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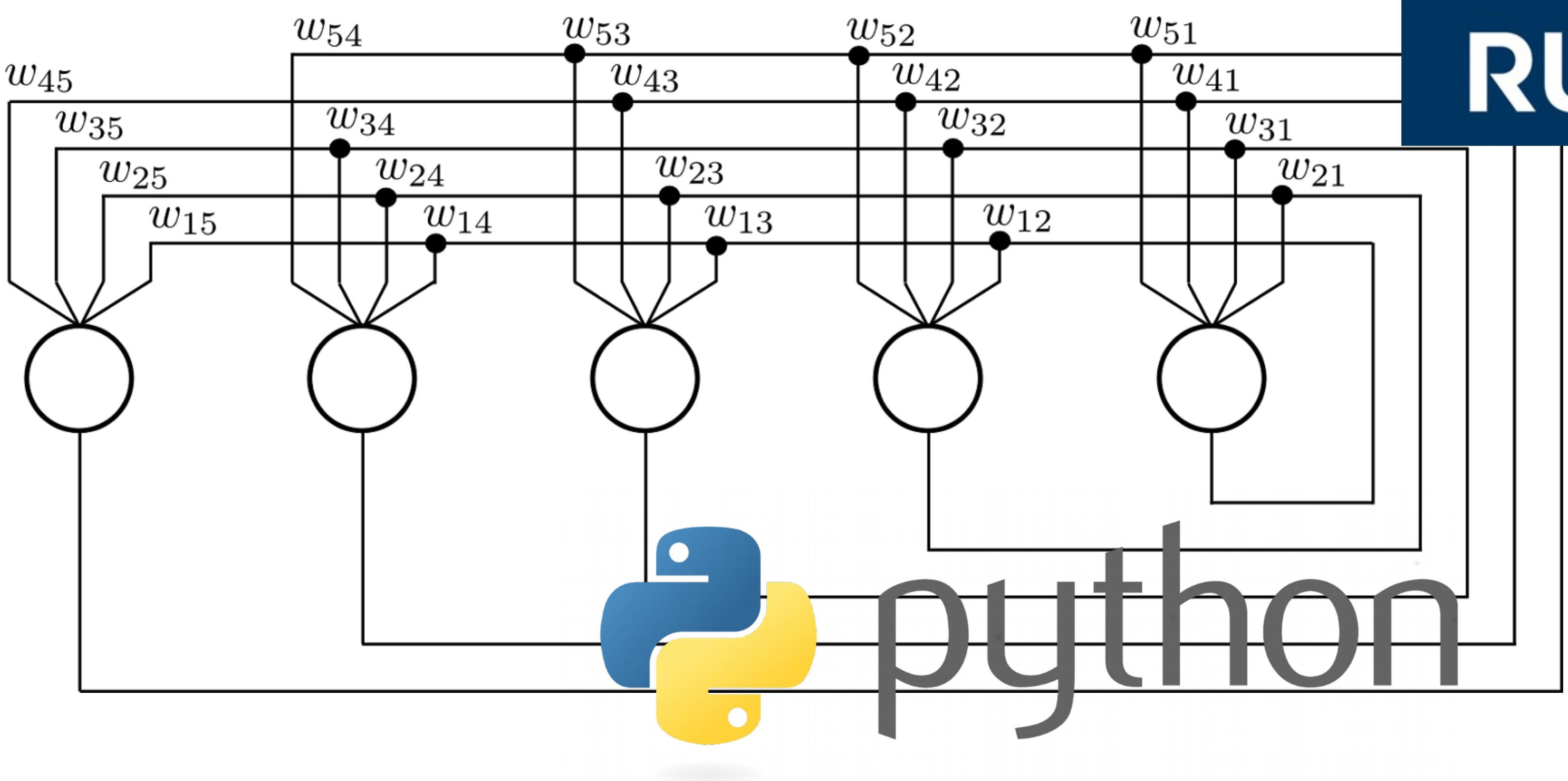

Artificial Neural Networks

Introduction to python

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WHAT'S IT ALL ABOUT?

These slides are meant as a reference. We will not go through all of them in a presentation.

Tutorial contents:

1. System setup

2. How to python
   - Operators, data types, built-in functions
   - Functions, modules and classes
   - Control structures (conditionals and loops)
   - Pythonians: args/kwargs, list comprehensions and iterators

3. Vector / matrix calculations with numpy

4. Plotting with pyplot

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SYSTEM SETUP

Version information

We will be using Python 3.6.8 with the following packages:

numpy 1.15.4
scipy 0.19.1
matplotlib 2.0.2
sklearn (scikit-learn) 0.19.1
tensorflow 1.12.0
keras 2.2.4

Code will most probably work on other versions as well, but we cannot guarantee

You can use the **virtual environment from Moodle**. Instructions are provided below.

