Machine Learning for Physicists

OnlineTutorials

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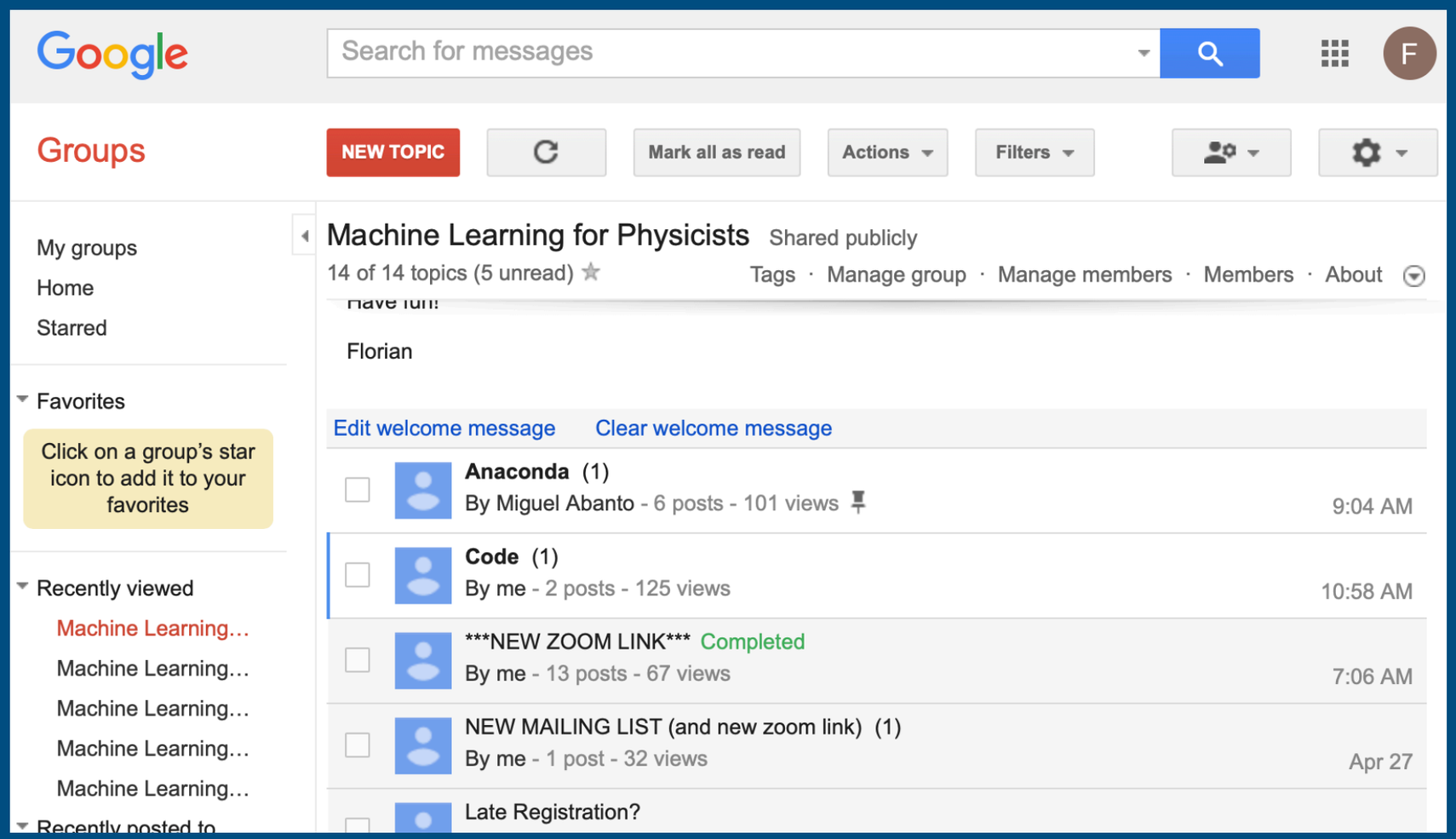
http://machine-learning-for-physicists.org

(Image generated by a net with 20 hidden layers)

