AI and Deep Learning

Multi-Layer Neural Networks and Non-linear Decision Boundary

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Agenda

- Learning revisited
- Place holder
- Linear decision boundary and XOR problem
- Multi-layer and non-linearity
- Complex boundary as you wish

Learning

① Parameters(w, b) initialization randomly
② Building computation graph of E by TensorFlow
③ Foreword propagation by putting values into the graph and calculate E
④ Back-propagation to get the influence of w, b on the error (applying chain rules)
⑤ Update w, b to adjust a decision boundary
⑥ go to ③

Learning

```
import tensorflow as tf
#----- training data
x_data = [-2, -1, 1, 2]
y_data = [0, 0, 1, 1]
#----- a neuron
w = tf.Variable(tf.random_normal([1]))
hypo = tf.sigmoid(x_data * w)
#----- learning
cost = -tf.reduce_mean(y_data * tf.log(hypo) +
          tf.subtract(1., y_data) * tf.log(tf.subtract(1., hypo)))
train =
tf.train.GradientDescentOptimizer(learning_rate=0.01).
minimize(cost)
```

①

Learning

```
sess = tf.Session()
sess.run(tf.global_variables_initializer())  ①
②
for i in range(1001):
    sess.run(train)   ③④⑤

    if i % 100 == 0:
        print( ' w: ' , sess.run(w),  ' cost: ' , sess.run(cost))
```

Learning finished after 1001 times updates

```
#----- test (classification)
x_data = [-2, 4]
print(sess.run(hypo))
```

Testing new data

- After learning,
- a neuron can classify new input data correctly.

x_data = [-2, -1, 1, 2]

```
#----- test (classification)
x_data = [-2, 4]
print(sess.run(hypo))
```

- Failure!
- Data is set only one time when the graph is created.
- **Still old data was used.**
- No feeding the new data into the predefined computational graph

Place Holder

- Marking certain places in a computational graph
- and then replace it with real data when it runs (is evaluated).

sess.run ( )

Place Holder

```
import tensorflow as tf

#----- training data
x_data = [[-2], [-1], [1], [2]]
y_data = [[0], [0], [1], [1]]

X = tf.placeholder (tf.float32)
Y = tf.placeholder (tf.float32)

#----- a neuron
w = tf.Variable (tf.random_normal([1]))
hypo = tf.sigmoid(X * w)
```

1. Place holders : X, Y
2. x_data → X, y_data → Y
3. Feeding real data when hypo, cost, and train operations are executed.

Place Holder

```
#----- learning
cost = -tf.reduce_mean(Y * tf.log(hypo) +
    tf.subtract(1., Y) * tf.log(tf.subtract(1., hypo)))

train =
tf.train.GradientDescentOptimizer(learning_rate=0.01).minimize(cost)

sess = tf.Session()
sess.run(tf.global_variables_initializer())

for i in range(1001):
  sess.run(train, feed_dict={X:x_data, Y:y_data})

  if i % 100 == 0:
    print(sess.run(w), sess.run(cost feed_dict={X:x_data, Y:y_data}))
```

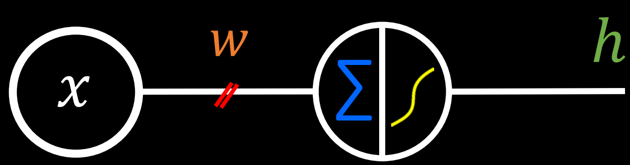
Place Holder

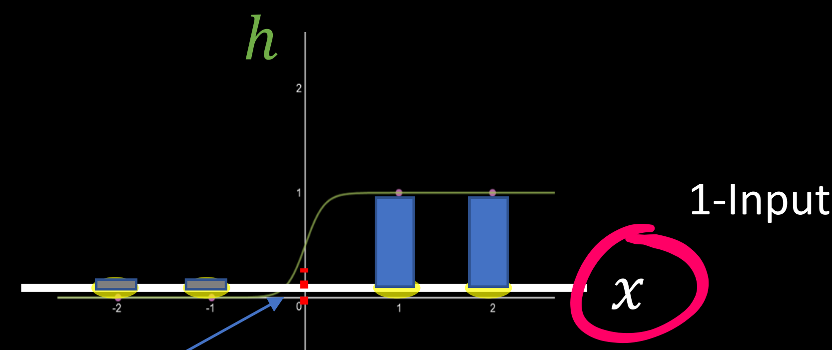
```
#----- testing(classification)
x_data = [-2, 4]
result = sess.run(hypo, feed_dict={X: x_data})
print(result)
```

