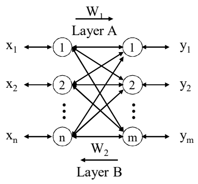
5.2 BAM Network

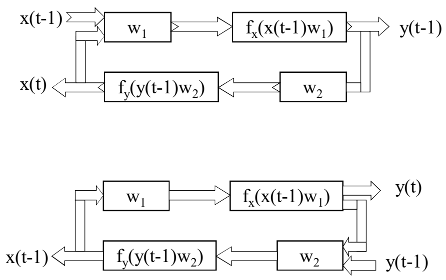
Bidirectional Associative Memory



$x(t)=f_y(f_x(x(t-1)W_1)W_2)$

$y(t)=f_x(f_y(y(t-1)W_2)W_1)$

Calculating process



(x_i , y_i), i=1,2,…,P

Learning rule

Assuming: $x\in\{-1,+1\}^N$, $y \in\{-1,+1\}^M$

Hebb learning formular $W_1=\sum_{k=1}^{P} x^T y$ $\quad W_2=\sum_{k=1}^{P} y^T x$ $\quad W_1=W_2^T$

Definition of energy function:

$$E(x,y)=-\frac{1}{2}xWy^T-\frac{1}{2}yW^Tx^T$$
$$=-xWy^T$$

$$x_i=\begin{cases}1, & yw_i^T>0\\ -1, & yw_i^T<0\end{cases}$$

$$y_i=\begin{cases}1, & xw^j>0\\ -1, & xw^j<0\end{cases}$$

w_i is the i^{th} row weight factors in the W

w^j is the j^{th} column weight factors in the W

$$\Delta E=-\Delta xWy^T$$
$$=-\sum \Delta x_i \sum y_j w_{ij}$$
$$=-\sum \Delta x_i y w_i^T$$

If $\Delta x_i>0$ then $yw_i^T>0$

If $\Delta x_i<0$ then $yw_i^T<0$

Therefore, $\Delta E<0$

Example 1

$x_1(1\ 0\ 1\ 0\ 1)$, $\quad y_1(1\ 1\ 1\ 1)$

$x_2(1\ 0\ 1\ 0\ 0)$, $\quad y_2(0\ 1\ 1\ 0)$

$x_3(0\ 1\ 0\ 1\ 1)$, $\quad y_3(1\ 0\ 0\ 1)$

Change the vectors to {-1,+1}

$x_1'(1\ -1\ 1\ -1\ 1)$, $\quad y_1'(1\ 1\ 1\ 1)$

$x_2'(1\ -1\ 1\ -1\ -1)$, $\quad y_2'(-1\ 1\ 1\ -1)$

$x_3'(-1\ 1\ -1\ 1\ 1)$, $\quad y_3'(1\ -1\ -1\ 1)$

$$W=\sum_{k=1}^{3}(x_k')^T y'^k=\begin{bmatrix}-1 & 3 & 3 & -1\\ 1 & -3 & -3 & 1\\ -1 & 3 & 3 & -1\\ 1 & -3 & -3 & 1\\ 3 & -1 & -1 & 3\end{bmatrix}$$

$sgn(x_1W)=sgn(1\ 5\ 5\ 1)=y_1$

$sgn(y_1W^T)=sgn(4\ -4\ 4\ -4\ 4)$

$=(1\ -1\ 1\ -1\ 1)$

change to binary

$sgn(y_1W^T)=(1\ 0\ 1\ 0\ 1)=x_1$

$\delta=(0\ 1\ 0\ 0\ 0)$

$x_1+\delta=(1\ 1\ 1\ 0\ 1)$

$sgn[(x_1+\delta)W]=sgn[2\ 2\ 2\ 2]$

$=y_1$

Chapter 6 ANN Hybrid System

6.1 Fuzzy Neural Network

6.2 Evolutionary Computation and Genetic Algorithm

6.3 A Hybrid System of Expert Systems and Neural Networks

6.1 Fuzzy Neural Network

Neural-fuzzy networks implements fuzz-logic inferencing through neural networks.