Please use the forum for discussions & useful code & nice examples

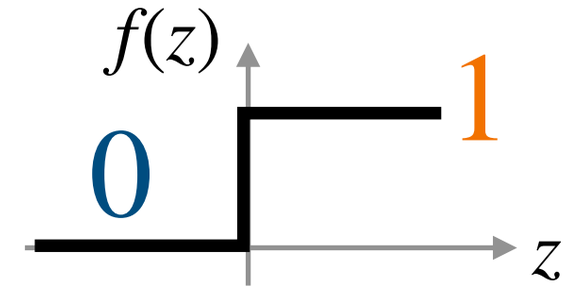


Machine Learning for Physicists

Quiz: single-layer neural networks

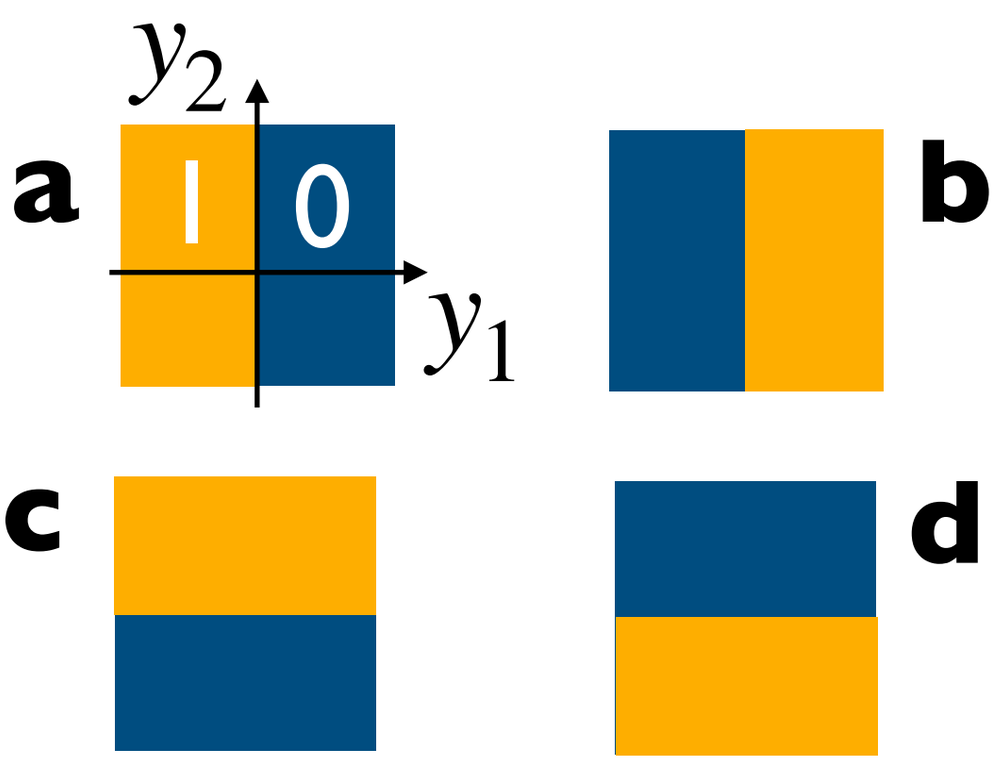
Machine Learning for Physicists

$f(z)$ is the step function:



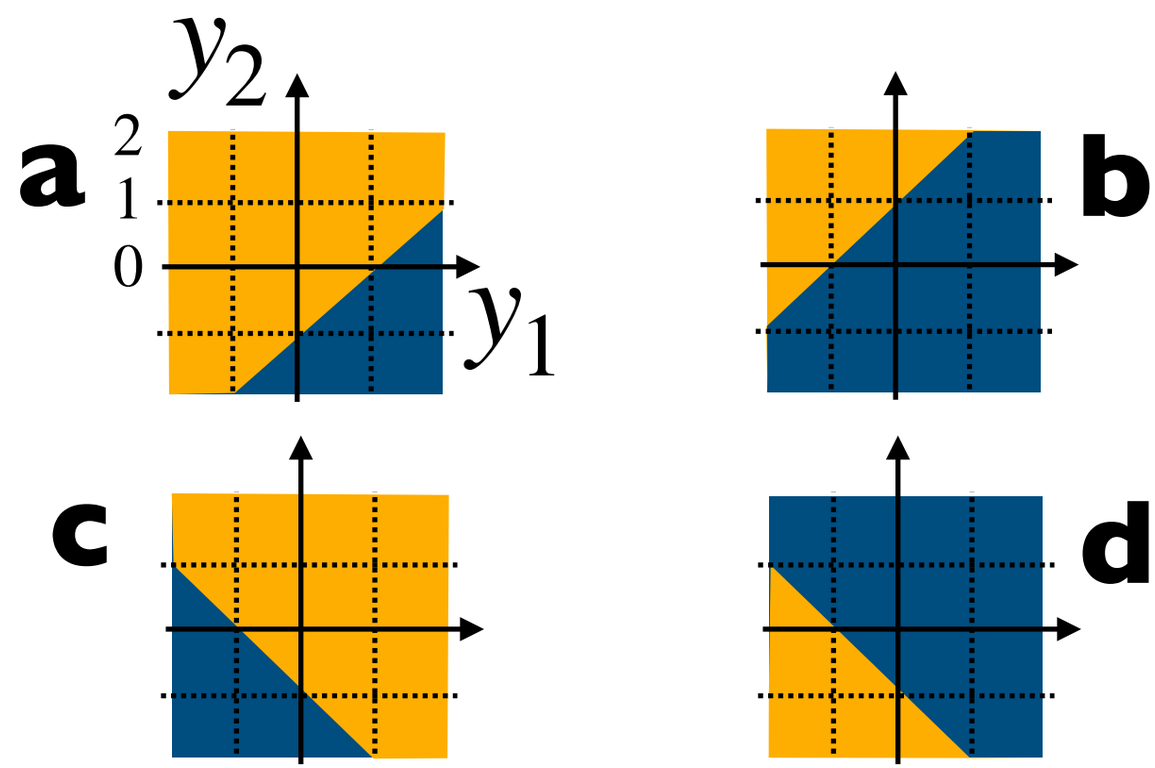
1

Which of these outputs is generated by $y^{\text{out}} = f(-y_2)$?



2

…and for $y^{\text{out}} = f(1 - y_1 + y_2)$?



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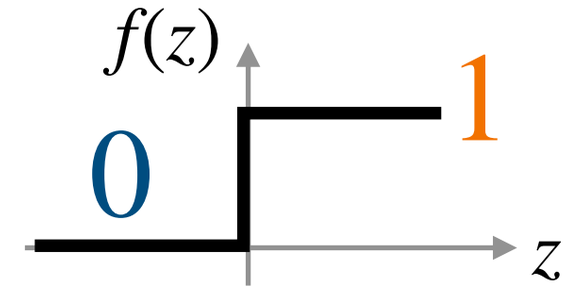
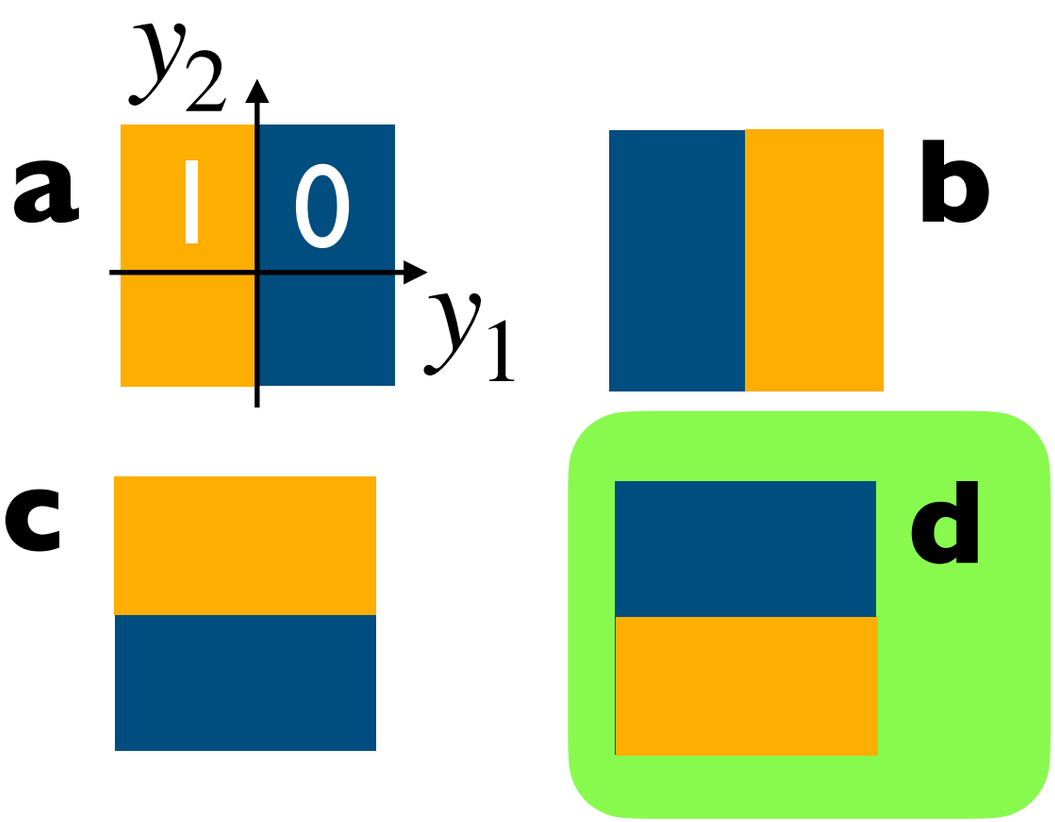


