Artificial Neural Networks

Plan of Attack

Plan of Attack

What we will learn in this section:

- The Neuron
- The Activation Function
- How do Neural Networks work? (example)
- How do Neural Networks learn?
- Gradient Descent
- Stochastic Gradient Descent
- Backpropagation

The Neuron

The Neuron

Image Source: www.austincc.edu

The Neuron

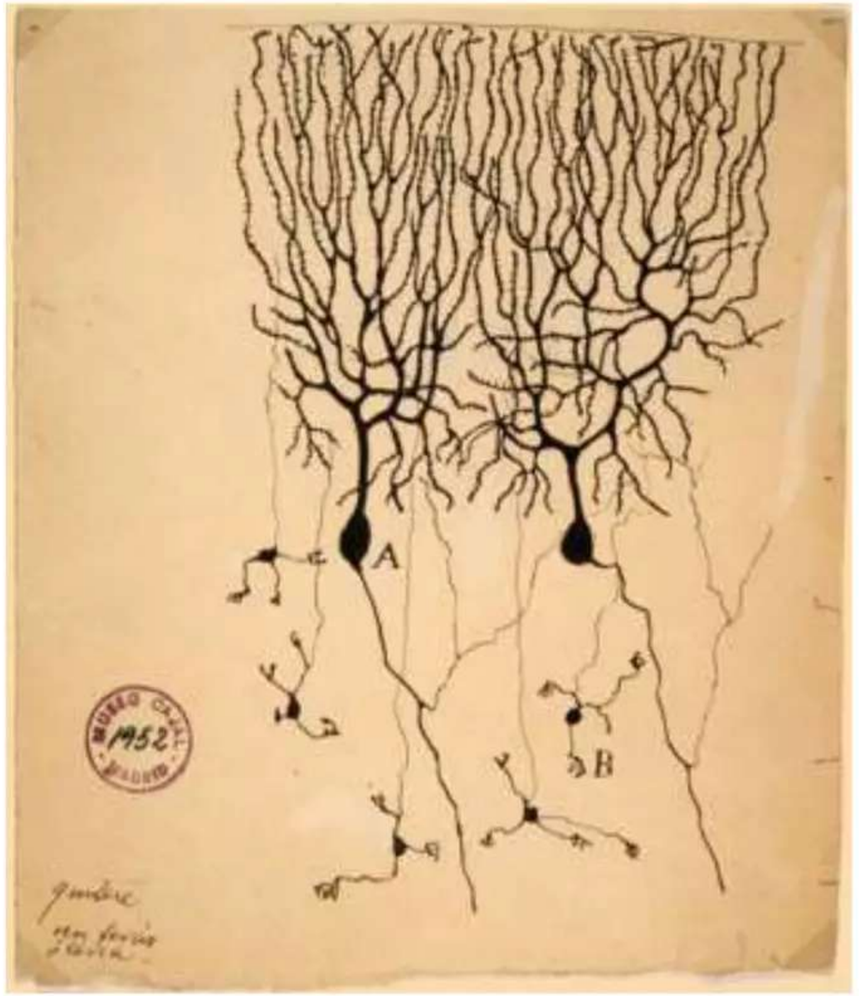

Image Source: Wikipedia

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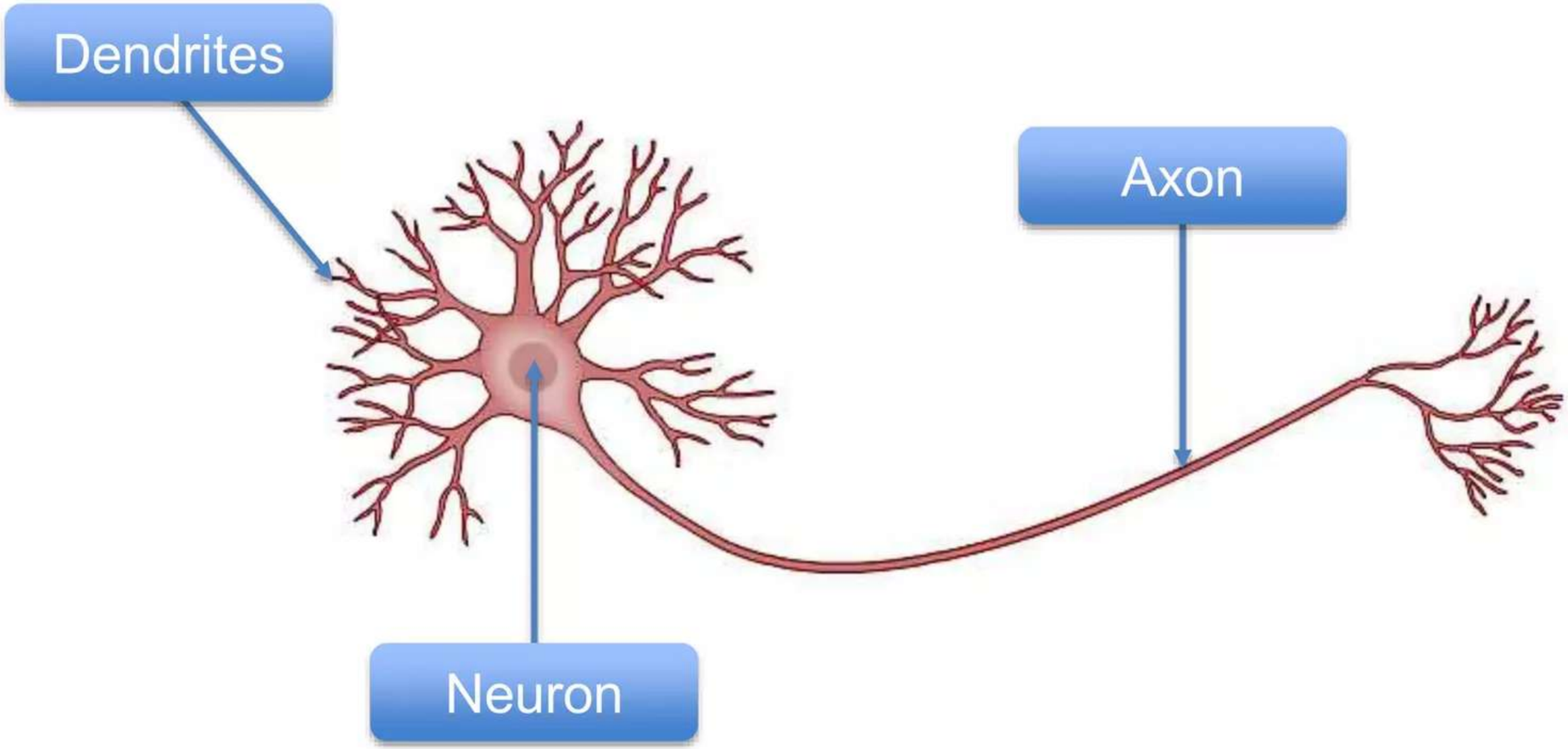

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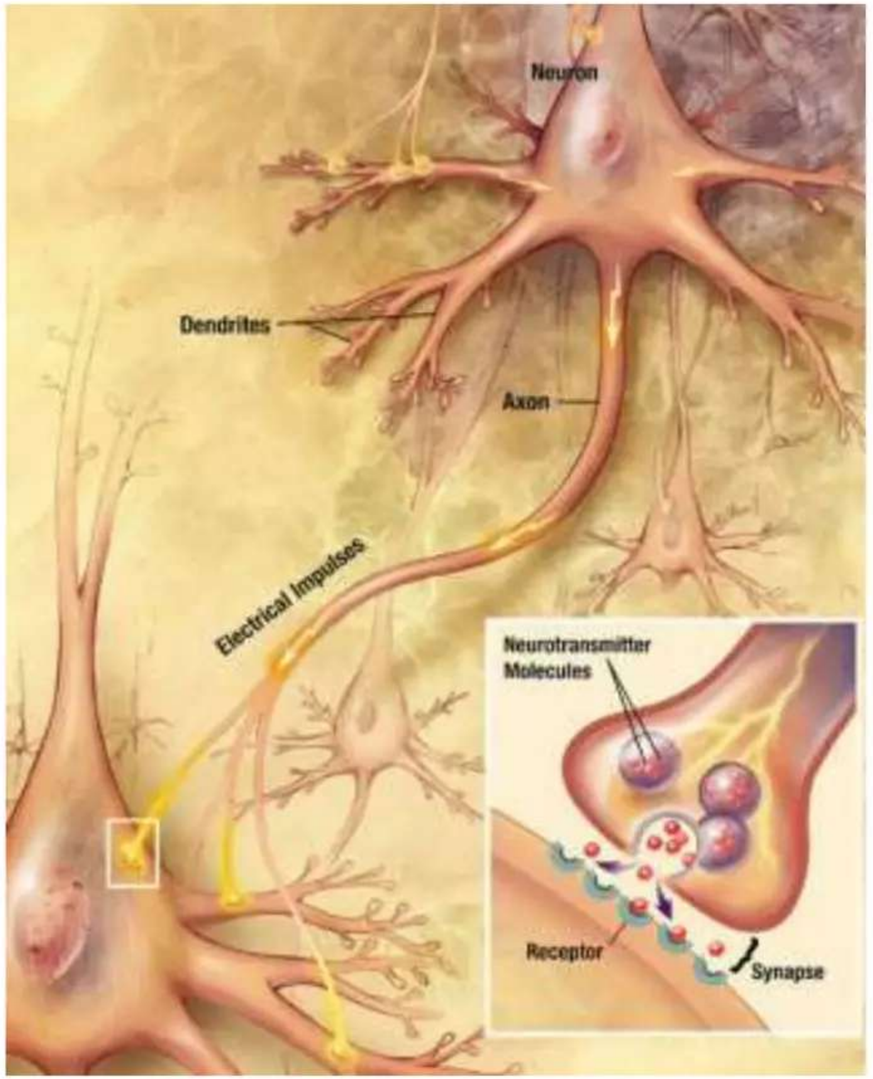

Image Source: Wikipedia

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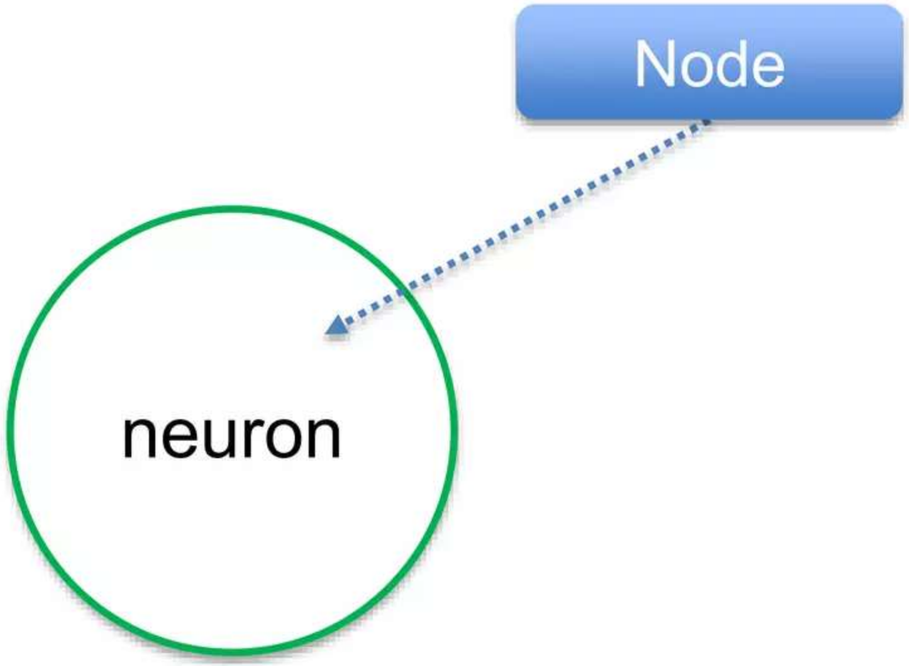

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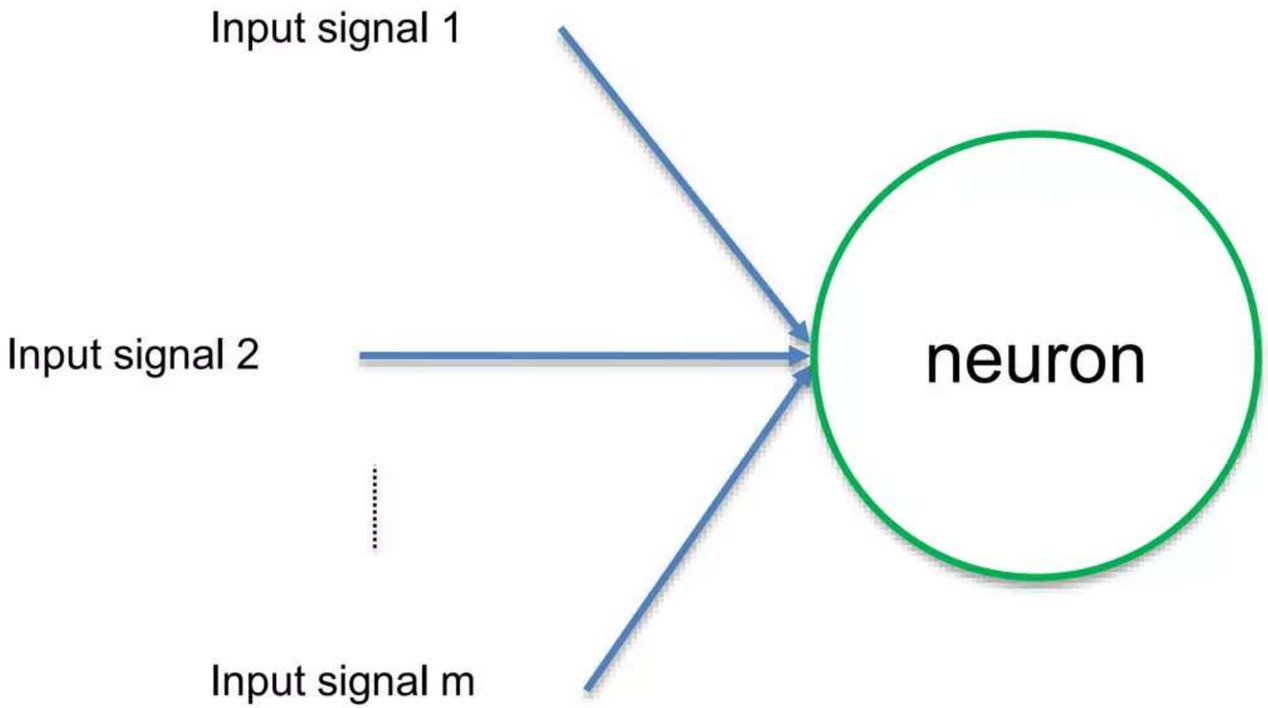

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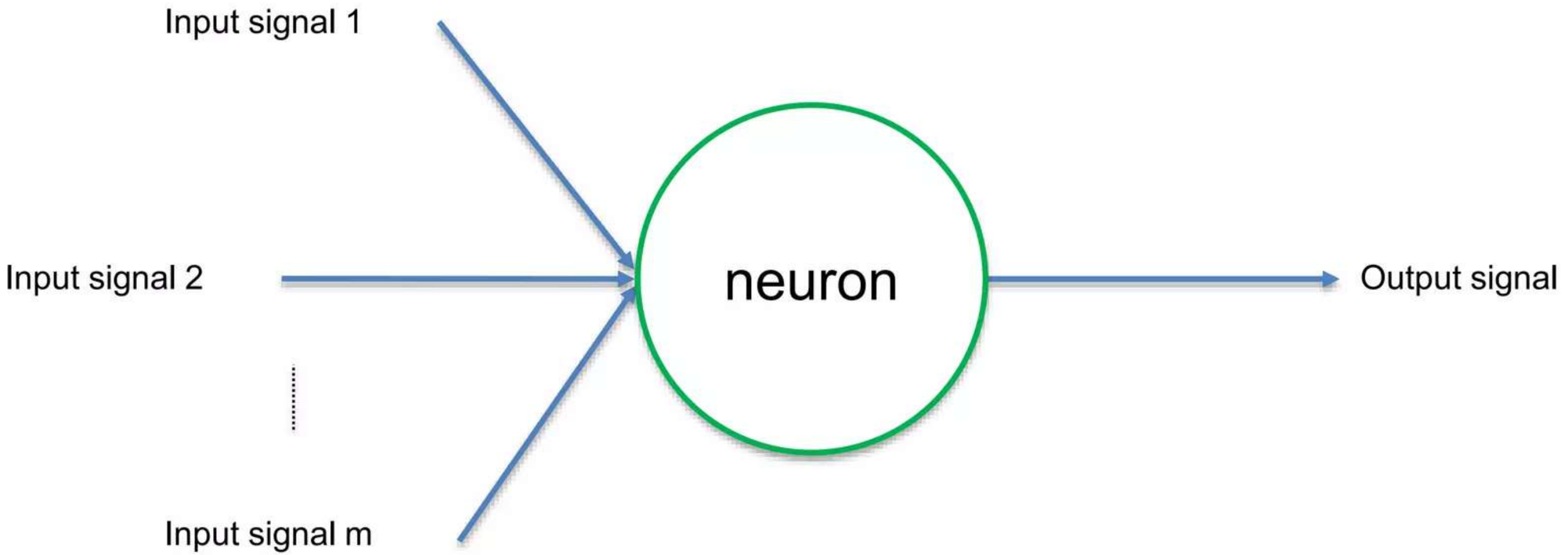

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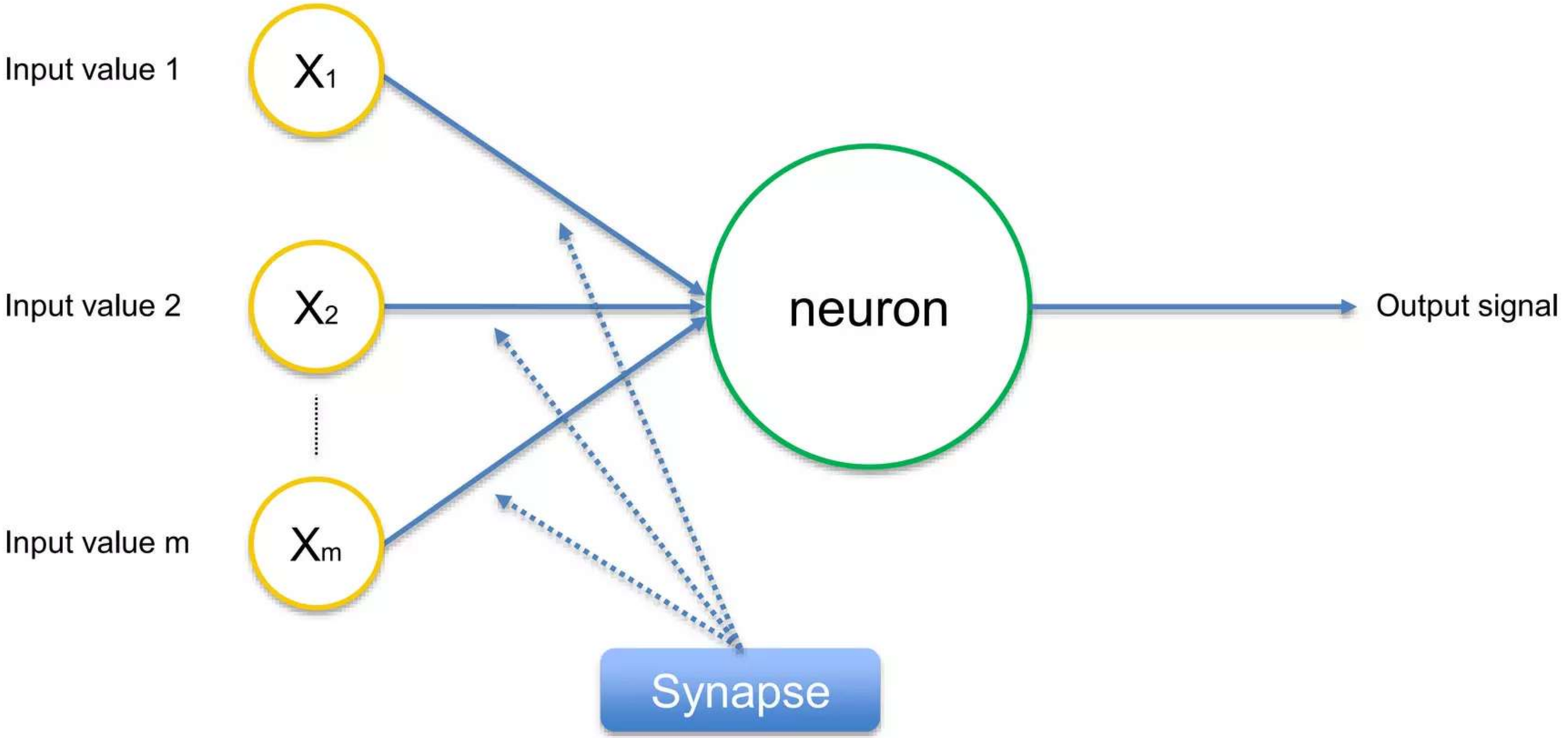

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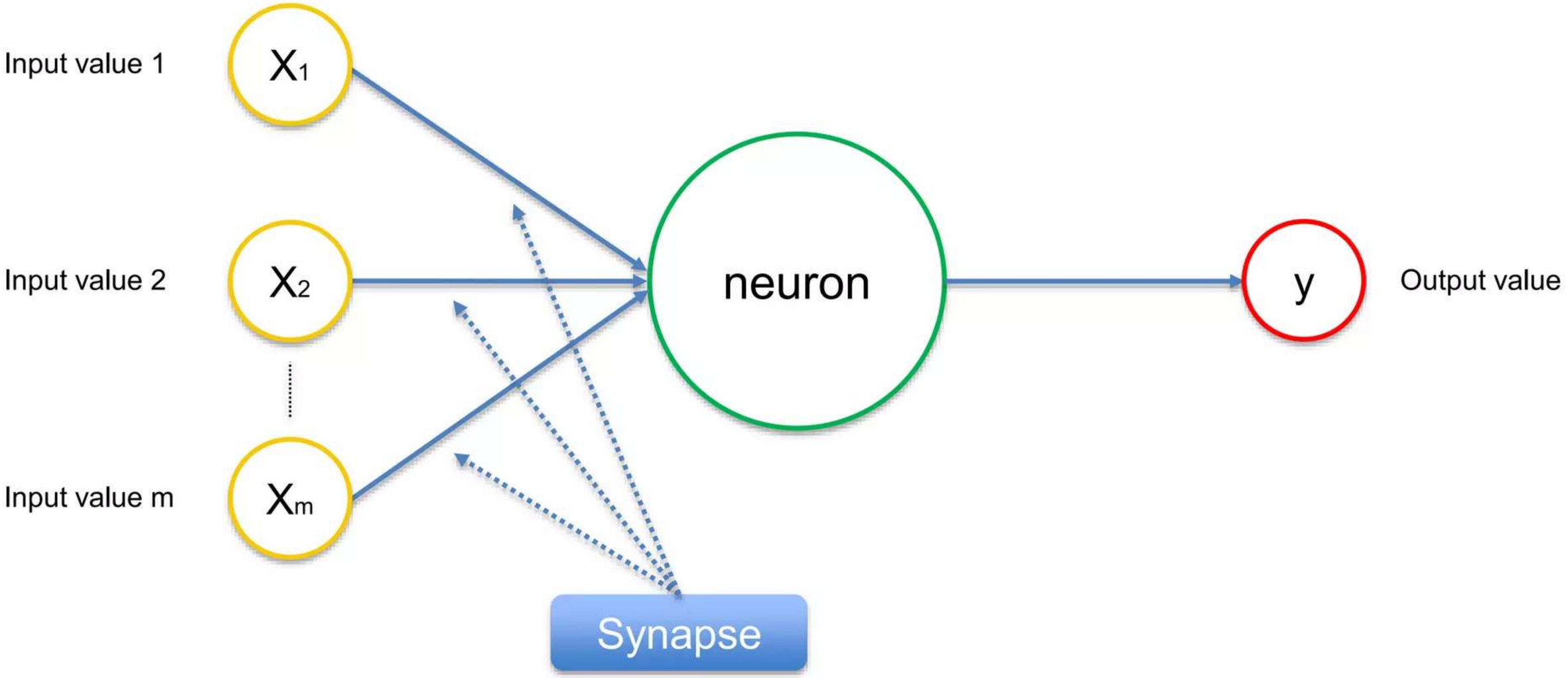

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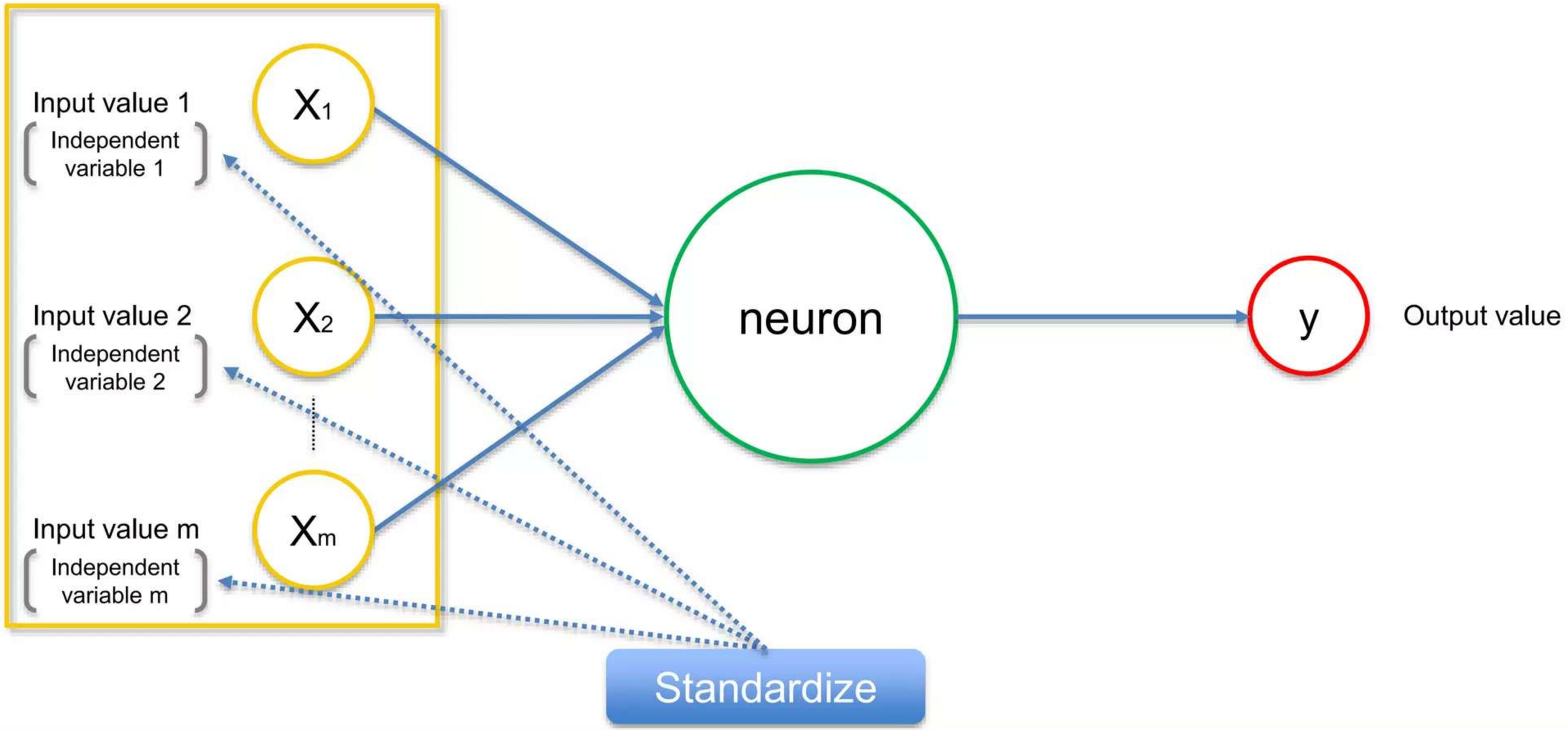
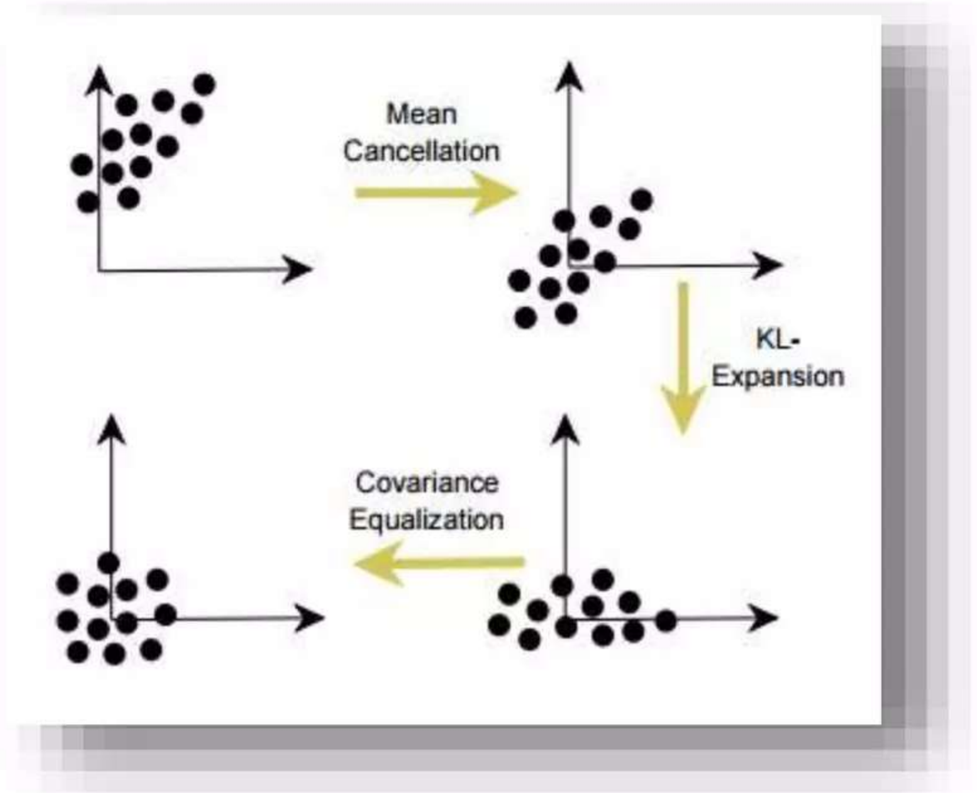


