Lecture 2:
Data Structures in Python

Introduction to Python
efl Data Science Courses

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1. Data Types vs. Data Structures

- You have just learned about the primitive data types:
  - int: iVar = 3
  - float: dVar = 3.0
  - string: sVar = „3“ or sVar = „three“
  - boolean: bVar = True
- With (primitive) data types:
  - you declare how you want to use the variable
  - you tell the interpreter (which translates your code into machine readable code) how the variable should be treated
  - the data type constrains how the variable may look, or how it may be treated: E.g, bVar /2→ TypeError: unsupported operand type(s) for /: 'str' and 'int'

1. Data Types vs. Data Structures

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- Data structures:
  - Organize and manage data
  - Enable you to store, access and operate on data efficiently
  - Provide a set of procedures/functions to manipulate the data structure and the data inside it
  - Various types of data structures: arrays, lists, tuples, dictionaries…

1. Data Types vs. Data Structures

Primitive Data Types

- Declare usage intention and interpretation
- Constrain look and operations

int
float
string
boolean

Data Structures

- Data Organization, Management, Storage
- Operations to efficiently manipulate the data inside them

Tuple: (1, 2)
List: [1,2,3,4]
Set: {2,1,4,3}
Dictionary: {„key“:“value“}

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2. Tuples

- Heterogeneous sequence of elements
- Tuples are immutable (see: https://docs.python.org/3/glossary.html#term-immutable)
- Accessing the elements is usually done via unpacking
- Can be used to assign multiple values, or retrieve multiple values

(1,2)

(1,2,A,S,5)

(1,2,[2,3,5])

Abelson, H., Sussman, G. J., & Sussman, J. (1985). Structure and Interpretation of Computer Programs. *Cambridge: MIT Press and New York: McGraw-Hill, 1985*.

2. Tuples – Assigning Values

- Tuples are constructed like this:

```
Texample = 1, 2
print(Texample)
# (1,2)
```

- We can also assign more values to a tuple structure

```
Texample2 = 1, 2, 3, 4, 5
print(Texample2)
# (1, 2, 3, 4, 5)
```

- We can also assign values of different data types to a tuple structure

```
Texample3 = 1, 2, 3.0, "hey", True
print(Texample3)
# (1, 2, 3.0, "hey", True)
```

2. Tuples - Indexing

- We can access tuple values via indexing.
- Indexing means that each element within a data structure is assigned a value, by which it is uniquely callable.
- Different Data Structures have different operations for indexing.
- Let‘s call the item with index 1 of our first tuple, by inserting **[x]** bedhind our varioable, whereas x is the index.

```
Texample[1]
# 2
```

- Why did we get the second element, but not the first?
- This has something to do with how indexing works:
- In programming, we usually use zero-based indexing because of performance and memory allocation reasons.
- Zero-based indexing: We start our index counting at the position 0.
- Let‘s try to call the first element then by asking for index 0.

index	0	1	2	3	4	5
content	4	6	3	2	7	9

```
Texample[0]
# 1
```

Dijkstra, E. W. Why numbering should start at zero, EWD 831, EW Dijkstra Archive, University of Texas at Austin, 1982.

2. Tuples – Indexing (2)

- Great! Now let‘s call index 4 of Texample2.

```
Texample2[4]
# 5
```

- If we know that a certain element is within the data structure, we can also ask for the index position of the element.
- We do this by using the .index() function.
- Ask for the index of the value 4.

```
Texample2.index(4)
# 3
```

- Good! But what if there are duplicates of this value in the data structure?

```
Texample4 = 1,4,3,4,4,5
Texample4.index(4)
# 1
```

- Only the index of the first occurence of the value is called.

Dijkstra, E. W. Why numbering should start at zero, EWD 831, EW Dijkstra Archive, University of Texas at Austin, 1982.

2. Tuples – Assigning Multiple Values

- Tuples are quite useful, if you want to save multiple values at once.
- It is also quite easy to assign multiple values from a tuple to multiple variables at once.

```
Texample5 = 3.0,4.0,12.0
dVarA, dVarB, dVarC = Texample5
```

- Tuples provide many more functions, which you should definitely explore, since they may be useful for data analysis.

