AI and Deep Learning

Multi-Layer Neural Networks and Non-linear Decision Boundary

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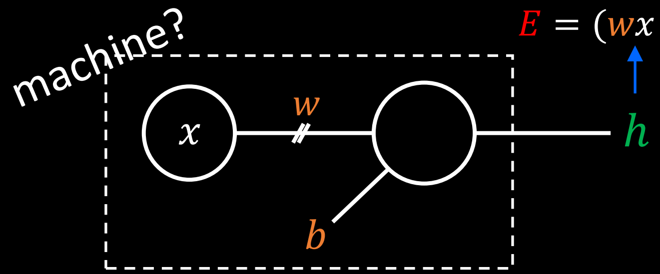
Agenda

- Machine Learning revisited
- Linear decision boundary
- XOR problem
- Non-linearity and multi-layer neural networks
- Complex nonlinear boundary as you like

Machine Learning

A neuron

$E = (wx - y)^2$



① Parameters(w, b) initialization randomly

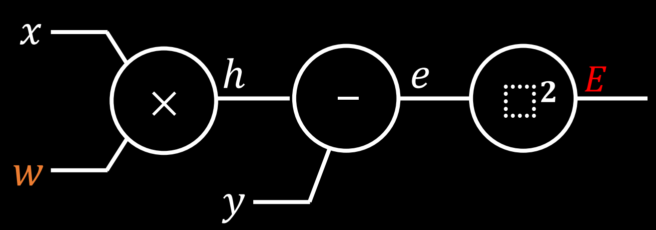
② Building computation graph of E by TensorFlow framework

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



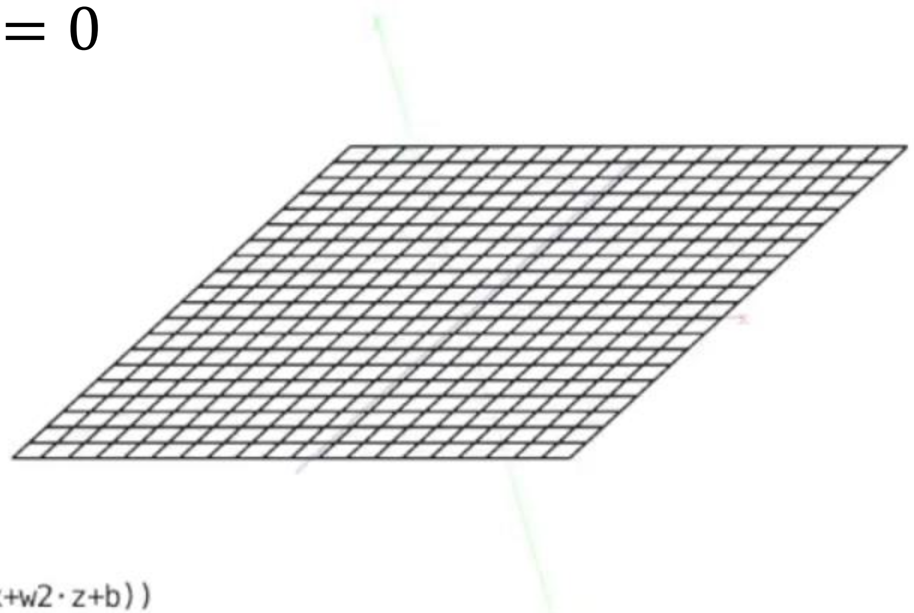
How to change the decision boundary

sigmoid(w1·length + w2·width + b)

db slope　　　　　　　db shift

$$w_1 x_1 + w_2 x_2 + b = 0$$

db rotation



surface(f(x,z)=sig(w1·x+w2·z+b))

slope → w1 = 0.00

rotation → w2 = 0.00

shift → b = 0.00

Machine 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]))  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)
```

Machine 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))
```

*hypo = tf.sigmoid(x_data * w)*

Testing new data

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

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

- When the computation graph is created, data is set only one time.
- **Still old data in the computation graph.**
- No feeding the new data[-2,4] into the precreated computational graph
- Therefore, not working!

Place Holder

- Marking certain place holders in a computational graph
- and then replace it with new data when it runs(evaluation).

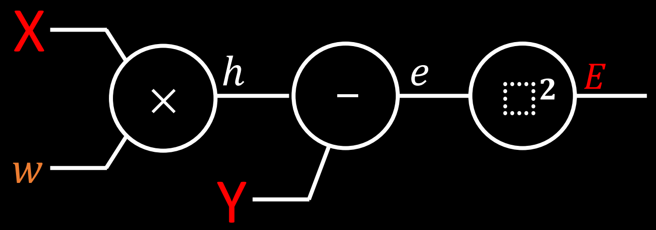
sess.run ( )