Using the Anaconda environment

- Download *Miniconda* (https://docs.conda.io/en/latest/miniconda.html, Python 3.* version) or *Anaconda* (*https://www.anaconda.com/distribution/*, Python 3.* version). In order to save time and disk space, *Miniconda* is recommended.
- Install Anaconda.
  Windows: You do not need to add python to your system path in the process.
- Download the file **annvenv.yml** from Moodle
- Open a terminal (Windows: the Anaconda Prompt)
- In the terminal / Anaconda Prompt, navigate to the directory in which **annvenv.yml** is located (use `cd dir/to/file`)
- Create the environment with
  ```
  conda env create -f annvenv.yml
  ```
- Activate it with
  ```
  conda activate annvenv
  ```

Next time you only need to do the last step (activation)

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Alternative

Of course you can install python and the packages without using the Anaconda environment.

For instance on Linux systems:

- Use your package manager to install python
  (e.g. on Ubuntu `apt-get install python3.6`)
- Use python's package manager *pip* to install the python packages
  (`pip install [package]==[version]`)

Multiple python versions

If you already have a different version of python installed, just installing python3.6 might not work, or make package management difficult.
Consider the following options

- Use your installed versions – as long as they are newer than the ones we use in this course it will work most probably (and as long as the primary version number is identical)
- Use pyenv to manage multiple python versions. It works on linux and mac. Information on installation can be found here: https://github.com/pyenv/pyenv-installer,
  for usage see here https://github.com/pyenv/pyenv#table-of-contents and here https://github.com/pyenv/pyenv/blob/master/COMMANDS.md

IDE: Spyder

Spyder is recommended as an IDE.
Spyder 3.3.6 is included in the Anaconda environment.

HOW TO PYTHON

Operators, data types, built-in functions

Operators

Arithmetic

`+    -    *    /    //    **    %`

Relational

`==    !=    <    <=    >    >=    is`

Assignment

`=    +=    -=    /=    [...]`

Logical

`and    or    not`

Data types

are implicit in python

Numbers

int: `42` float: `42.0` (can be `inf` or `nan`)

Lists and strings

`[1,2,3]` `'Hello'` `"Hello"`

String and list concatenation

`'Hello ' + 'world'` `[1,2,3] + [4,5,6]`

Others

bool: **`True`** / **`False`** NoneType: **`None`** **`Inf, NaN`**

Accessing list elements

lst = `[1, 2, 3, 4, 'potato']`

First element / last element

```
lst[0]          lst[-1]
```

List slicing

```
lst[start, stop, step]
```

start: first element (index) to include
stop: first element (index) to exclude
step: step size

Examples

```
lst[4:1:-2]
lst[2:]
lst[:-1]
lst[::-1]
```

More on lists

```
lst1 = [1, 2, 3]
```

Test if item is contained

```
3 in lst1
4 in lst1
```

In-place manipulation: extend / append

```
lst1.append([4, 'potato'])
lst1.extend([4, 'potato'])
```

Other useful functions

```
lst1.pop()   or  lst1.pop(2)
lst1.index('potato')
```
etc.

Dictionaries

`dct = {'one': 1, 'two': 2}` or `dct = dict(one=1, two=2)`

Dictionary access

```
dct['one']
```

`dct.keys()` `dct.values()`

Note:
You can also use numbers or tuples, e.g. `(1, 'a')` as keys

Built-in functions

<u>Console output</u>

`print()`

<u>Type conversion</u>

`str()`		`int()`		`float()`

<u>Numerical</u>

`abs()`

<u>List properties</u>

`len()`		`min()`		`max()`		`sum()`

<u>Other</u>

`range(start, stop, step)`

HOW TO PYTHON

Functions, modules and classes

Scripts

File **hello.py**:

```python
print("Hello World")
```

Navigate to the directory containing your script

```
python hello.py
```

Defining functions

File **fun.py**:

```
def inc(x=0):                    (var=default value)
    y = x + 1
    return y
```

Indentation is used to define hierarchical blocks. No start / end markers.
Best practice is to use one **tab**.