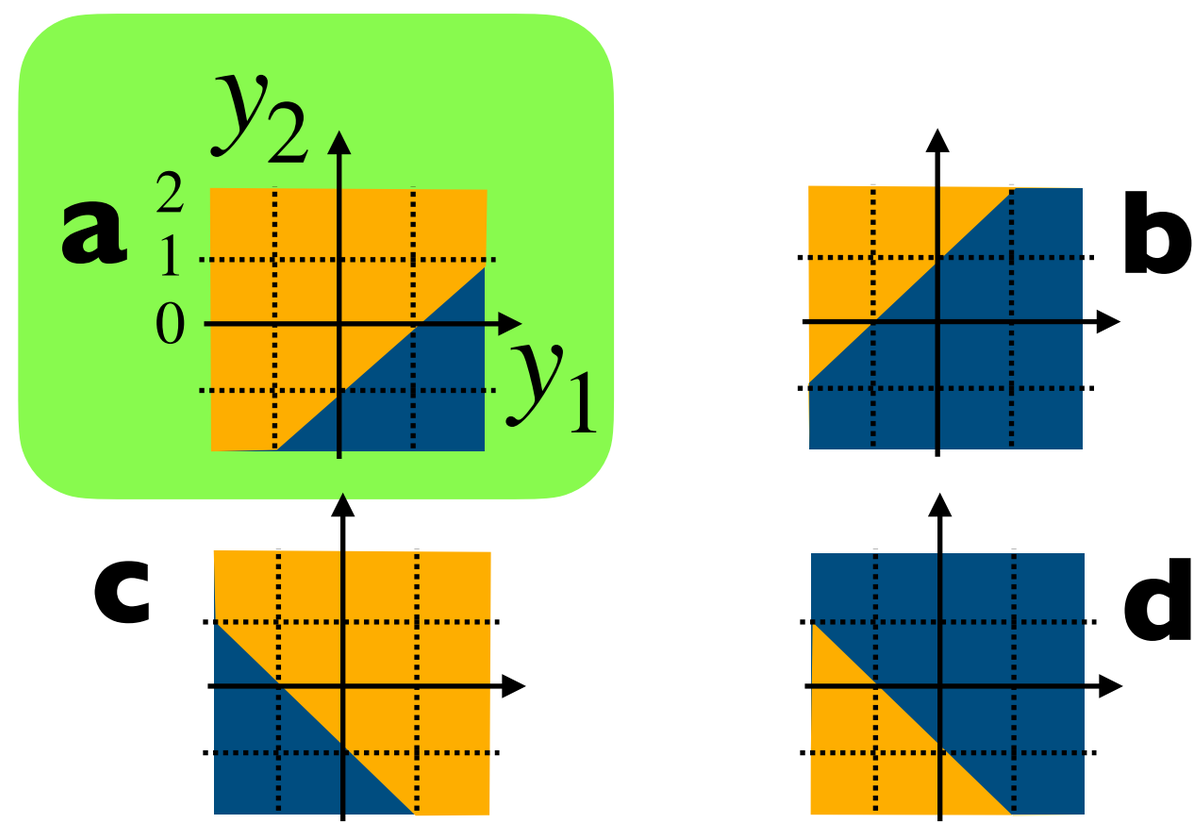
1

Which of these outputs is generated by $y^{\text{out}} = f(-y_2)$?



2

…and for $y^{\text{out}} = f(1 - y_1 + y_2)$?



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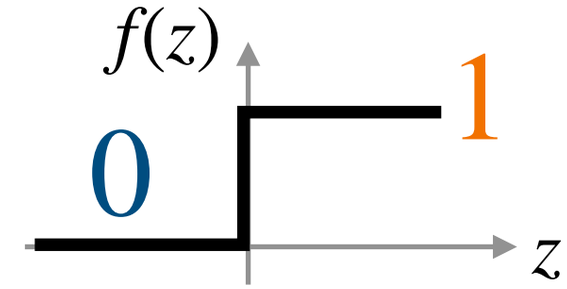
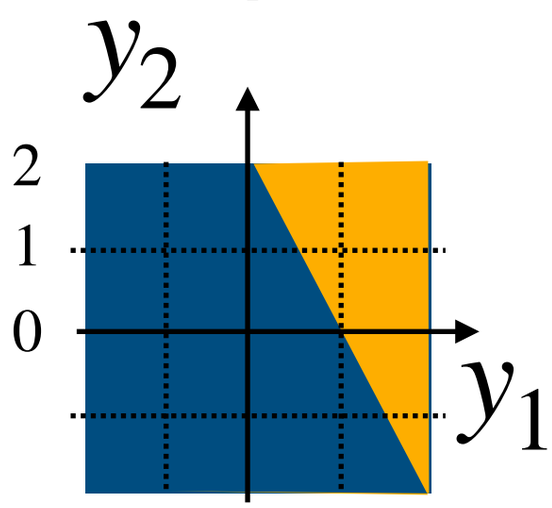