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}))
```

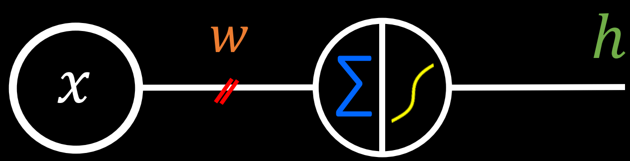
Place Holder

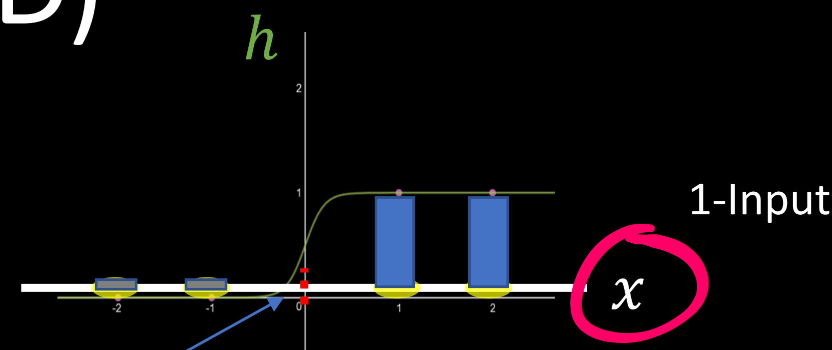
```
#----- testing(classification)
x_data = [-2, 4]
result = sess.run(hypo, feed_dict={X: x_data})
print(result)
```

Lab 15.py

- Classification into one of four classes
- Using placeholders

1-Input Neuron (1D)

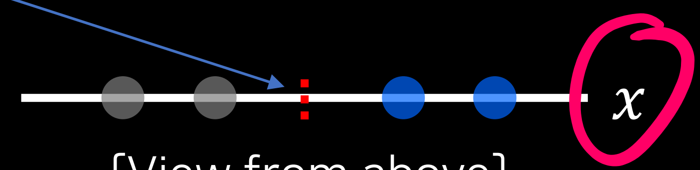




{Side view}

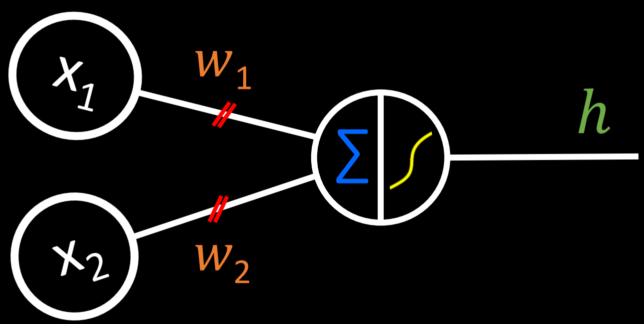
Decision boundary : Value

