A Radical-Partitioned Coded Block Adaptive Neural Network Structure for Large-Volume Chinese Characters Recognition

J. B. Kuo and M. W. Mao
Rm. 526, Dept. of Electrical Eng., National Taiwan University
Roosevelt Rd. Sec. 4, #1, Taipei, Taiwan 107
Fax:886-2-363-8247, Telephone:886-2-363-5251

Abstract

This paper presents a coded block adaptive neural network system using a radical-partitioned structure for large-volume Chinese characters recognition VLSI. Using the coded block adaptive neural network system with a radical-partitioned structure, 1000 frequently-used Chinese characters have been successfully trained in 139.2 hours using an 18 MIPs computer. According to the simulation results, the coded block system with a radical-partitioned structure provides an acceptable learning time, a good recognition rate and an excellent expansion capability for large-volume Chinese characters recognition using VLSI.

1. INTRODUCTION

A pattern recognition system, as shown in Fig. 1, is composed of a translation-invariant network and a standard adaptive two-layer network. The translation-invariant network is used to map a retinal image into multi-bit outputs [1]-[4]. The standard adaptive two-layer network [5][6] made of $2n^2$ adaptive neurons and $2n^4$ connections between them, can be trained to provide output responses corresponding to the original image as required. Software implementation of the adaptive neural network using back propagation [7]-[10] has been demonstrated. Le Cun et. al. [11] has introduced a structured neural network architecture to speed up learning for hand written digit recognition. In fact, for Western characters recognition, only about 36 alphanumerics are needed. However, for Chinese characters recognition, over twenty thousand characters are necessary. For large-volume Chinese characters recognition, learning speed is determined by the number of neurons and connections between them. How to train large-volume Chinese characters using an efficient neural network structure has been a challenging effort. Recently, a block adaptive network structure using n^2 local blocks for an $n \times n$ input array as shown in Fig. 2 has been used to enhance the learning speed [12][13] for alphanumerics recognition. However, the block adaptive network structure requires n^2 local blocks, which is still a bottleneck for training large-volume Chinese characters. A coded block neural network system, which requires an order-of-magnitude fewer local blocks, has been used to provide a faster learning process for the alphanumerics recognition [14][15]. In this paper, a coded block adaptive neural network system with a radical-partitioned structure for large-volume Chinese characters recognition is presented. In the following sections, the radical-partitioned coded block structure is introduced, followed by the algorithm used in the system and simulation results.

2. THE CODED BLOCK STRUCTURE

Fig. 2(a) shows the block adaptive network structure for an $n \times n$ input array [12][13]. In the block structure, the system is partitioned into n^2 blocks. Each block as shown in Fig. 2(b) contains $n+1$ neurons and $n^3 + n$ connections between them, which are grouped into two layers. Instead of $2n^4$ global connections in two layers of the standard structure, only n^3 local connections are needed in the first layer and n connections in the second layer of the local block structure. Compared to the standard structure, the second layer neurons in all local blocks are separated from one another. Therefore, not only the number of neurons can be minimized, but also the number of synapses can be greatly reduced. Consequently, the computation referred to each block during training can be shortened substantially. In addition, the local block structure can be easily concatenated to build a large adaptive network, which is especially useful for radical-partitioned Chinese characters recognition. Furthermore, each local block needs to consider convergence associated with only a portion of input patterns during training. Consequently, the block structure converges faster during training since it is much easier to identify different patterns in a multi-dimensional space. Compared to the standard adaptive neural network system, the local block system already shows a substantial improvement in enhancing the learning speed as a result of the property that each local block can be trained independently and the convergence can be more easily reached since a much smaller structure – a local block, is involved during training.

However, the block adaptive network structure requires n^2 local blocks, which is still a bottleneck for large-scale pattern recognition. A coded block system [14][15] as shown in Fig. 3 has been used to further improve the block system. Instead of n^2 local blocks, only less than n local blocks with outputs coded corresponding to the input patterns are used in the system. Using the coded block system, the training time can be shortened further owing to the drastic reduction in the number of local blocks. The coded local block system is suitable for training the system with small-volume Chinese characters. However, for training over 200 Chinese characters, the coded block adaptive neural network using back propagation algorithm suffers from convergence difficulties.