1 How can we obtain this output?



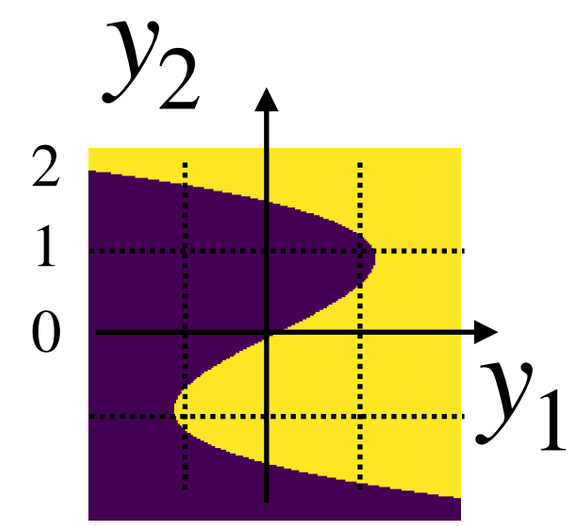
a $y^{\text{out}} = f(y_1 + y_2 - 2)$

b $y^{\text{out}} = f(2y_1 + y_2 - 2)$

c $y^{\text{out}} = f(2 - 2y_1 + y_2)$

d $y^{\text{out}} = f(y_1 - 2y_2)$

2 …and this one?



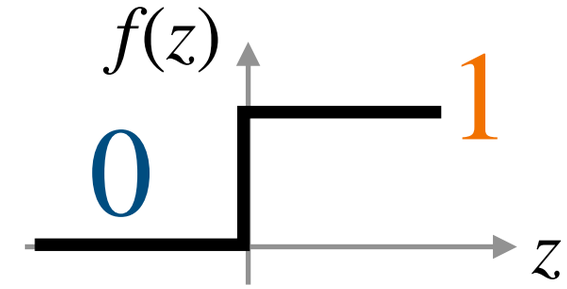
a $y^{\text{out}} = f(-2y_2 + y_1)$

b $y^{\text{out}} = f(y_2^3 - 2y_2 - y_1)$

c $y^{\text{out}} = f(y_2^3 - 2y_2 + y_1)$

d $y^{\text{out}} = f(-y_2^3 - 2y_2 + y_1)$

$f(z)$ is the step function:



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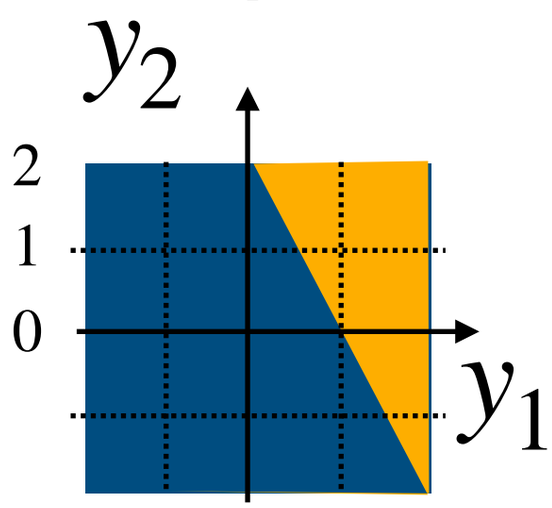

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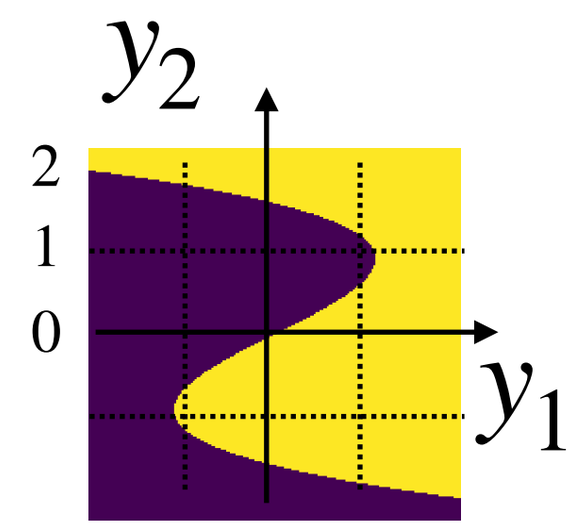

a $y^{\text{out}} = f(-2y_2 + y_1)$

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c $y^{\text{out}} = f(y_2^3 - 2y_2 + y_1)$

d $y^{\text{out}} = f(-y_2^3 - 2y_2 + y_1)$

Quiz: python

Machine Learning for Physicists

1

```
for j in range(2):
    print(j)
```

a 0 1

b 1 2

c 0 1 2

2

```
def f(n):
    if n<=2:
        return(n+f(n+1))
    else:
        return(42)
```

f(1)=?

a 85

b 45

c 44

d 42

e 3

1

```
for j in range(2):
    print(j)
```

a	0	1
b	1	2
c	0	1	2

2

```
def f(n):
    if n<=2:
        return(n+f(n+1))
    else:
        return(42)
```

f(1)=?

a	85
b	45
c	44
d	42
e	3

f(1)=1+f(2)=1+2+f(3)=1+2+42

```
a=np.array([[11,22],[33,44]])
```

1 a[0,1]=?

a 11 **c** 33

b 22 **d** 44

2 a[1]=?

a 22

b [11,22]

c [33,44]

d [22,44]

3 a[:,1]=?

a [22,44]

b [11,33]

c [33,44]

d [11,22]

```
a=np.array([[11,22],[33,44]])
```

1 `a[0,1]=?`

a 11 **c** 33

b 22 **d** 44

2 `a[1]=?`

a 22

b [11,22]

c [33,44]

d [22,44]

3 `a[:,1]=?`

a [22,44]

b [11,33]

c [33,44]

d [11,22]

$$\begin{array}{cc} a_{0,0} & a_{0,1} \\ \begin{pmatrix} 11 & 22 \\ 33 & 44 \end{pmatrix} \\ a_{1,0} & a_{1,1} \end{array}$$

```
a=np.array([[11,22],[33,44]])
```

1

```
a.flatten()=?
```

a [11,33,22,44]

b [11,22,33,44]

c [[11],[33],[22],[44]]

2

```
j0=np.array([1,0,1])
j1=np.array([0,0,1])
a[j0,j1]=?
```

a [11,33,44]

b error

c [22,11,44]

d [33,11,44]

