Design and Evaluation of Neural Networks for Coin Recognition by Using GA and SA

Yasue Mitsukura*, Minoru Fukumi* and Norio Akamatsu*

* Department of Information Science & Intelligent Systems, Faculty of Engineering
University of Tokushima 2-1, Minami-josanjima, Tokushima, 770-8506 JAPAN

[**Mailing Address**]

Yasue Mitsukura

Department of Information Science & Intelligent Systems, Faculty of Engineering
University of Tokushima 2-1, Minami-josanjima, Tokushima, 770-8506 JAPAN

e-mail: mitsu@is.tokushima-u.ac.jp

Abstract

In this paper, we propose a method to design a neural network(NN) by using a genetic algorithm(GA) and simulated annealing(SA). And also, in order to demonstrate the effectiveness of the proposed scheme, we apply the proposed scheme to a coin recognition example.

In general, as a problem becomes complex and large-scale, the number of operations increases and hardware implementation to real systems (coin recognition machines) using NNs becomes difficult. Therefore, we propose the method which makes a small-sized NN system to achieve a cost reduction and to simplify hardware implementation to the real machines.

The coin images used in this paper were taken by a cheap scanner. Then they are not perfect, but a part of the coin image could be used in computer simulations. Input signals, which are Fourier spectra, are learned by a three-layered NN. The inputs to NN are selected by using GA with SA to make a small-sized NN. Simulation results show that the proposed scheme is effencive to find a small number of input signals for coin recognition.

1 Introduction

Recently, the mechanism of information processing in the human brain is partly explained. The trials which realize these artificially as neural networks[1] have been performed. Furthermore, NN is widely used for pattern recognition, system identification, learning, adaptive control, and so on. As for the field of the pattern recognition, NN has been effectively used. In particular, the coin recognition methods using NNs are proposed abundantly[2]-[5]. However, as a problem becomes complex and large-scale, the amount of operation increases, hardware implementation to real systems (coin recognition machines using NNs) becomes difficult. To make a small-sized NN system conducts to simplify hardware implementation

Proceedings of the IEEE-INNS-ENNS International Joint Conference on Neural Networks (IJCNN'00)
0-7695-0619-4/00/$10.00 (C) 2000 IEEE

to the real systems. Therefore, in this paper, a new scheme which makes a small-sized NN system is proposed. Some schemes are proposed[4], [5], which make a small-sized NN system.

However it costs dear when an image is taken in with an imsge scanner because the perfect image of a coin is used for learning and recognition. When hardware implementation to an real system is considered, the most important points are follows:

1. Recognition accuracy must be a 100 percent or close to 100 percent.
2. It is a low cost system.
3. When it is applied to a real system, it doesn't consume recognition time.

In this paper, the above three points are taken into the consideration for lower cost. We could not use the whole of the coin image but use a part of the coin image taken by a cheap scanner. The purpose is to design a smaller NN system to attain the recognition rate which is close to the 100 percent.

On the other hand, much work on GA [2]-[4] and SA [6] has been carried out vigorously for a long time. GA is an engineering method of the mechanism of creature's heredity and evolution.

Furthermore, in order to avoid metastable states produced by quenching, metals are often cooled very slowly, which allows them to come into stable, structurally strong, low energy configurations. This algorithm is called annealing. The annealing gives the system the opportunity to jump out of local minima with a reasonable probability while the temperature is still relatively high. SA obtains a hint from this algorithm. There are disadvantage (falling in a local minimum and so on) when only GA is used or when only SA is used. Therefore by using GA and SA together, we can search a global one and moreover, obtain a desirable value by a short time. Then, a smaller number of NN inputs is obtained by using GA and SA. In this paper, first, the method for reduction of the operation quantity in the coin recognition problem is mentioned. Next, how to design NN by using GA and SA is described. Finally, in order to show the effectiveness of the proposed scheme, computer simulations are performed.