Although there are over twenty thousand Chinese characters, they can be categorized into around 230 radical groups. Each radical group has 5–200 characters containing an identical radical portion as shown in Fig. 4(a). Taking advantage of the radical properties, the coded block adaptive neural network system can be reconfigured as shown in Fig. 4(b) such that each coded block is assigned to be responsible for training Chinese characters having the same radical portion. Using a radical-partitioned structure as shown in Fig. 4(b), the coded block adaptive neural network can overcome the convergence difficulties during training since training of the large-volume Chinese characters can be divided into small procedures associated with radical blocks. In fact, the training of each radical blocks can be divided further into steps associated with internal local blocks. Therefore, using the coded block system with a radical-partitioned structure, the overall training procedure is simplified from two approaches. First, Chinese characters as input training patterns are categorized into several radical groups. Chinese characters in each radical group having an identical radical portion is assigned to a radical block. Second, the training of each radical block is divided into steps associated with several internal local blocks. Training of each internal local block is independent. Therefore, convergence during training is determined by a very small portion of the overall system - the internal local block in each radical block with a small portion of the Chinese characters to train. Therefore, convergence is guaranteed and training time is much shorter.

As shown in Fig. 4(b), above the coded radical blocks, there is a radical selector, which is used to identify the radical category of each input Chinese character during recognition. During recognition, dot products of the radical portion of the each input Chinese character and all radicals are carried out in the radical selector block. Then, the input character is transferred to the associated radical block for further processing according to the dot product result. Since only one radical block handles the second-step processing during recognition, the recognition time is greatly shortened as compared to the coded block adaptive neural network system without the radical-partitioned structure. Consequently, the coded block adaptive neural network system with the radical-partitioned structure can be advantageous for both training and recognition of large-volume Chinese characters.

3. PERFORMANCE

In order to investigate the potential of the coded block adaptive neural network system with a radical-partitioned structure for large-volume Chinese characters recognition, the performance in terms of learning time, reconfiguration based on simulation results has been obtained. 1000 24×24 Chinese characters in 25 frequently-used radical groups as shown in Fig. 5 have been used as the training patterns for the coded block adaptive neural network system with a radical-partitioned structure. Each radical block is trained with its 40 associated Chinese characters independently. Each of the radical blocks contains 16 internal local blocks. In the coded block adaptive neural network system with a radical-partitioned structure, a learning rate, η, which affects the learning speed of a block adaptive neural network system using back propagation algorithm [12]-[15], of $\eta = 0.2$ has been used. In addition, the number of first layer neurons in the local block structure, which also affects the learning time [12]-[15], is defined as 12.

Owing to the radical-partitioned structure used in the coded block neural network system, the training process can be divided into steps associated with the 400 internal local blocks in 25 radical blocks. Training each of the 400 internal local blocks is independent from one another. Table 1 shows the epoches needed for training each of 400 internal local blocks with 25 sets of Chinese characters. Each epoch of training each internal local block with 40 corresponding Chinese characters once took about 20 sec CPU time on an 18-MIPs computer. Each local block may have different number of epoches needed to accomplish training, which depends on the input patterns and the initial synaptic weights. Fig. 6 shows the learning curves in terms of average number of epoches needed for training each local block in all 25 radical blocks with its corresponding 40 Chinese characters. Among 16 internal local blocks, the training time varies. On the average, each local block in 25 radical blocks reaches a convergence within 100 epoches during training. The total learning time for training the 25 radical block system with 1000 Chinese characters is 139.2 hours CPU time on an 18 MIPs computer. Without the radical-partitioned coded block neural network system, the training time of 1000 Chinese characters is just not feasible.