- One problem with tuples is that their values are immutable.

```
Texample6 = 4.0,8.0,16.0
Texample6[1] = 12.0
```

```
Traceback (most recent call last):
  File "<ipython-input-12-128d3d34ee60>", line 2, in <module>
    Texample6[1] = 12.0
TypeError: 'tuple' object does not support item assignment
```

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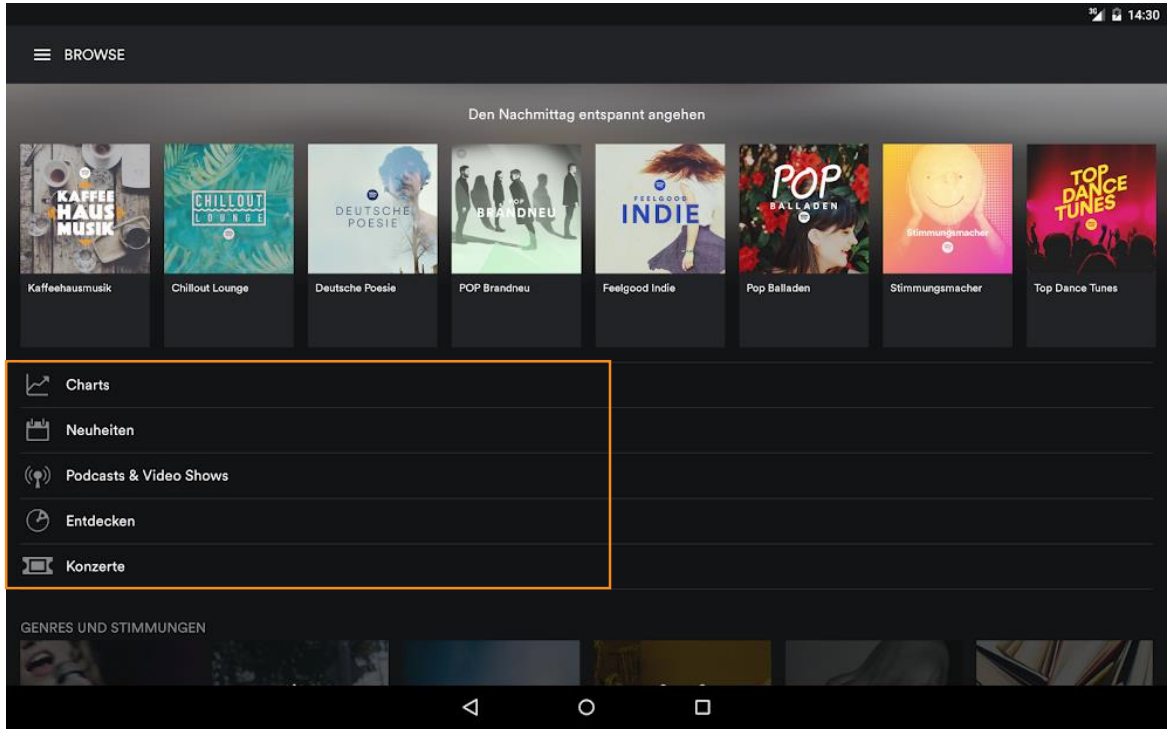
3. Lists

- As the name implies, variables inside lists are stored in a list-like data structure
- Elements are usually homogeneous
- Ordered, countable values, e.g. [1,2,3,4]
- Because of the order, lists are indexable
- The same values may occur multiple times
- Lists are a finite sequence, which may be altered
- The contents are mutable
- Lists may be initialized via the command `list()`

- Lists are very important and used in almost every app you use!



https://play.google.com/store/apps/details?id=com.spotify.music&hl=de

Abelson, H., Sussman, G. J., & Sussman, J. (1985). Structure and Interpretation of Computer Programs. *Cambridge: MIT Press and New York: McGraw-Hill, 1985*.

