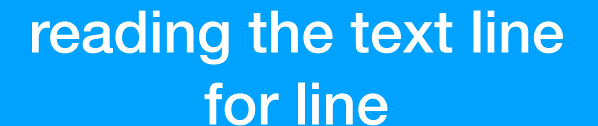
Standard Example

```
with open('alice.txt') as inputfile:
    count_symbols = 0
    count_lines = 0
    for line in inputfile:
        count_symbols += len(line)
        count_lines += 1
print(count_symbols, count_lines)
```

File is open in this part of code

Standard Example

```
with open('alice.txt') as inputfile:
    count_symbols = 0
    count_lines = 0
    for line in inputfile:
        count_symbols += len(line)
        count_lines += 1
print(count_symbols, count_lines)
```



Standard Example

```
with open('alice.txt') as inputfile:
    count_symbols = 0
    count_lines = 0
    for line in inputfile:
        count_symbols += len(line)
        count_lines += 1
print(count_symbols, count_lines)
```

Dictionaries

Thomas Schwarz, SJ

Dictionaries

- Python has a efficient association data structure — the dictionary
  - Dictionary pairs keys with values
    - Useful for: indices
    - Useful for: translations
    - Useful for: quick lookups
      - E.g.: first letters —> full email address
      - E.g.: human-readable URL —> IP address
      - …

Dictionaries

- Dictionaries are key-value stores
  - Keys — anything, but needs to be immutable
    - Remember: Lists are mutable, strings are immutable
  - Value — anything

Dictionaries

- Dictionaries are created by using curly brackets
  - Can use lists

```
dicc = {1: 'uno', 2: 'dos', 3: 'tres'}
```

  - Or can use assignment

```
dicc = {}
dicc[1] = "uno"
dicc[2] = "dos"
dicc[3] = "tres"
```

- Values are assigned / retrieved using the bracket notation

Dictionary

- Dictionary `dicc={}`
- Accessing values:

  `dicc['key']`

  - With default value

    `dicc.get(key, default_value)`

  - Or with if - else

    `if key in dicc:`

- Creating / changing values

  `dicc['key'] = value`

```
>>> dicc = {1: "uno", 2: "dos", 3: "tres"}
>>> dicc[1]
'uno'
>>> dicc[1] = "one"
>>> dicc[1]
'one'
```

Dictionary

- Deleting from a dictionary

```
dicc = {}
```

  - Use the `del` keyword
    - Raises a key error if the key is not in the dictionary

```
if key in dicc:
    del dicc[key]
```

  - Use the pop method, which returns the value

```
value = dicc.pop(key)
value = dicc.pop(key, default)
```

Dictionary

- Checking for existence
  - Use the “in” keyword

```
>>> dicc = {1: "uno", 2: "dos", 3: "tres"}
>>> 1 in dicc
True
>>> 4 not in dicc
True
```

Dictionaries

- A simple program that “learns” Spanish words

```
def test():
    dicc = {}
    while True:
        astr = input("Enter an English word: ")
        if astr == "Stop it":
            return
        elif astr in dicc:
            print(dicc[astr])
        else:
            print("I have not yet learned this word")
            val = input("Please enter the Spanish word: ")
            dicc[astr] = val
```

Dictionaries

- Dictionaries have an internal structure
    - You will learn in Data Structures how to build dictionaries yourselves
    - For the moment, enjoy their power
- You can print dictionaries
    - You will notice that they change structure after inserts and not reflect the order in which you inserted elements
    - This is because they optimize access

Dictionaries

- Deleting all entries in a dictionary
  - use the `clear()` method
- Deleting an entry without fear of creating a key error
  - Use an if statement
  - Use pop with a second argument None
    - `dicc.pop(1, None)`

Dictionaries

- Looping over keys
  - Simplest:
    - `for number in dicc:`
  - iterkeys( ) or iter works the same way
    - `for number in dicc.iterkeys():`
    - `for number in iter(dicc):`

Some Uses of Dictionaries

- Dictionaries can be used to count things.
  - Example: Count the number of letters in a file.
    - We open the file with encoding latin-1 so that there are no encoding errors

```
alphabet = "abcdefghijklmnopqrstuvwxyz"

with open("alice.txt", encoding = "latin-1") as infile:
    dicc = {}
    for letter in alphabet:
        dicc[letter]=0
```