The Neuron

Additional Reading:

Efficient BackProp

By Yann LeCun et al. (1998)



Link:

http://yann.lecun.com/exdb/publis/pdf/lecun-98b.pdf

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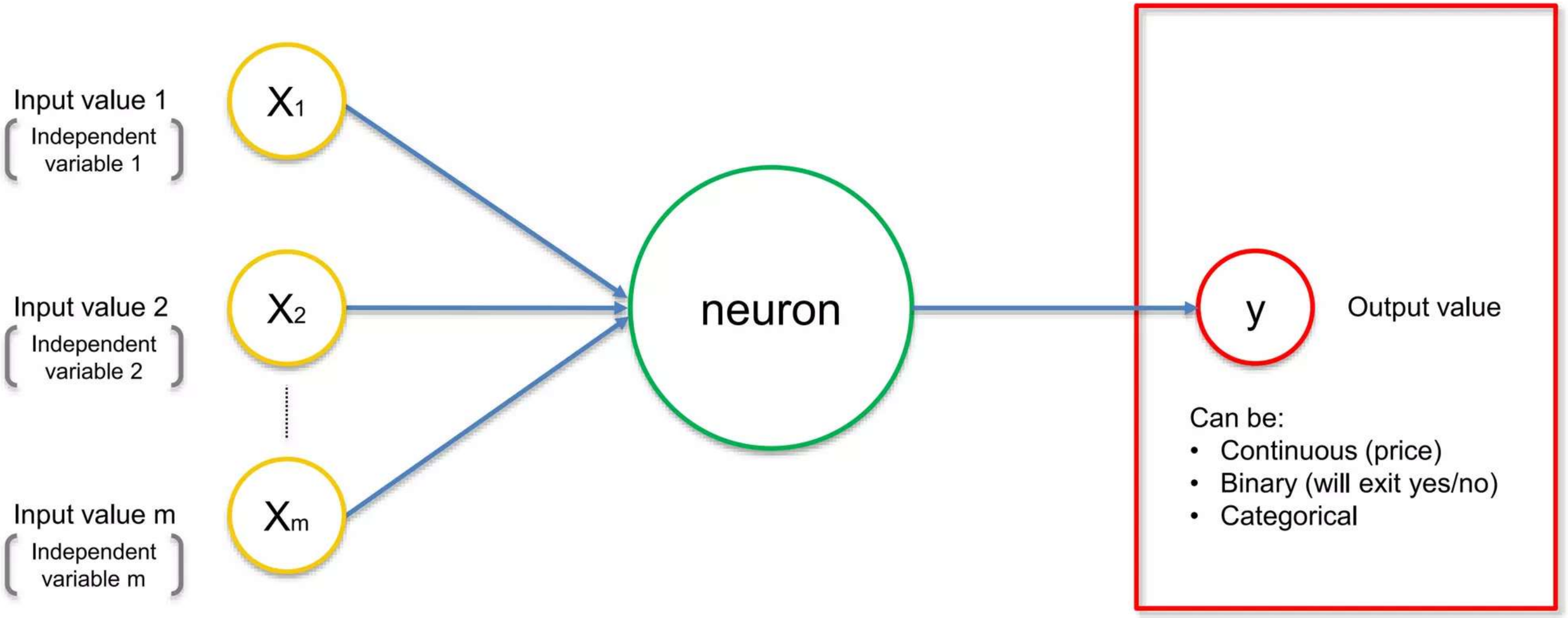

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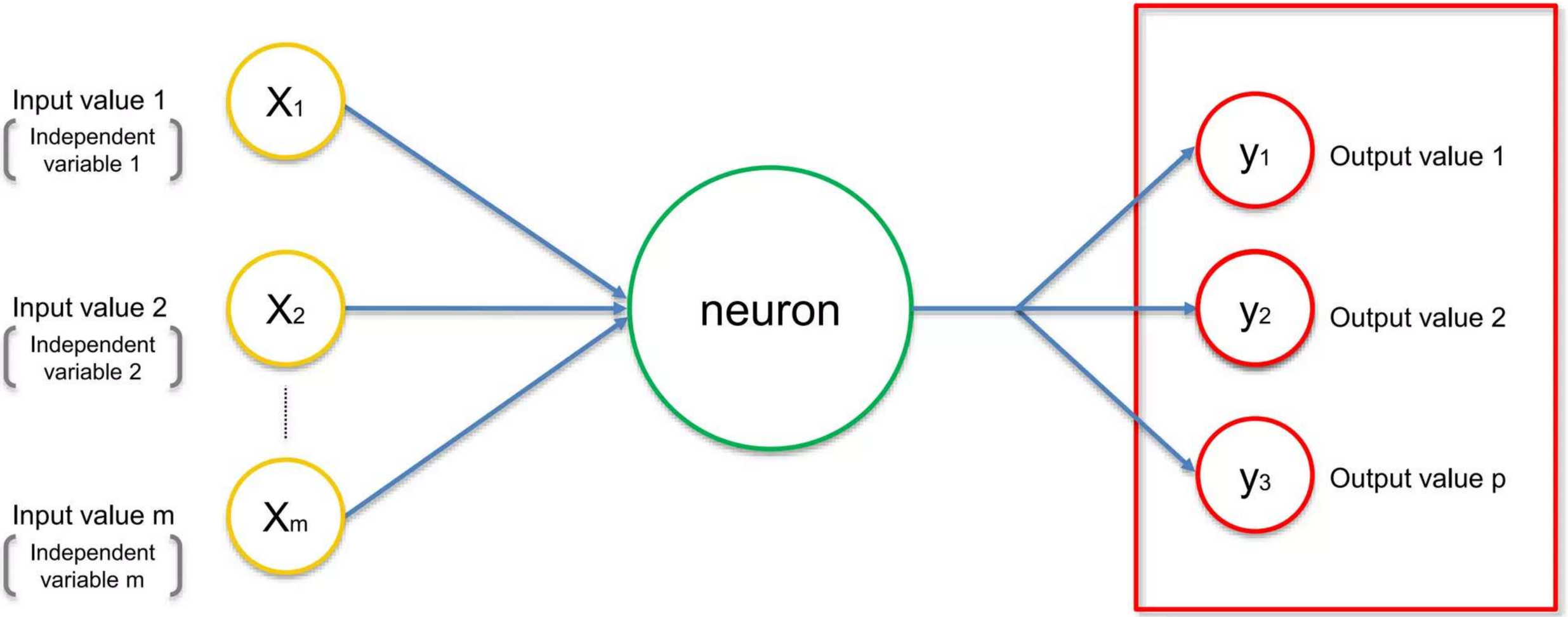

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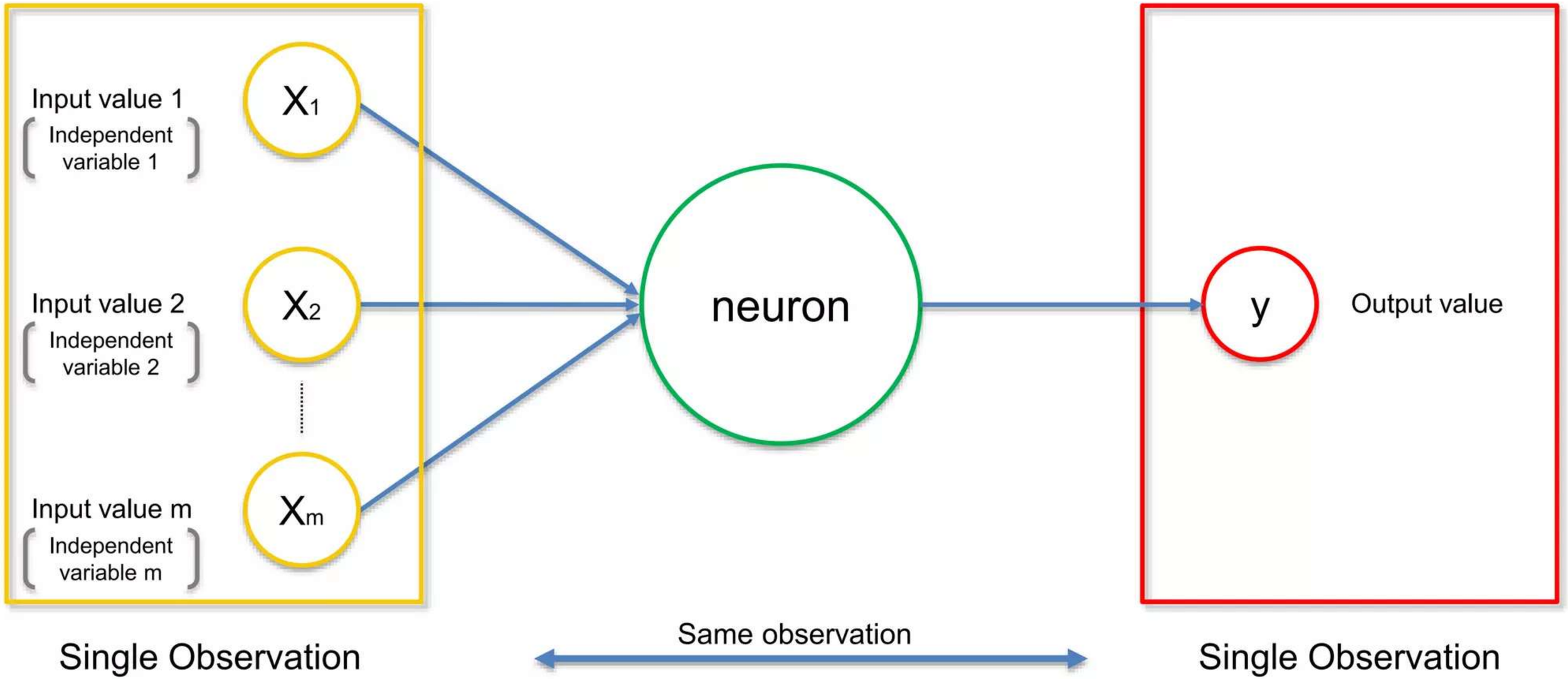

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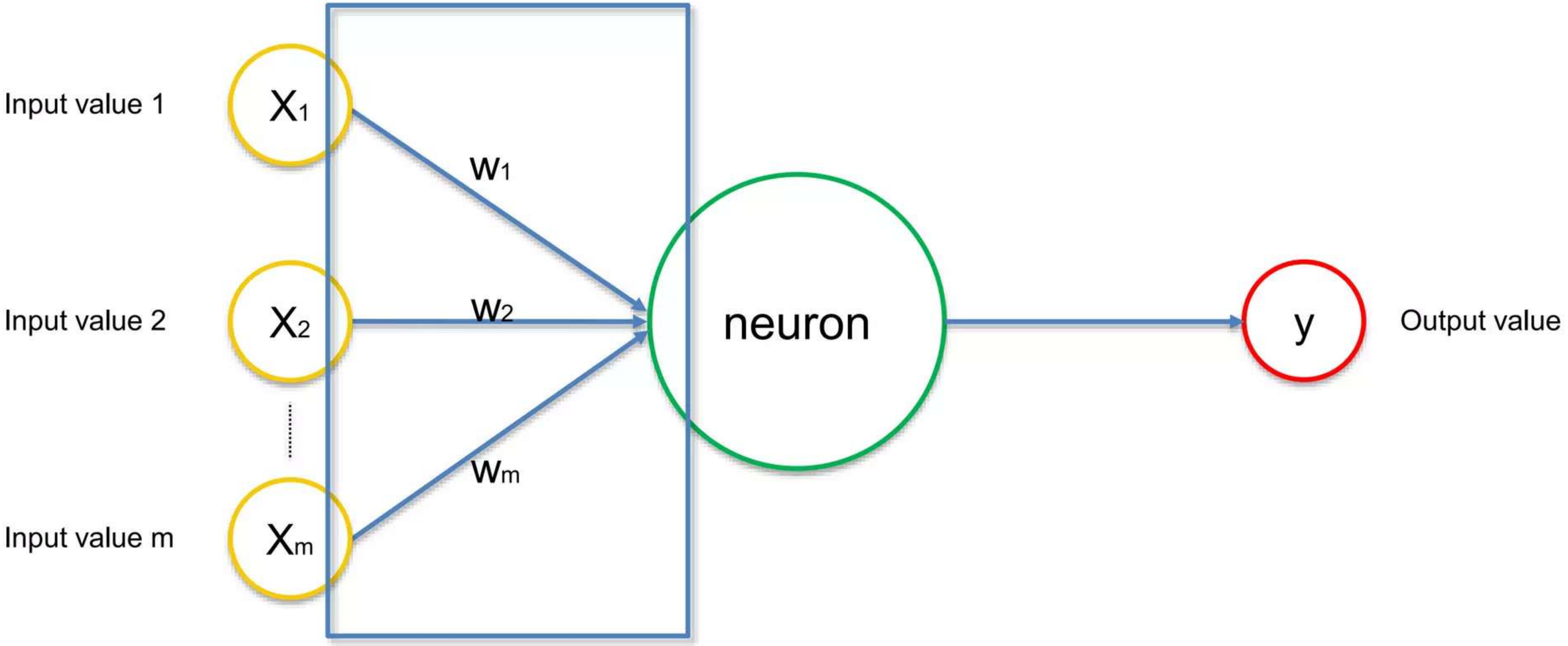

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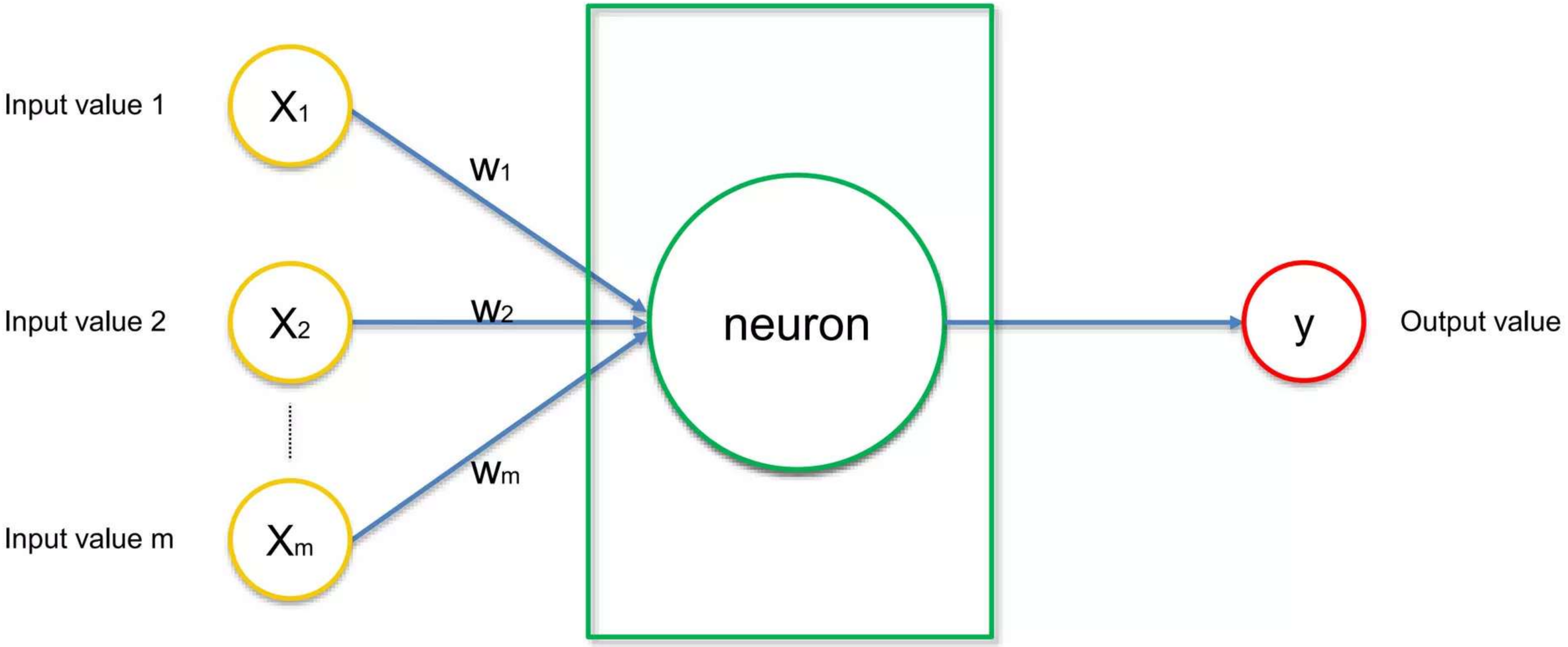

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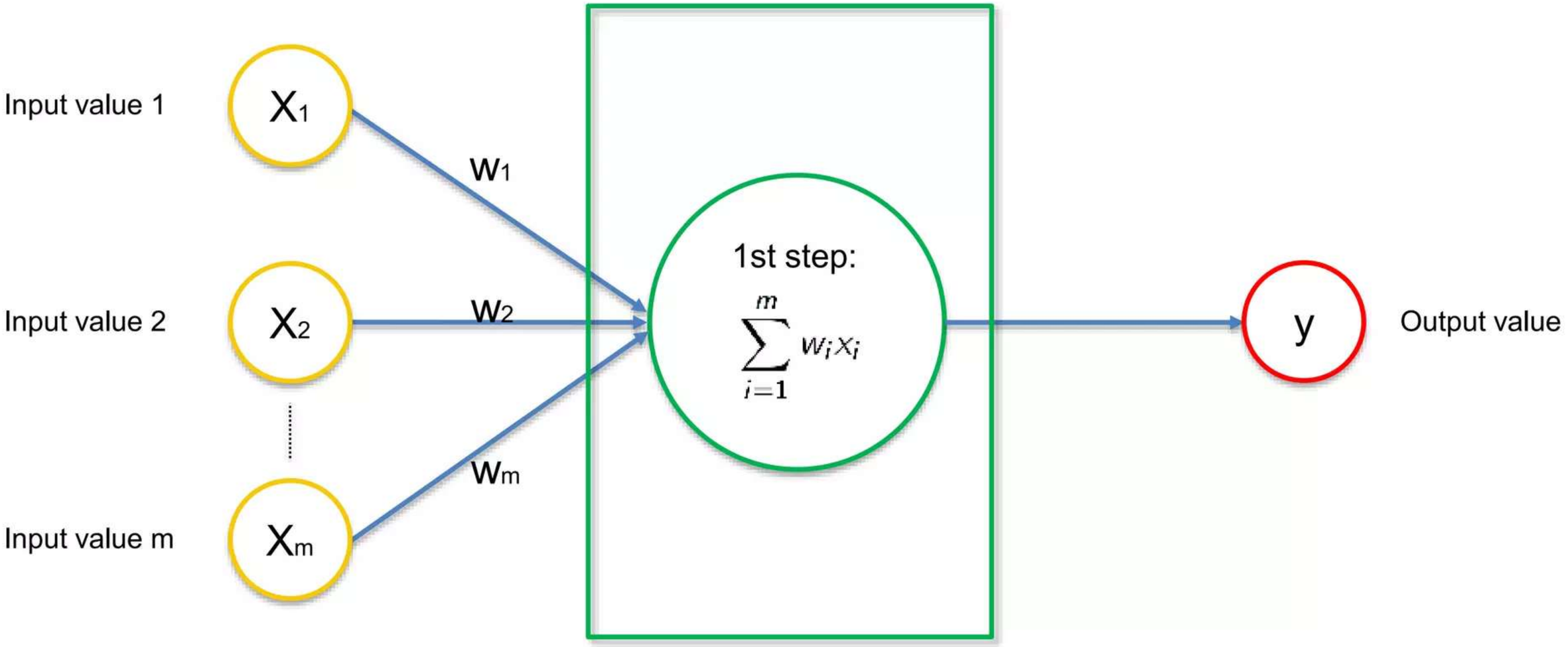

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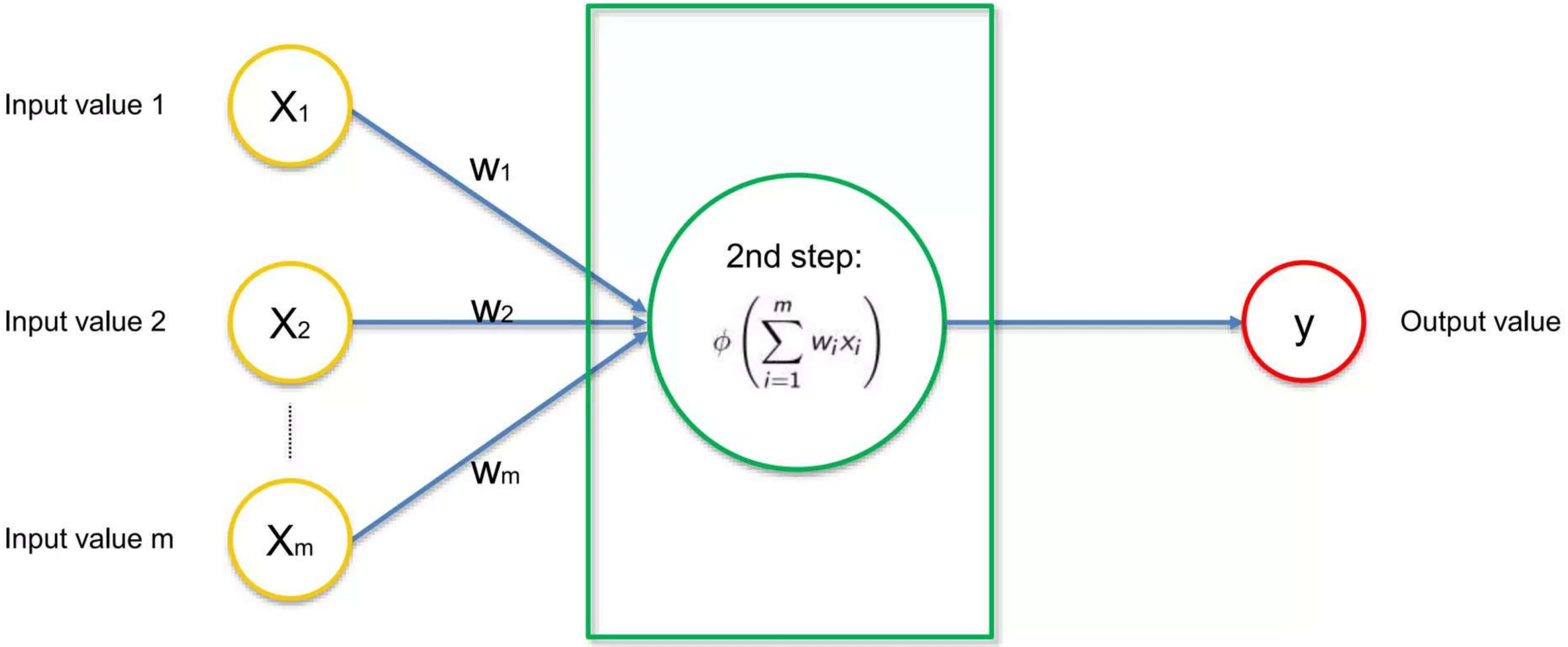