Lab 15.py

- Classification into one of four classes
- Using placeholders

1-Input Neuron

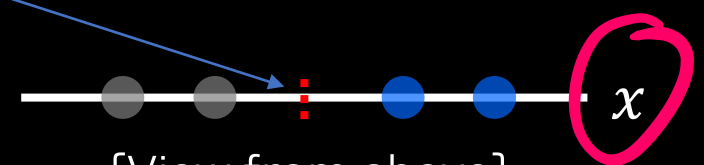




{Side view}

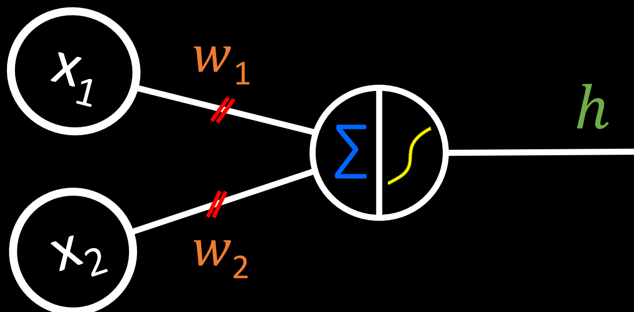
Decision boundary : Value

$$w \cdot x = 0$$
$$x = 0$$



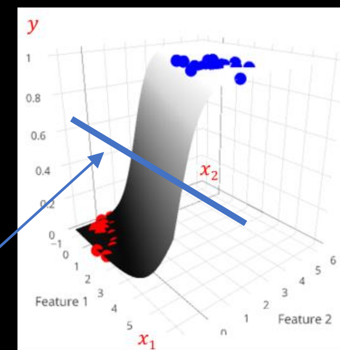
{View from above}

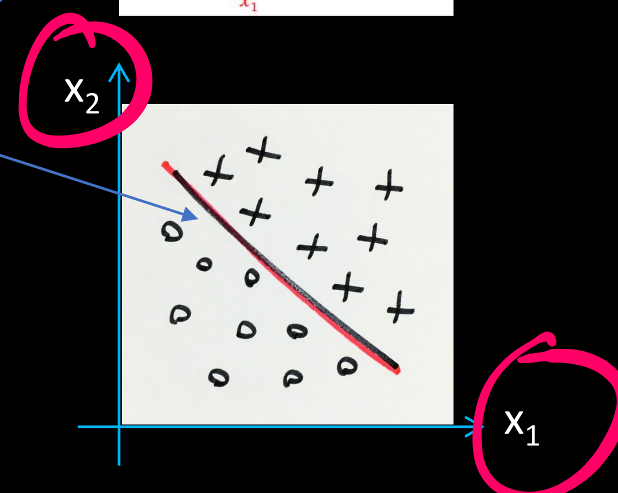
2-Input Neuron



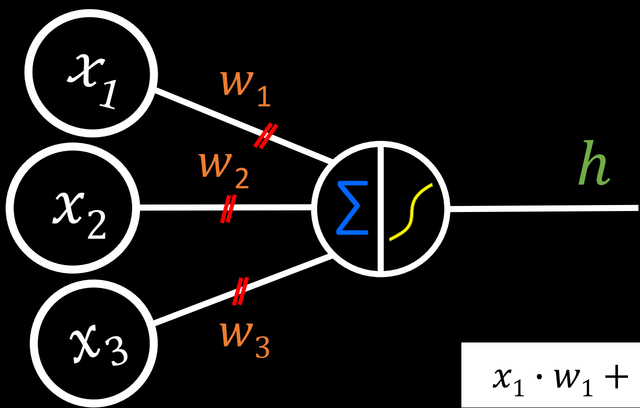
Decision boundary : Line

$$x_1 \cdot w_1 + x_2 \cdot w_2 = 0$$



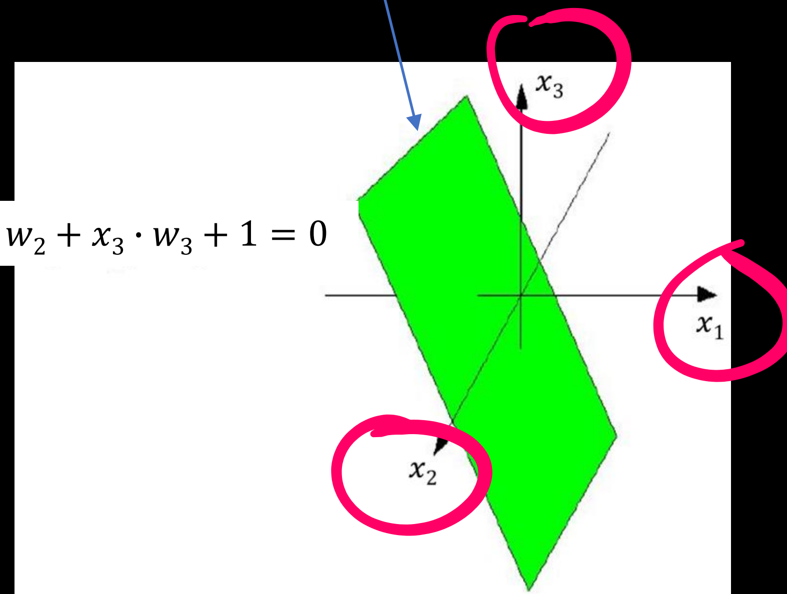


3-Input Neuron



Decision boundary : Plane

$$x_1 \cdot w_1 + x_2 \cdot w_2 + x_3 \cdot w_3 + 1 = 0$$



More than 4 inputs?

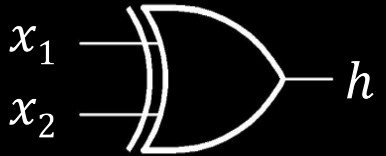
$$x_1 w_1 + \ x_2 w_2 + x_3 w_3 + x_4 w_4 + b = 0$$

→ hyperplane

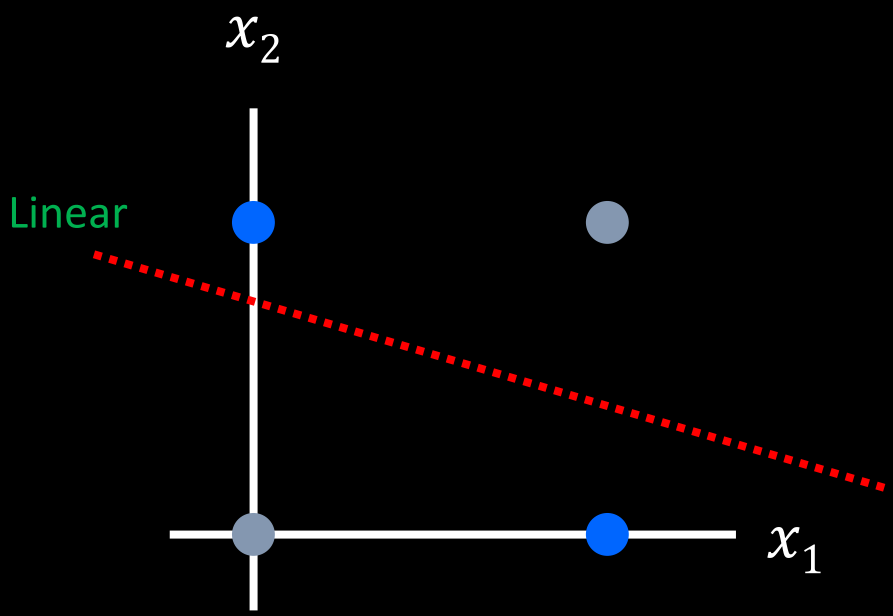
Linear Decision Boundary

(value, line, plane, hyperplane)

