Elective Course
Course Code: CS4103
Autumn 2025-26

Lecture #38

Artificial Intelligence for Data Science

Week-11:

MACHINE LEARNING (Part VI)

Introduction to Neural Network

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Artificial Neural Networks (ANNs) --- Origin

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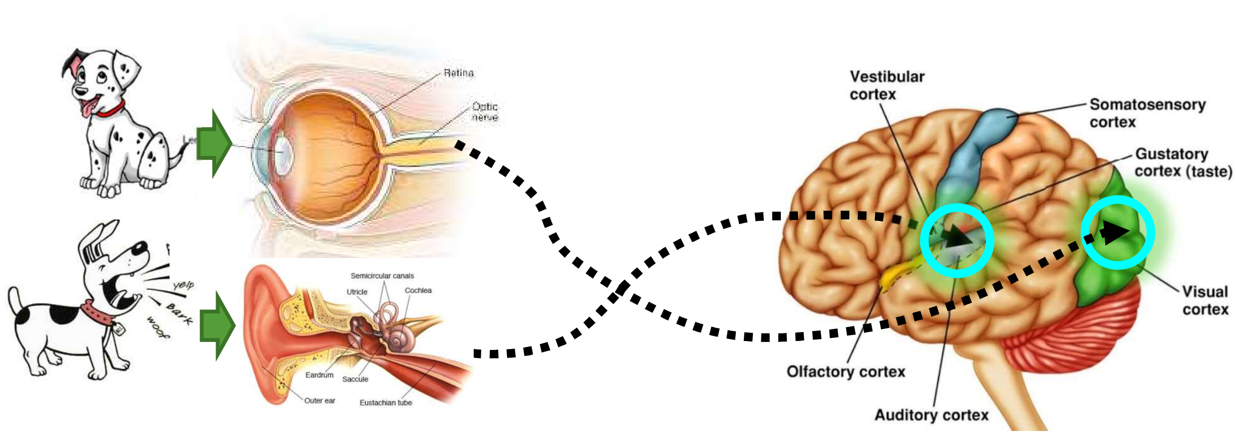
- ANNs- Information processing systems or algorithms that try to **mimic the brain**



Artificial Neural Networks (ANNs) --- Origin

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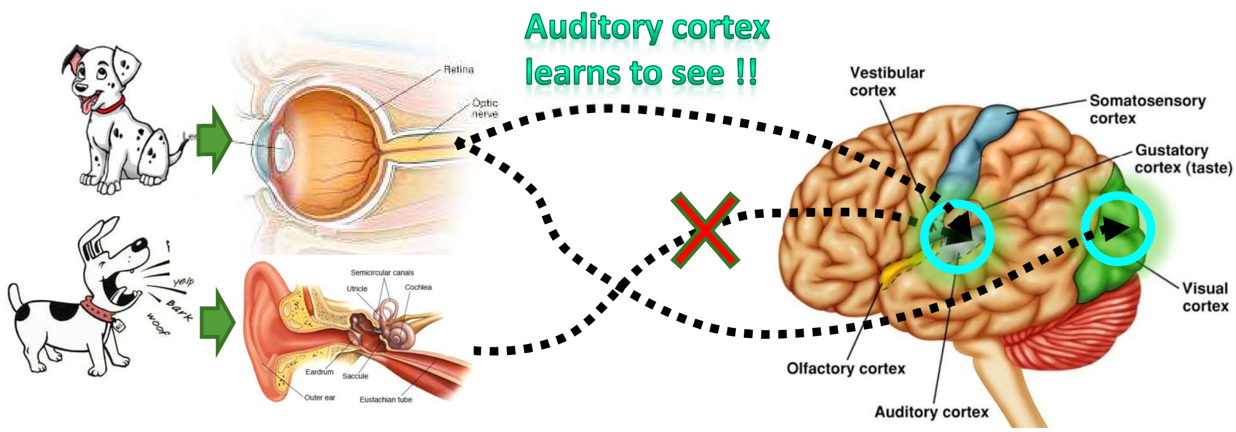
- The “one learning algorithm” hypothesis