Start python from the directory containing your file

```
import fun
fun.inc(1337)
fun.inc()
```

Modules

Directory structure:
fun.py
mod/__init__.py *(double underscore)*
mod/fun2.py

Script **fun2.py**:

```
def dec(x):
    y = x - 1
    return y
```

Now you can do:

```
import fun
from mod import fun2
a = fun.inc(1337)
fun2.dec(a)
```

Classes

File **potato.py**

```
class Potato():                (inheritance)

    def __init__(self, weight=100):
        self.weight = weight

    def report(self):
        print("This potato weighs " + self.weight + " grams.")
```

Now you can do:

```
import potato
p1 = potato.Potato()
p2 = potato.Potato(250)
p1.report()
p2.report()
```

HOW TO PYTHON

Control structures

if statements

```python
def sign(x):
    if x < 0:
        return -1
    elif x > 0:
        return 1
    else:
        return 0
```

for loops

```
for w in ['cat', 'window', 'defenestrate']:
    print(w)
```

or

```
for i in range(5):
     print(i)
```

enumerate can be useful

```
for i, w in enumerate(['one', 'two', 'three']):
    print(i, w)
```

while loops

```python
i = 0
while i < 10:
    print(i)
    i += 1
```

Note:
For both types of loops, the **`break`** and **`continue`** statements are available.

HOW TO PYTHON

Pythonians

*args, **kwargs

You can use pointers to lists or dictionaries to set function arguments

```
def add(x, y, z=1):
    return x + y + z

lst = [3, 4, 5]
dct = dict(x=3, a=10, y=4, z=5)
add(*lst)
add(**dct)
```

Lists provide arguments without keywords (*args)
while dicts provide arguments with keywords (**kwargs)

List comprehensions

Make a new list from a list

```
lst = list(range(10))
[abs(n-5) for n in lst]
```

We can also use conditionals

```
[abs(n-5) for n in lst if n != 5]
```

Iterators

Make an iterator from a list

```
it = iter([1, 8, 42, 1337, "over 9000"])
next(it)
next(it)
```

...

Generators work similarly, but programatically:

```
def gen():
    i = 0
    while True:
        yield i
        i += 1

g = gen()
next(g)
next(g)
...
```

MATRIX CALCULATIONS WITH NUMPY

What is numpy?

Package containing functions for vector calculations.

```
import numpy as np
```

Basic data structure: array

```
arr = np.array([2, 3, 5, 7, 11, 13, 17, 19])
arr
type(arr)
```

Access works the same as for lists

```
arr[0]
```

Number type and conversion

```
arr.dtype
arrF = arr.astype(float)
```

Defining arrays

```
arr1 = np.arange(5)
arr2 = np.zeros(5)
arr3 = np.ones(5)
```

<u>Arrays can have more than one dimension</u>

```
arr11 = np.array([[1,3,5,7,9], [2,4,6,8,10]])
arr22 = np.zeros((2,5))
arr33 = np.ones((2,5))
arrEy = np.eye(5)
```

unit matrix

<u>Shape</u>

```
arr10 = np.arange(10)
arr10.shape
arr10.reshape((2, 5))
```

Random numbers

2-by-5 matrix containing random floats between 0 and 1:

```
rand1 = np.random.rand(2,5)
```

10-element vector containing floats drawn from a "standard normal" distribution:

```
rand2 = np.random.randn(10)
```

Many more options, see the documentation!
Google: "numpy random"

Array indexing

Give indices for both dimensions

```
arr11[0, 4]
```

Access an entire column using a colon

```
arr11[:, 2]
```

Fancy indexing

Index an array with an array.

```
arr = np.array([2, 3, 5, 7, 11, 13, 17, 19])
ind = np.array([0,2,4,6])
arr[ind]
```

You can also edit elements accessed that way

```
arr[ind] = 0
```

Operations on arrays

Operators are element-wise:

```
a = np.array([[1,3,5], [-5,-7,-9]])
b = np.array([[2,4,6], [6,8,10]])
a+b
a*b
a<b
b-5
```

etc.

numpy element-wise functions (examples)

```
np.abs(a)
np.exp(b)
```

Basic data processing

```
a = np.array([[1,3,5], [-5,-7,-9]])
np.max(a)
np.min(a)
np.mean(a)
np.std(a)
```

Note that this is population std. For sample std use np.std(a, dof=1)

Select axis along which to process

```
np.mean(a, axis=0)
np.mean(a, axis=1)
```

Load and save arrays

```
np.save("a.npy", a)
a1 = np.load("a.npy")
```

np.nonzero()

Get indices of non-zero elements

```
arr0 = np.array([[0,1,2,0,3,0],[0,4,5,0,0,6]])
nnz = np.nonzero(arr0)
nnz
arr0[nnz]
```

Use it to find where condition is met

```
arr10 = np.arange(10)
nnz10 = np.nonzero(np.abs(arr10-5) > 2)
nnz10
arr10[nnz10]
```