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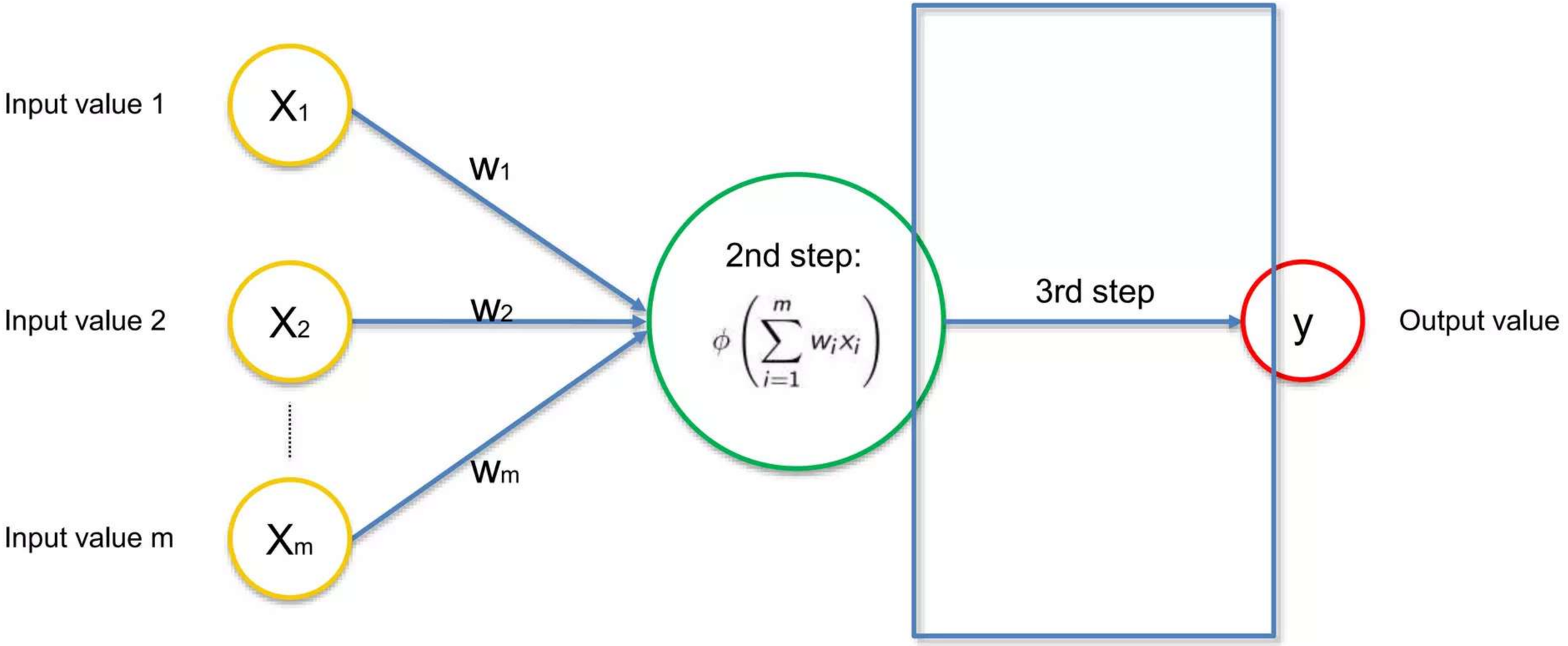
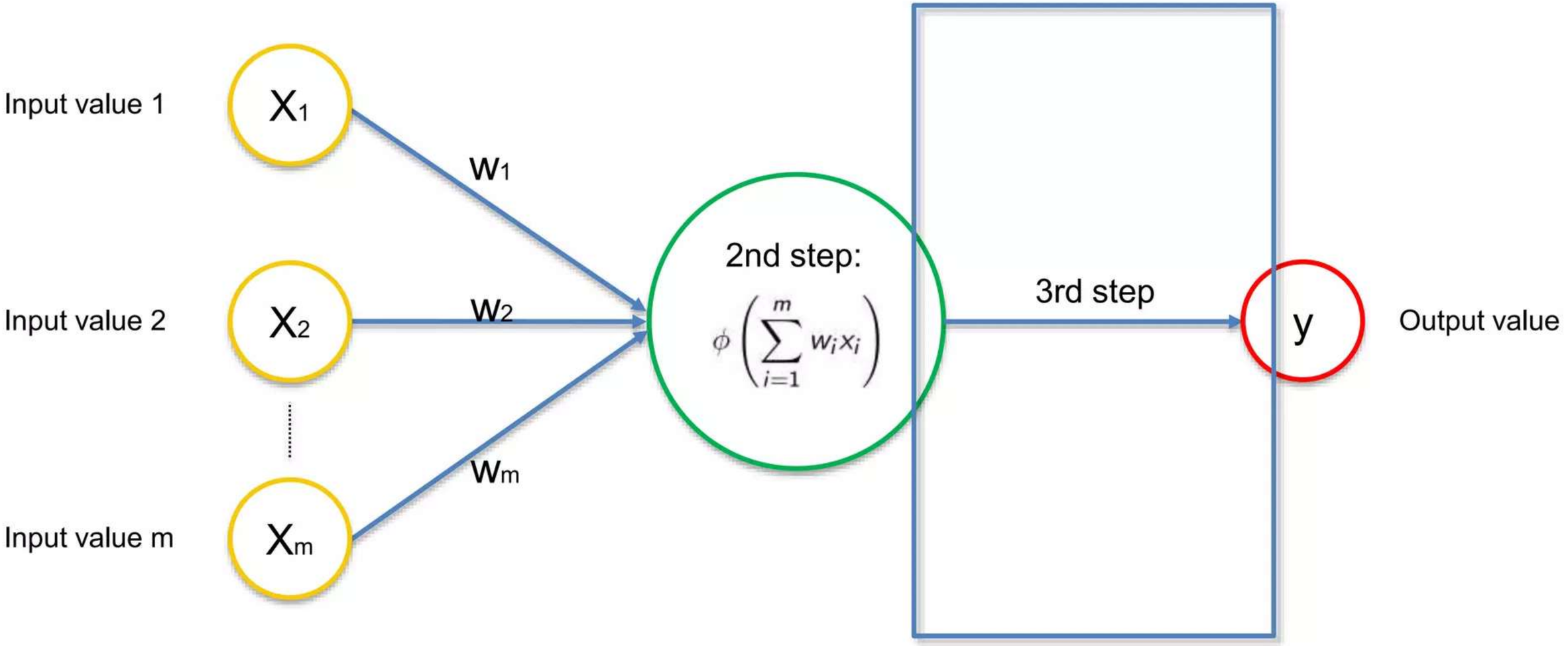


The Activation Function

The Activation Function



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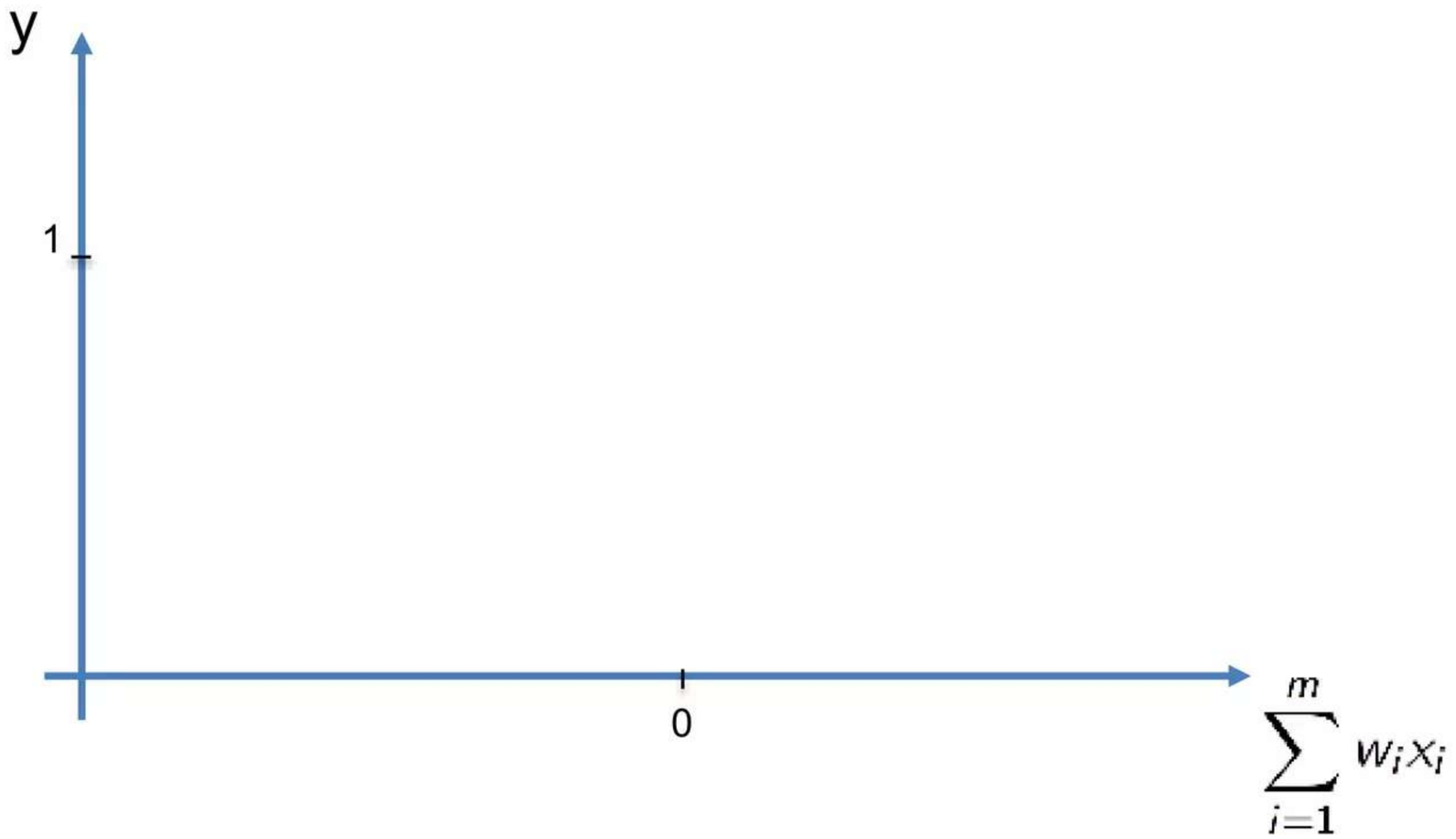
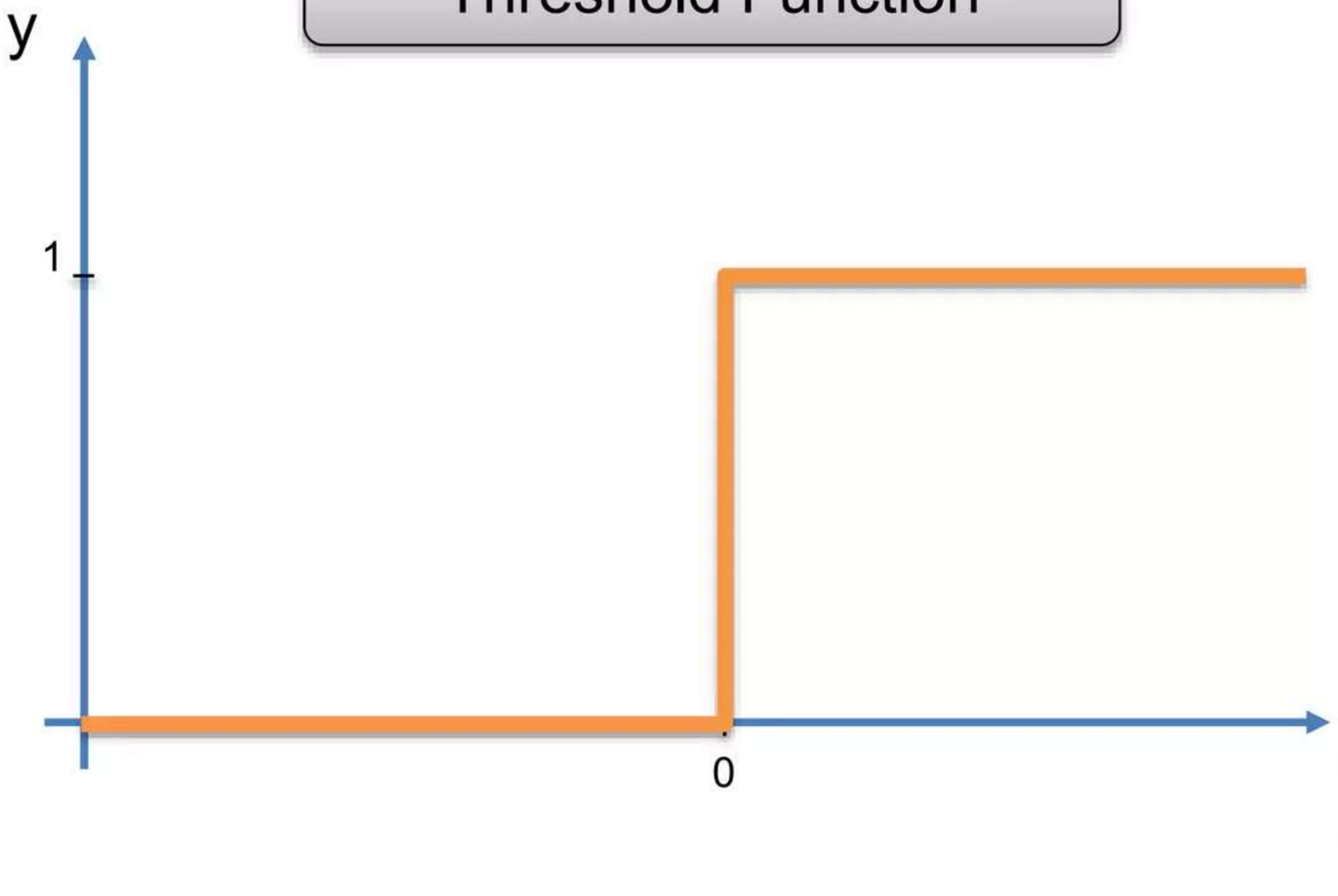


The Activation Function

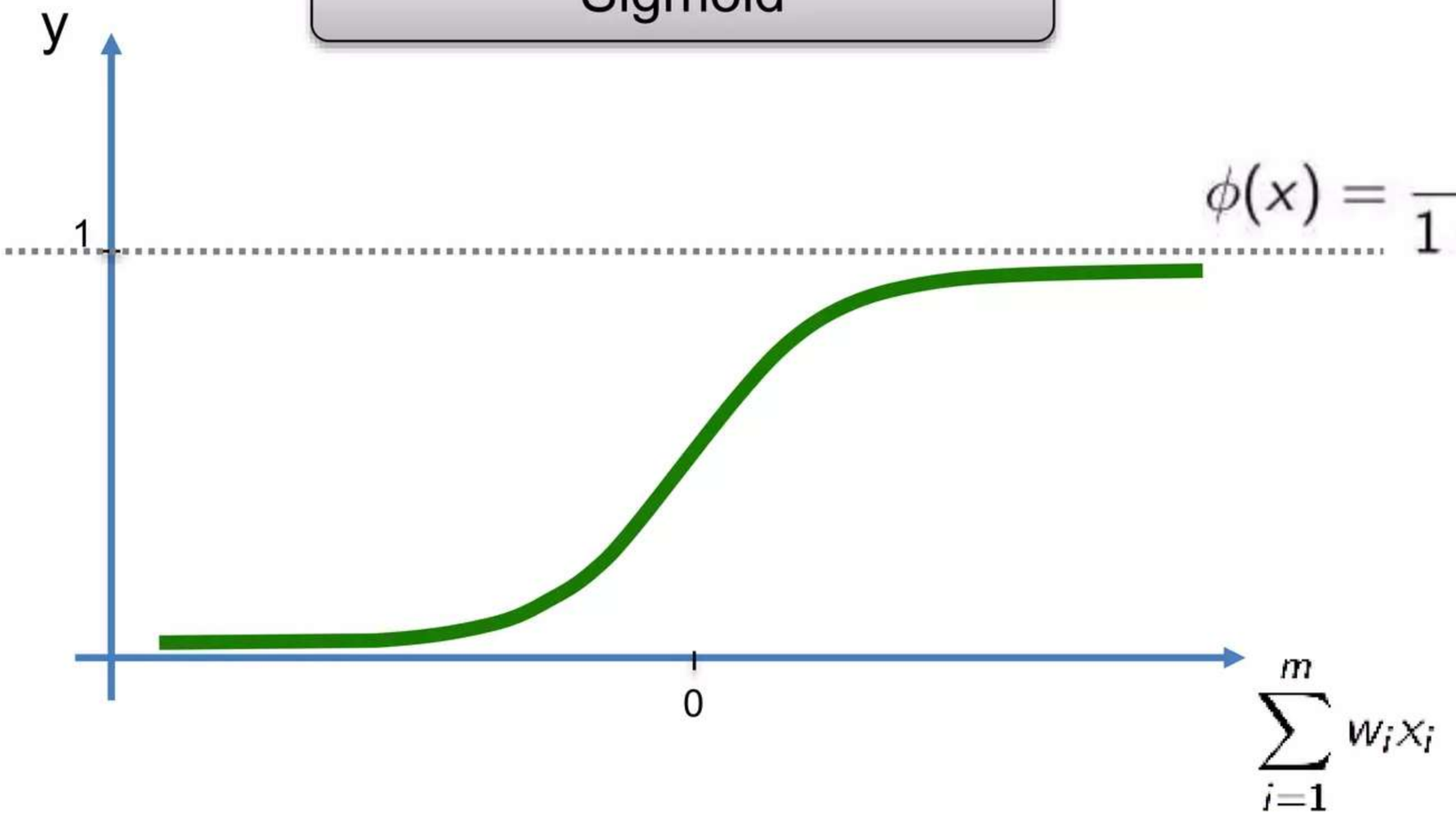
Threshold Function



$$\phi(x) = \begin{cases} 1 \text{ if } x \geq 0 \\ 0 \text{ if } x < 0 \end{cases}$$

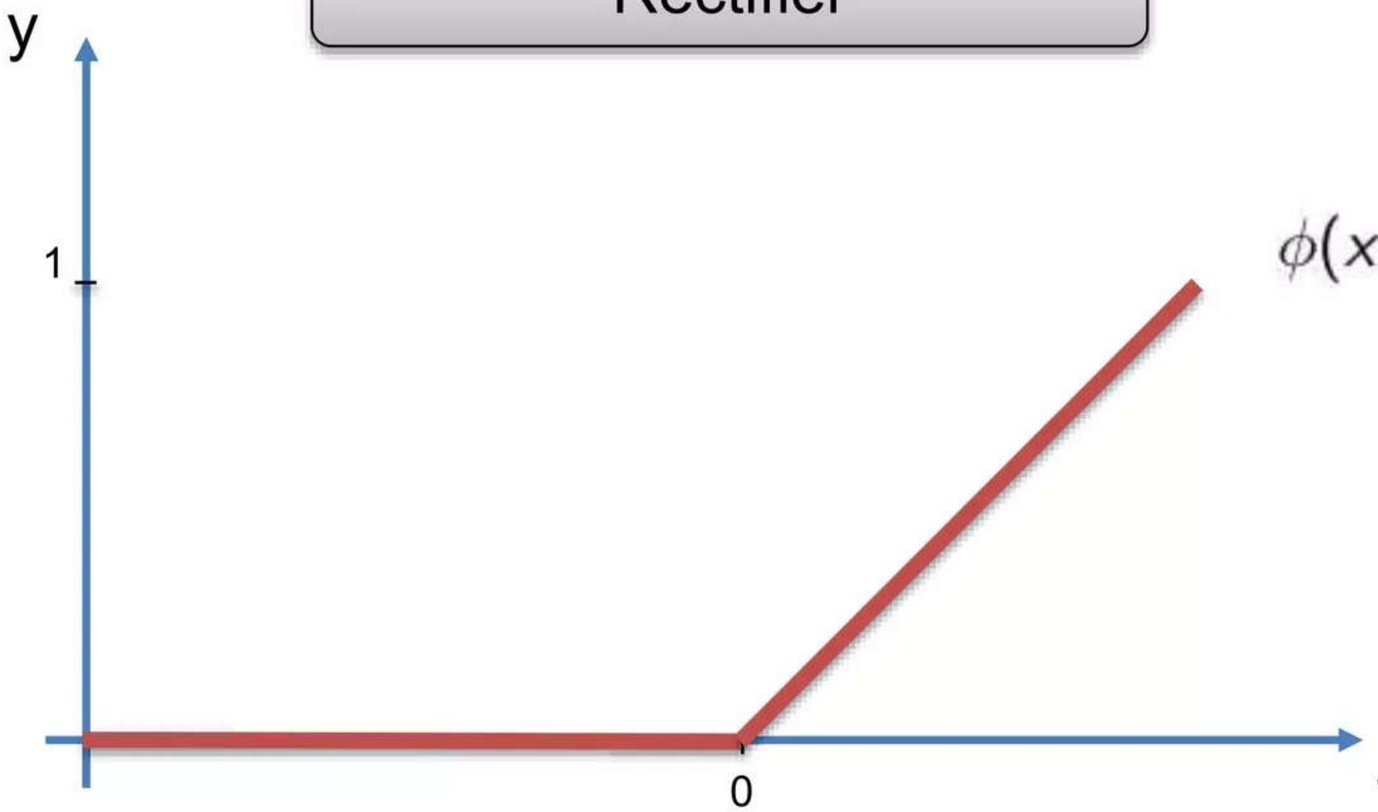
The Activation Function

Sigmoid



The Activation Function

Rectifier

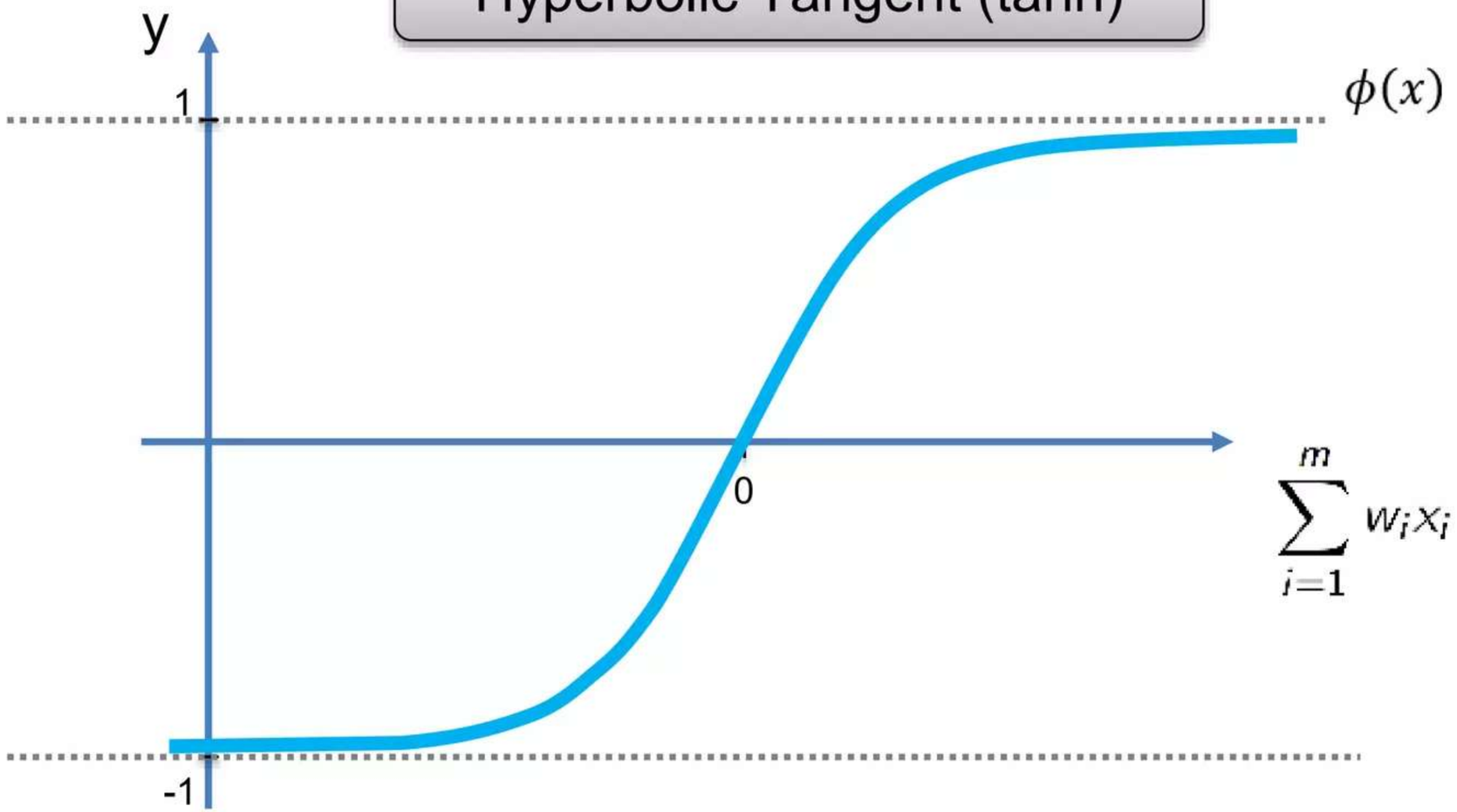


$$\phi(x) = \max(x, 0)$$

$$\sum_{i=1}^{m} w_i x_i$$

The Activation Function

Hyperbolic Tangent (tanh)



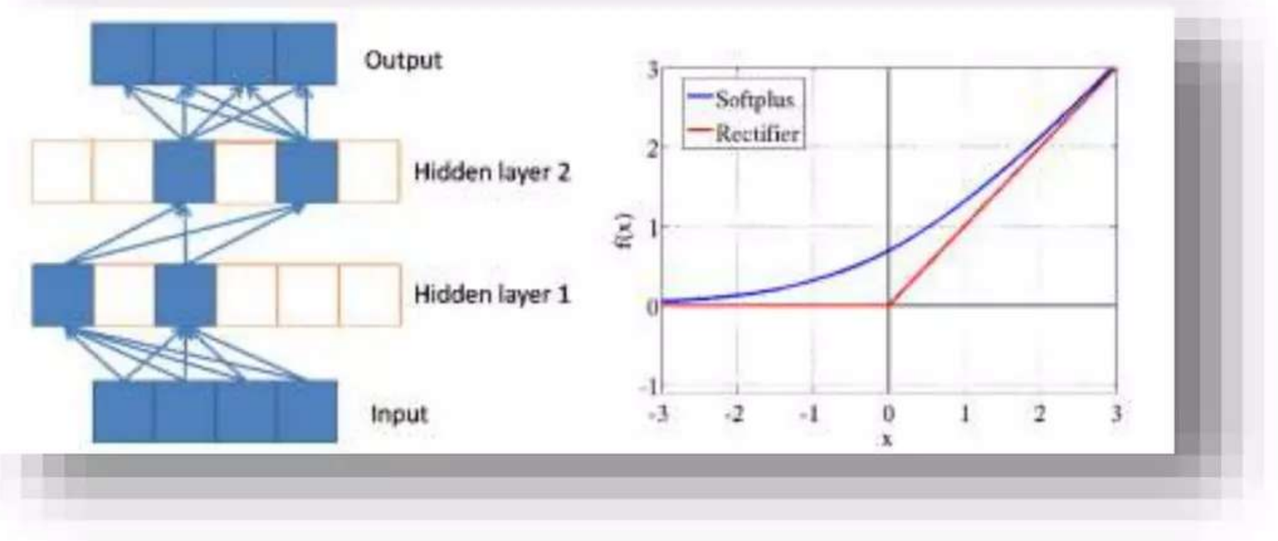
$$\phi(x) = \frac{1 - e^{-2x}}{1 + e^{-2x}}$$

The Activation Function

Additional Reading:

