

## The following is a perceptron trained for implementing AND gate

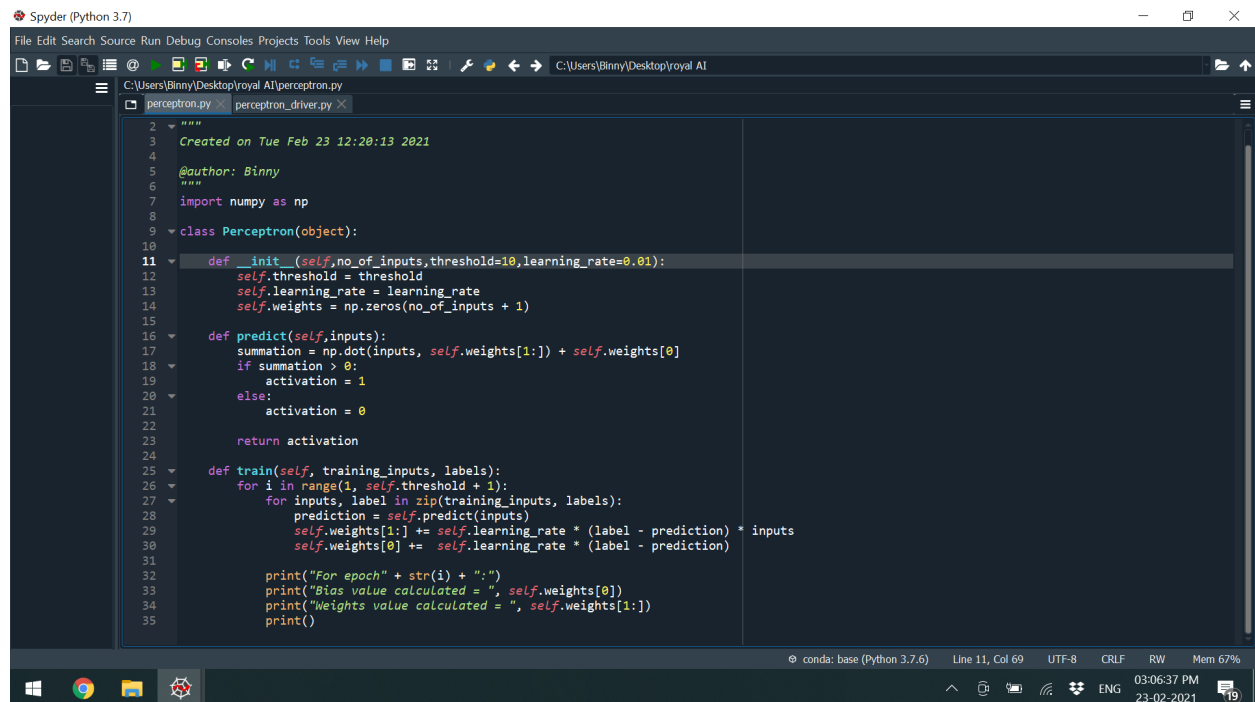
TASK1: Print the bias and weight vectors for individual epochs of the training phase