XOR



x_1	x_2	h
0	0	0
0	1	1
1	0	1
1	1	0



View from above

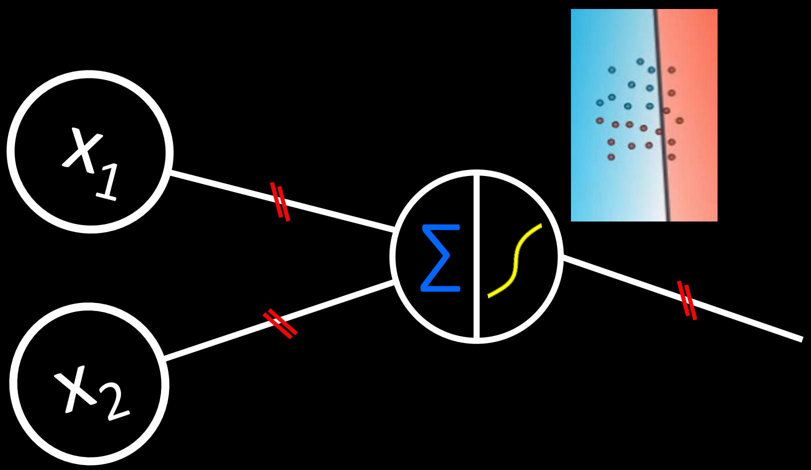
XOR

- Number of class : 2
- 1 decision boundary for 2-class classification
- Impossible to classify using a linear decision boundary

Lab 16.py

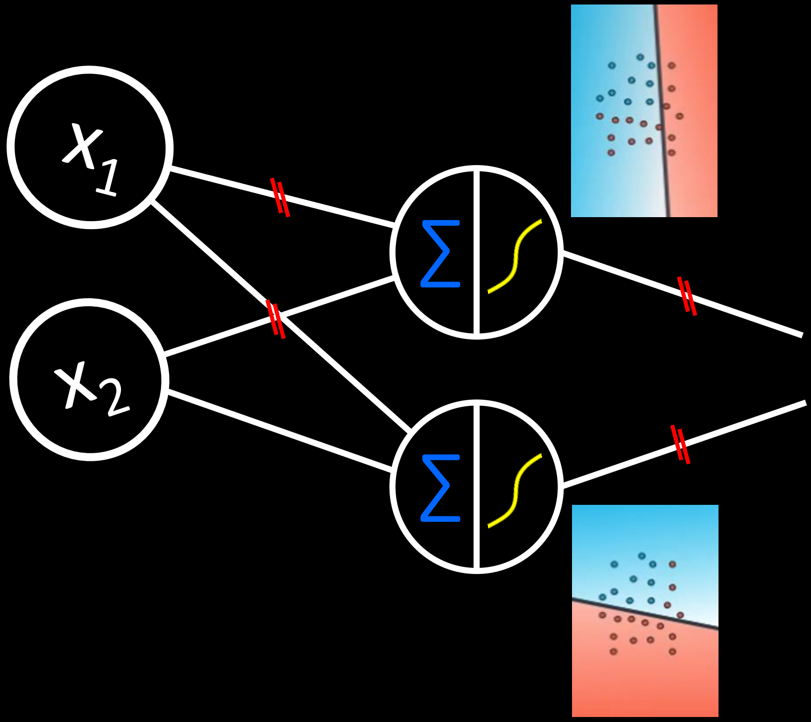
- XOR problem
- A neuron, 1 linear decision boundary
- Cannot be solved!

How to solve



by Luis Serrano, A friendly introduction to Deep Learning, UDACITY

How to solve



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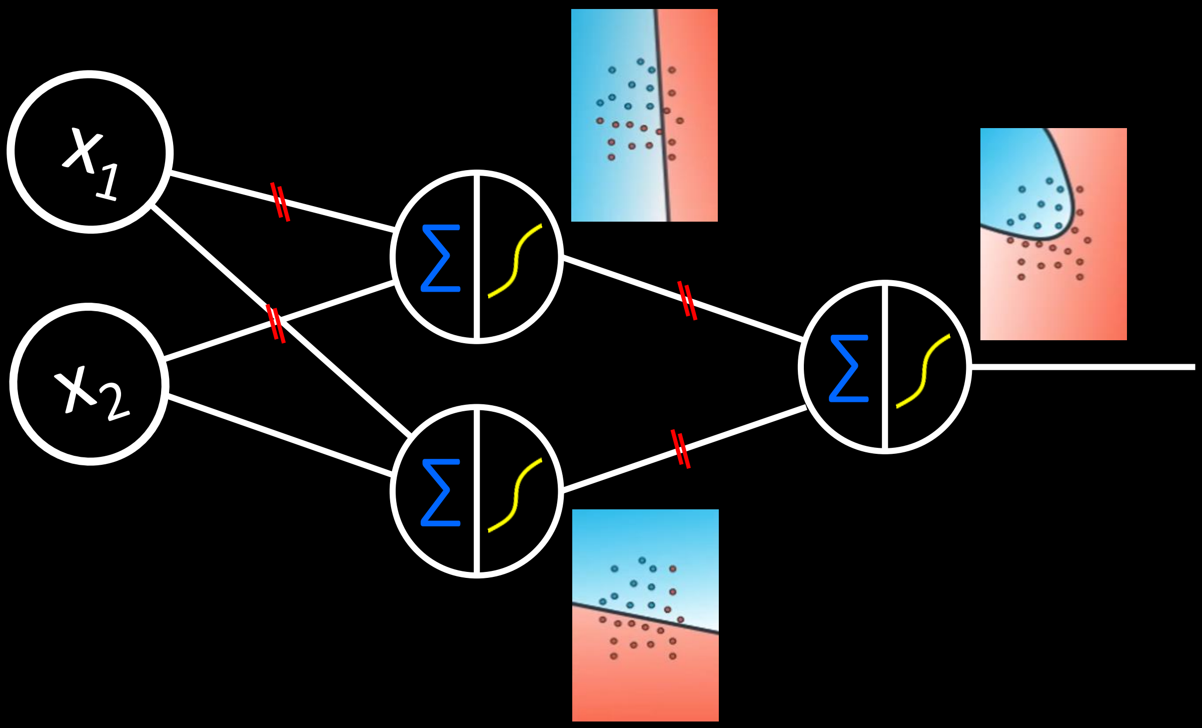
How to solve



