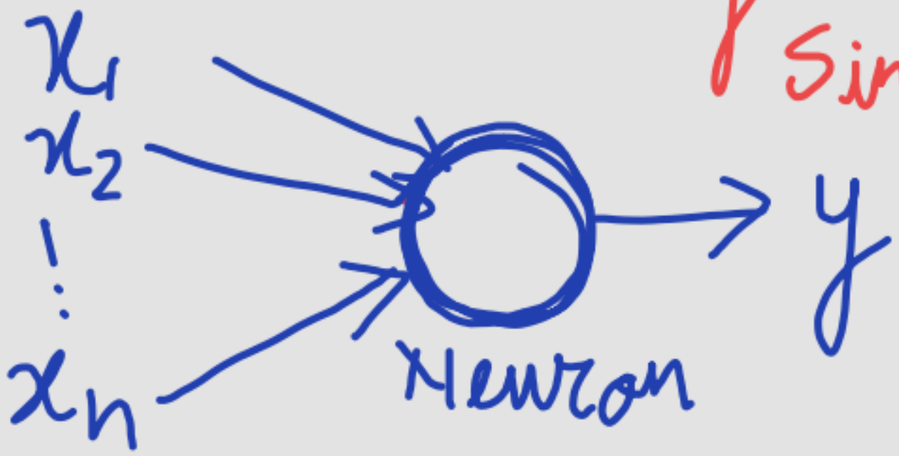
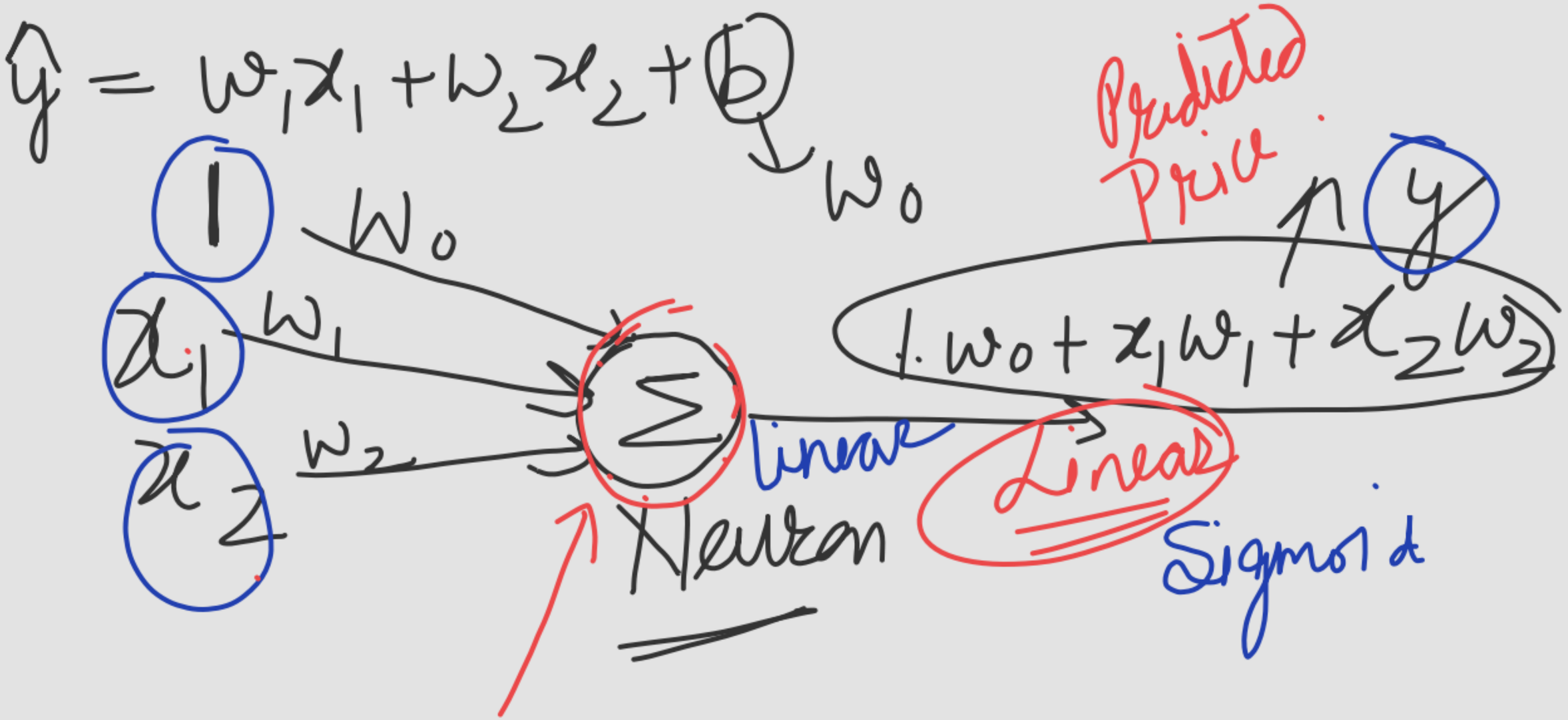
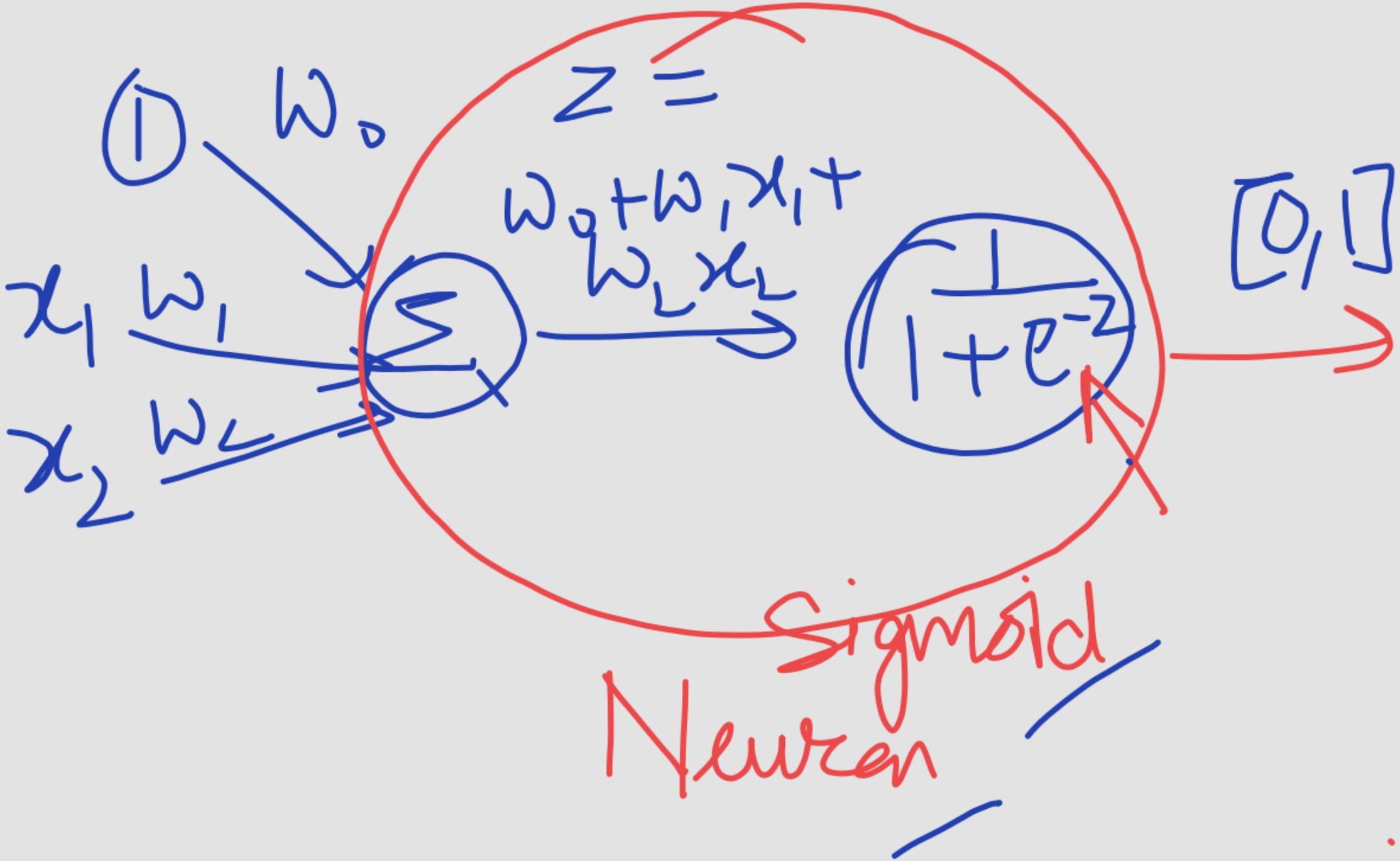
Artificial Neural Networks

Interconnected set of units called Neurons

Neuron: Computing unit that takes a no. of real-valued inputs & produces a single real-valued output.




$y = w_1x_1 + w_2x_2 + b$
w_0
Predicted Price
1
x_1
x_2
w_0
w_1
w_2
Σ
y
$1 \cdot w_0 + x_1w_1 + x_2w_2$
linear
Linear
Neuron
Sigmoid


1
w_0
$z =$
$w_0 + w_1 x_1 +$
$w_2 x_2$
x_1
w_1
x_2
w_2
Σ
$\frac{1}{1+e^{-z}}$
$[0,1]$
Sigmoid
Neuron

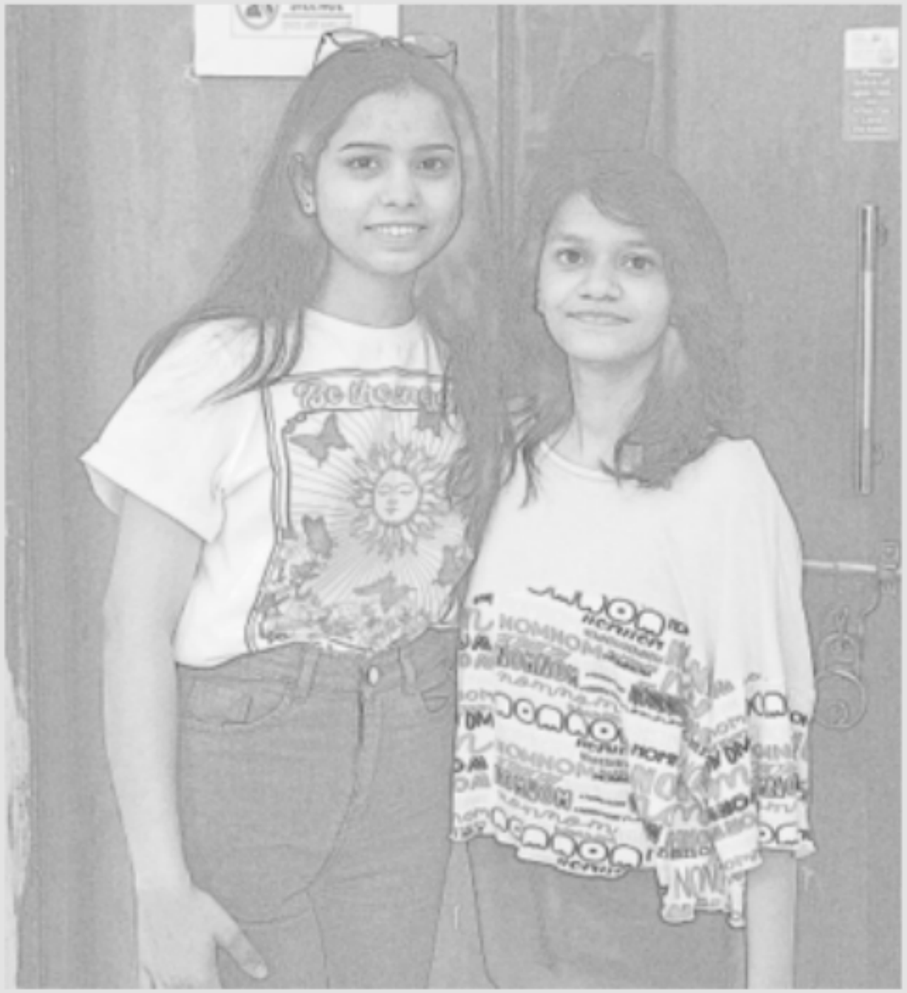
Analogy

Human Brain : Densely interconnected N/W of approx. 10^{11} neurons.

↳ Each connected on average to 10^4 neurons.

* Neuron's activity is excited or inhibited through connections to other neurons.

