

CS561 - ARTIFICIAL INTELLIGENCE LAB
ASSIGNMENT-6: Neural Networks

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Q1.) Simulate XOR gate

Execution :

python xor.py

Output :

Learning rate: 0.0

Output from neural network after 10,000 epochs:

[0.78119803] [0.78420007] [0.79517946] [0.79693324]

Learning rate: 0.1

Output from neural network after 10,000 epochs:

[0.09212181] [0.90918367] [0.90906182] [0.10190429]

Learning rate: 0.2

Output from neural network after 10,000 epochs:

[0.03335917] [0.9706048] [0.97060615] [0.03089138]

Learning rate: 0.30000000000000004

Output from neural network after 10,000 epochs:

[0.02764959] [0.97589252] [0.9757545] [0.02531433]

Learning rate: 0.4

Output from neural network after 10,000 epochs:

[0.02433824] [0.97707246] [0.97707273] [0.02510277]

Learning rate: 0.5

Output from neural network after 10,000 epochs:

[0.01917723] [0.98340585] [0.98339585] [0.01723038]

Learning rate: 0.6

Output from neural network after 10,000 epochs:

[0.01736361] [0.98509057] [0.98501607] [0.0154706]

Learning rate: 0.7

Output from neural network after 10,000 epochs:

[0.01658754] [0.98573961] [0.98573622] [0.01473012]

Learning rate: 0.7999999999999999

Output from neural network after 10,000 epochs:

[0.01490132] [0.98722088] [0.98721811] [0.01318543]

Learning rate: 0.8999999999999999

Output from neural network after 10,000 epochs:

[0.01385674] [0.98811535] [0.98811451] [0.01226622]

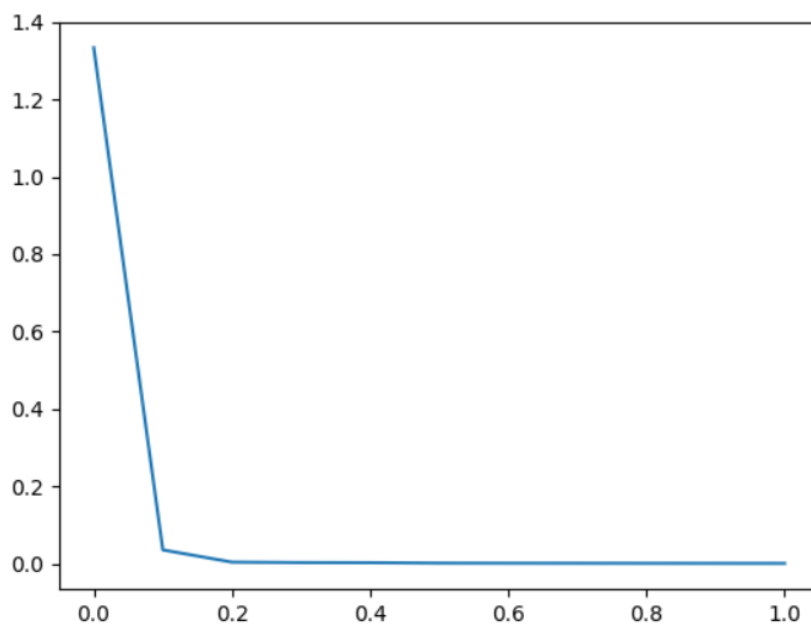
Learning rate: 0.9999999999999999

Output from neural network after 10,000 epochs:

[0.0129442] [0.9889434] [0.98894454] [0.01136498]

Format : [00] [01] [10] [11]

X-axis : learning rate; Y-axis : error.



Q2) Multi-layer Perceptron Classifier (MLP)

For IRIS : (5 models with different number of neurons)

Model: "sequential"

Layer (type)	Output Shape	Param #
dense (Dense)	(None, 2)	10
dense_1 (Dense)	(None, 2)	6
dense_2 (Dense)	(None, 3)	9
dense_3 (Dense)	(None, 3)	12

Total params: 37

Trainable params: 37

Non-trainable params: 0

Confusion Matrix :

```
[[ 0 12  0]
```

```
 [ 0  8  0]
```

```
 [ 0 10  0]]
```

Accuracy: 0.26666666666666666

F1 score: 0.14035087719298248

Recall: 0.3333333333333333

Precision: 0.08888888888888889

Model: "sequential_1"

Layer (type)	Output Shape	Param #
dense_4 (Dense)	(None, 4)	20
dense_5 (Dense)	(None, 2)	10

dense_6 (Dense)	(None, 3)	9
dense_7 (Dense)	(None, 3)	12

=====

Total params: 51
Trainable params: 51
Non-trainable params: 0

Confusion Matrix
[[12 0 0]
 [8 0 0]
 [0 0 10]]
Accuracy: 0.7333333333333333
F1 score: 0.5833333333333334
Recall: 0.6666666666666666
Precision: 0.5333333333333333