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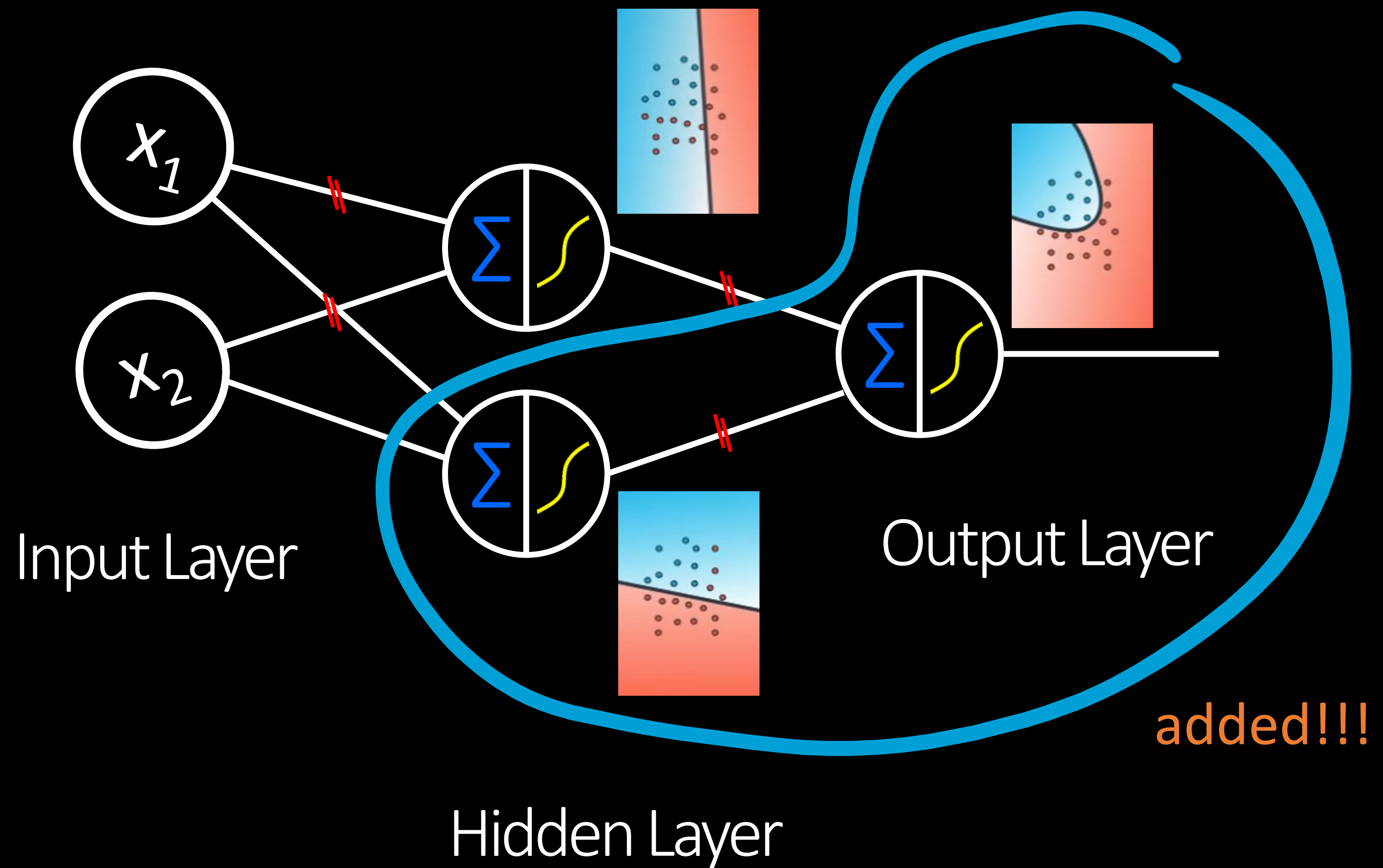
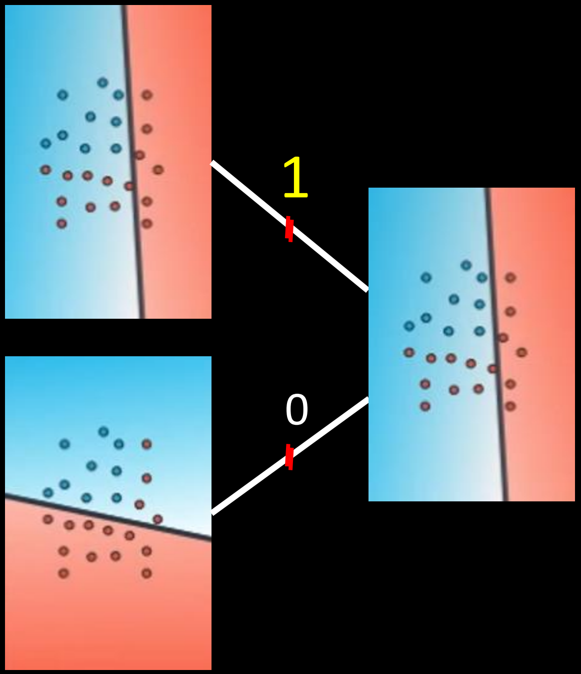
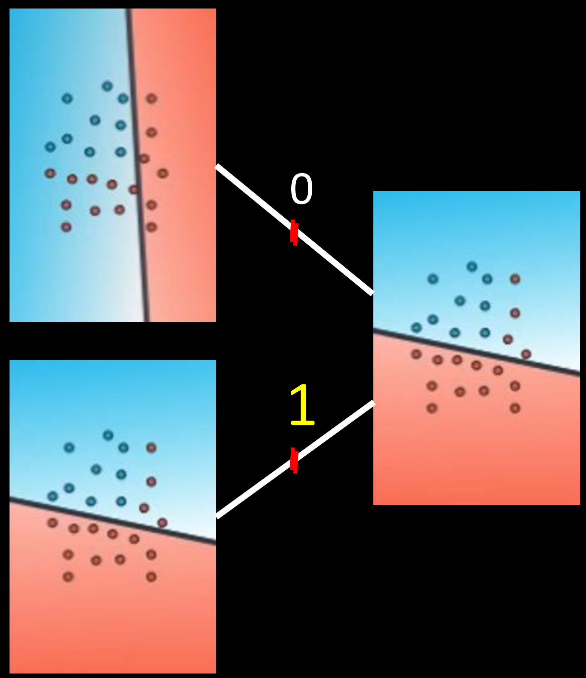
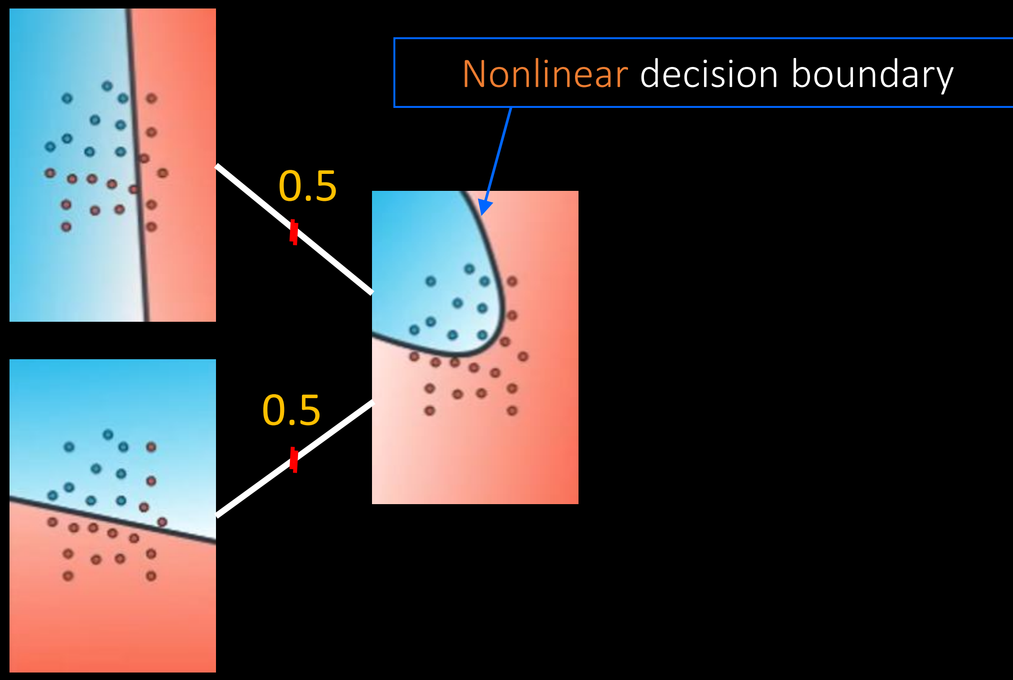
3-layer Neural Network