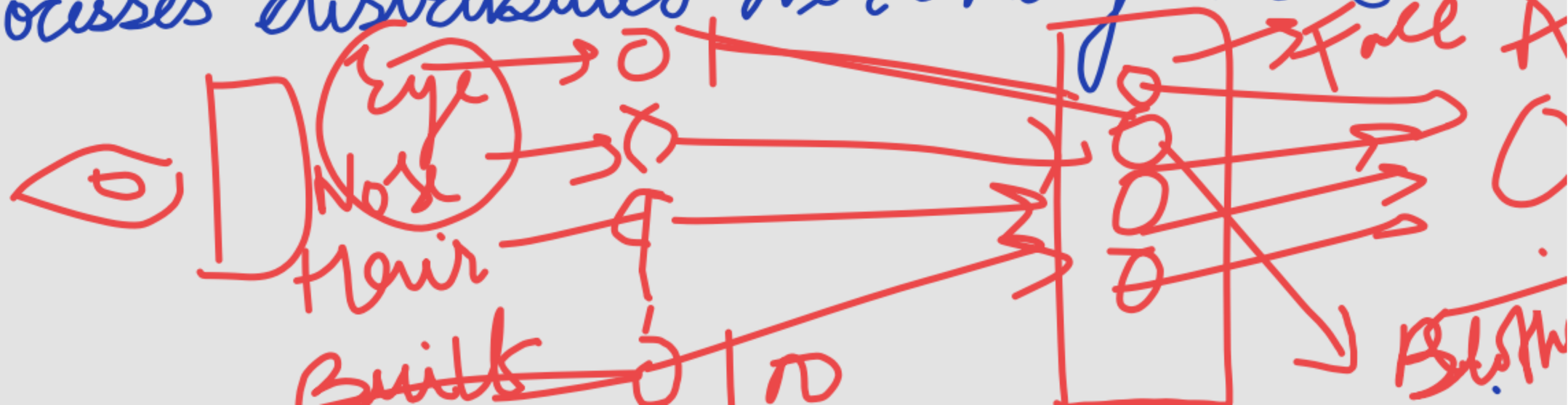
Guess who am I ?



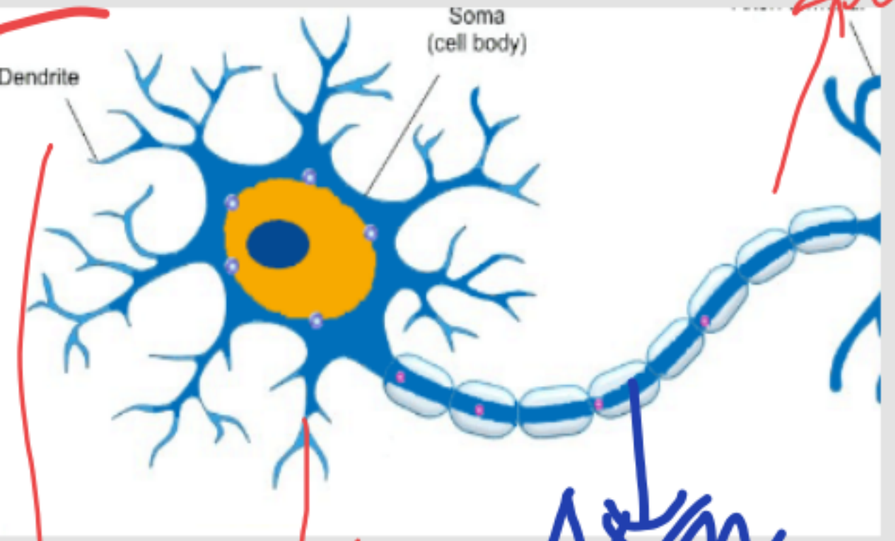
How Brain actually works?

→ It takes 10^{-1}s to recogniz your mother
↳ Around 100 neuron firings takes place during this 10^{-1}s.

→ Info processing ability of biological neural networks must follow high // processes distributed over many neurons



used to send messages to other neurons

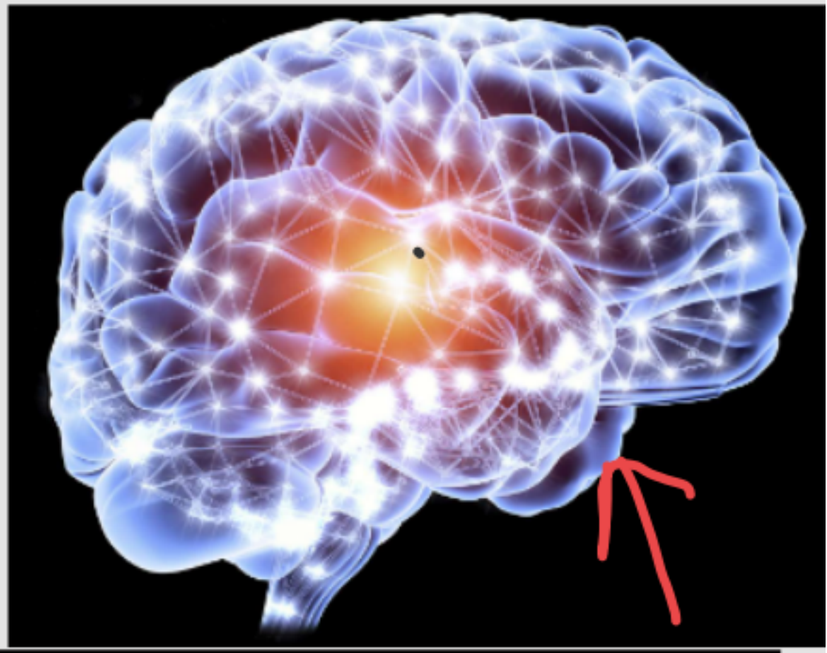


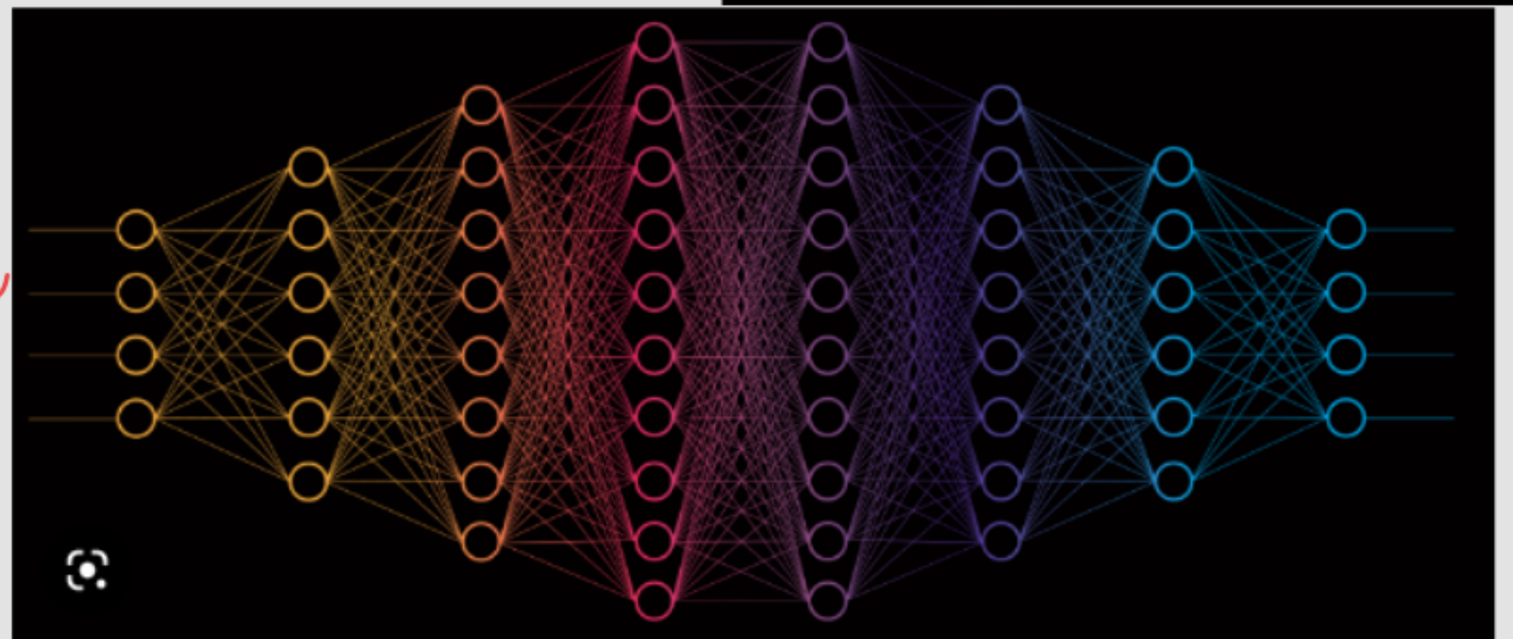
Axon

Neuron

→ where it receives messages from other neurons.

Neurons communicate with each other by sending a spike of activity if the weighted sum exceeds a threshold

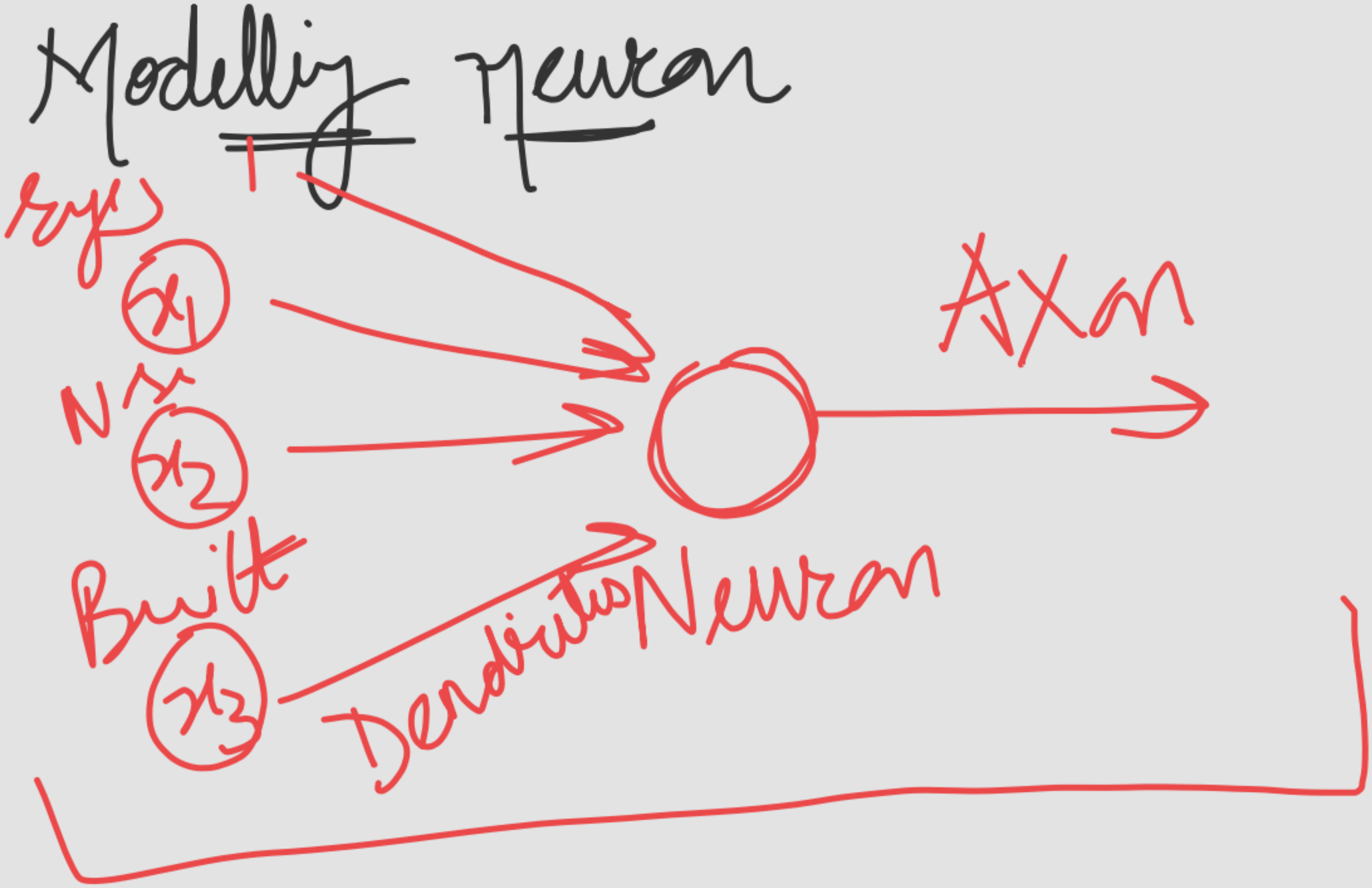




Research sheds light on how neurons control muscle movement | News Center...

How the brain recognizes objects | MIT

Brain can process images, can hear, can process sense of touch & many others!


Modelling Neuron
Inputs
x_1
x_2
x_3
Built
Dendrites
Neuron
Axon

Why Neural Networks?