Deep sparse rectifier neural networks

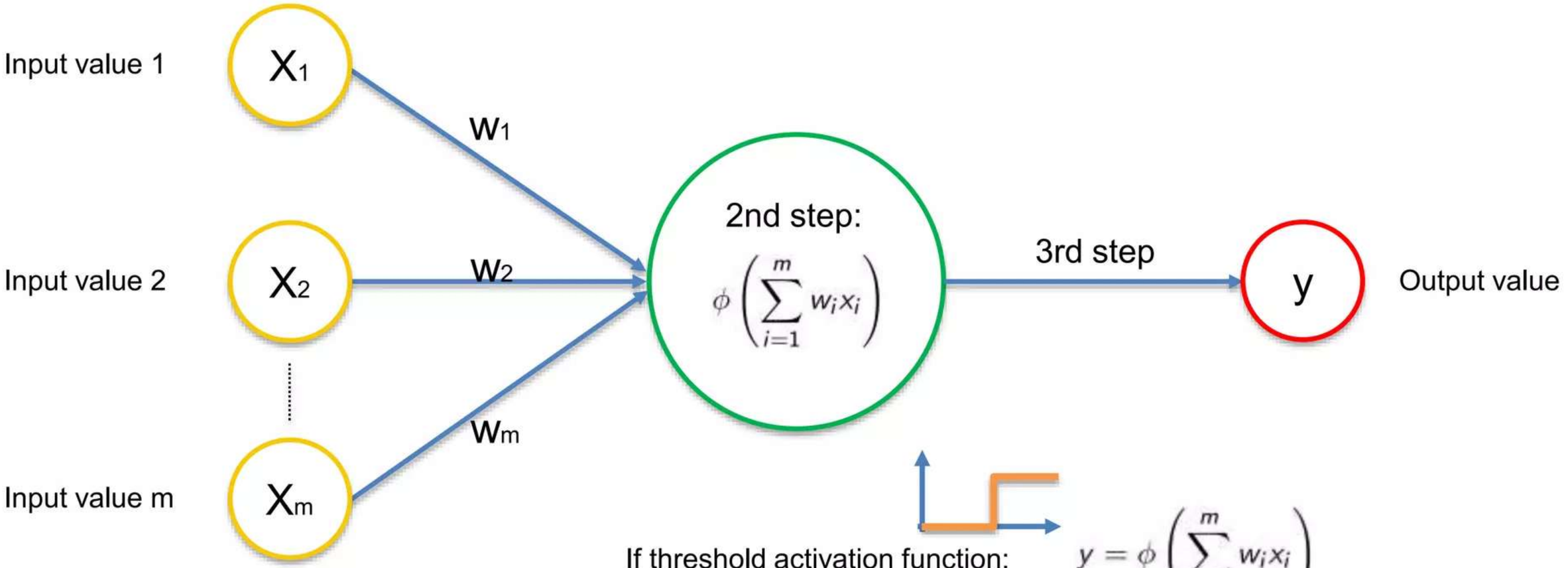
By Xavier Glorot et al. (2011)



Link:

http://jmlr.org/proceedings/papers/v15/glorot11a/glorot11a.pdf

The Activation Function



Assuming the DV is binary (y = 0 or 1)

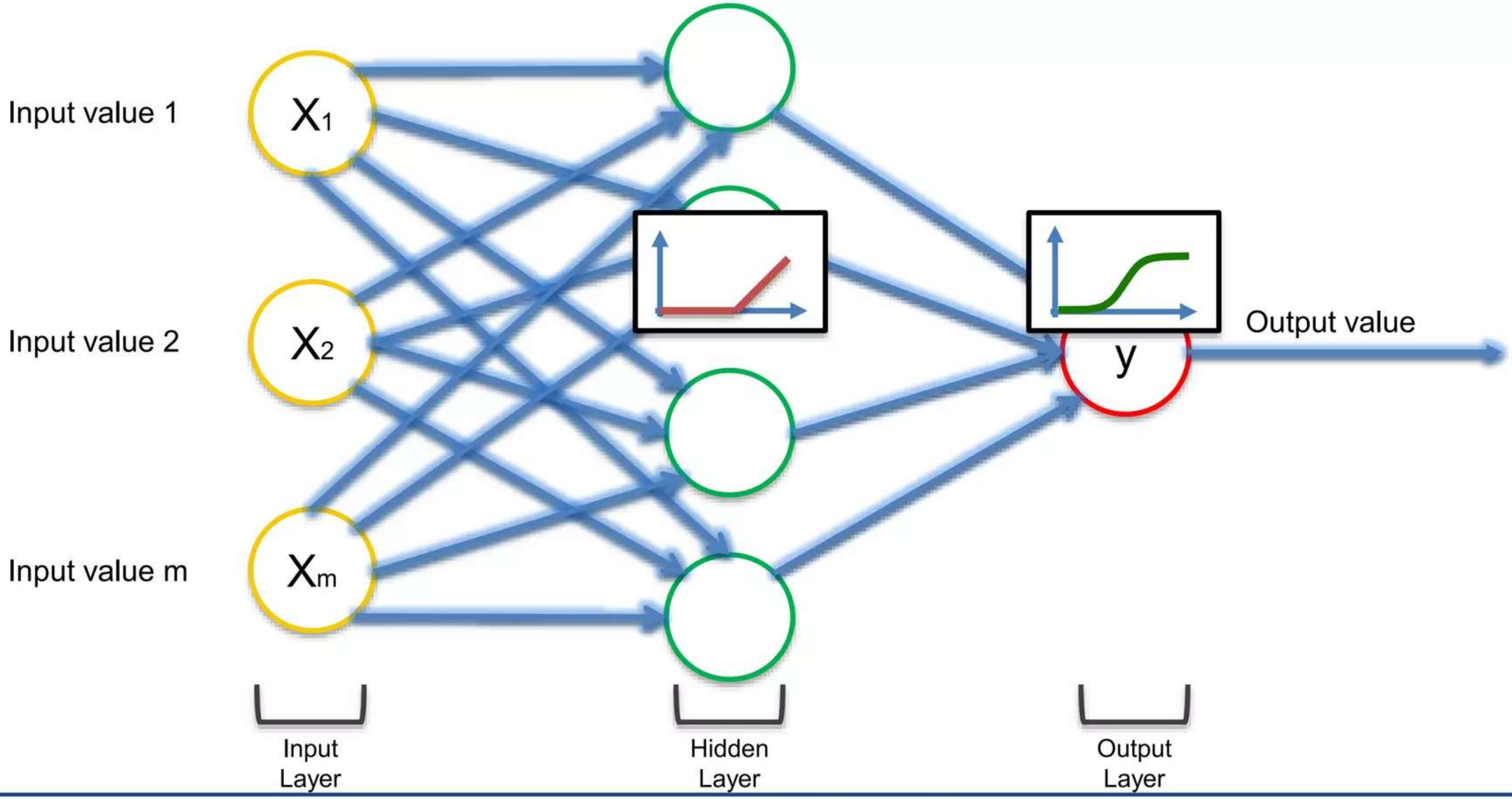
If threshold activation function:

$$y = \phi\left(\sum_{i=1}^{m} w_i x_i\right)$$

If sigmoid activation function:

$$\mathbb{P}(y = 1) = \phi\left(\sum_{i=1}^{m} w_i x_i\right)$$

The Activation Function



How do NNs Work?

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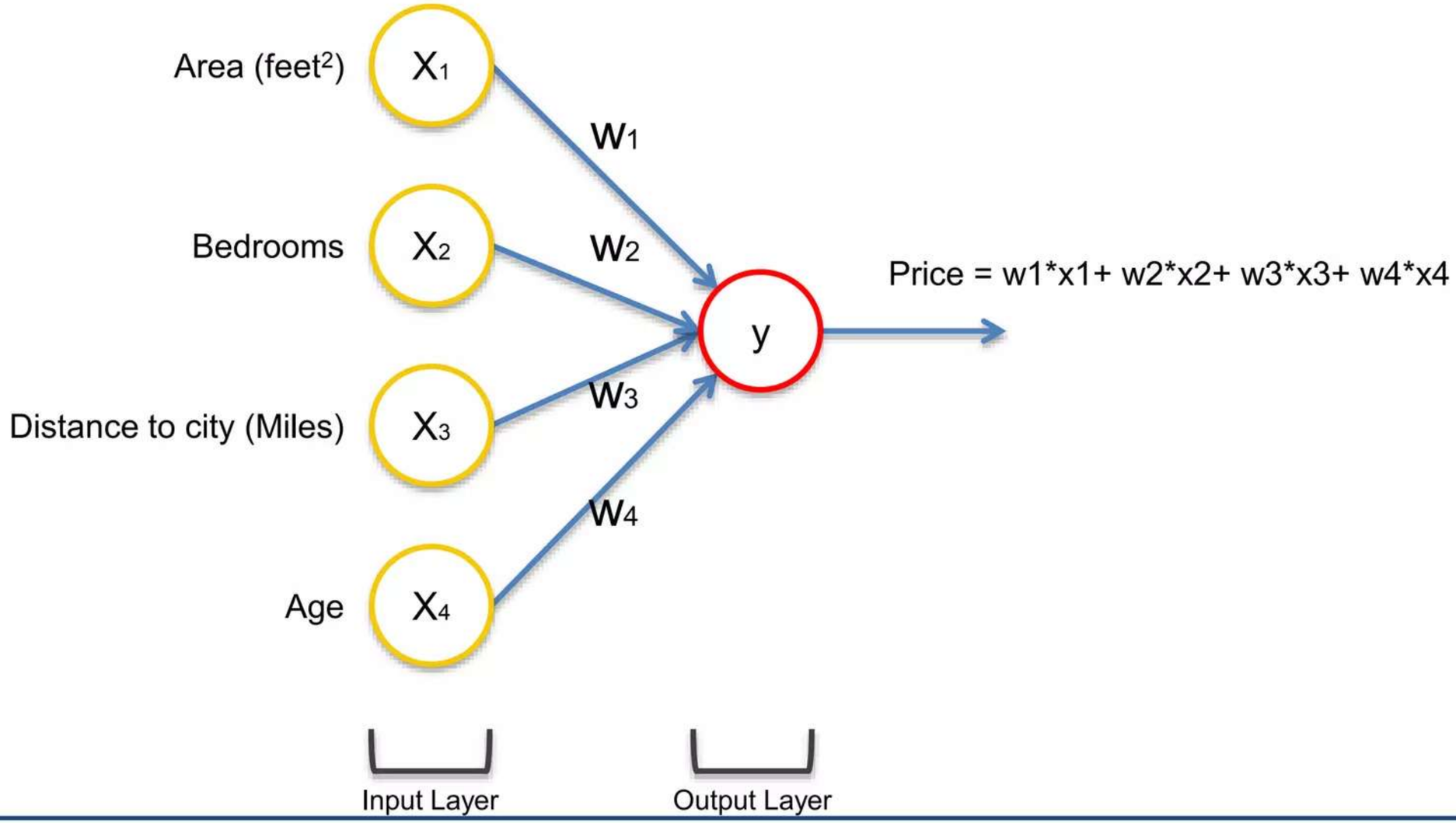

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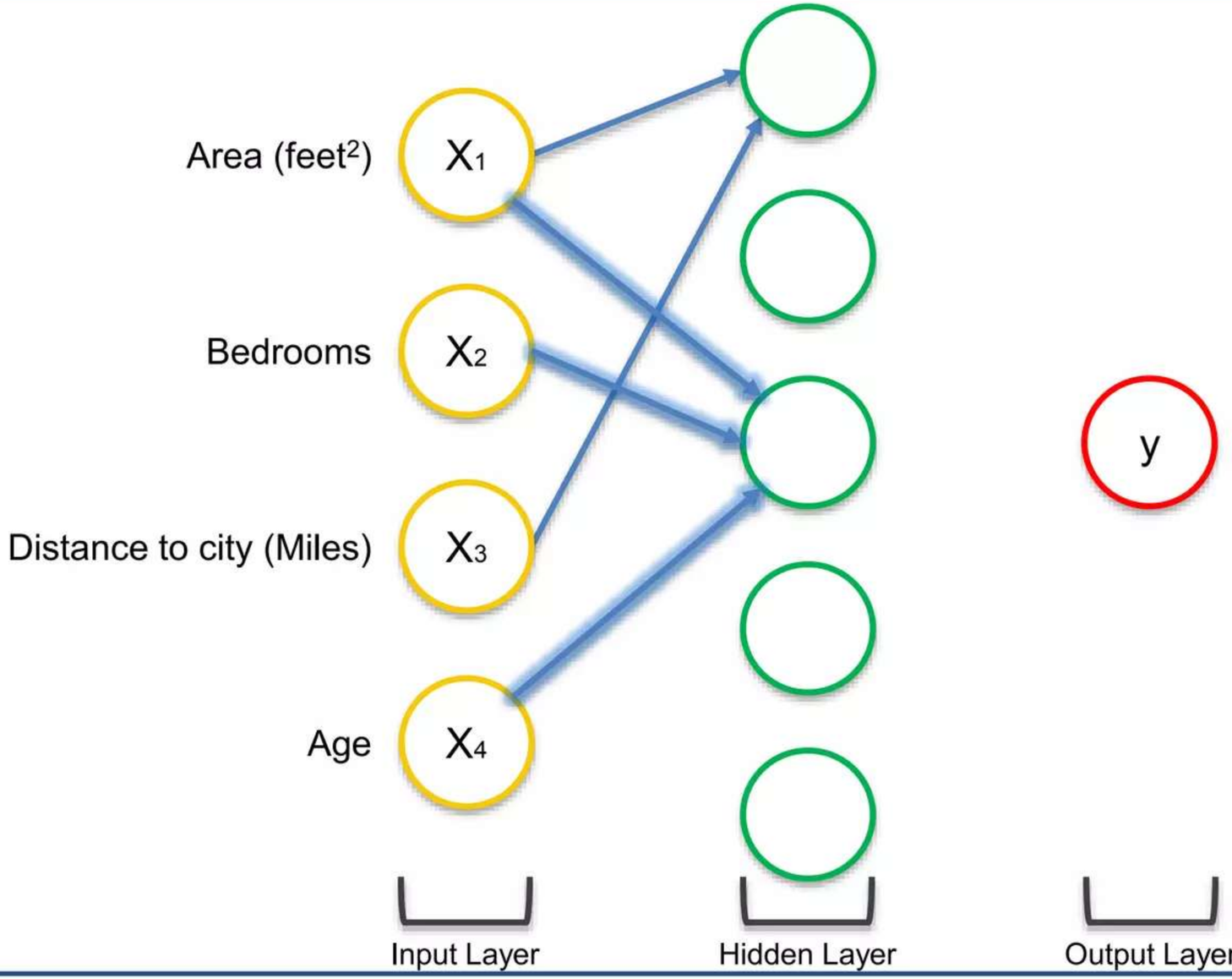

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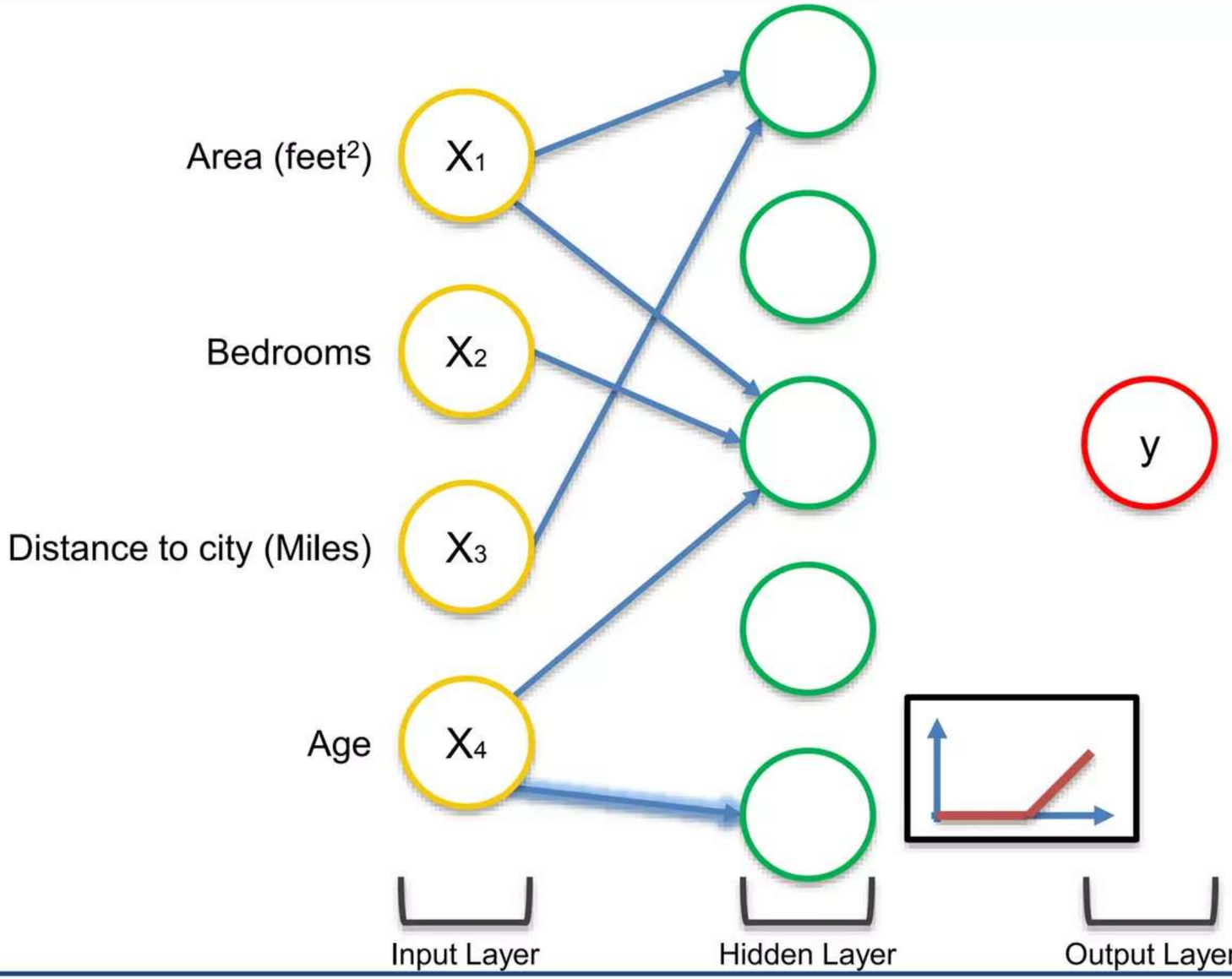

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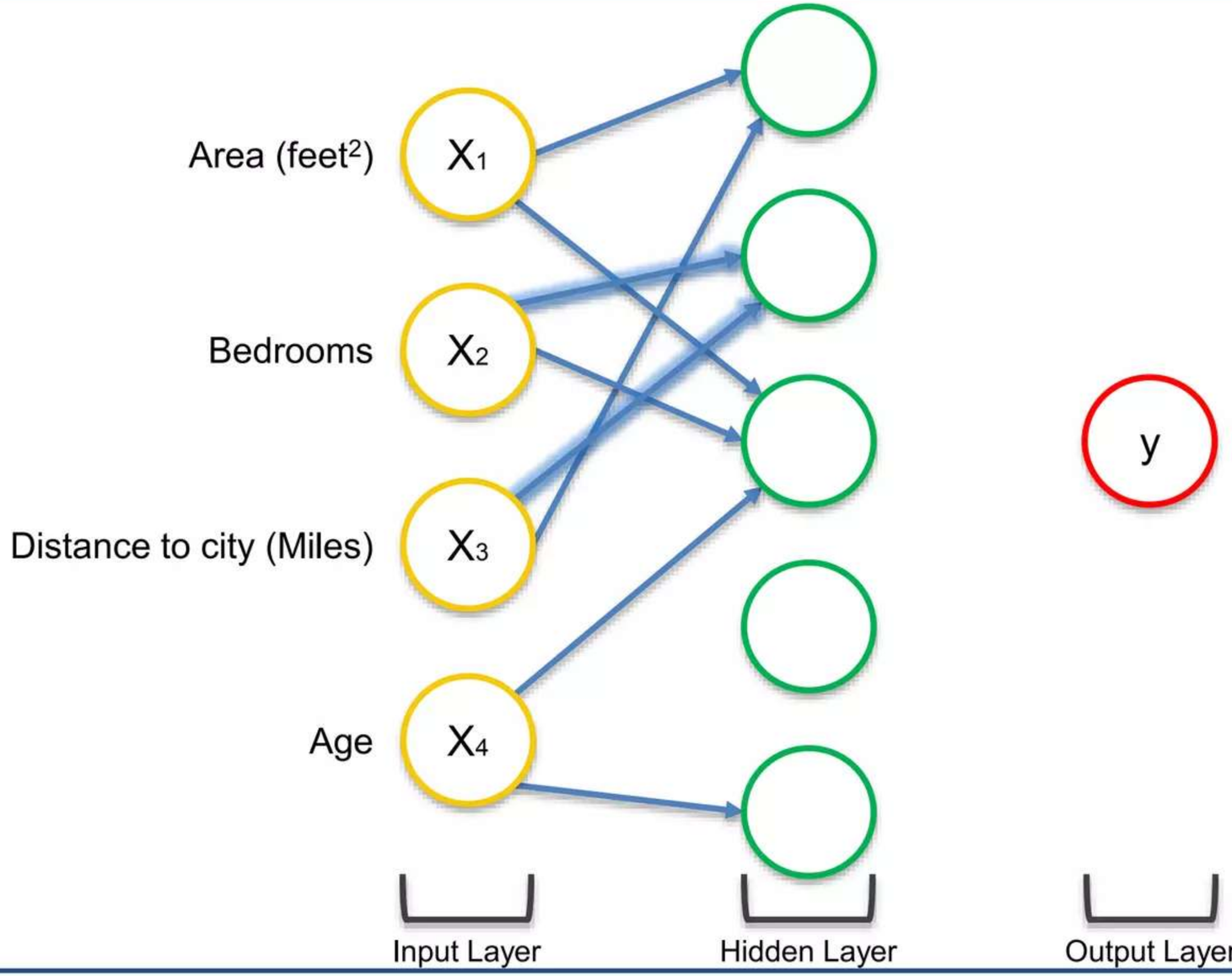

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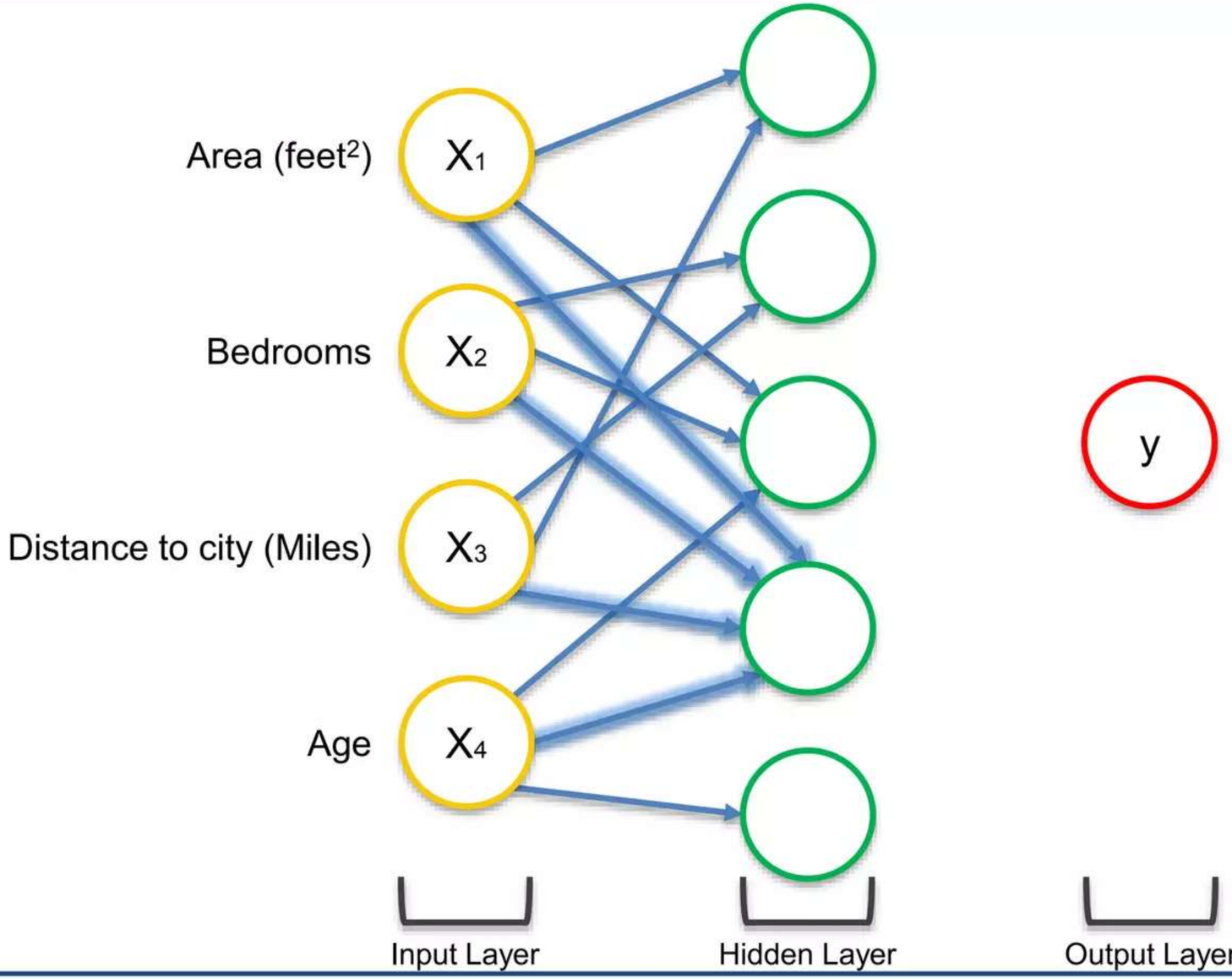

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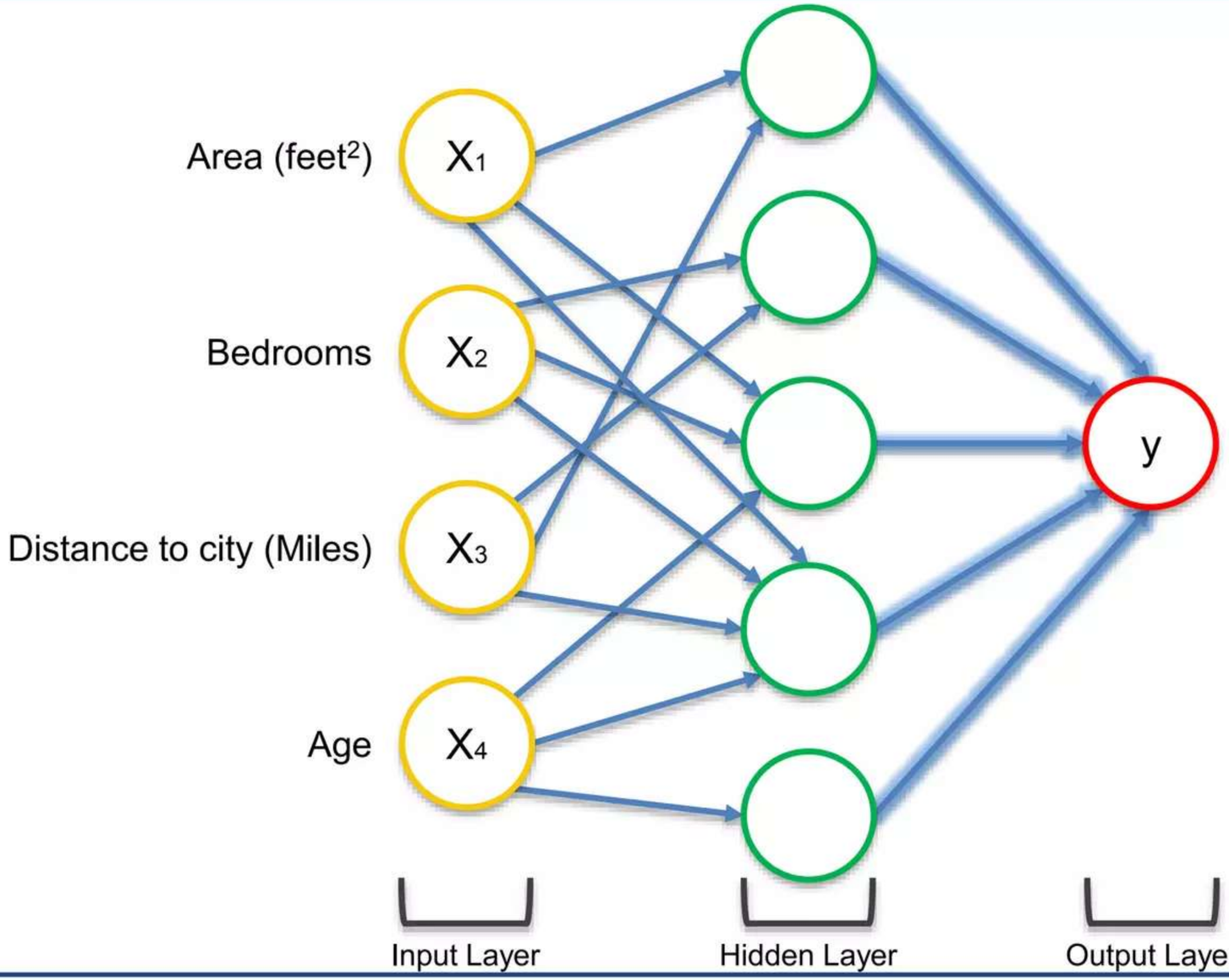