1. Fuzzy-logic Systems

Fuzzy logic grew out of a desire to quantify rule-based systems. It provides a way to quantify certain quantifiers such as ***approximately, often, rarely, several, few, and very.***

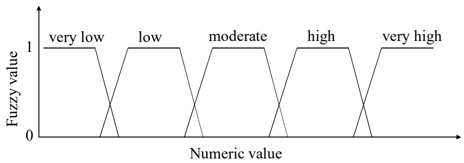
Relationship of fuzzy-logic systems to the two main areas of AI

knowledge type	Information framework: symbolic	numerical
structured (based on rules)	expert system	fuzzy-logic system
unstructured	————	neural network

A. Fuzzy set

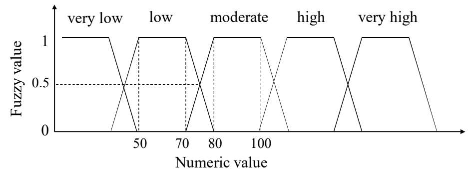
quantify the *degree of membership* with values between 0 (not a member) and 1 (definitely a member).

The following figure shows a representation of energy requirement in fuzzy terms.



B. Conversion Between Numeric and Fuzzy-Logic Variables

How to convert a numeric variable to a fuzzy-logic variable through *fuzzifier*, and to convert the fuzzy-logic variable back to a numeric variable through a *defuzzifier*.

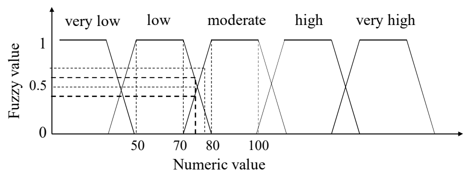


The numeric variable are denoted numeric(x) and the fuzzy-logic variables are denoted fuzzy(e.g., 50 to 70 for low,and 80 to 100 for moderate).

numeric(60)=fuzzy(0, 1, 0, 0, 0)

numeric(90)=fuzzy(0, 0, 1, 0, 0)

For numeric values in the transition regions, we use a linear interpolation between the beginning and ending values of the region.



$$numeric(74) = fuzzy(0, \frac{80-74}{80-70}, \frac{74-70}{80-70}, 0, 0) = fuzzy(0, 0.6, 0.4, 0, 0)$$

Similarly, we can convert the fuzzy-logic variable back to a numeric variable using the exact opposite process.

$$fuzzy(0, 0.3, 0.7, 0, 0) = numeric(0.3 = \frac{80-x_1}{80-70}) \quad or \quad numeric(0.7 = \frac{x_2-70}{80-70})$$

x_1=77 x_2=77

C. Union and Intersection of Fuzzy sets

Define two fuzzy sets:

I={i_1/x_1, i_2/x_2, …,i_n/x_n,}

J={j_1/x_1, j_2/x_2, …,j_p/x_p,}

where x_1,x_2,…are members of the set with degrees of membership i_1,i_2,…(for set I) and j_1,j_2,…(for set J).

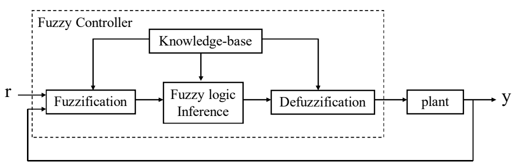
Union of two fuzzy sets:

$$I \cup J = \{(\max(i_1, j_1))/x_1, (\max(i_2, j_2))/x_2, \ldots\}$$

Intersection of two fuzzy sets:

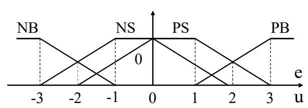
$$I \cap J = \{(\min(i_1, j_1))/x_1, (\min(i_2, j_2))/x_2, \ldots\}$$

D. Fuzzy Control



Fuzzy-logic variable (e,u)

