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Dictionaries

Their data structure, and how to work with them

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Contents

- Dictionary syntax
- Building a dictionary
- Accessing data inisde a dictionary
- Dictionary methods
- Dictionary as a matrix

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Built-in Python data structures

Python knows a number of built-in *compound* data types (containers), used to group objects.

Sequences

- Types: strings, lists, tuples
- Operations: Indexing, slicing, adding, multiplying, iteration & membership

Dictionaries

- Map keys to values through index
- Suitable for unstructured data

Sets

- Unordered and do not map keys to values

Dictionaries

- A dictionary is a *mapping* data structure
- It establishes a relationship between a **key** and a **value,** and maps each key to some value
- For instance, think about *capitals* as a dictionary, which uses a country name as key. *Capitals* would map *'Belgium'* to *'Brussels'*.

- Handy to store data organized by name, rather than position:
  - Index of a programming book
  - Contacts in your phone
  - Temperature records for each city of a country

Basics: Creating a dictionary

Dictionaries can be defined in two ways:

- Notation that uses curly brackets: ***{*** and ***}***
- Notation that uses the built-in function ***dict()***

```
landcover = {}                           # the empty dictionary
landcover["Natural grasses"] = 45        # this adds one entry to the dictionary
landcover["Agricultural grasses"] = 1
landcover["Deciduous"] = 11
landcover["Coniferous"] = 12
```

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Basics: Creating a dictionary

Now, we can take a look at its structure by printing the whole dictionary

```
print(landcover)
{'Natural grasses': 45, 'Agricultural grasses': 1, 'Deciduous': 11, 'Coniferous': 12}
```

Important

- Dictionaries are **not** ordered data structures
- Dictionaries are **not** sequences

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Basics: Creating a dictionary

We can also do it in one go:

landcover = {"Natural grasses":45, "Deciduous":11, "Coniferous":12, "Agricultural grasses":1}

An element is accessed using its key:

landcover["Coniferous"]

12

landcover["Natural grasses"]

45

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Basics: Keys and values

Dictionaries store **key:value** pairs

Keys must be immutable:

- Types of key:
  - Number : *landcover[45] = "Natural grasses"*
  - String : *landcover["Natural grasses"] = 45*
  - Tuple : *landcover[("Enschede", "52N","3E")] = 45*

  - But a key cannot be a list:

  landcover[["Enschede", latitude, longitude]] = 45

  TypeError: unhashable type: 'list'

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Basics: Keys and values

Values can be anything!

- If Enschede municipality has multiple land covers, we can store them all:

landcover["Enschede"] = ("coniferous", "built-up","agricultural grasses", "orchard", "reed")

Here as a tuple; could also have been a list.

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Basics: Keys and values

We can build our dictionary using the built-in **dict()** function:

mixed_forest = ("coniferous", "deciduous")
landcover = dict()
landcover["Hengelo"] = mixed_forest
landcover["Amsterdam"] = ("Built-up", "Greenhouses")

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Basics: Keys and values

With dict() function, we can define the dictionary at once, too:

mixed_forest = ("coniferous", "deciduous")
urban_area = ("built-up", "greenhouses")
landcover = dict(Veluwe = mixed_forest, Amsterdam = urban_area)

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Dictionary methods

Similar to lists and strings, dictionary methods are called like:

object.method()

Important methods:

- *.keys()*: returns a list of all the keys
- *.values()*: returns a list of the values
- *.items()*: returns the (key,value) pairs as a list

View: [(key, value), (key, value) … (key, value)]

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Updating a dictionary

Changing values:

landcover["agriculture"] = 999

landcover["grasses"] = 13

print(landcover)

{ 'agriculture': 999, 'coniferous': 12, 'deciduous': 11, 'grasses': 13 }

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Updating a dictionary

landcover = {'agriculture': 1, 'coniferous': 12,'deciduous': 11, 'grasses': 45}

Removal of an item with a given key is called "popping the item."

an_item = landcover.pop("grasses")

Populating a dictionary with the items of another dictionary:

new_landcovers = {"reed": 36, "greenhouse": 20}

landcover.update(new_landcovers)

print(landcover)

{'agriculture': 1, 'coniferous': 12, 'deciduous': 11, 'grasses': 45, 'reed':36, 'greenhouse':20}

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Updating dictionaries

landcover = {'agriculture': 1, 'coniferous': 12, 'deciduous': 11, 'grasses': 45}

Deletion of a single item:

del landcover["deciduous"]

print(landcover)

{'agriculture': 1, 'coniferous': 12, 'grasses': 45}

Removal of all items:

landcover.clear()

{}

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Iterations

Dictionary methods return lists, and lists are iterable!