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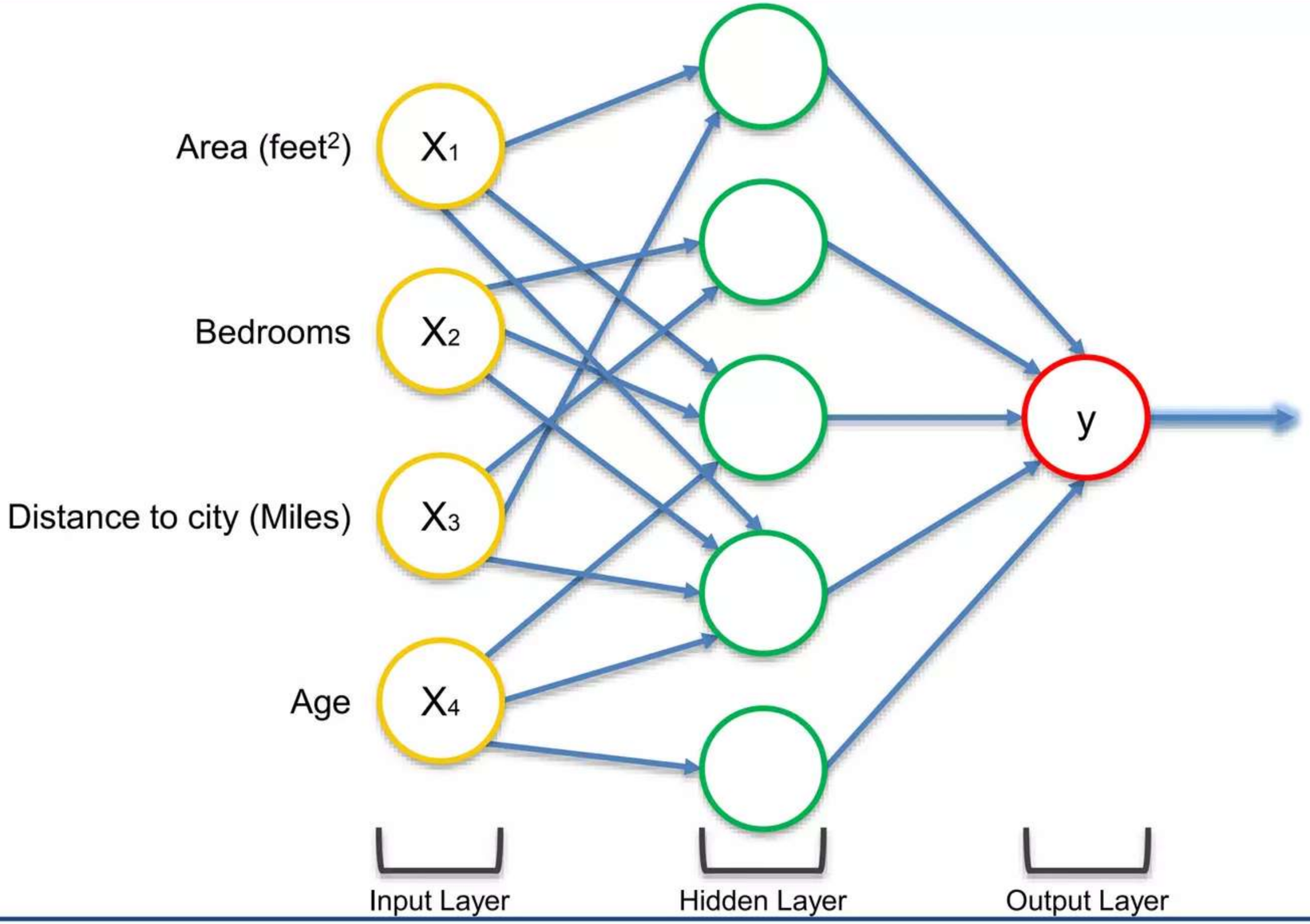

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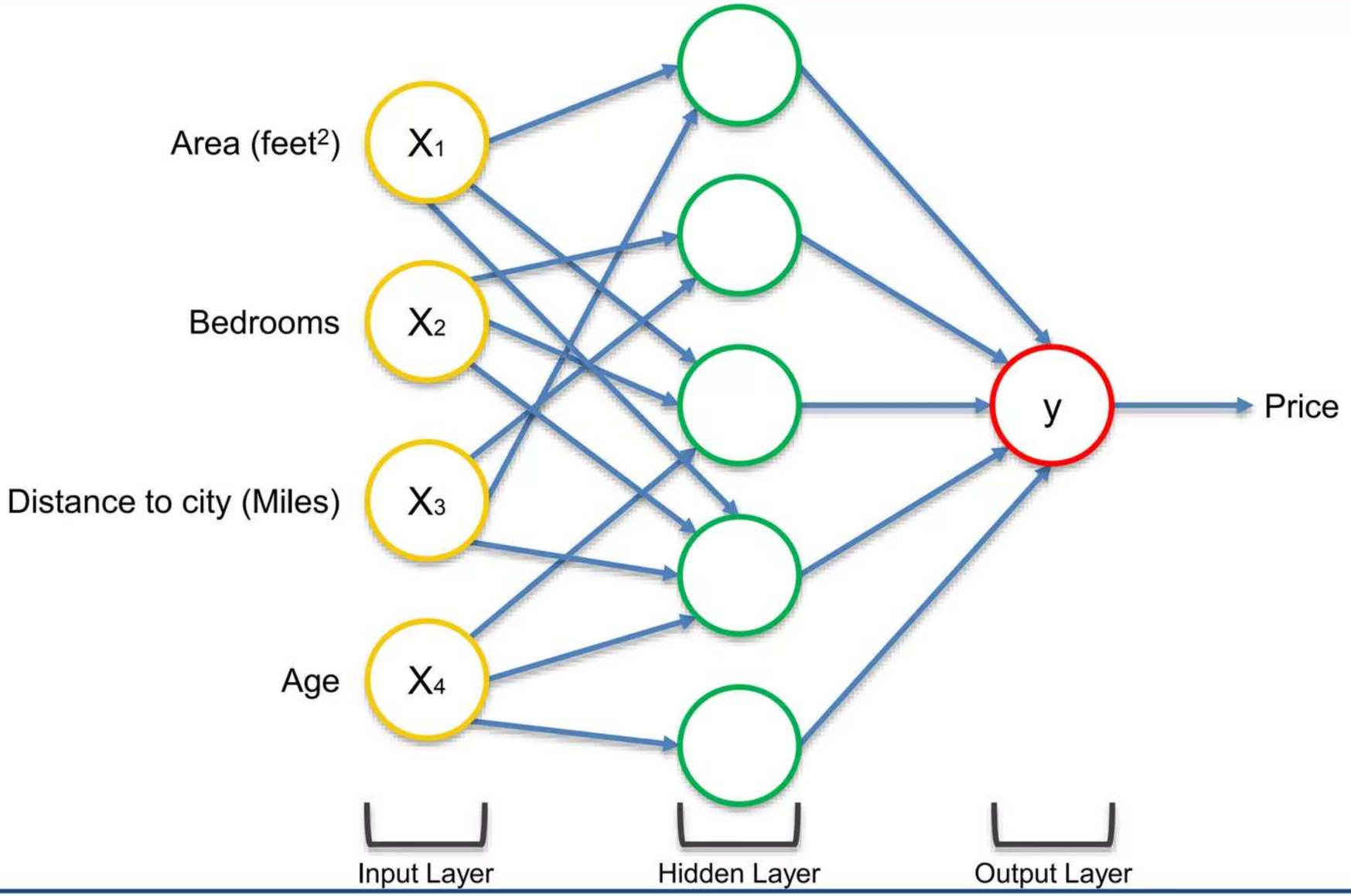

How do NNs Learn?

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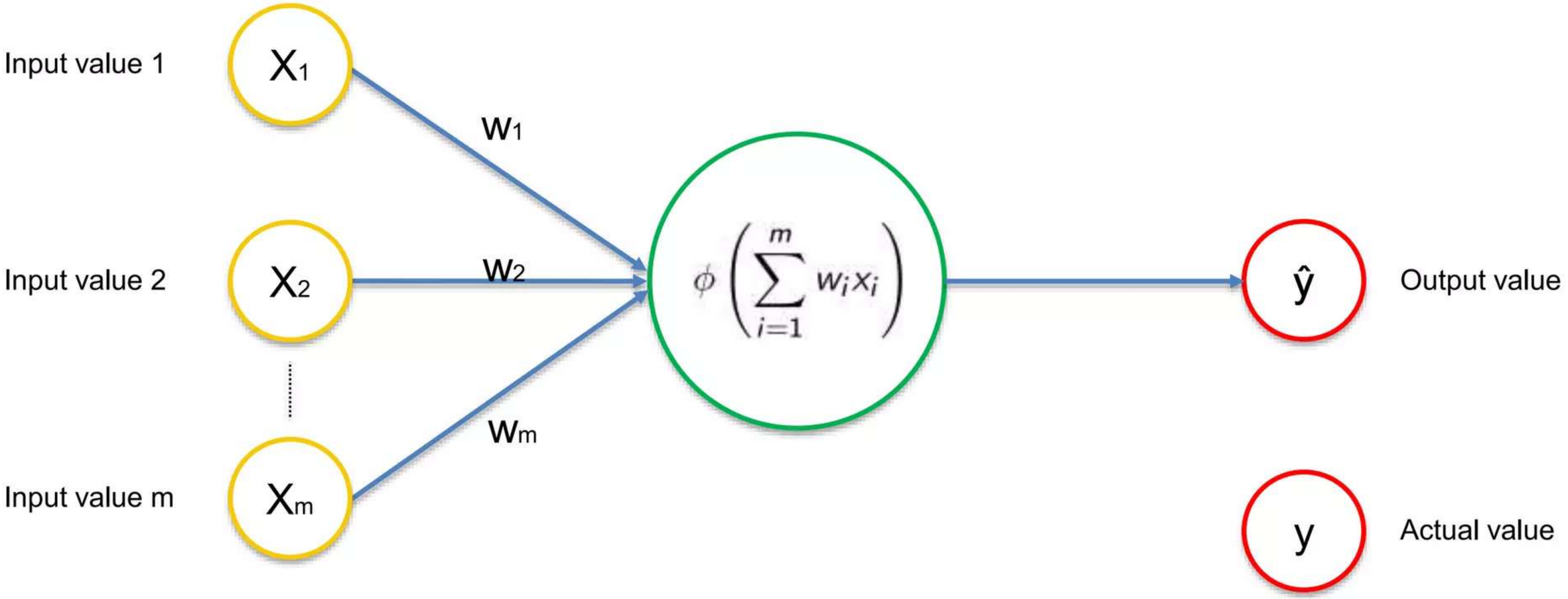

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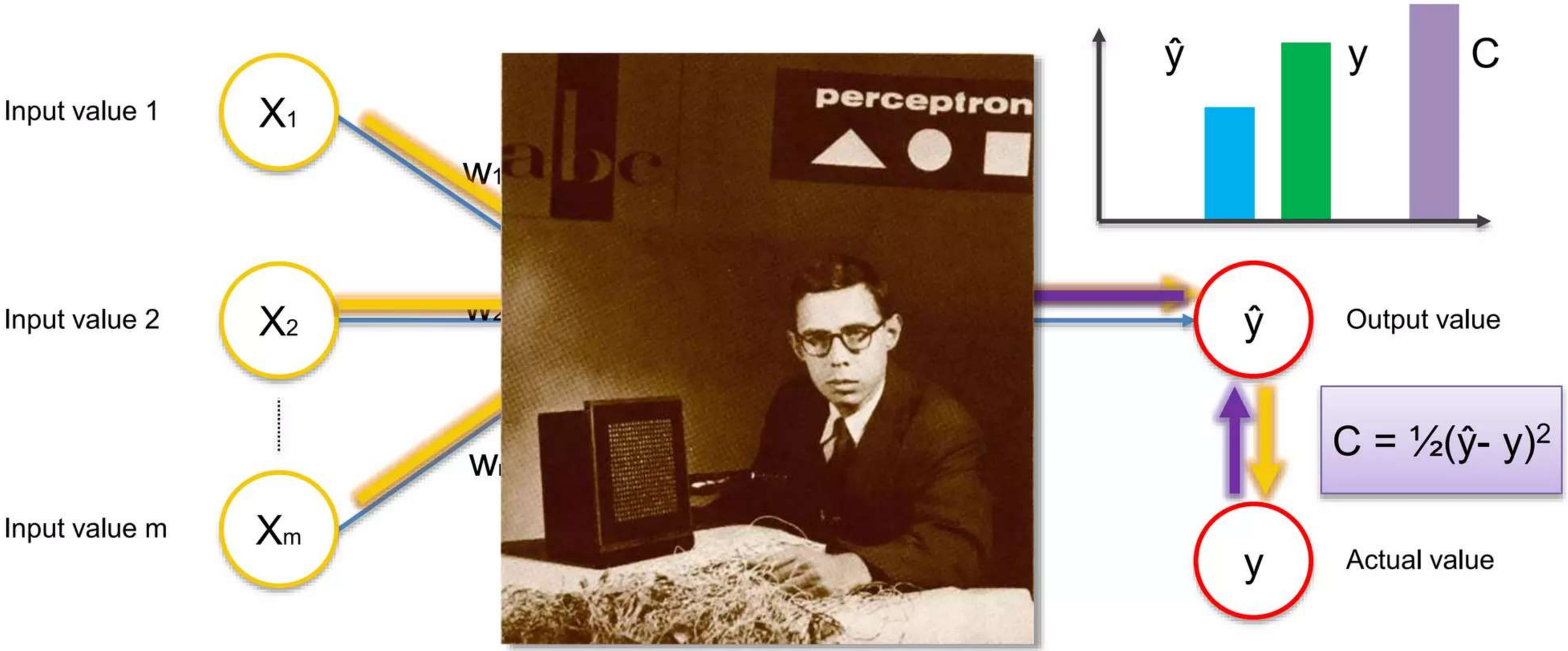

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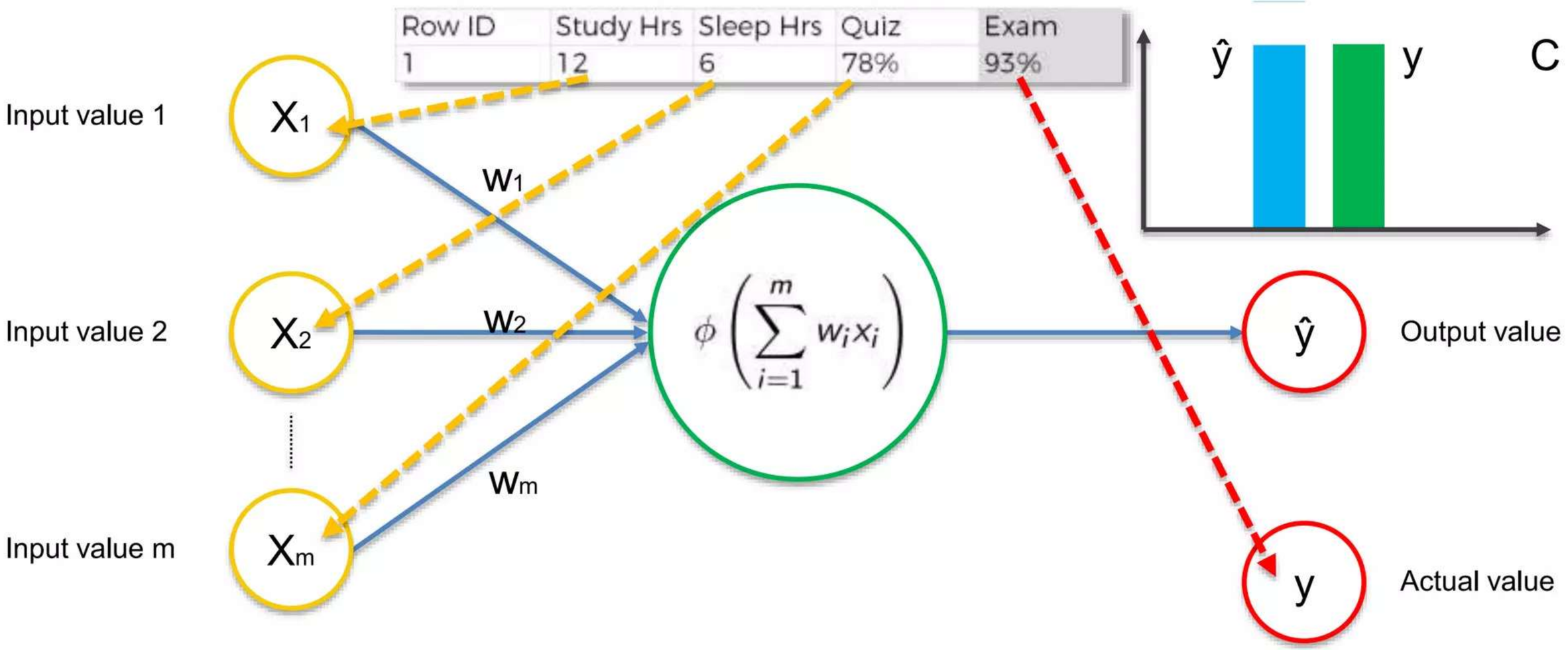

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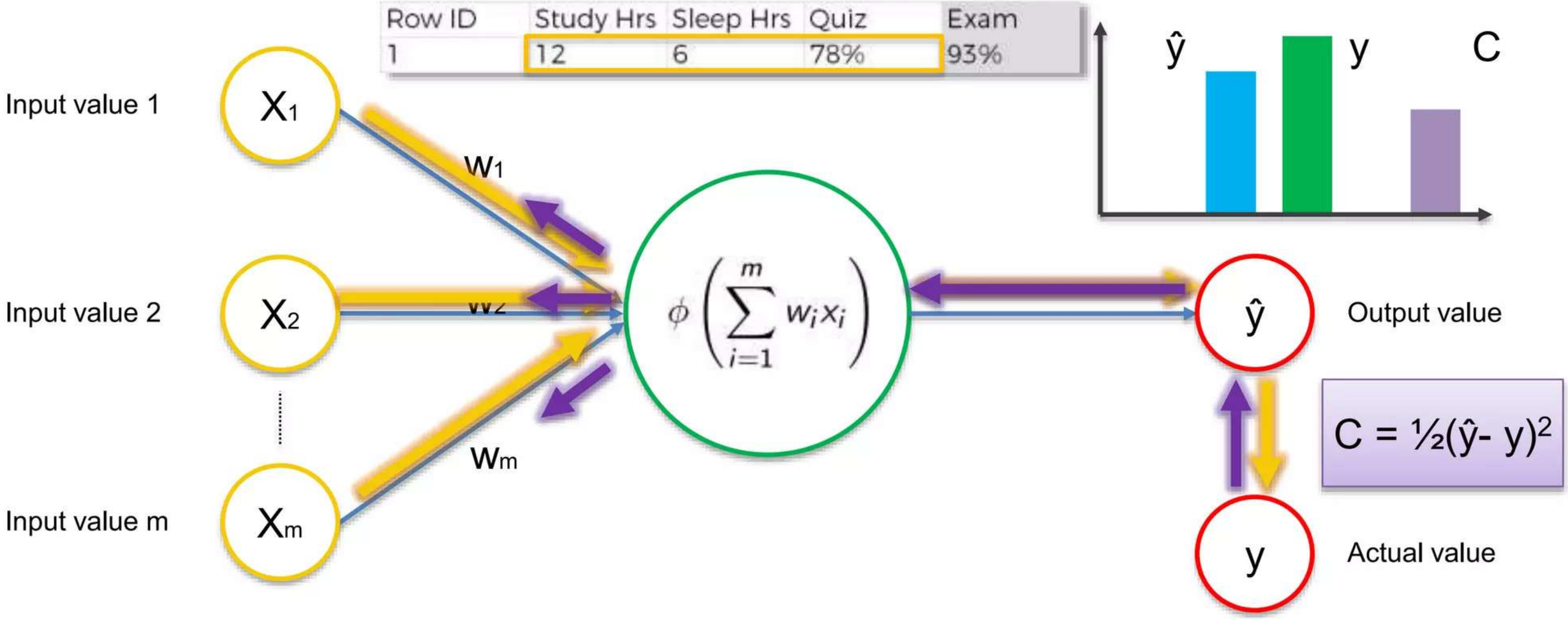

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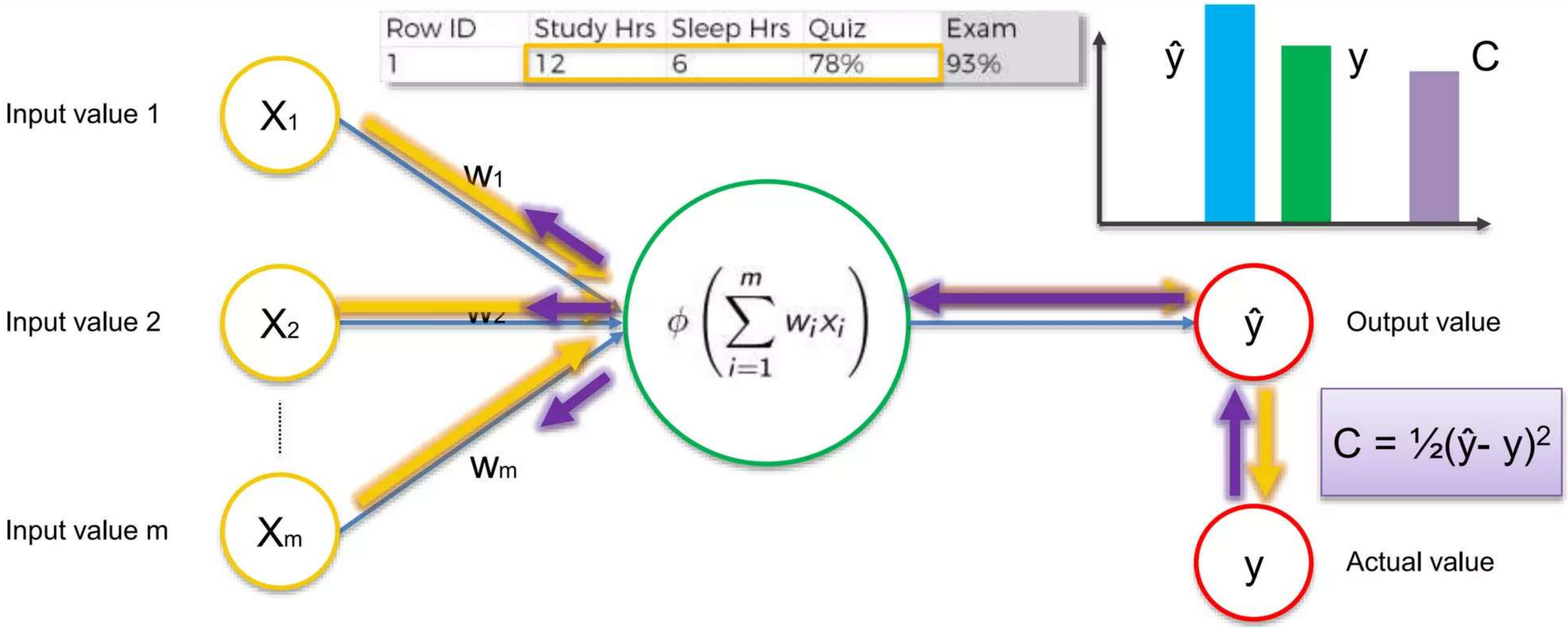

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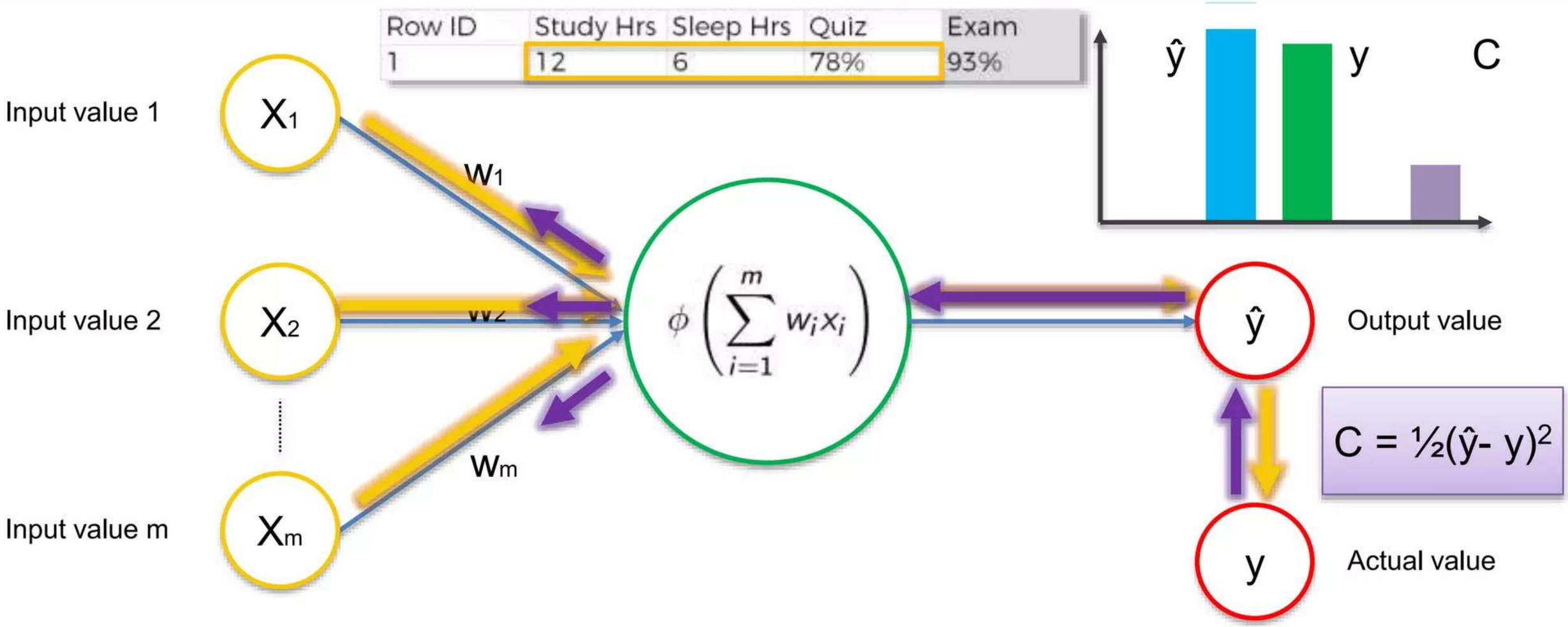