Artificial Neural Networks (ANNs) --- Origin

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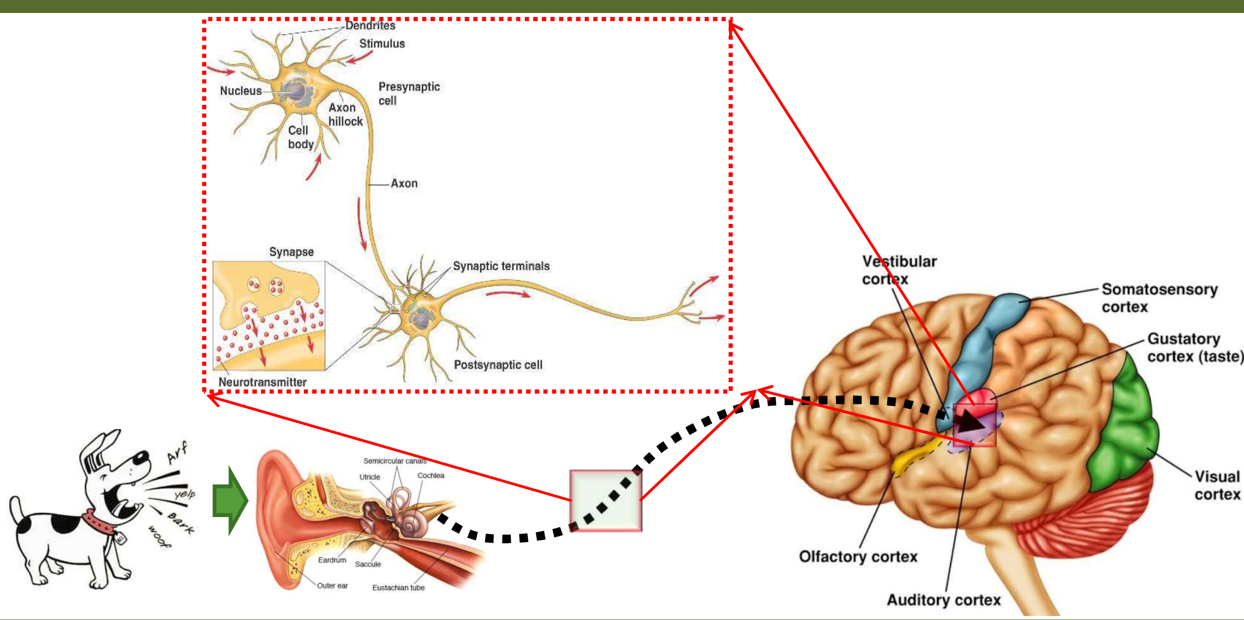

Neuron in the Brain

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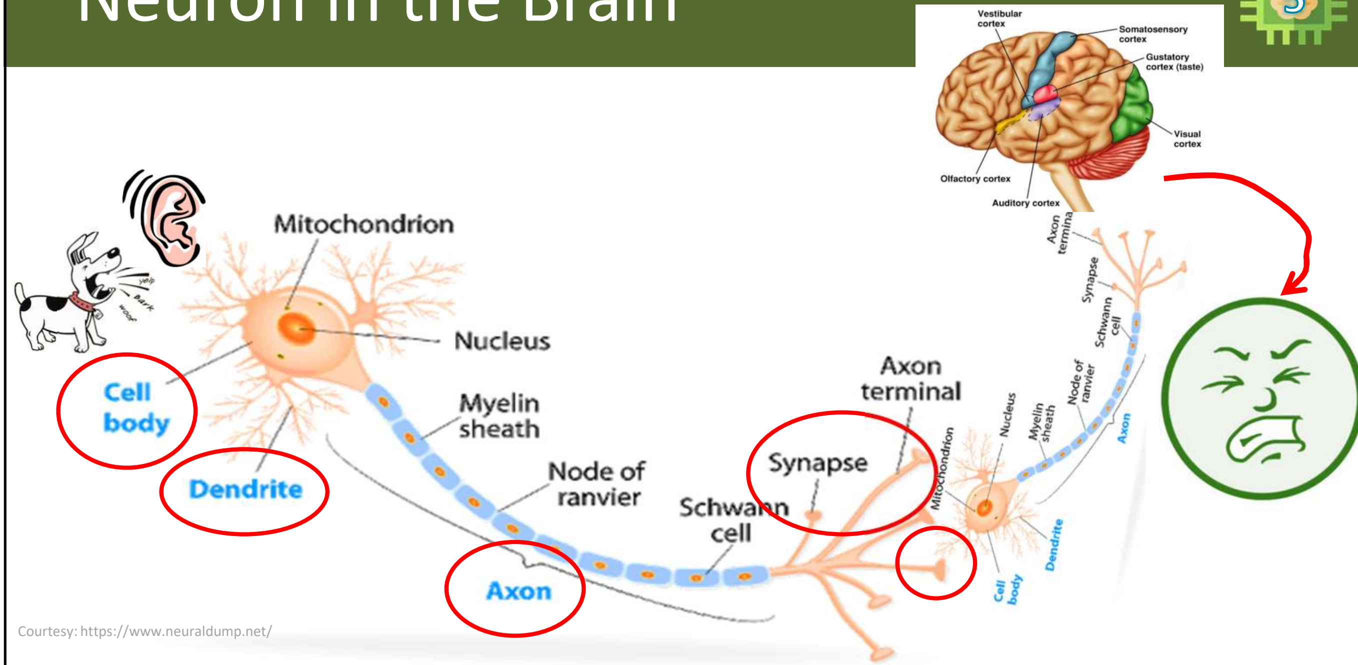