Problem:

> *Imagine that you have in a dictionary the **land covers for each city** in the Netherlands. You want to **print the names** of those cities that have patches of **coniferous** forest. You also want to **count** the number of cities with coniferous **patches** in the country. The dictionary has as **key** the **name** of the city, and as **value** the **tuple** with the associated landcovers.*

What computing strategy do you use to achieve this?

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Iterations

```
for key in landcover.keys():
   if "Coniferous" in landcover[key]:
      print("City: ", key)

patches = 0
for value in landcover.values():
   if "Coniferous" in value:
      patches += 1
print("Cities with coniferous patches: ", patches)
```

Can obviously combine the two computations in a single for loop. Which one?

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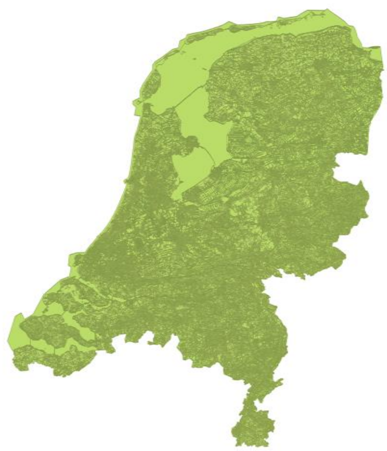
Vectors or rasters as dictionaries

Vector or raster files can be seen as dense matrices or as dictionaries
Storage of all values in memory may consume substantial resources
Not a wise choice when a significant percentage of the data is not needed
Solution:

- Store only the useful values
- Make use of a sparse matrix



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Rasters or matrices as dictionaries

At 1km pixel resolution:

- NL has 105,000 pixels
- Half of them fall over:
  - Water
  - Belgium or Germany
- Why would one store these values?

$$\begin{bmatrix} 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 3 & 0 \end{bmatrix}$$

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Rasters or Matrices as dictionaries

We only need to keep the positions of the non-zero values and write them down

That is:

- Row 0, Col 3, Value 1
- Row 2, Col 1, Value 2
- Row 4, Col 3, Value 3

Which gives:

matrix = {(0, 3):1, (2, 1): 2, (4, 3): 3}

$$\begin{bmatrix} 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 3 & 0 \end{bmatrix}$$

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Vectors or rasters as dictionaries

Creation of a sparse matrix from a dense matrix:

```
dense_matrix=[[0,0,0,1,0],[0,0,0,0,0],[0,2,0,0,0],[0,0,0,0,0],[0,0,0,3,0]]

sparse_matrix = {}
for i in range(5):
  for j in range(5):
    if dense_matrix[i][j] != 0:
      key = (i, j)
      value = dense_matrix[i][j]
      sparse_matrix[key] = value
print(sparse_matrix)
```

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Summary

- A dictionary is a data structure that stores **key:value** pairs, thus, mapping keys to values
- These pairs are not ordered
- The keys held in a dictionary are immutable, but their associated values are modifiable
- The methods *keys(), values()* and *items()* allow the iteration over and viewing of the dictionary content

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Sets

Their data structure and their operations

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Objectives

After this lecture, students can

- Describe the difference between sets and other data structures, and decide when to use sets in a given problem setting
- Illustrate the syntax of sets
- Code around sets

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Contents

- Set syntax
- Set operations
- Set methods
- Difference between set methods and set operations
- Iteration

Python data structures

Sequences
- Types: strings, lists and tuples
- Operations: Indexing, slicing, adding, multiplying, iteration and membership

Dictionaries
- Map keys to values through index
- Suitable for unstructured data

Sets
- Unordered and do not map keys to values

Set definition

Unordered collection of unique and immutable objects

a = set({ 'Landsat 1', 'Landsat 2', 'Landsat 3' })

A set cannot contain object of a mutable type (so no lists and dictionaries) but a set itself is *mutable* (insert or remove element objects), so a set cannot be the member of another set.

However, …

Trick to have set inside another set

To store a set inside another set you need to call the built-in function ***frozenset()*** which will create an immutable set

b = frozenset({ 'Landsat 2', 'Landsat 3' })
c = { 'Landsat 1', b }
print(c)
{ 'Landsat 1', frozenset({ 'Landsat 2', 'Landsat 3' }) }

Set creation

Use the *set()* built-in function and pass a collection of values

```
a = set( 'Landsat 1' )
print(a)
{'d', 'L', 's', 'n', 'a', 't', '1', ' '}

b = set( [ 'Landsat 1', 'Landsat 2', 'Landsat 3' ] )          # convert from list
print(b)
{ 'Landsat 1', 'Landsat 2', 'Landsat 3' }
```

Use curly braces

```
a = { 'Landsat 1', 'Landsat 2', 'Landsat 3' }
b = { 'Landsat 1', 'Landsat 2', 'Landsat 3', 4, 5 }
```

Observe that sets can have members of different type.

