CS521 O2
Information Structures with Python

Lecture 4

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Some slides adapted from Prof. Eugene Pinsky

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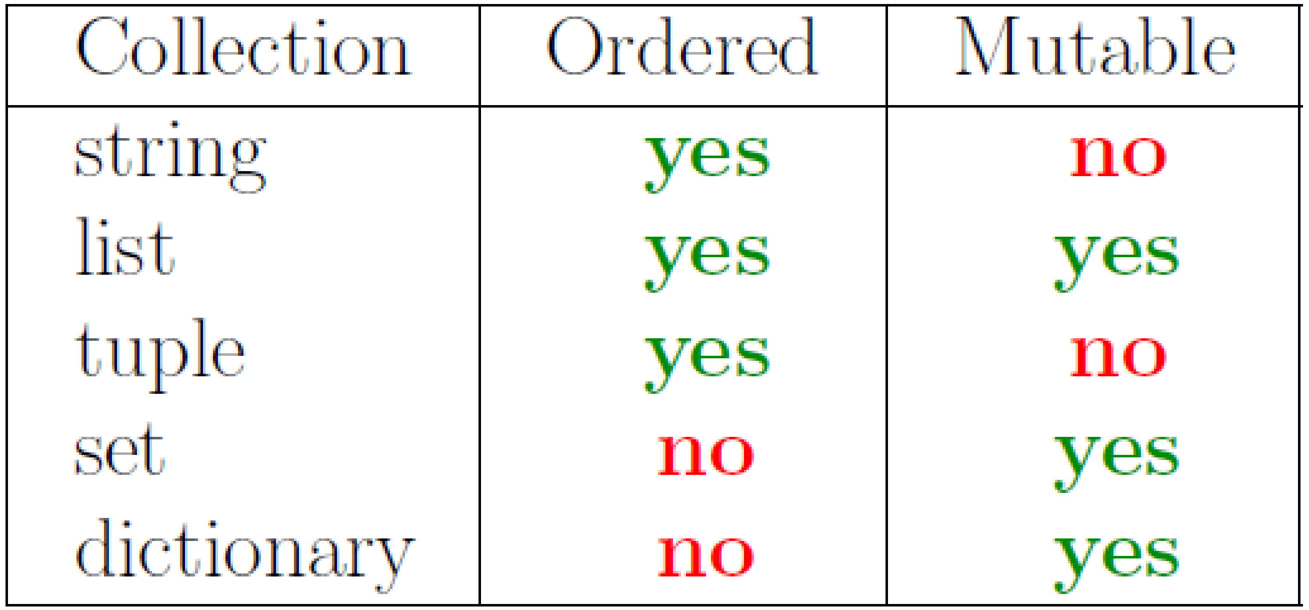
More on mutability



Collection	Ordered	Mutable
string	yes	no
list	yes	yes
tuple	yes	no
set	no	yes
dictionary	no	yes

- Strings are immutable and can only contain immutable elements
- Tuples are immutable, but can contain mutable objects, which can be modified in place
- Sets are mutable. But the elements contained in a set must be of immutable type - lists and dictionaries cannot be included in sets
- Dictionary keys cannot contain mutable objects

Hashing

- Hash tables are used to implement map and set data structures in many common programming languages
- Python uses hash tables for dictionaries and sets
- Hash table is an unordered collection of key-value pairs, where each key is unique
- Hashing is the process of using an algorithm to map data of any size to a fixed length. This is called a hash value.
- Hashing is used to create high performance, direct access data structures where large amount of data can be stored and accessed quickly.
- Hash values are computed with hash functions

Hashable

- An object is hashable if it has a hash value which never changes during its lifetime
- It can have different values during multiple invocations of Python programs
- A hashable object needs a __hash__() method and an __eq__() method to perform comparison
- Hashable objects can be used as a dictionary keys and a set members because these data structures use the hash value internally
- Primitive types are hashable
- Immutable objects with immutable elements are hashable – strings, frozen set, and some tuples
- Mutable collections (such as lists or dictionaries) are not hashable
- Objects which are instances of user-defined classes are hashable by default; they all compare unequal, and their hash value is their id()

Function hash()

- Function hash() returns the hash value of the object if it has one
- (x == y) compares hash values
- (x is y) compares id values
- Hash values are integers
- They are used to quickly compare dictionary keys during a dictionary lookup
- Functions are hashable
- Hash values of custom classes are set to their ids. By default, all instances of custom classes will have a hash value defined at creation and it will not change over time. Two instances of the same class will have two different hash values.

Non-hashable Tuples

- A tuple is hashable only if all its elements are hashable.

