Hopfield's Networks

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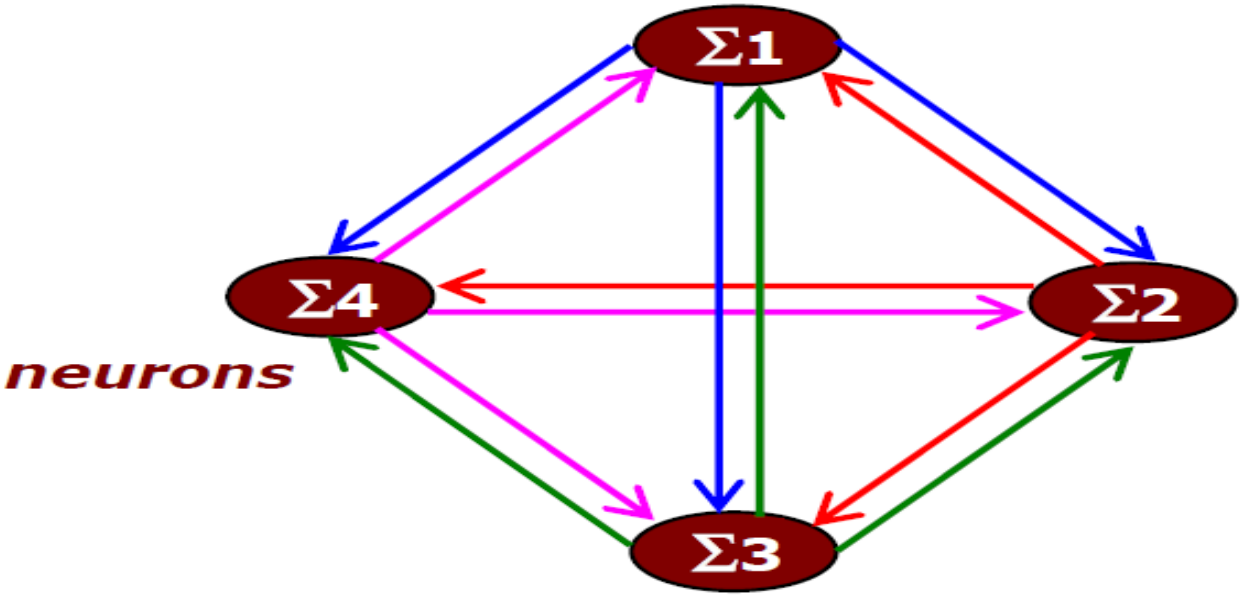
Hopfield Network

- **This is model proposed by John Hopfield in California Institute of Technology earlier 1980**
- **A Hopfield network is a type of neural network that allows stored patterns to be retrieved by context. This means that you can feed the network partial versions of patterns it has learned and it will return the corresponding correct pattern (usually).**

- **The dynamics of hopfields is that it compare its o/p recursively in time until the system become stable.**

- A Hopfield network is made up of nodes that are connected via weights in a fully
- connected and symmetric fashion with no self connections. If you need to see that in a
- formulaic fashion, here it is:
- 1. $w_{ii}=0$ for all i
- 2. $w_{ij}=w_{ji}$ for all i,j

Hopfield network figure



- **Hopfield model (single layer)**
- Auto-associative memory means patterns rather than associated pattern pairs, are stored in memory.
- Hopfield model is one-layer unidirectional auto-associative memory.

