Module 09: Additional Options for Organizing Data

Topics:

- Dictionaries
- Classes

Readings: ThinkP 11, 15, 16, 17

Collections of key-value pairs

- In CS115, you studied collections of key-value pairs, where
  - Key: describes something basic and unique about an object (e.g. student ID, SIN, cell's DNA signature)
  - Value: a property of that object (e.g. student's major, person name, type of organism)
- Key-value pairs are basic to computer applications:
  - Looking up someone in an online phonebook
  - Logging onto a server with your userid and password
  - Opening up a document by specifying its name

Dictionaries, or key-value collections

- Built into Python
- Use **{}** for dictionaries
- Very fast – key retrieval is *essentially* O(1)
- The type used for the key must be immutable (e.g. Str, Int)
- Any type can be used for the value
- Keys are not sorted or ordered
- No reverse look-up by value (brute-force only)

Creating Dictionaries

- Create a dictionary by listing multiple **`key:value`** pairs

```
wavelengths = {'blue': 400,
   'green': 500, 'yellow':600,
   'red':700}
```

- Create an empty dictionary

```
students = {}
```

Using a dictionary

- Retrieve a value by using its key as an index
  `wavelengths['blue'] => 400`
  `students[2001] => KeyError:2001`

- Update a value by using its key as an index
  `wavelengths['red'] = 720`

- Add a value by using its key as an index
  `wavelengths['orange'] = 630`

Dictionary methods and functions

Module is called **`dict`**

- **`len(d)=>`** number of pairs in **`d`**
- **`d.keys() =>`** a view of keys in **`d`**
- **`d.values() =>`** a view of values in **`d`**
  - Views can be used in for loops
- **`k in d =>`** **`True`** if **`k`** is a key in **`d`**
- **`d.pop(k) => value`** for **`k`**, and removes **`k:value`** from **`d`**
- See **`dir(dict)`** for more
- Automatically imported in your program

Specifying a dictionary's type

Since we have both keys and values, both must be specified:

```
(dictof Key_type Value_type)
```

Example: **`wavelengths`** is of type

```
(dictof Str Nat)
requires: keys are nonempty strings
          Each value > 0
```

When to use dictionaries

- Generally faster to look up keys in a dictionary than in a list
- Only use dictionaries if the order is not important
  - If order is important , use a list instead
- Very useful when counting number of times an item occurs in a collection (e.g. characters or words in a document)

Example: Counting number of times distinct characters occur in a string

```
## character_count: Str ->(dictof Str Nat)
def character_count (sentence):
    characters = {}
    for char in sentence:
        if char in characters:
            characters[char] =  \
                characters[char] + 1
        else:
            characters[char] = 1
    return characters
```

Next, find the most common character in a string

```
## most_common_character: Str -> Str
## requires: len(sentence) > 0

def most_common_character (sentence):
    chars = character_count(sentence)
    most_common = ""
    max_times = 0

    for curr_char in chars:
        if chars[curr_char] > max_times:
            most_common = curr_char
            max_times = chars[curr_char]
    return most_common
```

Run-time basics for important dictionary operations

For a dictionary **`d`** contains n keys, *assume* the following runtimes:

- **`d[k]`** is O(1)
- **`d[k] = v`** is O(1)
- **`k in d`** is O(1)
- **`list(d.keys())`** is O(n)
- **`list(d.values())`** is O(n)

Note: the dictionary runtimes are more complicated than this, but we will work with these assumptions

Exercise

Write a Python function **`common_keys`** that consumes two dictionaries with a common key type, and returns a list of all keys which occur in both dictionaries.

Dictionaries are mutable

- Dictionaries can be mutated:
  - Key:Value pairs added
  - Key:Value pairs deleted
  - Values updated for a particular Key
- Like lists, dictionaries can have aliases as well. Note that the following mutates **`d1`**.

```
d1 = {3:'three', 2:'two'}
d2 = d1
d2[1] = 'one'
```

A function can mutate a dictionary too

```
def purge(d):
    keys = list(d.keys())
    for k in keys:
        if d[k] == "":
            d.pop(k)
```

Suppose

```
dt = {2:'xx', 1:'x', 0:'',
      4:'xxxx', -3:'', 3:'xxx'},
```

what is the value of **`dt`** after calling **`purge(dt)`**?