TASK2: Determine the minimum threshold required to generate the correct output

TASK3: Observe the effect of changing the learning rate on the outputs

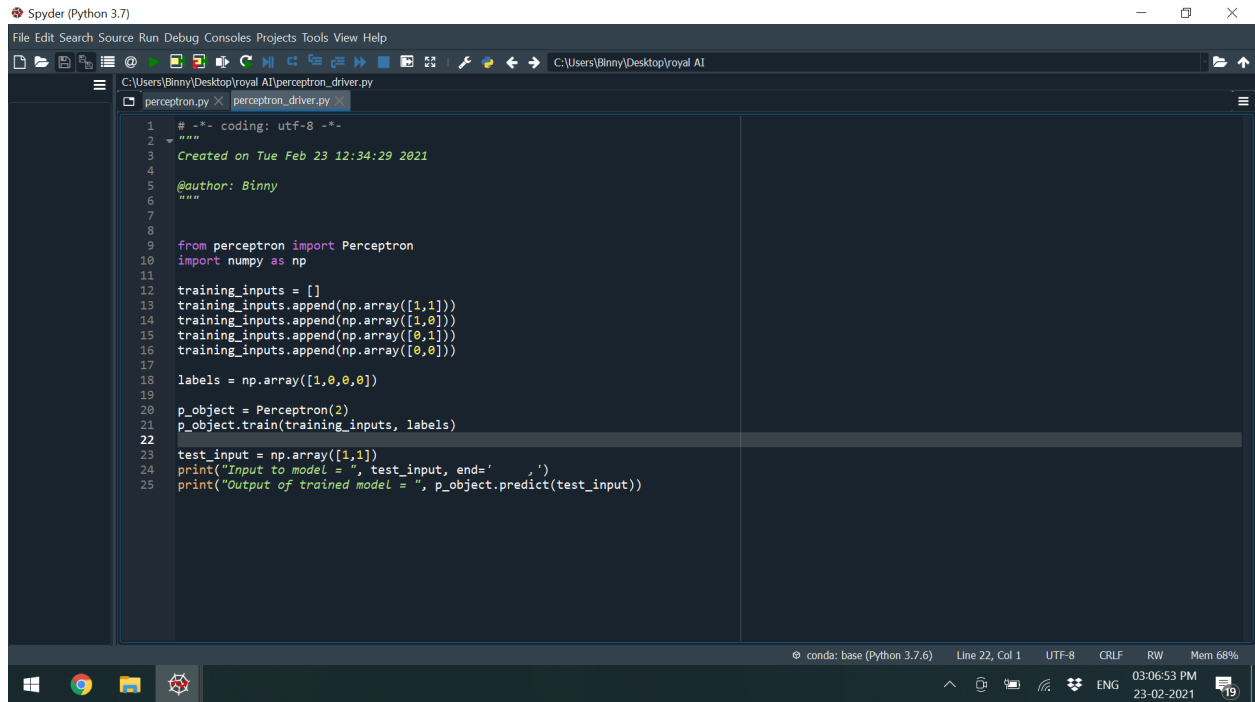
In the following sections, I'll implement each of the above-listed tasks:

The following is the code:



```
2 """
3 Created on Tue Feb 23 12:20:13 2021
4
5 @author: Binny
6 """
7 import numpy as np
8
9 class Perceptron(object):
10
11     def __init__(self, no_of_inputs, threshold=10, learning_rate=0.01):
12         self.threshold = threshold
13         self.learning_rate = learning_rate
14         self.weights = np.zeros(no_of_inputs + 1)
15
16     def predict(self, inputs):
17         summation = np.dot(inputs, self.weights[1:]) + self.weights[0]
18         if summation > 0:
19             activation = 1
20         else:
21             activation = 0
22         return activation
23
24     def train(self, training_inputs, labels):
25         for i in range(1, self.threshold + 1):
26             for inputs, label in zip(training_inputs, labels):
27                 prediction = self.predict(inputs)
28                 self.weights[1:] += self.learning_rate * (label - prediction) * inputs
29                 self.weights[0] += self.learning_rate * (label - prediction)
30
31         print("For epoch" + str(i) + ":")
32         print("Bias value calculated = ", self.weights[0])
33         print("Weights value calculated = ", self.weights[1:])
34         print()
```