Some Uses of Dictionaries

- Create and initialize a dictionary
  - We are only interested in letters

```
alphabet = "abcdefghijklmnopqrstuvwxyz"

with open("alice.txt", encoding = "latin-1") as infile:
    dicc = {}
    for letter in alphabet:
        dicc[letter]=0
```

Some Uses of Dictionaries

- Read the file line by line.
  - Read each letter in the line
    - After changing to lower case, update dictionary

```
alphabet = "abcdefghijklmnopqrstuvwxyz"

with open("alice.txt", encoding = "latin-1") as infile:
    dicc = {}
    for letter in alphabet:
        dicc[letter]=0
    for line in infile:
        for letter in line:
            letter=letter.lower()
            if letter in alphabet:
                dicc[letter]+=1
```

Some Uses of Dictionaries

- Now process the dictionary
  - Calculate the sum of values (i.e. the counts)
  - Pretty-print the results

```
for letter in alphabet:
    cum += dicc[letter]
for letter in alphabet:
    print("{:1s} {:5d} {:5.2f}%”.format(
              letter, dicc[letter], dicc[letter]/cum*100))
```

Some Uses of Dictionaries

- Using lists as dictionary values
  - in order to create an index of words in a file

Some Uses of Dictionaries

- Open file with encoding “latin-1”
  - Read file line by line
    - Break line into words
    - Normalize words by stripping and lowering

```
with open("alice.txt", encoding = "latin-1") as infile:
    index = {}
    word_count = 0
    for line in infile:
        for word in line.split():
            word_count += 1
            word = word.lower().strip(",.;:?![]-'\"")
```

Some Uses of Dictionaries

- Add word to dictionary if long enough

```
with open("alice.txt", encoding = "latin-1") as infile:
    index = {}
    word_count = 0
    for line in infile:
        for word in line.split():
            word_count += 1
            word = word.lower().strip(",.;:?![]-'\"")
            if len(word)>7:
                if word in index:
                    index[word].append(word_count)
                else:
                    index[word] = [word_count]
```

Some Uses of Dictionaries

- Print out results if word is frequent enough

```
for word in index:
    if len(index[word])>2:
        print(word, index[word])
```

A Teaser on Iterators

- Iterators are the hidden engine of many Python features
  - Iterators are almost like lists
    - You always can get the next element
      - Unless you are at the end of a list
  - But they are not lists:
    - All the elements in the list have to be there before the list can be used
      - They need to be stored in memory
      - Which uses up space
      - And can be disastrous if there are just too many

A Teaser on Iterators

- Iterators are only created when there is a need
- Iterators are often hidden from view
- But we will have to use them
  - For our purposes:
    - We can make them explicitly into lists because we are just not working with millions of data items
    - But hopefully, once we get to play with the grown-ups …
- Seriously, we get back to iterators

Multi-Dictionaries

- Problem:
  - Instead of associating one value with a key, we want to associate several values:
    - a “multi-dictionary”
- Solution:
  - The values of the dictionaries should be lists (or sets — coming week)

Multi-Dictionaries

- Example:
  - We want to pass through a file and create an index of important words with their occurrences

```
with open("alice.txt", encoding = "latin-1") as infile:
    dicc = {}
    word_number = 0
    for line in infile:
        for word in line.split():
            word = word.strip(":,.?![]'")
            word = word.lower()
            word_number +=1
            if len(word)>8:
                if word in dicc:
                    dicc[word].append(word_number)
                else:
                    dicc[word]=[word_number]
```

Calculating on Values

- Assume you have a dictionary with numerical values
  - For example: a dictionary with the prices of stocks on September 15, 2018

```
dstocks = {“tata”: 2063.30,
           “hdfc”: 2029.20,
           “hiul”: 1630.15,
            …
          }
```

