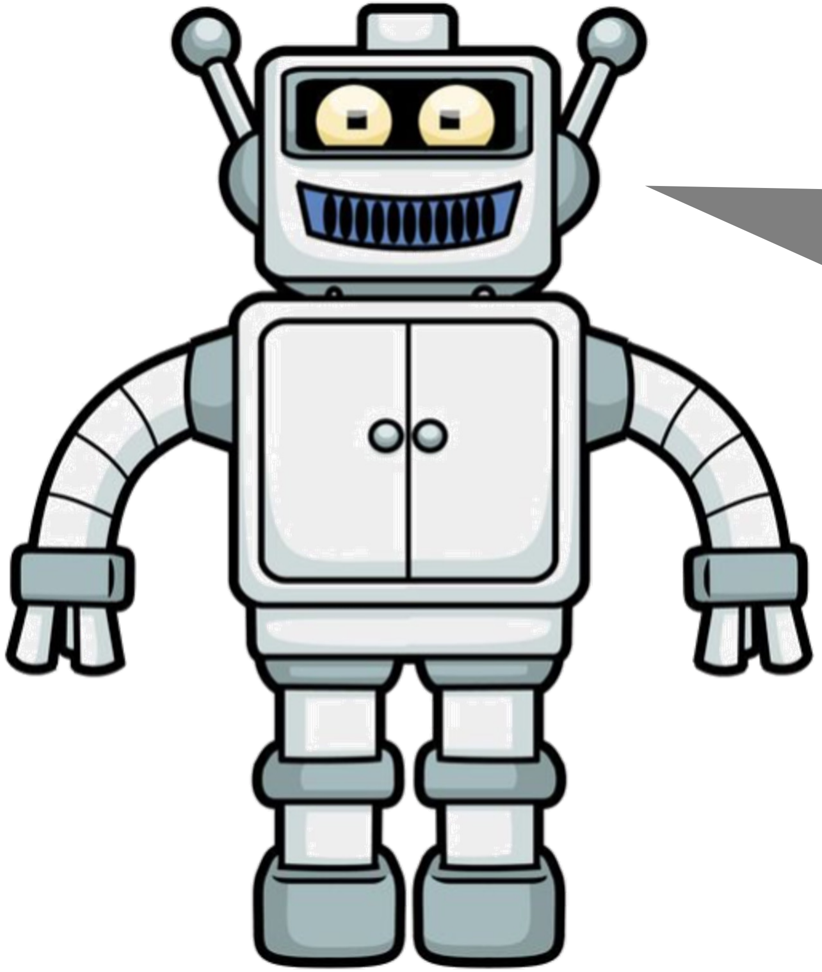
Reference: 3Blue1Brown video

AVRIL CUI



print("Neural Network Structure")

Content:

1. **Definition of a neuron**
2. **Neural network layers analogy**
3. **Weights**
4. **Activation functions**
5. **Gradient Descent**

Pause! What Do You See?

7

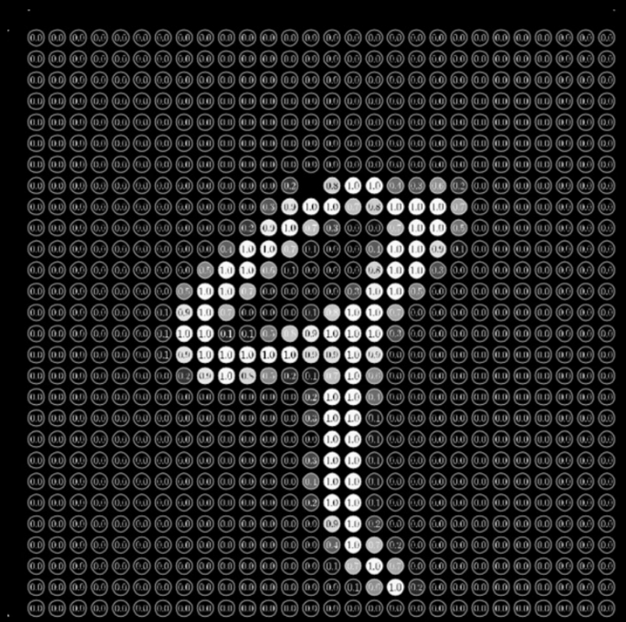
How do you "KNOW" it is seven? In other words, what is your proof?

