Segmentation with Machine Learning

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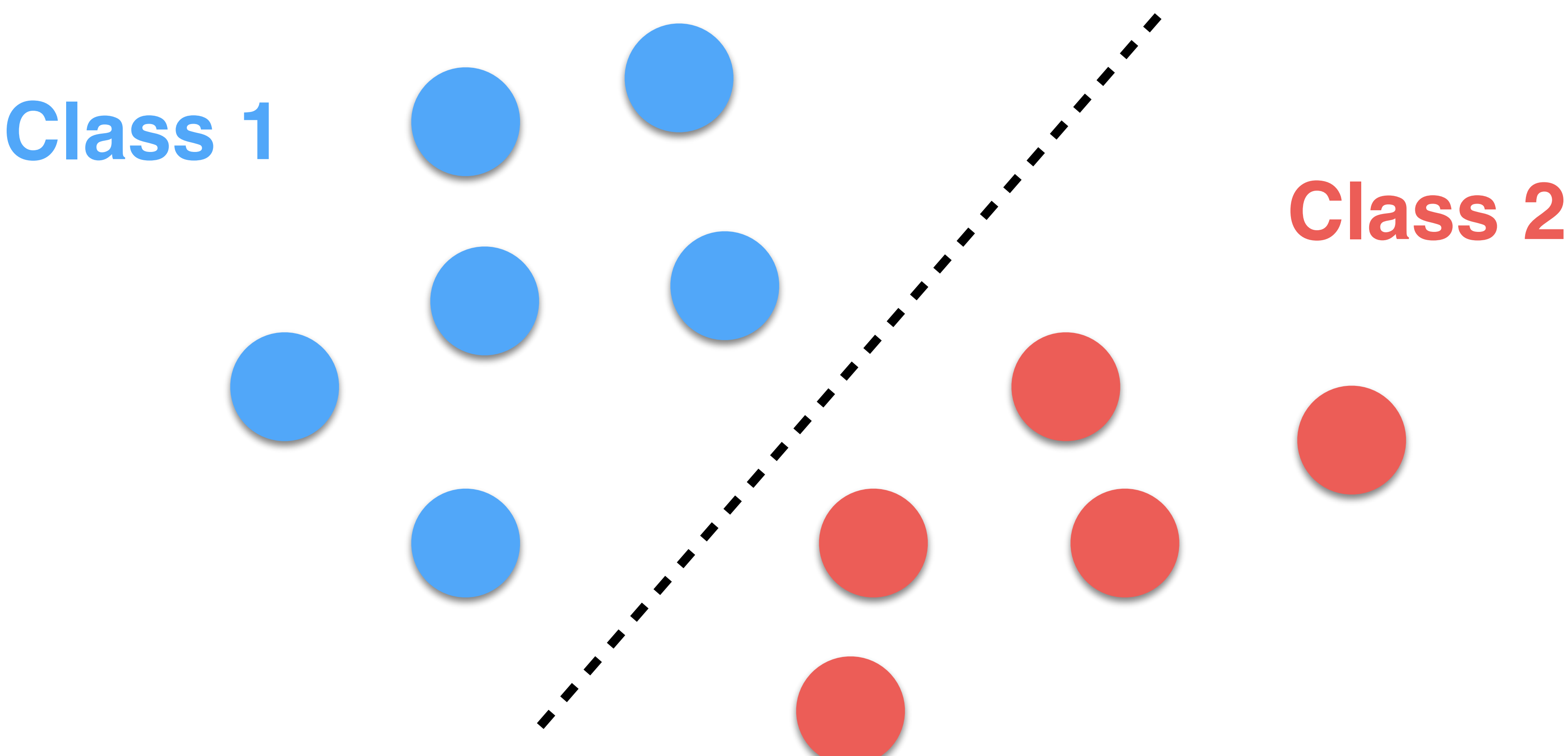
Machine Learning

- Machine learning algorithms:
  - The use of computers algorithm that may improve automatically through **experience** and/or **the use of data**.
  - **Unsupervised**: we do not have labels.
  - **Supervised**: we have labelled data:
    - Neural Networks.

Machine Learning

- Machine learning algorithms work very well for classification: drawing a plane or hyperplane to divide samples into classes.
- Similarly to k-Means (**unsupervised**) this works for segmentation too!



Machine Learning

Training Set

Model

Learning Method

Machine Learning: Learning

- **Training set**: a dataset of n couples: input and output.
  - The larger the better:
    - at least 10,000 couples for high-quality segmentation.
  - This represents a **knowledge** to be trained. “*Learn by example*”; i.e., *supervised learning*.

Machine Learning: Learning

- **Learning Method**: a mathematical model/function that transfers the **knowledge** of the training set to the model:
    - It is a mix between:
        - Minimization method (i.e., Gradient Descent);
        - Loss function (how to minimize the differences).

Machine Learning: Learning

- **Model**: a mathematical model that can store the **knowledge** of the dataset into its parameters (called ***weights***).

- For example:

  - A neural network;

  - A decision tree/forest.

Machine Learning: Supervised Learning

- There are two steps:
  - Learning
  - Prediction/Evaluation

Machine Learning: Supervised Learning

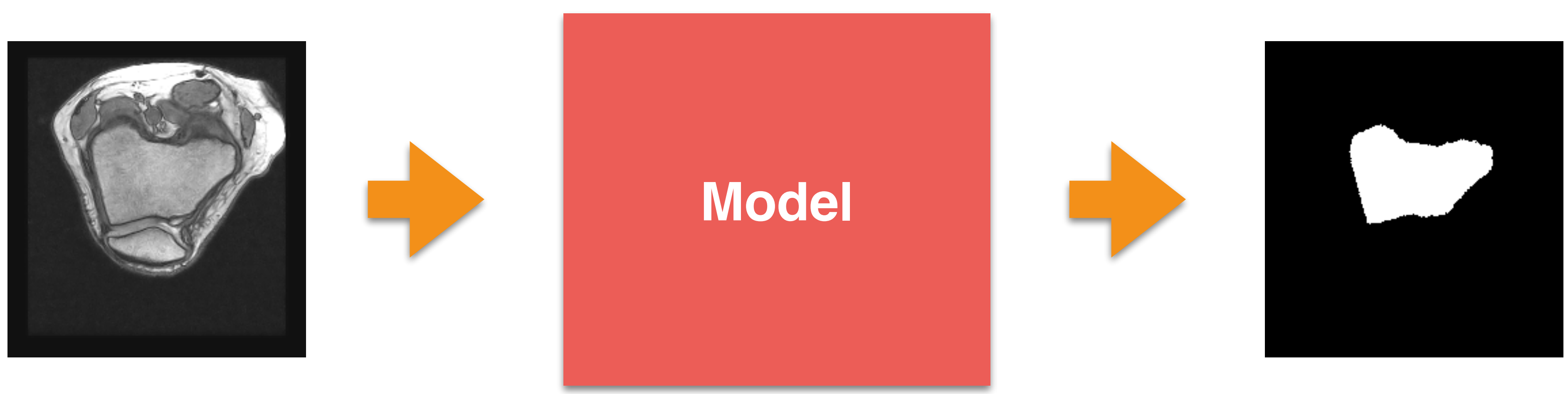
- We need to collect examples and transfer that knowledge into a model.

