International Journal of Fuzzy Logic and Intelligent Systems, vol. 2, no. 3, December 2002 pp. 215-220

Image Recognition by Learning Multi-Valued Logic Neural Network

Doo-Ywan Kim, Hwan-Mook Chung

Faculty of Computer & Information Communication Engineering,
Catholic University of Daegu
kimdy@amare.ac.kr, hmchung@amare.ac.kr

Abstract

This paper proposes a method to apply the Backpropagation(BP) algorithm of MVL(Multi-Valued Logic) Neural Network to pattern recognition. It extracts the property of an object density about an original pattern necessary for pattern processing and makes the property of the object density mapped to MVL. In addition, because it learn the pattern by using multiple valued logic, it can reduce time for pattern and space for memory to a minimum. There is, however, a demerit that existed MVL cannot adapt the change of circumstance.

Through changing input into MVL function, not direct input of an existed Multiple pattern, and making it each variable learn by neural network after calculating each variable into liter function. Error has been reduced and convergence speed has become fast.

Key Word : multiple valued logic, neural network, back propagation algorithm, Image Processing

1. Introduction

In various researches of neural network, the main concern is a pattern recognition using self-learning and parallel process structure, information process based on incomplete data, adaptation learning, and so on, which are being used a lot in a research of neural network[1]. Among them, the error BP algorithm proposed by Rumelhart showed distinguished performance in solving nonlinear problems such as classification, cognition, and control [2].

Kolmogorov proved that any multi-variable continuous functions, mapping from $[0,1]^n$ to R^m, can be approximated by a linear combination of 1-variable continuous function[3]. Nielsen theoretically showed, by applying this demonstration to a neural network, that there exists a multiple layer neural network that is able to exactly approximate a continuous function [4]. Also, Chiang and Fu tried an approximation of function by applying a multiple layer neural network having 2-degree sigmoid as an active function[5], and through using the ability of approximation like this, they processed pattern data by mapping it into reduced space. For processing the pattern, they processed the pattern by expressing density of an object as 2-valued logic, and the property for recognizing the pattern was extracted through GSP(global shape property). They changed the density of an object into 2-valued and dealt with a pattern through a neural network. However, technology of hardware and software has been improved gradually. A change from a computer based on letters and numbers to one based on the process of a multi-media data of image, voice, etc is occurring. Therefore, a change from 2-valued logic to multi-valued logic has been required.

The advantage of MVL are: it can manage data more quickly than 2-valued logic, it has high-density memory of data, and it reduces the number of input and output terminal during realization of logic circuit [6]. Based on this, the advantage of MVL neural network on a general liner neuron model is pattern separation ability and high speed of pattern recognition by use of MAX and MIN operators. However, because these networks cannot adapt themselves to gradual changes in their environment, we, by adding learning ability to these techniques, have been designing systems that can adapt themselves to environmental change, and be modified and be extended through learning .

Watanabe proposed that MVL operations would produce analog responses in order to be fed to a quantifier, and be trainable to classify the input pattern vectors according the special input called "desired responses"[7]. Also, he showed structure and characteristic of the neuron model of multi-valued input and output, used an target signal in learning algorithm, and extended output multiple signal, therefor he proved that neuron model can be composed of MVL neural network [8]. Zheng Tang described that the learning MVL network is derived directly from a canonical realization of MVL function and therefore its functional completeness was guaranteed [9]. Based on this MVL network has come to the front as strong technology of image processing and speech recognition.

This paper, with adding the learning ability, proposed MVL network using BP algorithm in order to be able to adapt itself to environmental change, and be modified and extended through learning. It got learning done through using neural network after converting input into liter function and calculating each variable by Min operator. Also a characteristic extraction was made by using low frequency of Wavelet transformation.