	-3	-2	-1	0	1	2	3
PB	0	0	0	0	0	0.5	1
PS	0	0	0	0	1	0.5	0
0	0	0	0.5	1	0.5	0	0
NS	0	0.5	1	0	0	0	0
NB	1	0.5	0	0	0	0	0



$$NS = \frac{0.5}{-2} + \frac{1}{-1}$$

Control rule table

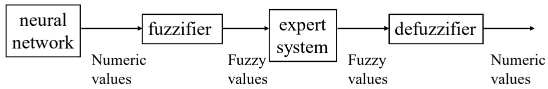
e	NB	NS	0	PS	PB
u	PB	PS	0	NS	NB

$R=(NB_e*PB_u)+(NS_e*PS_u)+(0_e*0_u)+(PS_e*NS_u)+(PB_e*NB_u)$

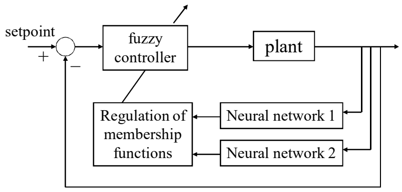
$u=e \circ R$

2. Neural-Fuzzy Networks

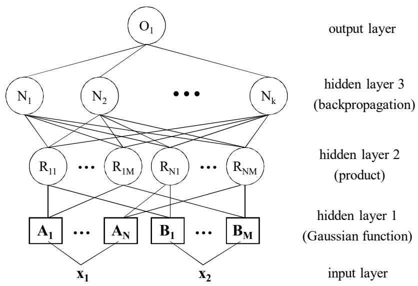
A. Neural-Fuzzy Networks for Expert Systems

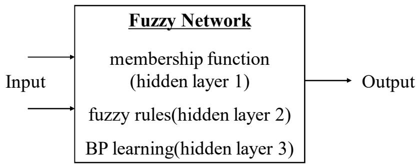


B. The architecture of the neural-fuzzy controller



3. Fuzzy Neural Network





Hidden layer 1:

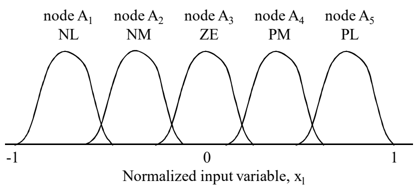
represents a radially symmetric (Gaussian) membership functions of A_i(i=1 to N) and B_j(j=1 to M) for the normalized input variables x_1 and x_2, respectively.

$\bar{x}$ is the center and σ is the standard derviation of a Gaussian membership function.

$$O^1_{A_i} = \exp\left[-\left(\frac{x_1-\bar{x}_1}{\sigma_{ai}}\right)^2\right]$$

$$O^1_{B_j} = \exp\left[-\left(\frac{x_2-\bar{x}_2}{\sigma_{bj}}\right)^2\right]$$

A common representation of the Gaussian membership function stored in hidden layer 1 of a fuzzy network.



Hidden layer 2:

Taking the dot product of the outputs of the membership functions(hidden layer 1) O^1_{Ai} and O^1_{Bi}.

$$O^2_l = O^1_{Ai} \bullet O^1_{Bj} = \min(O^1_{Ai}, O^1_{Bj}) \qquad (l = 1, M*N)$$

For example, the output of the first node(R_{11}) in the hidden layer 2 reflects whether the rule of A_1(x_1 is negative large) and B_1(x_2 is negative large) should be applied.

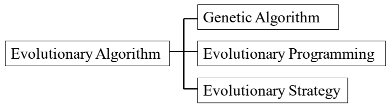
Hidden layer 3:

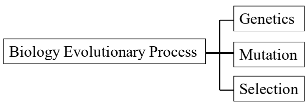
operates the same as a standard backpropagation network, having weight factors (w_{ij}) and a sigmoid transfer function. The weight factors are adjusted to map the firing strength of the fuzzy rules onto the desired output variable.

Hidden layer 4:

operate the same as a standard backpropagation network, as in layer 3.

6.2 Evolutionary Computation and Genetic Algorithm





GA basic operation

Step 1: Initiation

Step 2: Selection (reproduction)

e.g. using fitness function

Step 3: Crossover

Example 1

A	1 0 0 1 ⋮ 1 1 1	⇒	1 0 0 1 ⋮ 0 0 0	**C**
B	0 0 1 1 ⋮ 0 0 0		0 0 1 1 ⋮ 1 1 1	**D**

Example 2

A: 0 0 1 1 1 1
B: 1 1 1 1 0 0
Shield 0 1 0 1 0 1   0→A，1→B ▸A'
A': 0 1 1 1 1 0
B': 1 0 1 1 0 1