2 Coin recognition problem

2.1 The characteristics of the coin images

The task of a coin recognition system to be examined in this paper is to recognize four coin images properly by using the coin data which are not perfect. It is to do distinction of Japanese 500 yen coin and South Korean 500 won coin precisely. Because their size, weight, color, pattern, and so on are very similar for both coins, those similarities has have caused a trouble before[7]. Here, the input images to the system are shown in **Fig.1**. These are the images of a 500 yen coin and a 500 won coin.

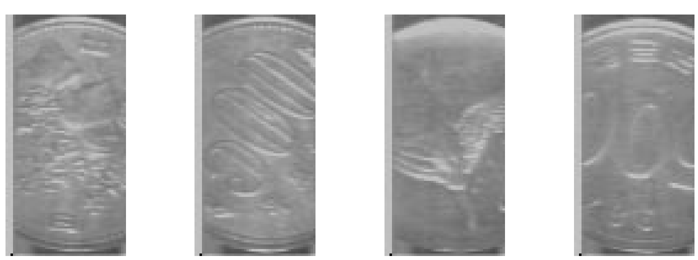

Fig.1 A 500 yen coin and a 500 won coin

2.1 The reduction of the amount of operation

The coin images in the polar coordinates are changed into ones in the orthogonal coordinates. Then, a two-dimensional Fourier Transform is carried out to those images, and their amplitude spectra are input signals to NN. However, when the coin images are divided into 16 segments along the radius direction

Proceedings of the IEEE-INNS-ENNS International Joint Conference on Neural Networks (IJCNN'00)
0-7695-0619-4/00/$10.00 (C) 2000 IEEE

and into 32 along the circumference direction, input signals to NN become 16 !_32 (=512). Then the size of NN is large and influences hardware implementation to an real system. Therefore, it is necessary to reduce the amount of operation in NN. The number of amplitude spectra after Fourier Transform was reduced to only the necessary minimum by using GA with SA together.

3 A Design of NN using GA and SA

3.1 The combination of GA and SA

GA is a search algorithm which imitates the mechanism of the creature's heredity and the evolution from the viewpoint of engineering. It is applied to the wide field of engineering as a technique of optimization. However, when a problem becomes complex and large-scale, it often falls to the local suitable answer, and it may not be able to obtain the global suitable answer by the simple genetic algorithms (simple GA) which has been used in many fields. On the other hand, a Simulated Annealing law, in which the nature of a probability distribution of the heat balance condition in statistical physics is used, is presented. It is possible to escape from the local minimum of an objective function by using it. There are many applications in many fields as a solution of combinatorial optimization problems. In general, by using this method, a better answer can be searched. In this paper, we use this method in order to search a small set of NN inputs. First, by using GA, a suitable value area are searched. Next, by using SA with the probability of r %, more suitable value are searched in the selected suitable value area by using GA.

3.2 The selection of the inputs of NN

Step1 Initialization : the values of genes of GA are set to 0 or 1 to specify whether or not amplitude spectra are used, and some parameters are set in GA and $i = 1$.

Step2 Calculation of the fitness function $\{f(i,j)\}$. Here, i, j denotes the i-th generation on the j-th individual.

Step3 Reproduction of the next generation's population $\{I^i\}$ through selection, crossover and mutation.

Step4 SA is carried out.

Step5 Go to [step2], setting i to $i + 1$.

Here, we use the following fitness function :

$$f(i) = A \text{ /(the number of individuals)} + B/ \text{ (the number of individuals)}$$

In (1), A is the ranking number which is assigned in turn by high recognition rate and B is the ranking number which is assigned by the number of 1's in the the chromosome of an individual in GA. By using this fitness function, we can obtain a high recognition rate and small-sized NN.

The procedure of SA are as follows:

Step1 Initial tempureture and an initial value are decided.

Step2 To make a more suitable value the following procedures are repeated until it becomes a heat balance condition.