  - You want the average, the maximum, the minimum … price

Solution

- You can access the values of a dictionary through the values method.
  - values( ) returns an iterator of all the values in the dictionary

```
>>> dst = {"apple": 256.34, "fb": 145.23, "ibm": 98.34, "ms": 198.75}
>>> dst.values()
dict_values([256.34, 145.23, 98.34, 198.75])
>>> max(dst.values())
256.34
>>> sum(dst.values())/len(dst.values())
174.665
```

Calculating with keys

- Problem:
  - You want to calculate on the keys of a dictionary
- Solution:
  - The keys( ) method returns an iterator of the keys of a dictionary

Finding the most common item in a list

- We use a dictionary as a counter.
  - First way: We can do so by ourselves.
    - Create a dictionary
      - Pass through the list

```
def most_frequent(lista):
    counter = {}
    for x in lista:
        counter[x]=counter.get(x, 0)+1
```

get specifies a
default value,
it is otherwise equivalent to
counter[x]

Finding the most common item in a list

- If we do not want to use get, we can just check whether the list-item is already in the dictionary

```
def most_frequent(lista):
    counter = {}
    for x in lista:
        if x in counter:
            counter[x]+=1
        else:
            counter[x]=1
```

Finding the most common item in a list

- After counting, we pass through the dictionary to find the maximum element.
  - Notice that we are interested in the key, not the value

```
def most_frequent(lista):
    counter = {}
    for x in lista:
        counter[x]=counter.get(x, 0)+1
    highest_seen = 0
    for x in counter:
        if counter[x]>highest_seen:
            best_key = x
            highest_seen = counter[x]
    return best_key
```

highest_seen contains the highest encountered **value**

Finding the most common item in a list

- After counting, we pass through the dictionary to find the maximum element.
  - Notice that we are interested in the key, not the value

```
def most_frequent(lista):
    counter = {}
    for x in lista:
        counter[x]=counter.get(x, 0)+1
    highest_seen = 0
    for x in counter:
        if counter[x]>highest_seen:
            best_key = x
            highest_seen = counter[x]
    return best_key
```

highest_seen is adjusted whenever we see a higher value in the counter

Finding the most common item in a list

- After counting, we pass through the dictionary to find the maximum element.
  - Notice that we are interested in the key, not the value

```
def most_frequent(lista):
    counter = {}
    for x in lista:
        counter[x]=counter.get(x, 0)+1
    highest_seen = 0
    for x in counter:
        if counter[x]>highest_seen:
            best_key = x
            highest_seen = counter[x]
    return best_key
```

but we also need to remember the key, which we record in best_key

Finding the most common item in a list

- After counting, we pass through the dictionary to find the maximum element.
    - Notice that we are interested in the key, not the value

```
def most_frequent(lista):
    counter = {}
    for x in lista:
        counter[x]=counter.get(x, 0)+1
    highest_seen = 0
    for x in counter:
        if counter[x]>highest_seen:
            best_key = x
            highest_seen = counter[x]
    return best_key
```

because the key with the highest counter value is the result that we return

Finding the most common item in a list

- But we can also use the work of others
  - The `Counter` in the collections module
    - You create a *new object* of type Counter

```
from collections import Counter

def most_frequent(lista):
    ctr = Counter()
```

Defines a new object called ctr
ctr is an object of type Counter

Finding the most common item in a list

- Counters are (updated) like dictionaries
  - But they have a default value of 0

```
from collections import Counter

def most_frequent(lista):
    ctr = Counter()
    for item in lista:
        ctr[item] += 1
```

Here we add 1 to the value of `ctr[item]`

No need to initialize!

Finding the most common item in a list

- Counters have a method called `most_common`
  - Argument is the number of most common items
  - Returns a list of pairs

```
from collections import Counter

def most_frequent(lista):
    ctr = Counter()
    for item in lista:
        ctr[item] += 1
    return ctr.most_common(1)[0][0]
```

- **Get a list of one elements.**
- **Get the first (and only) element of the list**
- **Get the first coordinate of that element**

Memoization

- (Some) Computer Scientists love recursion
  - A function calls itself
    - This is super-elegant and the more mathematically inclined pine for this elegance
  - But it is not necessarily very fast
    - The more engineeringly inclined think its a waste

Recursion

- When it works
  - Factorials
    - The factorial of n is n (n-1) (n-2) (n-3) … (4) (3) (2) (1)
    - Define it to be one for negative or zero n

Recursion

- This implementation has the function factorial call itself

```
def factorial(number):
    if number<1:
        return 1
    else:
        return number*factorial(number-1)
```

- Here we are calling on the function itself
- Will call factorial(number-1), which will call factorial(number-2), which will call factorial(number -3) … until we call factorial on 1, in which case the recursion stops.

