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Neural Networks



V Nohitha Reddy

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Perceptrons as Logical operators

Few logical operators can be represented as perceptron. They are AND, OR, NOT and XOR operators which help to create perceptrons. We need to know the truth tables of AND, OR, NOT and XOR. The truth tables of each operators are shown below.

AND operator perceptron

The AND operator takes 2 inputs and gives an output. The inputs can either be true or false and the output is true if both the inputs are true else false.

OR operator perceptron

The OR operator takes 2 inputs and gives an output. The inputs can either be true or false and the output is true if at least one of the input is true else false.

NOT operator perceptron

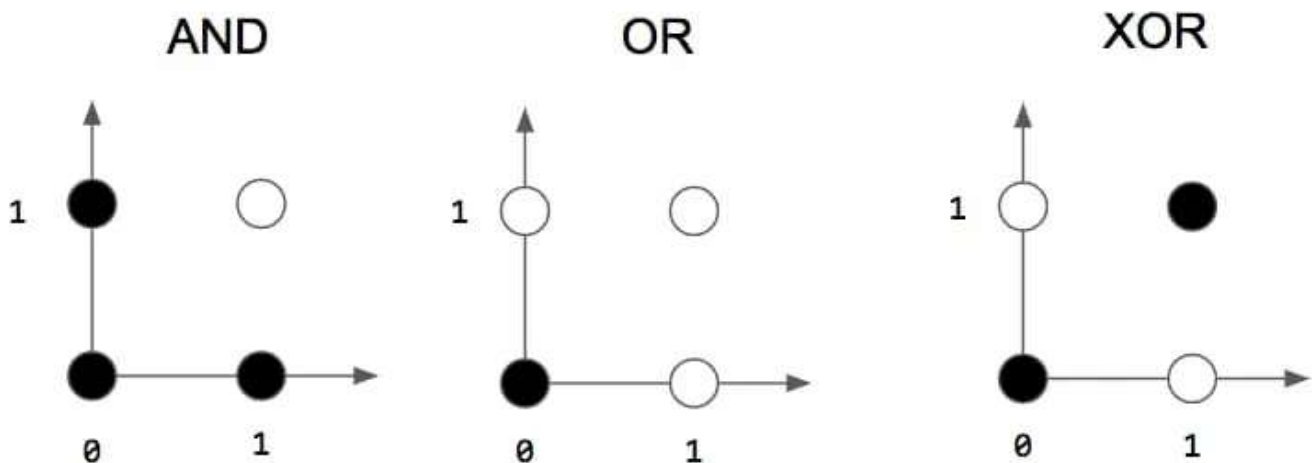
The NOT operator takes one input and gives an output. If input is true the output is false else vice versa.(Take w1 as 0 as only one input is required)

XOR operator perceptron

The XOR operator takes 2 inputs and gives an output. The inputs can either be true or false and the output is true if one of input is true else false.

NOT		AND			OR			XOR		
x	x'	x	y	xy	x	y	x+y	x	y	$x \oplus y$
0	1	0	0	0	0	0	0	0	0	0
1	0	0	1	0	0	1	1	0	1	1
		1	0	0	1	0	1	1	0	1
		1	1	1	1	1	1	1	1	0