Model: "sequential_2"

Layer (type)	Output Shape	Param #
=====		
dense_8 (Dense)	(None, 4)	20
dense_9 (Dense)	(None, 4)	20
dense_10 (Dense)	(None, 3)	15
dense_11 (Dense)	(None, 3)	12

=====

Total params: 67
Trainable params: 67
Non-trainable params: 0
Confusion Matrix :
[[0 12 0]
 [0 8 0]
 [0 0 10]]
Accuracy: 0.6
F1 score: 0.5238095238095238

Recall: 0.6666666666666666

Precision: 0.4666666666666666

Model: "sequential_3"

Layer (type)	Output Shape	Param #
dense_12 (Dense)	(None, 3)	15
dense_13 (Dense)	(None, 4)	16
dense_14 (Dense)	(None, 6)	30
dense_15 (Dense)	(None, 3)	21

Total params: 82

Trainable params: 82

Non-trainable params: 0

Confusion Matrix :

[[12 0 0]

[2 5 1]

[0 0 10]]

Accuracy: 0.9

F1 score: 0.8815628815628815

Recall: 0.875

Precision: 0.9220779220779222

Model: "sequential_4"

Layer (type)	Output Shape	Param #
dense_16 (Dense)	(None, 6)	30
dense_17 (Dense)	(None, 5)	35
dense_18 (Dense)	(None, 4)	24
dense_19 (Dense)	(None, 3)	15

=====

Total params: 104

Trainable params: 104

Non-trainable params: 0

Confusion Matrix :

[[0 12 0]

[0 8 0]

[0 0 10]]

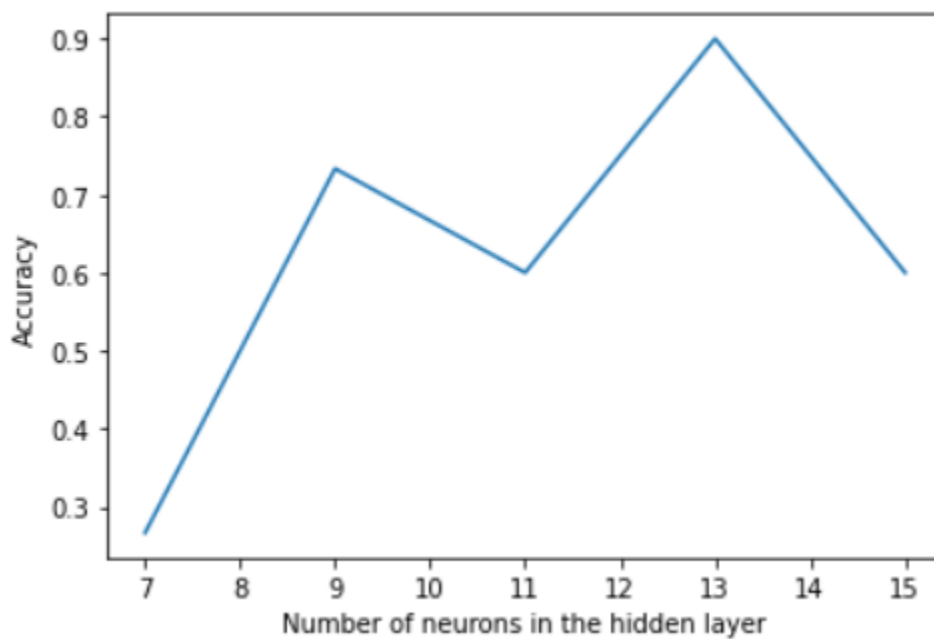
Accuracy: 0.6

F1 score: 0.5238095238095238

Recall: 0.6666666666666666

Precision: 0.4666666666666666

Plot :



For MNIST : (5 models with different number of neurons)

Model: "sequential"

Layer (type)	Output Shape	Param #
flatten (Flatten)	(None, 784)	0
dense (Dense)	(None, 200)	157000
dense_1 (Dense)	(None, 200)	40200
dense_2 (Dense)	(None, 300)	60300
dense_3 (Dense)	(None, 10)	3010

=====
Total params: 260,510
Trainable params: 260,510
Non-trainable params: 0

[[970	1	0	0	1	0	3	1	4	0]
[0 1123	3	2	0	1	2	1	3	0]	
[1 2 1008	3	2	0	1	7	8	0]		
[0 0 4 986	0	5	0	4	6	5]			
[1 0 4 0 962	0	2	1	1	11]				
[1 0 0 10 1 865	5	2	6	2]					
[4 4 1 1 4 6 936	0	2	0]						
[0 4 6 4 1 0 0 1005	3	5]							
[3 0 3 4 3 2 4 4 947	4]								
[2 2 0 6 8 1 0 4 3 983]]									

Accuracy: 0.9785
F1 score: 0.9783522667631722
Recall: 0.9782742507192216
Precision: 0.9784471325726326