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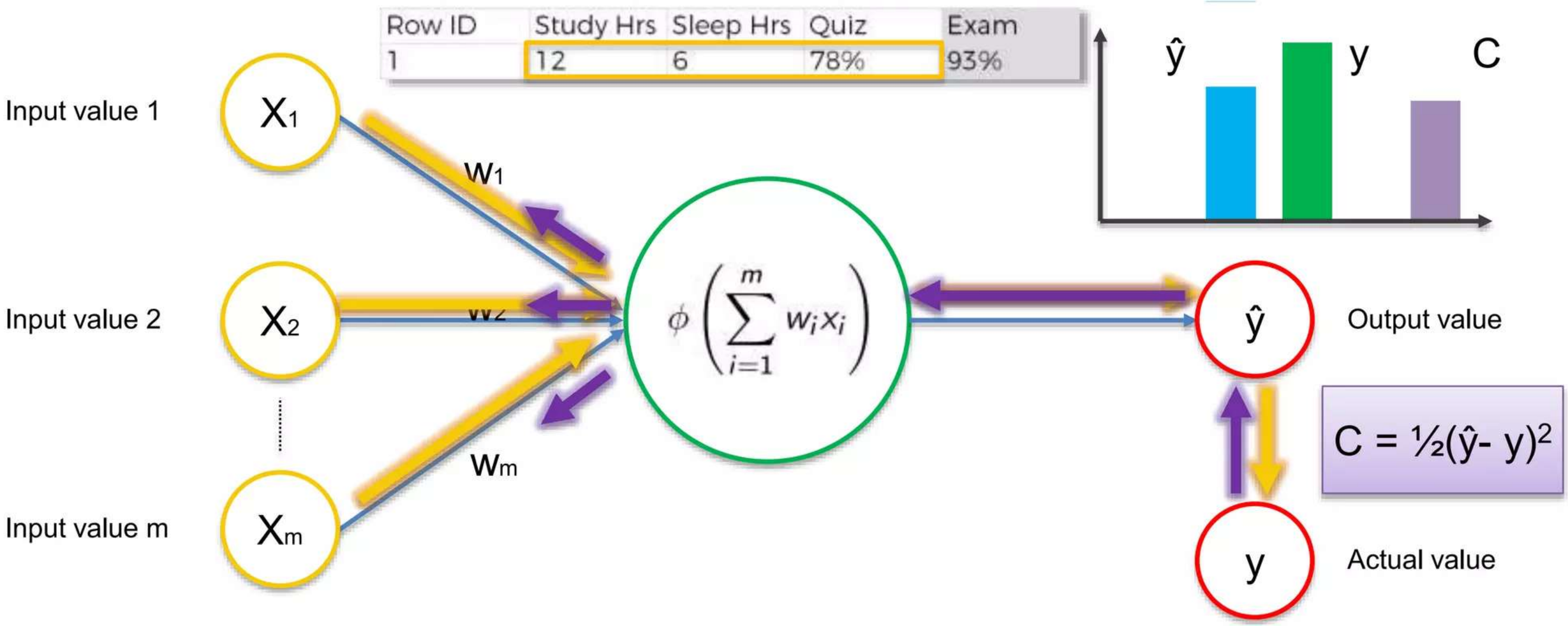

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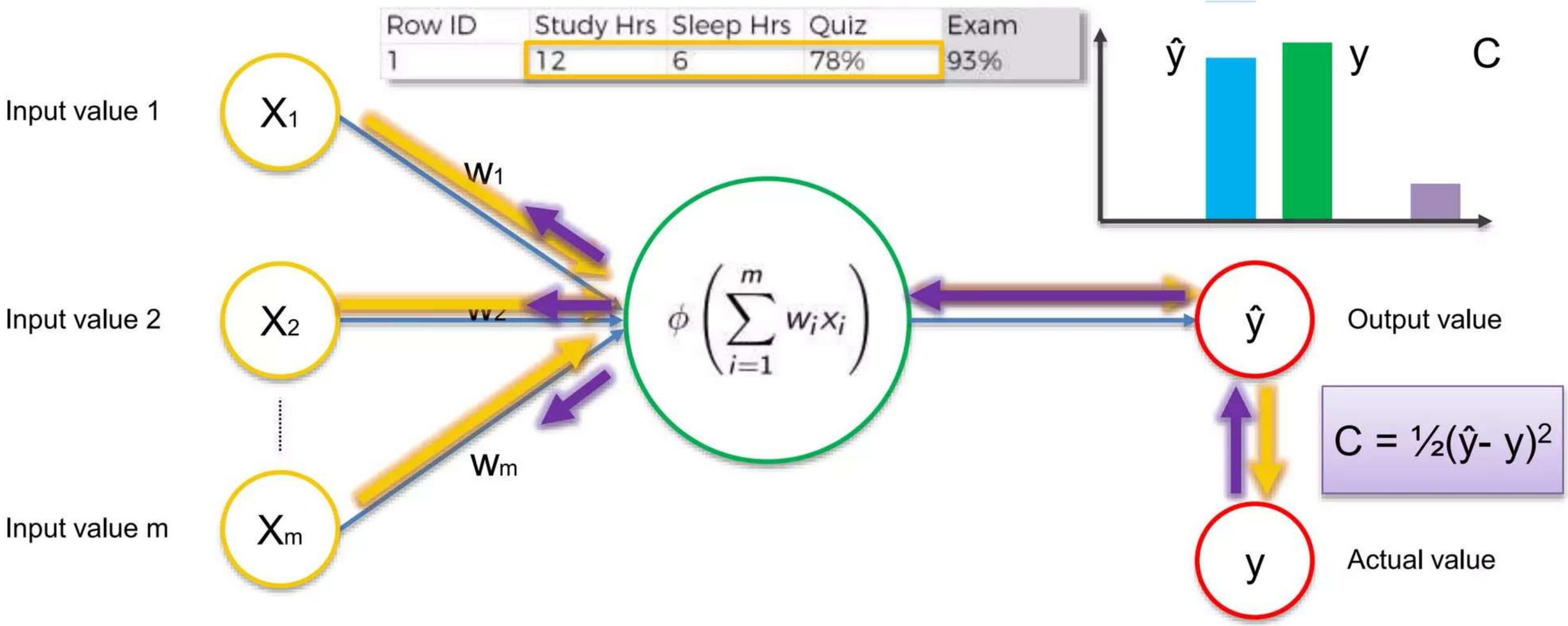

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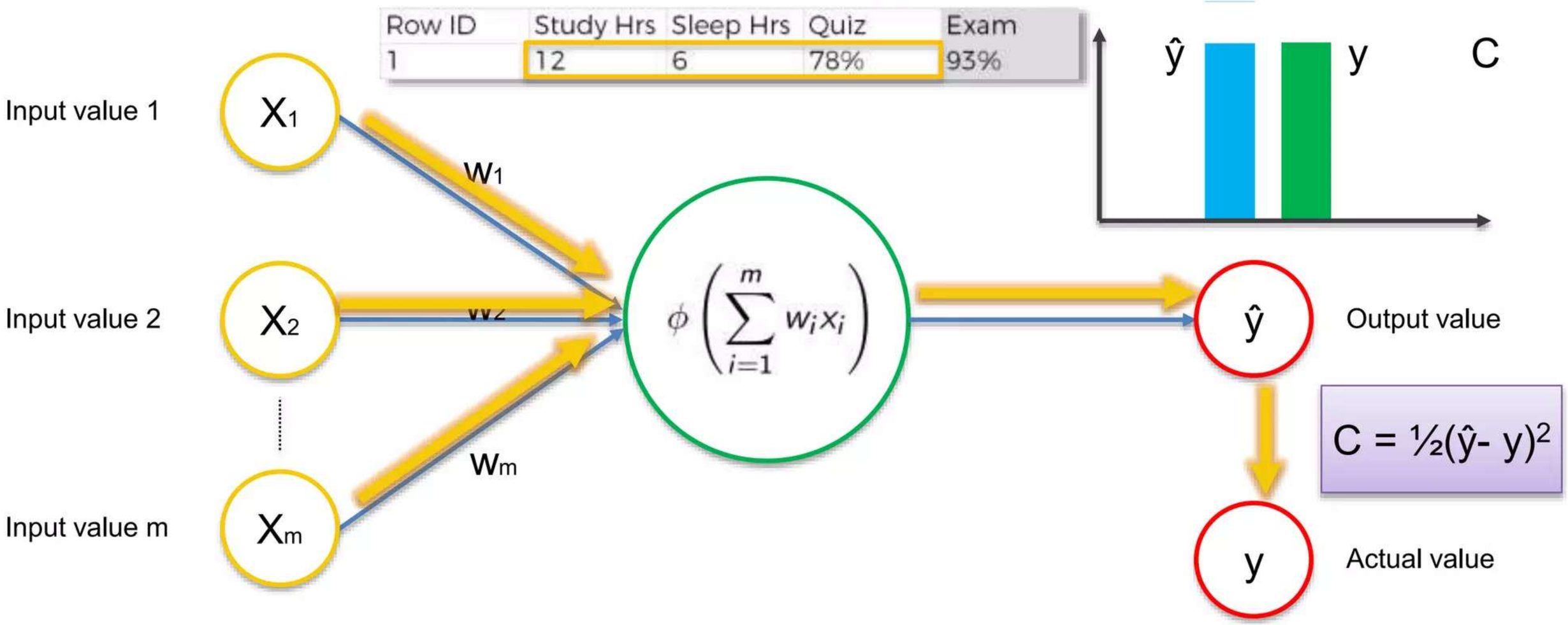

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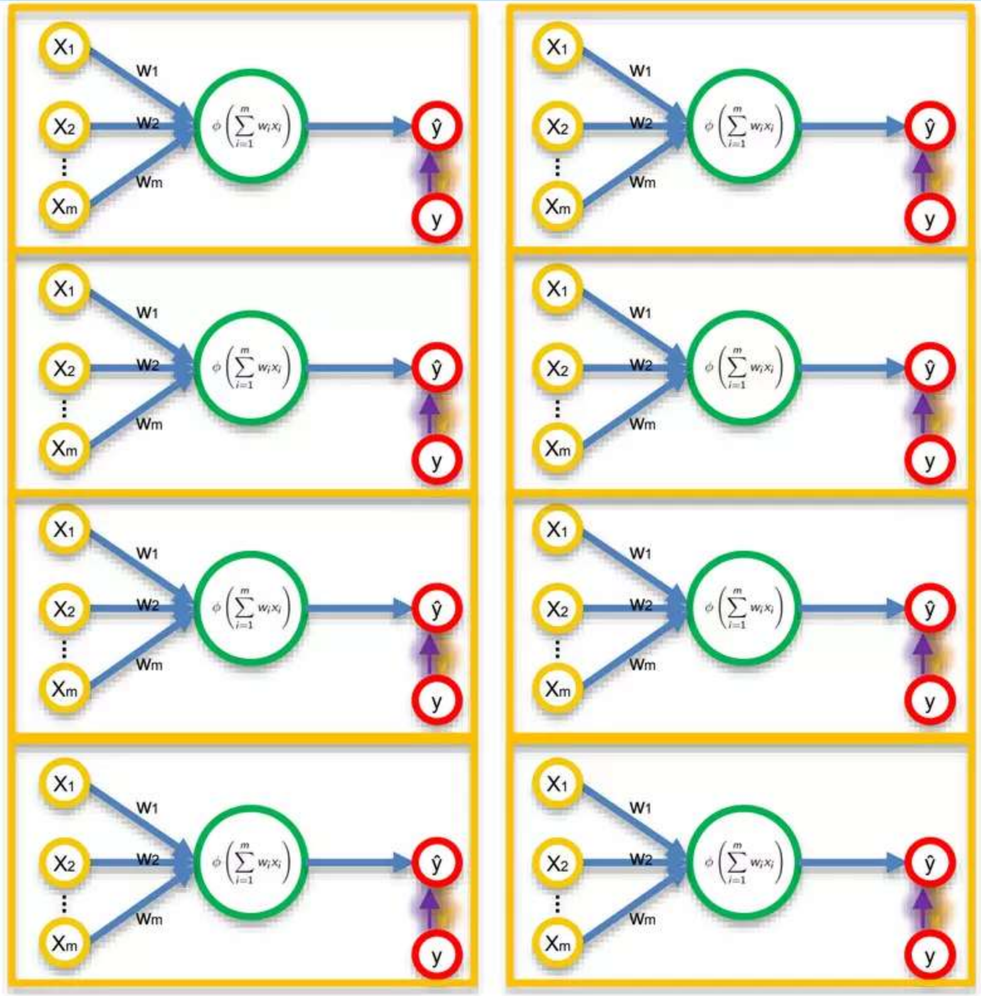
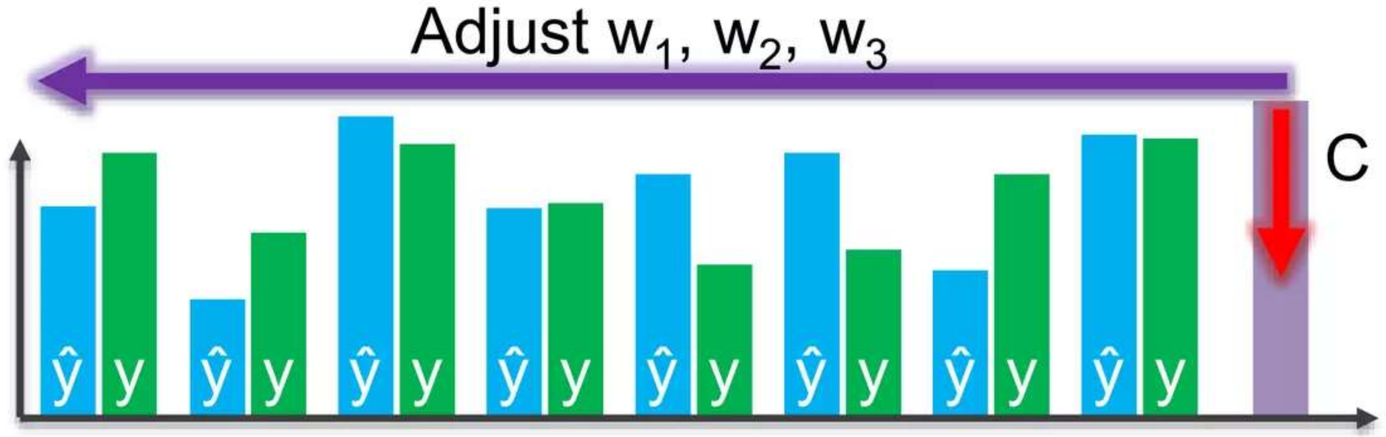


Row ID	Study Hrs	Sleep Hrs	Quiz	Exam
1	12	6	78%	93%
2	22	6.5	24%	68%
3	115	4	100%	95%
4	31	9	67%	75%
5	0	10	58%	51%
6	5	8	78%	60%
7	92	6	82%	89%
8	57	8	91%	97%

$$C = \sum \tfrac{1}{2}(\hat{y} - y)^2$$



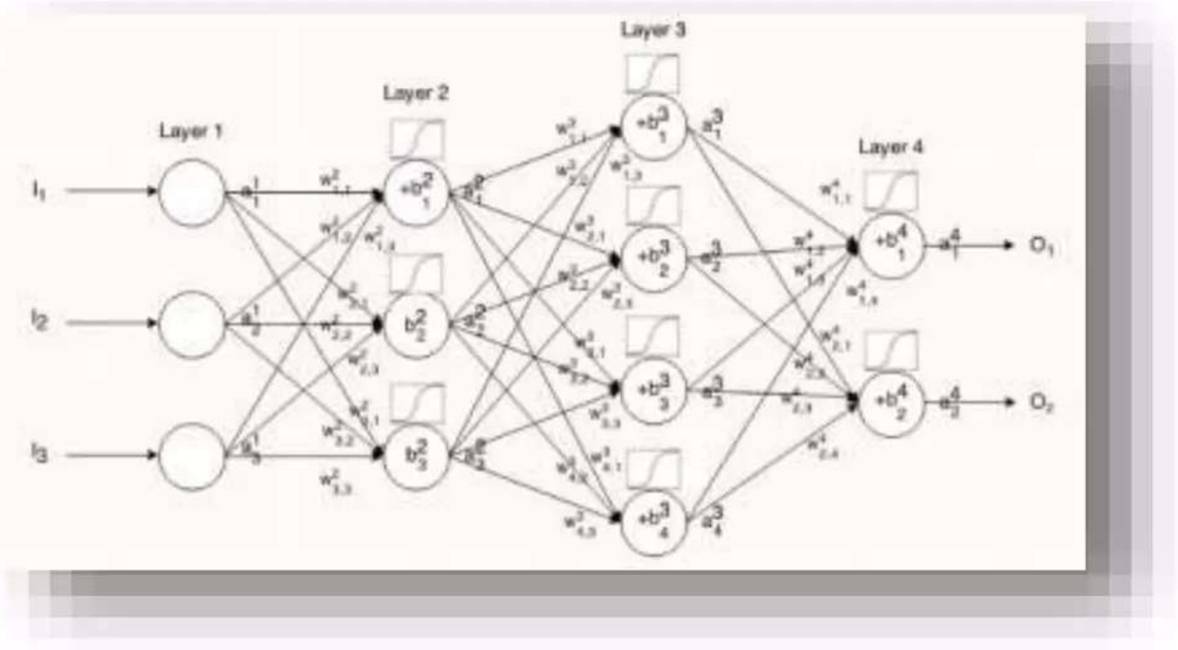
How do Neural Networks learn?

Additional Reading:

A list of cost functions used in neural networks, alongside applications

CrossValidated (2015)

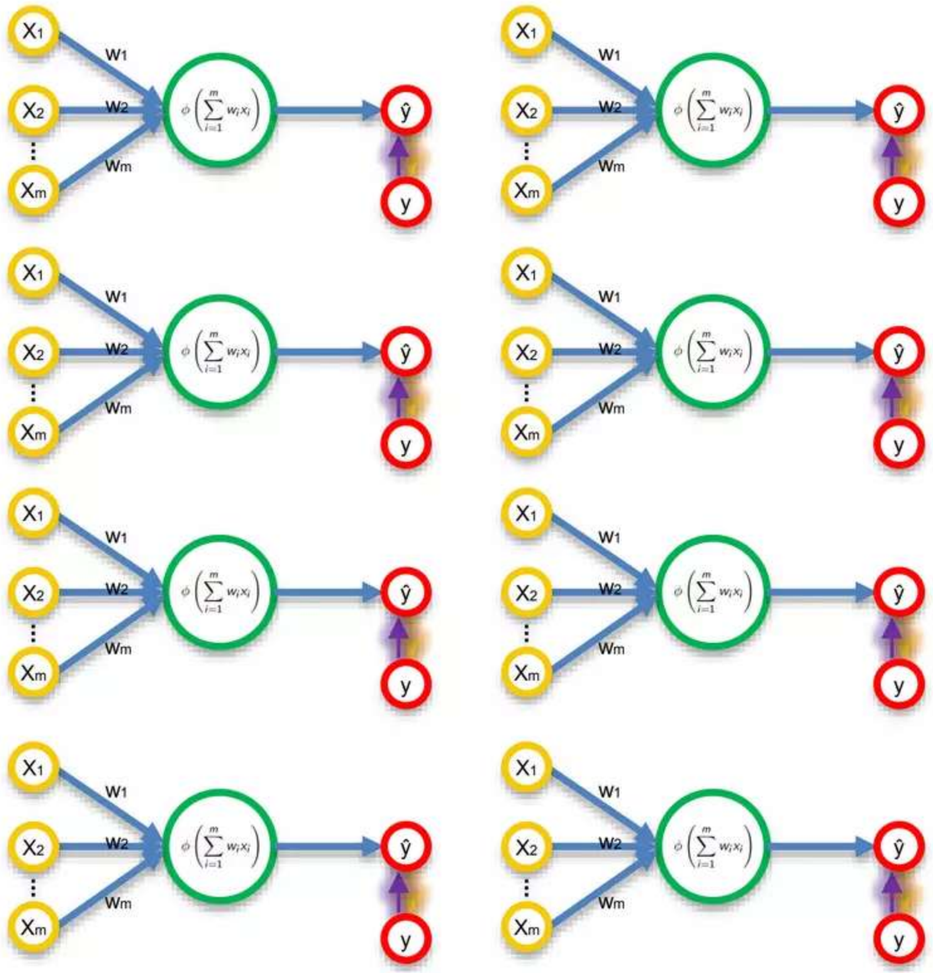
Link:



http://stats.stackexchange.com/questions/154879/a-list-of-cost-functions-used-in-neural-networks-alongside-applications

Gradient Descent

Gradient Descent



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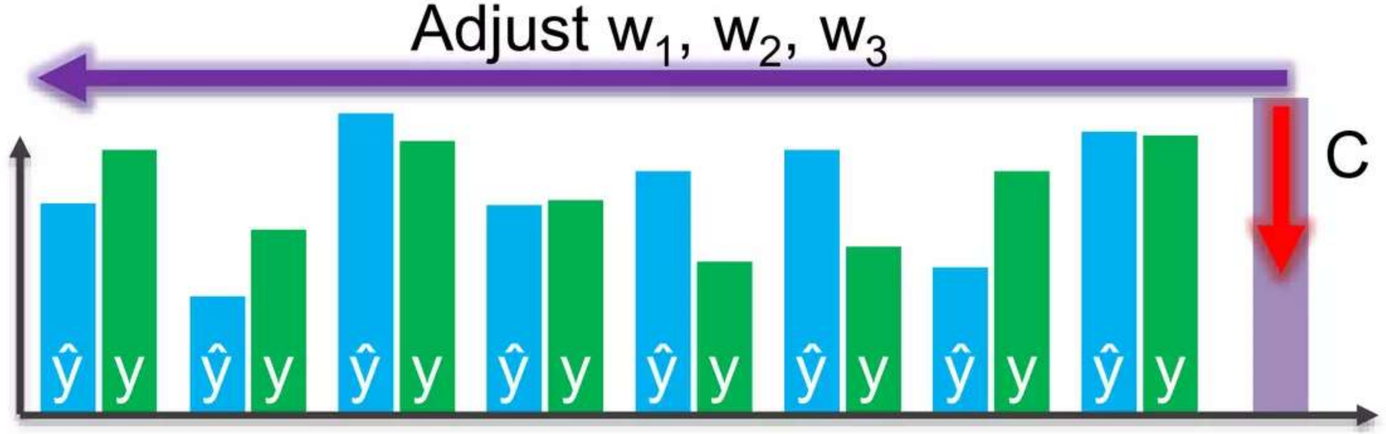
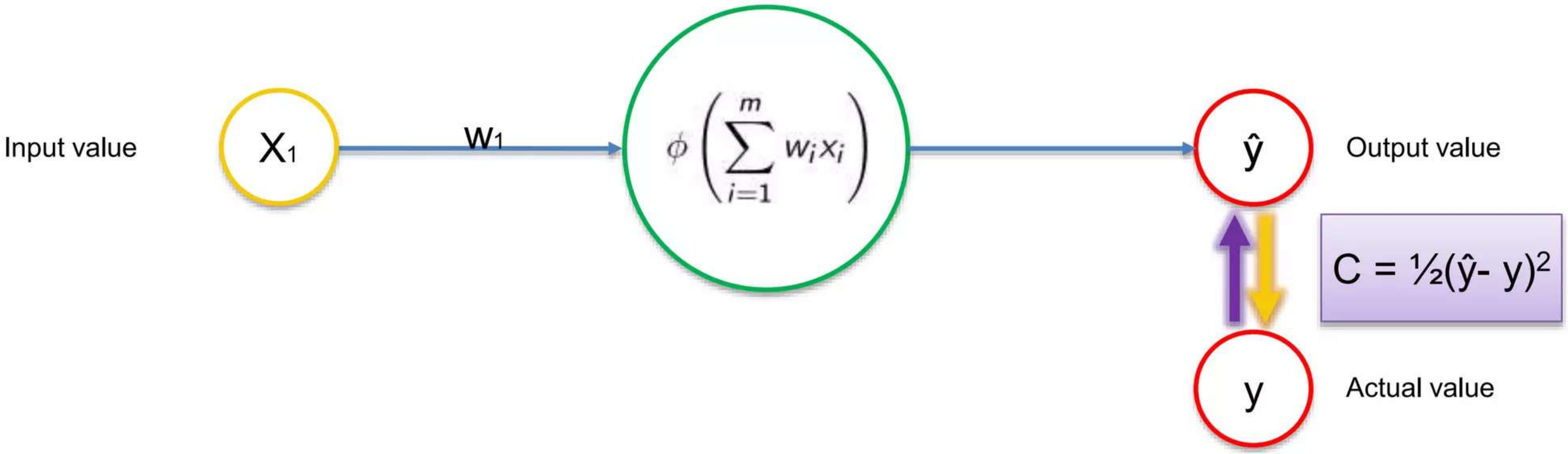
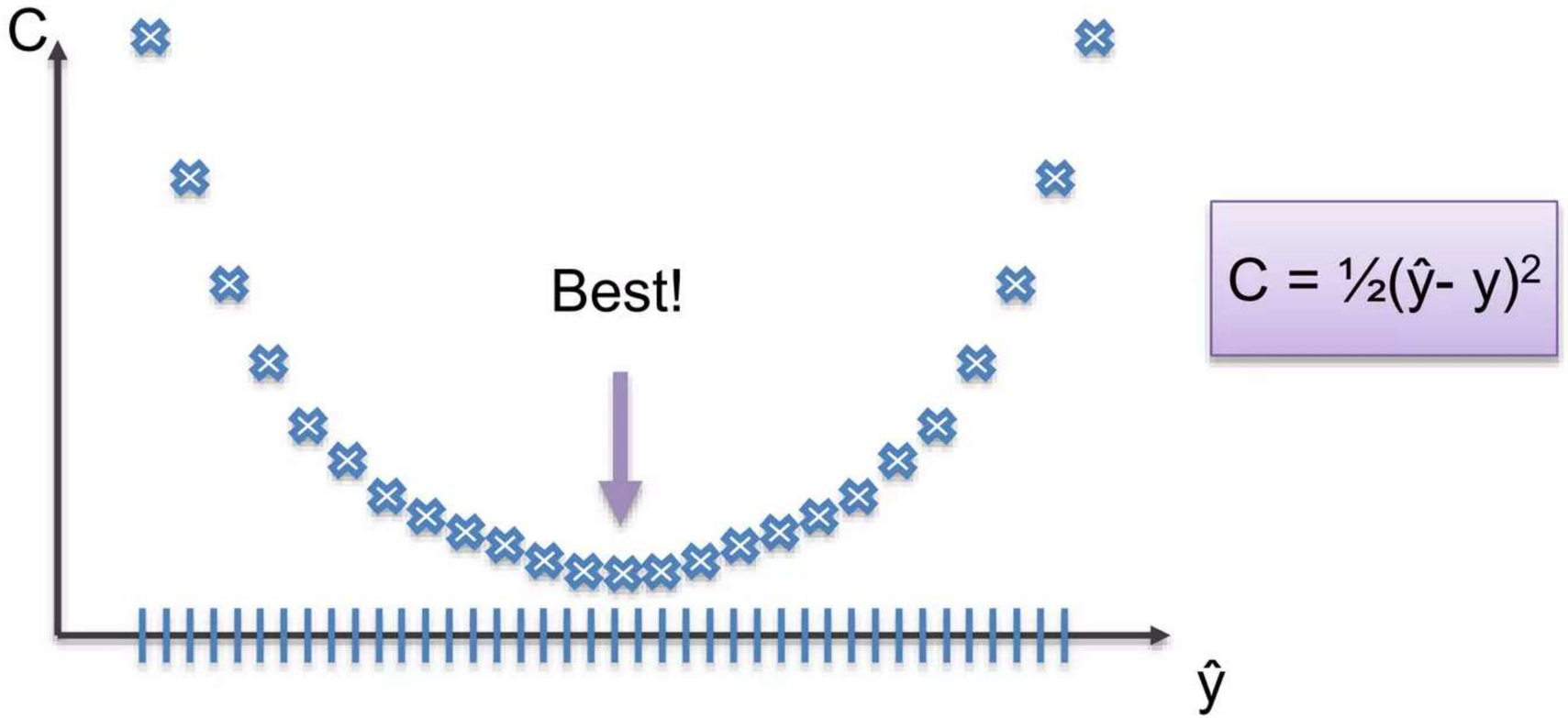