Courtesy: https://www.neuraldump.net/

Artificial Neural Network (ANN)

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- Artificial Neural Networks
  - Information processing model
  - Resembles biological neural network
  - Possesses large number of highly interconnected ***processing elements (neurons)***
  - **Objective:** to develop a computational device for modeling the brain

ANN vs. Biological Neural Network

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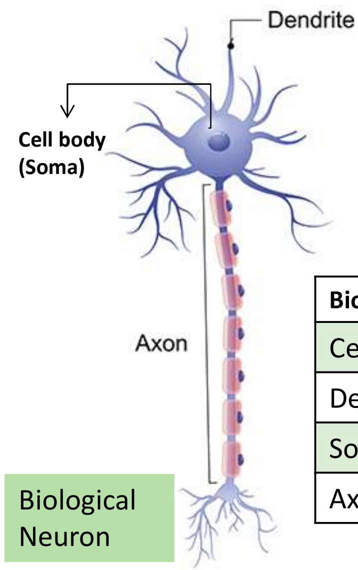

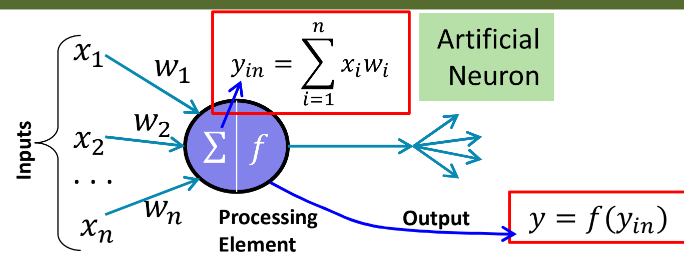

Biological Neuron	Artificial Neuron
Cell	Neuron
Dendrites	Interconnections/ Weighted-inputs
Soma (cell body)	Net input
Axon	Output

ANN vs. Biological Neural Network

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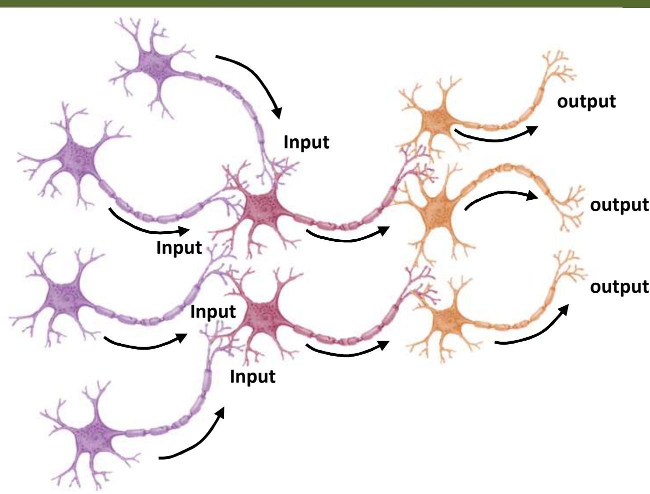
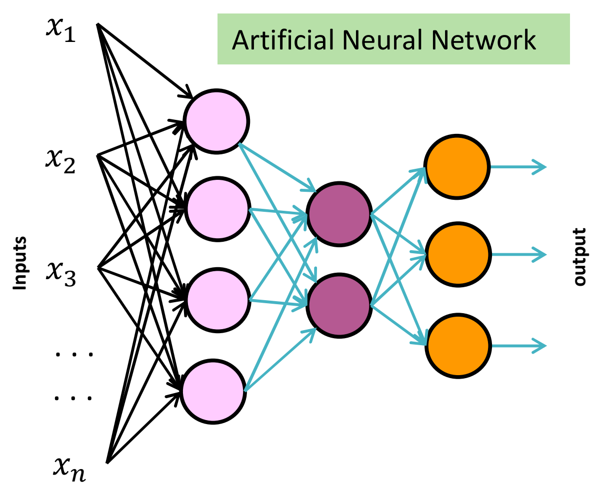