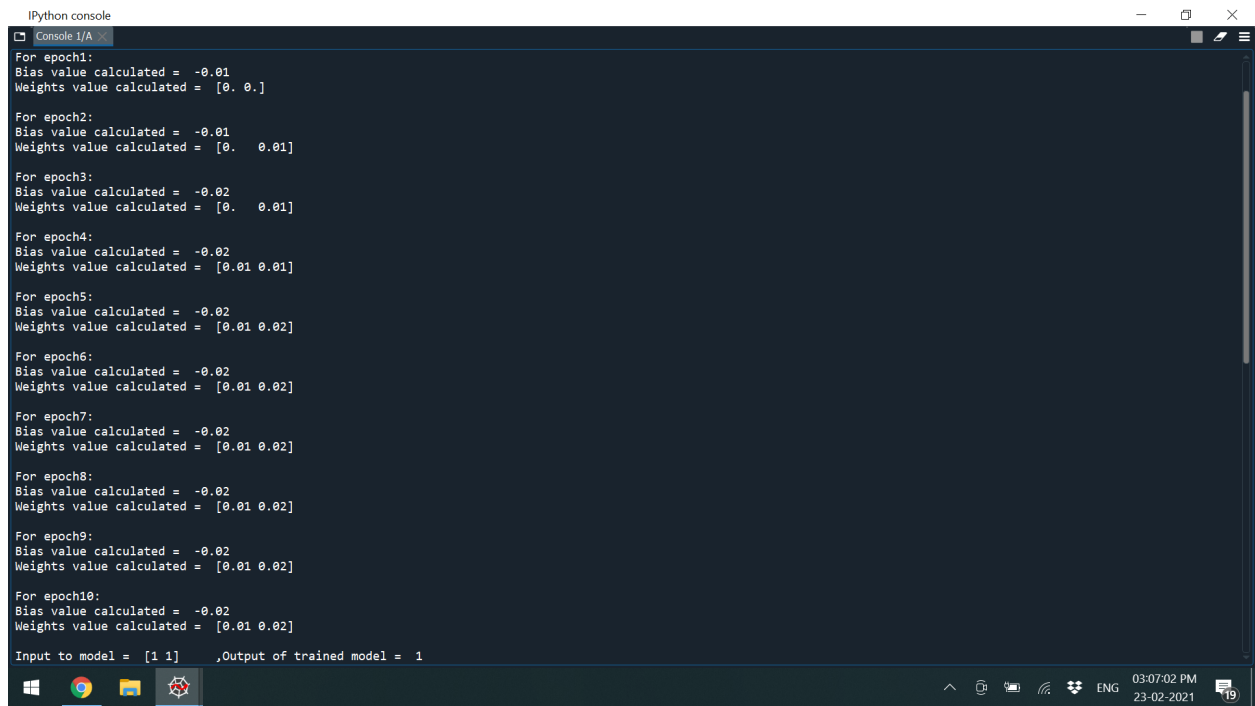
Fig 1. Skeleton code



```
1  # -*- coding: utf-8 -*-
2  """
3  Created on Tue Feb 23 12:34:29 2021
4
5  @author: Binny
6  """
7
8
9  from perceptron import Perceptron
10 import numpy as np
11
12 training_inputs = []
13 training_inputs.append(np.array([1,1]))
14 training_inputs.append(np.array([1,0]))
15 training_inputs.append(np.array([0,1]))
16 training_inputs.append(np.array([0,0]))
17
18 labels = np.array([1,0,0,0])
19
20 p_object = Perceptron(2)
21 p_object.train(training_inputs, labels)
22
23 test_input = np.array([1,1])
24 print("Input to model = ", test_input, end=' ')
25 print("Output of trained model = ", p_object.predict(test_input))
```