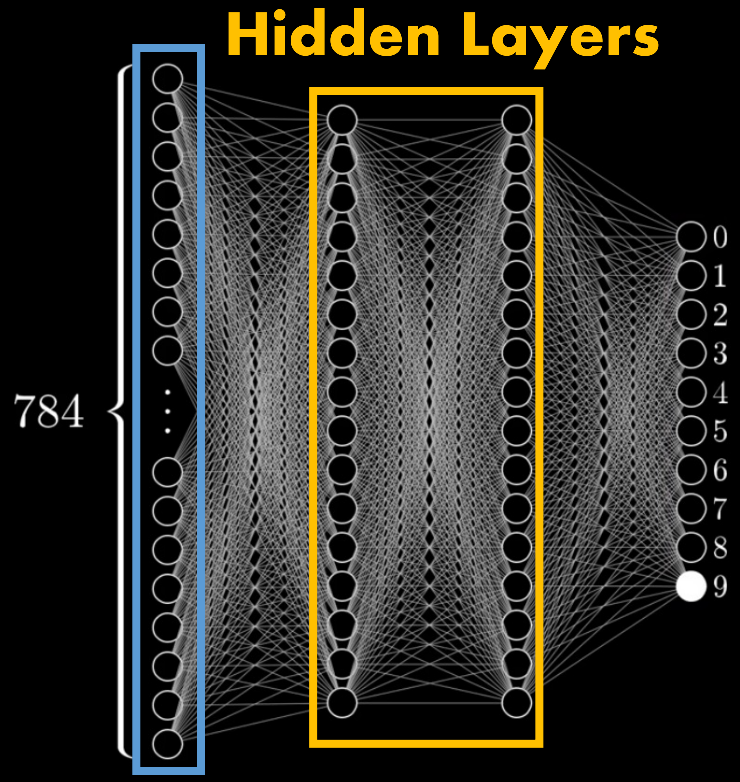
But how can the computer tell? Difficulty upgrade!