3

```
b=np.array([19,50])
a[:,0]=b[:]
a=?
```

a [[11,22],[19,50]]

b [[19,50],[33,44]]

c [[19,22],[50,44]]

d [[11,19],[33,50]]

```
a=np.array([[11,22],[33,44]])
```

1

```
a.flatten()=?
```

a [11,33,22,44]

b [11,22,33,44]

c [[11],[33],[22],[44]]

2

```
j0=np.array([1,0,1])
j1=np.array([0,0,1])
a[j0,j1]=?
```

a [11,33,44]

b error

c [22,11,44]

d [33,11,44]

3

```
b=np.array([19,50])
a[:,0]=b[:]
a=?
```

a [[11,22],[19,50]]

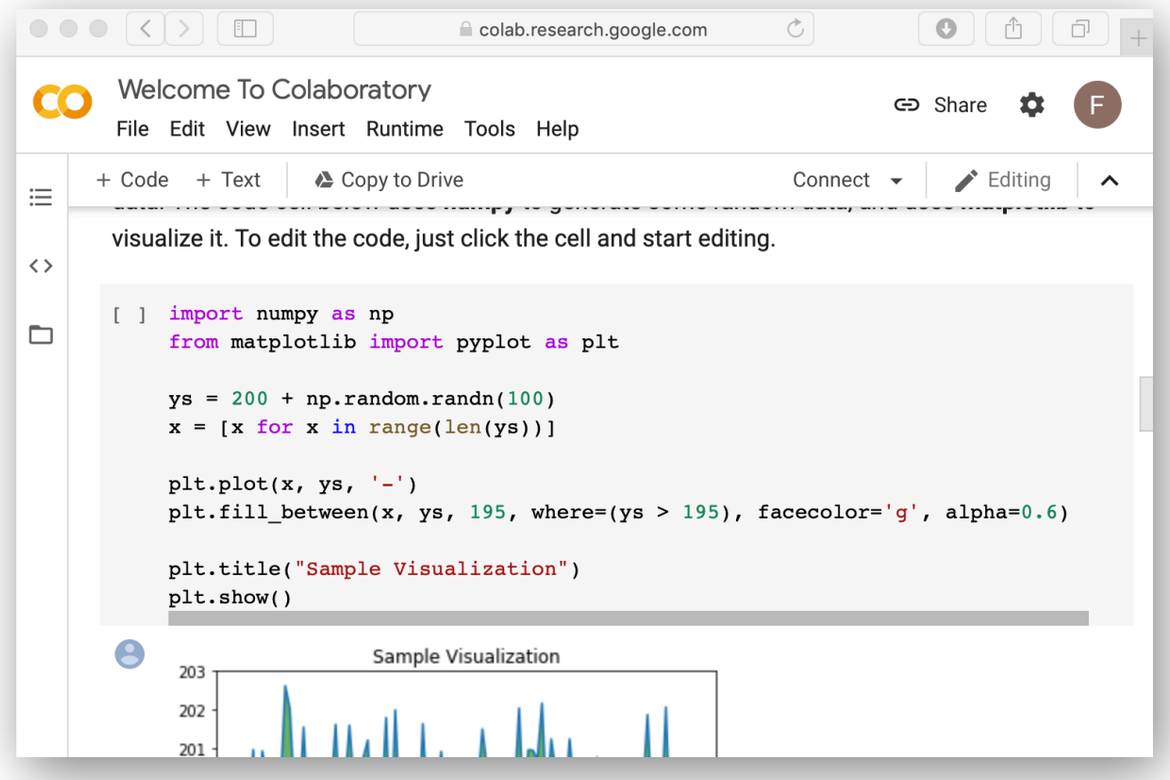
b [[19,50],[33,44]]

c [[19,22],[50,44]]

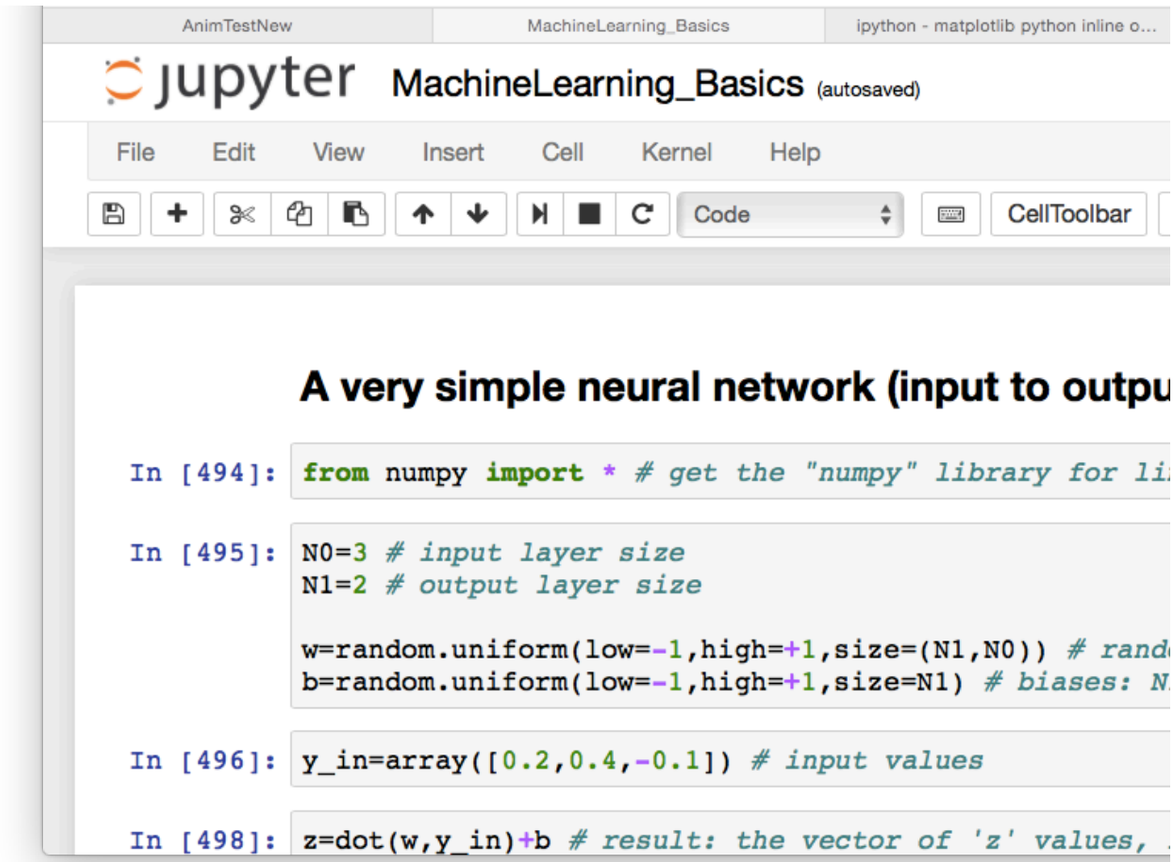
d [[11,19],[33,50]]