Recall: Structures in Scheme

To declare a new structure in Scheme:

```
(define-struct Country
  (continent leader population))
;; A Country is a
;; (make-Country Str Str Nat)
```

Classes: like structures (but different)

To declare a similar thing in Python:

```
class Country:
  '''Fields: continent (Str),
             leader (Str),
             population (Nat)'''
```

Using classes

- Python includes a very basic set-up for classes
- We will include several very important methods in our classes to help with
  - Creating objects
  - Printing objects
  - Comparing objects
- These methods will use the local name **`self`** to refer to the object being used

Constructing objects with `__init__`

```
class Country:
  '''Fields: continent (Str), leader (Str),
             population (Nat)'''
  def __init__(self, cont, lead, pop):
      self.continent = cont
      self.leader = lead
      self.population = pop
```

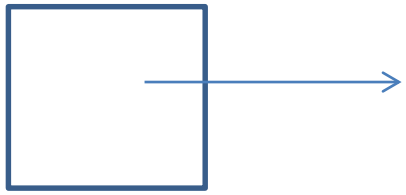
To create a `Country` object:

```
canada = Country("North America",
  "Trudeau", 35344962)
```

Memory model for classes

```
canada = Country("North
  America", "Trudeau", 35344962)
```

canada



continent	**"North America"**
leader	"Trudeau"
population	35344962

Accessing the fields of an object

```
india = Country("Asia", "Modi",
        1241491960)
print (india.continent)
print (india.leader == "Modi")
india.population += 1
```

`__str__` : Very helpful for debugging

```
>>> print(canada)
< __main__.Country instance at 0x0286EC10>
```

However, including the following

```
class Country:
  # __init__ code ...
  def __str__(self):
      return "CNT: {0.continent}; L: {0.leader};
              POP: {0.population}".format(self)
```

makes things much better!

```
>>> print(canada)
CNT: North America; L: Trudeau; POP: 34500000
```

Aliases

```
india_alias = india
india_alias.population += 1
```

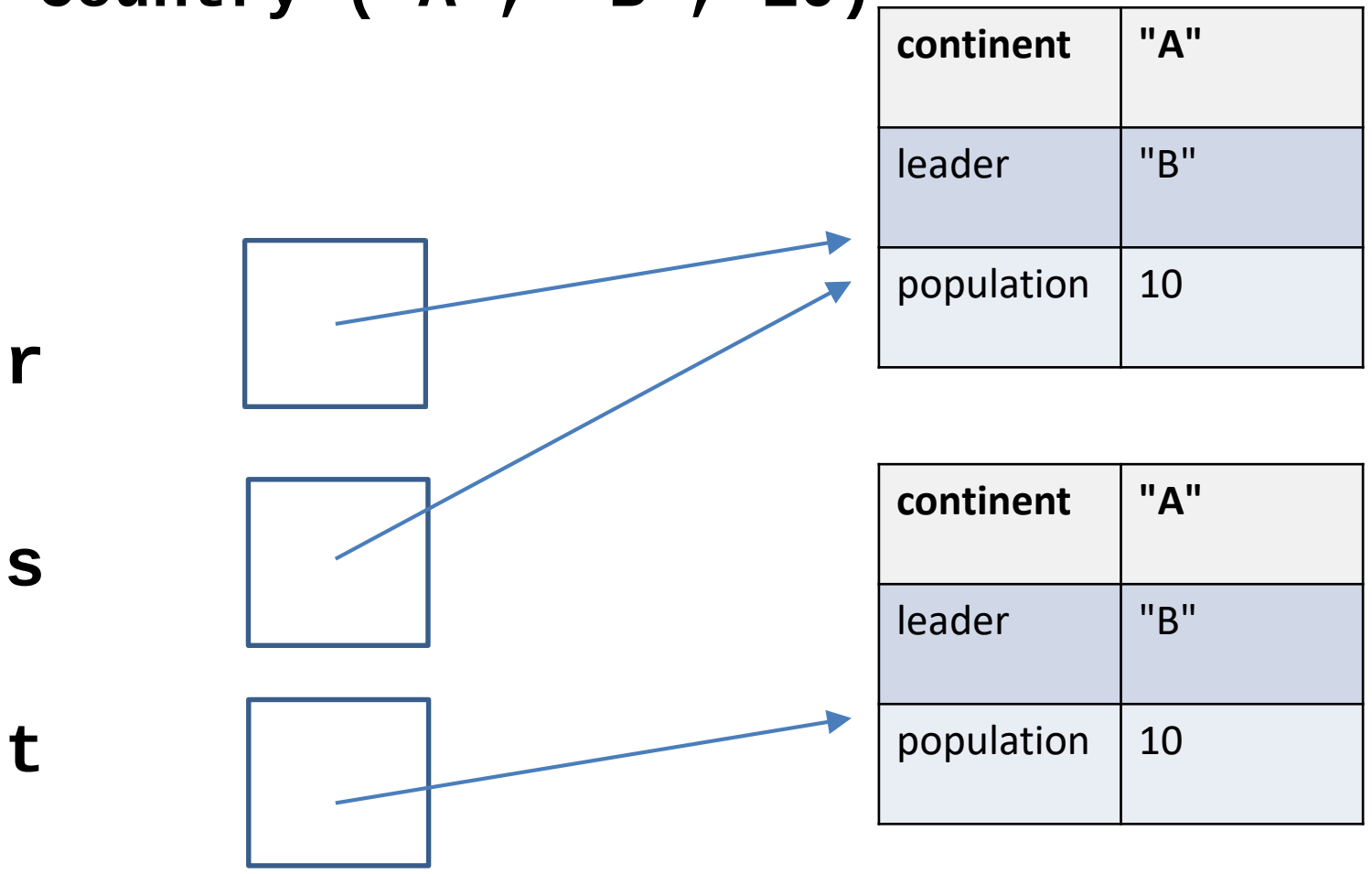
The population of both **`india`** and **`india_alias`** is increased (since there is only one **`Country`** object here)

