Australian National University

COMP1730/COMP6730
Programming for Scientists

Dictionaries and sets

Lecture outline

* Dictionaries: the Python `dict` type
* Sets: the Python `set` type

Dictionaries (the concept of mapping)

* A dictionary is **conceptually** a mapping
* In general, a mapping can be defined as a relation between inputs and outputs that associates a **unique** (i.e., one and only one) output to each input
* (Many) examples of mappings:
  - A continuous mathematical function $y = f(x)$ (mapping among x and y values)
  - A look-up index (e.g., mapping between words and page numbers in a book index, between names and phone numbers in a contact list, etc.)
  - ...
  - Even a Python list can be interpreted as a mapping between consecutive integers (list indices) and list elements

Dictionaries (definition)

- A dictionary is a **mapping** where the correspondence among inputs and outputs is **explicitly** stored (in an efficient way)
- Inputs are called keys and outputs are called values
- Each key is associated to one and only one value (recall that dictionaries are mappings!)
- If a given key is associated to a value, we refer to these two as a key–value pair, and say that dictionaries store key-value pairs
- Keys can be values of any **immutable type** (e.g., integers, strings, tuples, etc.), while values can be of any type (i.e., mutable or immutable)
- Dictionaries are also known as associative arrays, hash tables, symbol tables or simply maps in other programming languages

Common operations with dictionaries

* What can you do with a dictionaries?
  - Create new, empty dictionary
  - Store a value with a key
  - Is a given key stored in the dictionary?
  - Look up the value stored for a given key
  - Remove key
  - Enumerate keys, values, or key–value pairs
* A (common) misconception is to think that dictionaries are implemented using, e.g., two lists of the same length (one for the keys and another one for the values), or a single list of tuples
* This is **NOT** the case: a hallmark of dictionaries is that key look-up takes (amortised) constant time (as, e.g., index look-up in lists)

Python's `dict` type

Two example ways of creating dictionaries:

1. Using dictionary literals:

```
adict = {}
adict = dict()
adict = { (12,2015) : 33.4, (6,2016) : 148.3 }
adict = {"Australia":"Canberra", "Spain":"Madrid" }
```

   - Dictionary (and set!) literals use curly brackets (i.e., { and })
   - The literal can contain `key:value` pairs, which become the initial contents

2. Using a **dictionary comprehension** (example):

```
fin = open("data.tsv", "r")
adict = {line.split("\t")[0]:line.split("\t")[1] for line in fin}
fin.close()
```

Question: Can you tell what this latter code is doing?

Dictionary look-up read operations

- Is a given key `key` stored in the dictionary `adict`? (True/False)

  ```
  >>> key in adict
  ```

- Dictionary look-up read (get value associated to given key):

  ```
  >>> word_counter = { "be" : 2, "can" : 1 }
  >>> word_counter["can"]
  1
  ```

  Same syntax as sequence indexing (but with any key type!)

- Looking-up for nonexisting key produces a `KeyError` runtime error

  ```
  >>> word_counter["the"]
  Traceback (most recent call last):
    File "<stdin>", line 1, in <module>
  KeyError: 'the'
  ```

- We can use `if key in adict:` as a guard against the error

Dictionary look-up write operations

- Dictionary look-up write comes in two flavours
  - Add a new key-value pair
  - Update value associated to an existing key

```
>>> word_counter["the"] = 5    # Adds a new key--value pair
>>> word_counter
{'be': 2, 'can': 1, 'the': 5}
>>> word_counter["can"] += 1   # Updates value of existing key
>>> word_counter
{'be': 2, 'can': 2, 'the': 5}
```

- **IMPORTANT:** As opposed to lists, no need to use, e.g., `list.append(element)`, to add new element. Indexing + assignment does the job (see example)

More on dictionaries

- `dict` is a mutable type (as, e.g., lists, and NumPy arrays); see example in previous slide
- Keys **MUST BE** *immutable* (⋆)

```
>>> alist = [1,0]
>>> adict = { alist :  2 }
TypeError: unhashable type: 'list'
```

- A dictionary can contain keys of different (immutable) types
- Stored values can be of any type (mutable or immutable)

More mutating dictionary operations

- Removing keys:
  - `del adict[key]`
    Removes `key` from `adict`
  - `adict.pop(key)`
    Removes `key` from `adict` and returns the associated value
  - `adict.popitem()`
    Removes an arbitrary `(key, value)` pair and returns it
- `del` and `pop` cause a runtime error if `key` is not in dictionary; `popitem` if it is empty

Iteration over dictionaries

- `adict.keys()`, `adict.values()`, and `adict.items()` return *views* of the keys, values and key–value pairs
- Views are iterable, but *not* sequences

```
for item in adict.items():
    the_key = item[0]
    the_value = item[1]
    print(the_key, ':', the_value)
```

Programming examples

See code example file.