2. An Expression of a multi-valued logical Function

2.1 A basic definition

The fundamental facts about Modulus-M are defined as following:

[Definition 1]

① $A \oplus B = \overline{A} \oplus \overline{B}$

② $A \ominus B = \overline{A} \oplus (-1)\overline{B}$

③ $A + B = \max(A, B)$

④ $A \cdot B = \min(A, B)$

⑤ $A' = P \ominus A \quad (p = M \ominus 1)$

⑥ $\overset{\alpha\beta}{X} = \begin{cases} P & (\alpha \le X \le \beta) \\ 0 & (X < \alpha \text{ or } X > \beta) \end{cases}$

2.2 Composition of MVL function

when one cross point $X(p_1, \ldots, p_n)$ mapped from $(Z_m)^n$ to value of k of Z_m, then function f be represented as Table 1. where, k_i can be represented as $1 \le k_i \le p$.

Table 1 Truth table

$(p+1)^n$개

x_1	x_2	⋯	x_n	f
0	0	⋯	0	k_1
0	0	⋯	1	k_2
⋯	⋯	⋯	⋯	⋯
p	p	⋯	p	$k_{(p+1)^n}$

$$f = k_i \sum \overset{p_i p_j}{X_i} \cdot \overset{p_i p_j}{X_j} \quad i, j \in 1, 2, \ldots, n \tag{1}$$

[Definition 2]

Difference about MVL would be defined as below:

$$df(X) = \frac{\triangle f(X)}{\triangle X} \cdot \triangle X = f(\overline{X}) \ominus f(X) \quad (\overline{X} = X \oplus 1)$$

[Definition 3]

Partial derivation $d_{X_i p} f$ of MVL function f would be defined as below :

$$d_{X_i p} f = f(X_1, \cdots, X_i \oplus p, \cdots, X_n) \ominus f(X_1, \cdots, X_i, \cdots, X_n)$$

3. Configuration of an Learning MVL Neural Network

3.1 MVL Neural Network

Any MVL function can be expressed as sum- of-product.

$$f = k_i \sum \overset{p_i p_j}{x_i} \cdot \overset{p_i p_j}{x_j} \tag{2}$$

Fig.. 1 shows the structure of MVL neural network. Each node of an input layer, as literal function, is given by

$$X'_l = \overset{p_i p_j}{x_l} = \begin{cases} m-1 & p_i \le x \le p_j \\ 0 & otherwise \end{cases} \tag{3}$$

where, X'_l is liter literal operator, p_i and p_j are window parameter of liter literal function. The node functions in the same layer are of same type. As the values of the p_i and p_j change, the literal function varies accordingly, thus exhibiting various from of literal function. In an m-valued n-variable case, maximally $m \times n$ liter nodes are required in order that each input vector can be individually selected. Also the actional function $f(h)$ is called sigmoid function.

$$f(h) = \frac{1}{1 + \exp(-\lambda h)} \tag{4}$$

when $\lambda \to \infty$. Thus, the literal function can be described as

$$X'_l = (m-1) f(p - x_i) = (m-1) \frac{1}{1 + \exp\{-\lambda (p - x_i)\}} \tag{5}$$

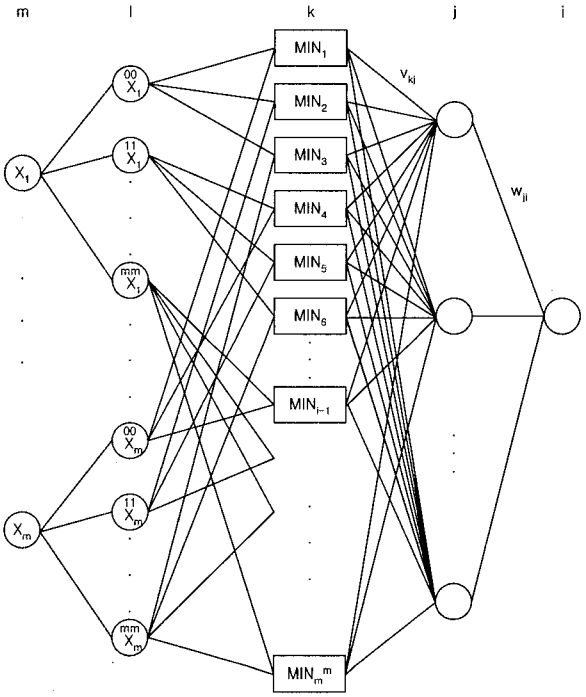

Fig. 1 Structure of MVL neural network

A node in k layer correspond to the MIN operation. Each node selects a particular area of the function and defines its function value 1, 2, ..., $(m-1)$ by means of the logic signal 1, 2, ..., $(m-1)$ included within the MIN term. Function of k layer is given by

$$MIN_k = MIN\left(\overset{p_i p_i}{x_1}, \overset{p_i p_i}{x_2}, \ldots, \overset{p_i p_i}{x_m} \right) \tag{6}$$