* Increase in Scale of data
  - features + Training Instances

☹ With ↑ in amount of data, traditional ML models are not able to perform well

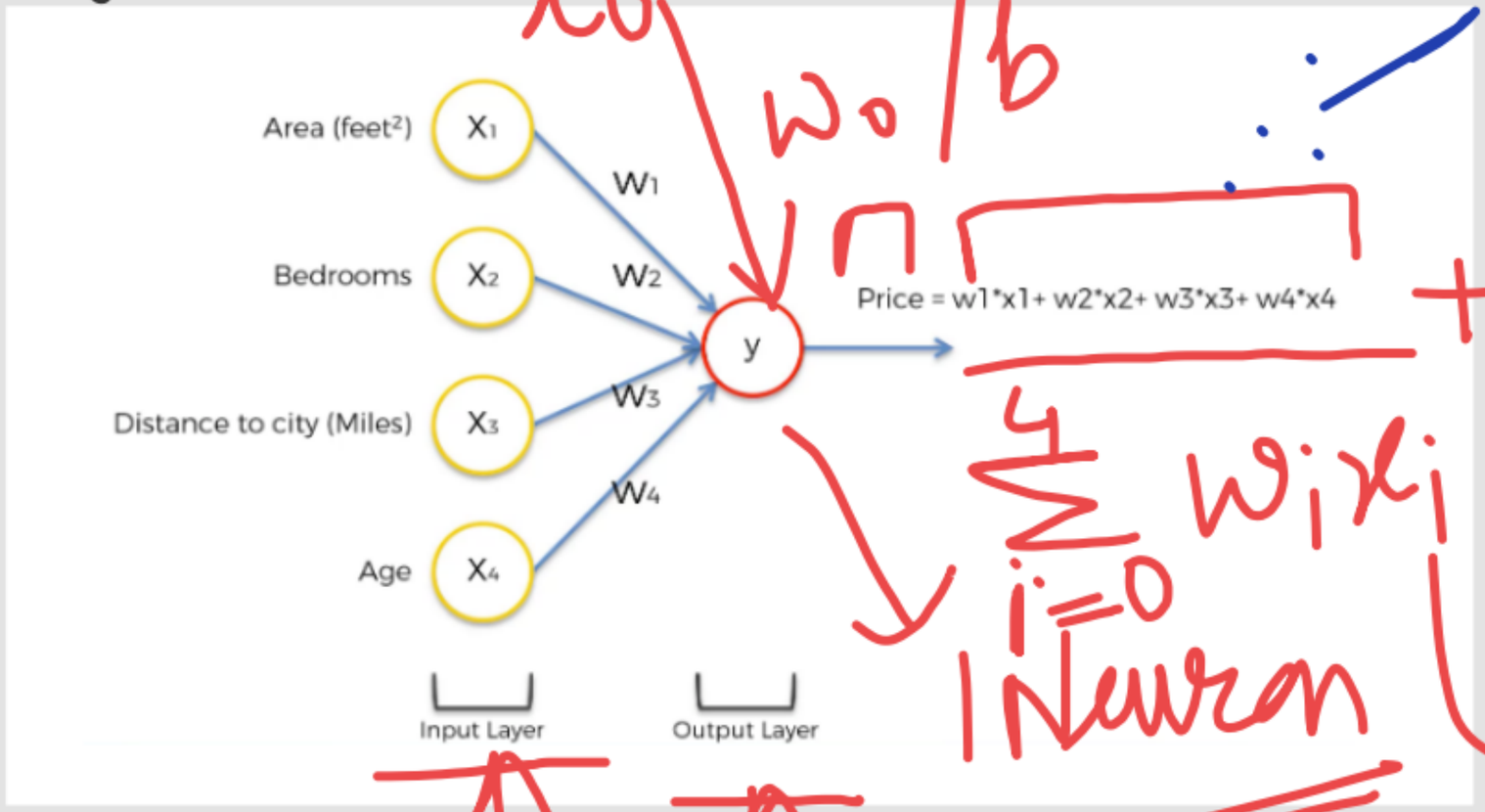
Scale is driving Deep neural networks!

→ Advancement in terms of processi

Space + Speed!

Applications of Neural Networks

① Housing Price Prediction



x_0

w_0 / b

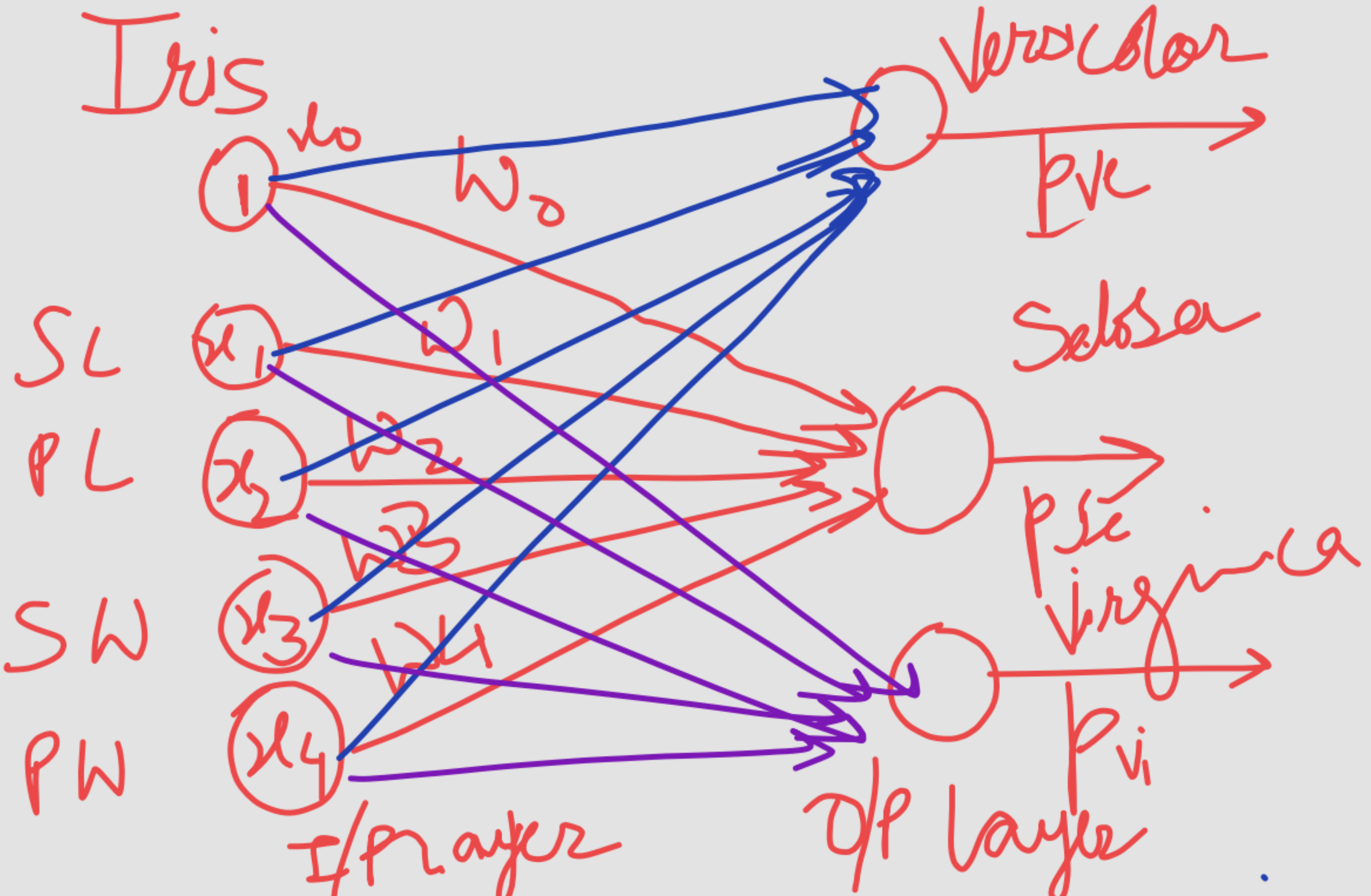
$+ w_0 x_0$

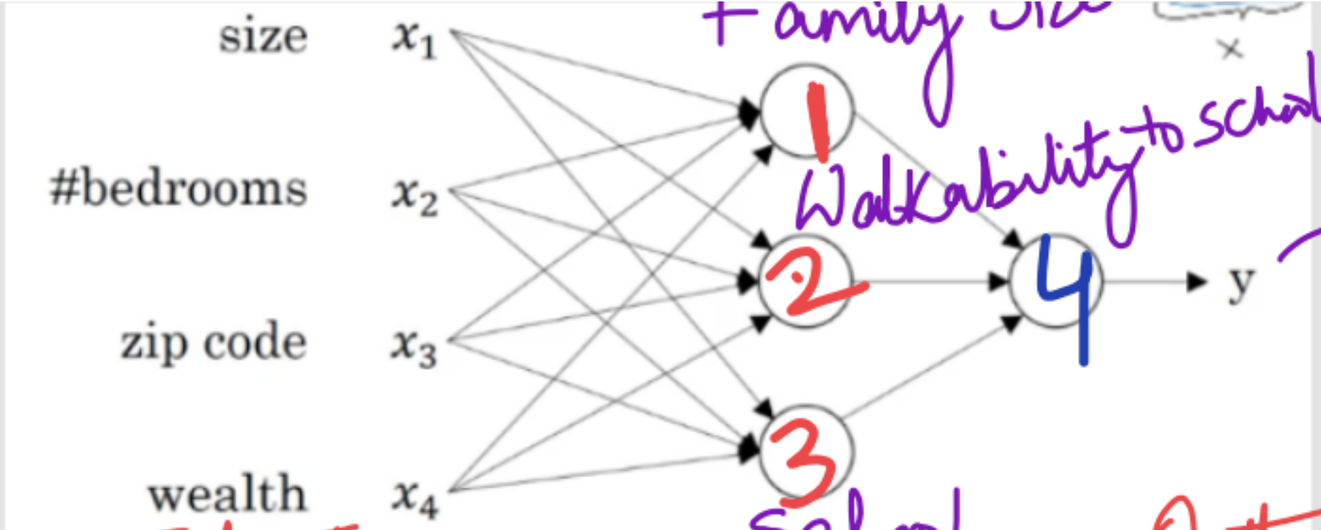
$b \quad 1$

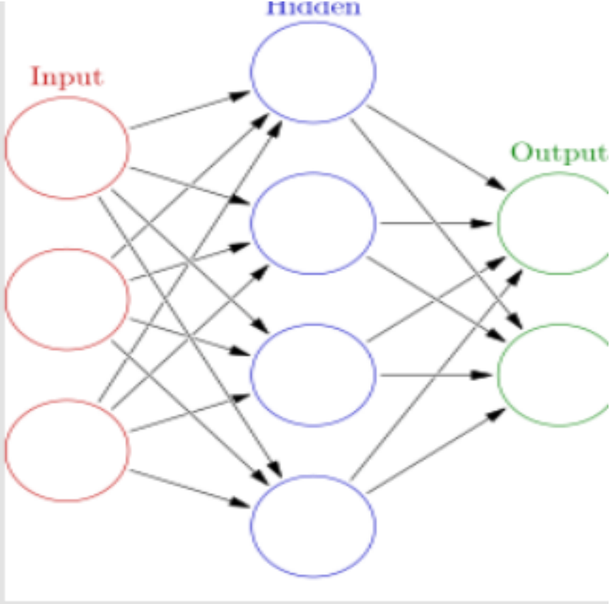
$\sum_{i=0}^{4} w_i x_i$

Neuron

$x_0 =$


Iris
Versicolor
SL
PL
SW
PW
Setosa
Virginica
I/P layer
O/P layer





Input Layer

Hidden Layers

Output Layer

Higher level Features

	Age	KM	Weight	HP	MetColor	CC	Doors
0	23.0	46986	1165.0	90	1	2000.0	3
1	23.0	72937	1165.0	90	1	2000.0	3
2	24.0	41711	1165.0	90	1	2000.0	3
3	26.0	48000	1165.0	90	0	2000.0	3
4	30.0	38500	1170.0	90	0	2000.0	3