Recursion

- This implementation has the function factorial call itself

```
def factorial(number):
    if number<1:
        return 1
    else:
        return number*factorial(number-1)
```

- The base case:
  - We cannot call recursion infinitely often, so we need one.

Recursion

- The Fibonacci numbers
  - The Fibonacci numbers are defined recursively
  - $f_0 = 0, \qquad f_1 = 1, \qquad f_n = f_{n-1} + f_{n-2}$

```
def fibonacci(number):
    if number <= 0:
        return 0
    if number == 1:
        return 1
    return fibonacci(number-1)+fibonacci(number-2)
```

Recursion

- But this implementation is inane!
  - Takes too long even for small numbers.
    - We can use the time-module in order to obtain the cpu-time
      - We do so once before and after execution of the function
    - This yields approximately the time it takes to execute the function

Recursion

- We just write a function that measures the time

```
def measure(function, number):
    start = time.time()
    function(number)
    print(number, time.time()-start)
```

Recursion

- Now we try it out with factorial and fibonacci
  - Not a problem with factorial

```
27 1.52587890625e-05
28 1.5974044799804688e-05
29 1.52587890625e-05
30 1.5735626220703125e-05
31 1.811981201171875e-05
32 1.71661376953125e-05
33 1.7881393432617188e-05
34 1.7881393432617188e-05
35 1.9073486328125e-05
36 1.9788742065429688e-05
37 1.8835067749023438e-05
38 2.09808349609375e-05
39 2.193450927734375e-05
```

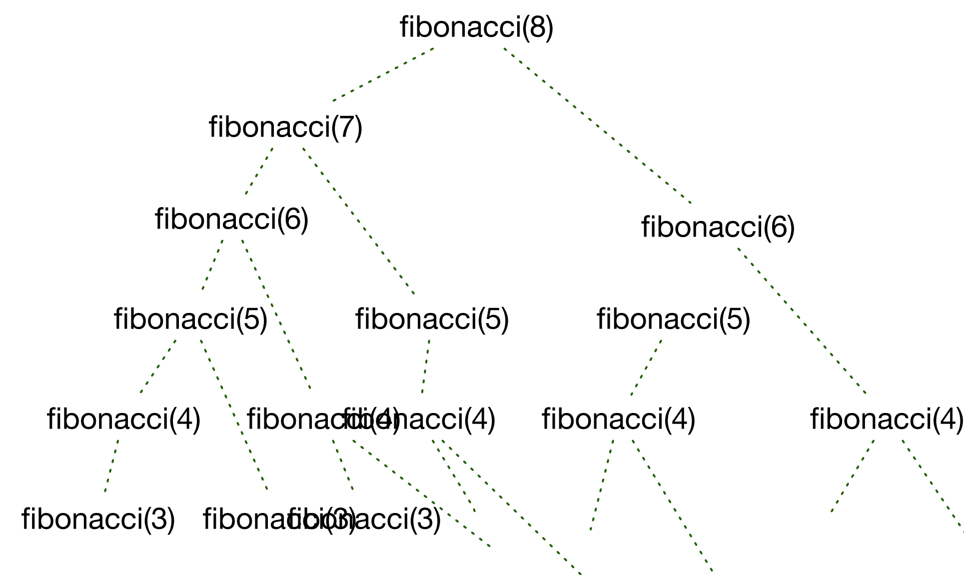
Recursion

- But disastrous for Fibonacci
- It takes 34 seconds in order to calculate fibonacci(39).

```
28 0.17530512809753418
29 0.27112603187561035
30 0.43769311904907227
31 0.7113552093505859
32 1.1374599933624268
33 1.846013069152832
34 2.994562149047852
35 4.856478929519653
36 7.8563339710235 6
37 12.681456804275513
38 20.5970380306243 9
39 33.9810550212860 1
```