3. Lists

- Lists are constructed by assigning comma-separated values in brackets **[ ]** like this:

```
LNumbers = [1,2,3,4,5]
print(LNumbers)
# [1,2,3,4,5]
```

- We can also assign values of different data types to a list structure

```
LVarious = [1, 2, 3.0, "hey", True]
print(LVarious)
# [1, 2, 3.0, "hey", True]
```

- If we want to declare a variable a list before filling it, we can use the list() operator

```
LEmpty = list()
print(LEmpty)
#[]
```

3. Lists – Indexing and Slicing

- Indexing works similar to the way we did with tuples.

```
LVarious[1]
# 2
LVarious.index(2)
#1
```

- Yet, we can do more interesting things with lists: we can slice them to get a specific range of values.
- We can slice by indicating an index range like [1:3], which gets all elements between 1 and 3. Let‘s do this.

```
LVarious[1:3]
#[ 2, 3.0, “hey”]
```

- Slicing can be very useful for getting and working on specific pieces of data.
- Let‘s assign this slice to another list variable.

```
LVariousPart = LVarious[1:3]
print(LVariousPart)
#[ 2, 3.0, “hey”]
```

Dijkstra, E. W. Why numbering should start at zero, EWD 831, EW Dijkstra Archive, University of Texas at Austin, 1982.

3. Lists – Assigning Values, append, pop

- Since lists are mutable, we can reassign values.
- Assign these values to the spotify list: Charts,Neuheiten,Podcasts & Video Shows, Entdecken, Konzerte

```
LSpotify = ["Charts","Neuheiten","Podcasts & Video Shows",
"Entdecken", "Konzerte"]
```

- Now, reassign the value of list element with ID 0 to “Aktuelle Charts”

```
LSpotify[0] = "Aktuelle Charts"
```

- We can also append elements to the lists. Append the element „Deine Songs“ by using the list.append function.

```
LSpotify.append("Deine Songs")
```

- Lists also provide two methods to delete elements from the lists. Use the .pop method first, then print the list.

```
LSpotify.pop()
print(LSpotify)
```

- Now use pop with index 3 like this: pop(3)

```
LSpotify.pop(3)
print(LSpotify)
```

Dijkstra, E. W. Why numbering should start at zero, EWD 831, EW Dijkstra Archive, University of Texas at Austin, 1982.

3. Lists – remove, insert

- **list.remove(x)** is the other option to remove elements from lists.
- For **x**, we provide the actual value (not index!) we want to remove from the list. Careful: if you have multiple values of the same kind in a list, only the first one is removed.

```
LSpotify.remove("Neuheiten")
print(LSpotify)
```

- Now we can see that the two elements we wanted to remove are gone.
- If we want to insert elements into the list, we can do this as well.
- The function **list.insert(i,x)** inserts the variable **x** at given index **i** into the list.
- Insert „Neuheiten“ at index 1.
- Insert „Entdecken“ at index 3.

```
LSpotify.insert(1,"Neuheiten")
LSpotify.insert(3,"Entdecken")
print(LSpotify)
```

Dijkstra, E. W. Why numbering should start at zero, EWD 831, EW Dijkstra Archive, University of Texas at Austin, 1982.

3. Lists – len, count, reverse

- There are also useful helper functions if you want to get information about your lists or rearrange it
- Get the length of the spotify list by calling list.len()

```
len(LSpotify)
```

- Count the occurrences of „Neuheiten“ in the spotify list with list.count(x)

```
LSpotify.count("Neuheiten")
```

- Reverse the list with list.reverse() print it, then reverse it again and print it again.

```
LSpotify.reverse()
print(LSpotify)
LSpotify.reverse()
print(LSpotify)
```

Dijkstra, E. W. Why numbering should start at zero, EWD 831, EW Dijkstra Archive, University of Texas at Austin, 1982.

3. Lists & Strings

- Lists are very important and versatile data structures! Make good use of them.
- Further methods and information on lists may be in the python documentation.

- Fun fact: lists and strings have many common properties, such as indexing and slicing operations.
- Try it out!

```
sTestString = "Lists are awesome and so are Strings!"
sTestString[3]
sTestString[0:5]
len(sTestString)
```

More info available at: https://docs.python.org/3/tutorial/datastructures.html

Abelson, H., Sussman, G. J., & Sussman, J. (1985). Structure and Interpretation of Computer Programs. *Cambridge: MIT Press and New York: McGraw-Hill, 1985*.

