Computational Structures in Data Science

Lecture:
Dictionaries and
Mutable Data

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Maps Project Next Week!

- **Partner Project**
  - See thread on Ed
- "Phases" break the project down:
  - **Phases 0 and 1 are easier** than 2 and 3.
- Checkpoint Weds 2/28
  - Worth 4/40 points, you need to make progress on Phase 0 and 1 (easier parts)
- Final Deadline Mar 8 (Mon)

Computational Structures in Data Science

Dictionaries

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Learning Objectives

- Dictionaries are a new type in Python
- Lists let us index a value by a number, or position.
- Dictionaries let us index data by other kinds of data.

Dictionaries

- Constructors:
  - `dict( <list of 2-tuples> )`
  - `dict( <key>=<val>, ...) # like kwargs`
  - **`{ <key exp>:<val exp>, …  }`**
  - `{ <key>:<val> for <iteration expression> }`
    - `>>> {x:y for x,y in zip(["a","b"],[1,2])}`
    - `{'a': 1, 'b': 2}`
- Selectors: **`<dict>[ <key> ]`**
  - <dict>.keys(), .items(), .values()
  - <dict>.get(key [, default])
- Operations:
  - Key in, not in, len, min, max
  - <dict>[<key>] = <val>

Demo

```
person = { 'name': 'Michael' }
person.get('name')
person['email'] = 'ball@berkeley.edu'
person.keys()
'phone' in person



text = 'One upon a time'
{ word : len(word) for word in text.split() }
```

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Mutability

Learning Objectives

- Distinguish between when a function mutates data, or returns a new object
  - Many Python "default" functions return new objects
- Understand modifying objects in place
- Python provides “is” and “==” for checking if items are the same, in different ways

Why does Mutability Matter?

- Mutable data is a reality — lists, dictionaries, objects (coming soon)
- It's a challenging aspect of programming
- There are common patterns, which you will *slowly* become familiar with and internalize.
- **Use your environment diagrams!**

Objects in Python

- An **object** is a bundle of data and behavior.
- A type of object is called a **class**.
- Every value in Python is an object.
  - string, list, int, tuple, et
- All objects have attributes
- Objects often have associated methods
  - lst.append(), lst.extend(), etc
- **Objects have a value (or values)**
  - Mutable: We can change the object after it has been created
  - Immutable: We cannot change the object.
- Objects have an *identity*, a reference to that object.

Immutable Object: string

- `course = 'CS88'`

- **What kind of object is it?**
  - `type(course)`
- **What data is inside it?**
  - `course[0]`
  - `course[2:]`

- **What methods can we call?**
  - `course.upper()`
  - `course.lower()`

- None of these methods modify our original string.

Mutable Objects: lists and dictionaries

- Immutable – the value of the object cannot be changed
  - integers, floats, booleans
  - strings, tuples
- Mutable – the value of the object can change
  - Lists
  - Dictionaries

```
>>> alist = [1,2,3,4]
>>> alist
[1, 2, 3, 4]
>>> alist[2]
3
>>> alist[2] = 'elephant'
>>> alist
[1, 2, 'elephant', 4]
```

```
>>> adict = {'a':1, 'b':2}
>>> adict
{'b': 2, 'a': 1}
>>> adict['b']
2
>>> adict['b'] = 42
>>> adict['c'] = 'elephant'
>>> adict
{'b': 42, 'c': 'elephant', 'a':
1}
```

Dictionaries

Constructors:

```
dict( hi=32, lo=17)
dict([('hi',212),('lo',32),(17,3)])
{'x':1, 'y':2, 3:4}
{wd : len(wd) for wd in "The quick brown fox".split()}
```

Selectors:

```
water['lo']
<dict>.keys(), .items(), .values()
<dict>.get(key [, default] )
```

Operations:

```
in, not in, len, min, max
'name' in course
```

Mutators

```
course['number' ] = 'C88C'
course.pop('room')
del course['room']
```

Immutability vs Mutability

- An immutable value is unchanging once created.
- Immutable types (that we've covered): int, float, string, tuple

```
a_string = "Hi y'all"
a_string[1] = "I" # ERROR
a_string += ", how you doing?"
an_int = 20
an_int += 2
```