The neuron in j layer is each valued set by result composed between variables. net_j and output O_j is as follows.

$$net_j = MIN_k \times v_{kj}^T \tag{7}$$
$$O_j = f(net_j) \tag{8}$$

where, $f(net_j)$ is sigmoid function.

In i layer, input weight sum of neuron net_i and, last output O_i is as follows.

$$net_i = O_j \times w_{ji}^T \tag{9}$$
$$O_i = F(net_i) \tag{10}$$

where, $F(net_i)$ used a liner function

3.2 An learning mechanism

Learning MVL network as stated above is neural forward network.. Assuming output values with O about simply multi-valued input, supervisor signal T corresponding to supervisor signal is created by a MVL function to have been given. Using error BP algorithm in network learning, they show formula minimizing a cost function as the following:

$$E = \frac{1}{2}\sum(T - O_i)^2 \tag{11}$$

By Error BP algorithm, weight adjustment-valued $\triangle w_{ji}$ connected from j layer to i layer is as followed.

$$\begin{aligned}\triangle w_{ji} &= -\eta\frac{\partial E}{\partial w_{ji}} = -\eta\frac{\partial E}{\partial O_i}\frac{\partial O_i}{\partial net_i}\frac{\partial net_i}{\partial w_{ji}} \\ &= \eta(T - O_i)F'(net_i)O_j\end{aligned} \tag{12}$$

Where, η is learning rate. adjustment-valued $\triangle w_{ji}$ is calculated as below.

$$\frac{\partial E}{\partial O_i} = -(T - O_i) \tag{13}$$
$$\frac{\partial O_i}{\partial net_i} = F'(net_i) = F(net_i)(1 - F(net_i)) \tag{14}$$
$$\frac{\partial net_i}{\partial w_{ji}} = \frac{\partial}{\partial w_{ji}}\sum w_{ji}O_j = O_j \tag{15}$$
$$\varepsilon_i = -\frac{\partial E}{\partial net_i} = (T - O_i)F'(net_i) \tag{16}$$

BP used gradient descending for error value(E) minimum. Where, $\eta(0 < \eta < 1)$ is learning rate, w_{ji} is weight from k to j.

$$\begin{aligned}\triangle v_{kj} &= -\eta\frac{\partial E}{\partial v_{kj}} = -\eta\frac{\partial E}{\partial O_j}\frac{\partial O_j}{\partial net_j}\frac{\partial net_j}{\partial v_{kj}} \\ &= \eta\left(-\frac{\partial E}{\partial O_j}\right)f'(net_j)O_k \\ &= \eta\sum_i \varepsilon_i w_{ji} f'(net_j)O_k = \eta\,\varepsilon_j O_k\end{aligned} \tag{17}$$

Where,

$$\frac{\partial E}{\partial O_j} = \sum\frac{\partial E}{\partial net_i}\frac{\partial net_i}{\partial O_j} = \sum_i \varepsilon_i w_{ji} \tag{18}$$

$$\begin{aligned}\varepsilon_j &= -\frac{\partial E}{\partial net_j} = -\frac{\partial E}{\partial O_j}\frac{\partial O_j}{\partial net_j} \\ &= \sum_i \varepsilon_i w_{ji} f'(net_j)\end{aligned} \tag{19}$$

For example, lets consider 4-valued 2-variable case. MVL function was always, in representative multi-valued method, composed by expansion of sum-of-product using MAX, MIN, and single operator.

$$\begin{aligned}&f(x_1, x_2) \\ &= 1 \cdot \begin{pmatrix} 00 & 00 \\ x_1 & x_2 \end{pmatrix} + 2 \cdot \begin{pmatrix} 00 & 33 \\ x_1 & x_2 \end{pmatrix} + 3 \cdot \begin{pmatrix} 22 & 22 \\ x_1 & x_2 \end{pmatrix}\end{aligned} \tag{20}$$