1
0

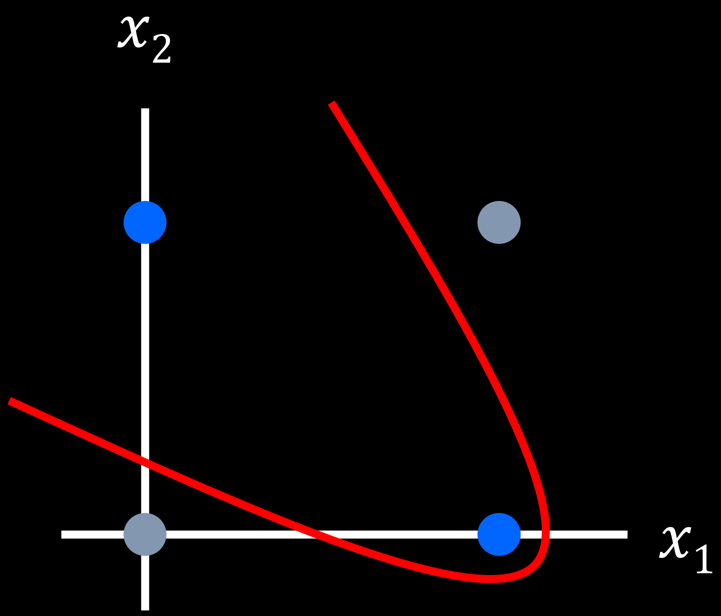

0
1



Nonlinear decision boundary
0.5
0.5

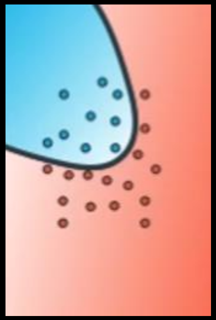
3-layer NN for nonlinear decision boundary