Fig 2. Driver code

The following is the output generated:



```
IPython console
Console 1/A
For epoch1:
Bias value calculated = -0.01
Weights value calculated = [0. 0.]

For epoch2:
Bias value calculated = -0.01
Weights value calculated = [0. 0.01]

For epoch3:
Bias value calculated = -0.02
Weights value calculated = [0. 0.01]

For epoch4:
Bias value calculated = -0.02
Weights value calculated = [0.01 0.01]

For epoch5:
Bias value calculated = -0.02
Weights value calculated = [0.01 0.02]

For epoch6:
Bias value calculated = -0.02
Weights value calculated = [0.01 0.02]

For epoch7:
Bias value calculated = -0.02
Weights value calculated = [0.01 0.02]

For epoch8:
Bias value calculated = -0.02
Weights value calculated = [0.01 0.02]

For epoch9:
Bias value calculated = -0.02
Weights value calculated = [0.01 0.02]

For epoch10:
Bias value calculated = -0.02
Weights value calculated = [0.01 0.02]

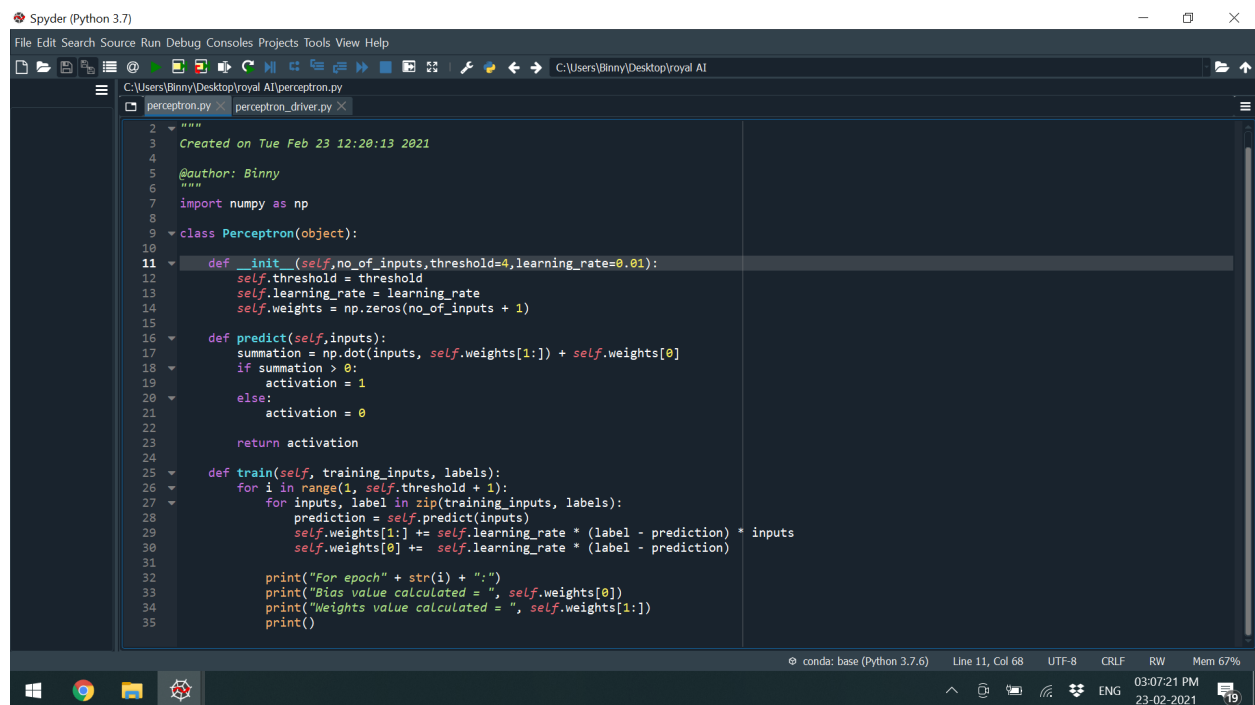
Input to model = [1 1] ,Output of trained model = 1
```

Fig 3. Output of model with threshold = 10 & learning\_rate = 0.01

In fig 3, I have printed the bias and weight vector for individual epochs, along with the test input given to the model and the corresponding output generated by the model.

Further, moving on to determine the minimum threshold required to get the correct output, we can observe in the above output that after epoch 5, we get constant values for bias and weights. So, it can be inferred that the minimum threshold required to train the model is 5.

In order to prove this, let us check the output for threshold = 4.