Hopfield network

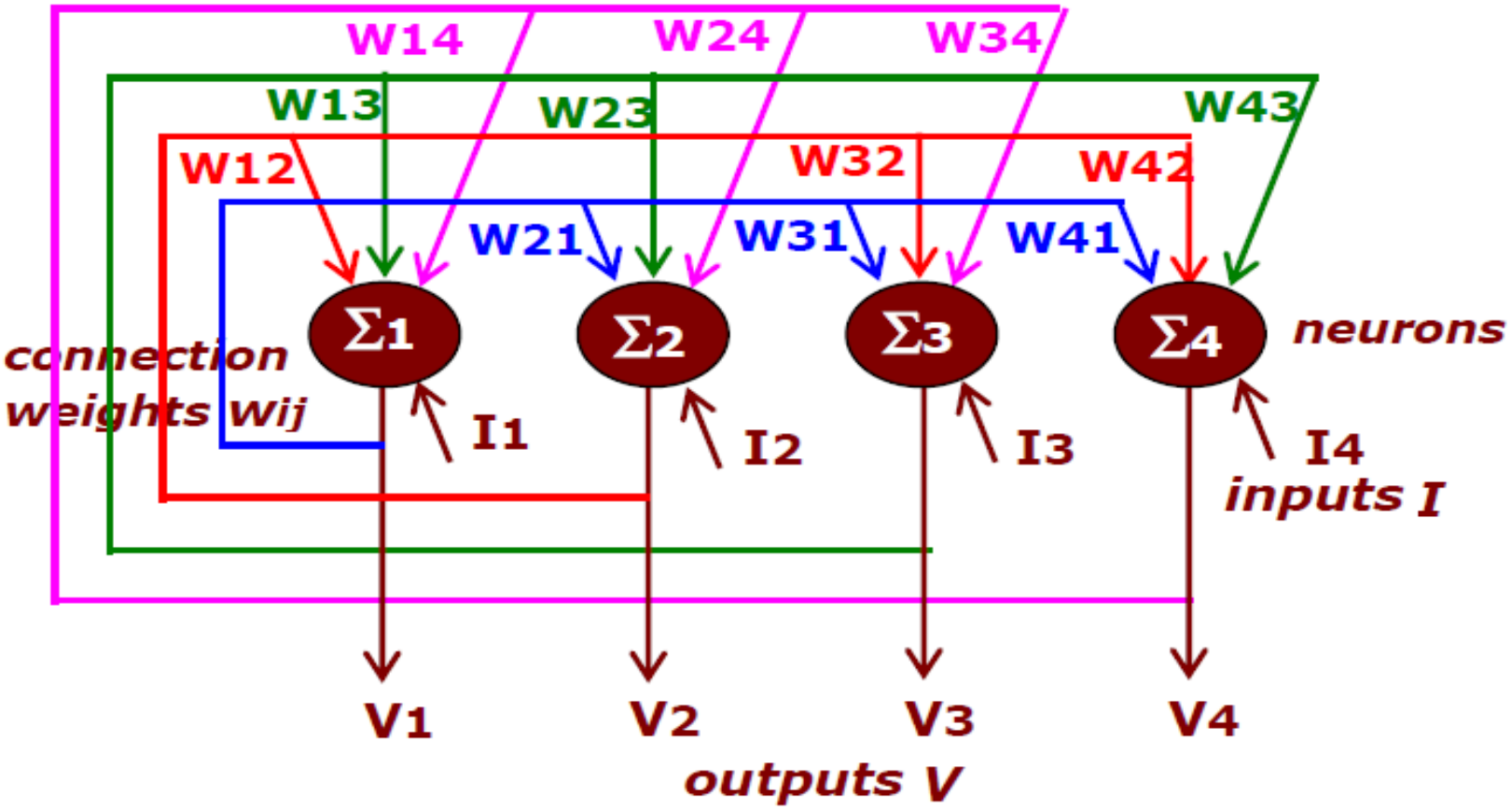


Fig. Hopfield model

- the model consists, a single layer of processing elements where each unit is connected to every other unit in the network but not to itself.
- connection weight between or from neuron **j to i is given by a** number **wij.**
- **The collection of all such numbers are represented** by the weight matrix **W**

which is square and symmetric, ie,

$$w_{ij} = w_{jI}$$

for **i, j = 1, 2, ... , m.**

- each unit has an external input **I which leads to a modification** in the computation of the net input to the units as
- $$\mathbf{input_j = \Sigma\, x_i\, w_{ij} + I_j}$$

  $$\mathbf{for\ j = 1, 2, \ldots, m.}$$

and $\mathbf{x_i}$ **is the ith component of pattern** $\mathbf{X_k}$

- each unit acts as both input and output unit. Like linear associator, a single associated pattern pair is stored by computing the weight matrix as $\mathbf{W_k = Y_k}$ **where** $\mathbf{X_K = Y_K}$

- **Weight Matrix : Construction of weight matrix W is accomplished by**

summing those individual correlation matrices, ie, $\mathbf{W = \alpha \Sigma W_k}$ **where k=1 to p**

α is the constant of proportionality, for normalizing, usually set to **1/p**

to store **p different associated pattern pairs. Since the Hopfield** model is an auto-associative memory model, it is the patterns rather than associated pattern pairs, are stored in memory

- **Decoding : After memorization, the network can be used for retrieval;**
  - the process of retrieving a stored pattern, is called decoding; given an input pattern **X, the decoding or retrieving is accomplished by** computing, first the net *Input as* ***input j = xi w i j*** ***where input j*** stands for the weighted sum of the input or activation value of node **j ,**

for **j = 1, 2, ..., n. and**

xi is the ith component of pattern Xk , and

- **then determine the units Output using a bipolar output function:**

$$Y_j = \begin{cases} +1 & \text{if input } j \geq \theta_j \\ -1 & \text{other wise} \end{cases}$$

where **θ j is the threshold value of output neuron j .**

- Note: The output units behave like linear threshold units; that compute a weighted sum of the input and produces a **-1 or +1 depending whether the** weighted sum is below or above a certain threshold value.

- Decoding in the Hopfield model is achieved by a collective and recursive relaxation search for a stored pattern given an initial stimulus pattern.
- Given an input pattern **X, decoding is accomplished by computing the**
- net input to the units and determining the output of those units using the output function to produce the pattern **X'. The pattern X' is then fed** back to the units as an input pattern to produce the pattern **X''.**
- **The** pattern **X'' is again fed back to the units to produce the pattern X'''.**
- The process is repeated until the network stabilizes on a stored pattern
- where further computations do not change the output of the units.

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