Step 4 : Mutation 0→1
1→0

Practice

Max{ $f(x)=x^2$ }, x=0 ~ 31

1. Initiation (binary code)

标号	串	X	适配值	占整体百分数
1	01101	13	169	14.4
2	11000	24	576	49.2
3	01000	8	64	5.5
4	10011	19	361	30.9
总计（初始种群整体）			1170	100

2. Selection(reproduction)

第一代群体的选择（复制）

标号	初始群体	X	$f(x)=x^2$	选择复制的概率	期望复制数	实际得到复制数
1	01101	13	169	0.14	0.58	1
2	11000	24	576	0.49	1.97	2
3	01000	8	64	0.06	0.22	0
4	10011	19	361	0.31	1.23	1
总计			1170	1.0	4.0	4
平均			293	0.25	1.0	1
最大值			576	0.49	1.97	2

169/1170=0.14 169/293=0.58

3. Crossover

复制交叉后的各项数据

新标号	复制后的匹配池	匹配对象（随机选取）	交叉点（随机取）	新种群	X值	$f(x)=x^2$
1	01101	2	4	01100	12	144
2	11000	1	4	11001	25	625
3	11000	4	2	11011	27	729
4	10011	3	2	10000	16	256
总 计						1754
平 均						439
最大值						729

平均值 293 → 439
最大值 576 →729

4. Mutation

取变异概率0.001， 种群共有4*5=20位，20*0.001=0.02位，所以本例无串位值的改变。至此，完成一代遗传。

Application in ANN

用遗传算法学习神经网络权值w_{ij}

1. 二进制编码

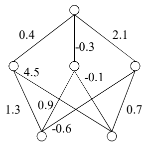
W字符串表示的值和实际数值间的关系：

$$w(i,j)=w_{\min}(i,j)+\frac{binary(t)}{2^n-1}[w_{\max}(i,j)-w_{\min}(i,j)]$$

如w在1~0间，4位二进制： $w=0+\frac{1111}{2^4-1}[1-0]=1$

W学习过程：交叉、变异，产生下一代网络。

2. Real number code



* code （0.4, -0.3, 2.1, 1.3, 0.9, -0.6, 4.5, -0.1, 0.7)

* estimate function $f=1/\Sigma e_i^2$

* Initiation
  determine the weight factors at random

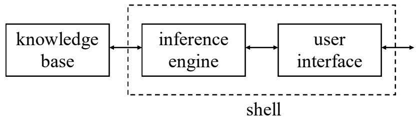
(0.4, -0.3, 2.1, 1.3, 0.9, -0.6, 4.5, -0.1, 0.7)
(0.7, -0.9, 1.2, 0.8, 1.4, 0.1, -1.1, 0.2, -1.1)

* crossover (0.4, -0.9, 1.2, 1.3, 1.4, 0.1, 4.5, 0.2, -1.1)

* mutation (0.4, -0.3, 2.1, 1.3, 0.9, -0.6, 4.5, -0.1, 0.7)
stochastic value -1.1 stochastic value -0.7
(0.4, -0.3, 1.0, 1.3, 0.9, -0.6, 4.5, -0.8, 0.7)

6.3 A Hybrid System of Expert Systems and Neural Networks

1. The structure of an expert system



knowledge in expert systems

Knowledge = facts + rules +heuristics

shell
1. Explains how the system reaches a conclusion
2. Explains why it needs certain information
3. Adds information to the knowledge base

2. Neural networks versus expert systems

Neural networks	Expert systems
example-based	rule-based
domain-free	domain-specific
finds rules	needs rules
little programming	much programming
easy to maintain	difficult to maintain
fault-tolerant	not fault-tolerant
needs a database	needs a human expert
fuzzy logic	rigid logic
adaptive system	requires reprogramming

3. Advantages and limitations of expert systems and neural networks

	Expert systems	Neural networks
very effective	In applying a fixed set of facts, rules and heuristic(i.e., knowledge) to a domain-specific problem, typically involving only simple mathematics.	In organizing and detecting patterns from unpredictable and/or imprecise input data, in learning by examples, and in generalizing to new situations.
less effective	In processing raw sensory data from the real, unpredictable world.	In providing in-depth solutions and full understanding of each problem as well as the reasoning behind its solution(i.e., no explanation capability).

4. An illustration of an expert network