Training data

23
46986
1165.0
90
1
2000
3

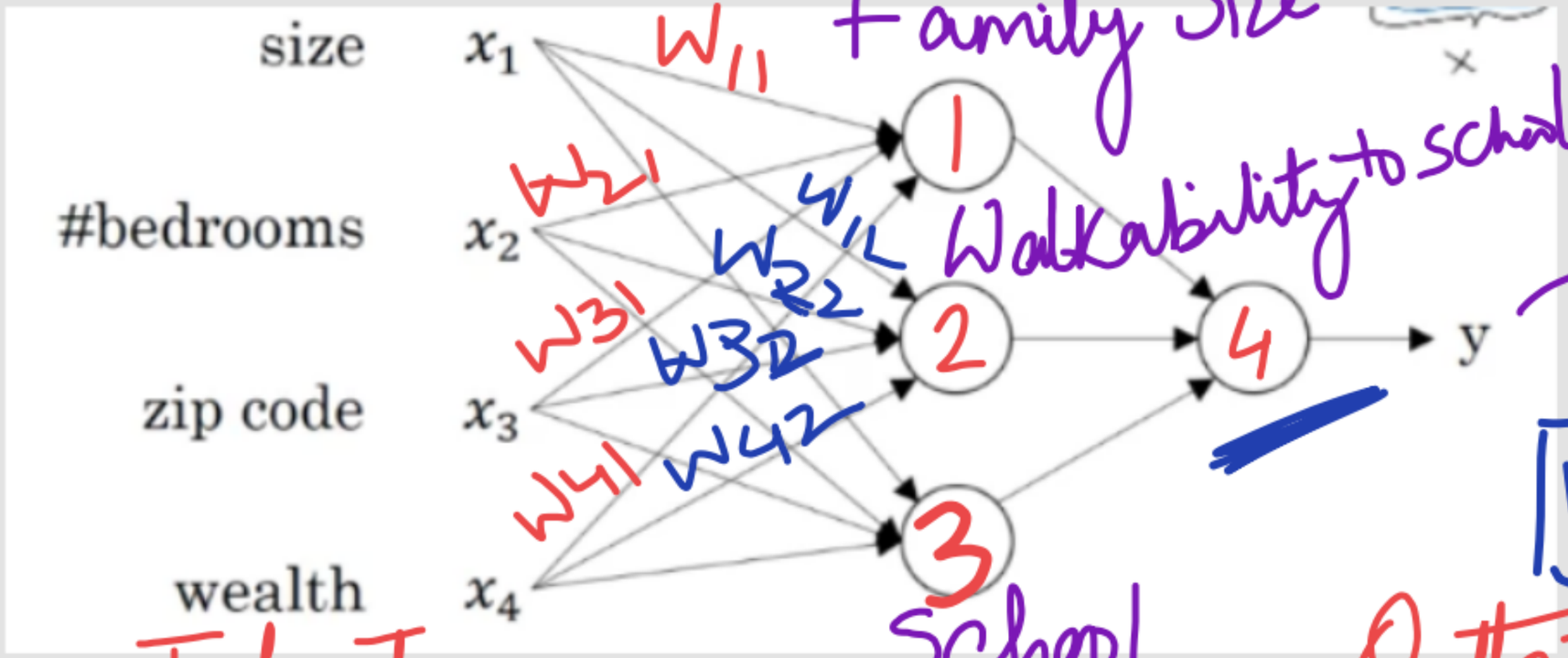
one row of data

price prediction

HL1 HL2 Hidden Layers

output Layer

O/P hidden from end user


size
#bedrooms
zip code
wealth
x_1
x_2
x_3
x_4
1
2
3
4
y
W_{11}
W_{21}
W_{31}
W_{41}
W_{12}
W_{22}
W_{32}
W_{42}
Family Size
Walkability
School Quality
Price
$N_3 = ?$
$W_{13} = 15$
Input Layer
Hidden Layer
Output Layer
$N_1 = W_{11} x_1 + W_{21} x_2 + W_{31} x_3 + W_{41} x_4 \ldots$
I/P feature
Neuron No.
$N_2 = W_{12} x_1 + W_{22} x_2 + W_{32} x_3 + W_{42} x_4$

No. of parameters to learn (excluding bias)

$= 15$

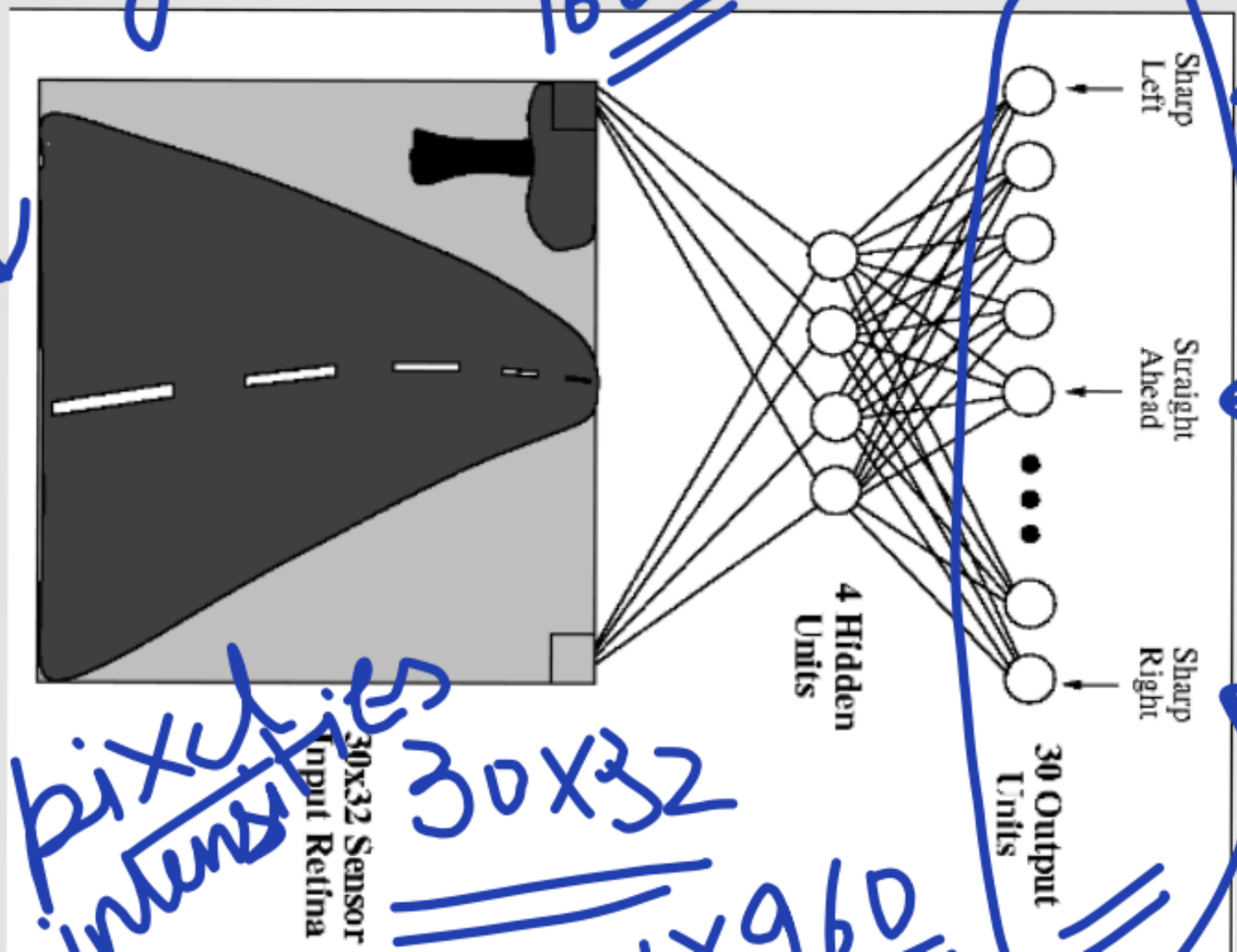
(2) Self-Driving CAR, ALVINN (1993)

→ uses a learned ANN to steer an auto vehicle driving

Image as I/P

Camera

960



pixel intensities

30x32

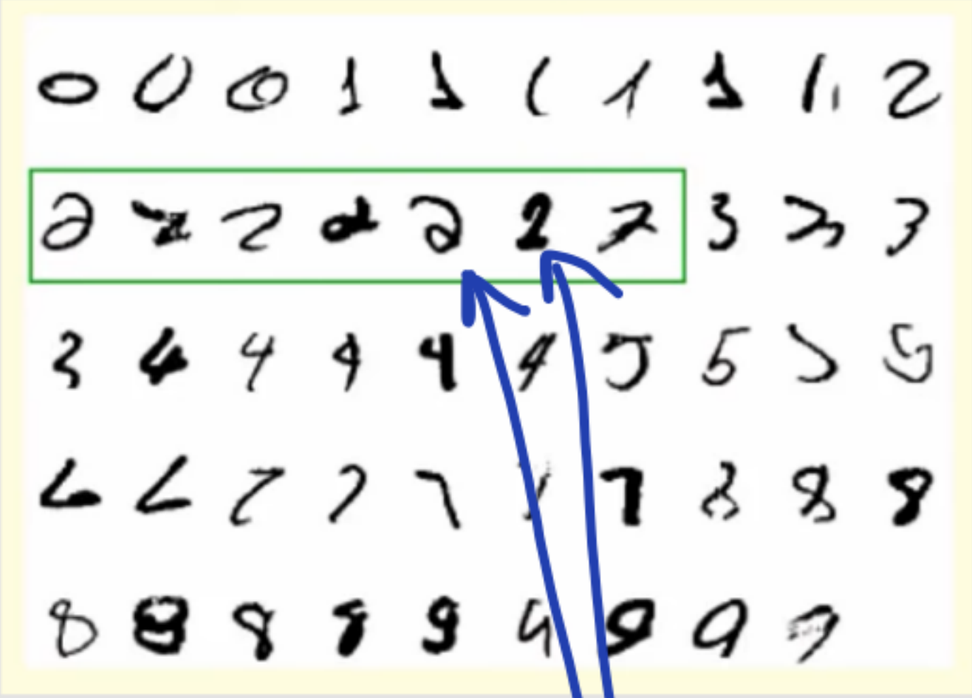
= 960

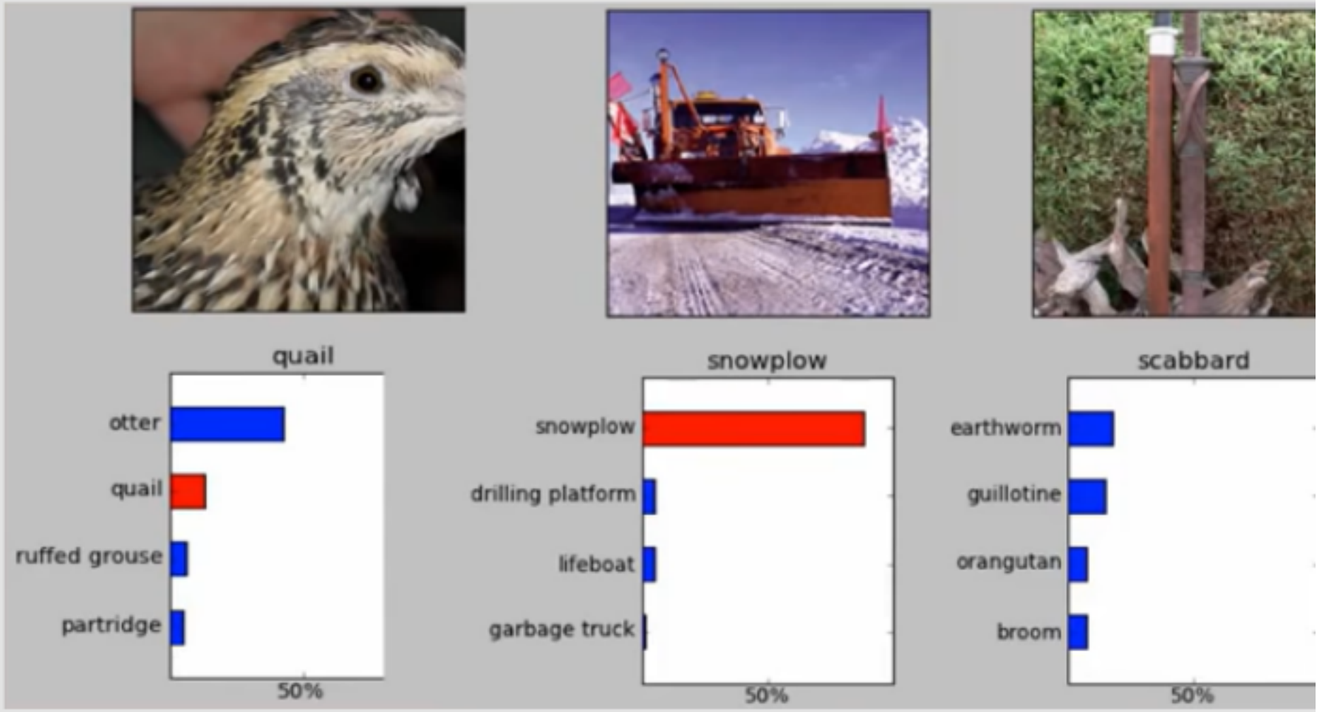
O/P

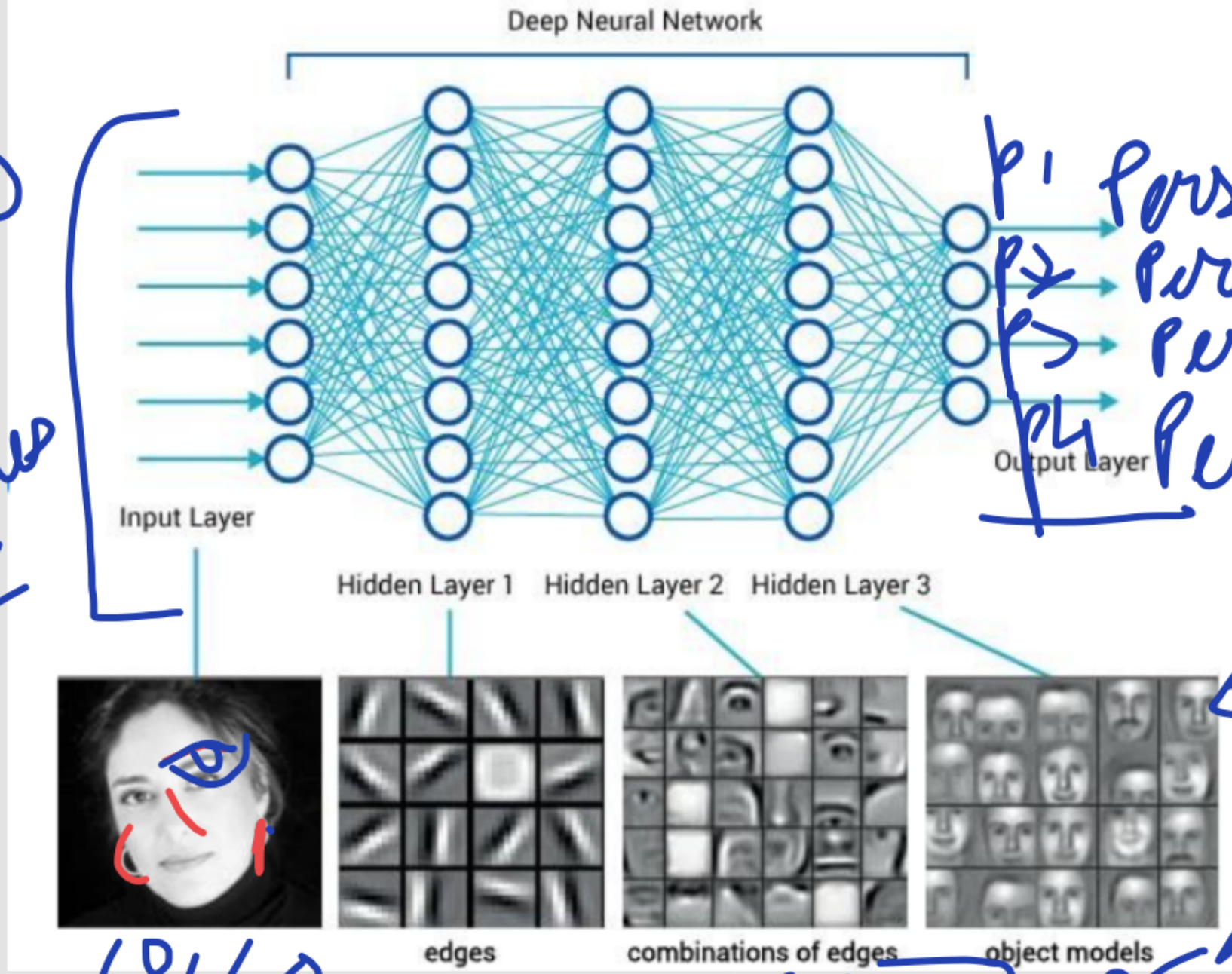
days

* ALVINN used its learned n/ws to drive at speeds upto 70 miles/hour & for distances of 90 miles on public highways.

