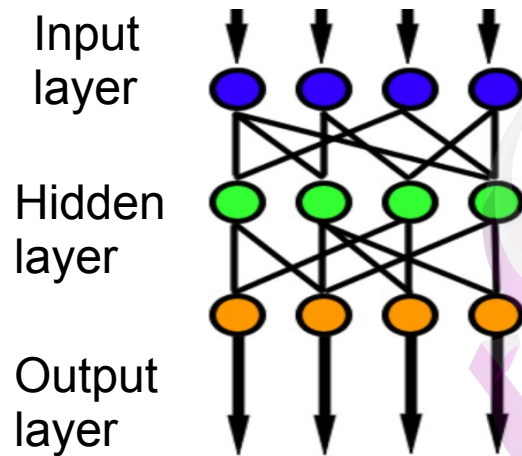


# Feed Forward NNs and Perceptron Definition

[https://en.wikipedia.org/wiki/Feedforward\\_neural\\_network](https://en.wikipedia.org/wiki/Feedforward_neural_network)

A feedforward neural network whose connections between the units do not form a cycle



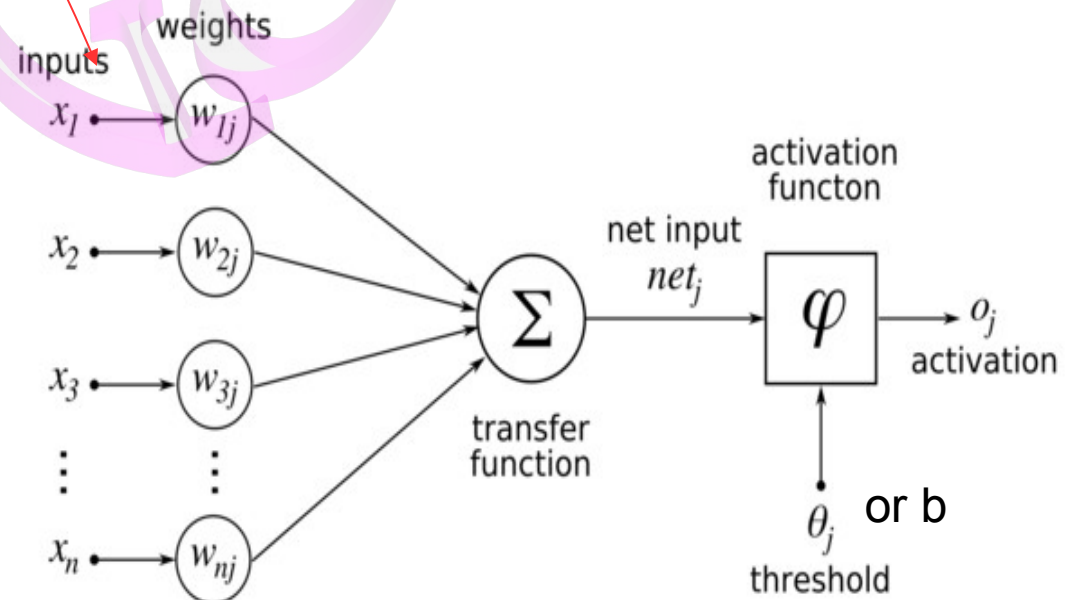
The Simplest form:

The perceptron is a network for supervised learning, a binary classifier, e.g., maps its input  $x$  to an output  $f(x)$

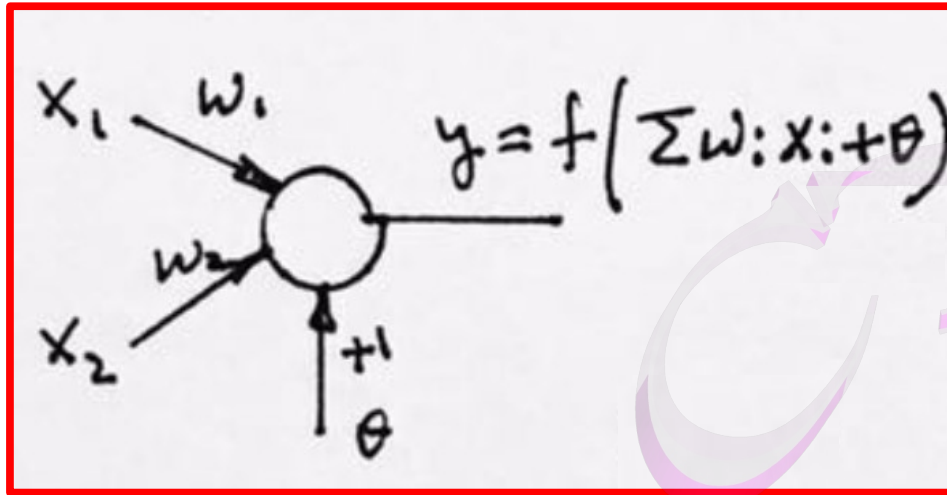
$$f(x) = \begin{cases} 1 & \text{if } w \cdot x + b > 0 \\ 0 & \text{otherwise} \end{cases}$$