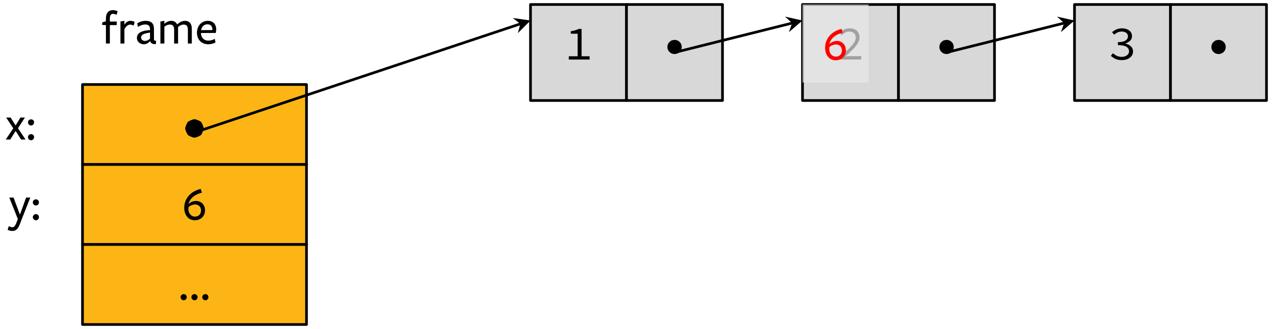
- A mutable value can change in value throughout the course of computation. All names that refer to the same object are affected by a mutation.
- Mutable types (that we've covered): list, dict

```
grades = [90, 70, 85]
grades_copy = grades # Not actually a copy!
grades[1] = 100 # grades_copy changes too!
words = {"agua": "water"}
words["pavo"] = "turkey"
```

Mutation in Environments

- A variable assigned a compound value (object) is a reference to that object.
- Mutable objects can be changed but the variable(s) still refer to it
  - x is still the same object, but it's values have changed.

```
x = [1, 2, 3]
y = 6
x[1] = y
x[1]
```



Mutating Lists: Example functions of the `list` class

- `append()` adds a single element to a list:

```
s = [2, 3]
t = [5, 6]
s.append(4)
s.append(t)
t = 0
```

Try in PythonTutor.

- `extend()` adds all the elements in one list to another list:

```
s = [2, 3]
t = [5, 6]
s.extend(4) # 🚫 Error: 4 is not an iterable!
s.extend(t)
t = 0
```

Try in PythonTutor. (After deleting the bad line)

Mutating Lists -- More Functions!

- `list += [x, y, z] # just like extend.`
  - You need to be careful with this one! It modifies the list.
- `pop()` removes and returns the last element:

```
s = [2, 3]
t = [5, 6]
t = s.pop()
```

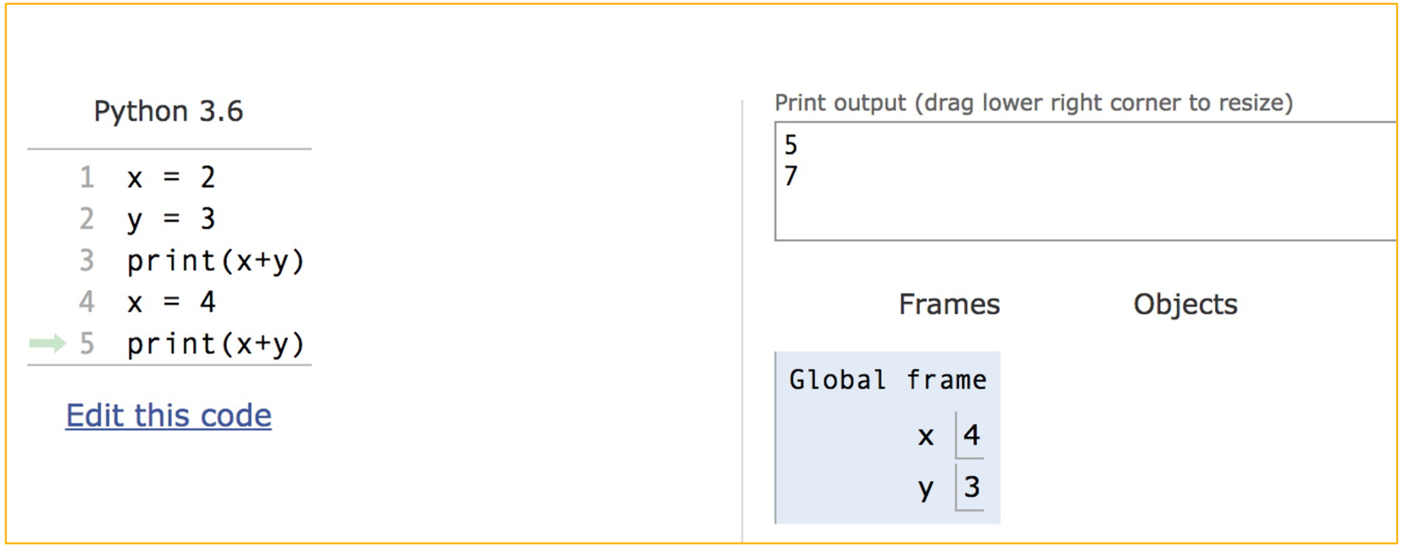
Try in PythonTutor.