Jupyter

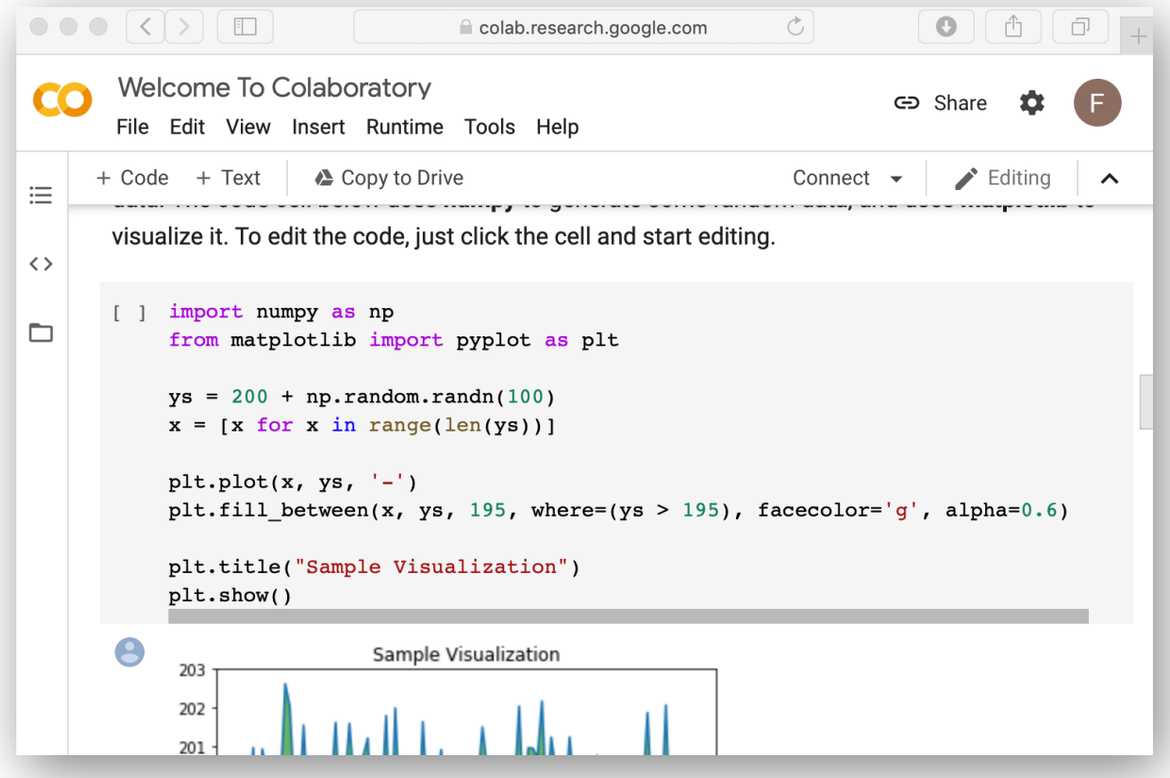
Colaboratory



Jupyter



Colaboratory



Practice session: Visualizing neural networks

Machine Learning for Physicists

Code (jupyter notebook): 01_MachineLearning_Basics_NeuralNetworksPython.ipynb
(or download code as pure python script)

see: website/course overview/lecture 1

This notebook shows how to calculate the forward-pass through a neural network in pure python, and how to illustrate the results for randomly initialized deep neural networks (as shown in the lecture).

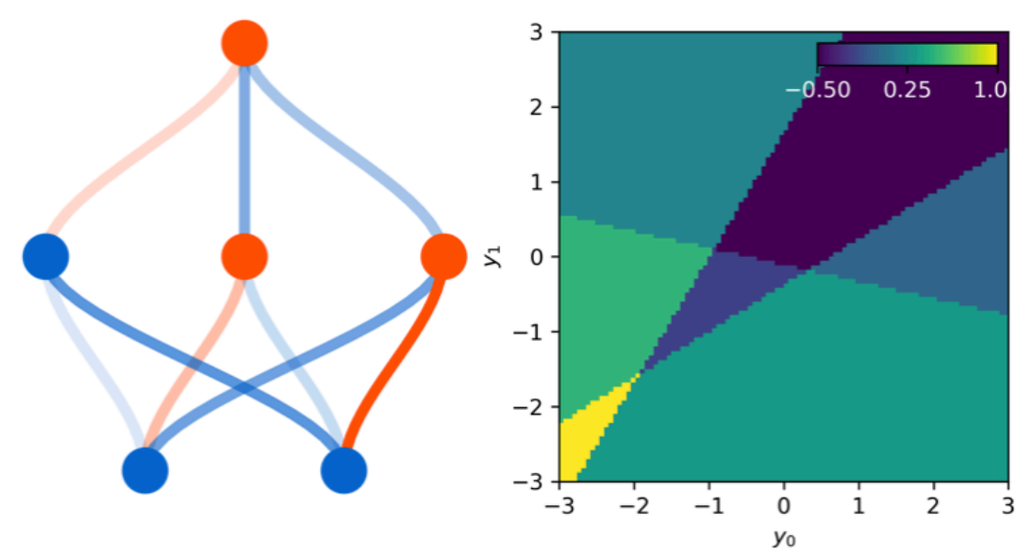
Notebooks for tutorials:
Tutorial: Network Visualization
Tutorial: Curve Fitting

Settings Help

01_tutoria 01_Machi

Code Python 3

```
0.5], # biases of 3 hi
s for output neuron
],
ctivations=[ 'jump', # activation fo
'linear' # activation for
],
y0range=[-3,3],y1range=[-3,3])
```