Member uniqueness

The elements in a set are unique, therefore, if you create a set with repeated elements, they will count for just one.

```
c = { 'Landsat 1', 'Landsat 1', 'Landsat 2', 'Landsat 3' }
print(c)
{ 'Landsat 1', 'Landsat 2', 'Landsat 3' }


{ 'Landsat 1', 'Landsat 1' } == { 'Landsat 1' }
True
```

You will find out that when working with really large sets, the characteristic of member uniqueness will make us *pay in performance* of operations. For instance, the union of two sets A and B, both with perhaps millions of members, will need to ensure that the result is a again a set, thus with member uniqueness.

Set operations

Sets support operations that we already know from mathematical set theory:

- Set difference
- Set intersection
- Set union
- Symmetric set difference
- Subset test
- Superset test

Operations involving sets

a = { 'Landsat 1', 'Landsat 2' }
b = { 'Landsat 1', 'Landsat 2', 'Landsat 3' }

Difference

a – b
set()
b – a
{ 'Landsat 3' }

Intersection

a & b *# Note the notation*
{ 'Landsat 1', 'Landsat 2' }

Union

a | b *# Note the notation*
{ 'Landsat 1', 'Landsat 2', 'Landsat 3' }

More set operations

a = { 'Landsat 1', 'Landsat 2' }
b = { 'Landsat 1', 'Landsat 2', 'Landsat 3' }

Symmetric difference

a ^ b
{ 'Landsat 3' }

Subset

a <= b
True

Superset

a >= b
False

Set operators as methods

a = { 'Landsat 1', 'Landsat 2' }
b = { 'Landsat 1', 'Landsat 2', 'Landsat 3' }

	Method	Operator	Result
Symmetric difference	a.symmetric_difference(b)	a ^ b	{ 'Landsat 3' }
Subset	a.issubset(b)	a <= b	True
Superset	a.issuperset(b)	a >= b	False
Difference	a.difference(b)	a – b	set()
Intersection	a.intersection(b)	a & b	{ 'Landsat 1', 'Landsat 2' }
Union	a.union(b)	a | b	{ 'Landsat 1', 'Landsat 2', 'Landsat 3' }

Methods versus operations

The methods *union, intersection, difference, symmetric_difference*, *issubset*, and *issuperset* accept any iterable as an argument. However:

{ 'Landsat 1', 'Landsat 2' } | 'Landsat 3'
TypeError: unsupported operand type(s) for |: 'set' and 'str'
{ 'Landsat 1', 'Landsat 2' } | ['Landsat 3']
TypeError: unsupported operand type(s) for |: 'set' and 'list'
{ 'Landsat 1', 'Landsat 2' } | { 'Landsat 3': 1978 }
TypeError: unsupported operand type(s) for |: 'set' and 'dict'

{ 'Landsat 1', 'Landsat 2' }.union('Landsat 3')
{'d', 'L', 's', 'n', 'Landsat 1', 'a', 't', ' ', 'Landsat 2', '3'}
{ 'Landsat 1', 'Landsat 2' }.union(['Landsat 3'])
{'Landsat 1', 'Landsat 2', 'Landsat 3'}
{ 'Landsat 1', 'Landsat 2' }.union({ 'Landsat 3': 1978 })
{'Landsat 1', 'Landsat 2', 'Landsat 3'}

Iteration over a set

a = { 'Landsat 1', 'Landsat 2', 'Landsat 3' }
for item in a:
print (item)
Landsat 2
Landsat 3
Landsat 1

It is like looping over a list, but the order in which items are handled is arbitrary, and may not be the same between different runs of the loop.

Why would one use a set?

Filter duplicates out of some collection

- *Elements in sets are unique*

Isolate differences in lists, strings and other iterable objects

- *Operations corresponding to mathematical set theory*

Perform order-neutral equality

- *Sets are unordered data structures*

Summary

A set is an unordered collection of unique and immutable objects

A set is neither a sequence nor a mapping

Use *set()* or *{…}* to create a new set

Sets support operations corresponding with mathematical set theory; theoretical papers on algorithms often use sets to define the algorithm

Operations and methods are slightly different

Sets support coded iteration

Sets are useful to filter and to compare collections