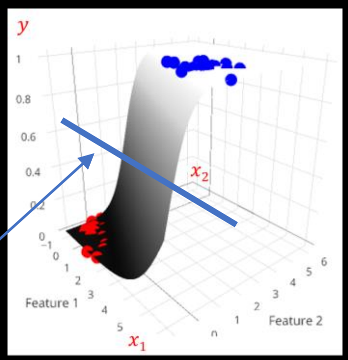
$$w \cdot x = 0$$
$$x = 0$$



{View from above}

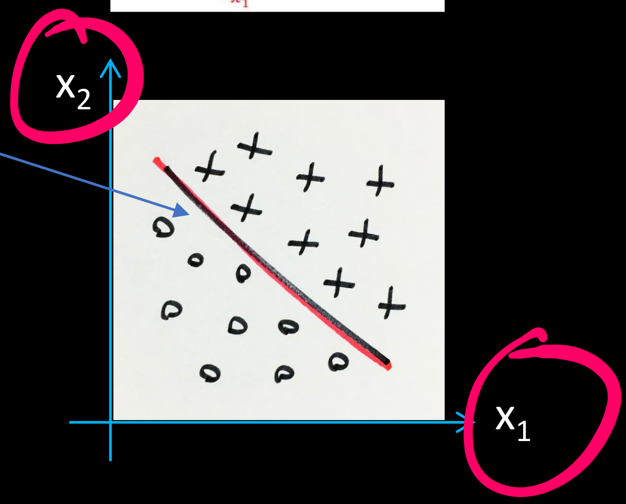
2-Input Neuron (2D)



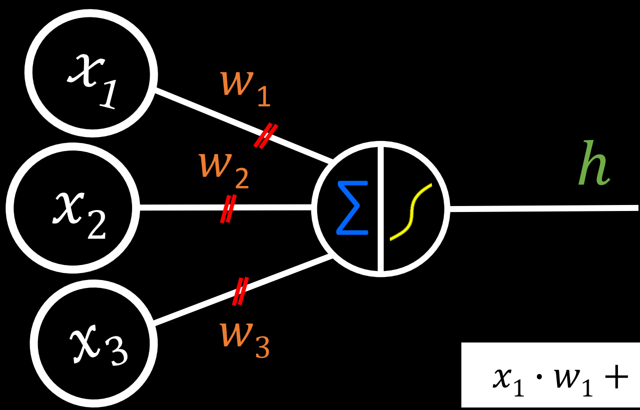


Decision boundary : Line

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

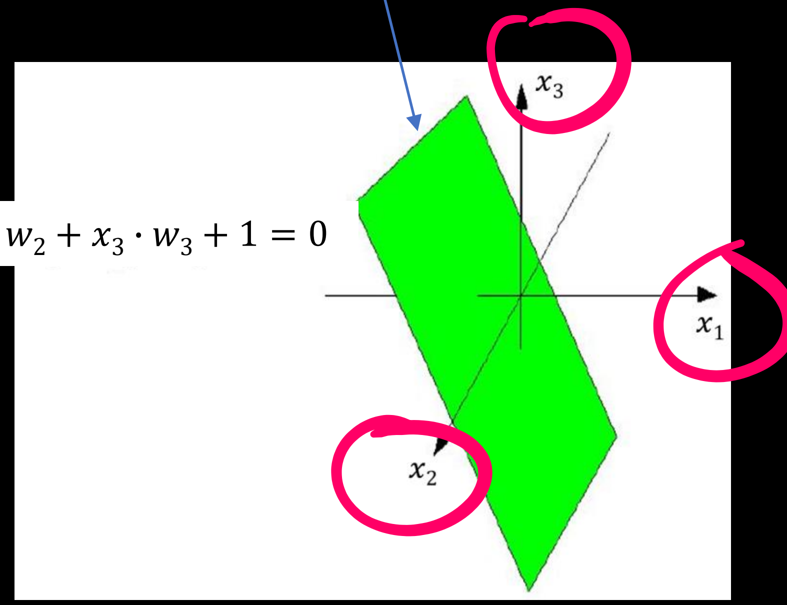


3-Input Neuron (3D)



Decision boundary : Plane

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



More than 4 inputs?

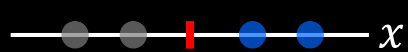