- `remove()` removes the first element equal to the argument:

```
s = [6, 2, 4, 8, 4]
s.remove(4)
```

Try in PythonTutor.

Python Tutor: Assignments Are References



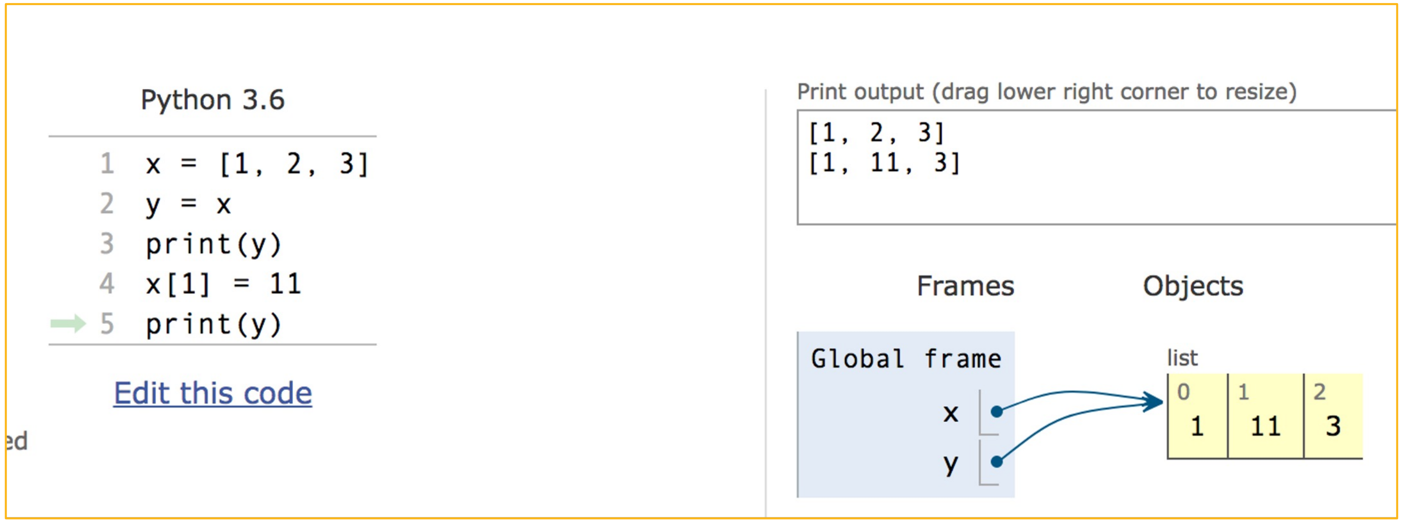
Python 3.6

```python
x = 2
y = 3
print(x+y)
x = 4
print(x+y)
```

Edit this code

Print output (drag lower right corner to resize)

```
5
7
```



Python 3.6

```python
x = [1, 2, 3]
y = x
print(y)
x[1] = 11
print(y)
```

Edit this code

Print output (drag lower right corner to resize)

```
[1, 2, 3]
[1, 11, 3]
```

Mutable Data Inside Immutable Objects

- Mutable objects can "live" inside immutable objects!
- An immutable sequence may still change if it contains a mutable value as an element.
- Be **very careful**, and probably **do not**do this!

```
t = (1, [2, 3])
t[1][0] = 99
t[1][1] = "Problems"
```

- Try in PythonTutor

Equality vs Identity

```
list1 = [1,2,3]
list2 = [1,2,3]
```

- **Equality**: exp0 == exp1
  evaluates to True if both exp0 and exp1 evaluate to objects containing equal values (Each object can define what == means)

```
list1 == list2 # True
```

- **Identity**: exp0 is exp1
  evaluates to True if both exp0 and exp1 evaluate to the same object
- Identical objects always have equal values.

```
list1 is list2 # False
```

- Try in PythonTutor.