$w \cdot x$  is the dot product  $\sum_{i=1}^m w_i x_i$

1. number of inputs:  $n$ ;
2. threshold  $\phi$  (or denoted as  $b$ ), or bias, does not affect the orientation of the decision function;
3. transfer functions can be step function or sigmoid



# Feed Forward NN Example (1/3)



Given 2 traffic signs, train neural network to detect them based on moments (features)



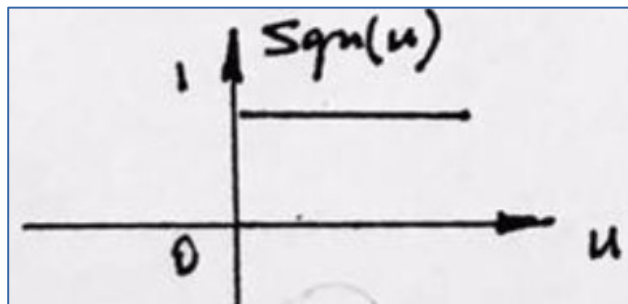
$$y = f(\sum w_i x_i + \theta) \quad \dots (1)$$

Where

$$y = f(\cdot) \text{ as } \text{sgn}(\cdot) \quad \dots (2)$$

$$M_{ij} = \sum_x \sum_y x^i y^j I(x, y)$$

Suppose moments of 2 traffic signs are computed for  $i=0, j=2$ , and  $i=2, j=0$ , shown below, and their values are plotted in the figure below



From stop sign group  
(3 stop sign samples)

From right turn group  
(3 right turns)

$$C_1: (1,2), (1,3), (2,3)$$

$$C_2: (2,1), (3,1), (3,2)$$

This is supervised learning for feed forward NNs

# Feed Forward NN Example (2/3)

First, initialize

$$w_i = 0.5, \text{ for } i=1,2$$

and

$$\theta = 0.5$$

From the given data set, choose (1,2) from  $C_1$ , for  $w_1$ :

$$w_1^+ = w_1^- + \eta(1-y)x_1 \Big|_{x_1=1} \\ = 0.5 + \eta(1-y) \cdot 1$$

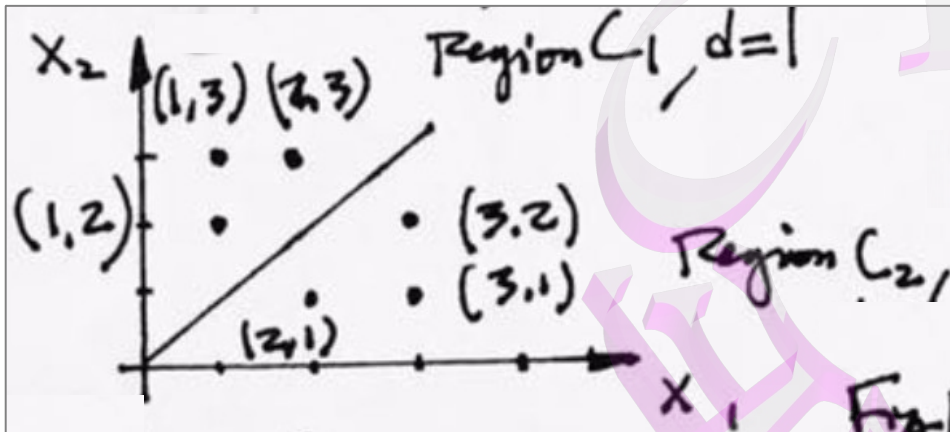
Then

$$y = f\left(\sum_{i=1}^2 w_i x_i + \theta\right) \\ = f(w_1 x_1 + w_2 x_2 + \theta) \\ = f(0.5 \times 1 + 0.5 \times 2 + 0.5) = f(2) \\ = \text{sgn}(2) = 1$$

$$w_1^+ = w_1^- + \eta(1-1)x_1 = w_1^- = 0.5$$

See my handout, continue this process

$$C_1: (1,2), (1,3), (2,3) \\ C_2: (2,1), (3,1), (3,2)$$



The training algorithm:

$$w_i^+ = w_i^- + \eta(d-y)x_i$$

... (3)

where

$\eta$  is gain.  
 $d$ : desired the output.  
 $y$ : actual output.