Table 2 Truth table of 4-valued

X_2 \ X_1	0	1	2	3
0	1	0	0	0
1	0	0	0	0
2	0	0	3	0
3	2	0	0	0

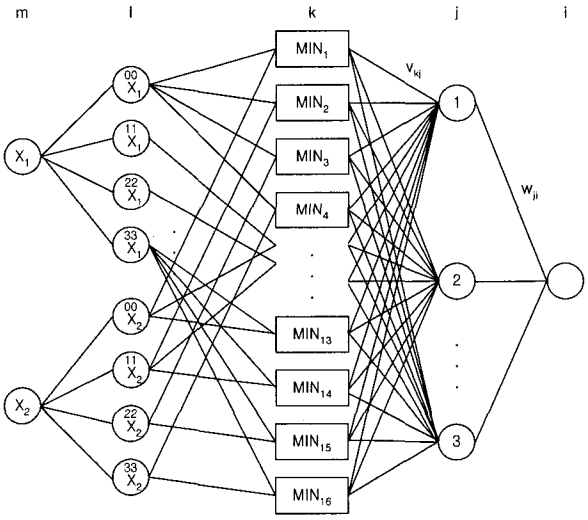

Fig. 2 Neural Network about 4-valued function

Different from representative MVL ways, a function consists of network forming a layer, and in order to the learn algorithm case of this paper, training of neural network was used. In 4-valued 2-variable, after converting into literal function corresponding to each variable, it made a MIN operation with each variable, it created 16 nodes and it created output about this, and it used training of a neural net in order to compose representative MVL network. Training was performed on the same initial parameter as described in the above simulation. The error was decreased through training process. A learning rule was used in order to compose weight. Fig. 2 showed a structure of MVL neural network about Table 2.

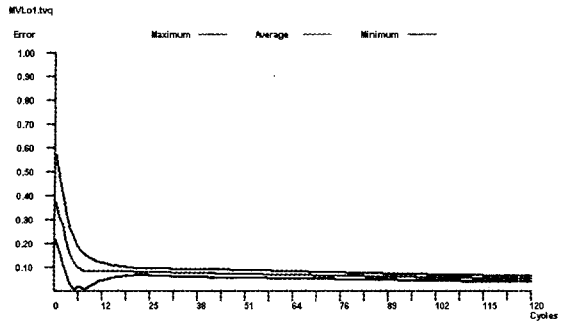

Fig. 3 Error about learning in MVL neural network

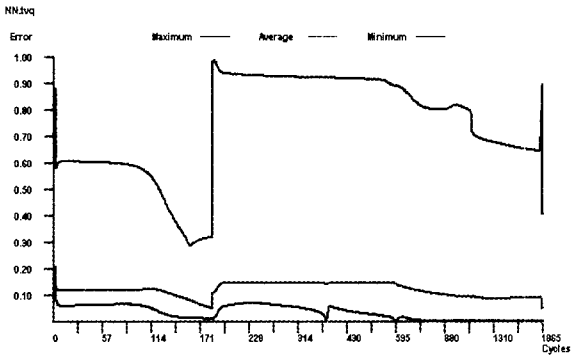

Fig. 4 Error about learning in general neural network

As for error convergence, in proposed MVL it was converged in 120 times neural, in Tanno it was converged in 154 times, and in general neural net it was converged in 1865 times.

3.3 A Pattern Characteristic Expression

2-valued of a pattern distinguishes between an object scope and background scope or can extract a boundary of a pattern during image processing by threshold value operation. On the other hand, a pattern expressed with multi-valued can make a clear pattern process with a way to have a component with a noise elimination. Therefore, here it maps to 4-valued with a density of an image and make a characteristic extraction with a transform of wavelet.

In Fig. 5, HL consists of horizontal high-pass, vertical low-pass operation, LH consists of horizontal low-pass, vertical high-pass operation, HH consists of high-pass in both directions, and LL band image shows a similar form with a circular image. Therefore, in this paper, a characteristic of low band interval of LL was extracted and learned, and after learning, recognition process was carried out.