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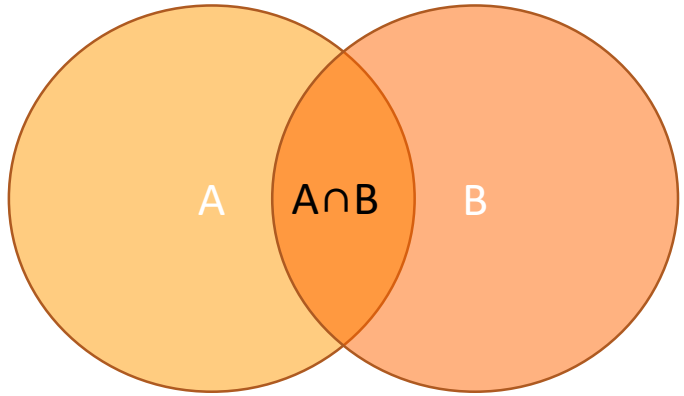
4. Sets

- Sets contain a set of values: {1,53,21}
- In Contrast to lists:
  - The values are unordered
  - Are not indexable
  - Values may occur only once → unique values
  - We do not retrieve specific element, we check if it is part of a set
- Sets are a finite set, which may be altered
- The set is mutable (e.g. extendable), the contents are not
- Operations on the set are similar to those of mathematical sets, e.g., union, intersect
- Sets may be initialized via the command `set()`



Abelson, H., Sussman, G. J., & Sussman, J. (1985). Structure and Interpretation of Computer Programs. *Cambridge: MIT Press and New York: McGraw-Hill, 1985*.

4. Sets

- Sets are constructed by assigning comma-separated values in curly brackets **{}** like this:

```
SNumbers = {1,2,3,4,5,1}
print(SNumbers)
# Out: {1, 2, 3, 4, 5}
```

- As discussed earlier, sets do only contain unique values. If we try to add multiple variables of the same value, only one will remain in the set.
- We can also assign values of different data types to a set structure

```
SVarious = {1, 2, 3.0, "hey"}
print(SVarious)
#Out[55]: {1, 2, 3.0, 'hey'}
```

- If we want to declare a variable a set before filling it, we can use the set() operator

```
SEmpty = set()
print(SEmpty)
#
```

4. Sets

- Since sets are unordered, we cannot perform indexing. Instead, we test for membership of a certain value in the set.
- Test the membership of 4 and 2 like this: ***value in SVarious***

```
4 in SVarious
Out: False
2 in SVarious
Out: True
```

- As we can see, this delivers us a boolean value.
- We could use this as a starting condition for some sort of algorithm. You will focus on this part in another lecture.

4. Sets – List to set

- Since one of the strengths of the set are the set operations you can perform, it is also possible in python to transform a list into a set (useful for certain occasions)

```
LtoSet = [1,2,3,5,2,4,12,523,123,21]
SfromList = set(LtoSet)
print(SfromList)
# {1, 2, 3, 4, 5, 523, 12, 21, 123}
```

- Be aware that your list loses ist order when it is converted to a set!

```
LfromSet = list(SfromList)
print(LfromSet)
```

- See?

4. Sets

- As stated earlier, sets support the functions for mathematical sets. For examples, see here.

```
>>> # Demonstrate set operations on unique letters from two words
...
>>> a = set('abracadabra')
>>> b = set('alacazam')
>>> a                                  # unique letters in a
{'a', 'r', 'b', 'c', 'd'}
>>> a - b                              # letters in a but not in b
{'r', 'd', 'b'}
>>> a | b                              # letters in a or b or both
{'a', 'c', 'r', 'd', 'b', 'm', 'z', 'l'}
>>> a & b                              # letters in both a and b
{'a', 'c'}
>>> a ^ b                              # letters in a or b but not both
{'r', 'd', 'b', 'm', 'z', 'l'}
```