The image shows a Spyder Python IDE window with a file named 'perceptron.py' open. The code defines a 'Perceptron' class with an initialization method, a 'predict' method, and a 'train' method. The 'train' method uses a threshold of 4. The IDE interface includes a menu bar, a toolbar, and a status bar at the bottom showing 'conda: base (Python 3.7.6)', 'Line 11, Col 68', 'UTF-8', 'CRLF', 'RW', and 'Mem 67%'. The system tray at the bottom right shows the time as 03:07:21 PM on 23-02-2021.

```
2 """
3 Created on Tue Feb 23 12:20:13 2021
4
5 @author: Binny
6 """
7 import numpy as np
8
9 class Perceptron(object):
10
11     def __init__(self, no_of_inputs, threshold=4, learning_rate=0.01):
12         self.threshold = threshold
13         self.learning_rate = learning_rate
14         self.weights = np.zeros(no_of_inputs + 1)
15
16     def predict(self, inputs):
17         summation = np.dot(inputs, self.weights[1:]) + self.weights[0]
18         if summation > 0:
19             activation = 1
20         else:
21             activation = 0
22         return activation
23
24     def train(self, training_inputs, labels):
25         for i in range(1, self.threshold + 1):
26             for inputs, label in zip(training_inputs, labels):
27                 prediction = self.predict(inputs)
28                 self.weights[1:] += self.learning_rate * (label - prediction) * inputs
29                 self.weights[0] += self.learning_rate * (label - prediction)
30
31         print("For epoch" + str(i) + ":")
32         print("Bias value calculated = ", self.weights[0])
33         print("Weights value calculated = ", self.weights[1:])
34         print()
```

Fig 4. Code with threshold 4

```
IPython console
Console 1/A
Weights value calculated = [0.01 0.02]

For epoch7:
Bias value calculated = -0.02
Weights value calculated = [0.01 0.02]

For epoch8:
Bias value calculated = -0.02
Weights value calculated = [0.01 0.02]

For epoch9:
Bias value calculated = -0.02
Weights value calculated = [0.01 0.02]

For epoch10:
Bias value calculated = -0.02
Weights value calculated = [0.01 0.02]

Input to model = [1 1] ,Output of trained model = 1

In [75]: runfile('C:/Users/Binny/Desktop/royal AI/perceptron_driver.py', wdir='C:/Users/Binny/Desktop/royal AI')
Reloaded modules: perceptron
For epoch1:
Bias value calculated = -0.01
Weights value calculated = [0. 0.]

For epoch2:
Bias value calculated = -0.01
Weights value calculated = [0. 0.01]

For epoch3:
Bias value calculated = -0.02
Weights value calculated = [0. 0.01]

For epoch4:
Bias value calculated = -0.02
Weights value calculated = [0.01 0.01]

Input to model = [1 1] ,Output of trained model = 0

In [76]: |
```

Fig 5. Output with threshold 4

It can be seen in fig 5 that for input (1,1) the output generated by the model is 0, which is the wrong output.

**Thus, the minimum threshold required to train the model to produce the correct output is 5.**

Now, moving on to observe the behavior of outputs upon changing the learning\_rate.