* Counting frequency of items (i.e., to build a histogram):
  – Frequency of bases in a DNA sequence; Words in a file (or web page)

Sets

- A *set* is an **unordered** collection of (immutable) values without duplicates
- Similar to dictionary but only keys (no values)
- What can you do with a set?
  - Create a new set (empty or from an iterable)
  - Add or remove values
  - Is a given element in the set? (membership)
  - Mathematical operators: union, intersection, difference (note: not complement!)
  - Enumerate values

Python's `set` type

* Set literals are written with { .. }, but with elements only, not key–value pairs:

```
>>> aset = { 1, 'c', (2.5, 'b') }
```

* { } creates an empty dictionary, not a set!
* A set can be created from any iterable:

```
>>> aset = set("AGATGATT")
>>> aset
{'T', 'A', 'G'}
```

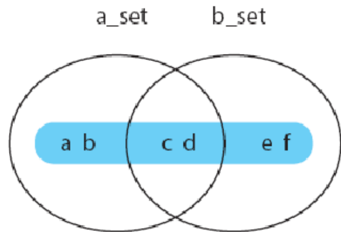
  - No duplicate elements in the set
  - No order of elements in the set

Set operators

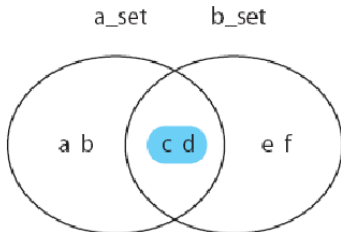
`elem in aset`	membership ($e \in A$)
`aset.issubset(bset)`	subset ($A \subseteq B$)
`aset | bset`	union ($A \cup B$)
`aset & bset`	intersection ($A \cap B$)
`aset - bset`	difference ($A \setminus B$, $A - B$)
`aset ^ bset`	symmetric difference

- Set operators return a new result set, and do not modify the operands.
- Also exist as methods (`aset.union(bset)`, `aset.intersection(bset)`, etc).

* The union of `a_set` and `b_set` is the set of all elements that are in `a_set`, in `b_set`, or in both.

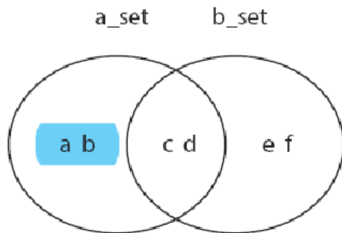


* The intersection of `a_set` and `b_set` is the set of elements that are in both `a_set` and `b_set`.

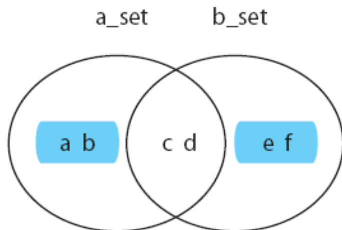


(Images from Punch & Enbody)

* The difference of `a_set` and `b_set` is the set of elements in `a_set` that are not in `b_set`.

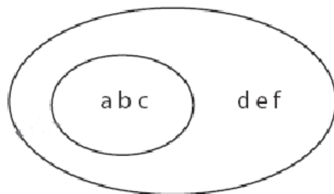


* The symmetric difference of `a_set` and `b_set` is the set of elements that are in either but not in both.



(Images from Punch & Enbody)

- `a_set` is a subset of `b_set` iff every element in `a_set` is also in `b_set`.
- $A \subseteq B$ iff $A \cap B = A$.

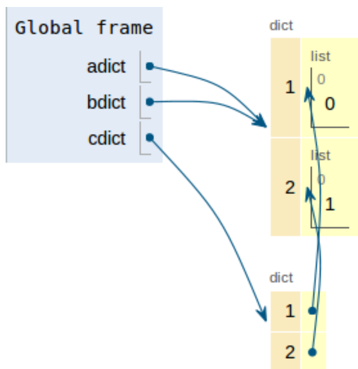


(Image from Punch & Enbody)

Copying

- Dictionaries and sets are mutable objects
- Like lists, dictionaries and sets store *references* to values
- `dict.copy()` and `set.copy()` create a *shallow* copy of the dictionary or set
  - New dictionary / set, but containing references to the same values
  - Dictionary keys and set elements are immutable, so shared references do not matter
  - Values stored in a dictionary can be mutable

```
adict = {1:[0],2:[1]}
bdict = adict
cdict = adict.copy()
bdict[1] = [2]
cdict[1] = [0, 0]
adict[2].append(1)
```



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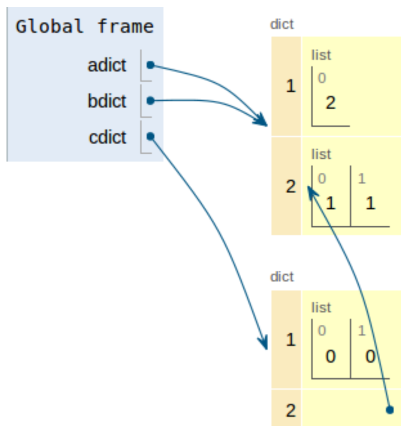

Take-home messages

* Dictionaries store mappings among keys (inputs) and values (outputs)
* As opposed to sequences, allows for arbitrary/generalized indices
* Implemented internally such that very fast lookup
* Key-value pairs have no ordering (code that assumes an ordering is wrong!)
* Set is different from dictionaries by having only keys (no values).