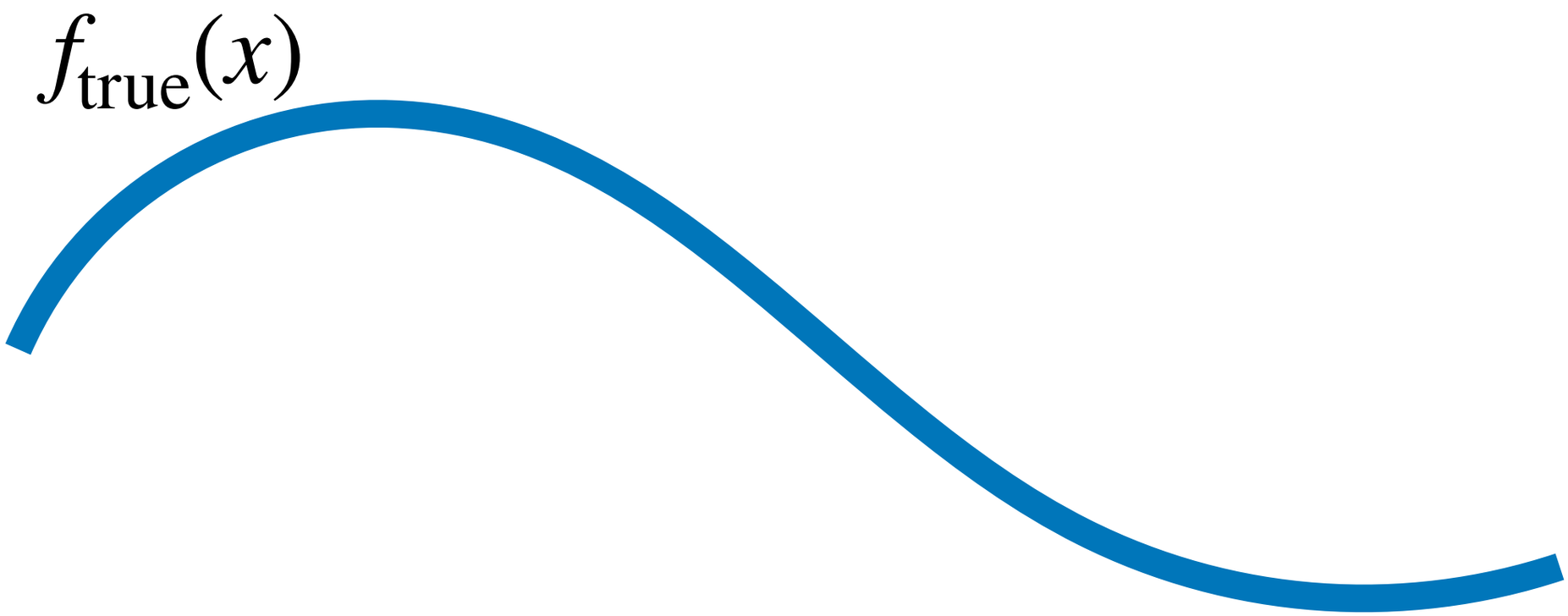
0 $_ 7 Python Mode: Ln 1, 01_tutorial_NetworkVisua

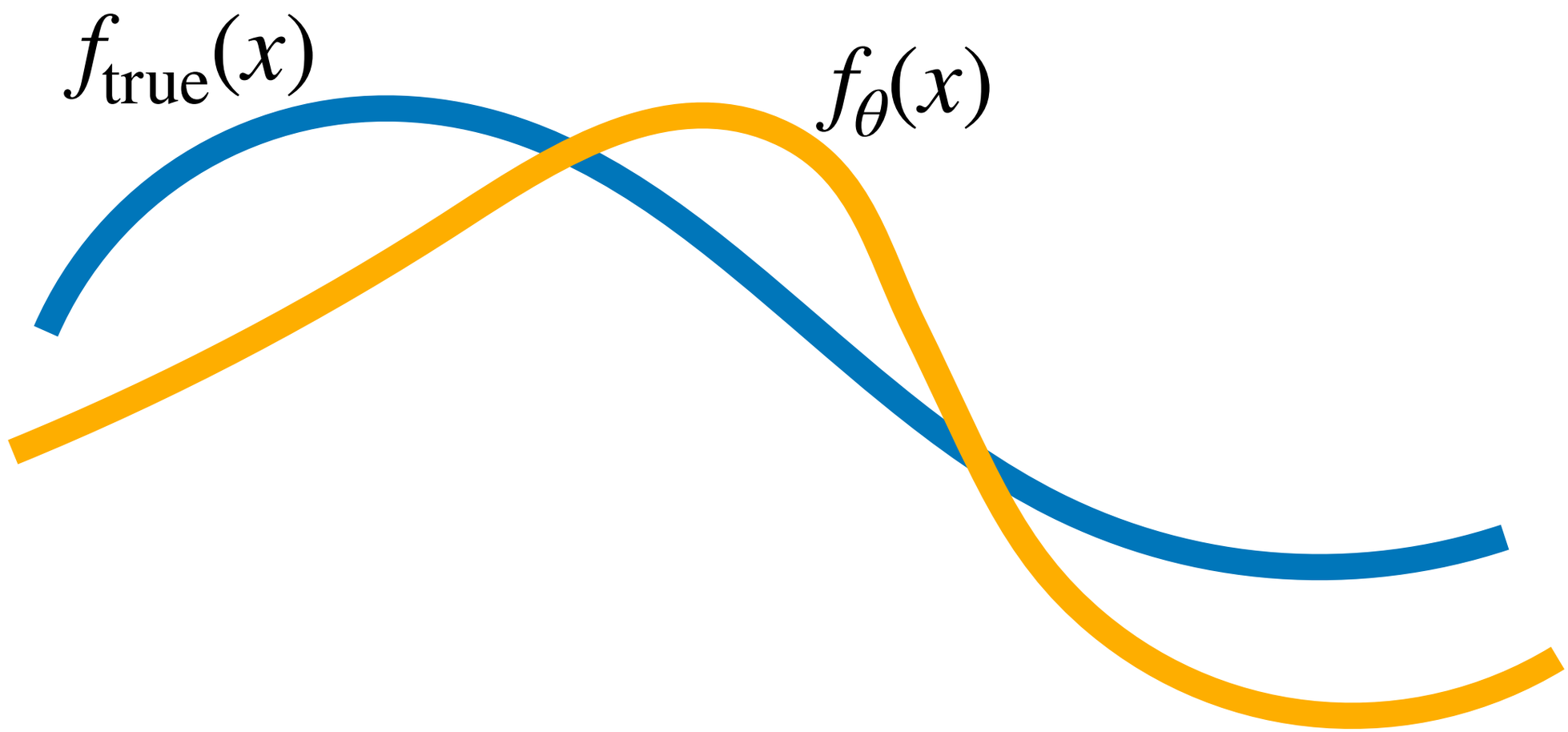
(1) Try to construct a square!