Neuron

Activation

A Neuron = placeholder for a number

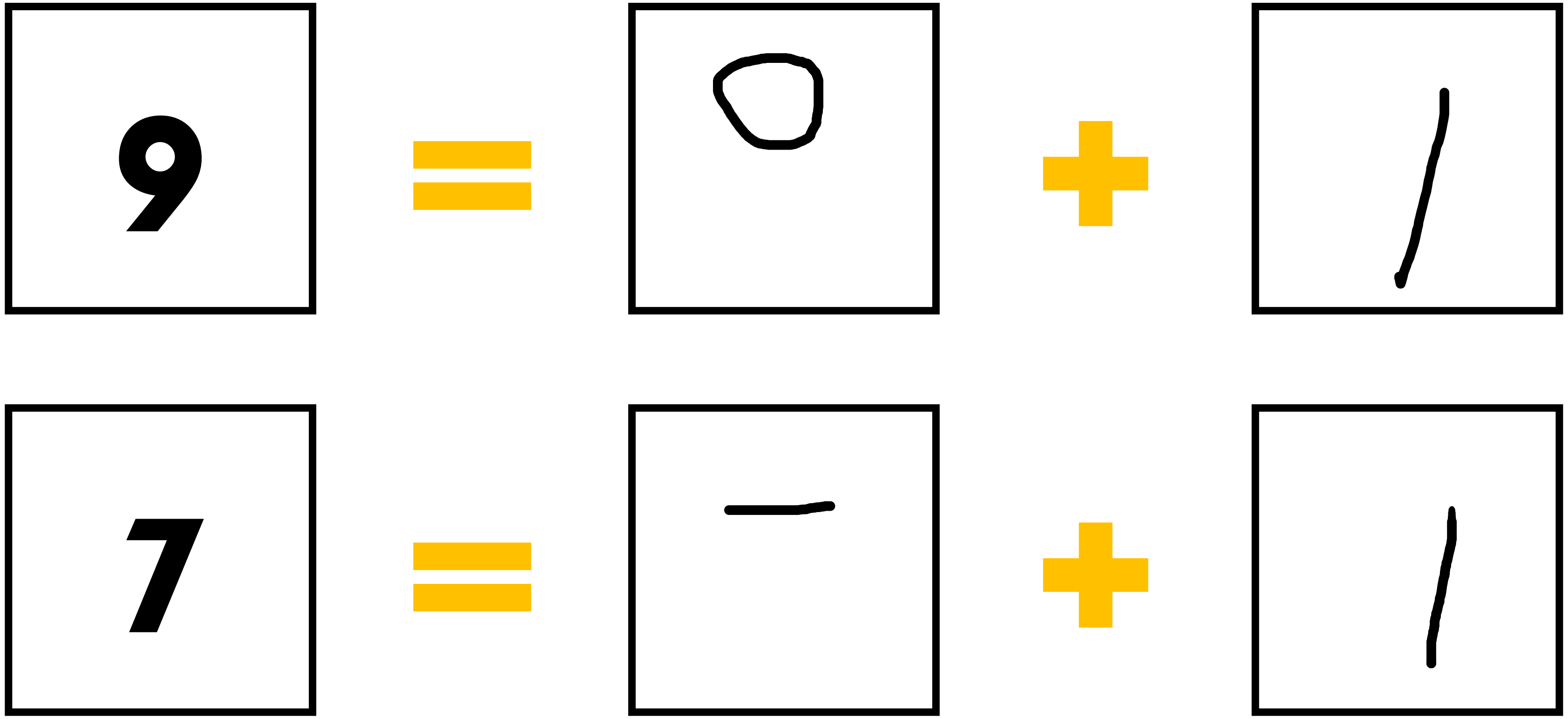




Network Layers

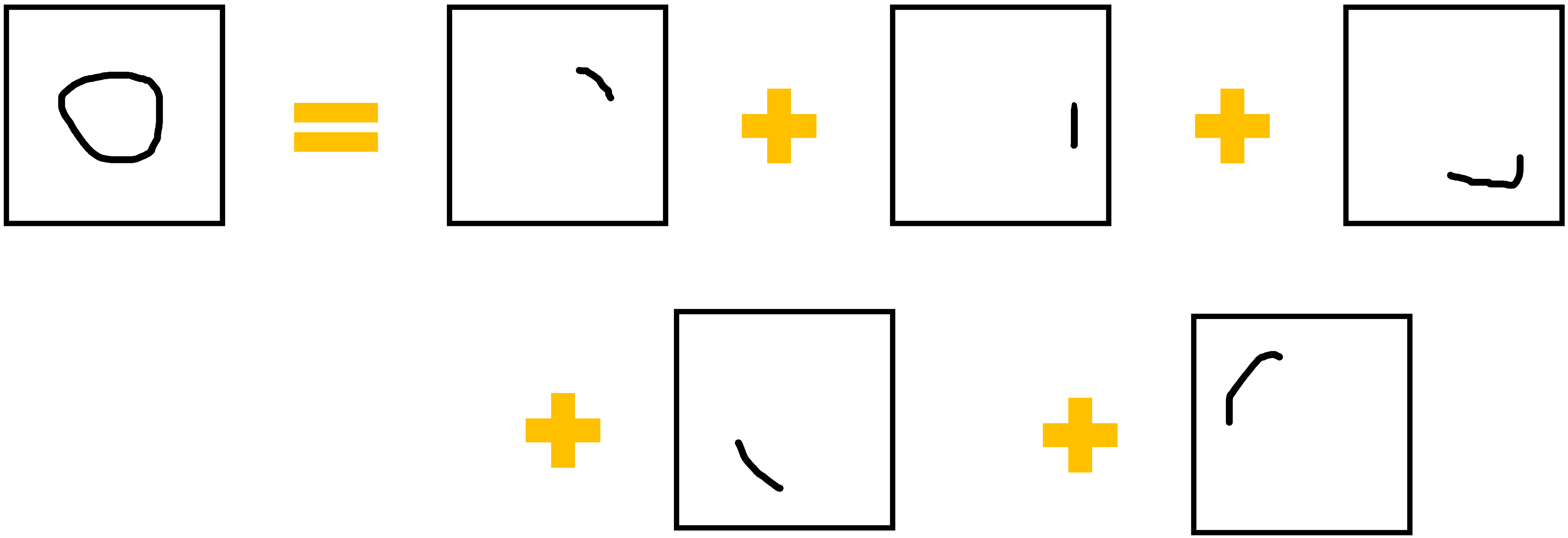
Before Going Forward...