A present value x is change for the suitable value x' by using the following:

When SA is used,

$$x = \begin{cases} x' & (c(x') < c(x)) \\ x' & (c(x') \geq c(x), \quad h \leq exp\{(c(x') - c(x))/T\}) \\ x & (c(x') \geq c(x), \quad h \geq exp\{(c(x') - c(x))/T\}) \end{cases}$$

When SA is not used,

$$x = \begin{cases} x' & (c(x') < c(x)) \\ x_b & (c(x') \geq c(x)) \end{cases}$$

where $c(x)$ is a fitness function in GA and h is a uniform random number in [0,1].

Step3 If the finishing condition (it is set in advance) is satisfied, then the procedure is stopped.

4 Computer simulations

In order to demonstrate effectiveness of the proposed scheme, computer simulations were done. The parameters of GA are shown in the following.

The number of individuals : 40
The number of generations : 40
Crossover : multi-points crossover
The probability of the mutation : 0.02

Moreover, SA is done with probability of a 20 percent, and the parameters of SA are shown in the following.

Temperature gradient: 0.90
Initial temperature : 1000
Finishing condition : $\alpha \leq 0.1$

In SA, 10 individuals which have a high ranking number are selected. Here, each individual has chromosome length of 512. These chromosomes of these selected individuals are divided by 32 and 32 small segments are produced, and then a binary string of each segment is changed into a decimal number. Then they are summed to be used in SA. That is, one individual has 32 additions. For the decimal numbers obtained from these individuals, the SA is carried out according to procedure in former section. The parameters of NN are shown in the following.

The number of layers : 3
The number of units of the input layer : not more than 512
The number of units of the middle layer : 20
The number of units of the output layer : 4
(head or tail of Japanese 500yen and South Korean 500yen)

And also, 120 sheets of the coin images are used for learning. Furthermore, 320 sheets of the coin images, which include the former 120 sheets, are used for recognition. At this time, in order to show the effectiveness of the proposed scheme, we perform two simulations. One is the conventional learning scheme by only GA. The other is proposed scheme. That is learning by GA-SA in **Fig.2**. In **Fig.2**, the X-axis is the number of generations and the Y-axis is the corresponding best fitness value at every generation. Furthermore, the search of only GA was continued as shown in **Fig.3**. From **Fig.2** and **Fig.3**, the better result was obtained by using GA and SA in the only 40 generations than that obtained using only GA in the 120 generations. From these results, by using GA and SA, we can obtain the suitable fitness value in the early generation. Here, the number of NN inputs was 221 by using GA and SA. This is the 56 percent reduction of NN inputs. In this case, the total number of weights is 4524. It is clear that the amount of calculation is drastically reduced compared with all inputs 10344 in the fully-connected NN. For the purpose of comparing, we applied the Back Propagation (BP) method as a conventional method to the fully-connected NN. We can obtain the 99.68 percent recognition accuracy. On the other hand, 99.68 percent recognition accuracy can be obtained by the proposed scheme, too. However, for hardware implementation, the proposed scheme works better than the fully-connected NN.

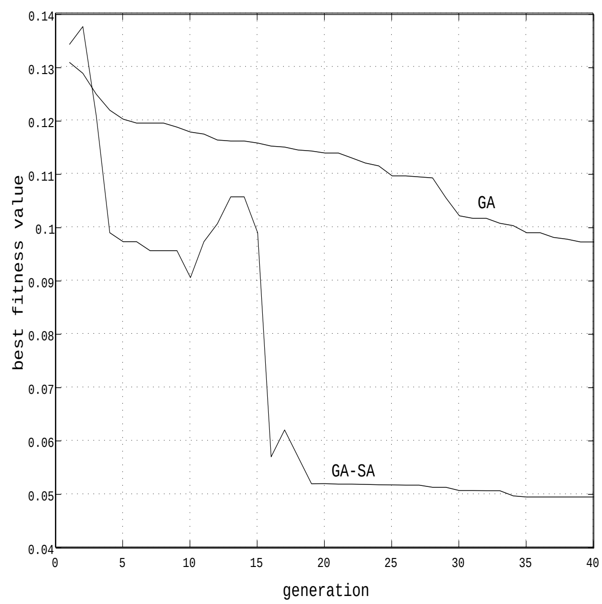

Fig.2 The learning by using GA-SA and GA.