$$x_1w_1 + \ x_2w_2 + x_3w_3 + x_4w_4 + b = 0$$

→ hyper<u>plane</u>

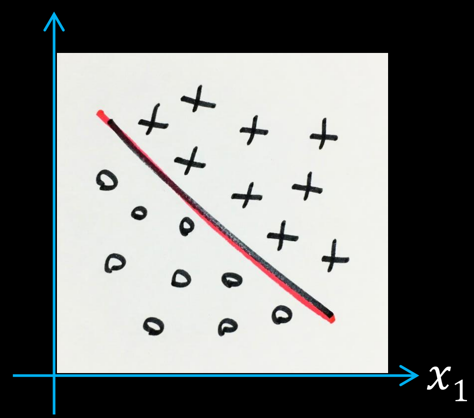
초평면

Linear Decision Boundary

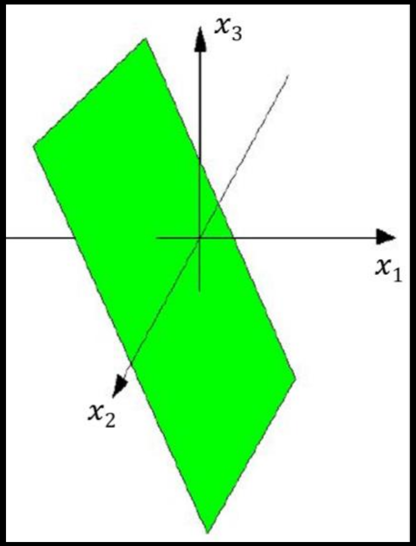
value



line

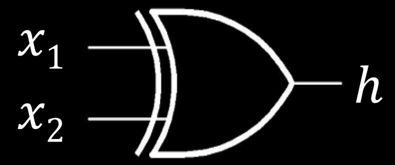


plane



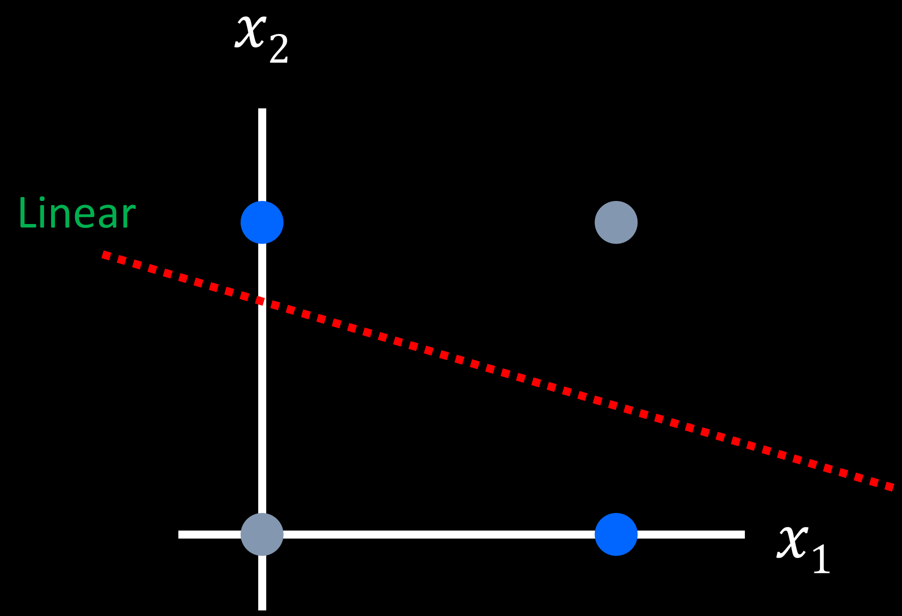
hyperplane

XOR (2D)



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

Truth table



View from above

XOR (2D)

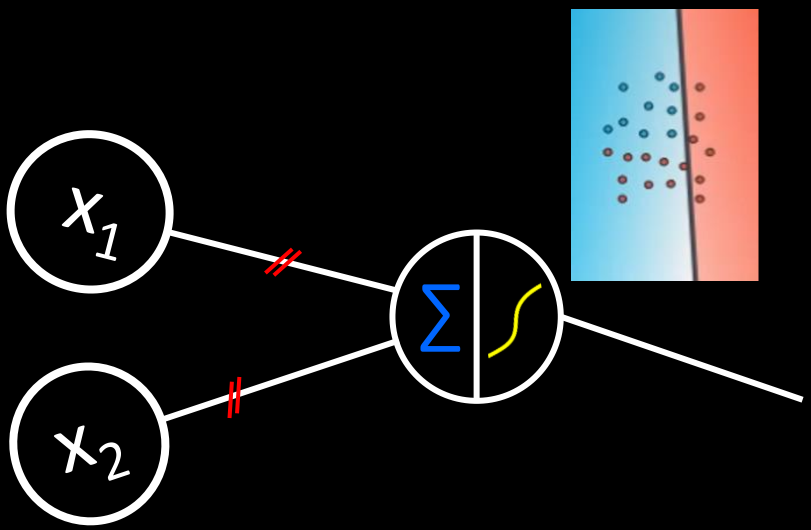
Binary Cross-Entropy Loss

- Number of class : 2 (0 or 1)