Biological Neural Network



ANN vs. Biological Neural Network

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Criteria	Brain	Computer
Speed	Execution time in ms	Execution time in ns
Processing	Can perform massive parallel computation; but slower	Can perform several parallel computation; but faster
Size and Complexity	10^{11} neurons and 10^{15} interconnections; Complex	Complexity depends on application and designer
Storage Capacity	Information is stored in synapse strength	Information is stored in memory May cause overload
Tolerance	Fault tolerant	Not fault tolerant
Control Mechanism	Complicated process, based on chemical action	Simpler process

Basic Models of ANNs

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- ANN models are primarily specified by the following entities:
  1. Model's ***Synaptic Interconnections***
  2. ***Training or learning rules*** for adapting and adjusting the connection weights
  3. ***Activation functions***

Model’s Synaptic Interconnections

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- **Five basic types** of neuron connection architectures
  1. Single-layer feed-forward network
  2. Multi-layer feed-forward network
  3. Single node with its own feedback
  4. Single-layer recurrent network
  5. Multilayer recurrent network

Model’s Synaptic Interconnections

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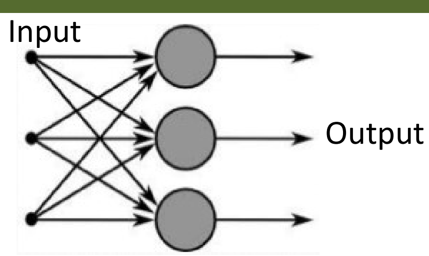
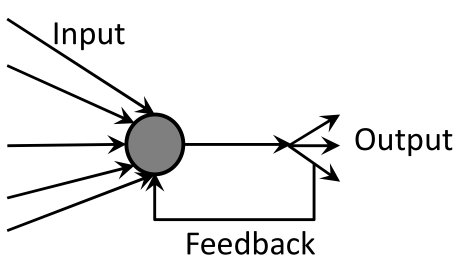
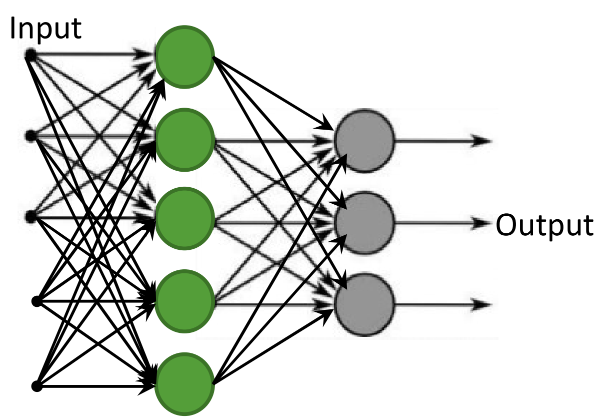