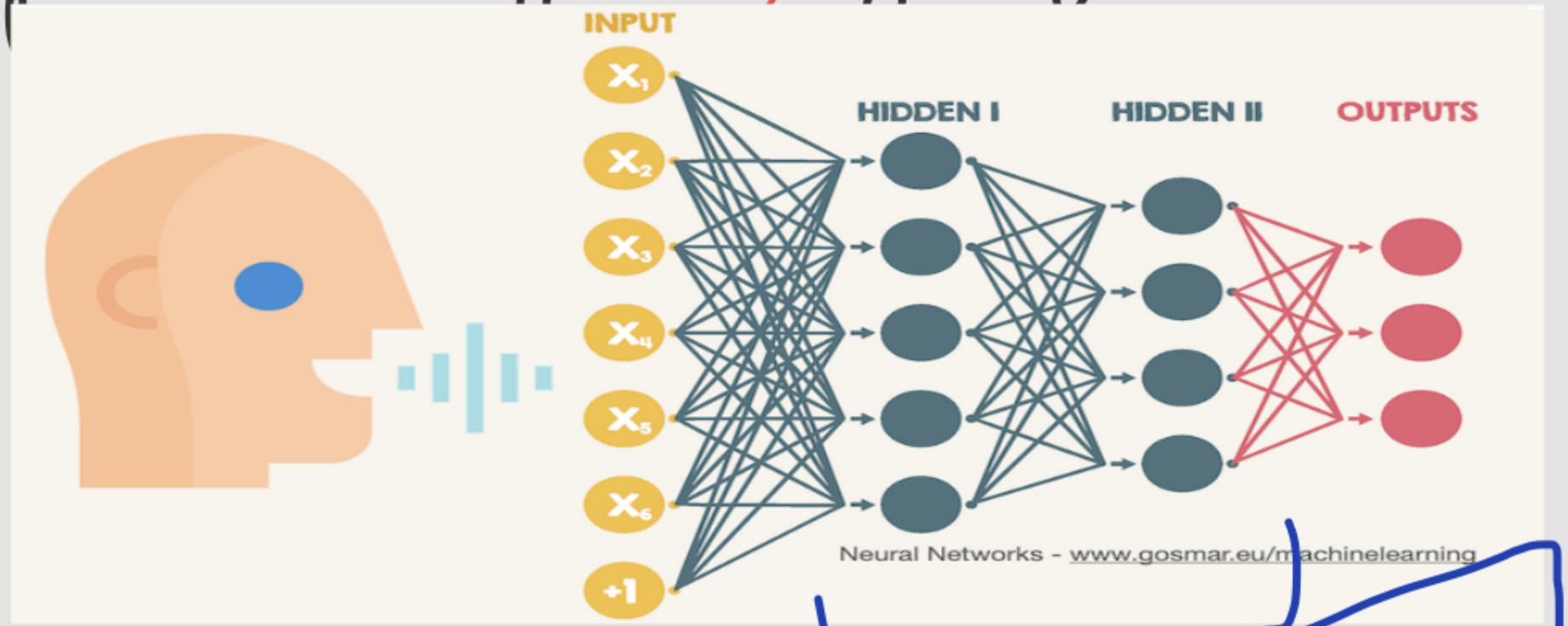
⑤ Image Recognition / Object Detection

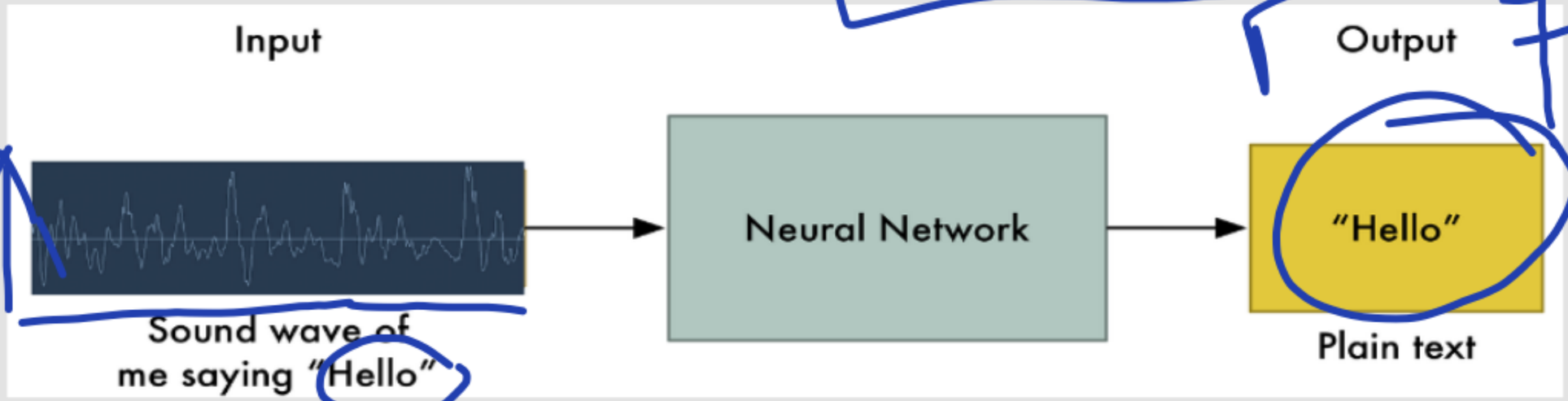





Deep Neural Network
Input Layer
Hidden Layer 1
Hidden Layer 2
Hidden Layer 3
Output Layer
P1 Person 1
P2 Person 2
P3 Person 3
P4 Person 4
edges
combinations of edges
object models

④ Speech Recognition, eg: Audio to Text





Which all Big firms are using Neural Networks?

Below is a list of top 10 companies involved in the deep neural network market:

- Google.
- IBM.
- Intel.
- Microsoft.
- Qualcomm.
- OpenAI.
- NeuralWare.
- Starmind.

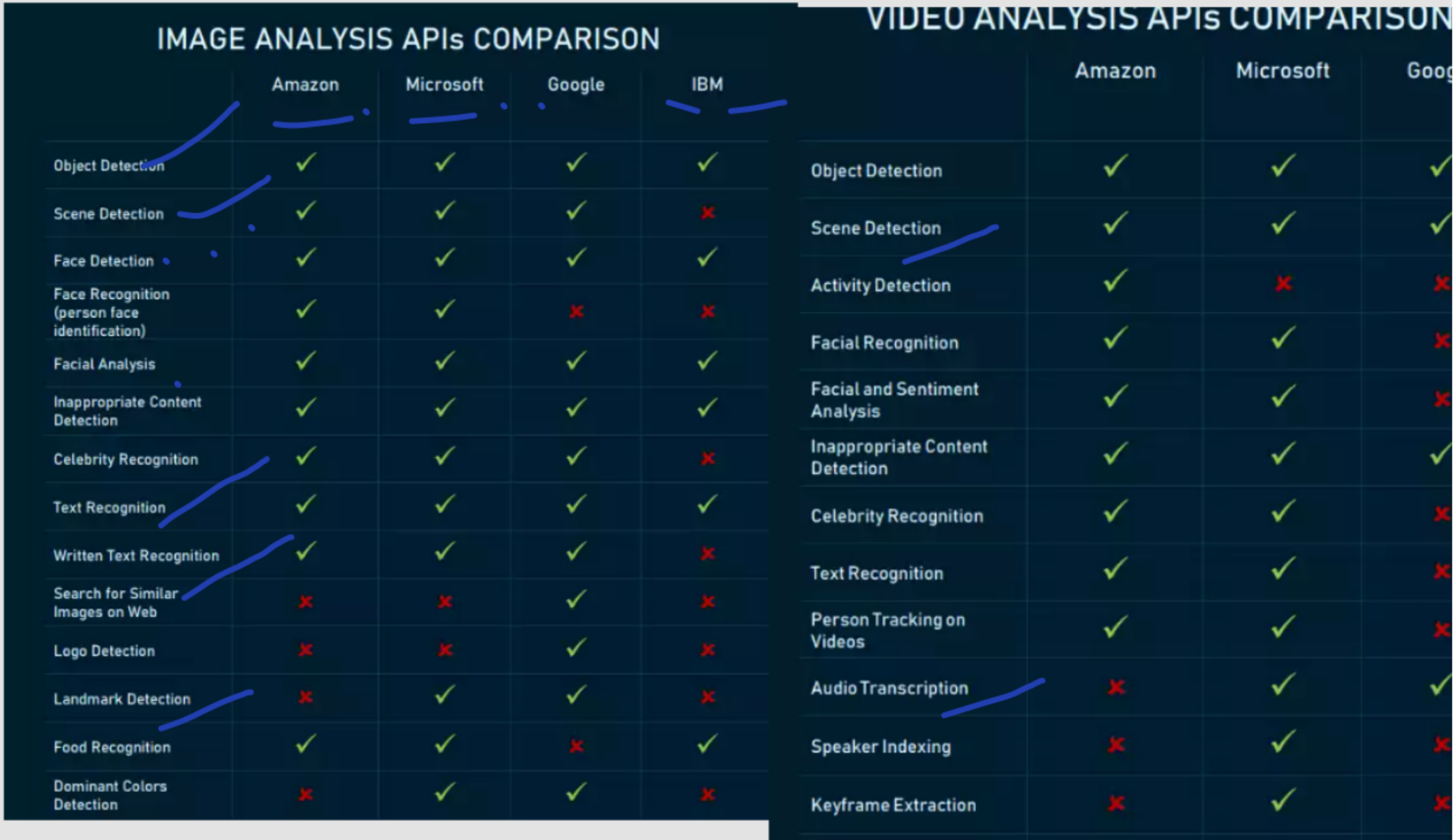


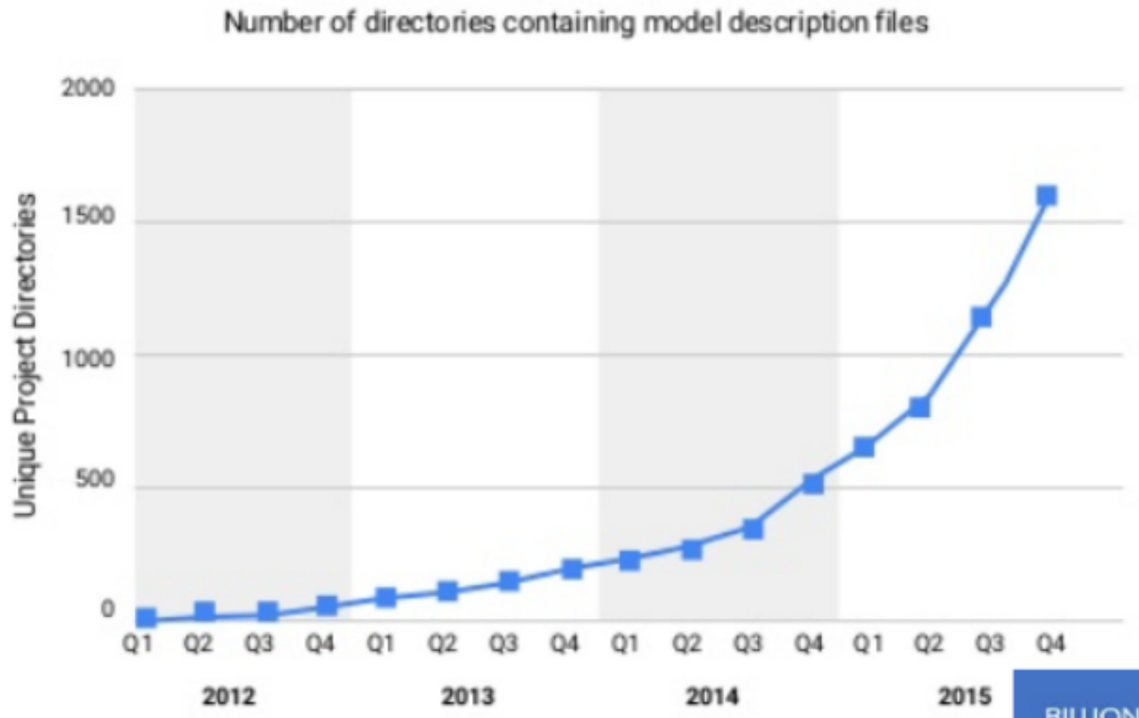
IMAGE ANALYSIS APIs COMPARISON

	Amazon	Microsoft	Google	IBM
Object Detection	✓	✓	✓	✓
Scene Detection	✓	✓	✓	✗
Face Detection	✓	✓	✓	✓
Face Recognition (person face identification)	✓	✓	✗	✗
Facial Analysis	✓	✓	✓	✓
Inappropriate Content Detection	✓	✓	✓	✓
Celebrity Recognition	✓	✓	✓	✗
Text Recognition	✓	✓	✓	✓
Written Text Recognition	✓	✓	✓	✗
Search for Similar Images on Web	✗	✗	✓	✗
Logo Detection	✗	✗	✓	✗
Landmark Detection	✗	✓	✓	✗
Food Recognition	✓	✓	✗	✓
Dominant Colors Detection	✗	✓	✓	✗

