Programming Principles in Python (CSCI 503/490)

Sets, Comprehensions, and Generators

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(some slides adapted from Dr. Reva Freedman)

Dictionary

- AKA associative array or map
- Collection of key-value pairs
  - Keys must be unique
  - Values need not be unique
- Syntax:
  - Curly brackets {} delineate start and end
  - Colons separate keys from values, commas separate pairs
  - `d = {'DeKalb': 783, 'Kane': 134, 'Cook': 1274, 'Will': 546}`
- No type constraints
  - `d = {'abc': 25, 12: 'abc', ('Kane', 'IL'): 123.54}`

Collections

- A dictionary is **not** a sequence
- Sequences are **ordered**
- Conceptually, dictionaries need no order
- A dictionary is a **collection**
- Sequences are also collections
- All collections have length (`len`), membership (`in`), and iteration (loop over values)
- Length for dictionaries counts number of key-value **pairs**
  - Pass dictionary to the `len` function
  - ```
    d = {'abc': 25, 12: 'abc', ('Kane', 'IL'): 123.54}
    len(d) # 3
    ```
    ```

Mutability

- Dictionaries are **mutable**, key-value pairs can be added, removed, updated
- `d = {'DeKalb': 783, 'Kane': 134, 'Cook': 1274, 'Will': 546}`
- `d['Winnebago'] = 1023 # add a new key-value pair`
- `d['Kane'] = 342        # update an existing key-value pair`
- `d.pop('Will')          # remove an existing key-value pair`
- `del d['Winnebago']     # remove an existing key-value pair`
- `d.update({'Winnebago': 1023, 'Kane': 324})`
- `d.update([('Winnebago', 1023), ('Kane', 324)])`
- `d.update(Winnebago=1023, Kane=324)`

Dictionary Methods

Method	Meaning
`<dict>.clear()`	Remove all key-value pairs
`<dict>.update(other)`	Updates the dictionary with values from `other`
`<dict>.pop(k, d=None)`	Removes the pair with key `k` and returns value or default `d` if no key
`<dict>.get(k, d=None)`	Returns the value for the key `k` or default `d` if no key
`<dict>.items()`	Returns iterable view over all pairs as (key, value) tuples
`<dict>.keys()`	Returns iterable view over all keys
`<dict>.values()`	Returns iterable view over all values

Dictionary Methods

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<dict>.items()	Returns iterable view over all pairs as (key, value) tuples
<dict>.keys()	Returns iterable view over all keys
<dict>.values()	Returns iterable view over all values

Assignment 3

- To be announced soon

User Study

Quiz Tuesday

Iteration

- Even though dictionaries are not sequences, we can still iterate through them
- Principle: Don't depend on order
- ```
  for k in d:
      print(k, end=" ")
  ```
- This only iterates through the **keys**!
- We could get the values:
- ```
  for k in d:
      print('key:', k, 'value:', d[k], end=" ")
  ```
- …but this is kind of like counting through a sequence (not pythonic)

Dictionary Views

- ```
  for k in d.keys():      # iterate through keys
      print('key:', k)
  ```
- ```
  for v in d.values():    # iterate through values
      print('value:', v)
  ```
- ```
  for k, v in d.items(): # iterate through key-value pairs
      print('key:', k, 'value:', v)
  ```
- `keys()` is superfluous but is a bit clearer
- `items()` is the enumerate-like method
  ```

Exercise: Count Letters

- Write code to take a string and return the count of each letter that occurs in a dictionary
- ```
  count_letters('illinois')
  # returns {'i': 3, 'l': 2, 'n': 1, 'o': 1, 's': 1}
  ```
  ```

Exercise: Count Letters

- ```
  def count_letters(s):
      d = {}
      for c in s:
          if c not in d:
              d[c] = 1
          else:
              d[c] += 1
      return d
  count_letters('illinois')
  ```
  ```

Exercise: Count Letters

- ```
  def count_letters(s):
      d = {}
      for c in s:
          d[c] = d.get(c, 0) + 1
      return d
  count_letters('illinois')
  ```
  ```

Exercise: Count Letters (using collections)

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- ```
  from collections import defaultdict
  def count_letters(s):
      d = defaultdict(int)
      for c in s:
          d[c] += 1
      return d
  count_letters('illinois')
  ```
  ```

Exercise: Count Letters (using collections)

- ```
  from collections import defaultdict
  def count_letters(s):
      d = defaultdict(int)
      for c in s:
          d[c] += 1
      return d
  count_letters('illinois')
  ```

- ```
  from collections import Counter
  def count_letters(s):
      return Counter(s)
  count_letters('illinois')
  ```

Sorting

- Order doesn't really mean anything in a dictionary
- There is no .sort or .reverse method
- We can iterate through items in sorted order using sorted
- ```
  d = count_letters('illinois')
  for k, v in sorted(d.items()):
      print(k, ':', v)
  ```
- reversed also works on dictionary views
- sorted and reversed work on any iterable (thus all collections)
  ```