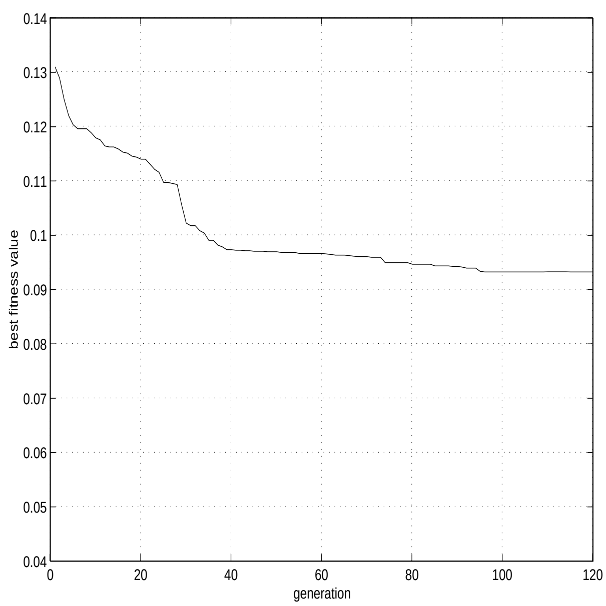

Fig.3 The learning by using GA.

0-7695-0619-4/00/$10.00 (C) 2000 IEEE

5 Conclusions

In this paper, we propose a designing method of NN by using GA and SA. Furthermore, in order to show the effectiveness of the proposed scheme, we applied it to a computer simulation for coin recognition. The features of the proposed scheme are summarized as follows:

- This system is a low cost system.
- The suitable NN inputs can be obtained in the early generation by using GA and SA.
- Recognition accuracy close to 100 percent can be obtained.

References

[1] S.Haykin : Neural Networks, Macmillan College Publishing Company (1994)

[2] D.E.Goldberg: Genetic Algorithm in Search , Optimization & Machine Learning , Addison-Wesley (1992)

[3] H.Kitano!′Genetic Algorithm!$Industrial library(1993) (in japanese)

[4] D.B.Fogel:Evolutionary Computation, IEEE press (1995)

[5] K.F.Man,et al. : Genetic Algorithm for Control and Signal Processing, Springer (1997)

[6] F.Takeda and S.Omatu : Rocognition System of US Dollers Using a Neural Network with Random Masks, Proc. of the International Joint Conference on Neural Networks, Vol.2, pp. 2033-2036 (1993).

[7] F.Takeda, S.Omatu!′The development of neuro coin recognition machine board!$Trans. of the institute of electrical engineers of JAPAN, Vol.1 116-C, No.3, pp.336-340 (1996).

[8] M.Fukumi, S.Omatu!′Designing an Architecture of a Neural Network for Coin Recognition by a Genetic Algorithm, Trans. of the institute of electrical engineers of JAPAN, Vol.113-D, No.12, pp.1403-1409(1993) (in japanese)

[9] F.Takeda, et al.: Bank Note Recognition System Using Neural Network with Random Masks, Proc. World Cong. on Neural Networks, Vol.1, pp.241-244 (1993)

[10] S.Lee and Y.Choi : Robust Recognition of Handwritten Numerals Based on Dual Cooperative Networks, Proc. of Int. Joint Conf. on Neural Networks, Vol.3, pp.760-767 (1992)

[11] "Foreign Coins in Toll Change Cause Mix-ups, Anger Derivers":*The Daily Yomiuri* (June 30,1992)

[12] M.Kawamata, T.Higuchi : Multi Dimensional Digital Signal Processing, Asakura Publishing co. Ltd., Tokyo (1995) (in japanese)

Proceedings of the IEEE-INNS-ENNS International Joint Conference on Neural Networks (IJCNN'00)
0-7695-0619-4/00/$10.00 (C) 2000 IEEE