hence,



# Feed Forward NN Example (3/3)

Step by step from my handout, till  $w_i$  converged as

$$\begin{cases} w_1^+ = -0.4 \\ w_2^+ = -0.1 \end{cases}$$

The convergence is achieved when  $w_i$  no longer updates and exhausted the input data

Now the NN is trained. We can conduct test (deployment)

Suppose from Stop sign we have (4,2), use the trained NN we have

$$\begin{aligned} y &= f\left(\sum_{i=1}^2 w_i x_i + \theta\right) \\ &= f(w_1 x_1 + w_2 x_2 + \theta) = \\ &= f(-0.4 \times 4 - 0.1 \times 2 + 0.5) = f(-1.3) = 0 \end{aligned}$$

therefore, (4,2) belongs to  $C_2$ .  
(which is correct! see the figure illustration)  
see Fig.



# Appendix A: Raw Moments

The "raw moment" of order  $(p + q)$  for image  $f(x,y)$  is defined as:

$$M_{pq} = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} x^p y^q f(x, y) dx dy \quad (1)$$



For the discrete function, we have:

$$M_{ij} = \sum_x \sum_y x^i y^j I(x, y) \quad (2)$$

Note: image  $I(x,y)$  can be binary image or gray scale images. But we start the discussion from the binary images first.

We can treat image intensity as its probability density function

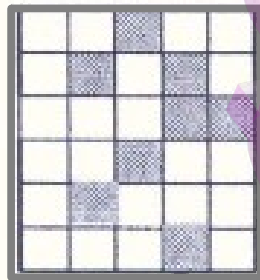
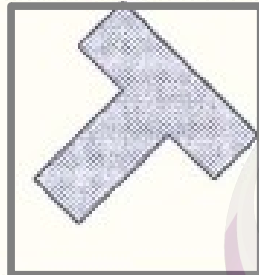
$$\sum_x \sum_y I(x, y) \quad (3)$$

Reference: Robot Vision, by BPK, Horn, Chapter 3, pp. 46-64

# Appendix B

## Example On Simple Pattern Recognition

Given two binary images, derived from two objects, T and O, design a technique to identify them



Example: Computation of  
(1) Area (size);  
(2) X-bar;  
(3) Y-bar;  
(4) Orientation, theta angle  
(5) Perimeter of an object

Fig1(a),(b)

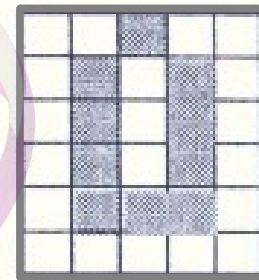
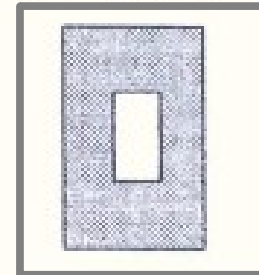


Fig2(a),(b)

Good continuation or noise? What to do with this noise?