Neural networks have renown properties in reconfigurability and fault-tolerance, which are important for a reliable pattern recognition system [16][17]. In addition to an acceptable learning time, the local block structure has good properties in reconfigurability and expansion capability. Fig. 7 shows the the average output percentage error associated with the radical-partitioned coded block system using random input samples with percentage random error taken from several radicals. Recognizing a character out of 1000 Chinese characters as shown in Fig. 5 took about $0.5sec$ CPU time on an 18 MIPs computer. The case with 40 random samples with percentage random error taken from 2 radicals indicates the highest recognition rate. The cases with more random samples with percentage random error taken from more radical sections show a worse recognition rate. The cases with over 400 random samples seem to have a near constant recognition rate of over 80% regardless of the number of samples used. In fact, the overall recognition rate exceeds 80% regardless of the input percentage error. The recognition rate can be enhanced if preprocessing of the input characters before the selector block can be done.

4. DISCUSSION

The coded block adaptive neural network system with a radical-partitioned structure has an excellent expansion capability for large-volume Chinese characters recognition. Depending on applications, the radical block associated with Chinese characters belonging to the same radical group can be trained sequentially and glued together with other radical blocks. Consequently, in building a large Chinese characters system, the training process does not have to start from the very beginning every time. Instead, the previous trained radical blocks, which relate to the Chinese characters of identical radicals, can be used. Only the new untrained characters need to be trained. Consequently, the cost in training can be greatly reduced. With the radical-partitioned structure, radical coded blocks can be concatenated to build a large coded block adaptive neural network system for large-volume Chinese characters recognition. In addition, the convergence of training the growing system is always guaranteed since each time only the newly-added characters belonging to the same radical group need to be trained.

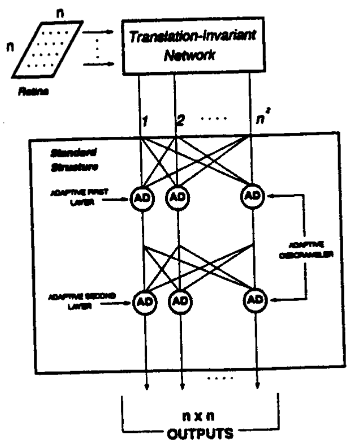
5. CONCLUSION

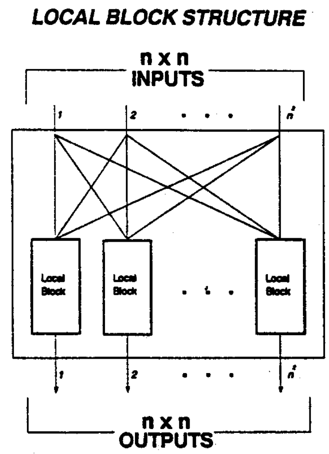
In conclusion, an efficient coded block adaptive neural network system with a radical-partitioned structure suitable for large-volume Chinese characters recognition, has been successfully trained with 1000 Chinese characters in 139.2 hours CPU time on a 18 MIPs computer. According to simulation results, the coded block adaptive network with a radical-partitioned structure provides an acceptable learning time, a good reconfigurability, and an excellent expansion capability.

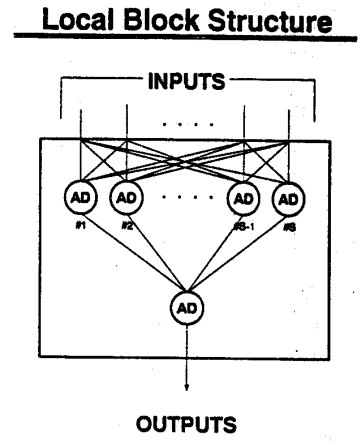
REFERENCES

[1] B. Widrow, et. al., "Layered Neural Nets for Pattern Recognition," *IEEE T.ASSP*, 7/88.
[2] B. Widrow et. al., "Neural Nets for Adaptive Filtering and Adaptive Pattern Recognition," *IEEE*