An example

Learning Method

Machine Learning: Supervised Prediction/Evaluation

- After learning the dataset, we just need to pass data to the model (i.e., we evaluate it) to get results:

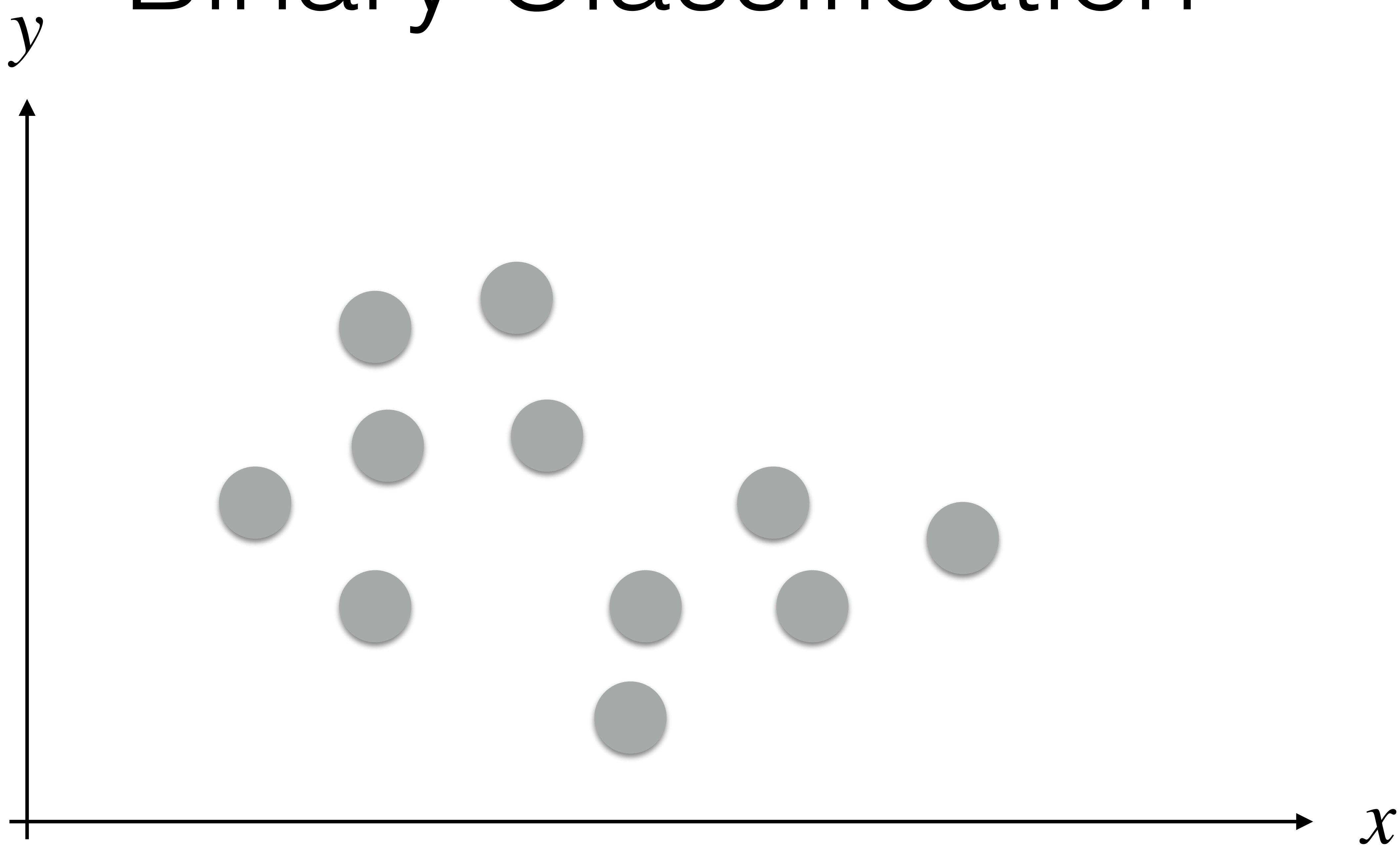


Input

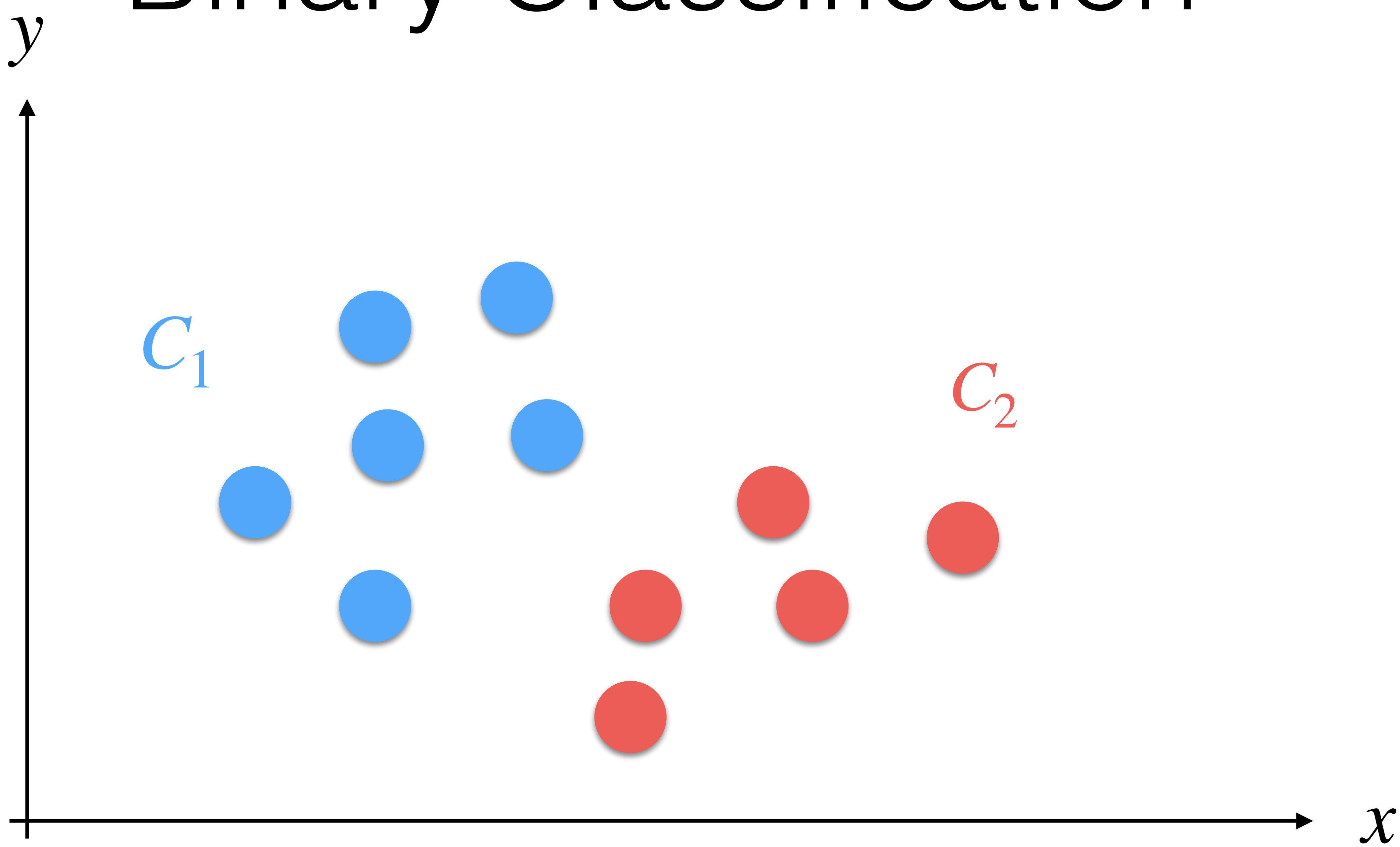