Also useful

Number of elements that meet condition

```
np.sum(np.abs(arr10-5) > 2)
```

Compare entire arrays

```
np.array_equal(a, b)
```

Check for invalid data

```
t1 = np.isnan(a)
t2 = np.isinf(b)
```

any / all

```
np.any(t1)
np.all(t2)
```

Inner and outer product

$$\mathbf{a} \cdot \mathbf{b} = \mathbf{a}^{\mathrm{T}} \mathbf{b} = \begin{pmatrix} a_1 & a_2 & \cdots & a_n \end{pmatrix} \begin{pmatrix} b_1 \\ b_2 \\ \vdots \\ b_n \end{pmatrix} = a_1 b_1 + a_2 b_2 + \cdots + a_n b_n = \sum^{n} a_i b_i$$

(inner product)

$$\mathbf{u} \otimes \mathbf{v} = \mathbf{u}\mathbf{v}^{\mathrm{T}} = \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix} \begin{bmatrix} v_1 & v_2 & v_3 \end{bmatrix} = \begin{bmatrix} u_1 v_1 & u_1 v_2 & u_1 v_3 \\ u_2 v_1 & u_2 v_2 & u_2 v_3 \\ u_3 v_1 & u_3 v_2 & u_3 v_3 \\ u_4 v_1 & u_4 v_2 & u_4 v_3 \end{bmatrix}$$

(outer product)

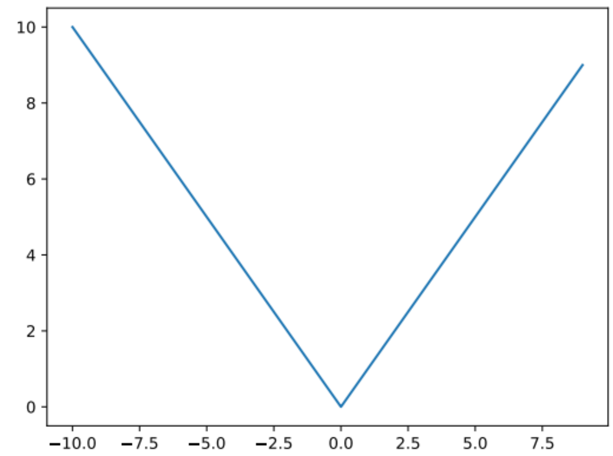
`np.inner()` / `np.dot()` and `np.outer()`

For matrix multiplication, use `np.matmul(A,B)` or `A @ B`

PLOTTING WITH PYPLOT

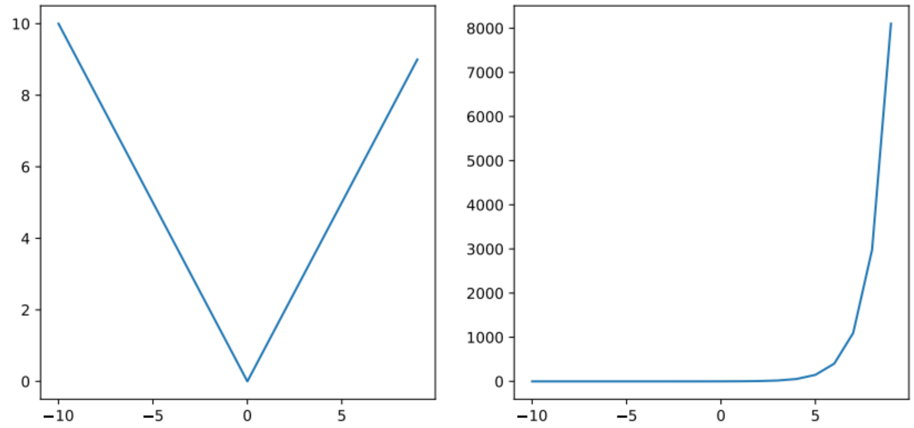
Plot

```
import matplotlib.pyplot as plt
x = np.arange(20)-10
y = np.abs(x)
plt.plot(x,y)
plt.show()
```