(2) What happens when you take a sigmoid hidden layer and a 'jump' (stepfunction) output layer? Which shapes can you construct?

Practice session: Nonlinear curve fitting

Machine Learning for Physicists


$f_{\text{true}}(x)$



e.g. $$f_\theta(x) = \frac{\theta_0}{(x - \theta_1)^2 + 1}$$

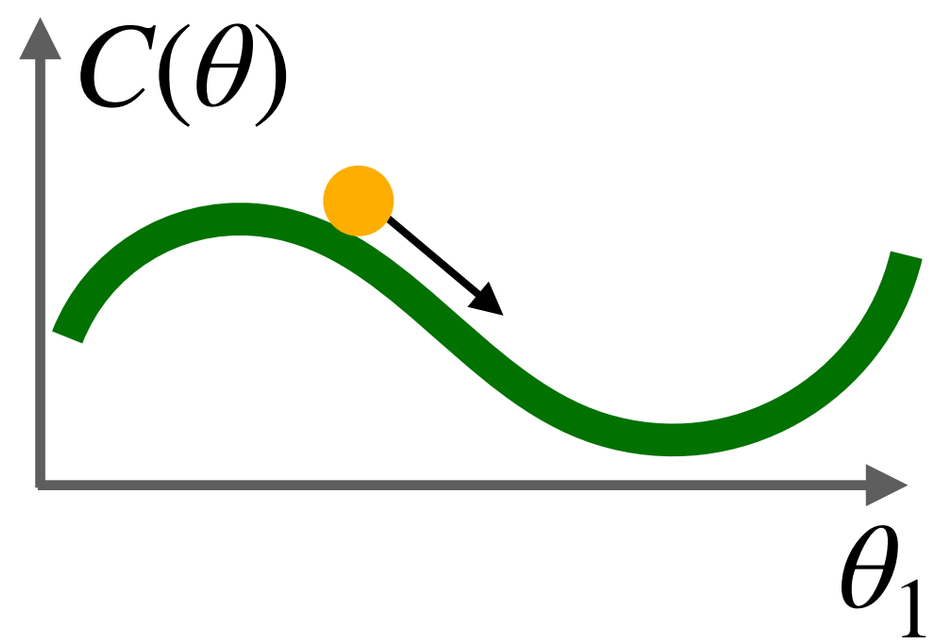
"least squares fitting":
consider quadratic deviation

$$C(\theta) = \frac{1}{2}\left\langle (f_\theta(x) - f_{\text{true}}(x))^2 \right\rangle$$

(average over x)

gradient descent ("down the hill"):

$$\delta\theta_j = -\eta \frac{\partial C}{\partial \theta_j}$$



stochastic: sample x

Code (jupyter notebook): 01_MachineLearning_Basics_NeuralNetworksPython.ipynb
(or download code as pure python script)

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Notebooks for tutorials:

Tutorial: Network Visualization

Tutorial: Curve Fitting

Settings Help

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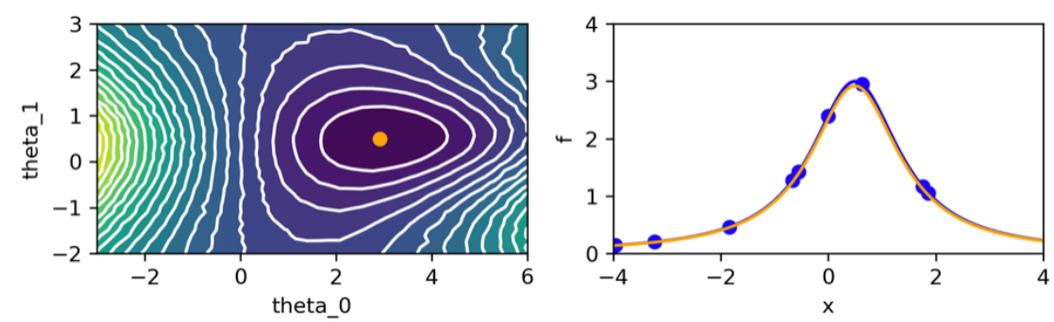
Markdown Python 3

```
ax[1].scatter(x,true_f(x),color="blue")
ax[1].plot(x_sweep,f(theta,x_sweep),color="ora
ax[1].set_xlim(-4,4)
ax[1].set_ylim(0.0,4.0)
ax[1].set_xlabel("x")
ax[1].set_ylabel("f")

plt.show()
sleep(0.3)
```



Your own examples!

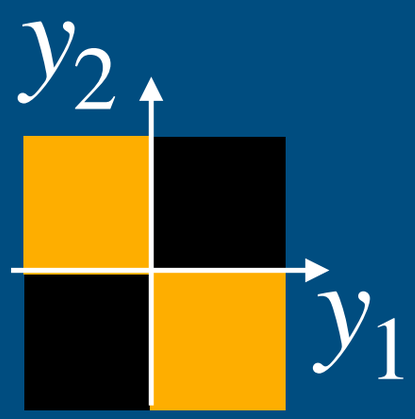
0 7 Python 3 | Mode: Ln 1, 01_tutorial_CurveFitting.i

Suggested Homework

Machine Learning for Physicists

* 1 Implement a network that computes XOR

2 Implement a network that approximately computes XOR, with 1 hidden layer(!)



* minimum

* 3 Visualize the results of intermediate layers in a multi-layer randomly initialized NN

4 What happens when you change the spread of the random weights?

5 Explore cases of curve fitting where there are several (non-equivalent) local minima. Is sampling noise helpful?