Output

A Simple Example

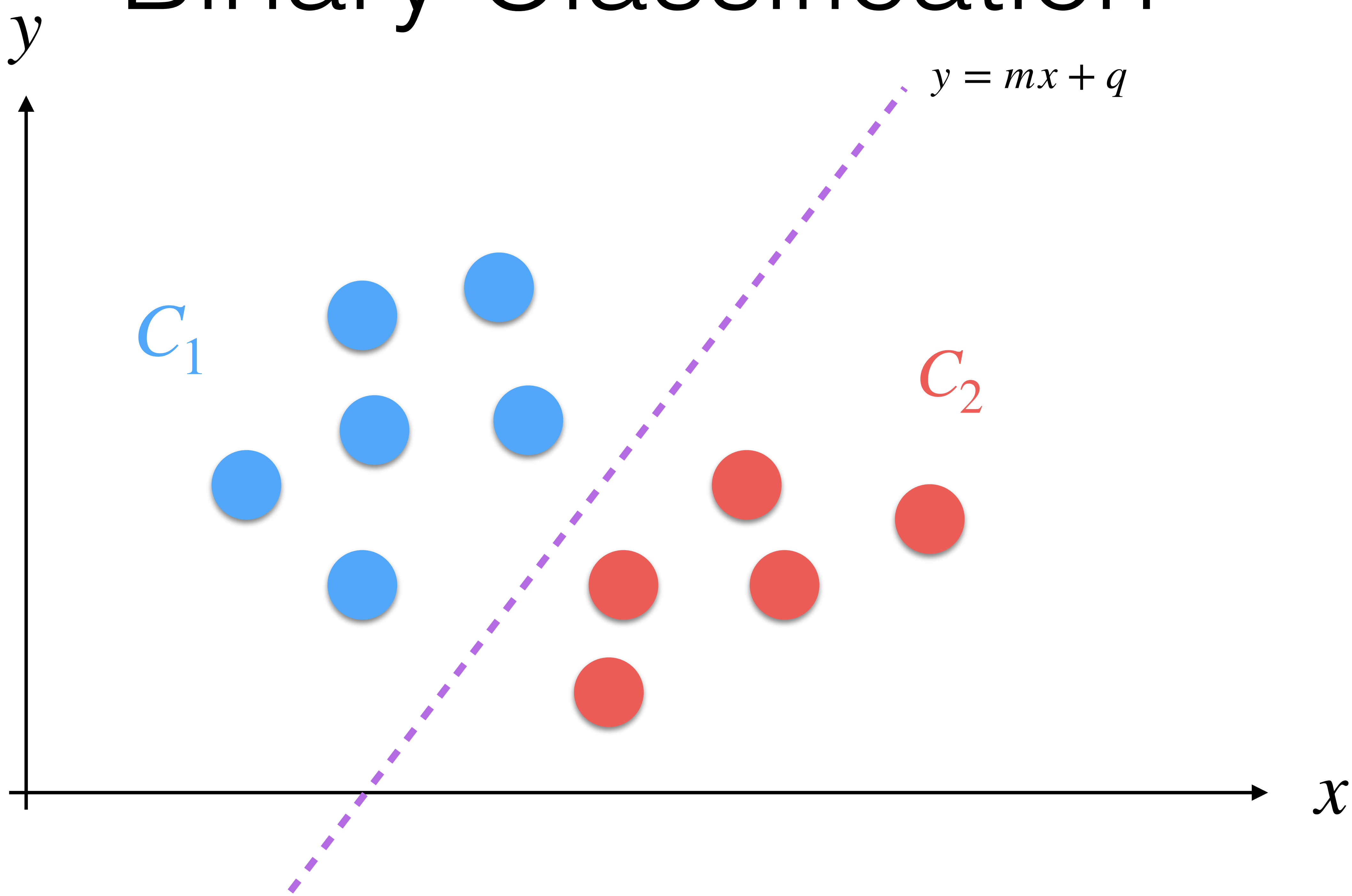
Machine Learning: Binary Classification



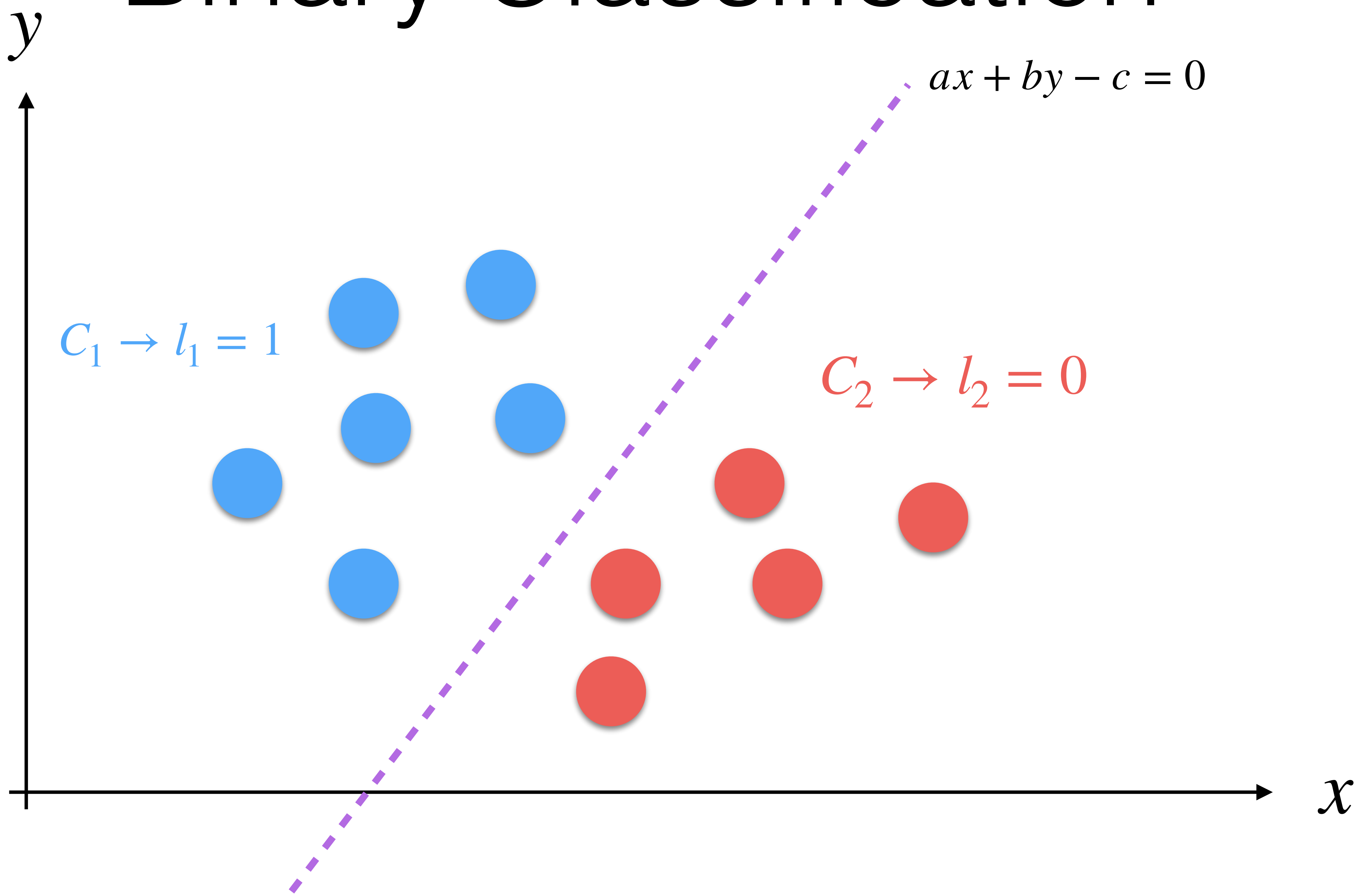
Machine Learning: Binary Classification



Machine Learning: Binary Classification



Machine Learning: Binary Classification