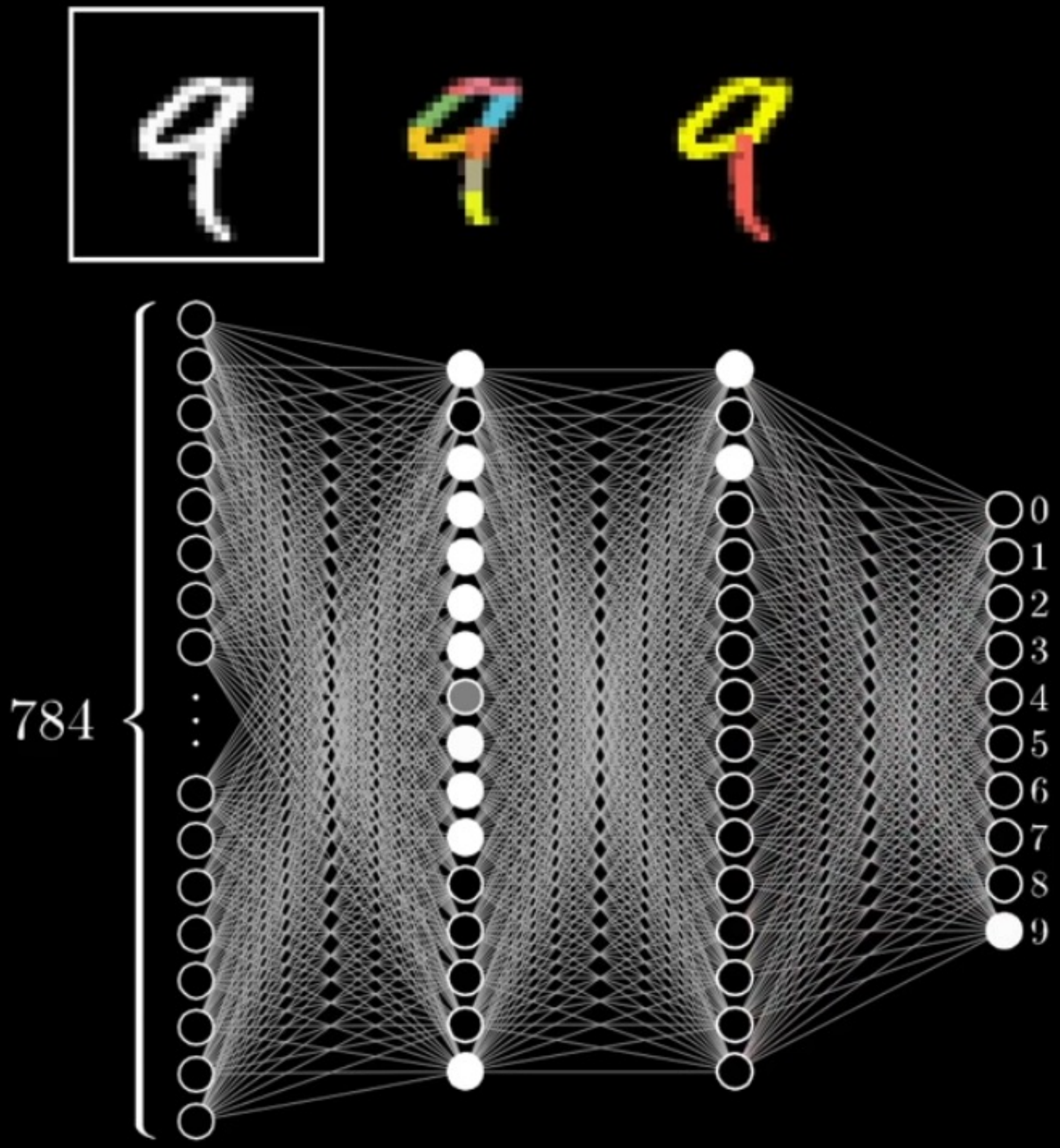
What does these layers do???



And how to recognize patterns?

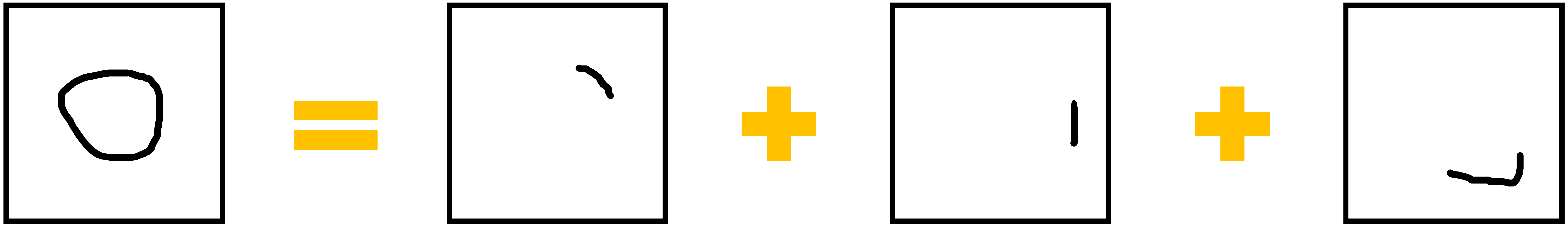
Well, smaller edges



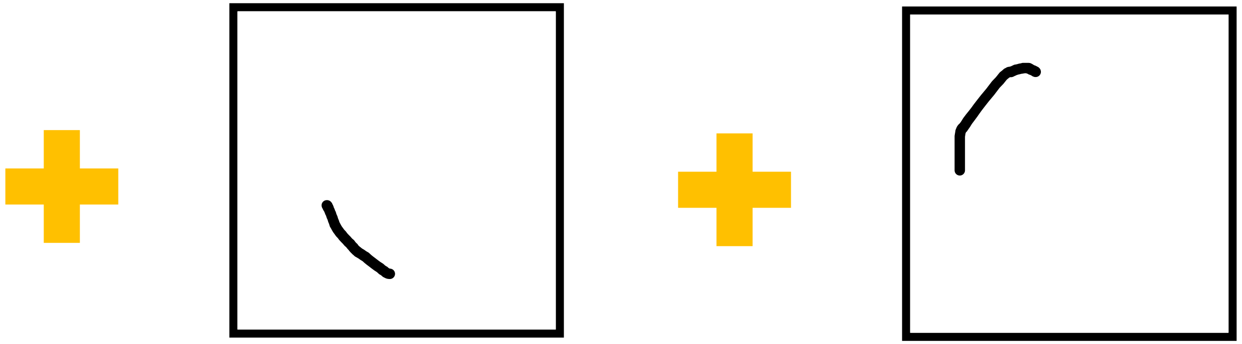

784
0
1
2
3
4
5
6
7
8
9

And how to recognize patterns?