Single-layer feed-forward network



Single node with its own feedback



Multi-layer feed-forward network

Model's Synaptic Interconnections

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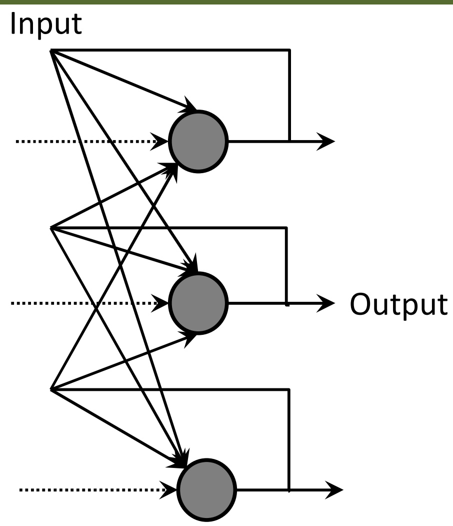
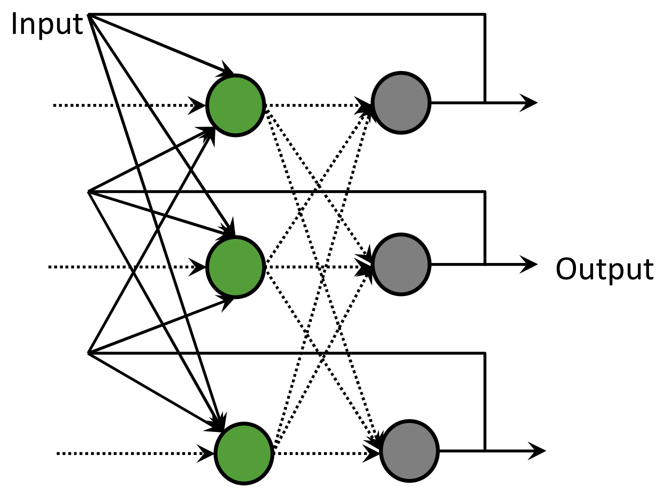


Single-layer recurrent network



Multi-layer recurrent network

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ANN---Basic Terminologies

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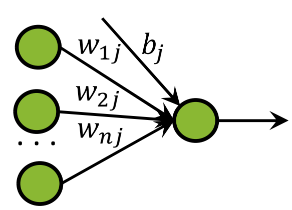
- Weights
- Bias
- Activation Function
- Learning rate
- Momentum factor

$W =$

w_{11}	w_{12}	…	w_{1m}
w_{21}	w_{22}	…	w_{2m}
…	…	…	…
w_{n1}	w_{n2}	…	w_{nm}



$$f(net) = \begin{cases} 1, if \quad net \geq \theta \\ -1, if \quad net < \theta \end{cases}$$

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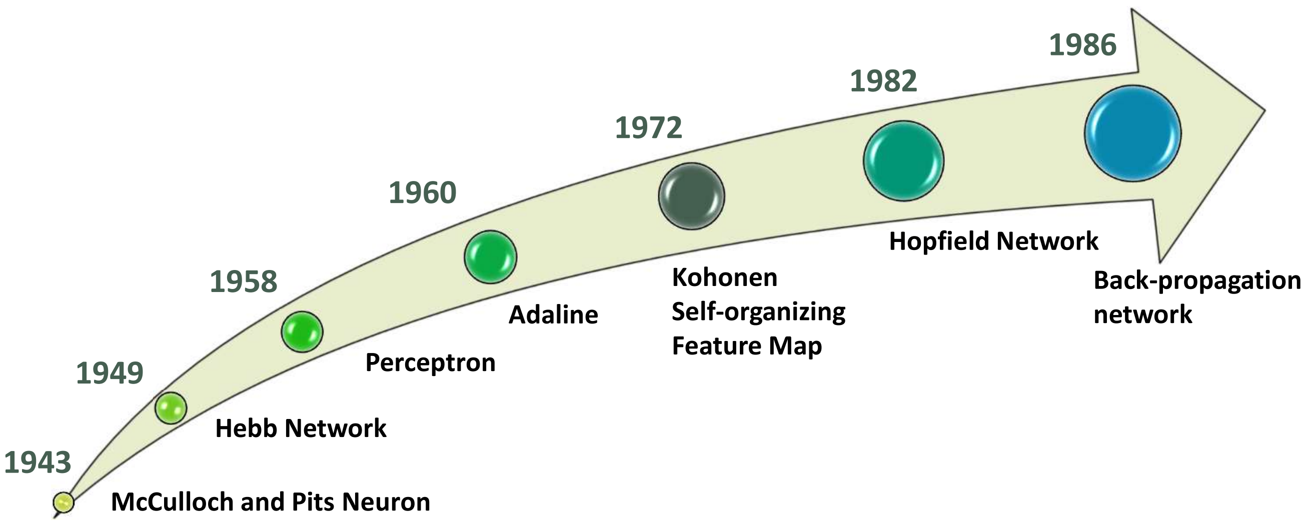
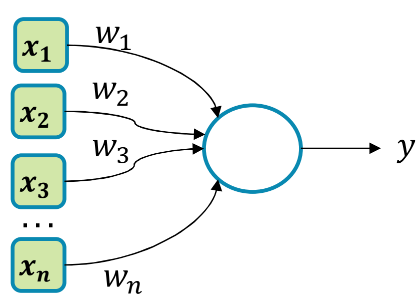
Evolution of ANNs