Recursion

- What is the problem?
  - Look at what happens if we calculate fibonacci(9).
  - We calculate fibonacci(8) and fibonacci(7)
    - Since the first one also calculates fibonacci(7), we calculate fibonacci(7) twice.
    - And it gets worse for fibonacci(6), fibonacci(5), …



Memoization

- A simple trick to speed up recursive functions is to remember values that we have already calculated.
- Create a dictionary (possibly global) that stores values already calculated
    - Before any calculation check whether the desired value is in the dictionary
    - If we calculate something, we put the value into the dictionary

Memoization

```
fdic={0: 0, 1:1}

def fibonacci2(number):
    if number in fdic:
        return fdic[number]
    else:
        retval = fibonacci2(number-1)+fibonacci2(number-2)
        fdic[number] = retval
        return retval

for i in range(41):
    measure(fibonacci2, i*50)
```

Memoization

```
fdic={0: 0, 1:1}

def fibonacci2(number):
    if number in fdic:
        return fdic[number]
    else:
        retval = fibonacci2(number-1)+fibonacci2(number-2)
        fdic[number] = retval
        return retval

for i in range(41):
    measure(fibonacci2, i*50)
```

- Defining the dictionary

Memoization

```
fdic={0: 0, 1:1}

def fibonacci2(number):
    if number in fdic:
        return fdic[number]
    else:
        retval = fibonacci2(number-1)+fibonacci2(number-2)
        fdic[number] = retval
        return retval

for i in range(41):
    measure(fibonacci2, i*50)
```

- Check whether value is in the dictionary

Memoization

```
fdic={0: 0, 1:1}

def fibonacci2(number):
    if number in fdic:
        return fdic[number]
    else:
        retval = fibonacci2(number-1)+fibonacci2(number-2)
        fdic[number] = retval
        return retval

for i in range(41):
    measure(fibonacci2, i*50)
```

- Calculation is necessary

Memoization

```
fdic={0: 0, 1:1}

def fibonacci2(number):
    if number in fdic:
        return fdic[number]
    else:
        retval = fibonacci2(number-1)+fibonacci2(number-2)
        fdic[number] = retval
        return retval

for i in range(41):
    measure(fibonacci2, i*50)
```

- But we store the result in the dictionary in case we use it in the future

Memoization

```
fdic={0: 0, 1:1}

def fibonacci2(number):
    if number in fdic:
        return fdic[number]
    else:
        retval = fibonacci2(number-1)+fibonacci2(number-2)
        fdic[number] = retval
        return retval

for i in range(41):
    measure(fibonacci2, i*50)
```

- And now we measure

Decorators

- Python uses decorators to allow changing functions
- A decorator is implemented by:
  - Creating a function of a function that returns the amended function

Decorators

```
def timeit(function):
    def clocked(*args):
        start_time = time.perf_counter()
        result = function(*args)
        duration = (time.perf_counter() - start_time)
        name = function.__name__
        arg_string = ', '.join(repr(arg) for arg in args)
        print('Function {} with arguments {} ran
              in {} seconds'.format(
            name, arg_string, duration))
        return result
    return clocked
```

Decorators

- Decorator takes a function with positional arguments as function
- Decorator defines a new version of the argument function
- And returns it.

Decorators

```
def timeit(function):
    def clocked(*args):
        start_time = time.perf_counter()
        result = function(*args)
        duration = (time.perf_counter() - start_time)
        name = function.__name__
        arg_string = ', '.join(repr(arg) for arg in args)
        print('Function {} with arguments {} ran
               in {} seconds'.format(
            name, arg_string, duration))
        return result
    return clocked
```

Decorators

- To use a decorator, just put its name on top of the function definition
  - Decorator generator is executed when module is imported (or generator is defined)
  - When decorated function is defined, the modified version is created

Decorators

```
@timeit
def fibonacci(n):
    if n == 0:
        return 0
    if n == 1:
        return 1
    else:
        return fibonacci(n-1)+fibonacci(n-2)
```