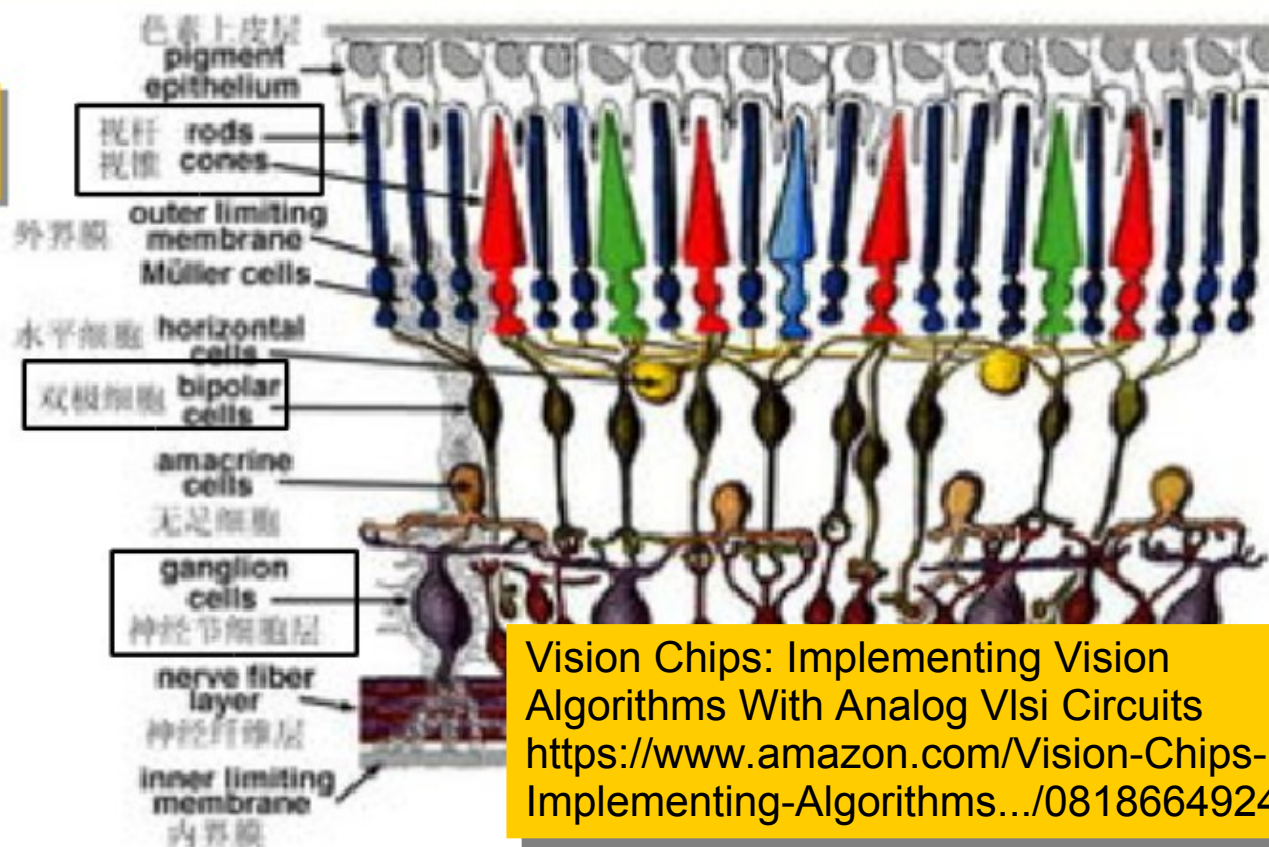
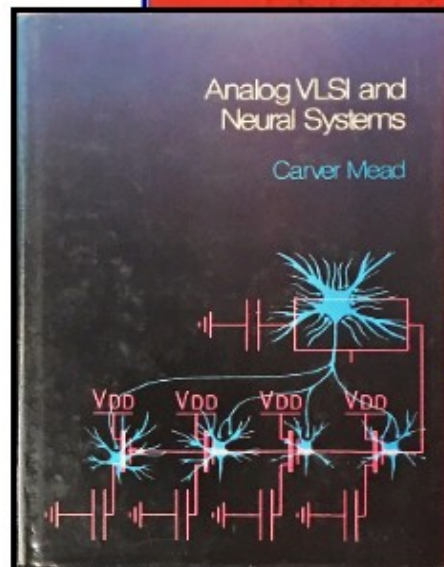
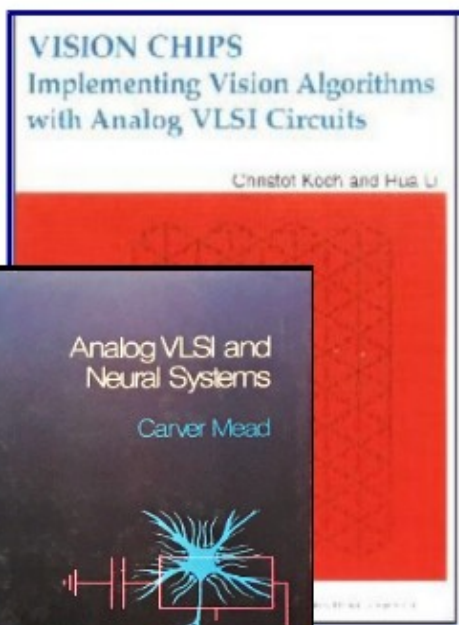
Feature Vector		Size	X-bar	Y-bar	Orientation	Perimeter	
V_1(v1,..., v5)	T	v11	v12	v13	v14	v15	From Fig1(b)
V_2(v1,..., v5)	L	v21	v22	v23	v24	v25	From Fig2(b)



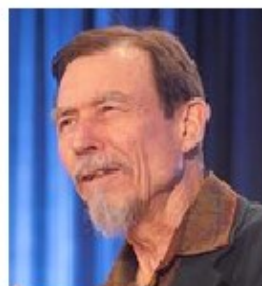
# Biologically Inspired Techniques

## Rod, cone, bipolar cells and ganglion cells

Joint edited book with Professor Koch and myself



Vision Chips: Implementing Vision Algorithms With Analog Vlsi Circuits  
<https://www.amazon.com/Vision-Chips-Implementing-Algorithms.../0818664924>



Prof. Mead



Prof. Koch



Prof. H. Li



VLSI Implementation

Harry Li, Ph.D.