Machine Learning: Classification

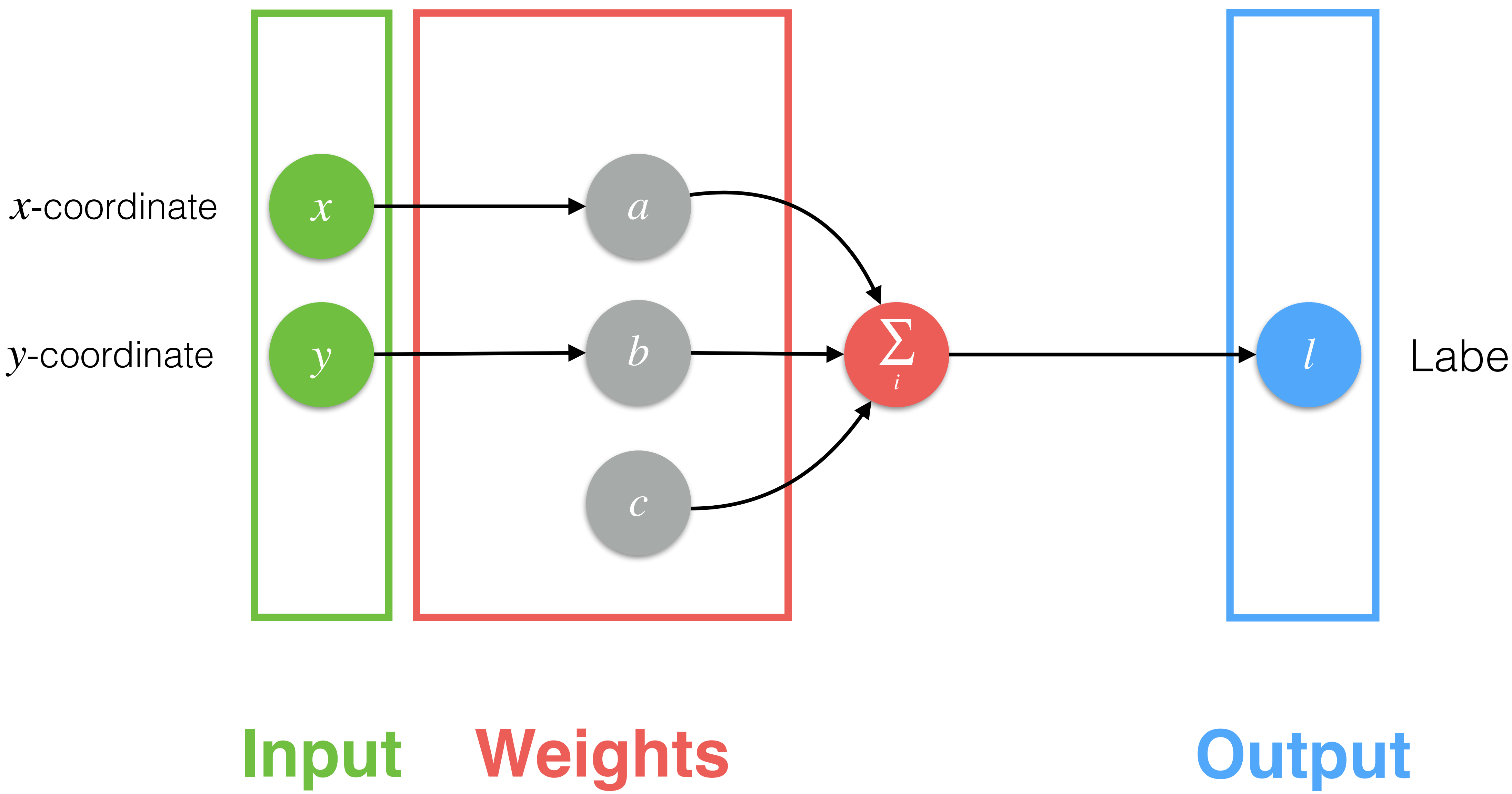
- Now, if we get a new sample $\mathbf{p}^i = (x^i, y^i)$ belongs C_1 we have:

$$ax^i + by^i - c \geq 0$$

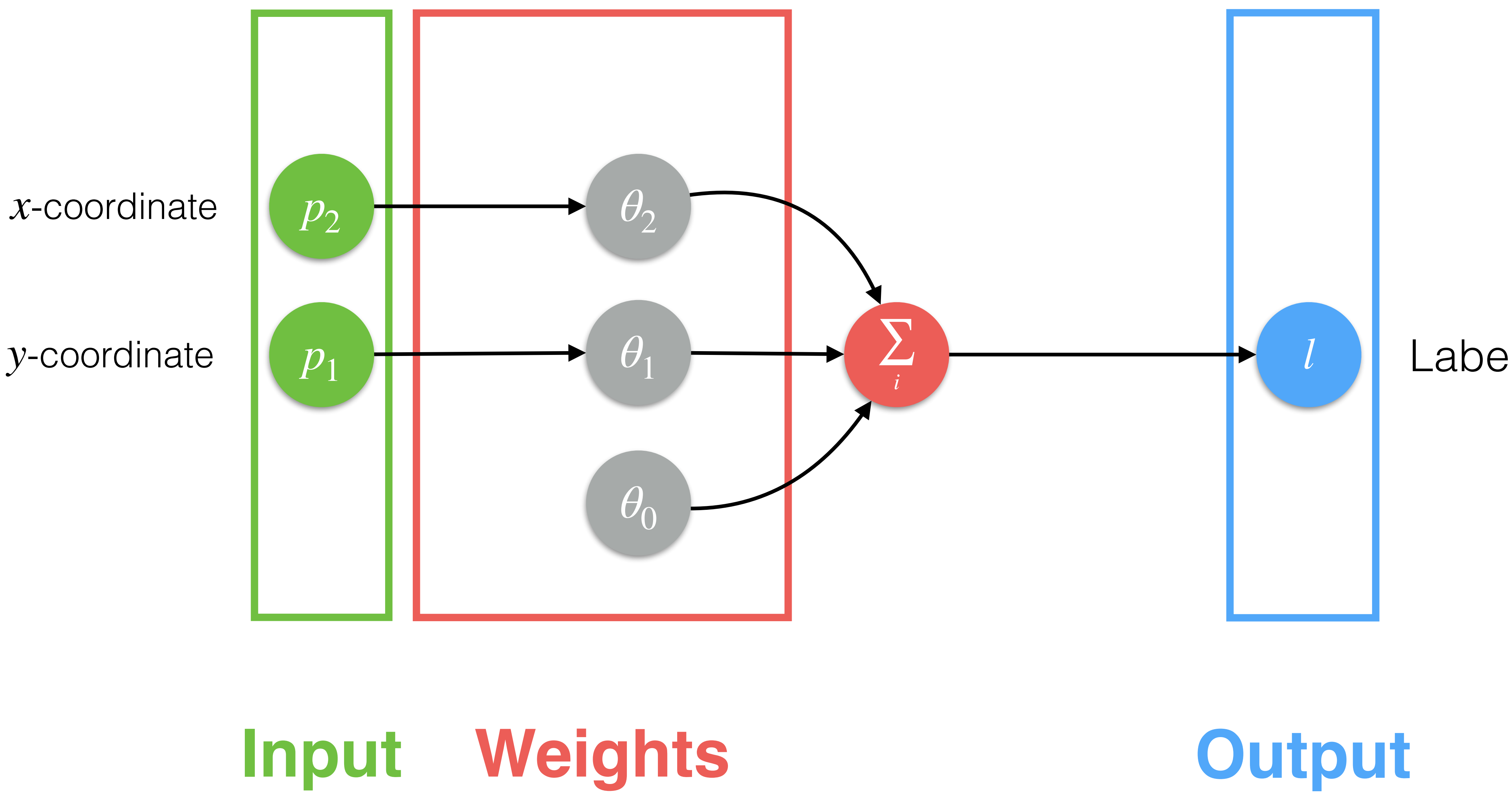
- If it belongs to C_2 we have:

$$ax^i + by^i - c < 0$$

Neural Networks: Our Model h



Neural Networks: Our Model h



Machine Learning: Classification

- Our model can be so defined as:

$$h(\mathbf{p}, \theta) = [\mathbf{p}, 1]^{\mathsf{T}} \cdot \theta$$

Neural Networks: Supervised Learning

- We need to collect m couples $(\mathbf{p}^j, l^j)$.
- We need to minimize an error function J:

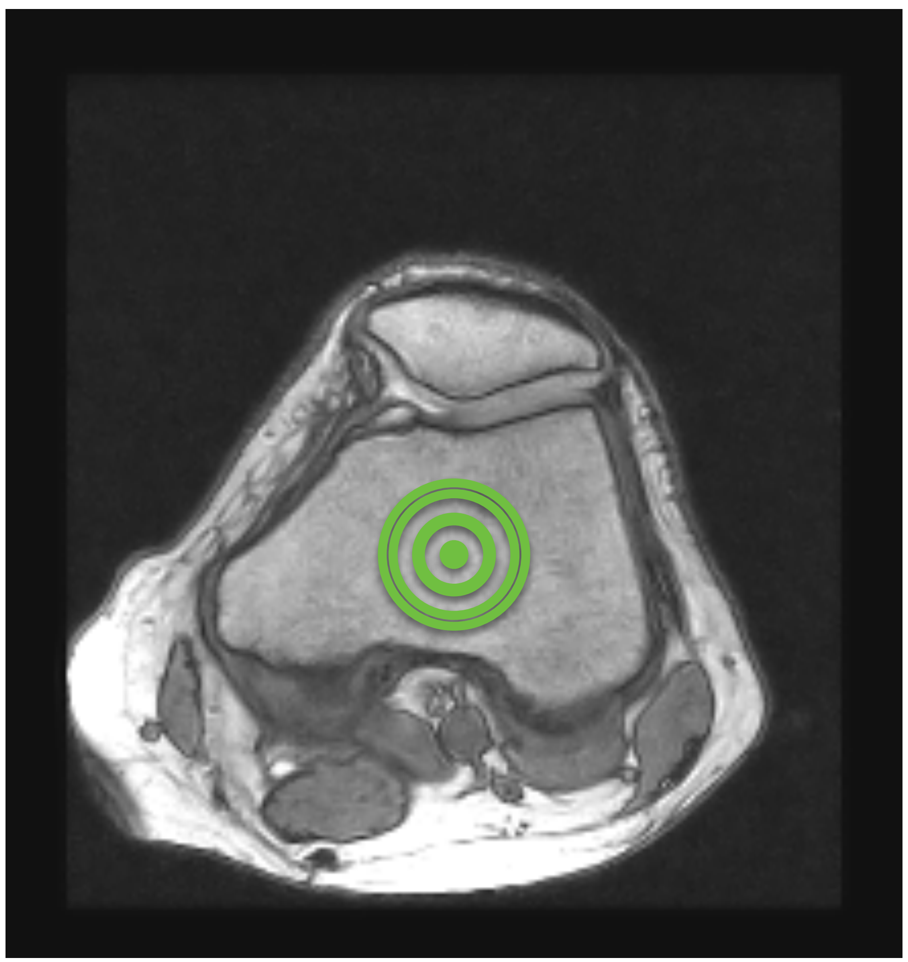
$$\arg\min_{\theta} \frac{1}{2} \sum_{j=1}^{m} \left(h(\mathbf{p}^j, \theta) - l^j \right)^2$$

- How do we minimize it?
  - Gradient descent.
  - Starting solution for θ? Random values in $[-1,1]$.

A Segmentation Example

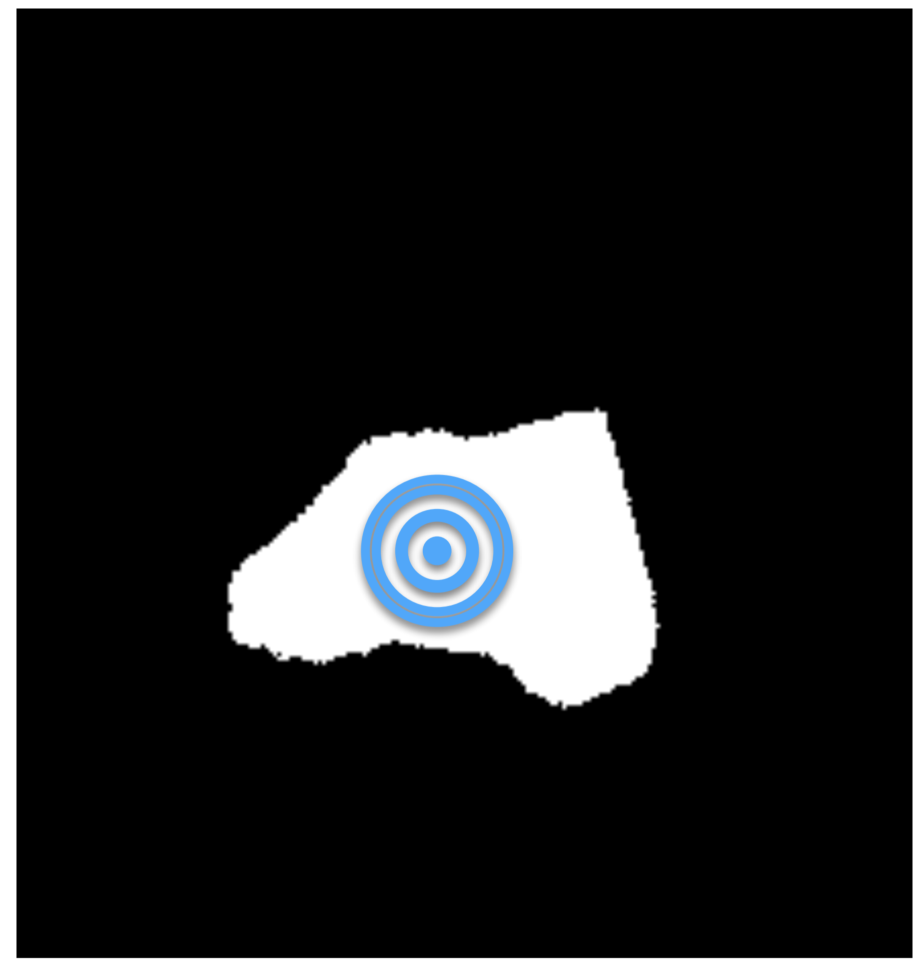
Neural Networks: Dataset Set (1)

Input



$\mathbf{p}^1 = (100,100,0.67)$

Output



$l^1 = 1$

Neural Networks: Dataset Set (2)