VIDEO ANALYSIS APIs COMPARISON

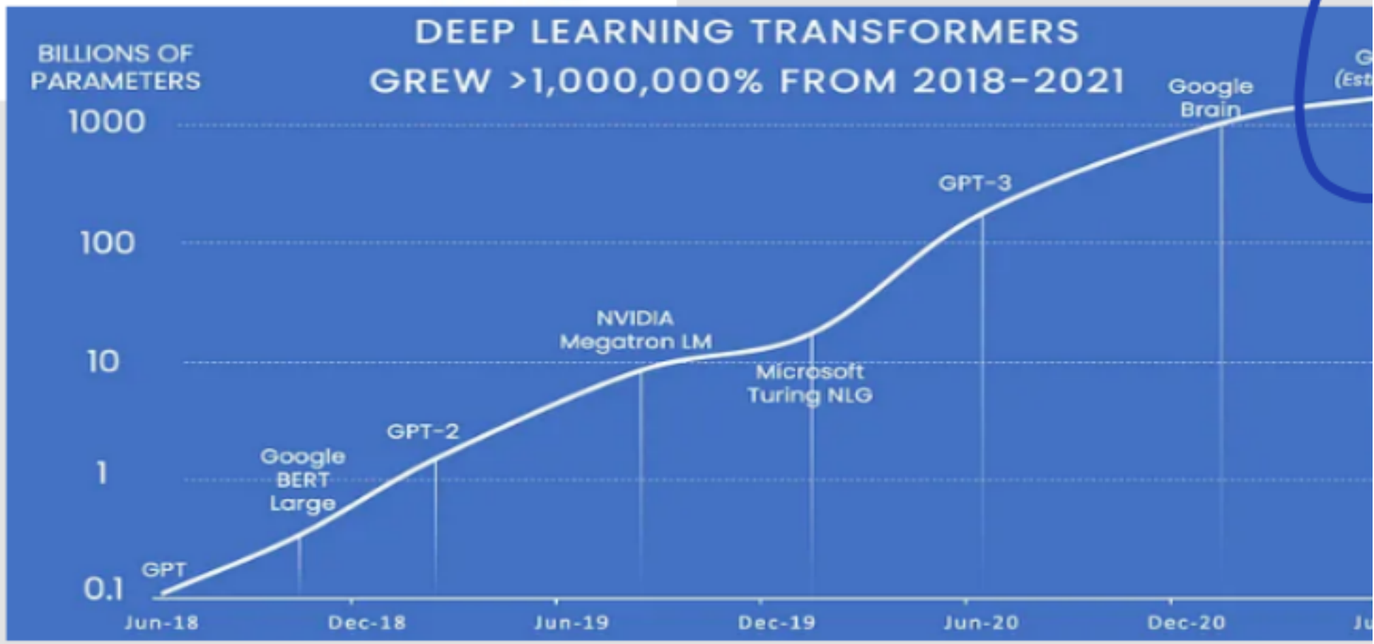
	Amazon	Microsoft	Goog
Object Detection	✓	✓	✓
Scene Detection	✓	✓	✓
Activity Detection	✓	✗	✗
Facial Recognition	✓	✓	✗
Facial and Sentiment Analysis	✓	✓	✗
Inappropriate Content Detection	✓	✓	✓
Celebrity Recognition	✓	✓	✗
Text Recognition	✓	✓	✗
Person Tracking on Videos	✓	✓	✗
Audio Transcription	✗	✓	✓
Speaker Indexing	✗	✓	✗
Keyframe Extraction	✗	✓	✗

Growing Use of Deep Learning at Google



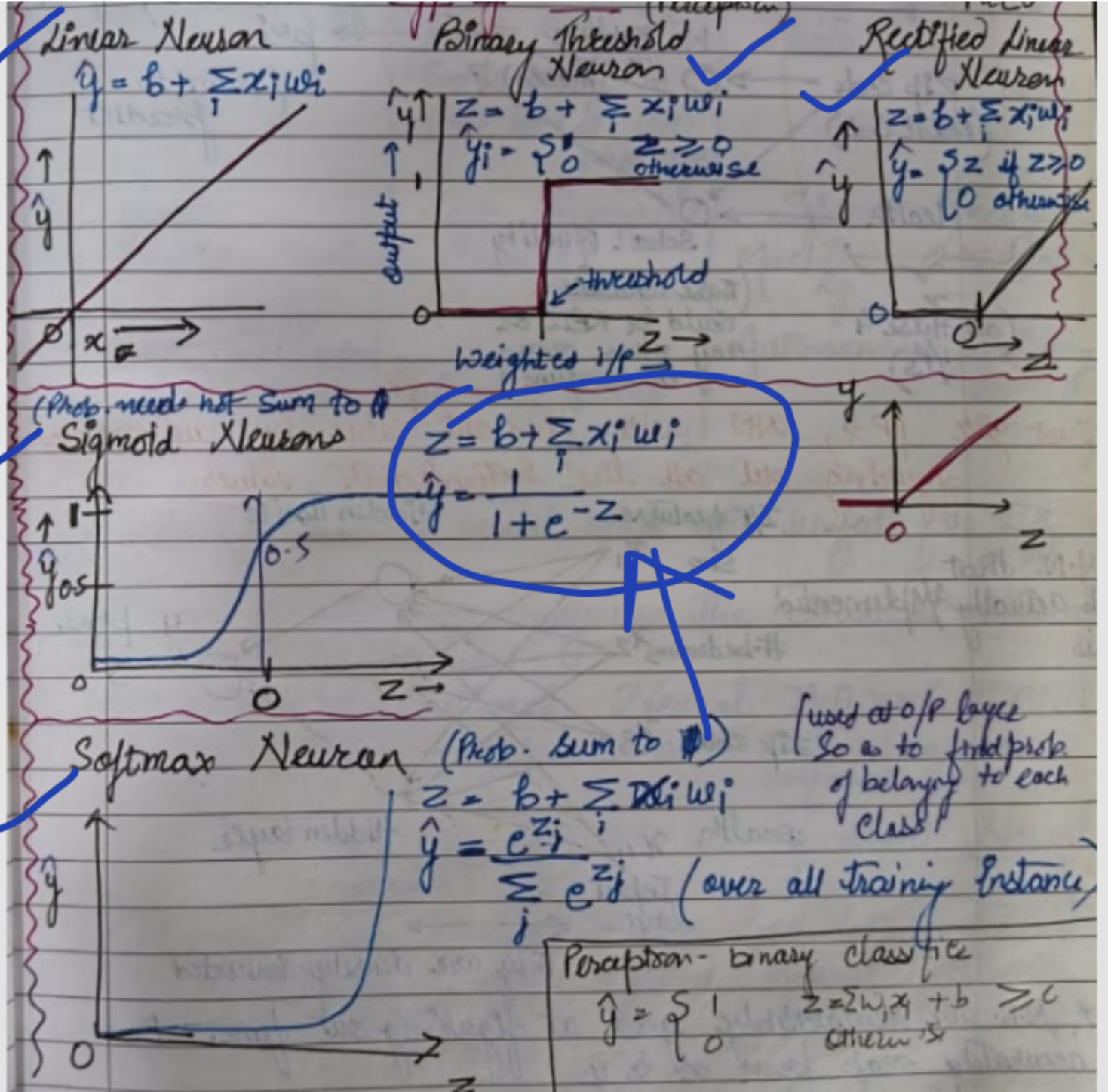
Across many products/areas

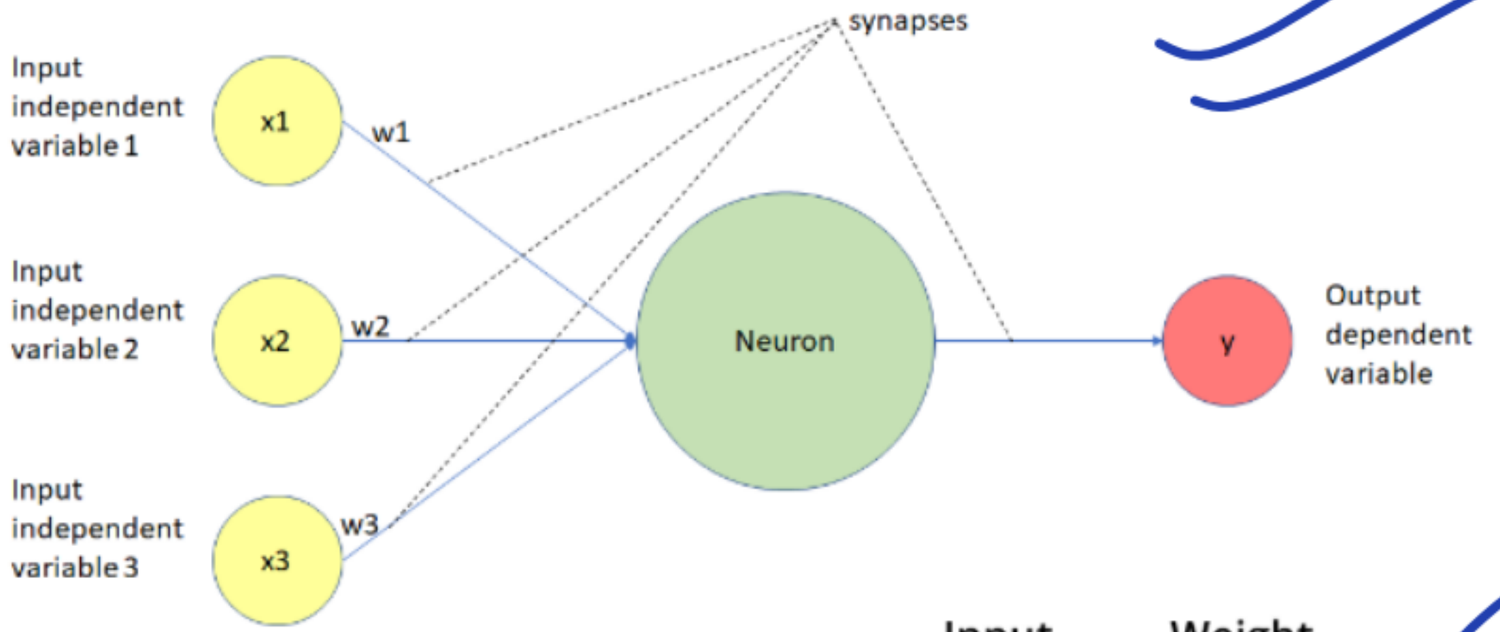
- Apps
- Maps
- Photos
- Gmail
- Speech
- Android
- YouTube
- Translation
- Robotics Research
- Image Understanding
- Natural Language Understanding
- Drug Discovery