Gradient Descent



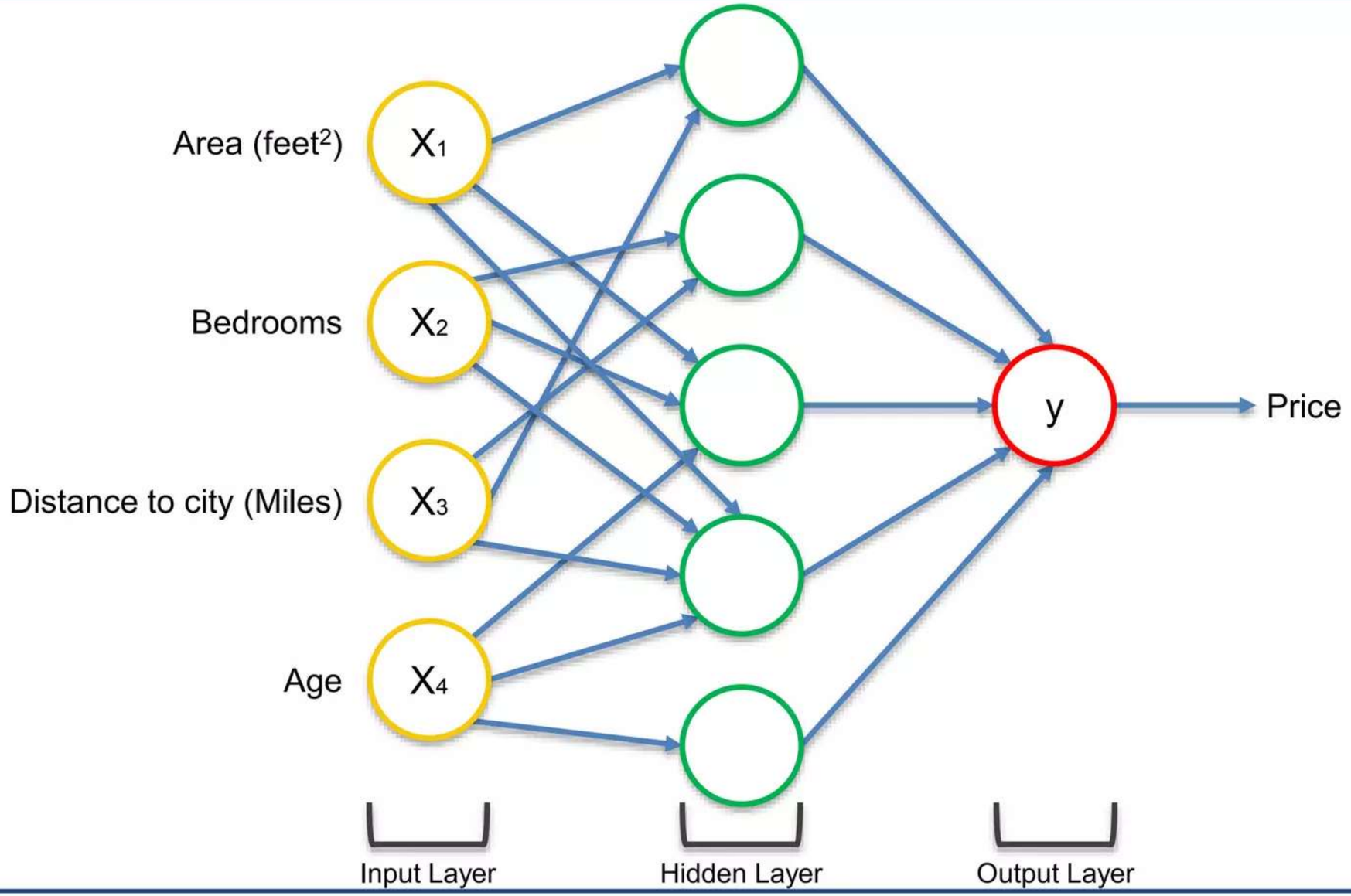
Gradient Descent



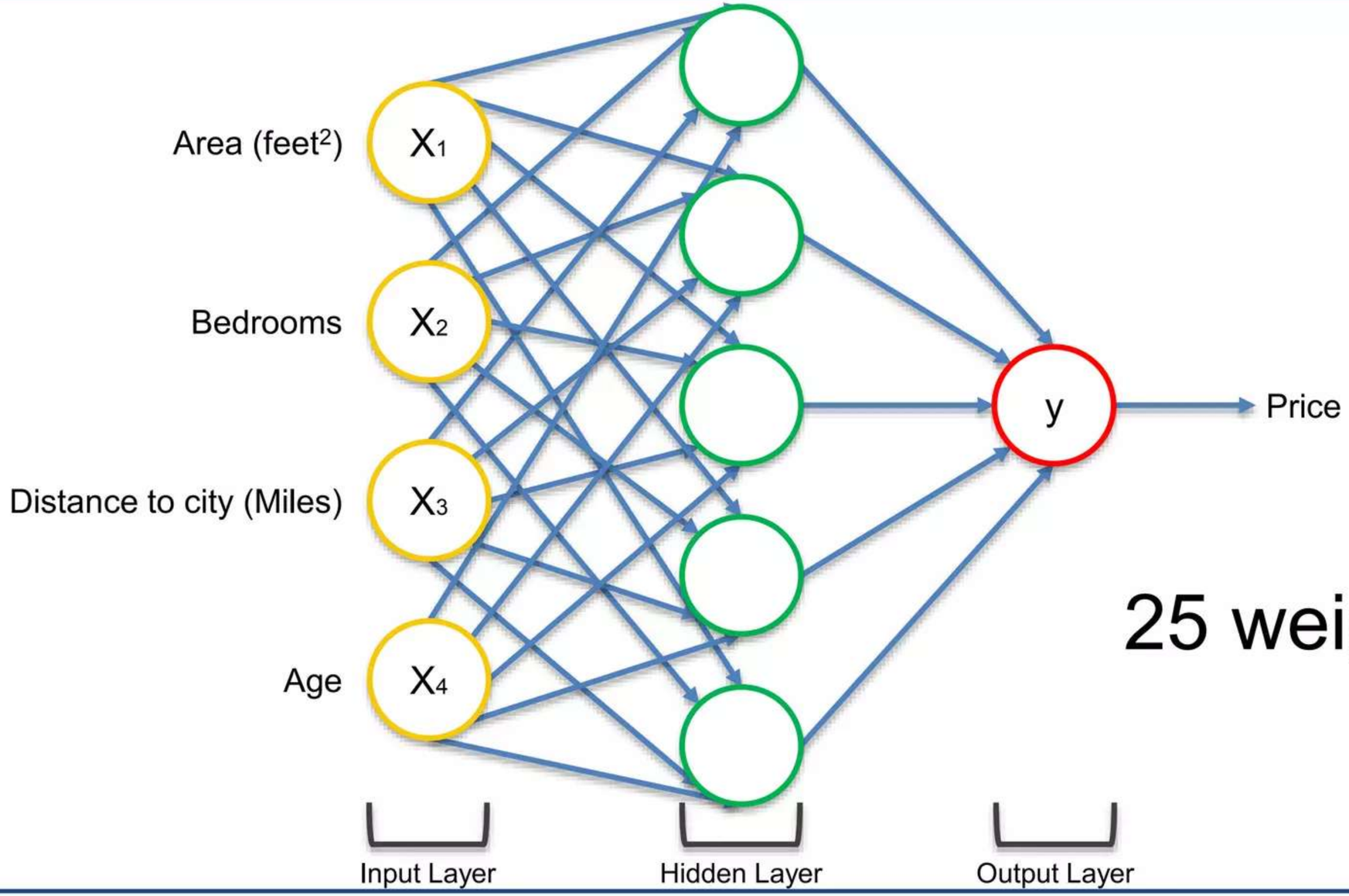
$$C = \frac{1}{2}(\hat{y} - y)^2$$

Curse of Dimensionality

Gradient Descent



Gradient Descent



25 weights

Gradient Descent

$1{,}000 \times 1{,}000 \times \ldots \times 1{,}000 = 1{,}000^{25} = 10^{75}$ combinations

Sunway TaihuLight: World's fastest Super Computer

93 PFLOPS

93×10^{15}

$10^{75} / (93 \times 10^{15})$

$= 1.08 \times 10^{58}$ seconds

$= 3.42 \times 10^{50}$ years

Gradient Descent

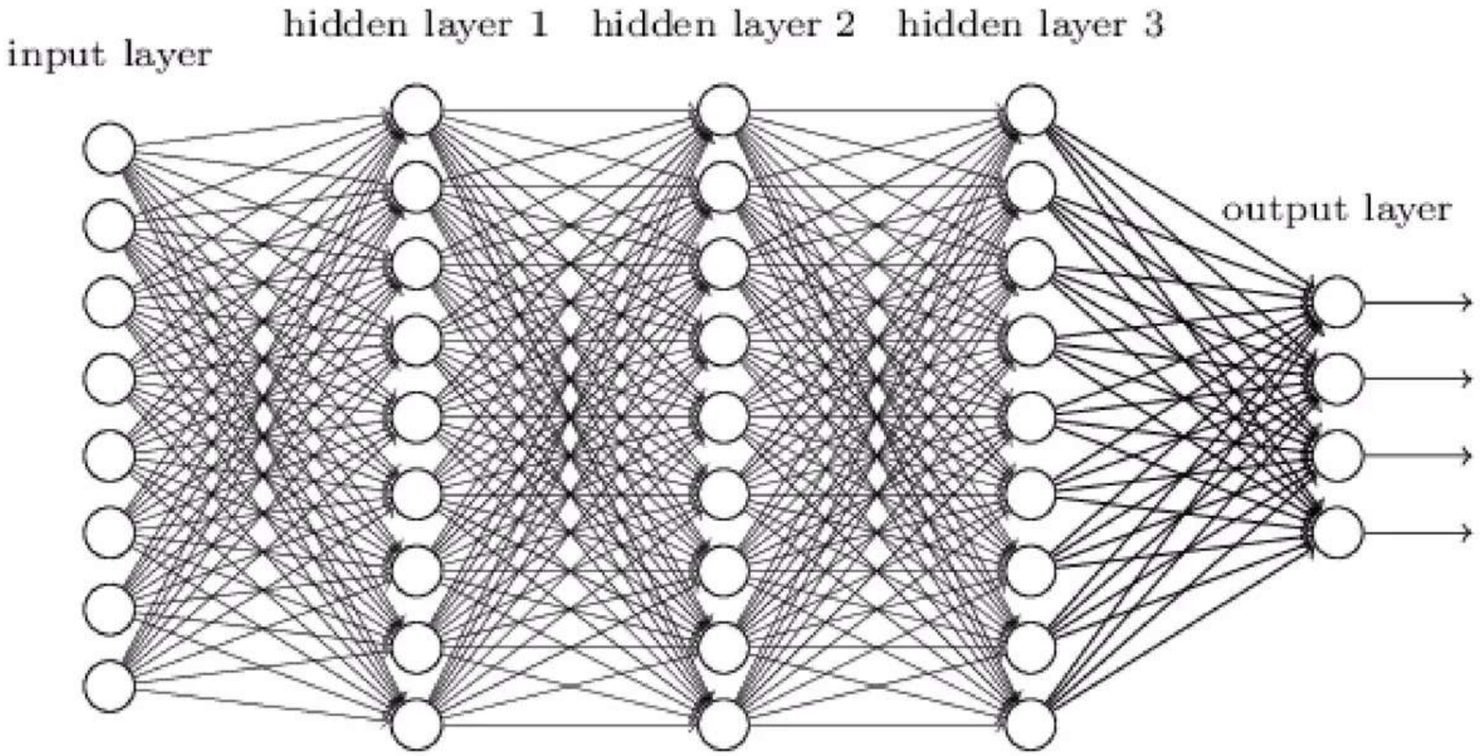
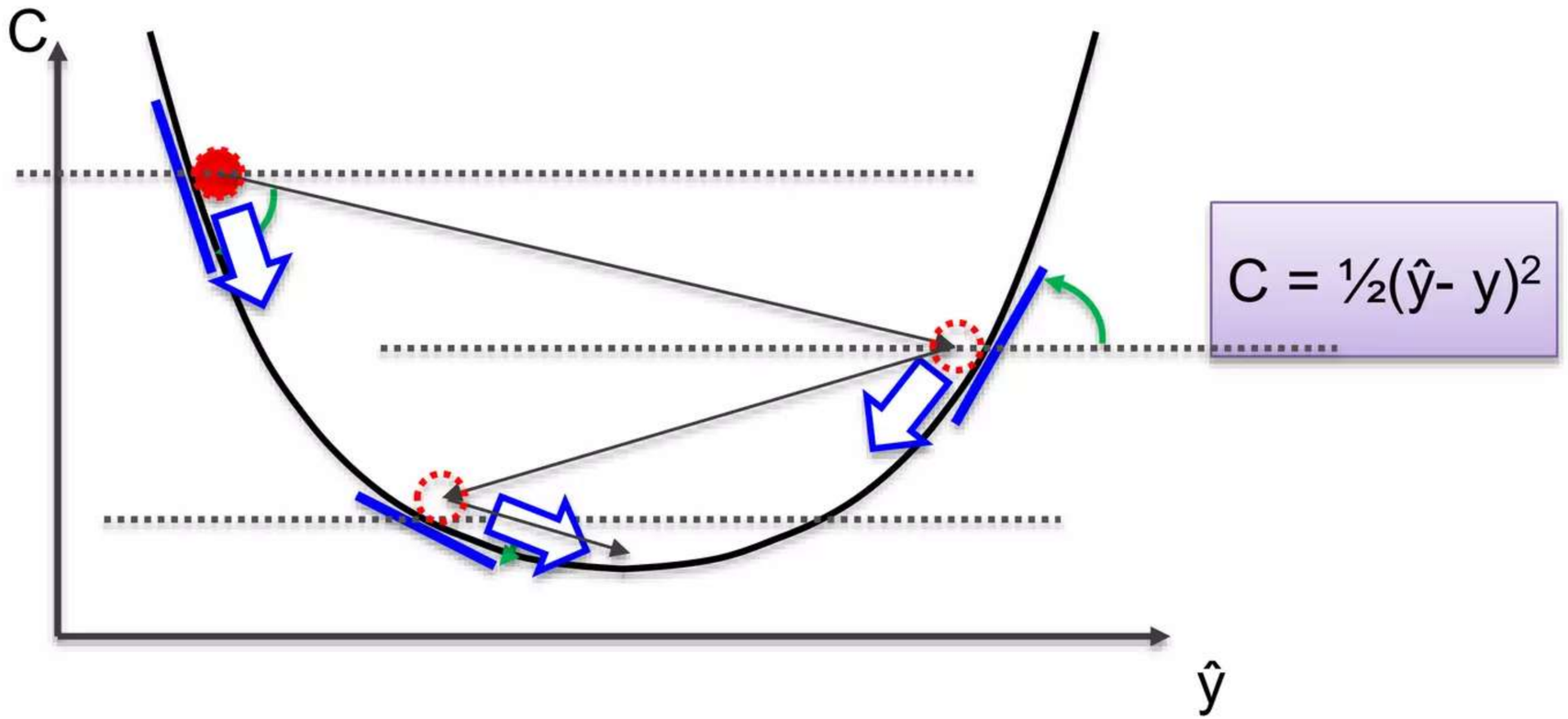


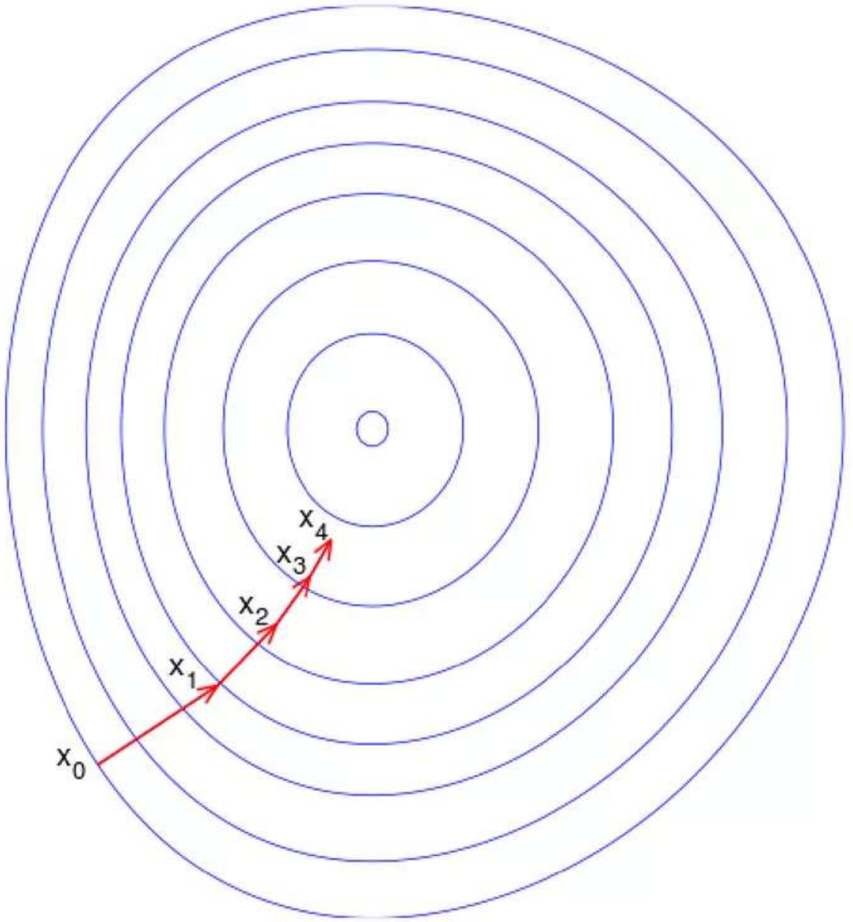
Image Source: neuralnetworksanddeeplearning.com