Perceptron: Introduction

- Frank Rosenblatt (American psychologist) proposed the ***classical perceptron model*** (1958)
- Carefully analyzed by Minsky and Papert ---- ***perceptron model*** (1969)

$$y = \begin{cases} 1 \ \ if \displaystyle\sum_{i=1}^{n} w_i x_i \geq \theta \\ 0 \ \ if \displaystyle\sum_{i=1}^{n} w_i x_i < \theta \end{cases}$$



Perceptron: Introduction

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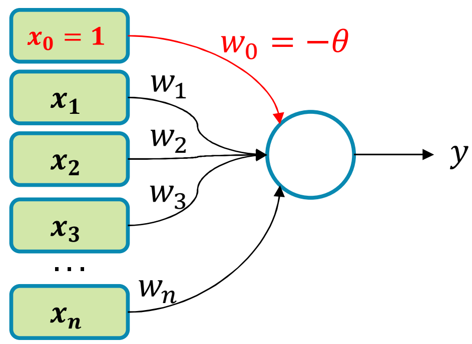
- Re-writing activation function:

$$y = \begin{cases} 1 \;\; if \sum_{i=1}^{n} w_i x_i - \theta \geq 0 \\ 0 \;\; if \sum_{i=1}^{n} w_i x_i - \theta < 0 \end{cases}$$

- More accepted convention:

$$y = \begin{cases} 1 \;\; if \sum_{i=0}^{n} w_i x_i \geq 0 \\ 0 \;\; if \sum_{i=0}^{n} w_i x_i < 0 \end{cases}$$

$x_0 = 1, w_0 = -\theta$



Perceptron: Learning Algorithm

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Algorithm: Perceptron Learning Algorithm

$P \leftarrow inputs \;\; with \;\; label \;\; 1;$
$N \leftarrow inputs \;\; with \;\; label \;\; 0;$
Initialize $\mathbf{w}$ randomly;
while $!convergence$ **do**
  Pick random $\mathbf{x} \in P \cup N$;
  if $\mathbf{x} \in P \;\; and \;\; \sum_{i=0}^{n} w_i * x_i < 0$ **then**
    $\mathbf{w} = \mathbf{w} + \mathbf{x}$;
  end
  if $\mathbf{x} \in N \;\; and \;\; \sum_{i=0}^{n} w_i * x_i \geq 0$ **then**
    $\mathbf{w} = \mathbf{w} - \mathbf{x}$;
  end
end
//the algorithm converges when all the inputs are classified correctly

Perceptron Learning Example

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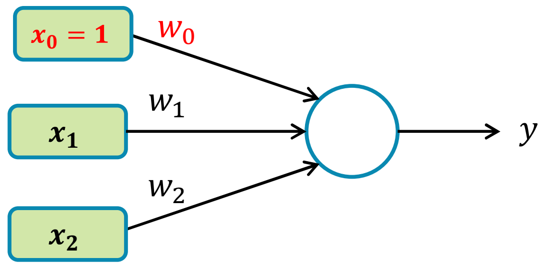
- Implement OR function with binary inputs and binary targets using perceptron training algorithm