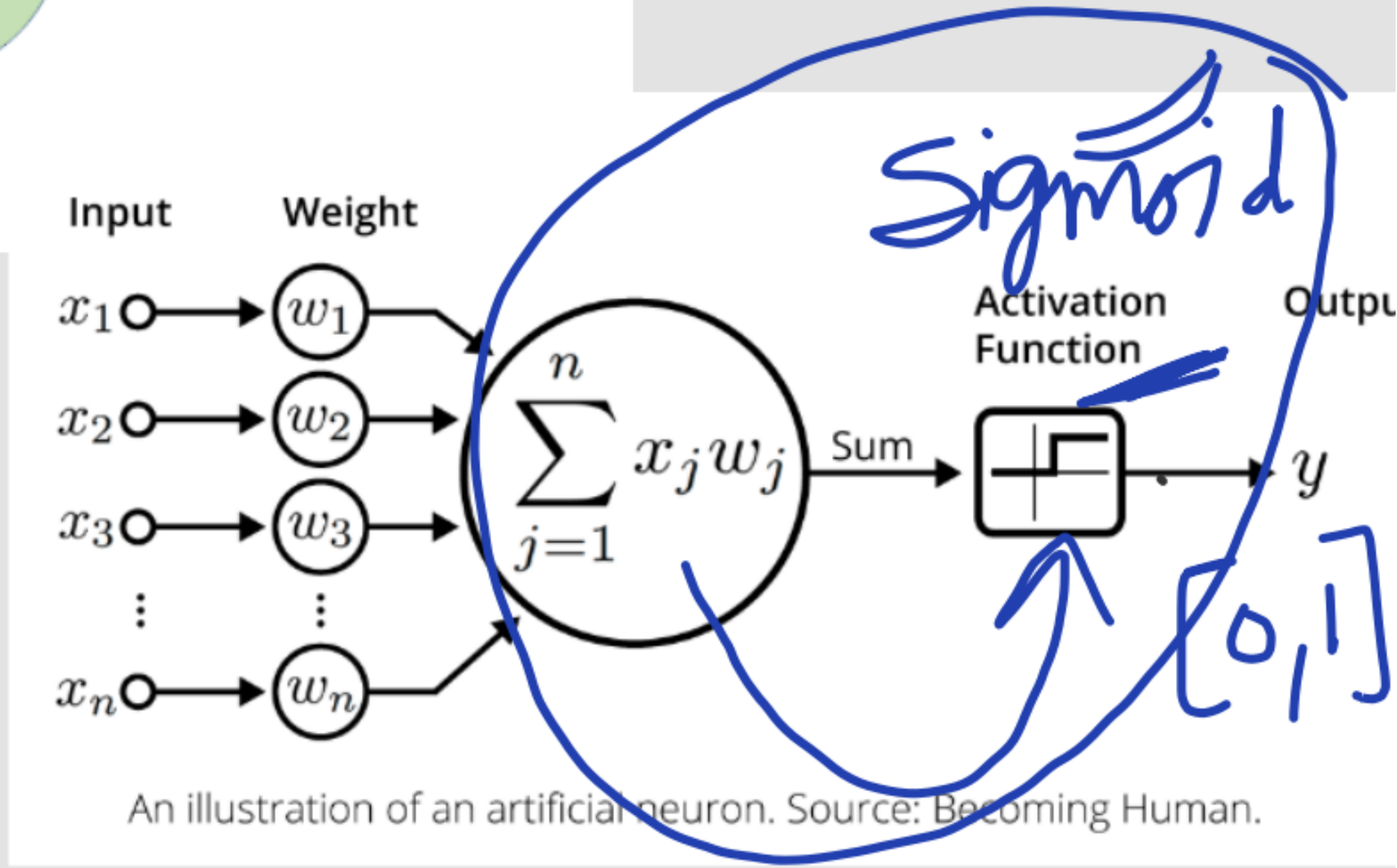


Types of Neurons

Hidden layer ReLU







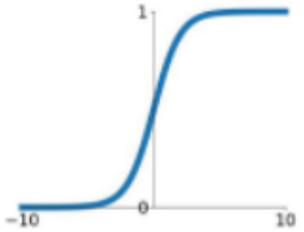
An illustration of an artificial neuron. Source: Becoming Human.

(Used when the data is not linearly separable)

Activation Functions

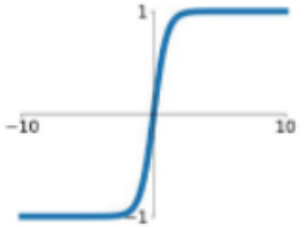
Sigmoid

$$\sigma(x) = \frac{1}{1+e^{-x}}$$



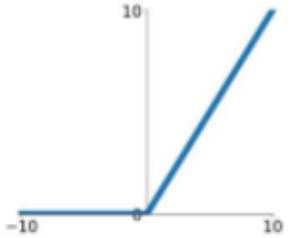
tanh

$$\tanh(x)$$



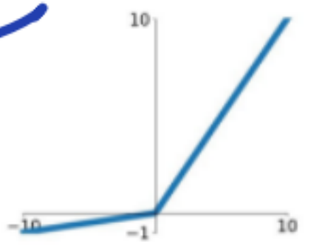
ReLU

$$\max(0, x)$$



Leaky ReLU

$$\max(0.1x, x)$$

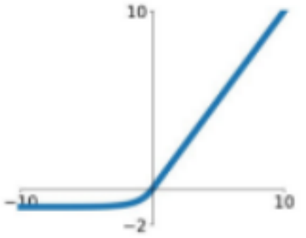


Maxout

$$\max(w_1^T x + b_1, w_2^T x + b_2)$$

ELU

$$\begin{cases} x & x \geq 0 \\ \alpha(e^x - 1) & x < 0 \end{cases}$$

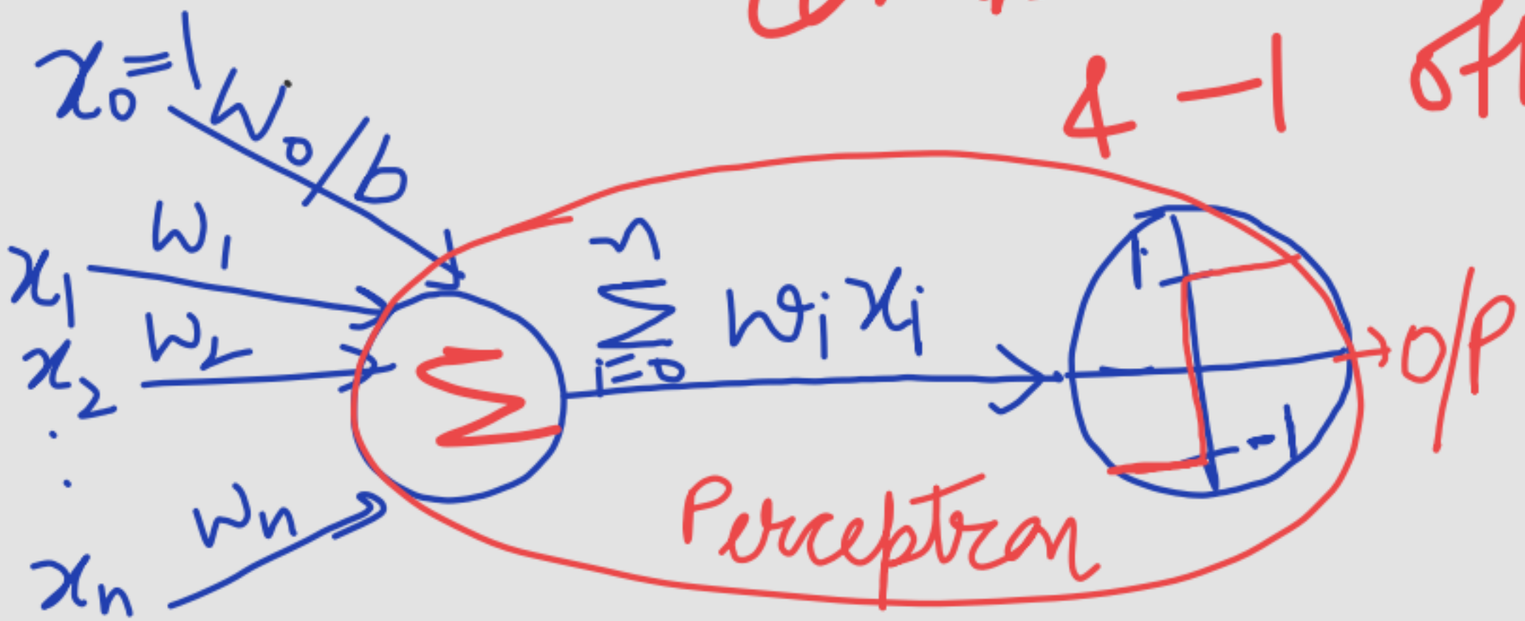


Perceptron ← Ch-4 ← ANN

Binary Thresholded neuron

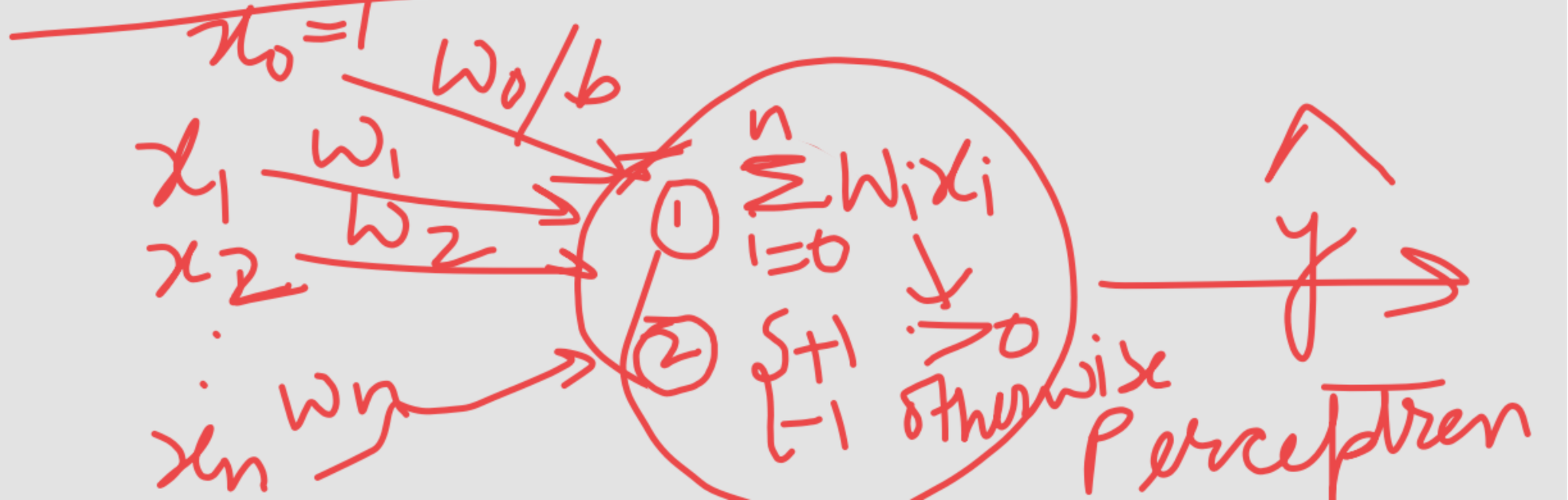
→ Takes real valued I/Ps

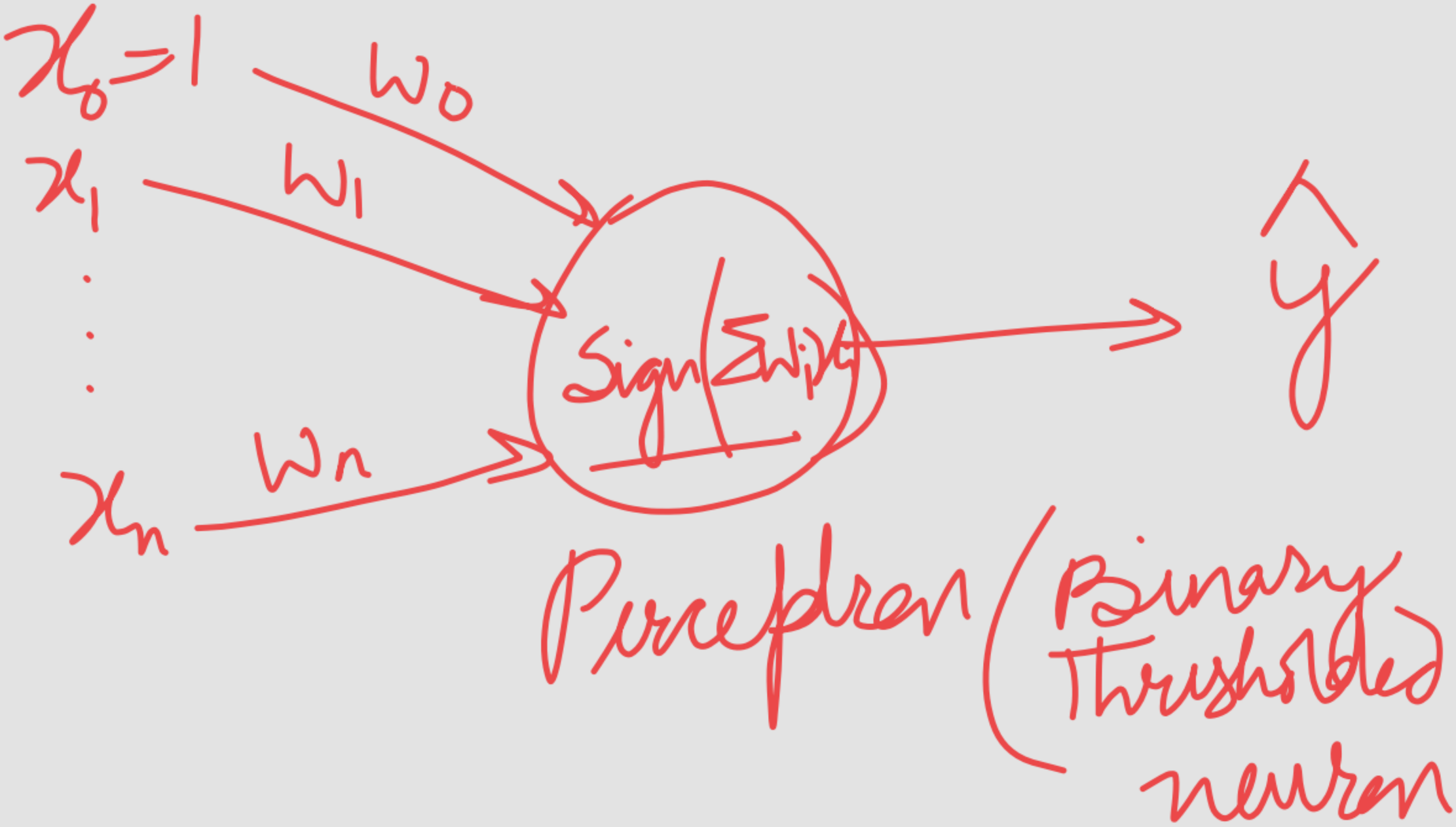
→ Calculate a linear combination of I/Ps & output 1 if linear combination is greater than 0 & -1 otherwise.



$$\hat{y} = f(x_1, x_2, \cdots x_n)$$

$$= \begin{cases} +1 & \text{if } \sum_i w_i x_i > 0 \\ -1 & \text{otherwise} \end{cases}$$





Perceptron (Binary Thresholded neuron)

Binary Thresholded Neuron

$$\hat{y} = f(x_1, x_2 \ldots, x_n)$$

$$= \begin{cases} +1 & \text{if } w_0 x_0 + w_1 x_1 + \cdots w_n x_n > 0 \\ -1 / 0 & \text{otherwise } (\sum w_i x_i \leq 0) \end{cases}$$

(b, 1)

Explain how can a single perceptron be used to represent the following Boolean functions?