https://docs.python.org/3/tutorial/datastructures.html#sets

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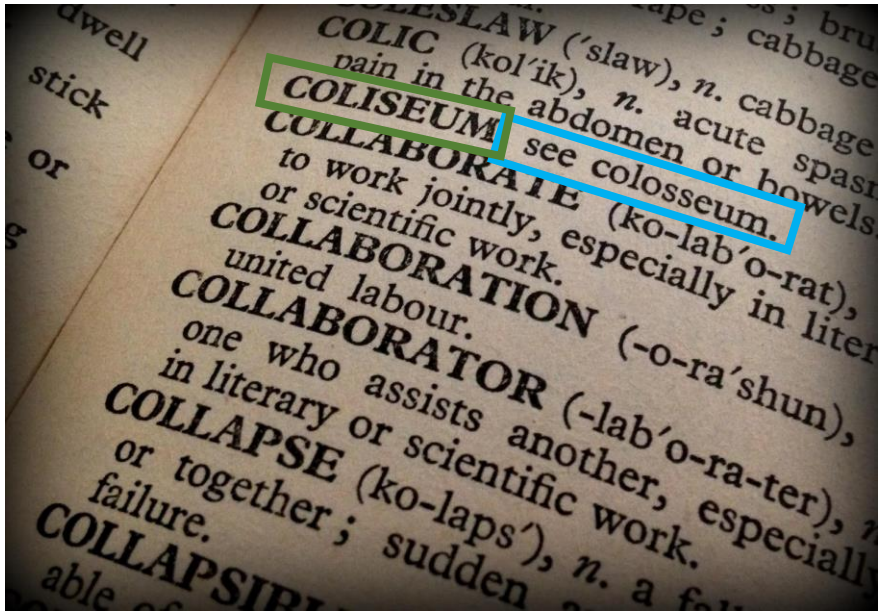
5. Dictionaries

- Are built on top of sets
- Dictionaries are sets of key-value pairs, with the first element being the key, the second element being the value: {key : value}
- Keys must be of an immutable type, unique within the dictionary
- In Contrast to lists:
  - The values are unordered
  - Are not indexed via a simple index
  - keys may occur only once → unique
- In Contrast to sets:
  - Indexing is done via key
  - We can retrieve specific key-value pairs or keys* and values alone.
  - the values of key-value pairs are mutable
- Think of real-world dictionaries!
- dicts may be initialized via the command dict() or {}



*keys for specific values are not retrievable by a provided function, yet can be retrieved by simple algorithms. See here: https://stackoverflow.com/questions/8023306/get-key-by-value-in-dictionary

https://docs.python.org/3/tutorial/datastructures.html#dictionaries

Abelson, H., Sussman, G. J., & Sussman, J. (1985). Structure and Interpretation of Computer Programs. *Cambridge: MIT Press and New York: McGraw-Hill, 1985*.

5. Dictionaries – Keys and Values

- Dicts are constructed by assigning a number of key-value pairs in curly brackets **{},** separated by commas like this:

```
DNumbers = {"One":1,"Two":2,"Three":3}
print(DNumbers)
# {'One': 1, 'Two': 2, 'Three': 3}
```

- Keys can be of type int, string or float. Let‘s use the respective int values as keys

```
DNumbers_nKeys ={1:1,2:2,3:3}
print(DNumbers_nKeys)
# {1: 1, 2: 2, 3: 3}
```

- Values can be of any type. Let‘s create a dict with int keys and string values.

```
DNumbers_sVals = {1:"One",2:"Two",3:"Three"}
print(DNumbers_sVals)
# {1: 'One', 2: 'Two', 3: 'Three'}
```

5. Dictionaries – Get and Change Values

- Values can be retrieved easily via commands.
- Retrieve the values from `DNumbers_sVals`, where the key is 3 and 1 like this: Dvar[3]

```
DNumbers_sVals[3]
DNumbers_sVals[1]
```

- Since you know how to access these values, you can manipulate them.
- Change the value of the key-value pair with the key 3 to „I made this“

```
DNumbers_sVals[3] = "I made this."
print(DNumbers_sVals[3])
# I made this.
```