x_1	x_2	t
0	0	0
0	1	1
1	0	1
1	1	1



Perceptron: Learning

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	Input			Target	Net Input	Calculated output	Weights		
	x_1	x_2	x_0	t	y_{in}	y	w_1	w_2	w_0
							0	0	0
EPOCH-1	0	0	1	0	0	1	0	0	-1
	0	1	1	1	-1	0	0	1	0
	1	0	1	1	0	1	0	1	0
	1	1	1	1	1	1	0	1	0
EPOCH-2	0	0	1	0	0	1	0	1	-1
	0	1	1	1	0	1	0	1	-1
	1	0	1	1	-1	0	1	1	0
	1	1	1	1	2	1	1	1	0
EPOCH-3	0	0	1	0	0	1	1	1	-1
	0	1	1	1	0	1	1	1	-1
	1	0	1	1	0	1	1	1	-1
	1	1	1	1	1	1	1	1	-1

Perceptron: Learning

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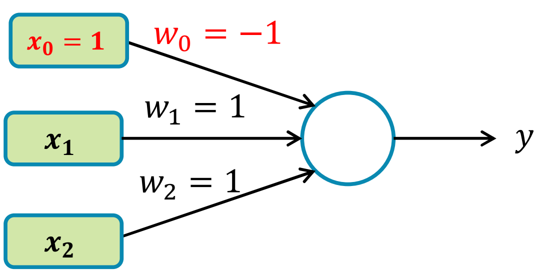
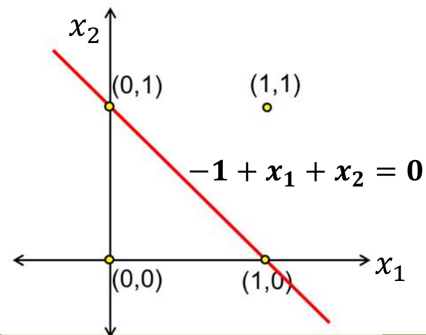
EPOCH-4

Input			Target	Net Input	Calculated output	Weights		
x_1	x_2	x_0	t	y_{in}	y	w_1	w_2	w_0
						1	1	-1
0	0	1	0	-1	0	1	1	-1
0	1	1	1	0	1	1	1	-1
1	0	1	1	0	1	1	1	-1
1	1	1	1	1	1	1	1	-1





Points to Remember

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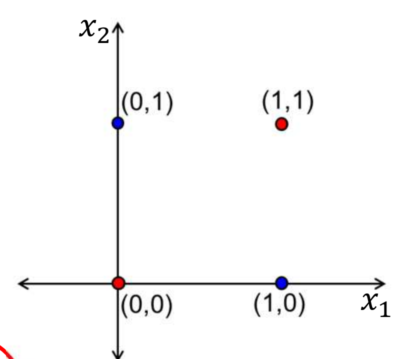
- *Real valued inputs are allowed* in perceptron
- A *single perceptron* cannot learn a function that is **not linearly separable**

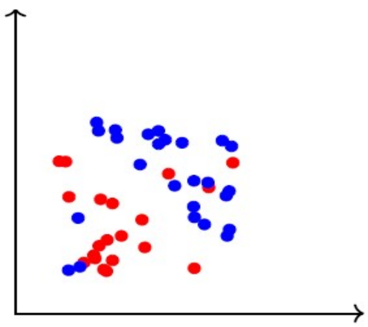
x_1	x_2	Target (XOR)	Objective	
0	0	0	$w_0 + w_1x_1 + w_2x_2 < 0$	$\Rightarrow w_0 < 0$
0	1	1	$w_0 + w_1x_1 + w_2x_2 \geq 0$	$\Rightarrow w_2 \geq -w_0$
1	0	1	$w_0 + w_1x_1 + w_2x_2 \geq 0$	$\Rightarrow w_1 \geq -w_0$
1	1	0	$w_0 + w_1x_1 + w_2x_2 < 0$	$\Rightarrow w_1 + w_2 < -w_0$

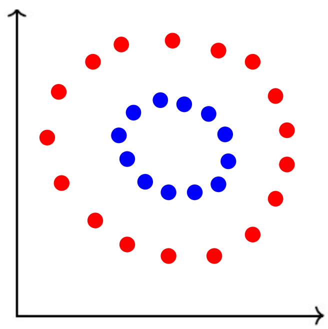
Contradictory!



Points to Remember

- Most real-world data is **not linearly separable** and will always contain some outliers





How do we implement functions that are not linearly separable ?

Questions?