-Artificial Neural Network-

Adaptive Resonance Theory(ART)

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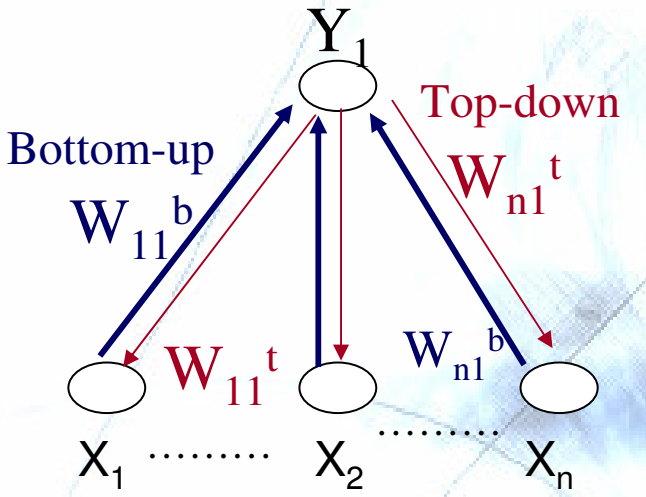
Introduction

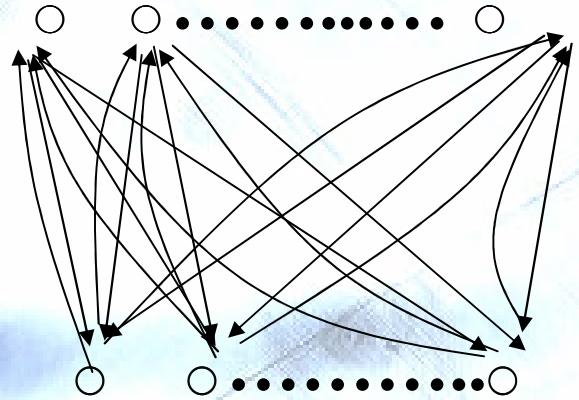
- ART = Adaptive Resonance Theory
- The ART network is proposed by Grossberg in 1976.
- There are two commonly used models:
  - ART1：this model takes only binary input
  - ART2：this model takes continuous or binary input

Introduction (cont.)

- The ART network features：
  - ① It is a two layered network with the forward & backward process until the message resonate.
  - ② ART is a kind of unsupervised learning network.
  - ③ The input and output layers are connected by the bottom-up weights for competitive learning and by the top-down weights for ouster pattern learning.
  - ④ When unfamiliar input is fed in, the ART network will dynamically generate the output node for representing the data cluster.

ART Network Architecture



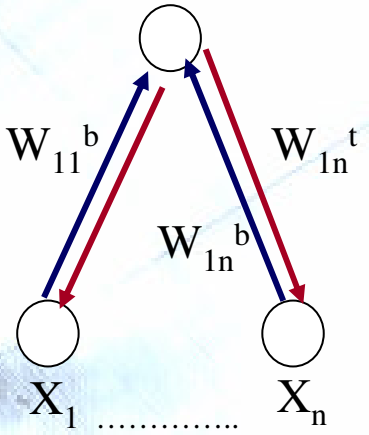


- Input layer： $X \in \{0,1\}$
- Output layer：a cluster layer
  The network starts from only one node and grows until all the input pattern are learned.
- Connections：every input node has one bottom-up link to output node and one top-down link to input node.

ART Process Steps (1/3)

1. Setup network, i.e. the input nodes。

2. Set initial weights, i.e., $W_{i1}^{\ t} = 1 \quad w_{i1}^{\ b} = \frac{1}{1+N}$



3. Input the pattern X

4. Calculate the “matching value” for every output node j .

$$net_j = \sum_i W_{ij}^{b} \cdot X_i$$ （at the very beginning, j=1 ）

5. Find the winning node j*

6. Calculate “similar value” $V_j^* = \frac{\sum W_{ij^*}^{t} \cdot X_i}{\sum X_i}$

ART Process Steps (2/3)

7. Do the vigilance test for winning node

Case 1：if $V_j < \rho$（vigilance value）

➔This means the input pattern does not similar to the connected weights and, hence, it does not belongs to this j* cluster.

➔ Find the next winning output node to see if it can pass the vigilance test, otherwise, generate a new output node.

$$W_{ik}^{t} = X_i$$

$$W_{ik}^{b} = \frac{X_i}{0.5 + \sum_i X_i}$$

Setup new output node k：

if j = j*, then Y_k=1, else Y_k=0

ART Process Steps (3/3)

Case2：if $V_j \geqq \rho$

➔This means the input pattern matches to the output node j*. Therefore, the j* node is the cluster for representing this pattern X.