Computer, 3/88.
[3] D. E. Rumelhart et. al., "Parallel Distribution Processing, " *MIT*, 1986.
[4] *Darpa Neural Network Study*, October 1987-February 1988.
[5] G. Mirchandani, and W. Cao, "On Hidden Nodes for Neural Nets, " *IEEE T. CAS*, 5/89.
[6] D. S. Touretzky et. al., "What's Hidden in the Hidden Layers, " *Neural Networks*, 8/89.
[7] W. P. Jones et. al., "Back-Propagation: A Generalized Delta Learning Rule, " *Byte*, 10/87.
[8] Keiji Yamada, Hiroyuki Kami, Jun Tsukumo, and Tsutomu Temma, "Handwritten Numeral Recognition by Multi-layered Neural Network with Improved Learning Algorithm, " *IJCNN*, 1989.
[9] T. P. Vogl, et. al., "Accelerating the Convergence of the Back Propagation Method, " ***Biol. Cybern.***, 88.
[10] D. J. Burr, "Experiments on Neural Net Recognition of Spoken and Written Text, " *IEEE T.ASSP*, 7/88.
[11] Y. Le Cun, et. al., "Handwritten Digit Recognition: Application of Neural Network Chips and Automatic Learning, " *IEEE Comm. Mag*, 11/89.
[12] J. B. Kuo et. al., "A Structured Adaptive Neural Network for Pattern Recognition," Digest of 1991 International EDMS
[13] J. B. Kuo, C. C. Chen, and C. C. Hsiao, "A Block Adaptive Neural Network Structure for Pattern Recognition VLSI," to be published in the IEE Proc. on Devices, Circuits and Systems
[14] J. B. Kuo, et. al., "A Coded Block Adaptive Block Adaptive Neural Network Structure for Pattern Recognition VLSI," Digest of 1991 International Symposium on VLSI Tech., Systems, and Applications
[15] J. B. Kuo and W. C. Mao, "An Adaptive Neural Network Structure with Coded Local Blocks for Pattern Recognition VLSI," Proc. of 1991 IJCNN
[16] J. Feldman and D. Ballard, "Connectionist Models and Their Properties, " *CognitiveScience*, 3/82.
[17] J. S. Denker and B. S. Wittner, "Network Generality, Training Required and Precision Required, " *IEEE Conf. Neural Information Processing Systems*, 11/87.

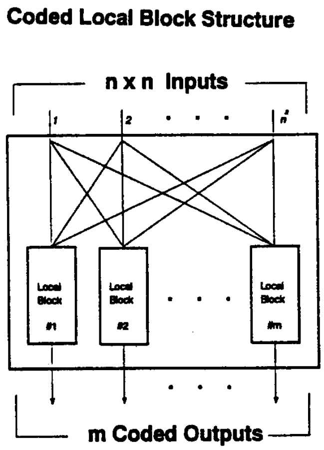


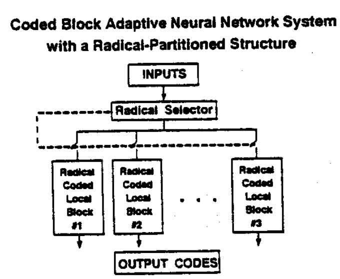




'ig. 1 A pattern recognition system composed of a translation-invariant neural network and an adaptive two-layer net- work.

Fig. 2 (a) A block adaptive neural network structure b) The local block structure.