Decorators

- If we execute this function, we get to see how often fibonacci is called on arguments already executed

```
>>> fibonacci(10)
Function fibonacci with arguments 1 ran in 5.140000070014139e-07 seconds
Function fibonacci with arguments 0 ran in 1.0870000011209413e-06 seconds
Function fibonacci with arguments 2 ran in 0.1692790839999958 seconds
Function fibonacci with arguments 1 ran in 1.2330000060956081e-06 seconds
Function fibonacci with arguments 3 ran in 0.2676633440000131 seconds
Function fibonacci with arguments 1 ran in 9.800001003129e-07 seconds
Function fibonacci with arguments 0 ran in 1.0470000120221812e-06 seconds
Function fibonacci with arguments 2 ran in 0.09880945999999824 seconds
Function fibonacci with arguments 4 ran in 0.4692909440000079 seconds
Function fibonacci with arguments 1 ran in 6.519999997103303e-07 seconds
Function fibonacci with arguments 0 ran in 1.0500000087176886e-06 seconds
Function fibonacci with arguments 2 ran in 0.1128122700000626 seconds
Function fibonacci with arguments 1 ran in 1.958000012791672e-06 seconds
Function fibonacci with arguments 3 ran in 0.2168502800000273 seconds
Function fibonacci with arguments 5 ran in 0.7868284680000102 seconds
Function fibonacci with arguments 1 ran in 5.6999999742402e-07 seconds
Function fibonacci with arguments 0 ran in 1.0729999928571488e-06 seconds
Function fibonacci with arguments 2 ran in 0.11366798399998856 seconds
Function fibonacci with arguments 1 ran in 1.2930000110600304e-06 seconds
Function fibonacci with arguments 3 ran in 0.2176230820000029 seconds
Function fibonacci with arguments 1 ran in 5.839999914769578e-07 seconds
```

Memoization with lru_cache

- We can define our own memoization decorator
  - But Python has one that uses an LRU cache
    - Memoization is LRU cache with an infinite cache size
    - Import from functools lru_cache

```
@functools.lru_cache
def fib(n):
    if n <= 1:
        return n
    else:
        return fib(n-1)+fib(n-2)
```

Sets and Frozen-Sets

Python Sets

- Python also has a set structure
  - Python optimizes membership queries
  - Sets are unordered and do not contain duplicate elements

Python Sets

- Define a set by using curly braces
  - `my_set = {'apple', 'orange', 'banana'}`
  - Caution: `{ }` is an empty dictionary, use
    - `empty = set()`

Python Sets

- Set operations:
  - Use add to place elements into the set

```
>>> my_set.add('a')
>>> my_set.add('b')
>>> my_set.add('a')
>>> print(my_set)
{'a', 'b'}
```

  - Adding the same element twice does not change the set

Python Sets

- Set operations:
  - To remove an element, use remove
  - Which fails if the parameter is not in the set

```
>>> my_set.remove('a')
>>> print(my_set)
{'b'}
>>> my_set.remove('a')
Traceback (most recent call last):
  File "<pyshell#9>", line 1, in <module>
    my_set.remove('a')
KeyError: 'a'
```

Python Sets

- Set operations:
  - Set operations union, intersection, difference are defined
  - Equality operations are defined
    - `set_1 < set_2` means proper subset

Python Sets

- Set operations:

`s1	s2`	union
`s1 & s2`	intersection
`s1 - s2`	set difference
`s1 ^ s2`	symmetric difference

Python Sets

- Best use: remove doublettes from list
  - Convert the list into a set, then convert back

```
>>> lista = [1, 2, 3, 4, 2, 1, 5, 1, 7]
>>> listb = list(set(lista))
>>> listb
[1, 2, 3, 4, 5, 7]
```

Python Sets

- Sets are ***mutable***
  - If you need a set as an index, use a frozenset
    - You cannot change a frozenset (other than reassigning another set to it)
    - The constructor will take an iterable

```
fs = frozenset([1,2,3])
```

    - You can still use operations on a frozenset such as intersection

```
>>> fs = frozenset([1,2,3])
>>> ft = frozenset([1, 'one', 1.0])
>>> fs & ft
frozenset({1})
```