Well, smaller edges

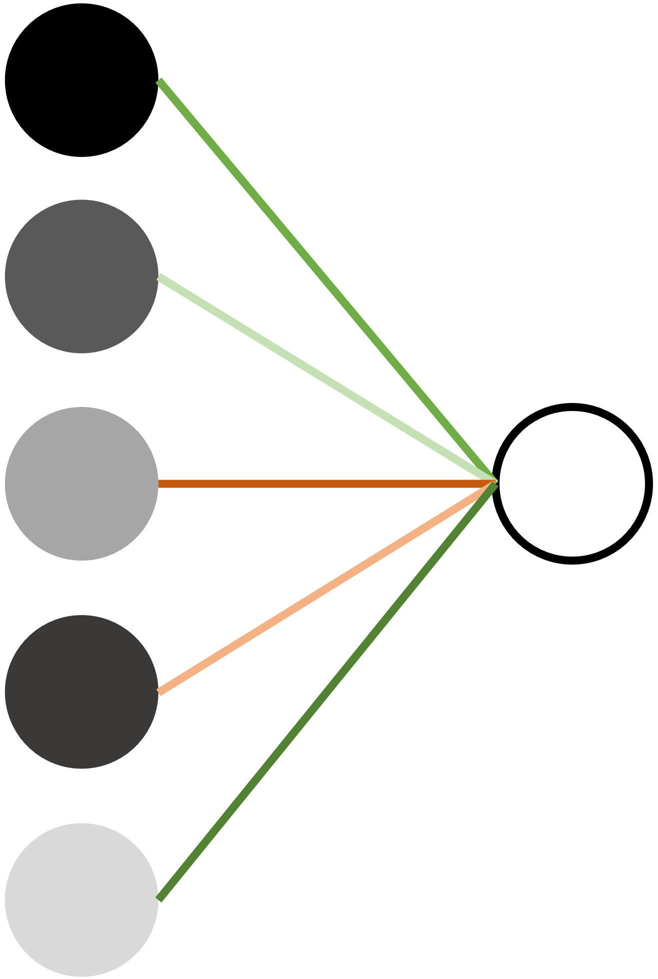


*Although this is not exactly how neural networks “learn,” this is an intuitive (or human method) way to visualize the layers.



Weights & Parameters

Weights and Parameters



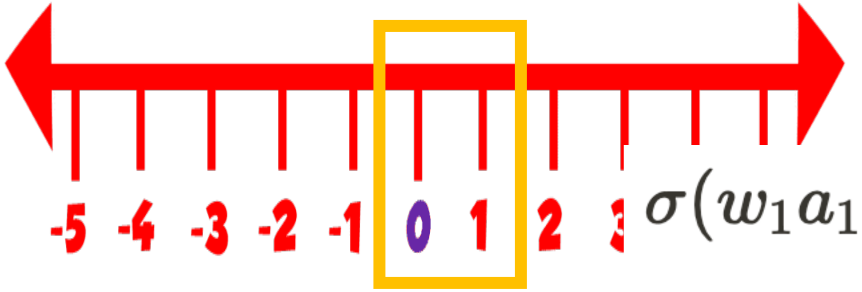
$$w_1a_1 + w_2a_2 + ... + w_na_n$$

Ideally, we want the pixels (neurons) at the region to be highly positive and all the rest to be zero!

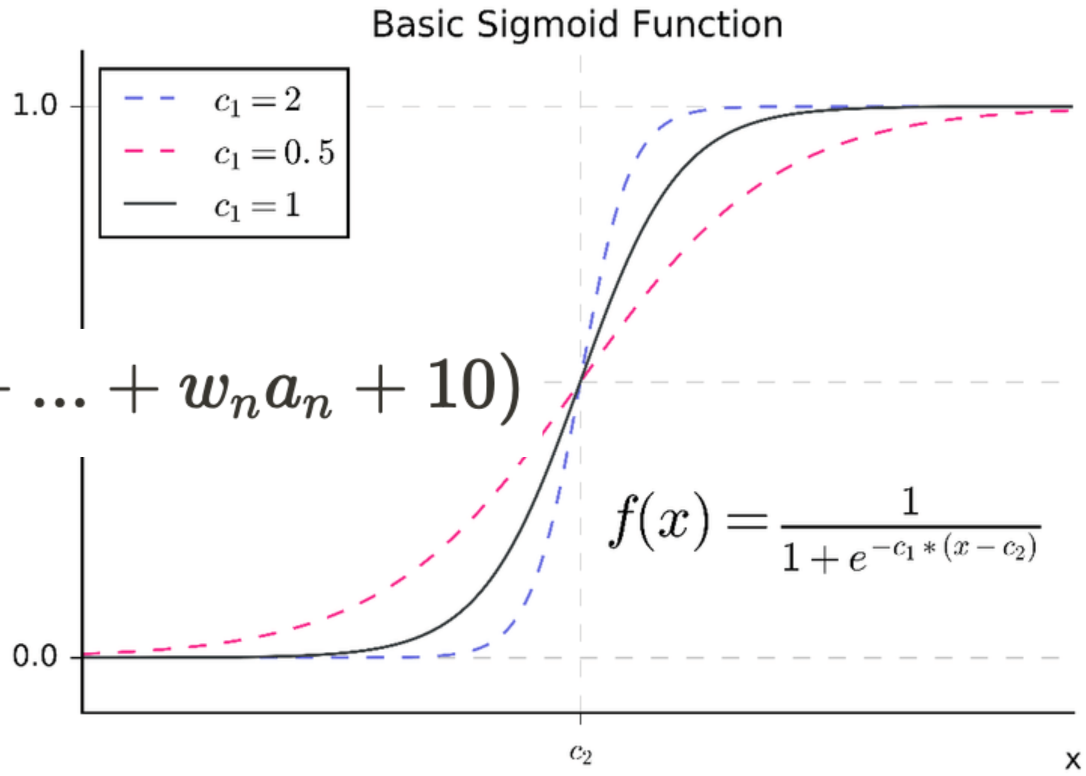
Even better, if we want an edge around the region, then we want those respective neurons to be negative.