- Tuples with mutable collections are not hashable
  - ✓ Iteration can be applied
  - ✓ In-place modification can be done – we may end up with tuples with “identical” collectoins

- A hashable tuple cannot contain lists, sets, or dictionaries

Copying in Python

- Assignment statements in Python do not create copies of objects, they only bind names to an object

- For mutable objects or collections of mutable objects, we may want to create real copies of these objects - we want copies that we can modify without the original being modified at the same time

- For sets, dictionaries, and lists, there is difference between shallow and deep copying:
  - ✓ A shallow copy constructs a new collection object and then populating it with references to the child objects found in the original.
  - ✓ A deep copy means first constructing a new collection object and then recursively populating it with copies of the child objects found in the original.

None object

- In many other languages, null is just a synonym for 0, but null in Python is a full-blown object
- None is a singleton - the NoneType class only ever gives you the same single instance of None
- Like True and False, None is an immutable keyword
- None is falsy, which means not None is True
- None is the value a function returns when there is no return statement in the function

Algorithms

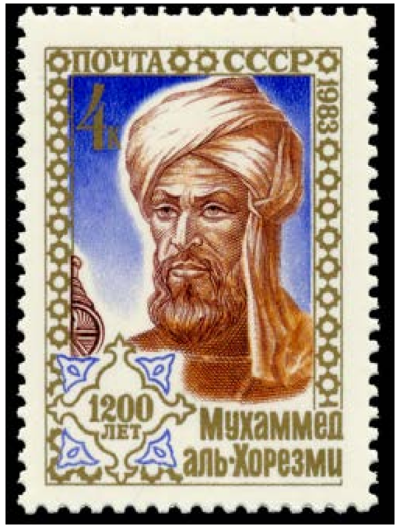
An **algorithm** is a procedure or a set of instructions used to perform or complete a particular task

- Finite set of instructions

- Origins from mathematics (Muhammad ibn Mūsā al-Khwārizmī, “father of algebra”)

- Lost in translation, the name of al-Khwārizmī became Algoritmi and changed meaning into “calculation methods”

- In mathematics and computer science, an algorithm is a step-by-step procedure for solving a problem or class of problems

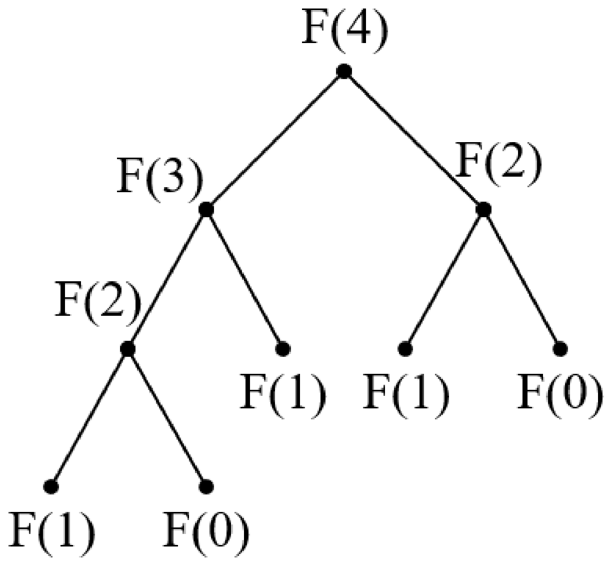


Using For loop or While loop to solve the problem

Fibonacci number: $Fn = F_{n-1} + F_{n-2}$ and $F_1 = 1$, $F_0 = 0$. **0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 56, ...**

```
START
Initialize an array $F[]$ with $F[0]=0$ and $F[1]=1$
Read user input an integer no less than 0 and save it in $n$
If $0 <= n <= 1$
        result = $F[n]$
Else if $n >= 2$
        Set $i=2$
        REPEAT
                $F[i]=F[i-1]+F[i-2]$
                $i=i+1$
        If $i > n$ end REPEAT
        result = $F[n]$
Else
        result = “The input $n$ must be an integer no less than 0”.
Endif

Output the result
END
```



Exercise:

- Give an example of two immutable objects x; y with the same hash value h and x == y is True

- Give an example of two immutable objects x; y with the same hash value h and x == y is False

- Which objects are hashable?

a. “seven”
b. {1:”A”, 2:”B”}
c. (1, 2, 3)
d. {1, 2, 3}
e. ([4, 5], 6)

Exercise:

- What will the result be?

```
x = [1 ,2 ,3]; y = x
print (id(x )== id(y))

x = [1 ,2 ,3]; y = [1, 2, 3]
print (id(x )== id(y))

x = [1 ,2 ,3]; y = x.copy()
print (id(x )== id(y))

x = [[1 ,2] ,3]; y = x. copy ()
x [0][0] = 100; print (x, y)
```

Key takeaways

- Strings are immutable and can only contain immutable elements
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