XOR

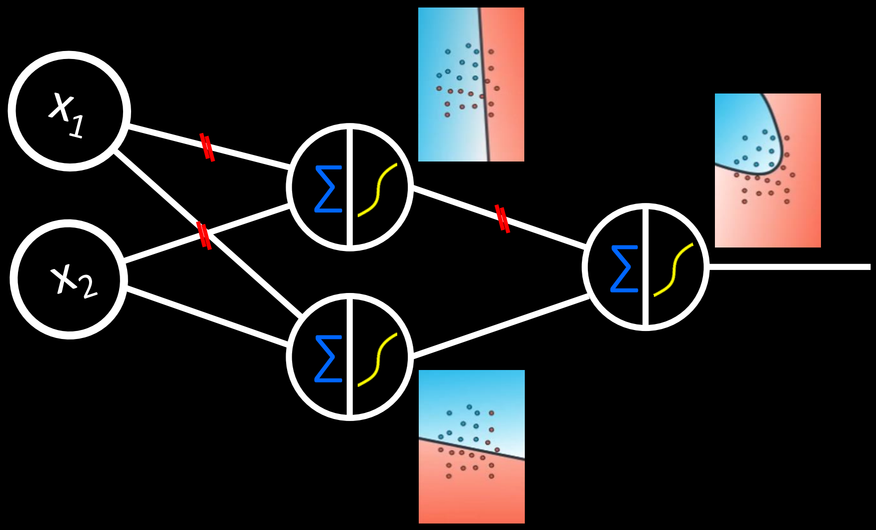


View from above

View from above



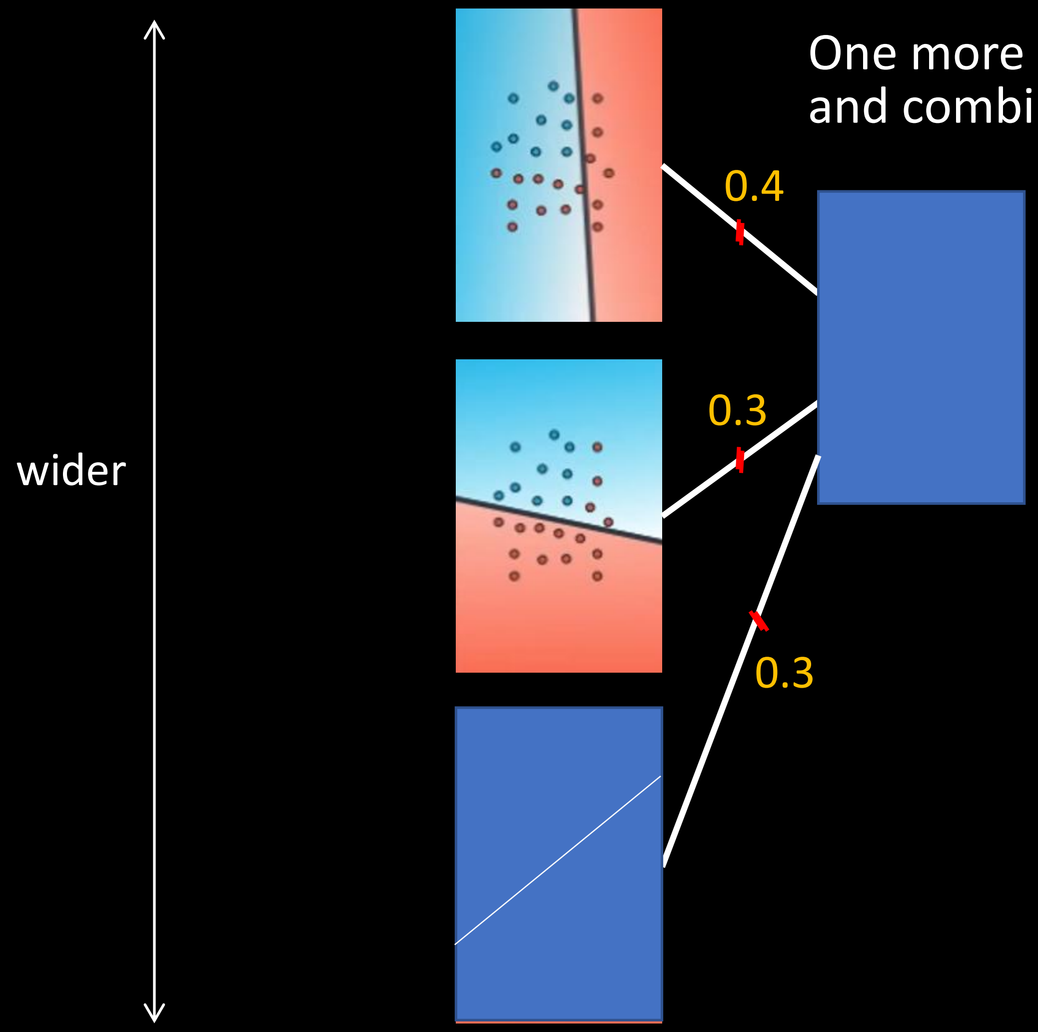
Side view



Lab 17.py

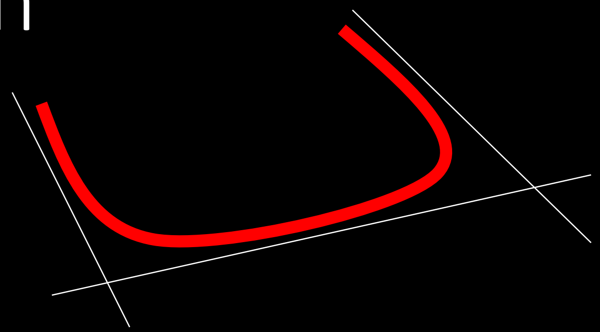
- Solving XOR gate problem using 3-layer neural network
- The way to create non-linear decision boundary

One more linear (go wider) and combination



Nonlinear Decision Boundary

- Combination of three linear decision boundaries

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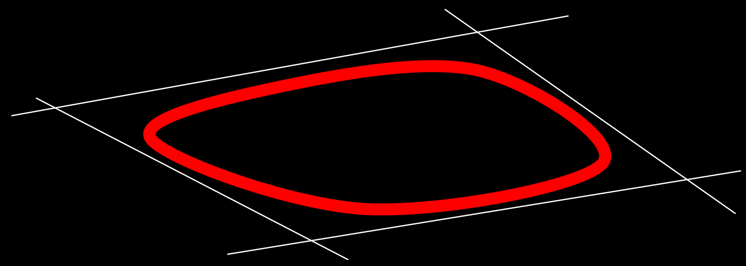
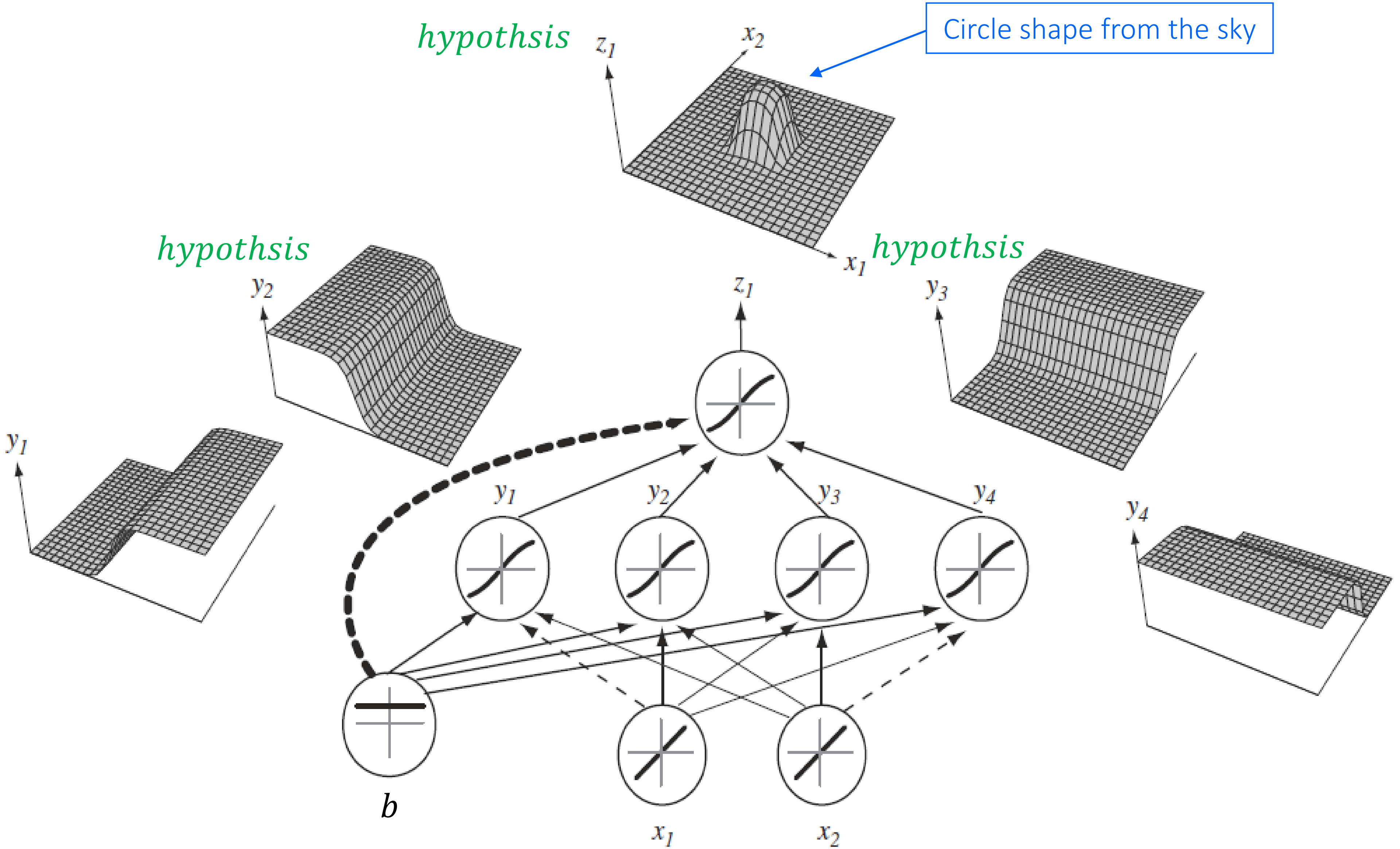
Nonlinear Decision Boundary