Gradient Descent

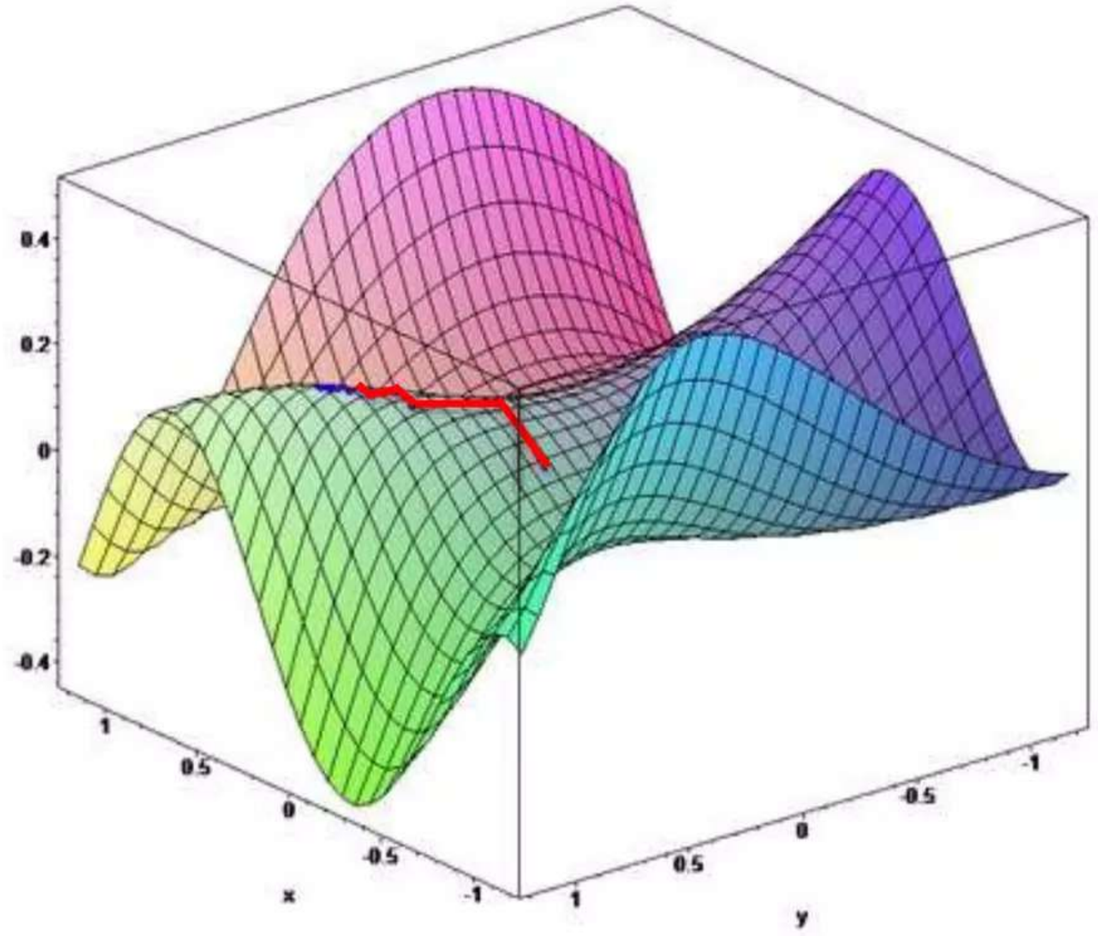
Gradient Descent

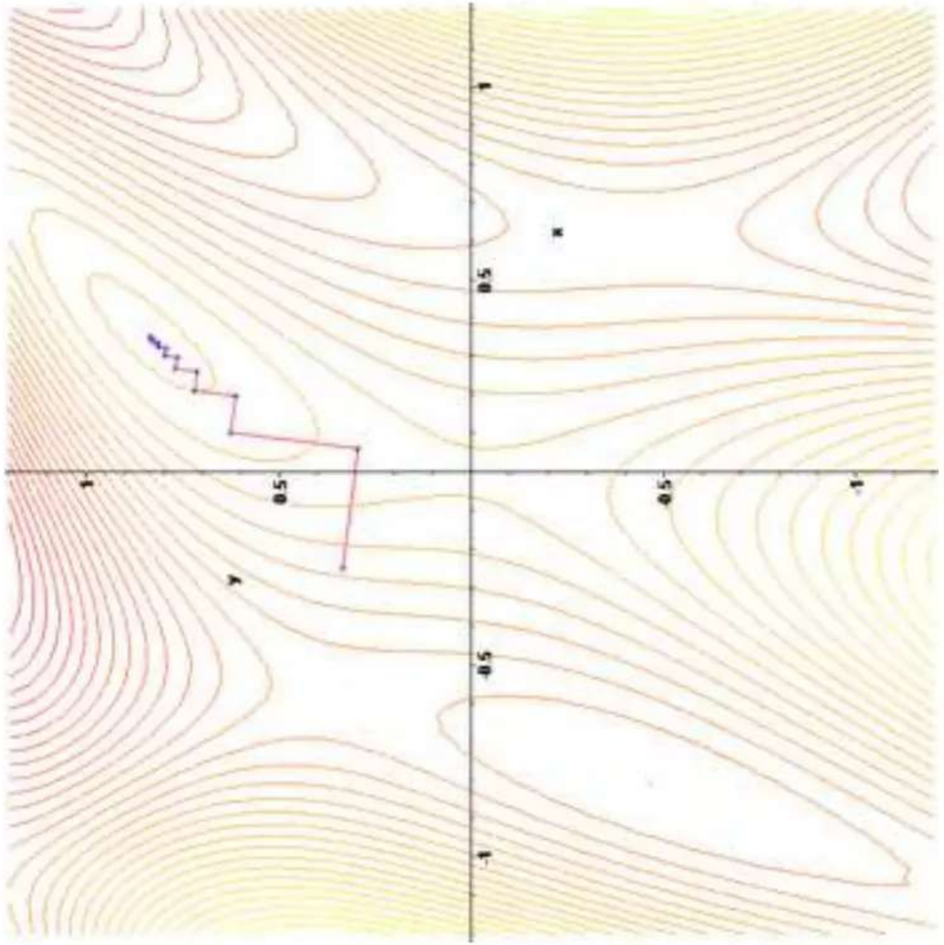


Gradient Descent



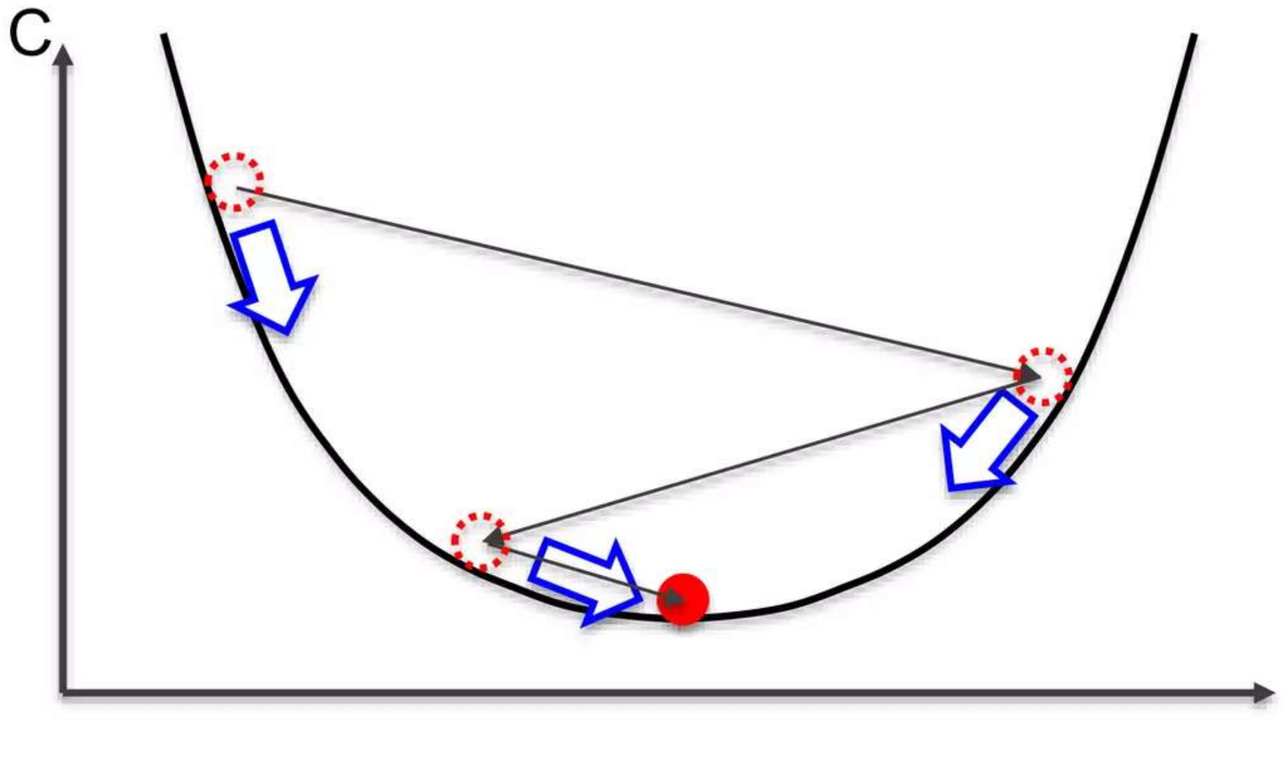
Gradient Descent





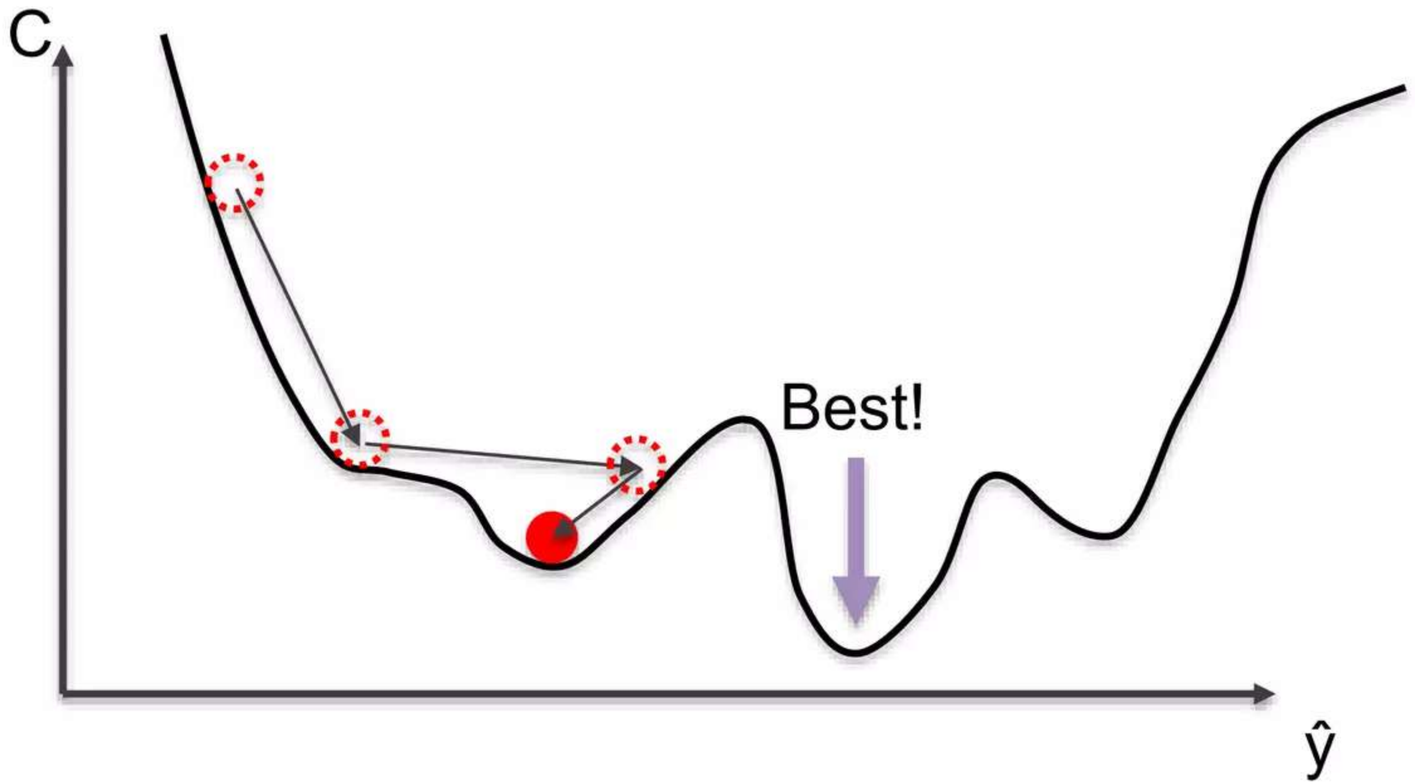
Stochastic Gradient Descent

Stochastic Gradient Descent

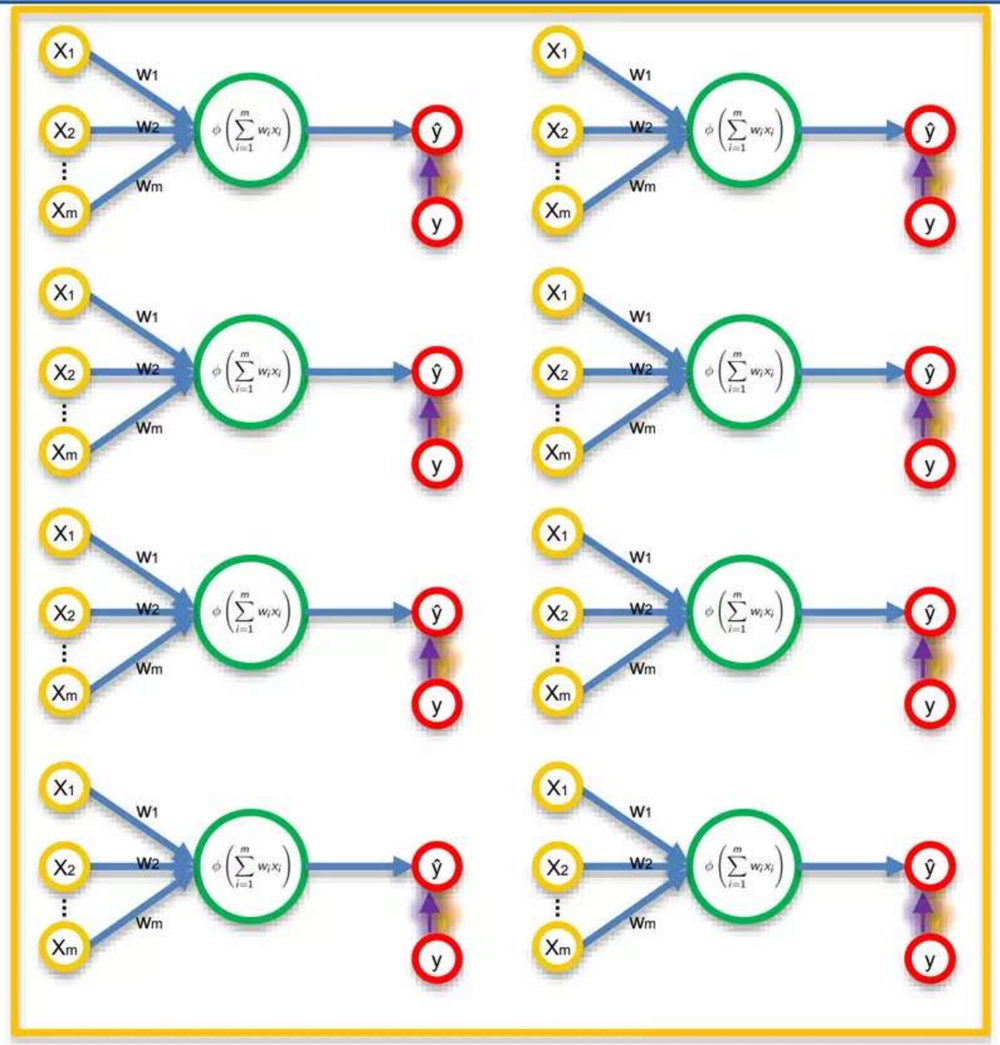


$$C = \frac{1}{2}(\hat{y} - y)^2$$

Stochastic Gradient Descent

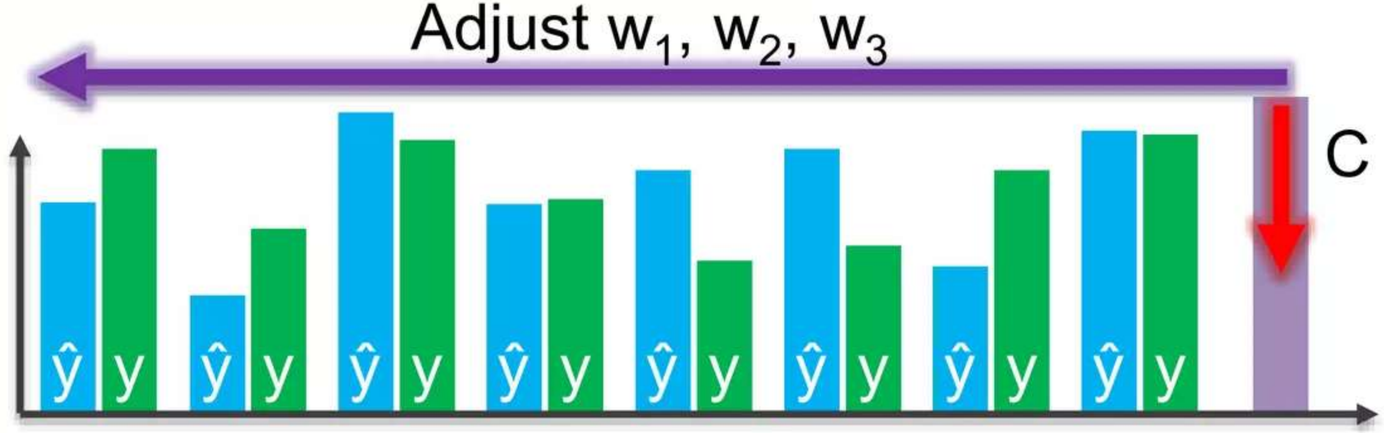


Stochastic Gradient Descent

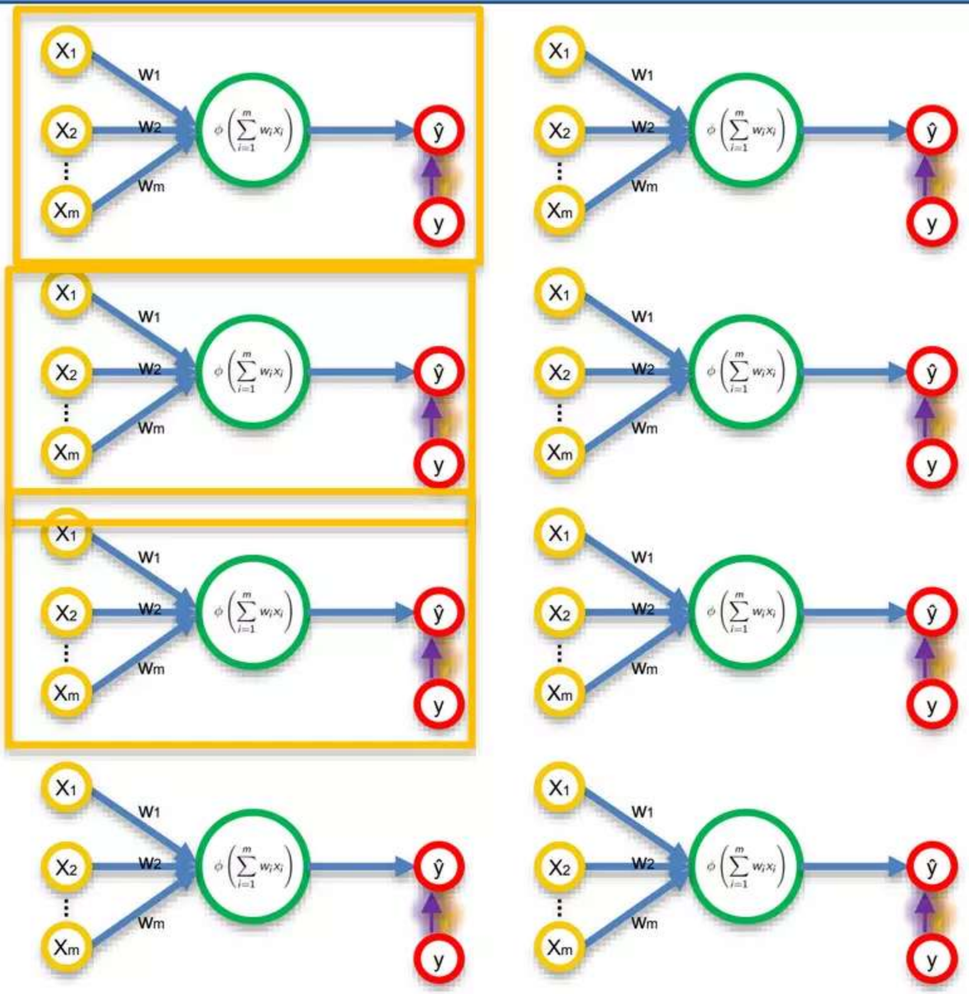


Row ID	Study Hrs	Sleep Hrs	Quiz	Exam
1	12	6	78%	93%
2	22	6.5	24%	68%
3	115	4	100%	95%
4	31	9	67%	75%
5	0	10	58%	51%
6	5	8	78%	60%
7	92	6	82%	89%
8	57	8	91%	97%

$$C = \sum \tfrac{1}{2}(\hat{y} - y)^2$$



Stochastic Gradient Descent



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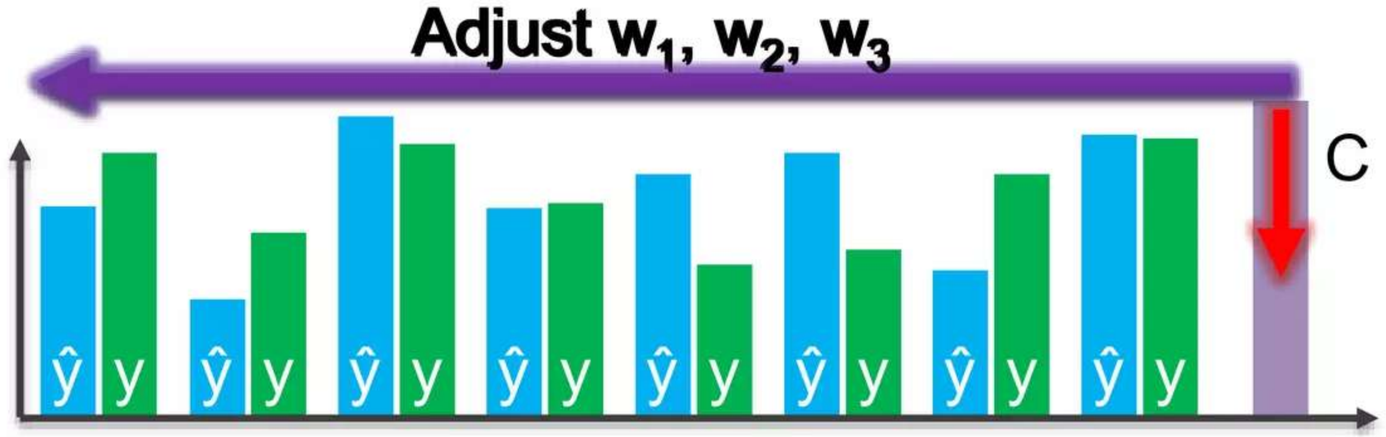
8	57	8	91%	97%

$$C = \sum \tfrac{1}{2}(\hat{y} - y)^2$$



Stochastic Gradient Descent

Upd w's

Row ID	Study Hrs	Sleep Hrs	Quiz	Exam
1	12	6	78%	93%
2	22	6.5	24%	68%
3	115	4	100%	95%
4	31	9	67%	75%
5	0	10	58%	51%
6	5	8	78%	60%
7	92	6	82%	89%
8	57	8	91%	97%

Batch Gradient Descent

Upd w's
Upd w's
Upd w's
Upd w's
Upd w's
Upd w's
Upd w's
Upd w's

Row ID	Study Hrs	Sleep Hrs	Quiz	Exam
1	12	6	78%	93%
2	22	6.5	24%	68%
3	115	4	100%	95%
4	31	9	67%	75%
5	0	10	58%	51%
6	5	8	78%	60%
7	92	6	82%	89%
8	57	8	91%	97%

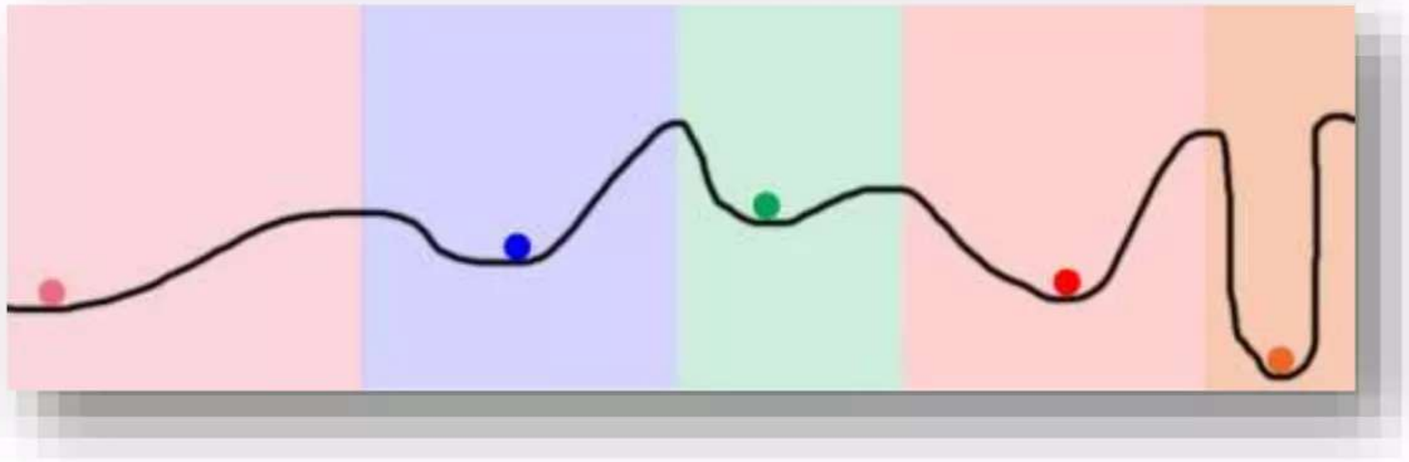
Stochastic Gradient Descent

Stochastic Gradient Descent

Additional Reading:

A Neural Network in 13 lines of Python (Part 2 - Gradient Descent)

Andrew Trask (2015)



Link:

https://iamtrask.github.io/2015/07/27/python-network-part2/

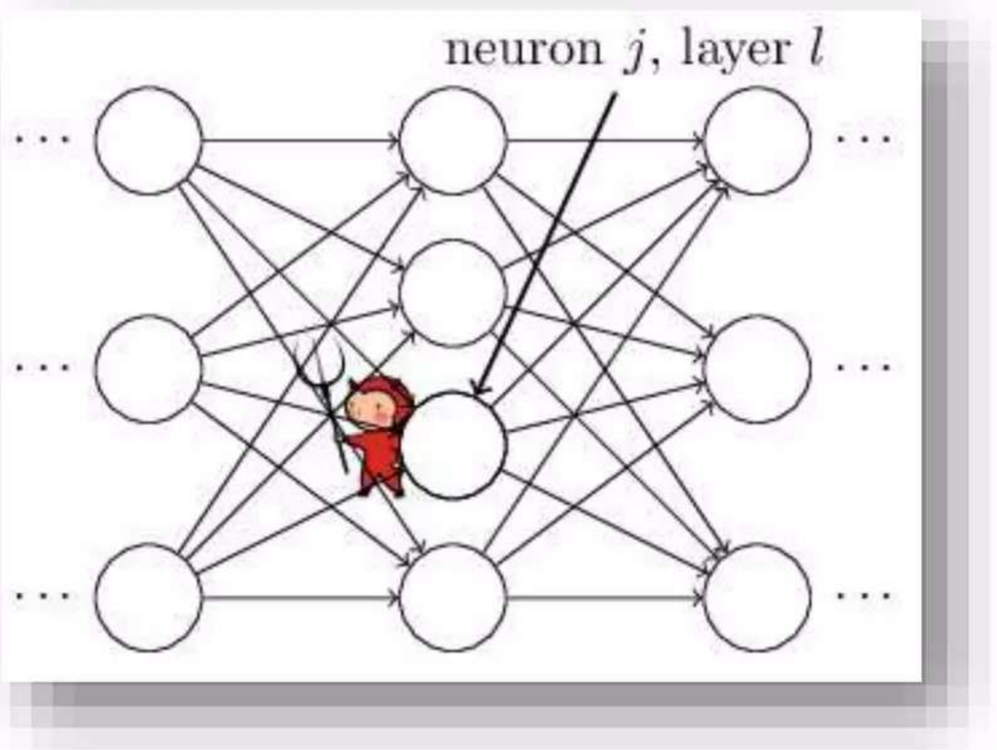
Stochastic Gradient Descent

Additional Reading:

Neural Networks and Deep Learning

Michael Nielsen (2015)

Link:



http://neuralnetworksanddeeplearning.com/chap2.html

Backpropagation

Gradient Descent

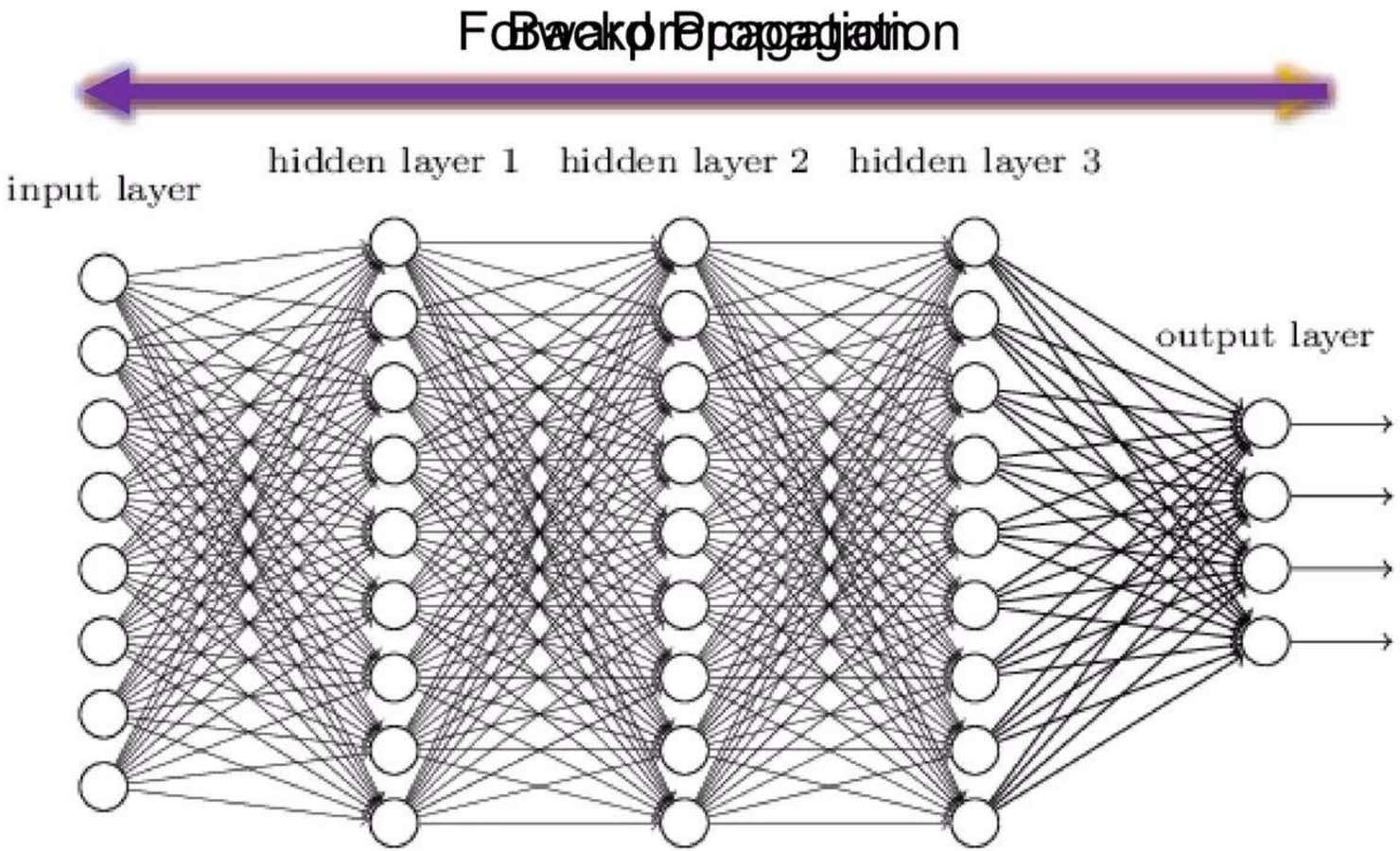


Image Source: neuralnetworksanddeeplearning.com

Stochastic Gradient Descent

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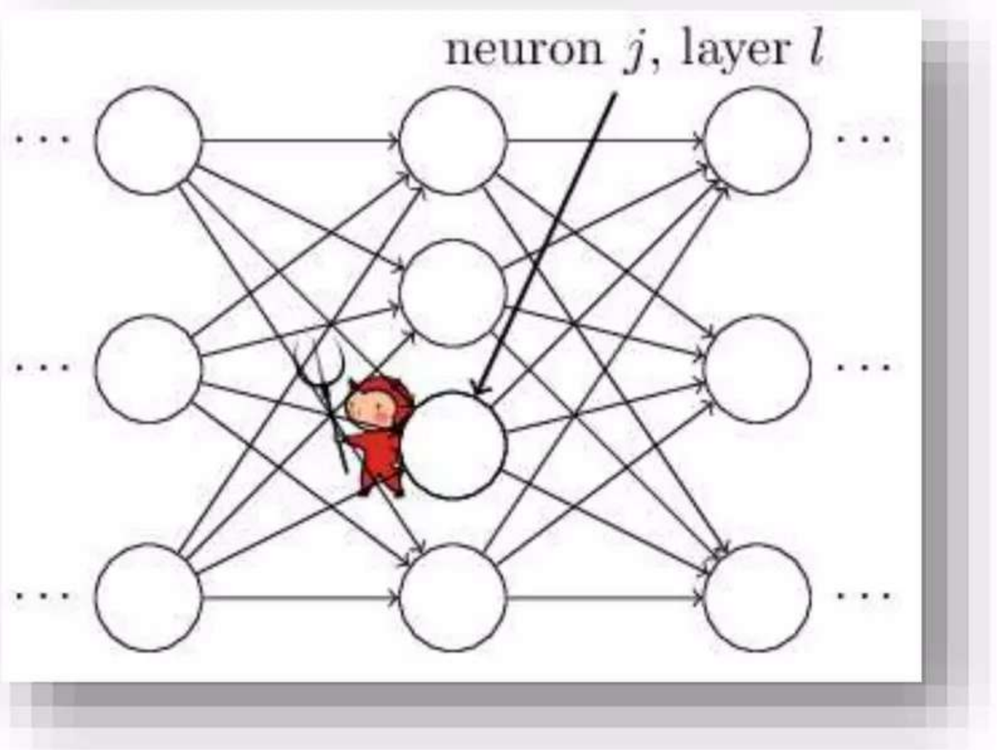

http://neuralnetworksanddeeplearning.com/chap2.html

Training the ANN with Stochastic Gradient Descent

STEP 1: Randomly initialise the weights to small numbers close to 0 (but not 0).

STEP 2: Input the first observation of your dataset in the input layer, each feature in one input node.

STEP 3: Forward-Propagation: from left to right, the neurons are activated in a way that the impact of each neuron's activation is limited by the weights. Propagate the activations until getting the predicted result y.

STEP 4: Compare the predicted result to the actual result. Measure the generated error.

STEP 5: Back-Propagation: from right to left, the error is back-propagated. Update the weights according to how much they are responsible for the error. The learning rate decides by how much we update the weights.

STEP 6: Repeat Steps 1 to 5 and update the weights after each observation (Reinforcement Learning). Or:
Repeat Steps 1 to 5 but update the weights only after a batch of observations (Batch Learning).

STEP 7: When the whole training set passed through the ANN, that makes an epoch. Redo more epochs.