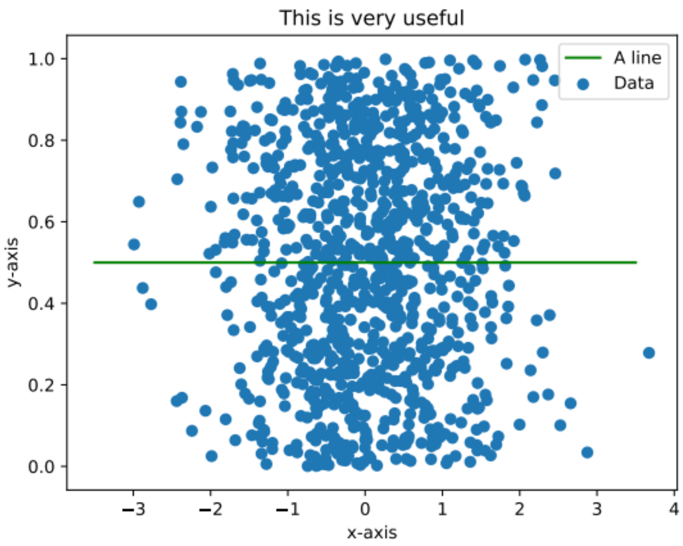
Subplot

```
plt.subplot(1,2,1)
plt.plot(x,y)
y2 = np.exp(x)
plt.subplot(1,2,2)
plt.plot(x,y2)
plt.show()
```



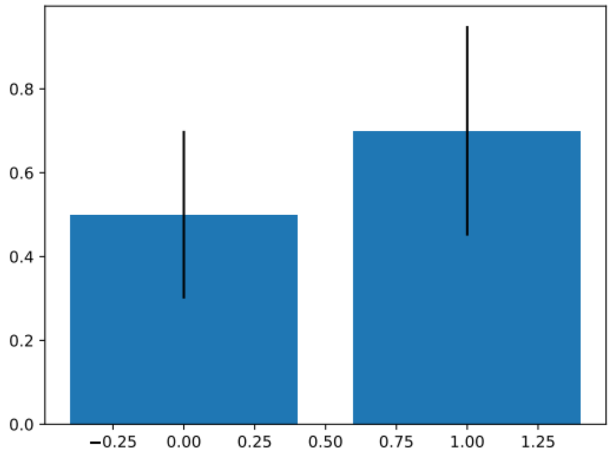
Scatter (and more...)

```
xr = np.random.randn(1000)
yr = np.random.rand(1000)
plt.scatter(xr,yr,label="Data")

plt.plot([-3.5, 3.5], [0.5, 0.5],
   color='g', label="A line")

plt.xlabel("x-axis")
plt.ylabel("y-axis")
plt.title("This is very useful")

plt.legend()

plt.savefig("example.pdf")
plt.show()
```



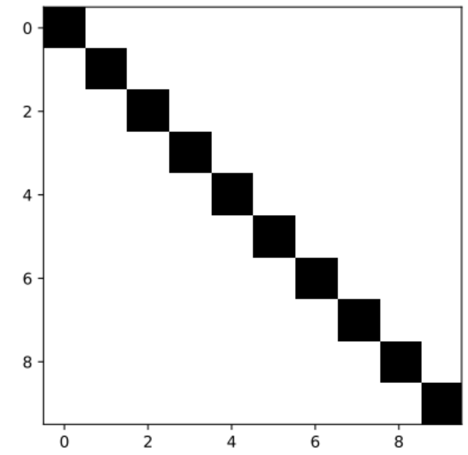
Bar

```
x = [0, 1]
y = [0.5, 0.7]
std = [0.2, 0.25]
plt.bar(x, y, width=0.8, yerr=std)
plt.show()
```



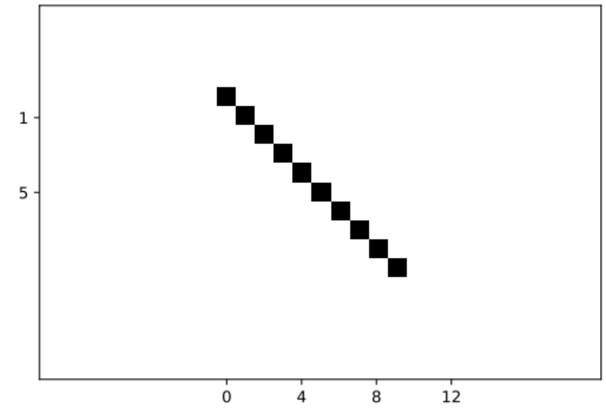
Imshow

```
m = np.eye(10)
plt.imshow(m, interpolation='none', cmap="Greys")
plt.show()
```

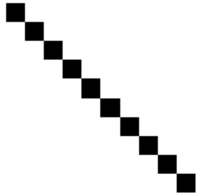


More options

```
plt.imshow(m, interpolation='none',
                       cmap="Greys")
plt.xlim([-10,20])
plt.ylim([15,-5])
plt.xticks([0,4,8,12])
plt.yticks([1,5])
plt.show()
```




```
plt.axis('off')
```



DONE!