∴ in this case, all we have to do is to update weights.

$$W_{ij*}^{t} = W_{ij*}^{t} \cdot X_i$$

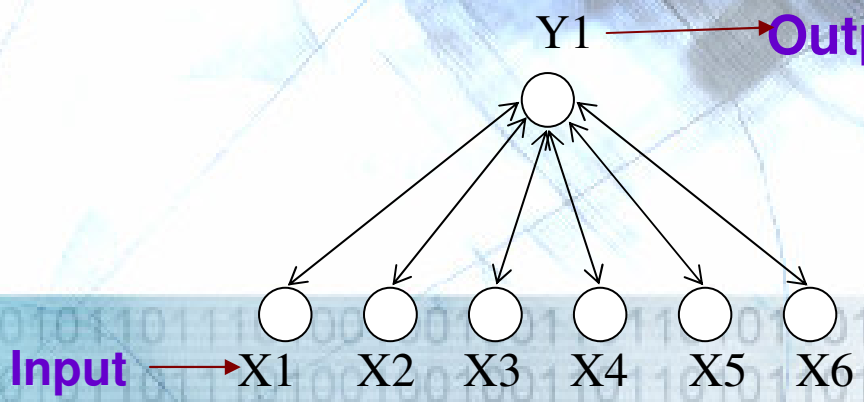
$$W_{ij*}^{b} = \frac{W_{ij}^{t} \cdot X_i}{0.5 + \sum_i W_{ij*}^{t} \cdot X_i}$$

8. Repeat from step 3 to step 7 for all the input patterns. The network terminates when all the input is fed into ART network.

Example (1/6)

Please find the cluster for the following patterns.

1	XOX OXO	2	OXO XOX	3	XXX OOO	4	OOO XXX	5	XXO OXX	6	OXX XXO
7	XOO OXO	8	OOX OXO	9	OXO XOO	10	OXO OOX	11	XXX OXO	12	OXO XXX



令圖形

X :用數字1表示

O :用數字0表示

Example (2/6)

1. Let ρ =0.5

$$W_{11}^t = 1 \quad W_{12}^t = 1 \cdots\cdots W_{16}^t = 1 \quad \Rightarrow \quad W_{10}^t = \{\ 1,\ 1,\ 1,\ 1,\ 1,\ 1\}$$

$$W_1^b = \{\frac{1}{7}, \frac{1}{7}, \frac{1}{7} \ldots\ldots \frac{1}{7}\}$$

2. Input 1st pattern X_1 = { 1,0,1,0,1,0 }

3. calculate matching value（匹配值）

$$\text{net}_1 = \sum_i W_{i1}^b \cdot X_2 = \frac{3}{7}$$

$$\underset{j}{Max}[net_j] \Rightarrow net_1 \qquad j^*=1$$

Example (3/6)

4. Calculate “similar value”

$$V_j^* = \frac{\sum W_{ij^*}^t \times X_i}{\sum X_i} = \frac{3}{3} = 1$$

∵$V_{j^*} > \rho$（=0.5）

（通過vigilance test, 所以引用case 2）

update weights

$$W_{ij^*}^t = W_{ij^*}^t \cdot X_i \Rightarrow W_1^t \{1,0,1,0,1,0\}.$$

$$W_{ij^*}^b = \frac{W_{ij^*}^t \cdot X_i}{0.5+3} \Rightarrow W_1^b = \{\frac{1}{3.5}, \frac{0}{3.5}, \frac{1}{3.5}, \frac{0}{3.5}, \frac{1}{3.5}, \frac{0}{3.5}\}$$

Example (4/6)

- Input 2nd pattern: X= {0,1,0,1,0,1}
- match value $net_1=0$
- $net_j^*=net_1$
- Similar value

$$V_{j^*}=\frac{\sum W_{ij^*}^t \cdot X_i}{\sum X_i}=\frac{0}{3}=0$$

$\because V_{j^*} < \rho\,(=0.5)$ ∴沒有通過vigilance test,所以引用case1

∵no other output node, ∴generate Y_2 &assign new weights

$W_2^t=\{0,1,0,1,0,1\}$ $W_2^b=\{\frac{0}{3.5},\frac{1}{3.5},\frac{0}{3.5},\frac{1}{3.5},\frac{0}{3.5},\frac{1}{3.5}\}$

Example(5/6)

- input 3th pattern X = { 1,1,1,0,0,0 }
- match value net1 = $\frac{2}{3.5} \Rightarrow 0.57 \rightarrow net_1$

$$\text{net2} = \frac{1}{3.5} \Rightarrow 0.285 \rightarrow net_1$$

$$j^*=1 \qquad V_j^* = \frac{2}{3} = 0.66 > \rho \ (= 0.5)$$

- 引用Case2, so we do the weight updating
- W_1^t = { 1,0,1,0,0,0 }

$$W_1^b = \{ \frac{1}{3.5}, \frac{0}{3.5}, \frac{1}{3.5}, \frac{0}{3.5}, \frac{0}{3.5}, \frac{0}{3.5} \}$$

Example(6/6)

- The final clustering of this example is 8 cluster for 12 input patterns.