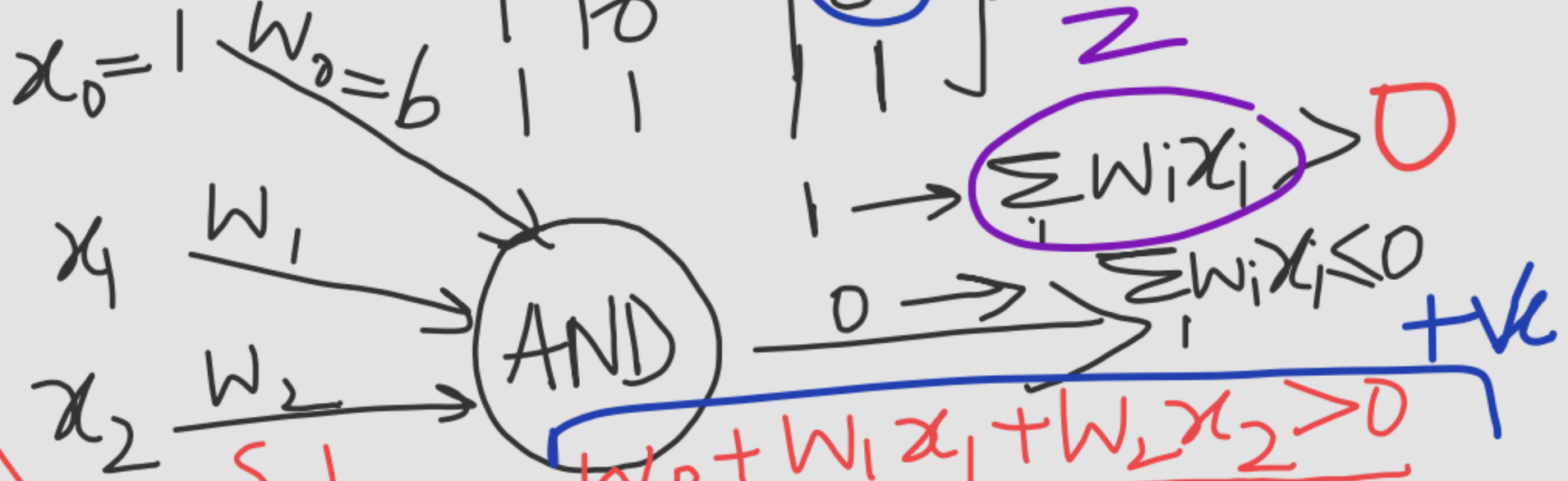
1. AND
2. OR
3. NOT
4. NAND
5. NOR
6. XOR
7. XNOR

AND

x_1	x_2	y
0	0	0
0	1	0
1	0	0
1	1	1

0 : F
1 : T

$W_0 = -1$
$W_1 = 1$
$W_2 = 1$

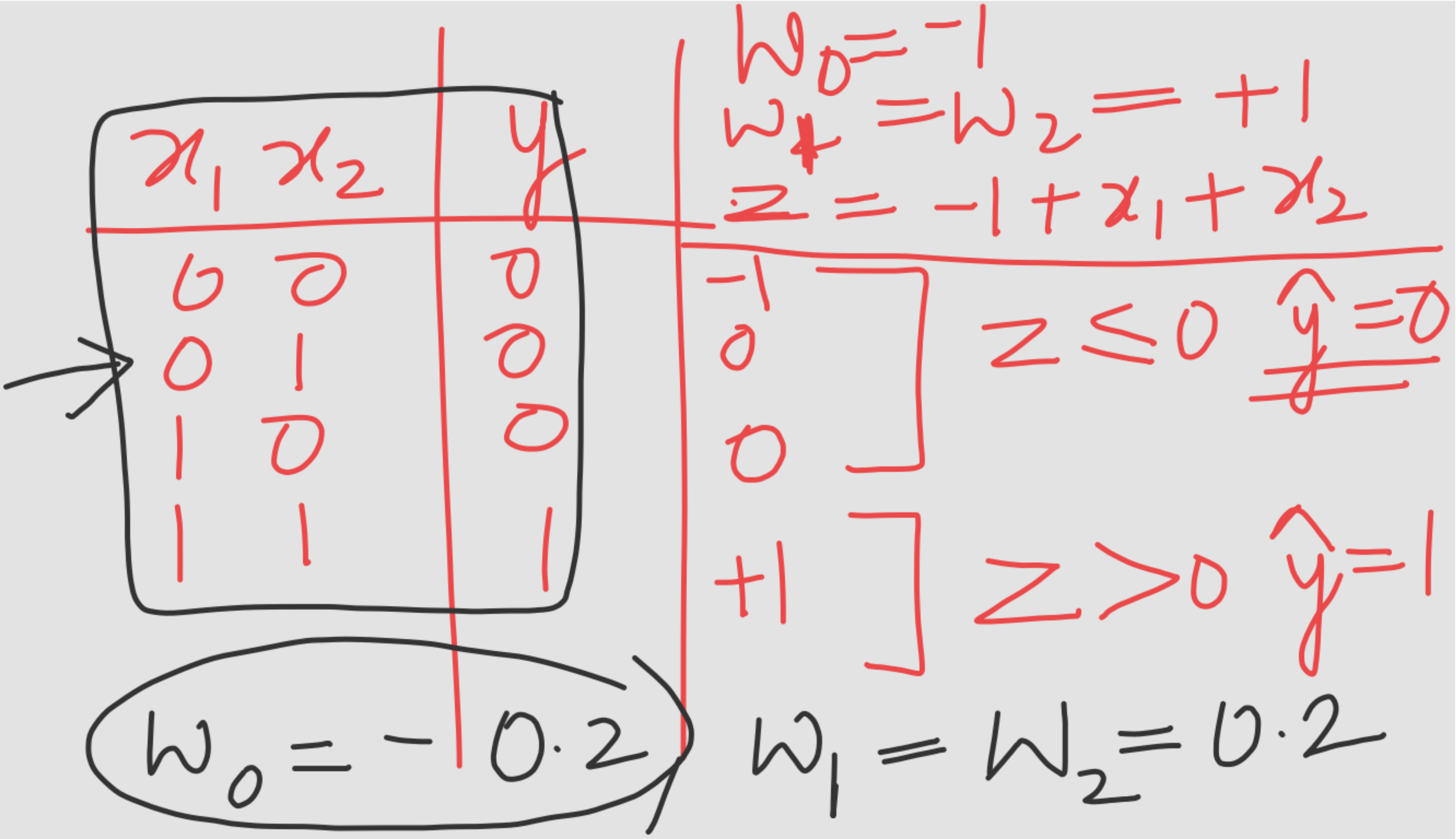


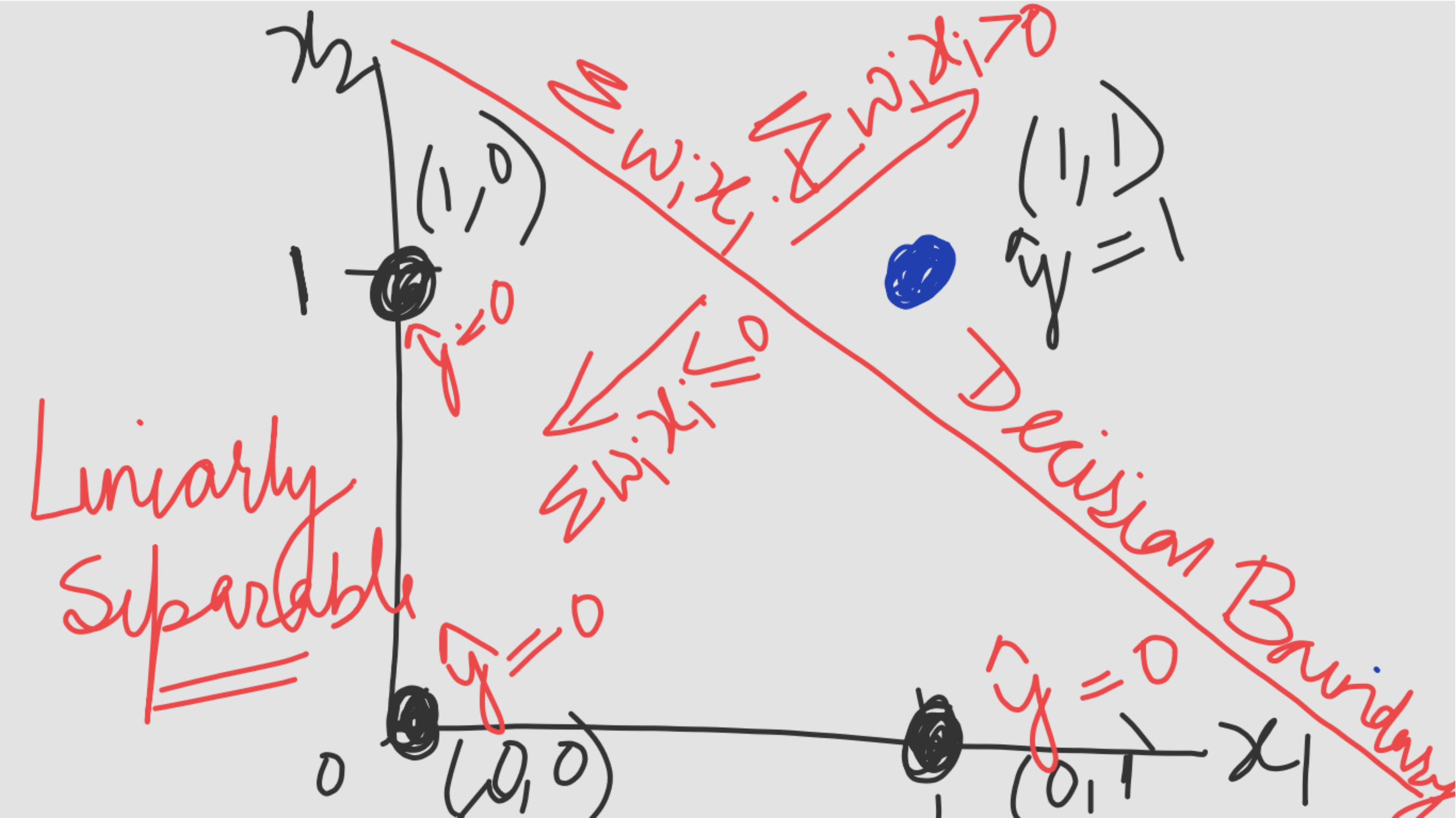
$$\wedge \quad y = \begin{cases} 1 \\ 0 \end{cases}$$

W_1 W_0 W_2

0.5, −0.8, 0.5

$$Z = -0.8 + 0.5x_1 + 0.5x_2$$


x_1 x_2 y
0 0 0
0 1 0
1 0 0
1 1 1
$w_0 = -1$
$w_1 = w_2 = +1$
$z = -1 + x_1 + x_2$
-1
0
0
$z \leq 0$ $\hat{y} = 0$
+1
$z > 0$ $\hat{y} = 1$
$w_0 = -0.2$
$w_1 = w_2 = 0.2$


x_2
x_1
1
0
(1,0)
(0,0)
(0,1)
(1,1)
$\hat{y}=1$
$\hat{y}=0$
$\hat{y}=0$
$\hat{y}=0$
$\sum w_i x_i > 0$
$\sum w_i x_i = 0$
Decision Boundary
Linearly Separable