What if you want another copy of an object, rather than an alias?

- Create a new object, and set all the fields

```
india_copy = Country
  (india.continent, india.leader,
  india.population)
```

```
r = Country("A", "B", 10)
s = r
t = Country ("A", "B", 10)
```



Comparing objects for equality

- Are two objects actually aliases? Use **`is`**
  `india_alias is india  → True`
  - **`india_copy is india → False`**
- Are the fields of two objects equal?
  - Would like
    - **`india_copy == india → True`**
  - But, that is not the default in Python
  - We need to provide another function first

`__eq__` : specifying object equality

For objects `x, y`, `x==y` → `True`

only if `x` and `y` are aliases

If we want `x==y` => `True` if the corresponding fields are equal, we can specify this by providing a function called `__eq__`

```
class Country:
  # __init__ and __str__ code ...
  def __eq__(self, other):
    return isinstance(other, Country) and
        self.continent == other.continent and\
        self.leader == other.leader and\
        self.population == other.population
```

Exercise: Write a function that returns **`Country`** with higher population

```
def higher_population(c1, c2):
      if c1.population >= c2.population:
            return c1
      else:
            return c2
canada = Country("North America", "Trudeau",
                 34108752)
us = Country("North America", 'Obama', 311591917)
## Test 1: second country has higher population
check.expect("T1", higher_population(canada, us),
             us)
```

Exercise

Write a function **`leader_most_populous`** that consumes a nonempty list of **`Country`** objects, and returns the leader of the most populous country in the list.

There's a lot more to Python classes

- Use **`dir(c)`** to see available methods and fields, where **`c`** is object or the type name
- Classes join a related set of values into a single compound object (like Scheme structures)
- With classes, we can attach methods to types of objects (like for **`str`**, **`list`**, **`dict`**)

Class Methods

- Functions defined within the class (should be indented the same as **`__init__`**)
- First parameter is always **`self`**:
  - The function can mutate the fields of **`self`**.
  - The function can use the fields of **`self`** in calculations and comparisons.
- Class methods are called using the same dot notation as the string and list methods.
- Class methods are like other functions. They may
  - Return values (or not)
  - Print information (or not)

Example **`Country`** class method:

```
# Must be indented same amount as __init__
def election(self, winner):
  print("Election Results:")
  if self.leader == winner:
     print("{0} re-elected".format(
           self.leader))
  else:
     print("{0} replaces {1} as leader".format(
           winner, self.leader))
     self.leader = winner
```

Using `election`

```
>>> us = Country("North America",
                 "Obama", 307006550)
>>> us.election("Trump")
Election Results:
Trump replaces Obama as leader
>>> us.leader
Trump
```

Object-oriented design

- Classes are used to associate methods with the objects they work on
- Classes and modules allow programmers to divide a large project into smaller parts
- Different people can work on different parts
- Managing this division (and putting the pieces back together) is a key part of software engineering
- See CS246 or CS430 to learn more

Goals of Module 09

- Use dictionaries to associate keys and values for extremely fast lookup
- Be able to define a class to group related information into a single compound object