- Another method to only get values from dictionary keys is dict.get(). Use this method to get they value of the keys 1 and then 11.

```
DNumbers_sVals.get(1,'This is the message, if no such key is in the dict.')
# 'One'
DNumbers_sVals.get(11,'This is the message, if no such key is in the dict.')
# 'This is the message, if no such key is in the dict.'
```

5. Dictionaries – Get Error

- Values can be retrieved easily via commands.
- Retrieve the values from `DNumbers_sVals`, where the key is 4 like this: Dvar[4]

```
DNumbers_sVals[4]
```

- What just happened? We received this error message:

```
Traceback (most recent call last):
  File "<ipython-input-31-bcbf0f01b928>", line 1, in <module>
    print(DNumbers_sVals[4])
KeyError: 4
```

- We got this error because we asked for a key(-value-pair) that is not existent within the dictionary.
- Be aware of this error when handling dictionaries.

5. Dictionaries – Data Structures as Values

- Values of dicts can be literally any type, they can even be data structures like lists or dicts.
- Create a `DSomeDicts` dict that holds `DNumbers and DNumbers_nKeys.` The keys should be strings containing the names of the two.

```
DSomeDicts = {"DNumbers":DNumbers, "DNumbers_nKeys": DNumbers_nKeys}
print(DSomeDicts)
# {'DNumbers': {'One': 1, 'Two': 2, 'Three': 3}, 'DNumbers_nKeys': {1: 1, 2: 2,
3: 3}}
```

- If we try to use the indexing method with brackets, or the get method, we can retrieve the data structure that is part of our dictionary. Get the data structure `DNumbers.`

```
DSomeDicts["DNumbers"]
DSomeDicts.get("DNumbers")
# {'One': 1, 'Two': 2, 'Three': 3}
```

- Change the value of the key DNumbers to this list: [1,2,3]. Then print DSomeDicts.

```
DSomeDicts["DNumbers"] = [1,2,3]
print(DSomeDicts)
# {'DNumbers': [1, 2, 3], 'DNumbers_nKeys': {1: 1, 2: 2, 3: 3}}
```

5. Dictionaries – Add and Remove K-V Pairs

- Similar to changing key-value pairs by assigning a new value to a key, you can add elements to a dict with ease.
- Use dict[key] = value to create a new value in DNumbers. Use „SomeInt“ as key and 1337 as a value.

```
DNumbers["SomeInt"] = 1337
print(DNumbers)
# {'One': 1, 'Two': 2, 'Three': 3, 'SomeInt': 1337}
```

- You can also remove elements from the dictionary by removing a key.
- Use the dict.pop(<key>) method to remove the key-value pair with the key Dnumbers from DSomeDicts.

```
DNumbers.pop("SomeInt")
print(DNumbers)
# {'One': 1, 'Two': 2, 'Three': 3}
```

- There are many more functions for dictionaries, such as merging two dicts!
- Check these out to get the best out of your dictionary usage: https://docs.python.org/3/library/stdtypes.html#dict

Wrap-Up

Data Structures are used for Data Organization, Management, Storage
and efficient manipulation of data with special operations that are provided by them.

We have learned about 4 data structures:

- Tuples: Can be used to assign multiple values, or retrieve multiple values
- Lists: Ordered, indexable, flexible; provides a lot of functionality and will be of use in many situations.
- Sets: Unordered, operations on the set are similar to those of mathematical sets.
- Dicts: Unordered. Data is stored in key-value (K-V) pairs. K-V may be easily retrieved and manipulated.
  Flexible data structure, that will be equally important to the list.

References

Abelson, H., Sussman, G. J., & Sussman, J. (1985).
Structure and Interpretation of Computer Programs. *Cambridge: MIT Press and New York: McGraw-Hill, 1985*.

Dijkstra, E. W. Why numbering should start at zero, EWD 831, EW Dijkstra Archive, University of Texas at Austin, 1982

Ernesti, J.; Kaiser, P.: Python 3 – Das umfassende Handbuch. 4. 2015.

https://docs.python.org/3/tutorial/

https://docs.python.org/3/library/stdtypes.html