Sets

Sets

- Sets are dictionaries but without the values
- Same curly braces, no pairs
- `s = {'DeKalb', 'Kane', 'Cook', 'Will'}`
- Only one instance of a value is in a set—sets **eliminate duplicates**
- Adding multiple instances of the same value to a set doesn't do anything
- ```
  s = {'DeKalb', 'DeKalb', 'DeKalb', 'Kane', 'Cook', 'Will'}
      # {'Cook', 'DeKalb', 'Kane', 'Will'}
  ```
- Watch out for the empty set
  - `s = {} # not a set!`
  - `s = set() # an empty set`
  ```

Sets are Mutable Collections

- Sets are **mutable** like dictionaries: we can add, and delete
- Again, no type constraints
  - `s = {12, 'DeKalb', 22.34}`
- Like a dictionary, a set is a **collection** but not a sequence
- Q: What three things can we do for any collection?

Collection Operations on Sets

- `s = {'DeKalb', 'Kane', 'Cook', 'Will'}`
- Length
  - `len(s) # 4`
- Membership: fast just like dictionaries
  - `'Kane' in s # True`
  - `'Winnebago' not in s # True`
- Iteration
  - ```
    for county in s:
        print(county)
    ```
    ```

Mathematical Set Operations

- `s = {'DeKalb', 'Kane', 'Cook', 'Will'}`
  `t = {'DeKalb', 'Winnebago', 'Will'}`
- Union: `s | t # {'DeKalb', 'Kane', 'Cook', 'Will', 'Winnebago'}`
  - Unlike dictionaries, is commutative for sets (`s | t == t | s`)
- Intersection: `s & t # {'DeKalb', 'Will'}`
- Difference: `s - t # {'Kane', 'Cook'}`
- Symmetric Difference: `s ^ t # {'Kane', 'Cook', 'Winnebago'}`
- Object method variants: `s.union(t)`, `s.intersection(t)`, `s.difference(t)`, `s.symmetric_difference(t)`
- Disjoint: `s.isdisjoint(t) # False`

Mutation Operations

- add: `s.add('Winnebago')`
- discard: `s.discard('Will')`
- remove: `s.remove('Will') # generates KeyError if not exist`
- clear: `s.clear() # removes all elements`
- Variants of the mathematical set operations (have augmented assignments)
  - `update` (union): `|=`
  - `intersection_update: &=`
  - `difference_update: -=`
  - `symmetric_difference_update: ^=`
- Methods take any **iterable**, operators require **sets**

Comprehensions

Comprehension

- Shortcut for loops that **transform** or **filter** collections
- Functional programming features this way of thinking:
  Pass functions to functions!
- Imperative: a loop with the actual functionality buried inside
- Functional: specify both functionality and data as inputs

List Comprehension

- ```
  output = []
  for d in range(5):
      output.append(d ** 2 - 1)
  ```

- Rewrite as a map:
  - `output = [d ** 2 - 1 for d in range(5)]`
- Can also filter:
  - `output = [d for d in range(5) if d % 2 == 1]`
- Combine map & filter:
  - `output = [d ** 2 - 1 for d in range(5) if d % 2 == 1]`
  ```

Comprehensions using other collections

- Comprehensions can use existing collections, too (not just ranges)
- Anything that is **iterable** can be used in the for construct (like for loop)
- `names = ['smith', 'Smith', 'John', 'mary', 'jan']`
- `names2 = [item.upper() for item in names]`

Any expression works as output items

- Tuples inside of comprehension
  - `[(s, s+2) for s in slist]`
- Dictionaries, too
  - `[{'i': i, 'j': j} for (i, j) in tuple_list]`
- Function calls
  - ```
    names = ['smith', 'Smith', 'John', 'mary', 'jan']
    names2 = [item.upper() for item in names]
    ```
    ```

Multi-Level and Nested Comprehensions

- **Flattening** a list of lists
  - `my_list = [[1,2,3],[4,5],[6,7,8,9,10]]`
    `[v for vlist in my_list for v in vlist]`
  - `[1,2,3,4,5,6,7,8,9,10]`
- Note that the for loops are in order
- Difference between **nested** comprehensions
  - `[[v**2 for v in vlist] for vlist in my_list]`
  - `[[1,4,9],[16,25],[36,49,64,81,100]]`

Comprehensions for other collections

- Dictionaries
  - ```
    {k: v for (k, v) in other_dict.items()
     if k.startswith('a')}
    ```
  - Sometimes used for one-to-one map inverses
    - How?
    ```

Comprehensions for other collections

- Dictionaries
  - ```
    {k: v for (k, v) in other_dict.items()
     if k.startswith('a')}
    ```
  - Sometimes used for one-to-one map inverses
    - `{v: k for (k, v) in other_dict.items()}`
    - Be careful that the dictionary is actually one-to-one!
- Sets:
  - `{s[0] for s in names}`
    ```

Tuple Comprehension?

- `thing = (x ** 2 for x in numbers if x % 2 != 0)`
  `thing # not a tuple! <generator object <genexpr> …>`
- Actually a **generator**!
- This **delays** execution until we actually need each result