Activation Functions

Standardized Output



$$\sigma(w_1a_1 + w_2a_2 + \ldots + w_na_n + 10)$$



Sigmoid, AKA logistic curve

Bias

Hi neuron,
Please light up only if the weighted sum is greater than ten!

$$\sigma(w_1 a_1 + w_2 a_2 + \ldots + w_n a_n + \boxed{10})$$

"Bias"

And... This is just one neuron!
All 784 neurons in our example have weights and biases.
This resulted in 13,002 parameters!

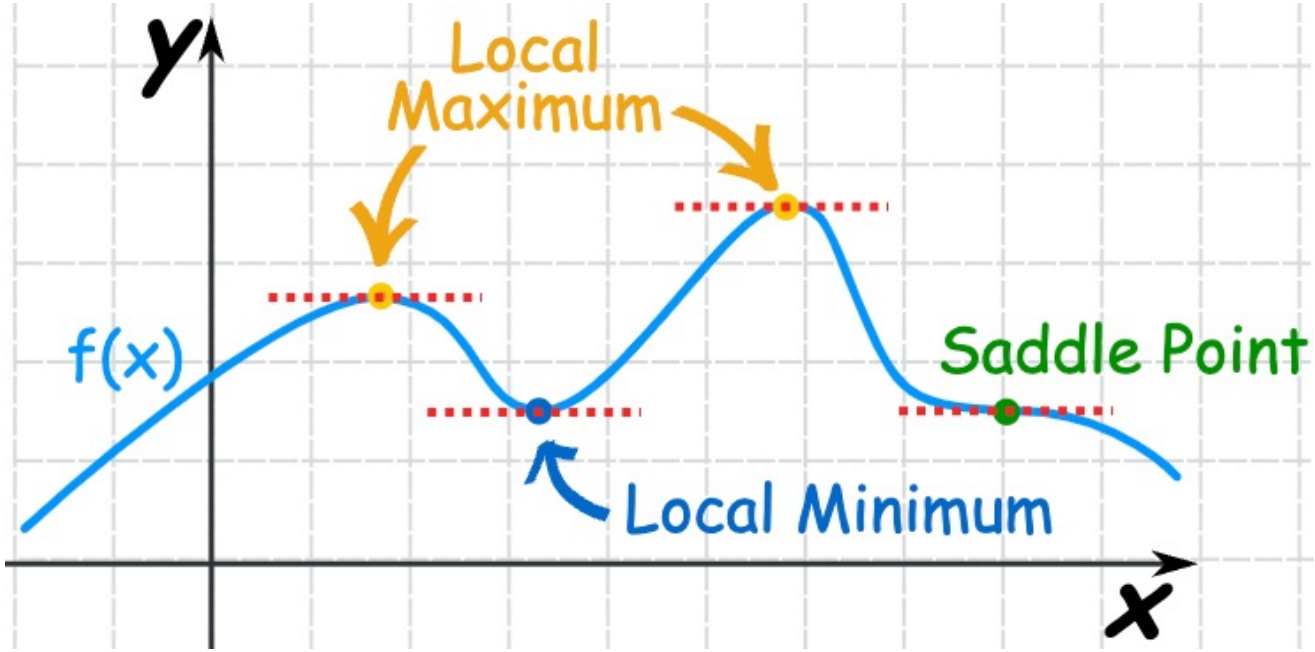
LEARN:

Find the right (most optimal) weights and biases.

Gradient Descent

Everything is CALCULUS!