- 1-decision boundary for 2-class classification
- However, impossible to classify using a single linear decision boundary

Lab 16.py

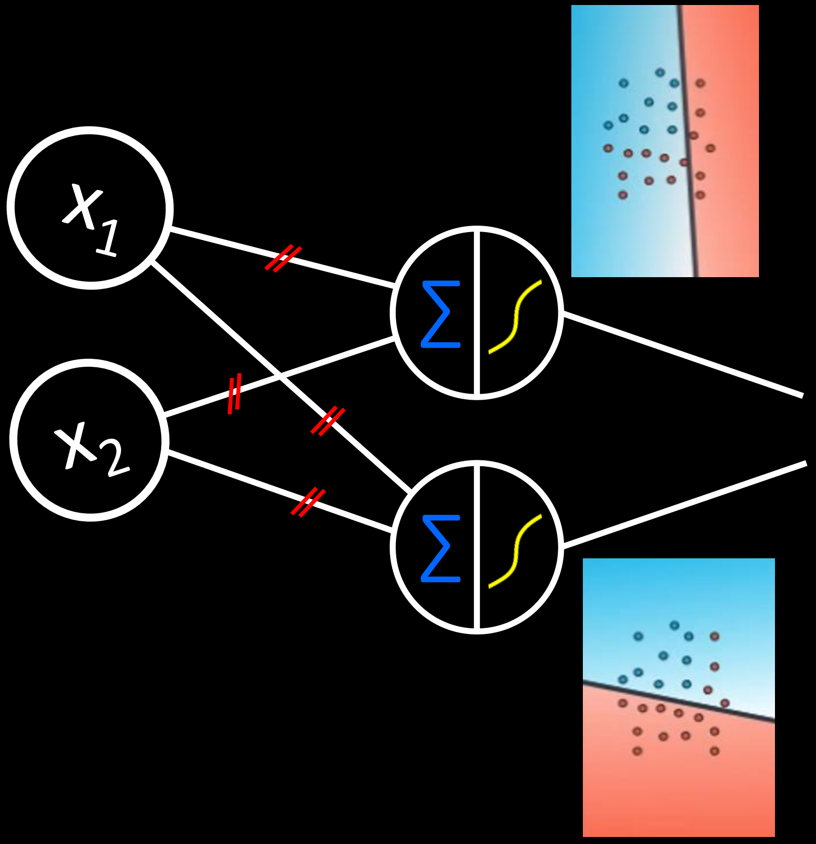
- XOR problem
- A neuron, 1 linear decision boundary
- Cannot be solved!

How to solve



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

How to solve



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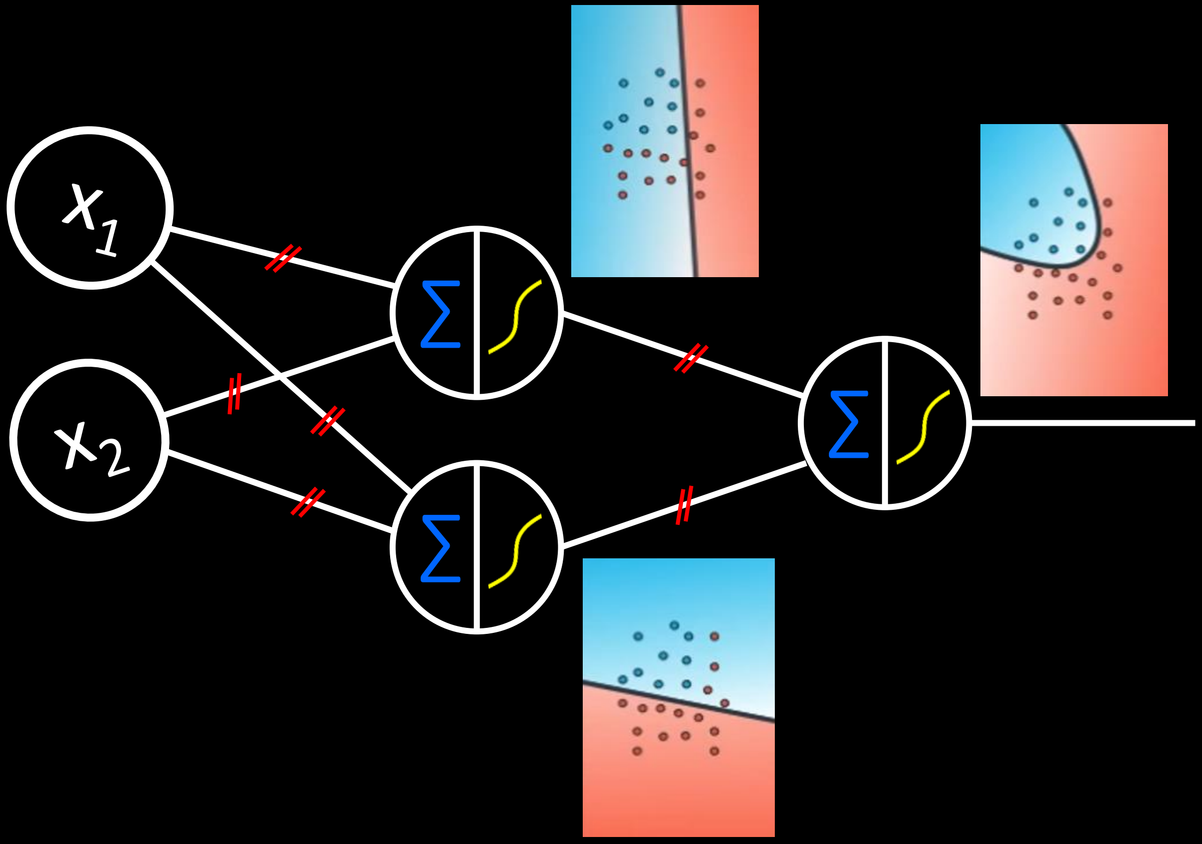
How to solve



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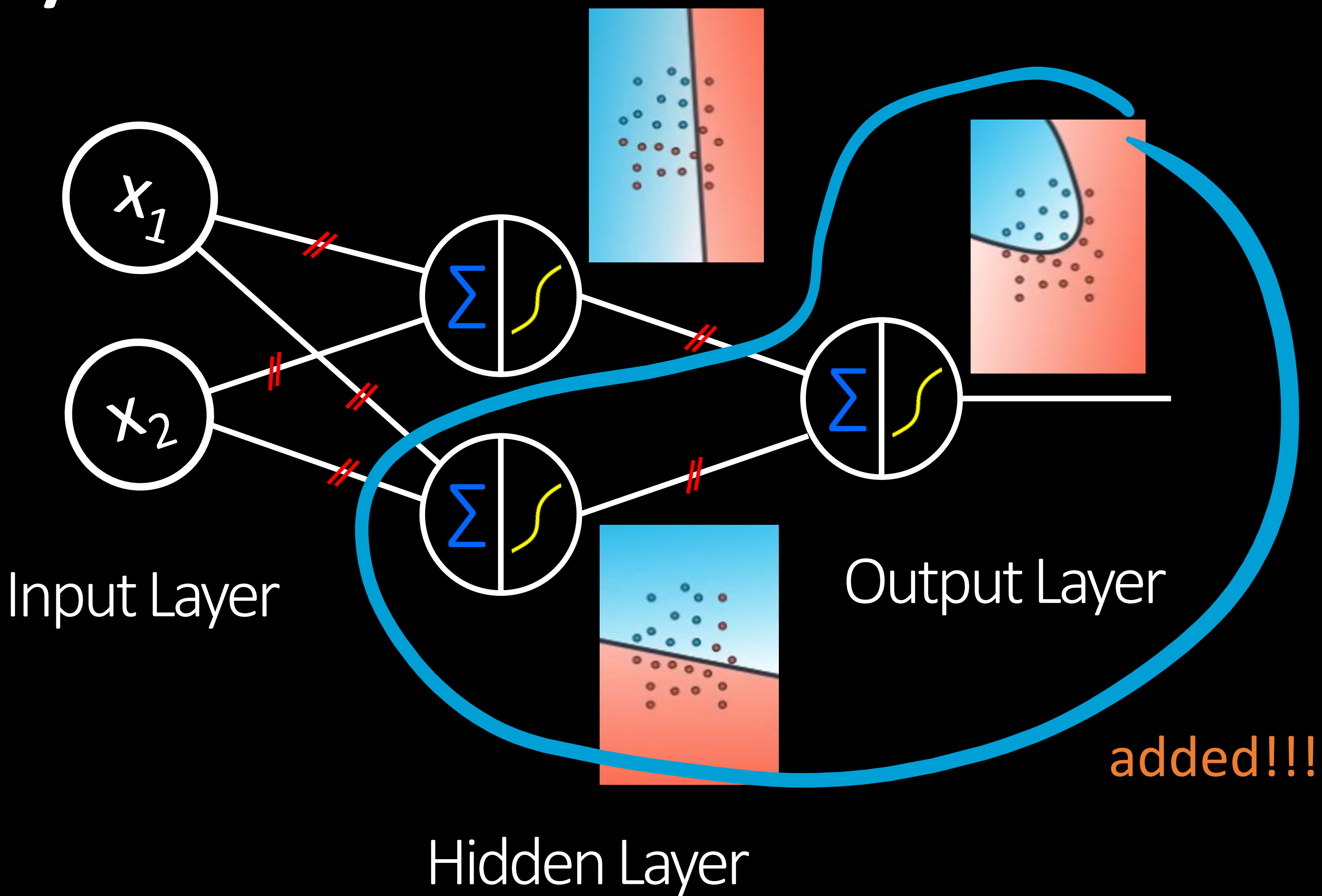