Model: "sequential_1"

Layer (type)	Output Shape	Param #
flatten_1 (Flatten)	(None, 784)	0
dense_4 (Dense)	(None, 400)	314000
dense_5 (Dense)	(None, 200)	80200
dense_6 (Dense)	(None, 300)	60300
dense_7 (Dense)	(None, 10)	3010

Total params: 457,510
 Trainable params: 457,510
 Non-trainable params: 0

```

[[ 970  0  0  1  0  2  3  1  3  0]
 [ 0 1126  4  0  0  1  2  1  1  0]
 [ 3  1 1011  2  1  0  2  7  4  1]
 [ 2  1  5 990  0  4  0  2  4  2]
 [ 1  0  3  1 964  0  3  0  1  9]
 [ 2  0  0  9  2 873  3  0  2  1]
 [ 5  2  3  1  5  7 933  1  1  0]
 [ 0  3 10  2  0  0  0 1005  3  5]
 [ 3  1  4  5  1  2  1  2 951  4]
 [ 2  3  0  1  7  5  0  1  3 987]]

```

Accuracy: 0.981
 F1 score: 0.9808397705613527
 Recall: 0.9808197894807801
 Precision: 0.9808762926539447

Model: "sequential_2"

Layer (type)	Output Shape	Param #
flatten_2 (Flatten)	(None, 784)	0
dense_8 (Dense)	(None, 500)	392500

dense_9 (Dense)	(None, 200)	100200
dense_10 (Dense)	(None, 200)	40200
dense_11 (Dense)	(None, 10)	2010

=====

Total params: 534,910

Trainable params: 534,910

Non-trainable params: 0

```
[[ 973  0  0  1  0  0  2  1  3  0]
 [ 0 1125  4  0  0  1  3  1  1  0]
 [ 3  1 1012  3  1  0  2  4  5  1]
 [ 0  0  5 992  0  3  0  1  4  5]
 [ 1  1  4  1 959  0  3  2  1 10]
 [ 2  0  0 11  1 868  3  1  3  3]
 [ 4  3  1  1  4  3 941  0  1  0]
 [ 0  2  6  3  0  0  0 1010  2  5]
 [ 6  0  3  4  2  2  1  3 949  4]
 [ 3  2  0  3  5  3  0  5  2 986]]
```

Accuracy: 0.9815

F1 score: 0.9813631150533917

Recall: 0.9812800296986977

Precision: 0.9814740749239652

Model: "sequential_3"

Layer (type)	Output Shape	Param #
=====		
flatten_3 (Flatten)	(None, 784)	0
dense_12 (Dense)	(None, 300)	235500
dense_13 (Dense)	(None, 400)	120400
dense_14 (Dense)	(None, 600)	240600

dense_15 (Dense) (None, 10) 6010

=====

Total params: 602,510

Trainable params: 602,510

Non-trainable params: 0

```
[[ 972  0  1  0  0  0  2  1  4  0]
 [  0 1124  3  0  0  1  2  2  3  0]
 [  4  1 1010  2  3  0  2  4  4  2]
 [  0  0  1 995  0  3  0  4  4  3]
 [  2  1  6  0 955  0  3  2  1 12]
 [  3  0  1  8  1 867  3  1  6  2]
 [  3  3  2  0  7  6 936  0  1  0]
 [  0  4  8  0  0  0  0 1005  1 10]
 [  3  1  2  4  3  2  1  2 952  4]
 [  3  2  0  6  9  2  0  4  2 981]]
```

Accuracy: 0.9797

F1 score: 0.9795576520937601

Recall: 0.9794778408937637

Precision: 0.9796591049954431

Model: "sequential_4"

Layer (type)	Output Shape	Param #
=====		
flatten_4 (Flatten)	(None, 784)	0
dense_16 (Dense)	(None, 600)	471000
dense_17 (Dense)	(None, 500)	300500
dense_18 (Dense)	(None, 400)	200400
dense_19 (Dense)	(None, 10)	4010

=====

Total params: 975,910

Trainable params: 975,910

Non-trainable params: 0

```
[[ 973  0  1  0  1  0  1  1  3  0]
 [  0 1127  2  1  0  1  1  1  2  0]
 [  4  1 1009  5  1  0  2  4  5  1]
 [  0  0  2 991  0  5  0  3  3  6]
 [  2  1  4  0 963  0  3  2  1  6]
 [  2  0  0 10  1 866  5  1  4  3]
 [  3  2  3  0  9  4 937  0  0  0]
 [  0  2  6  1  1  0  0 1009  3  6]
 [  2  0  3  5  4  4  2  2 949  3]
 [  3  2  0  5  7  3  0  4  1 984]]
```

Accuracy: 0.9808

F1 score: 0.9805905080671007

Recall: 0.980536621451418

Precision: 0.9806611799436153

Plot :