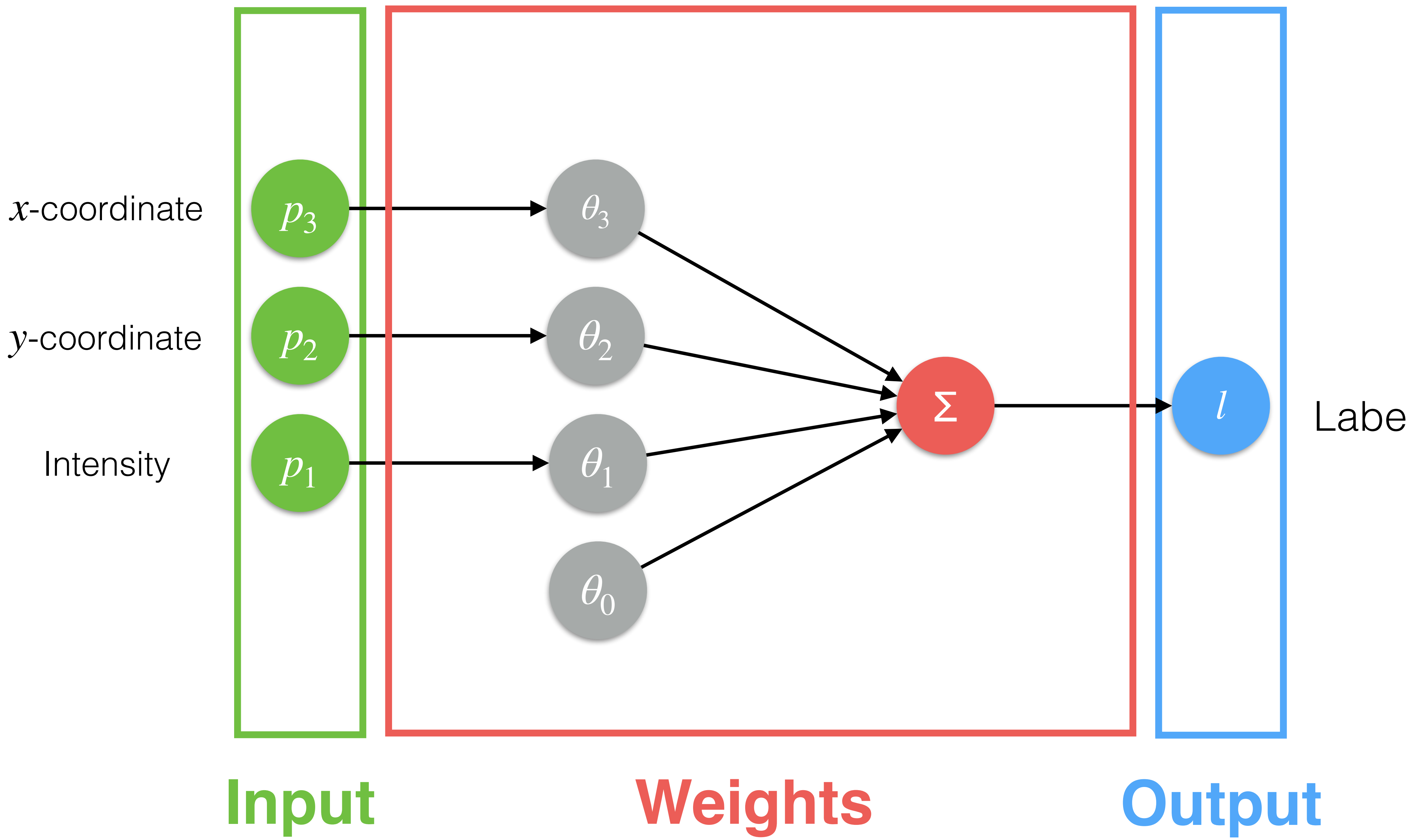
Input

$\mathbf{p}^2 = (20,20,0.01)$

Output

$l^2 = 0$

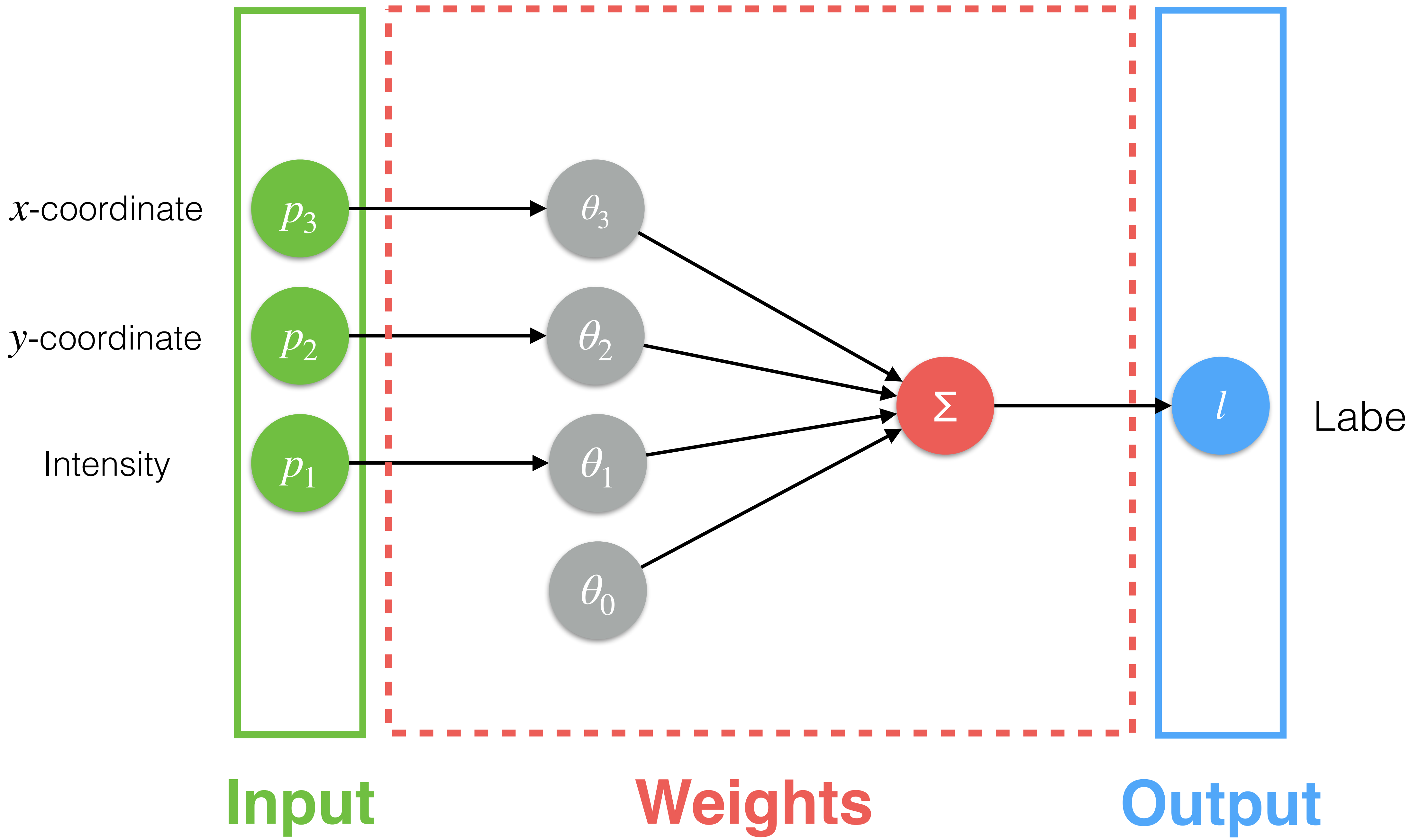
Neural Networks: The Model



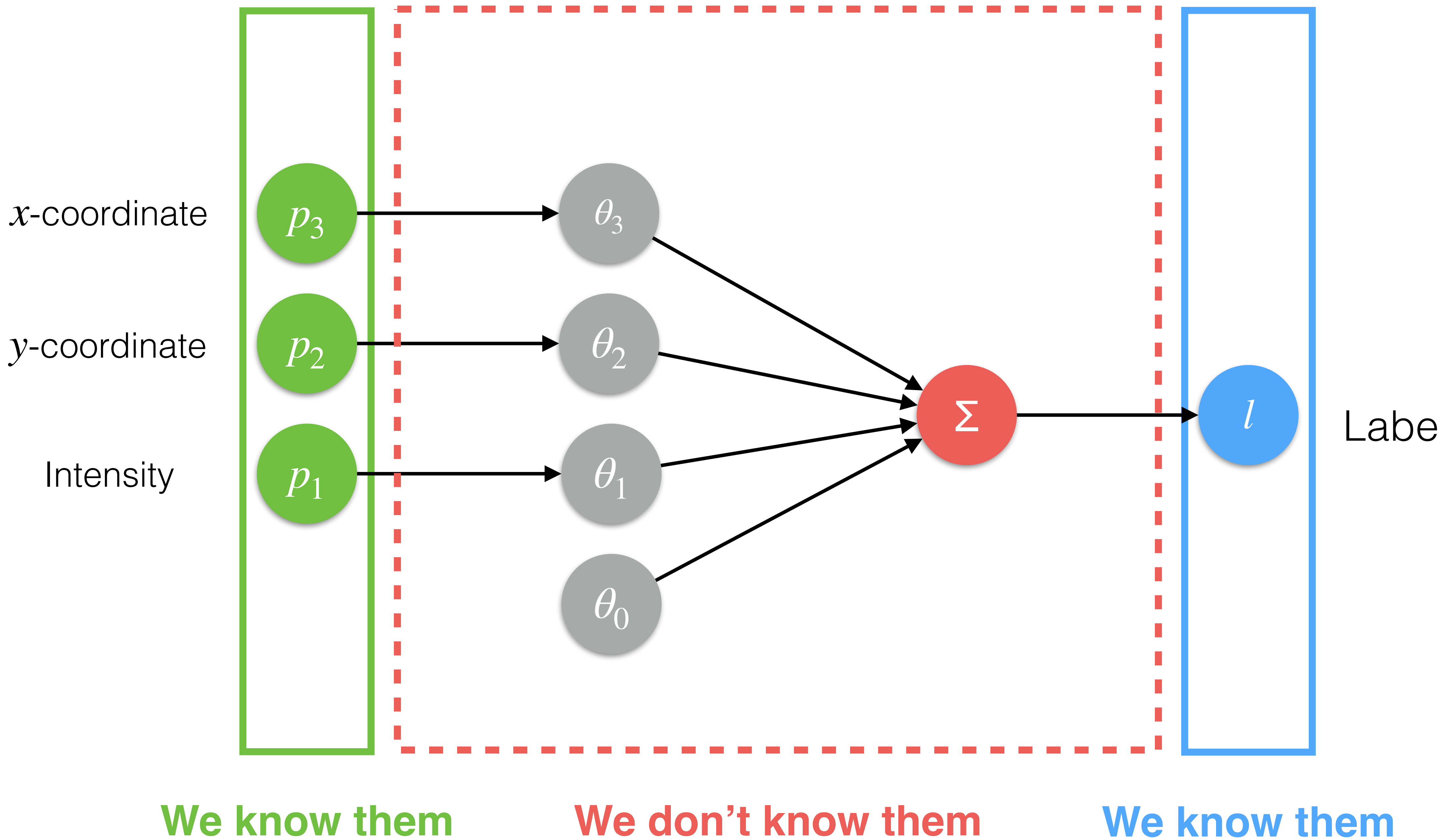
Machine Learning: Dataset Set (3)

- The dataset needs to be balanced:
  - The same amount of examples for both classes: ROI and background.
- The dataset needs to be divided into:
  - Training set —> samples to train the network
  - Evaluation set —> samples to check if the model is not overfitting or under fitting.