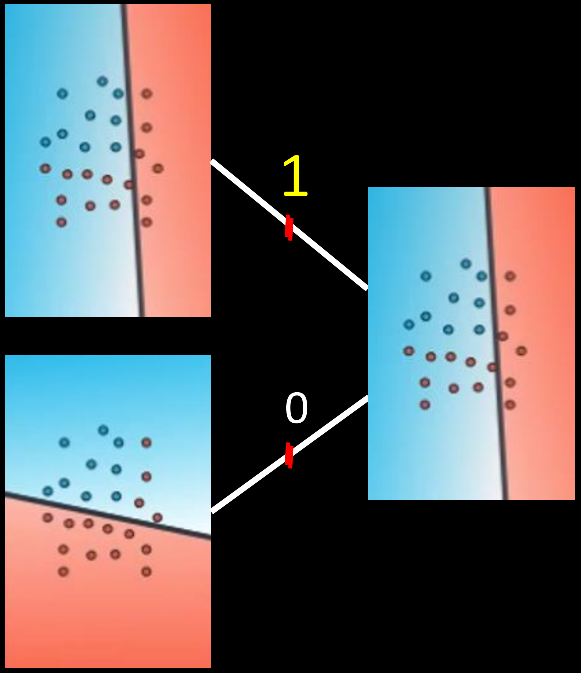
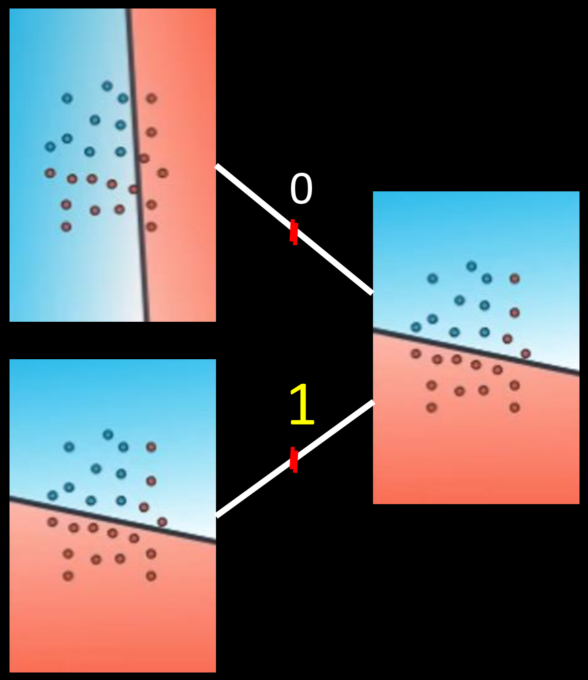
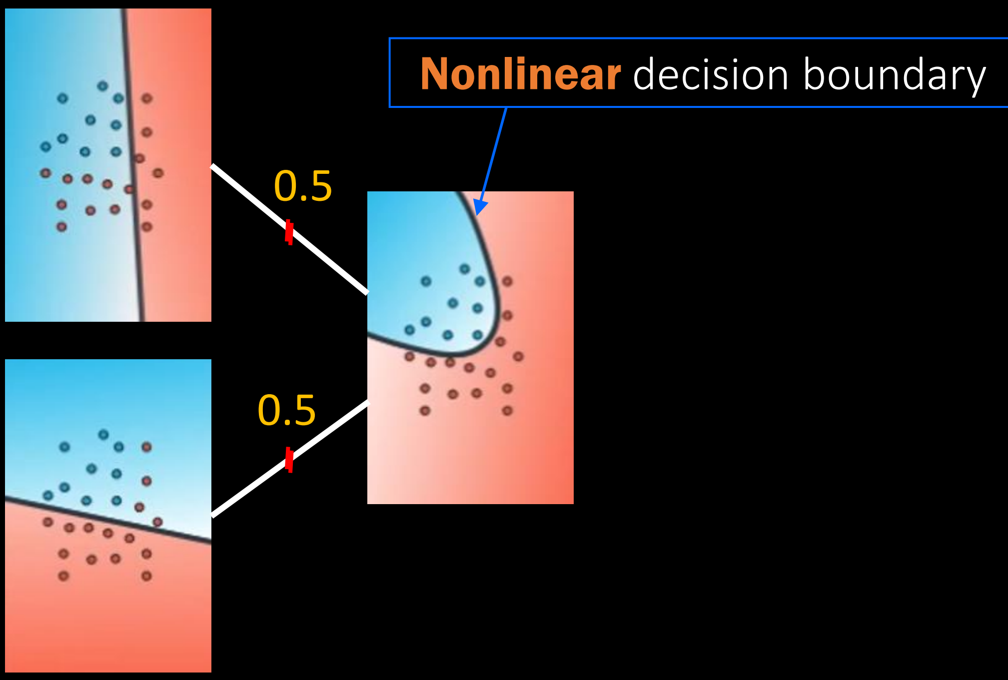
3-layer Neural Network




1
0

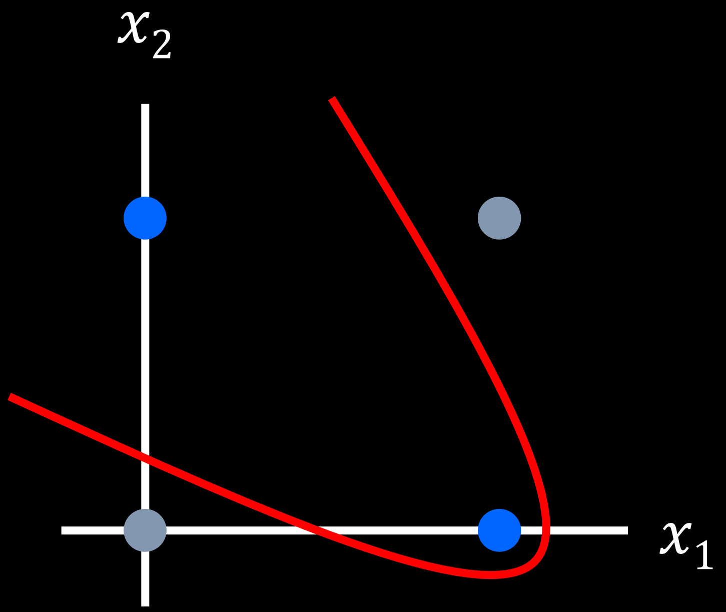

0
1



What is a **linear** decision boundary?

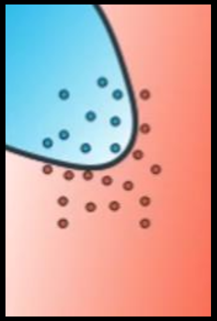
3-layer NN for **nonlinear** decision boundary

XOR

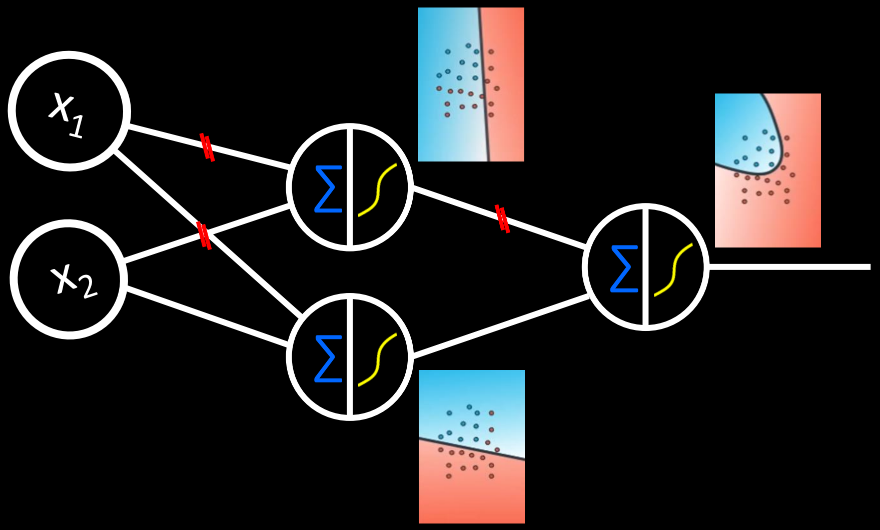


View from above

View from above

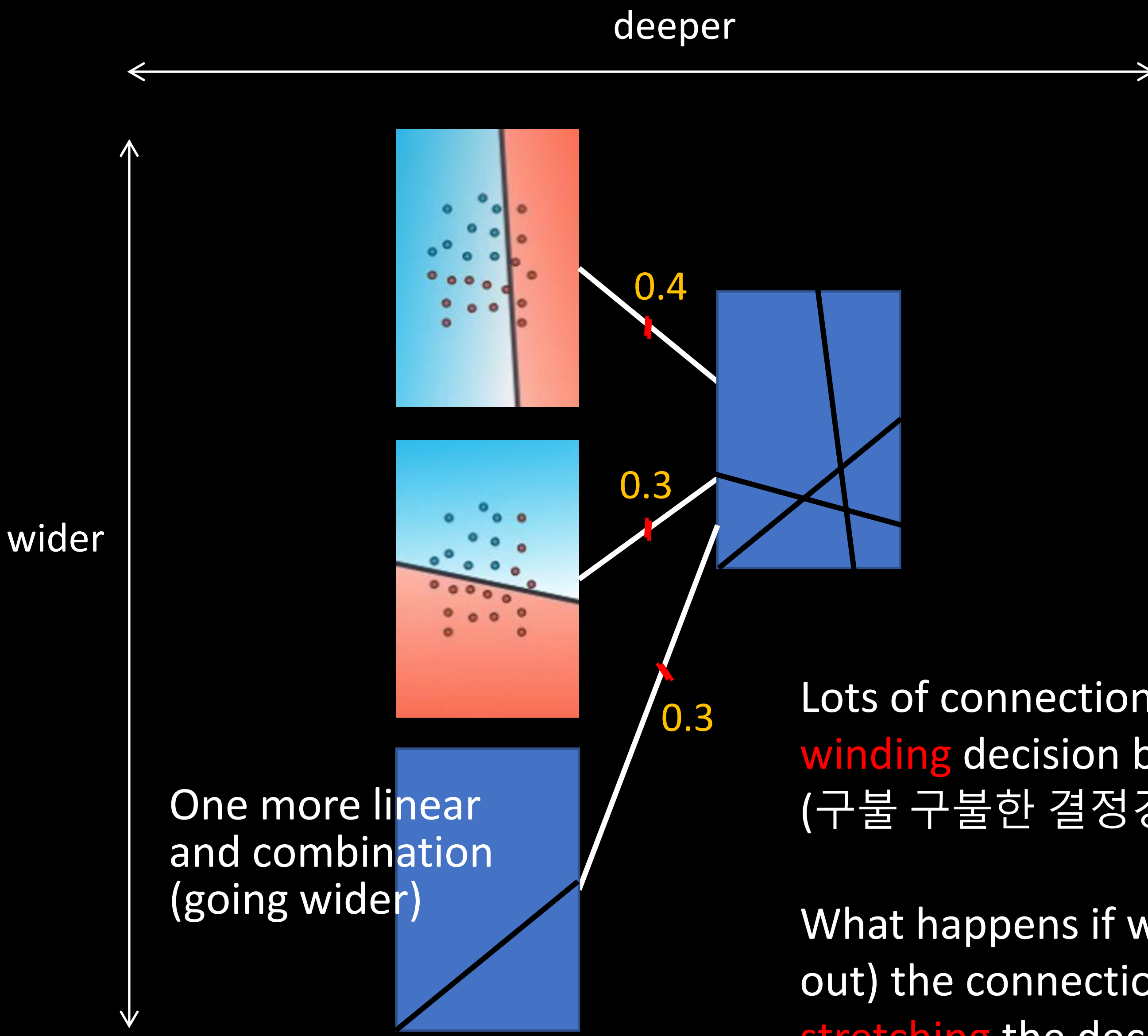