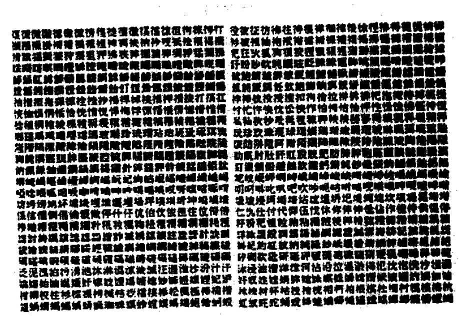
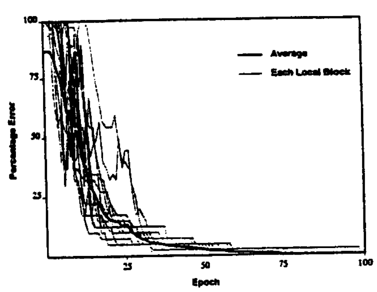
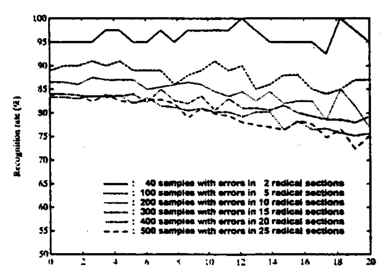


Fig. 3 The coded block adaptive neural network structure.

Fig. 4 (a) The radical of Chinese characters. (b) The coded block adaptive neural network system with a radical-partitione structure for large-volume Chinese characters recognition.

Fig. 5 The 1000 Chinese characters used as the training patterns.





Rad	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Rad1	0	35	51	77	84	28	68	25	112	80	14	25	27	35	36	47
Rad2	0	23	23	28	32	43	55	23	30	37	18	40	70	11	23	22
Rad3	0	121	31	21	33	38	27	52	28	21	38	33	28	44	89	11
Rad4	0	63	158	142	69	144	328	178	47	79	33	38	23	19	31	48
Rad5	0	198	24	24	30	42	25	102	72	44	80	61	18	47	118	28
Rad6	0	478	188	113	86	33	24	116	308	213	77	238	24	81	38	17
Rad7	0	0	0	16	42	24	15	53	29	13	31	51	14	103	31	28
Rad8	0	38	33	46	43	210	238	23	86	108	60	35	41	31	14	98
Rad9	0	68	34	208	28	161	91	230	50	28	63	122	44	90	38	12
Rad10	0	21	27	133	28	162	79	12	15	18	121	29	23	91	33	20
Rad11	0	60	63	87	188	29	132	108	171	148	27	19	20	32	9	128
Rad12	0	132	193	187	73	288	101	238	40	36	33	40	31	38	28	38
Rad13	0	18	20	20	66	73	53	31	98	0	32	18	41	39	41	23
Rad14	0	81	32	134	34	20	208	68	37	30	20	18	11	74	98	68
Rad15	0	0	0	31	23	29	18	90	21	90	38	37	19	28	31	75
Rad16	0	11	8	11	12	119	40	44	73	14	30	88	14	36	25	24
Rad17	0	0	0	108	190	38	31	23	42	79	44	55	38	70	13	57
Rad18	0	31	430	110	93	52	67	31	41	40	33	188	50	72	19	97
Rad19	0	60	60	33	74	81	28	19	148	40	48	64	35	189	87	24
Rad20	0	0	0	70	34	432	108	97	58	34	117	48	64	18	189	22
Rad21	0	28	40	112	31	174	28	102	32	43	51	38	79	58	187	38
Rad22	0	0	0	20	198	22	18	27	58	274	37	39	12	33	38	98
Rad23	0	44	72	71	48	83	18	18	18	13	11	28	68	144	40	127
Rad24	0	86	90	26	42	28	58	42	25	132	20	158	188	33	41	148
Rad25	0	43	48	61	403	138	25	30	41	92	24	118	16	91	138	27
Ave.	0	65	65	77	78	100	78	73	58	72	47	63	38	60	58	48

Fig. 6 The average learning time for each of the 16 internal local blocks of all 25 radical blocks in the coded block adaptive neural network with with a radical-partitioned structure using the back propagation algorithm. 25 radical groups of 1000 Chinese characters have been used as the training patterns. Each radical block has 40 Chinese characters as the training patterns.

Fig. 7 The reconfigurability of the code block neural network system with a radical-partitioned structure. The average output percentage error vs. input percentage error curves for the system using random input samples with percentage random error taken from several radicals.

Table 1 Numbers of epoches needed for training local blocks in all radical blocks.