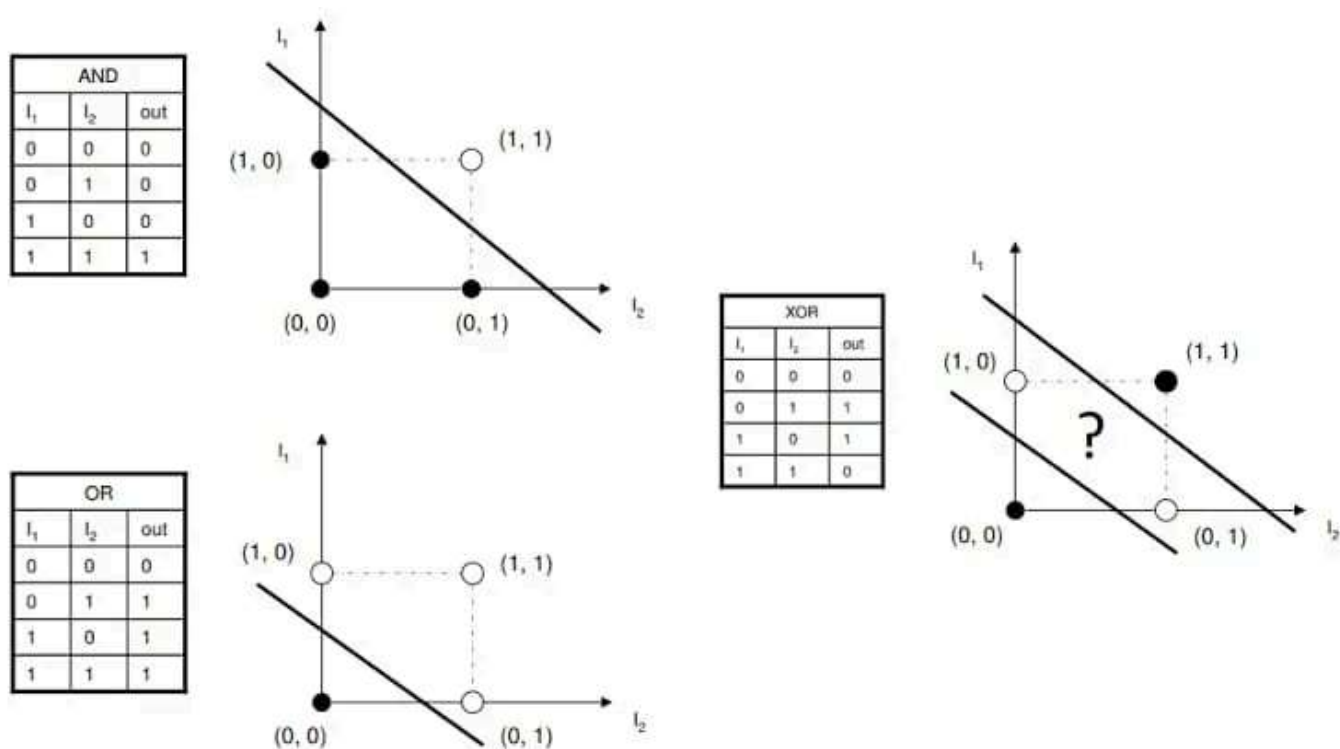
Truth tables of operators



AND, OR and XOR perceptrons respectively

Based on the truth tables the above graphs are plotted. The black points are under the rejected region and the white points are under accepted region. Line is drawn separating the rejected and accepted region and a linear equation is obtained of the form $w_1x_1 + w_2x_2 + b = 0$.

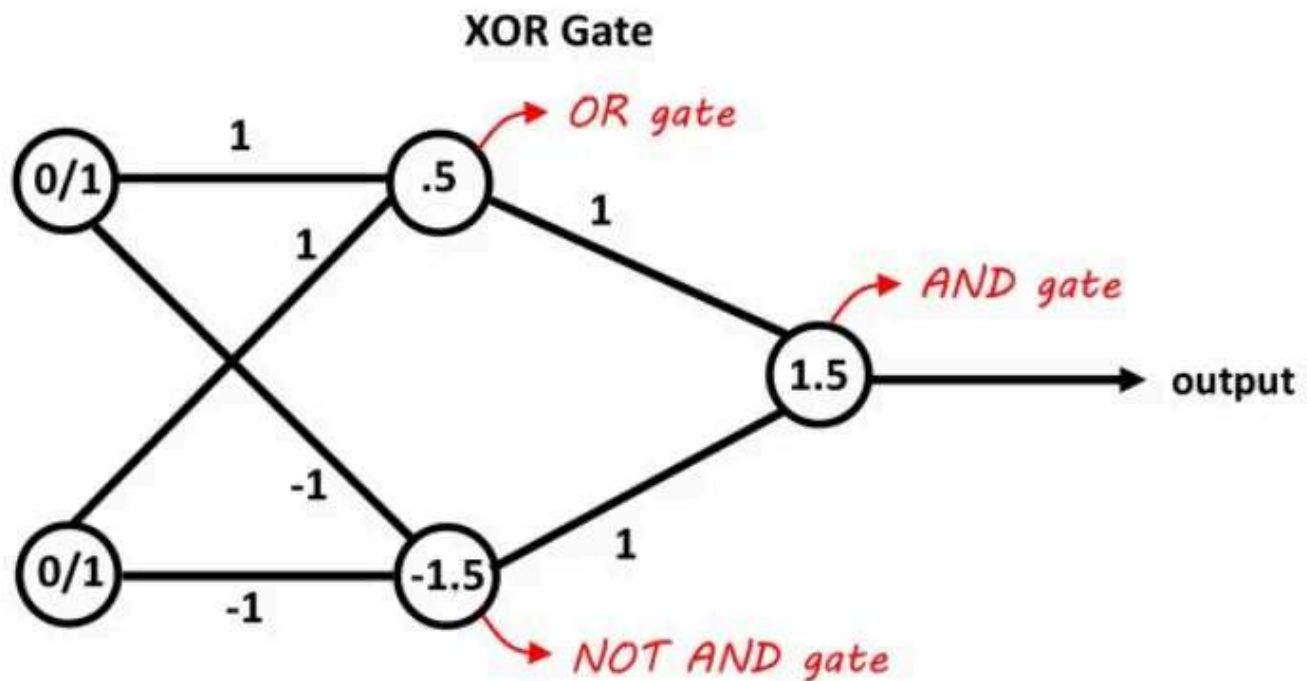
Here, in XOR it is hard to separate rejected and accepted region by a line. Then how do we do it? Look at below figure. We should use a multi-layer perceptron to solve it.