- Merging four linear decision boundaries



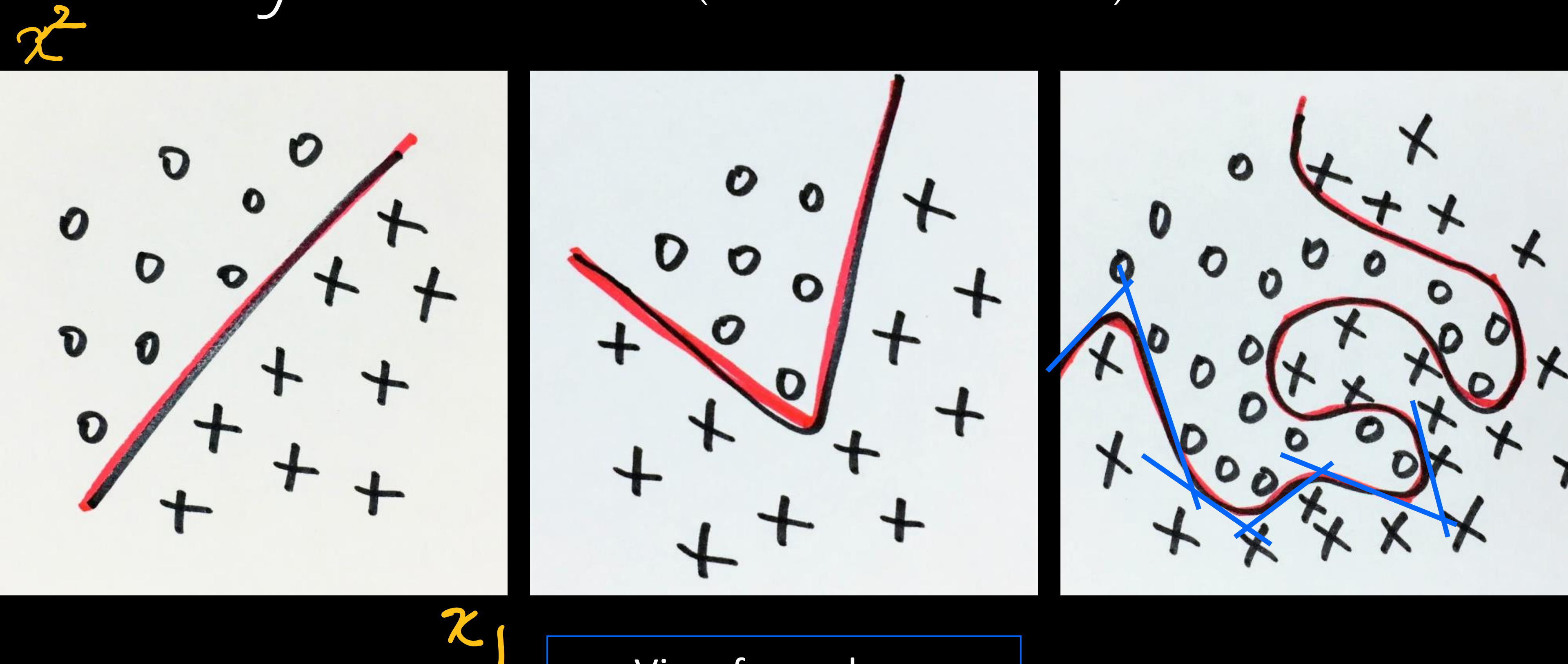
View from above

Nonlinear Decision Boundary



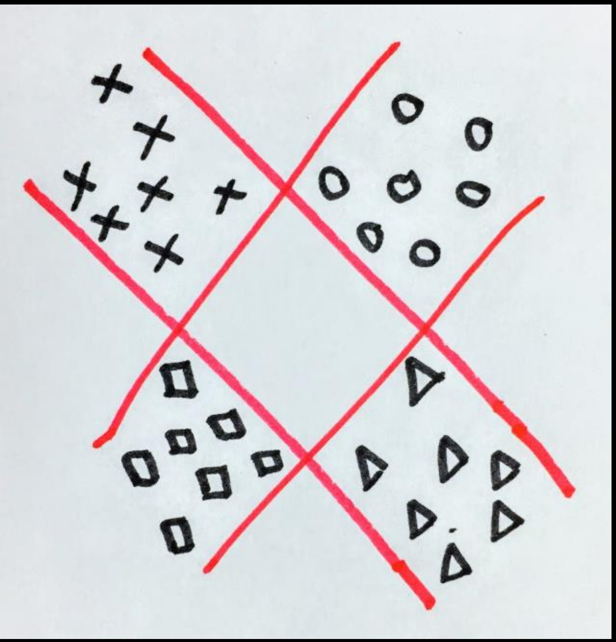
Side view

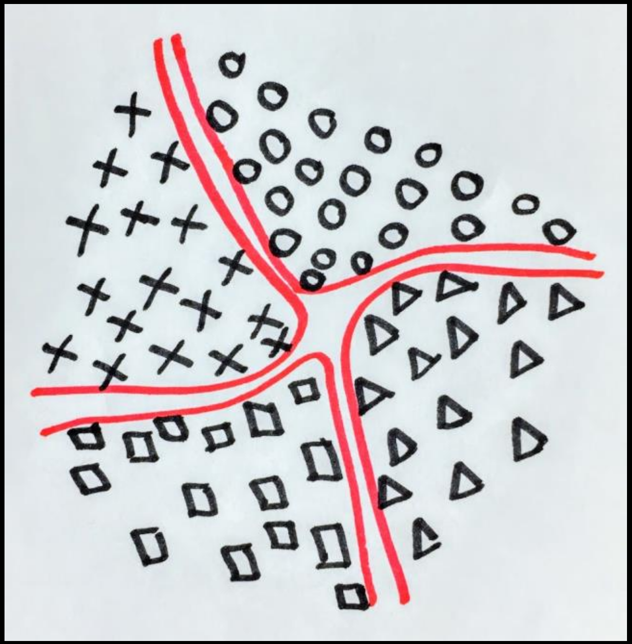
As you wish (2 classes)

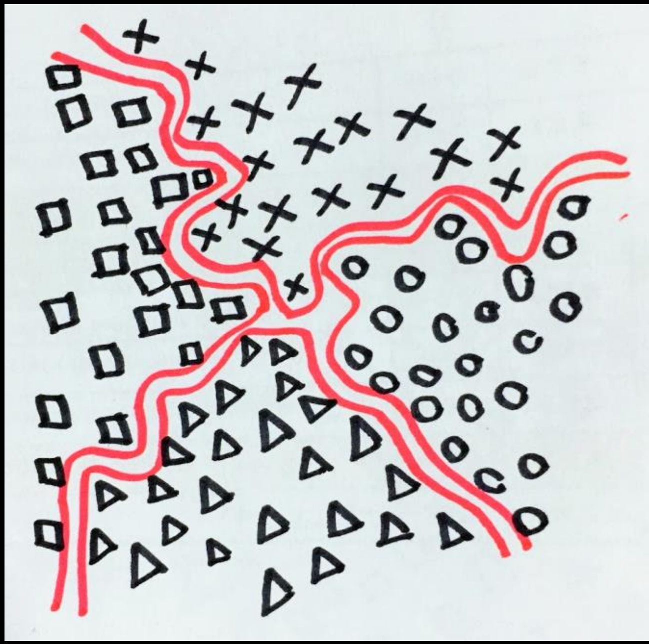


View from above

As you wish (4 classes)



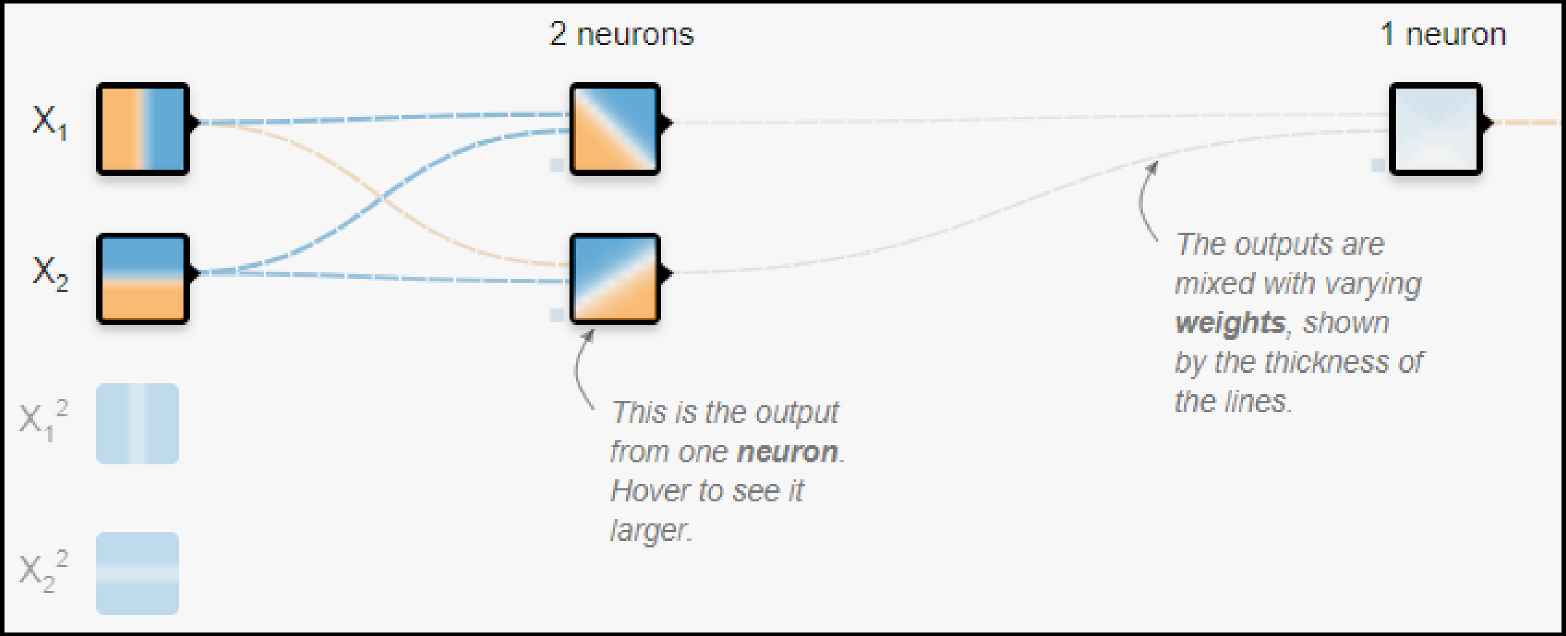




From the above

More neurons, more complex (detail) decision boundary

http://playground.tensorflow.org



As you wish

go wider & deeper

- to make more complex nonlinear decision boundaries.
- We can classify anything we imagine.

The way of machine learning

- learning over and over again just like human being
- If it misrecognizes, just say ‘Nope, you were wrong’, which makes it update its weights to do better next time.
- Try it over and over again just like a child.

Learning or Programming?

"This (machine learning) is the next transformation...the programming paradigm is changing. Instead of programming a computer, you teach a computer to learn something and it does what you want"

— Eric Schmidt, Google

Change of Paradigm

Not programming,
but data-driven learning
(parameter tuning)