In the subsequent section, I'll be illustrating the outputs produced for different learning\_rates.

```
Spyder (Python 3.7)
File Edit Search Source Run Debug Consoles Projects Tools View Help
C:\Users\Binny\Desktop\royal AI\perceptron.py
perceptron.py x perceptron_driver.py x

2 """
3 Created on Tue Feb 23 12:20:13 2021
4
5 @author: Binny
6 """
7 import numpy as np
8
9 class Perceptron(object):
10
11     def __init__(self, no_of_inputs, threshold=5, learning_rate=0.2):
12         self.threshold = threshold
13         self.learning_rate = learning_rate
14         self.weights = np.zeros(no_of_inputs + 1)
15
16     def predict(self, inputs):
17         summation = np.dot(inputs, self.weights[1:]) + self.weights[0]
18         if summation > 0:
19             activation = 1
20         else:
21             activation = 0
22         return activation
23
24     def train(self, training_inputs, labels):
25         for i in range(1, self.threshold + 1):
26             for inputs, label in zip(training_inputs, labels):
27                 prediction = self.predict(inputs)
28                 self.weights[1:] += self.learning_rate * (label - prediction) * inputs
29                 self.weights[0] += self.learning_rate * (label - prediction)
30
31         print("For epoch" + str(i) + ":")
32         print("Bias value calculated = ", self.weights[0])
33         print("Weights value calculated = ", self.weights[1:])
34         print()
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Spyder (Python 3.7)
File Edit Search Source Run Debug Consoles Projects Tools View Help
C:\Users\Binny\Desktop\royal AI\perceptron.py
perceptron.py x perceptron_driver.py x

2 """
3 Created on Tue Feb 23 12:20:13 2021
4
5 @author: Binny
6 """
7 import numpy as np
8
9 class Perceptron(object):
10
11     def __init__(self, no_of_inputs, threshold=5, learning_rate=0.005):
12         self.threshold = threshold
13         self.learning_rate = learning_rate
14         self.weights = np.zeros(no_of_inputs + 1)
15
16     def predict(self, inputs):
17         summation = np.dot(inputs, self.weights[1:]) + self.weights[0]
18         if summation > 0:
19             activation = 1
20         else:
21             activation = 0
22         return activation
23
24     def train(self, training_inputs, labels):
25         for i in range(1, self.threshold + 1):
26             for inputs, label in zip(training_inputs, labels):
27                 prediction = self.predict(inputs)
28                 self.weights[1:] += self.learning_rate * (label - prediction) * inputs
29                 self.weights[0] += self.learning_rate * (label - prediction)
30
31             print("For epoch" + str(i) + ":")
32             print("Bias value calculated = ", self.weights[0])
33             print("Weights value calculated = ", self.weights[1:])
34             print()
35

```

Fig 8. Code with threshold = 5 and learning\_rate = 0.05

```

IPython console
Console 1/A
Weights value calculated = [0. 0.2]

For epoch3:
Bias value calculated = -0.4
Weights value calculated = [0. 0.2]

For epoch4:
Bias value calculated = -0.4
Weights value calculated = [0.2 0.2]

For epoch5:
Bias value calculated = -0.4
Weights value calculated = [0.2 0.4]

Input to model = [1 1] ,Output of trained model = 1

In [77]: runfile('C:/Users/Binny/Desktop/royal AI/perceptron_driver.py', wdir='C:/Users/Binny/Desktop/royal AI')
Reloaded modules: perceptron
For epoch1:
Bias value calculated = -0.005
Weights value calculated = [0. 0.]

For epoch2:
Bias value calculated = -0.005
Weights value calculated = [0. 0.005]

For epoch3:
Bias value calculated = -0.01
Weights value calculated = [0. 0.005]

For epoch4:
Bias value calculated = -0.01
Weights value calculated = [0.005 0.005]

For epoch5:
Bias value calculated = -0.01
Weights value calculated = [0.005 0.01]

Input to model = [1 1] ,Output of trained model = 1

In [78]:

```

Fig 9. Output of model with threshold = 5 and learning\_rate = 0.05

It can be analyzed from Fig 6-9, that by changing the learning\_rate; the values of bias and weights change. However, there is a notable relation observed between the learning\_rate( $\alpha$ ), bias( $w_0$ ), and weights( $w_1, w_2$ ) which can be represented as follows:

$$w_0 = 2 * \alpha$$

$$w_1 = \alpha$$

$$w_2 = 2 * \alpha$$

Further, as per my analysis, for this particular perceptron with the implementation of AND gate, changing the learning\_rate does not change the minimum threshold value of 5. It only changes the values of bias and weights, giving the correct output at epoch 5.