Side view



Lab 17.py

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

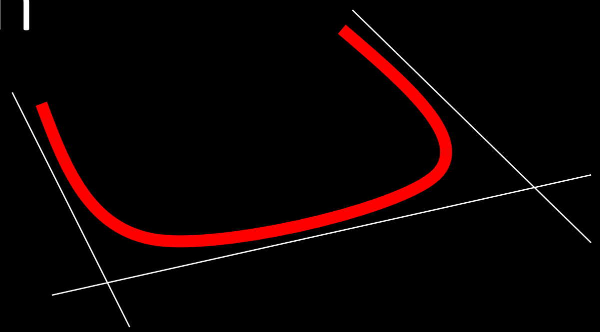


Lots of connections give us a winding decision boundary (구불 구불한 결정경계).

What happens if we cut(drop-out) the connections? stretching the decision boundary (펴진 결정경계).

Nonlinear Decision Boundary

- Combination of three linear decision boundaries

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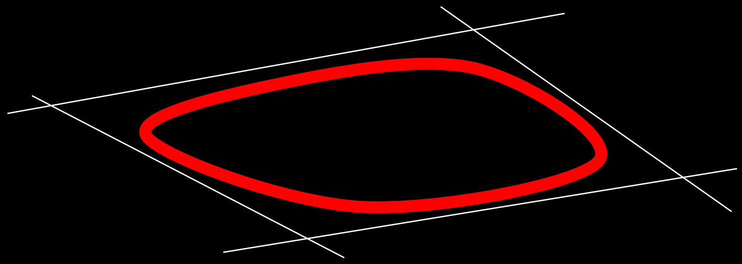
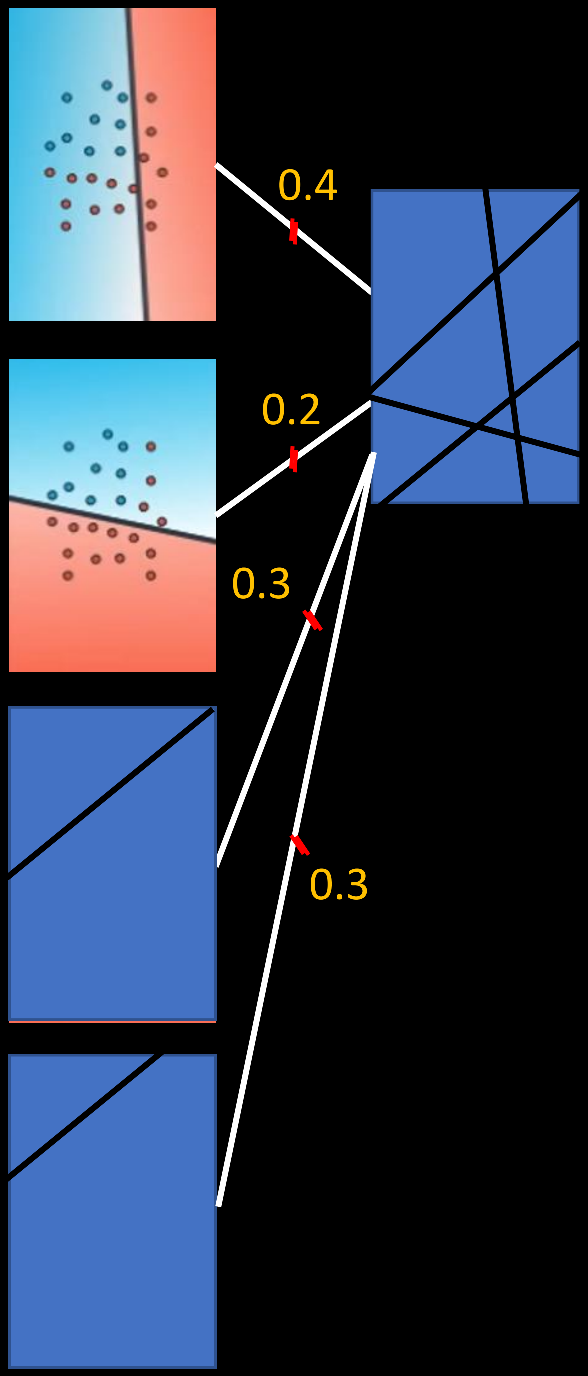
