Computational Structures in Data Science

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Lecture #8: Efficiency vs Readability

Computation Concepts today

- More on Mutability
- Recap: Exceptions and Exception Handling
- More on Scoping
- Sequences, Iterables, Generators

Recap: Mutable Data Types

- Certain data types in python are mutable:
  - List, set
- Other data types in Python are immutable
  - Tuples
  - Primitive data types: integer, long, float, string, bool
- Dictionary:
  - Dictionary keys must be immutable
  - Dictionary values can be mutable or immutable

Recap: Mutable Data Types

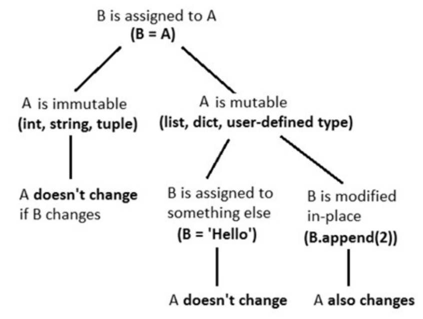
List Mutability

```
x = [1,2,3,4,5]
x[1] = 10

x[4] = 50

x += [60,70]
```

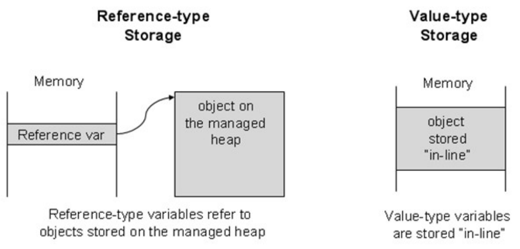
What will the following code do?

```
x = (1, 2, 3)
x[0] = 10 # What will this do?

d = {}
key = [1, 2]
value = [3, 4]
d[key] = value  # What will this do?
```

Mutability: Quick Diagram



Mutability: How it Works


Reference-type Storage
Value-type Storage
Memory
Reference var
object on the managed heap
Memory
object stored "in-line"
Reference-type variables refer to objects stored on the managed heap
Value-type variables are stored "in-line"

Notice that the reference-type "refers" to an object somewhere else in memory, namely, the managed heap. On the other hand, value-type objects (in most cases) are stored directly in the current, working memory.

Mutability: Why?

- Programming is a compromise between understandability and efficiency
  - Humans want to read and understand and maintain
  - Computers works the way they work

- Example:

  Passing a string to a function by reference or by copying.

  Which one is more efficient for large strings?

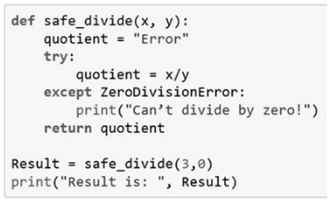
  Which one is probably more intuitive?

Recap: Exceptions

- Python raises an exception whenever an error occurs:
  - ZeroDivisionError
  - IndexError
- Python handles errors by terminating immediately and printing an error message.
- Exceptions can be handled by the program, preventing a crash (next slide)
- Programs can also raise exceptions of their own (later in the course)

Recap: Handling Exceptions

- Using *try* statement with *except* clause to prevent program crash.
- The following program won't crash even if you divide by 0:



```
def safe_divide(x, y):
    quotient = "Error"
    try:
        quotient = x/y
    except ZeroDivisionError:
        print("Can't divide by zero!")
    return quotient

Result = safe_divide(3,0)
print("Result is: ", Result)
```

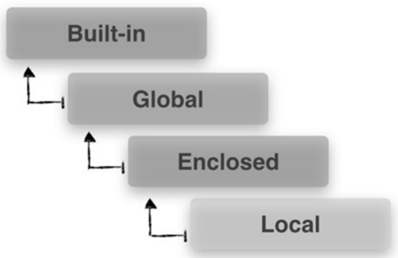
```
Can't divide by zero!
Result is:  Error
```

Why Exceptions?

- Exceptions are raised by the CPU and the operating system or by the program.
- Examples:
  - Division by Zero
  - File not Found
- More exceptions types: https://tinyurl.com/nl2yhry

- Exceptions allow to pass the condition on to the calling function for proper handling.

Recap: Variable Scope (Python)



Recap: Variable Scope

```
a_var = 'global value'

def a_func():
    global a_var
    a_var = 'local value'
    print(a_var, '[ a_var inside a_func()
]')

print(a_var, '[ a_var outside a_func() ]')
a_func()
print(a_var, '[ a_var outside a_func() ]')
```

Output?

```
global value [ a_var outside a_func() ]
local value [ a_var inside a_func() ]
local value [ a_var outside a_func() ]
```

More on Variable Scope

```
a_var = 'global variable'

def len(in_var):
    print('called my len() function')
    l = 0
    for i in in_var:
        l += 1
    return l

def a_func(in_var):
    len_in_var = len(in_var)
    print('Input variable is of length', len_in_var)

a_func('Hello, World!')
```

Output?

More on Variable Scope

```
a_var = 'global variable'

def len(in_var):
    print('called my len() function')
    l = 0
    for i in in_var:
        l += 1
    return l

def a_func(in_var):
    len_in_var = len(in_var)
    print('Input variable is of length', len_in_var)

a_func('Hello, World!')
```

Output?

Sequences

- **A sequence has:**
  - **a finite length,**
  - **is empty when it has length 0,**
  - **is indexed by a positive integer, with the first element being 0.**
- **Examples:**
  - Lists
  - Tuples
  - Strings
- **Not**: dictionary (no indexing)

Iterables

- **Any object that you can use a for loop over**
- **Sequence => Iterable (not both ways)**
- **Examples:**
  - **Lists**
  - **Strings**
  - **Tuples**
  - **Dictionaries**
- **Functions that return special data types**
  - **Range**
  - **Zip**
  - **Map**

Are these data types sequences or iterables?

Sequence vs Iterable

```
>>> x = range(10)
>>> x
range(0, 10)
>>> len(x) # We can get the length
10
>>> x[5] # We can index
5
```

```
>>> y = map(lambda x: x**2, [1, 2, 3])
>>> y
<map object at 0x101a3cb38>
>>> len(y) # We can't get length Error!
>>> y[0] # We can't index
```

Iterables: Why?

- **Lazy evaluation: Each value is computed on demand. No all values have to be stored in memory!**
- **If we want to save a value, we need to either bind it to a variable or loop**

Allows us to work with huge amounts of data!

Generators: Why?

- **Generators return iterables and can be of infinite length.**

```
def naturals():
        i = 1
        while True:
                yield i
                i += 1

>>> for elem in naturals():
... print(elem)
...
1
2
3
(keeps going, never ends)
```

Conclusion

Mutability, Scoping, Exceptions, Sequences, Iterables, and Generators:

- **The computer does not need them**
- **Decades of practice in programming have shown: Humans need them. The resulting code is better.**

More on these: In the labs.

- **Next lectures: Object Oriented Programming (they say a biologist invented it)**