A Wavelet transformation, which is a theory that analyzes a signal with band partition encode and multi-resolution, expresses an input signal as the sum of base function. There is a characteristic that the result transformed through Wavelet transformation simultaneously has frequency and space information. Base function of Wavelet transformation is

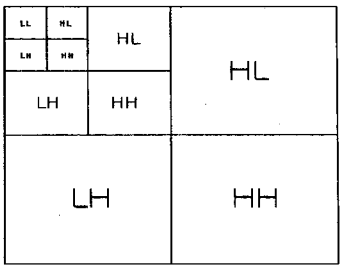

Fig. 5 decomposition of Wavelet

created by expansion and movement of Wavelet transformation. Therefore, a component of relevant base function can be gotten, if a signal and inner product which are being analyzed are taken while expansion coefficient of Wavelet function is being changed and moved along a space axis. They show Wavelet transformation formula with a part of orthogonal transfer as below.

$$\psi_{(u,v)}(x) = \frac{1}{\sqrt{u}}\psi\left(\frac{x-v}{u}\right) \tag{21}$$

$$G(u, v) = \int g(x)\psi_{(u,v)}(x)dx \tag{22}$$

Where, $\psi(x)$ is Wavelet function and $\psi_{(u,v)}(x)$ is a component of Wavelet base function $\psi_{(u,v)}(x)$ having an expansion coefficient u and an moving coefficient v. Wavelet transformation has a scaling function and Wavelet function that are two base function, but it makes a characteristic with a filter having low-frequency-pass characteristic, and a filter having high-frequency-pass characteristic individually, and shows low-frequency-pass filter and high-frequency-pass filter with the vector as formula (23), (24).

$$\tilde{h}(n) = \frac{\delta(n)+\delta(n+1)}{\sqrt{2}} \; or \; \frac{1}{\sqrt{2}}[1\ 1] \tag{23}$$

$$\tilde{g}(n) = \frac{\delta(n)-\delta(n+1)}{\sqrt{2}} \; or \; \frac{1}{\sqrt{2}}[1\ -1] \tag{24}$$

4. An Application Example About A Pattern

Algorithm for the pattern process using a MVL neural network is as follows.

(Step 1) Map into 4-valued, using the density value of pattern.
(Step 2) Extract characteristic valued in order to learn 4-valued image. Extract characteristics frequency of low by using an image decomposition way of Wavelet transformation.
(Step 3) learning input patterns about the characteristic of pattern with MVL neural network.
(Step 4) Carry out a recognition process if learning is over.

This experimentation, not with a total image, but with the characteristics of the part of extracted face image, tried to compare the difference between general neural network and

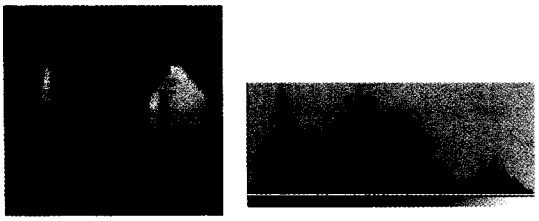

Fig. 6 Original pattern of image

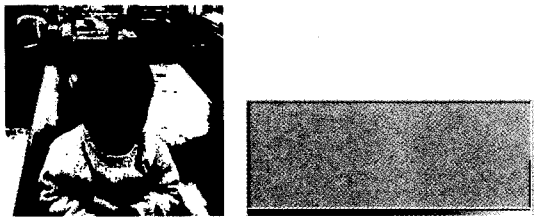

Fig. 7 2-valued pattern of image

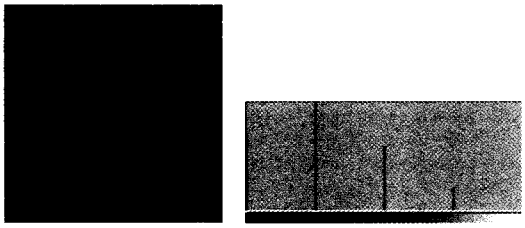

Fig. 8 4-valued pattern of image

MVL neural network. Using the advantage that MVL function has through the above images, it expressed with multi-valued the density of an object necessary during processing a pattern. If the density of multi-valued, expressed thus, is adapted to pattern process system by using MVL neural network, we can know that by decrease of an uncertain boundary of a pattern recognition, a clear pattern can be gotten.