Identity and == vs is

How do we know if two names (variables) are the same exact object? i.e. Will modifying one modify the other?

```
>>> alist = [1, 2, 3, 4]
>>> alist == [1, 2, 3, 4]  # Equal values?
True
>>> alist is [1, 2, 3, 4]  # same object?
False
>>> blist = alist          # assignment refers
>>> alist is blist         # to same object
True
>>> blist = list(alist)    # type constructors copy
>>> blist is alist
False
>>> blist = alist[ : ]     # so does slicing
>>> blist is alist
False
>>> blist
[1, 2, 3, 4]
>>>
```

What is the meaning of `is`?

- is in Python means two items have the exact same *identity*
- Thus, `a is b` implies `a == b`
- **`Why?`** Each object has a function **`id()`** which returns its "address"
  - We won't get into what this means, but it's essentially an internal "locator" for that data in memory.
  - Think of two houses which have the exact same floor plan, look the same, etc. The are "the same house" but each have a unique address. (And thus are different houses)
- Think this is tricky? cool? amazing?
- Take CS61C (Architecture) and CS164 (Programming Languages)

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Passing Data Into Functions

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Learning Objectives

- Passing in a mutable object in a function in Python lets you modify that object
- Immutable objects don't change when passed in as an argument
- Making a new name doesn't affect the value outside the function
- Modifying mutable data **does** modify the values in the parent frame.

Mutating Arguments

- Functions can mutate objects passed in as an argument
- Declaring a new variable with the same name as an argument only exists within the scope of our function
  - You can think of this as creating a new name, in the same way as redefining a variable.
  - This will **not** modify the data outside the function, even for mutable objects.
- **BUT**
  - We can still directly modify the object passed in…even though it was created in some other frame or environment.
  - We directly call methods on that object.
- View Python Tutor

Understanding Python: What should we return?

- Why do some functions return `None`?
- Why do some functions return a value?

Functions that mutate an argument **usually** return None!

C88C / 61A / Data Science View: Avoid mutating data unless it's necessary!

Mutations are useful, but can get confusing quickly. This is why we focus on *functional programming* - map, filter, reduce, list comprehensions, etc.

Functions that Mutate vs Return New Objects

- Lists:
  - sorted(list) – retiurns a new list
  - list.sort() – modifies the list, returns None
  - list.append() – modifies the list, returns None
  - list.extend() – modifies the list, returns None

Python Gotcha’s: a += b and a = a + b

- Sometimes similar ***looking*** operations have very different results!
- Why?
- = always binds (or re-binds) a value to a name.
- Python Tutor

```
def add_data_to_thing(thing, data):
     print(f"+=, Before: {thing}")
     thing += data
     print(f"+=, After: {thing}")
     return thing

def new_thing_with_data(thing, data):
     print(f"=, Before: {thing}")
     thing = thing + data
     print(f"=, After: {thing}")
     return thing
```

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Mutable Functions

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Learning Objectives

- Remember: Each function gets its own new frame
- Inner functions can access data in the parent environment
- Use an inner function along with a mutable data type to capture changes

Making Functions that Capture and change state

- We want to make a function, which returns a function that can change the state.
- Python Tutor Link

```
def make_counter():
    counter = [0]
    def count_up():
            counter[0] += 1
            return counter
    return count_up

c = make_counter()
print(c)
c()
c()
c()
```

Functions with Changing State

- Goal: Use a function to repeatedly withdraw from a bank account that starts with $100.
- Build our account: `withdraw = make_withdraw_account(100)`
- First call to the function:

```
withdraw(25)        # 75
```

- Second call to the function:

```
withdraw(25)        # 50
```

- Third call to the function:

```
withdraw(60)        # 'Insufficient funds'
```

How Do We Implement Bank Accounts?

- A mutable value in the parent frame can maintain the local state for a function.
- View in PythonTutor

```
def make_withdraw_account(initial):
    balance = [initial]

    def withdraw(amount):
        if balance[0] - amount < 0:
            return 'Insufficient funds'
        balance[0] -= amount
        return balance[0]
    return withdraw
```

Implementing Bank Accounts

- A mutable value in the parent frame can maintain the local state for a function.

```
def make_withdraw_account(initial):
    balance = [initial]

    def withdraw(amount):
        if balance[0] - amount < 0:
            return 'Insufficient funds'
        balance[0] -= amount
        return balance[0]
    return withdraw
```

View in PythonTutor