Finding maximum/minimum



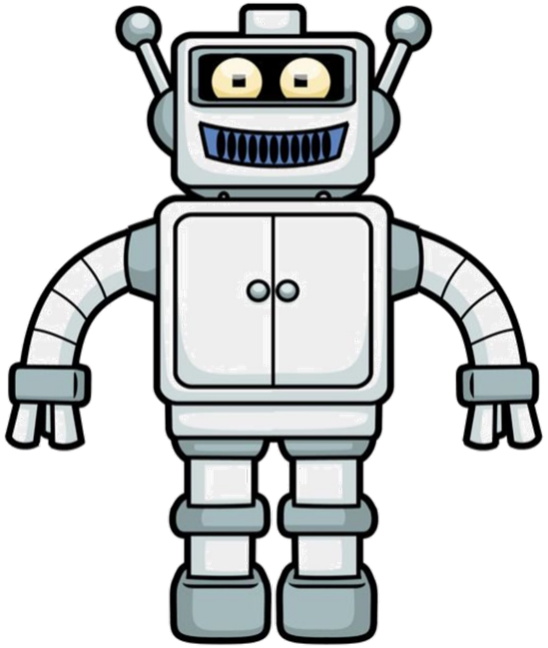
Cost Function: the Error

What we tried to minimize

$$\frac{\sum_{i=0}^{n}(x_{p,i} - x_{a,i})^2}{n}$$

How exactly does this work?

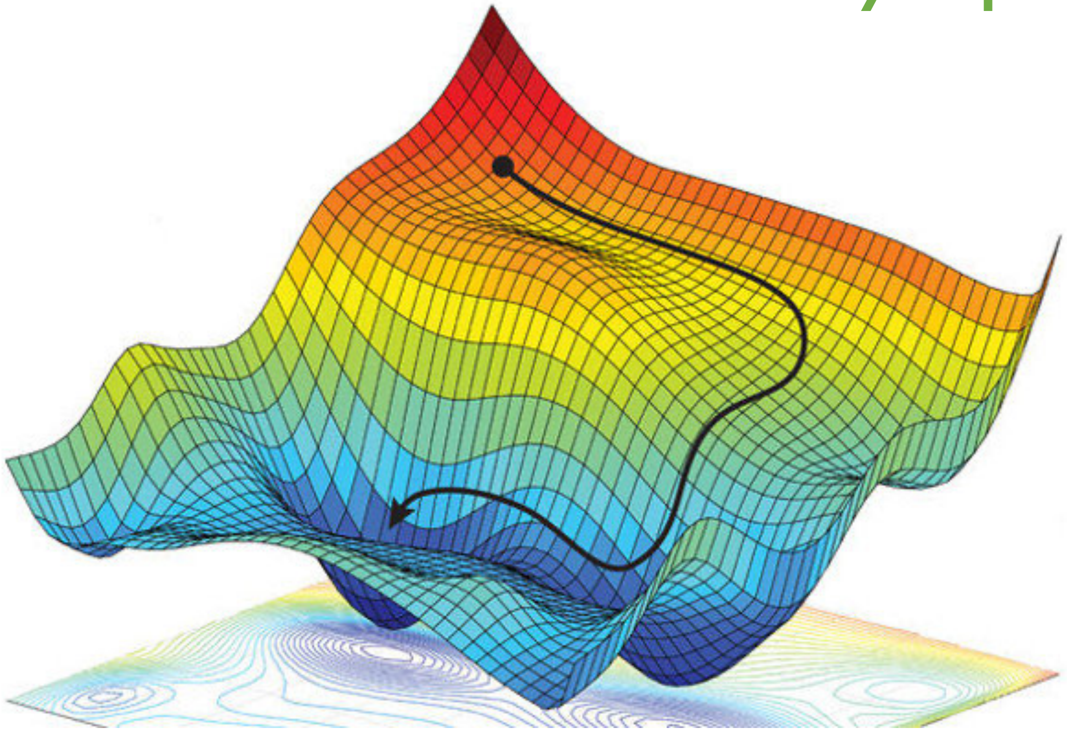
1. Prepare a training set (large!) with labels (supervised)
2. Initialize weights and biases randomly
3. Calculate the cost
4. Use gradient descent to start minimizing (decreasing the cost



Well, it's easy to find the minimum point of a two-dimensional function. But what do we do if it's 13002 dimensions?

Gradient Descent

AH, my multivariable class actually helps!



Core idea: the function decreases the fastest at the direction of the negative gradient!