Nonlinear Decision Boundary

- Merging four linear decision boundaries

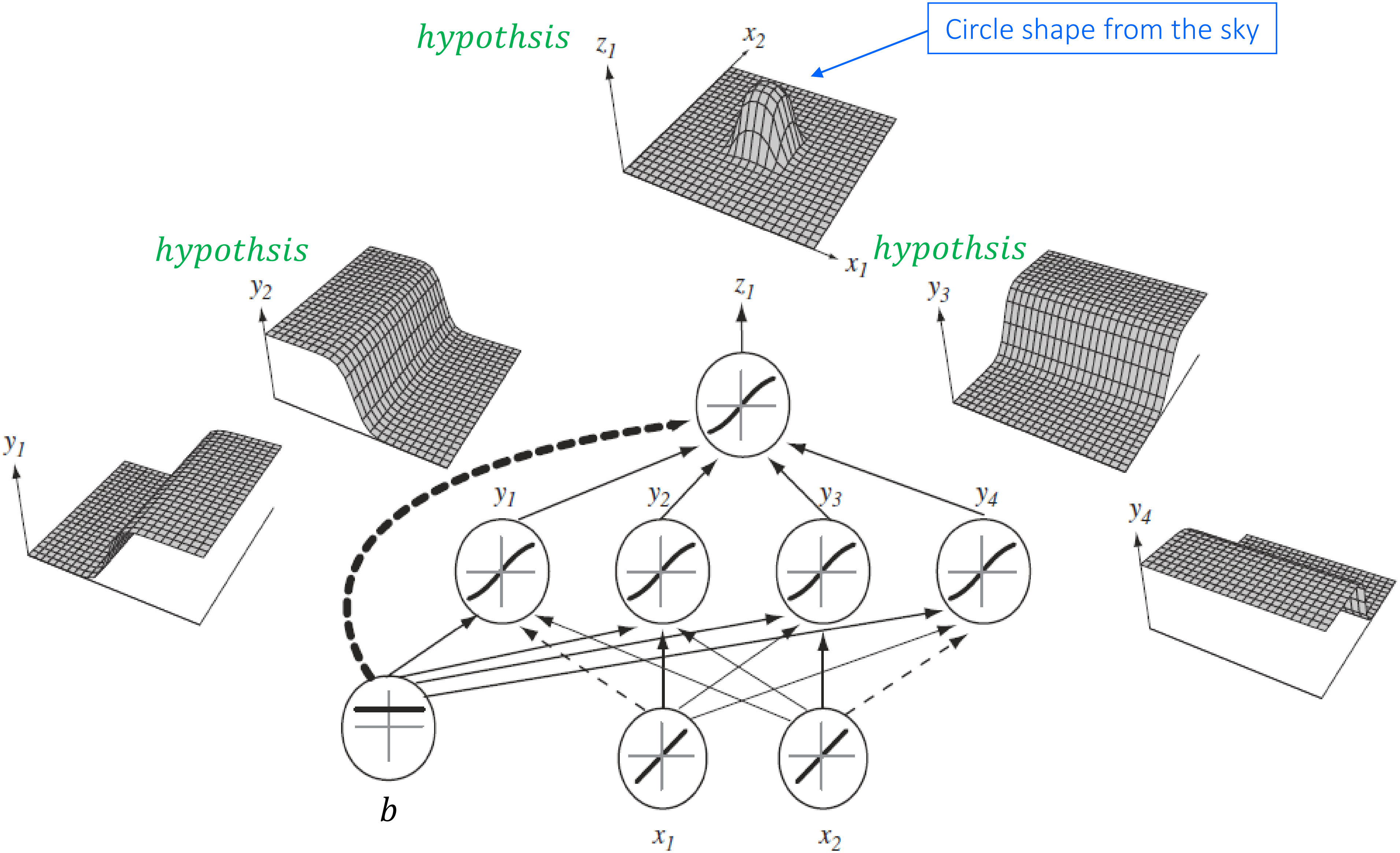


View from above



0.4
0.2
0.3
0.3

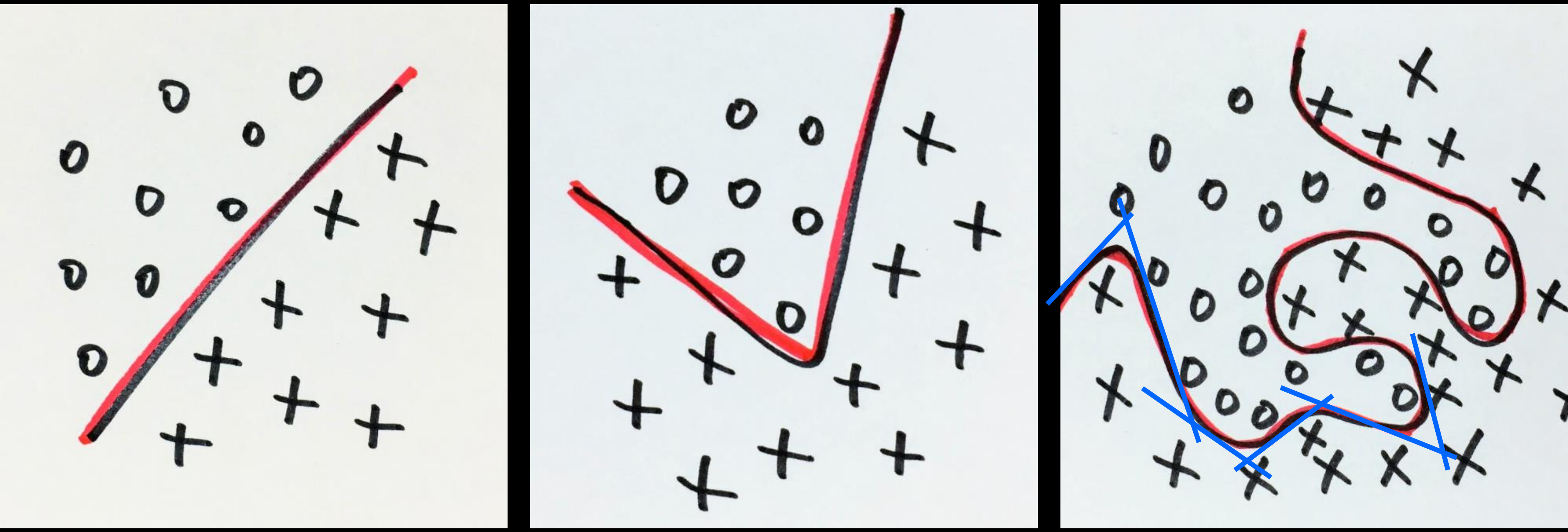
Nonlinear Decision Boundary



Side view

As you wish (2 classes)

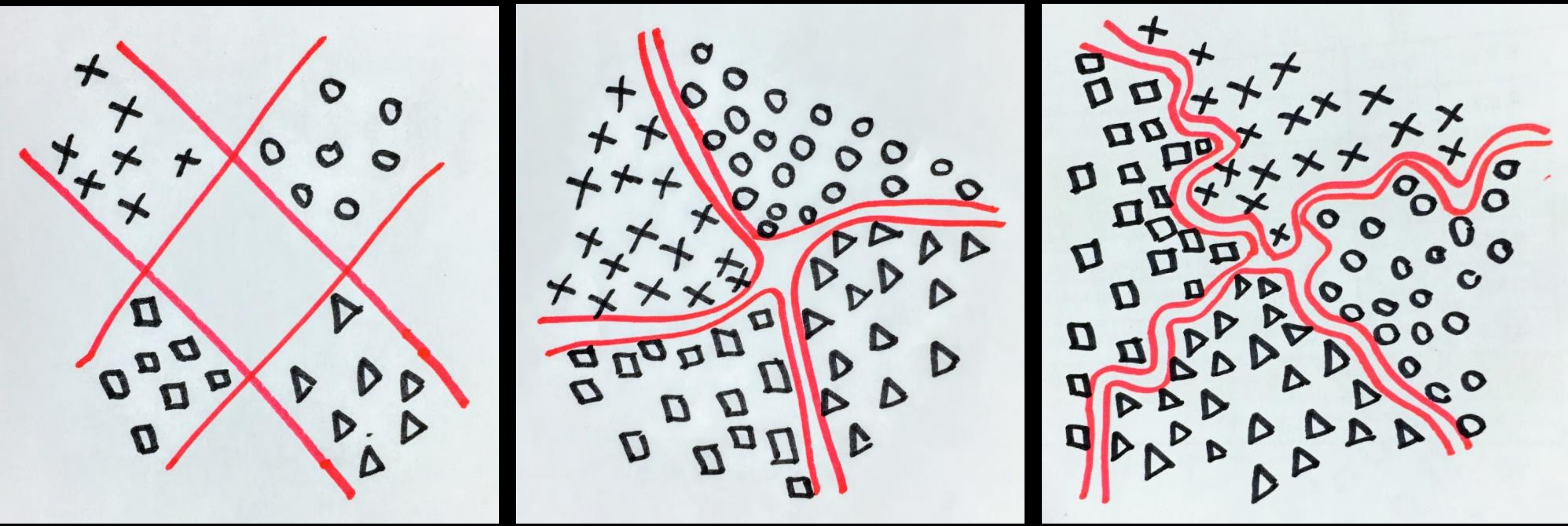
x^2



x_1

View from above

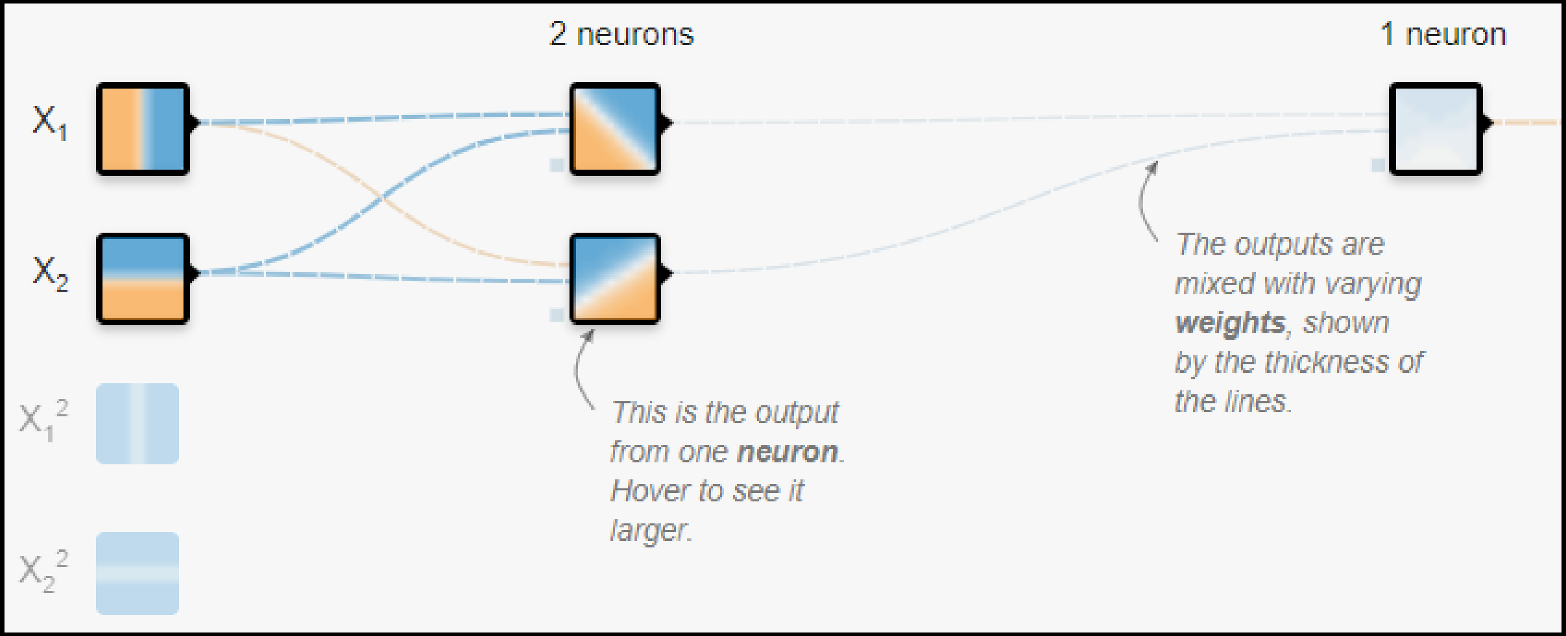
As you wish (4 classes)



View from above

More neurons (wider & deeper),
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)