Neural Networks: Training Phase

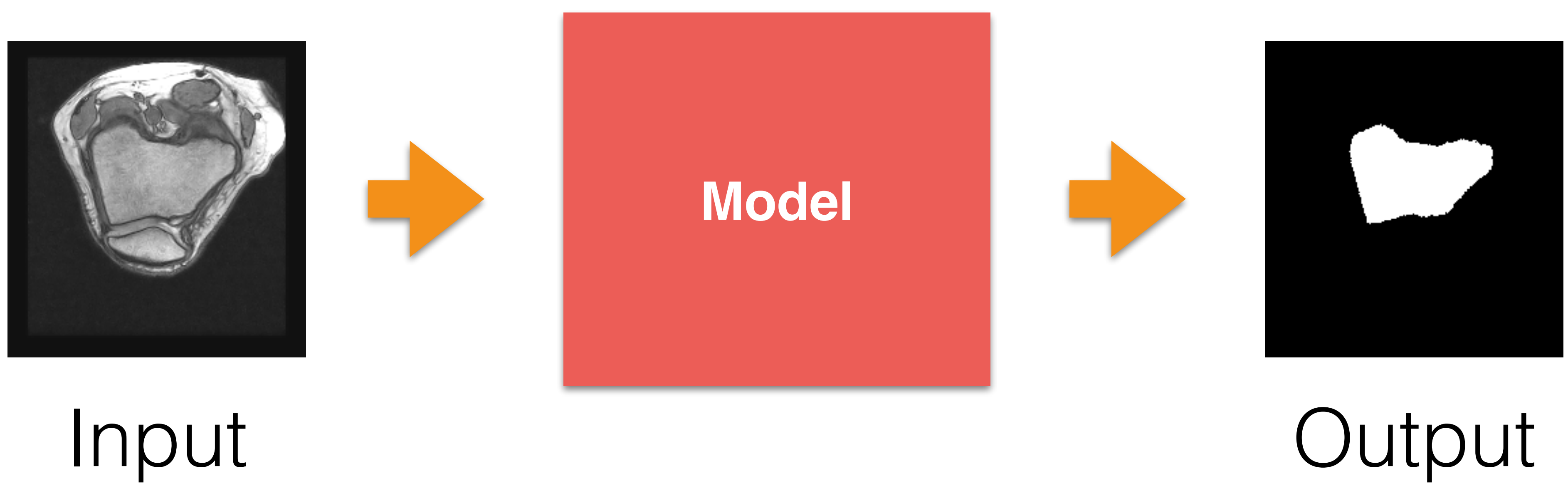


Neural Networks: Training Phase

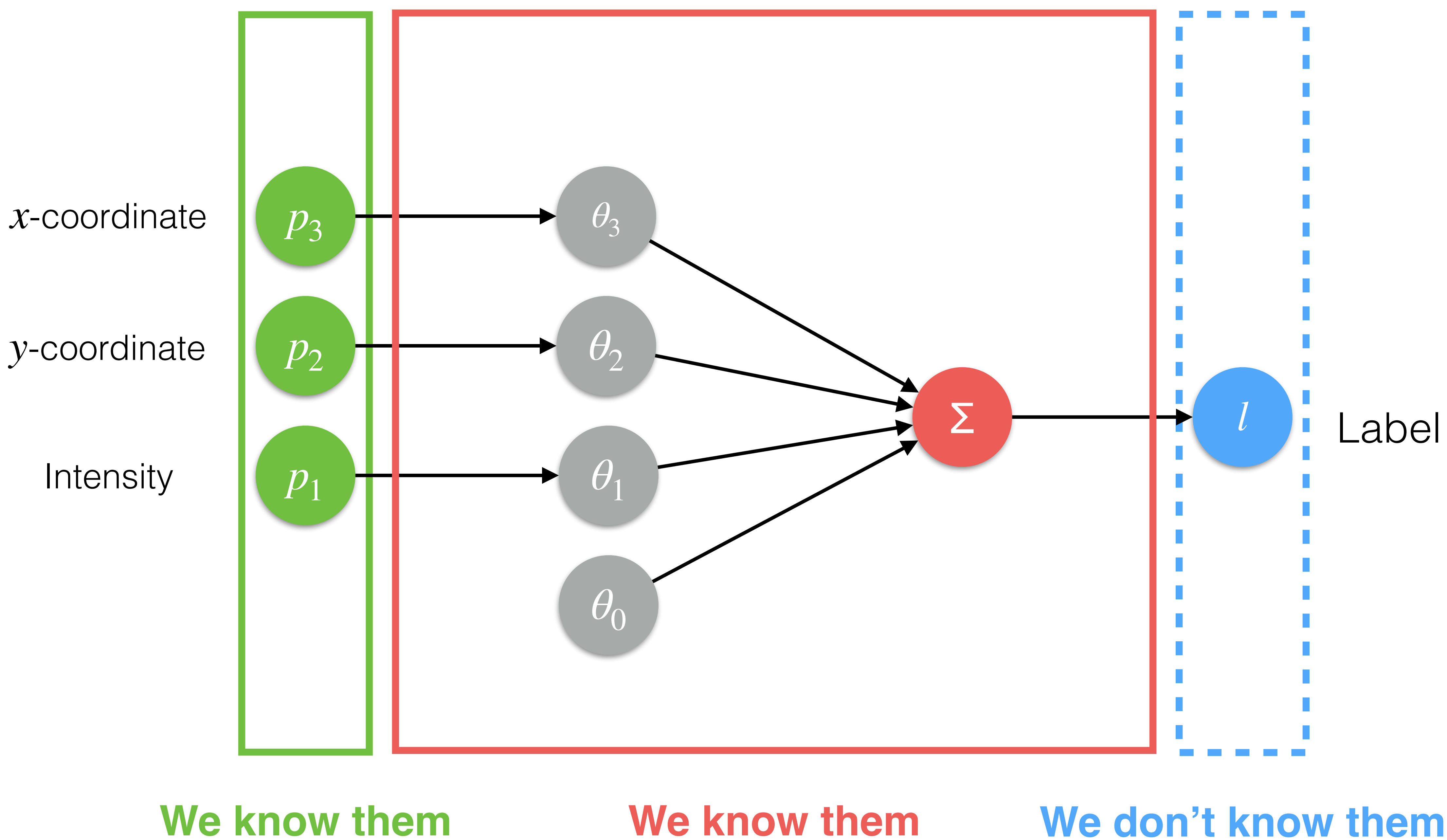


Machine Learning: Prediction Phase

- After learning, we can use our network on new images to segment the image:



Neural Networks: Training Phase

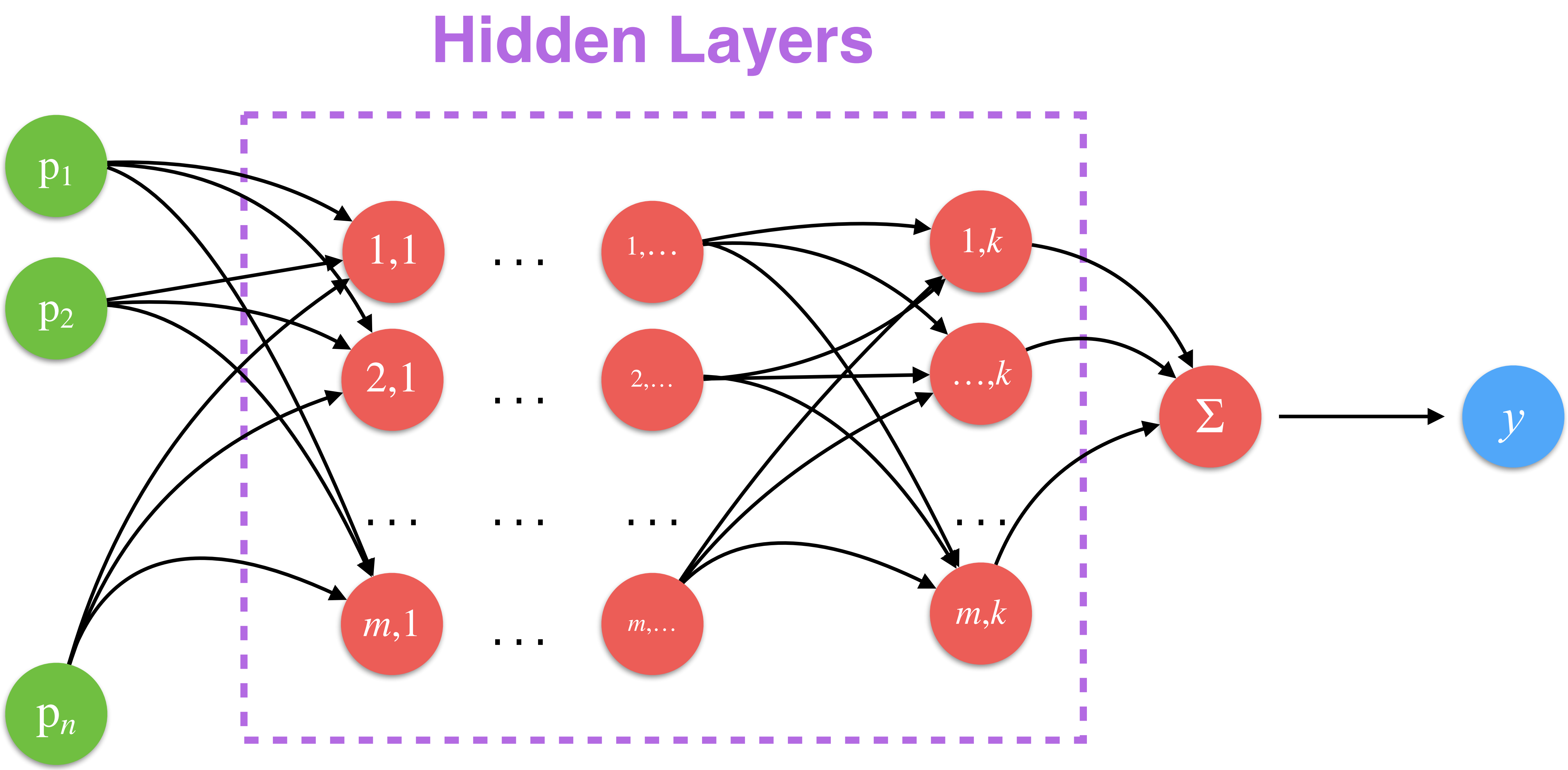


More Complex Examples

More Complex Nets

- To achieve high-quality results, a network needs to “see” and “understand” more data at the same time; not only a couple such as the pixel coordinates and its pixel intensity and its classification as in the previous example!
- We need to use more pixels/voxels at the same time:
  - How?
    - Adding and mixing more neurons

Neural Networks: Bigger Networks



$y = h^{i,j}(\mathbf{p}, \theta)$

Neural Networks

- Advantages:
  - fully automatic!
  - computationally fast to evaluate (not the learning though); especially using GPUs.
- Disadvantages:
  - they required many many examples:
    - more than 1,000 to get some decent results;
    - better >10,000 training example!

that’s all folks!