One more layer is taken to classify points correctly in XOR Perceptron

Multi-layer XOR perceptron

We build a multi-layer XOR perceptron using AND, OR and NOT. Observe the below figure.



Neural network representation of Multi-layer XOR perceptron

The figure shows there are input layer and a hidden layer and an output. There are two inputs which can be either 0 or 1, given to hidden layer. The hidden layer process the input and gives an output. Since there is input layer, hidden layer and output, it is called as multi-layer XOR perceptron.

AND to OR perceptron

There are two ways to convert AND perceptron to OR perceptron. They are

1. Increase weights or
2. Decrease the bias

Perceptron trick

As previously, we used a multi-layered perceptron to solve the problem. We can not solve it in real life as there might be complex structures which can not be done by ourselves. So, we have to give an idea and teach them how to build themselves.

How can we separate the data that most of the rejected points are in the rejected region and most of the accepted points are in the accepted region, leaving few incorrectly classified points?

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Computer chooses some random line and also a linear equation for it. Now, we check how badly it is classified and then turn the line around until the maximum points are correctly classified and only few points are incorrectly classified. Then just move the line closer to one of the incorrectly classified point and over the point and check again classification is correct or not. Repeat this until the points are correctly classified.

learning rate

Now, consider an example of linear equation $2x_1 + x_2 - 5 = 0$, where the equation is > 0 then it lies in accepted region else, if it is < 0 then it lies in the rejected region. Consider point(3,2) is a misclassified point which is to be in rejected region but it is in the accepted region. As we saw previously, the line should go closer to the point and over it to classify it correctly.

So, how we get the line closer to the point? We use (3,2) and modify to solve it. Take parameters 2,1 and -5. We take 3,2 point and 1 as bias. Subtract them as the misclassified point is in positive region and add them if a misclassified point is in negative region.

2 1 -5

(-)3 2 1

-1 -1 -6

The obtained parameters are forming a line where position of the line is changed drastically towards the point. But, there are more points in the region, so if we change drastically, other classified points may change. Hence, we need to take small steps to modify the line towards the point.

Term Learning rate is taken to make small steps. Learning rate is small then we are taking small steps else vice versa. So, consider learning rate as 0.1, and multiply it with 3, 2, 1 and then subtract from the parameters of the line.

2 1 -5

(-)0.3 0.2 0.1

0.7 0.8 -5.6

The linear equation now becomes $0.7x_1 + 0.8x_2 - 5.6 = 0$ and the line moves closer to the point with a small step. Repeat this until the point moves closer to point and over it and classify correctly. This is the trick of perceptron algorithm.

Perceptron algorithm

After getting to know the perceptron trick, we can develop perceptron algorithm.

The **pseudo algorithm for perceptron** is as below:

1. *Start with random weights and bias. ($w_1, w_2, w_3, \dots, w_n, b$)*

2. *For every misclassified point ($x_1, x_2, \dots, x_n$)*

2.1 *if prediction = 0:*

for $i = 1 \dots n$

change $w_i + (\alpha)x_i$

change b to $b + \alpha$

2.2 *if prediction = 1:*

for $i = 1 \dots n$

change $w_i - (\alpha)x_i$

change b to $b-\alpha$

Repeat all the steps until no error or until error is small.

Here, α is the learning rate. The learning rate can be 0.01, 0.02, 0.1... or anything. Take random weights and bias, then for every misclassified point if prediction is false(0) then update weights and bias as in algorithm. if prediction is true(1) then update weights and bias according to the algorithm.

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