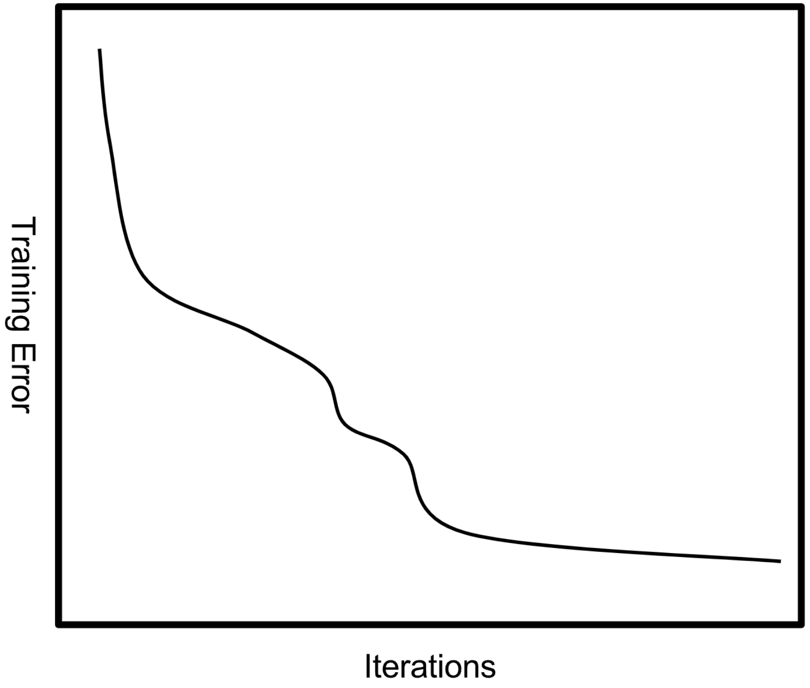
$$\nabla f(x,y,z) = < f_x, f_y, f_z >$$

Simple Algorithm

```python
def simple_gd(gradient, start, learn_rate, n_iter=50, tolerance=1e-06):
    """
        gradient: function with input vector and output gradient
        start: random starting point
        learn_rate: eta, controls magnitude of vector update
        n_iter: number of iterations
        tolerance: terminates the program if the difference is reached
    """
    vector = start
    vector_lst = [start]
    for _ in range(n_iter):
        vector -= learn_rate * gradient(vector)
        vector_lst.append(vector)
        if abs(learn_rate * gradient(vector)) <= tolerance:
            break
    return vector, vector_lst
```

Stochastic Gradient Descent

More efficient!



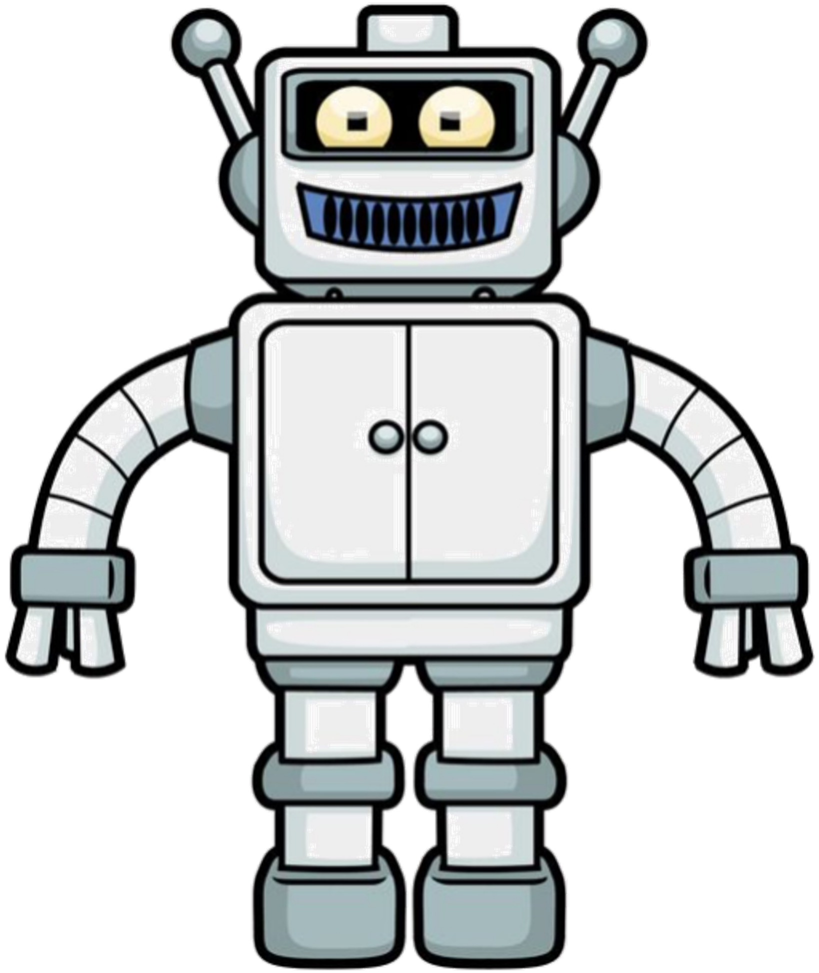
Gradient Descent

Stochastic Gradient Descent

A drunk man walking down a hill... But faster!

Next Steps

1. **Calculate gradient (partial derivatives): Backpropagation**
2. **Understanding what actually happened in the learning process**
3. **Understanding stochastic gradient descent and learning rate's role**



Thank you!