Fig. 9 Wavelet transform

In order to learn a pattern by using MVL neural network, the node number of j layer was set to six, the rate of learning was 0.6, momentum was 0.8, and learning was performed in order for error to be converged at 0.01. the total error was converged in a 161 times, and was converged after carried out in 150 times when learned with noise pattern about learned image. On the other hand, it was converged in 845 times when carried out on the same condition with existing neural network.

5. Conclusion

MVL has advantage such as it can deal with same amounts of information with high-speed process, Memory density of information is large, the number of input/output terminal decrease during designing a logic circuit.

In this paper, MVL neural net has less error value and higher-speed of convergence than general neural network, comparing the difference between learning multi-valued pattern through general neural network and through MVL neural network. Also, in case of, by using the merit of MVL, expressing the necessary density of an object with multi-valued and adapting the density of multi-valued that is expressed thus during pattern processing, we know that decrease of uncertain boundary and clearer pattern can be gotten.

Reference

[1] V. Milutinovice and P. Antognetti, "Neural Networks : Concepts, Application and Implementation", Prentice-Hall, pp. 110-148, 1992.

[2] D.E. Rumelhart, G.E. Hinton, R.J. Wiliams, "Learning Internal Representations by Error Propagation", Parallel Distributed Processing ; Explorations in the Microstructure of Congnition, Vol. 1, pp.318-362, 1986.

[3] R.H. Nielsen, "Kolmogorov's Mapping Neural Network Existence Theorem", IJCNN' 87, Vol. 3, pp.11-13, 1987.

[4] R.H. Nielsen, "Theory of the Back- propagation Neural network", IJCNN'89, Vol. 1, pp.593-605, 1989.

[5] C.C. Chiang, H.C. Fu, "A Variant of second Order Multilayer Perceptron and Its Application to Function Approximation", IJCNN '92, Vol. 3, pp.887-892, 1992.

[6] H.M. Chung, "다치 논리 함수의 구조 해석과 전개", 한국정보과학회지, Vol. 13, No. 3, pp.155-166, 1986.

[7] T. Watanabe, M. Matsumoto, M. Enokida, "A design of multiple-valued logic neuron", ISMVL, pp.418-425, 1990.

[8] Zheng Tang, Qi-ping Cao, Okihiko Ishizuka, "A Learning Multiple-Valued Logic Network:Algebra, Algorithm, and Applications", IEEE TRANS. ON COMPUTERS, VOL. 47, NO. 2, pp.247-251, 1998.

[9] Zheng Tang, Okihiko Ishizuka, Koichi Tanno, "Learning Multiple-Valued Logic Networks Based on Back Propagation", ISMVL, pp. 270-275, 1995.

Doo-Ywan Kim
He received the B.S., Kyungnam University, Korea, in 1997, and M.S. Catholic University of Daegu Korea, in 1997. He currently working towards the Doctor degree in Catholic University of Daegu Korea.
His research interests are in MVL, Fuzzy Logic, Neural Network, Rough set.

Phone : +82-53-850-2741 Fax : +82-53-850-2741
E-mail : kimdy@amare.ac.kr

Hwan-Mook Chung
He was born November, 10 1944. He received the B.S. degrees in Electronic Engineering from Hanyang university, Seoul, Korea. in 1972, and the M.S. and Ph. D. degrees in Mathematics from Inha University, Korea, in 1982 and 1987, respectively.
Since 1984, he has been a faculty member of the School of Computer and Information Communication Engineering at the Catholic University of Daegu, where he is currently a Professor. From 1986 to 1987, He was a visiting researcher, Department of Information Science, University of Tokyo, Japan. From 1995 to 1996, he was a visiting professor, Department of Information Science, Meiji University, Japan. From 2000 to 2001, he was a president of the Korea Fuzzy Logic and Intelligent System Society. His research interest are Multi-valued Logic, Fuzzy & Rough theory, Neuro computing and Agent. He is a member of IEEE, KITE, JISS and KFIS.

Phone : +82-53-850-2741 Fax : +82-53-850-2741
E-mail : hmchung@amare.ac.kr