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Studies on Image Recognition of Human Sperms Using a Neural Network

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Abstract. Three layered neural network was applied for the pattern recognition problem of human spermatozoa in clinical test. The goodness of recognition rate was studied in relation to the number of hidden layer cells and of output layer cells. The proposed method provided better results than conventional template matching technique. Parallel processing of the back propagation learning algorithm was also studied using Transputers and its performance was evaluated.

1 Introduction

The number of spermatozoa in human semen and their motility are one of the important clinical tests. For this problem, image processing techniques using binary images have been developed. They succeeded in the processing of characteristics of moving spermatozoa. However, more detailed information such as the number of spermatozoa which stop moving and even the morphological characteristic are needed in practical clinical applications. We have developed an image processing system which utilized a template matching technique for the pattern recognition of spermatozoa[1]. However, the problem was left in preparing reasonable templates depending on the variety of spermatozoon's shape and also of spermatozoon-like substances or cells.

In this study, we propose a method of training of neural network for the pattern recognition of spermatozoa. A three layered network was used for the learning of the charactaristics of spermatozoa and other substances. The back propagation algorithm was used for the training of neural network. This method provides a powerful mean of automatic generation of template patterns through the supervisary learning of the neural network itself. Especially, effects of the number of cells in hidden layer and in output layer are investigated in relation to the goodness of recognition rate. Next, a multi-processor architecture using Transputers is studied from the viewpoint of parallel-processing of neural network computation. The load sharing problem for the training algorithm by several processors is investigated.

2 Image Processing Hardware System

Total system configuration of hardwares is shown in Fig.1. The image processor in Fig.1 performs a realtime

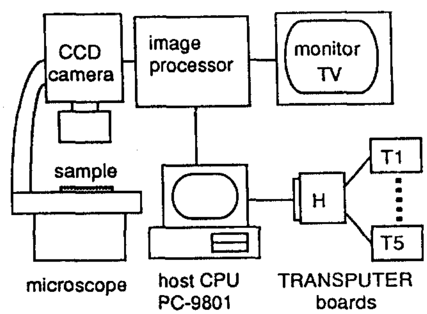

Fig. 1 System configuration

processing of the following two operations for 512 × 512 pixels picture :

1. 5 × 5 mask scanning operation defined by an arbitrary function in look-up table.

2. Operation between two pictures.

Each Transputer chip (INMOS Corp.) is a 32 bits microprocessor with own local memory and with 4 communication ports, and performs 10 MIPS(1.5 MFlops) operation[6]. In this study, six Transputers were used for the simulation of three layered neural network. The connection diagram is shown in Fig.2.

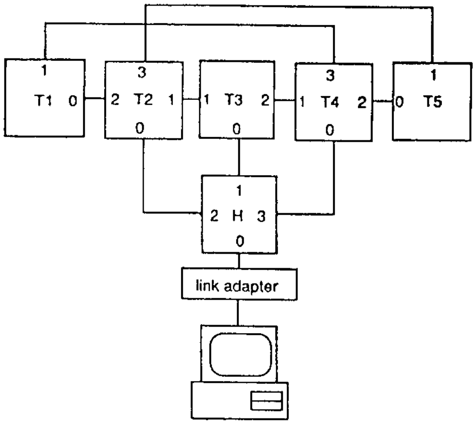

Fig. 2 Connection of Transputers

3 Pattern Recognition by Neural Network

3.1 Specimen of human sperm

A typical microscopic photograph of human semen is shown in Fig.3. The photograph was taken by using a

Fig. 3 Photograph of sperm

phase contrast microscope with factors of 100. We can observe there spermatozoa, other substances or cells and video signal noise. The problem is first to count the number of spermatozoa in such a figure. Next problem is to discriminate the difference of each spermatozoon and further to measure its motility. The latter problem is not discussed in this paper.

The original pictures are first pre-processed, if necessary. These are processing for the compensation of shading effect, image enhancement by histogram transformation and noise filtering. Next, for the data processing followed, a number of 12×12 pixels subregion containing the head of spermatozoa are extracted from a picture. These data are used for the training of neural network. Similarly, subregions containing other substances are also prepared as training data.

3.2 Three layered neural network

Multi-layered neural networks have been applied for pattern classification problems. This is based on their ability for learning and for generalization of acquired knowledge. Three layered network structure in Fig.4 is used in this study. Application of this neural network is

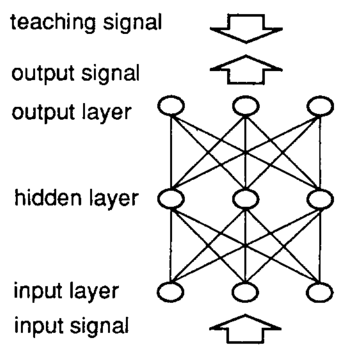

Fig. 4 Multi-layered neural network

devided in two processes. The first process is a learning (or training) phase. The network is trained by the back propagation algorithm[2)4)] with supervisory signals *a priori* given. In this case, input signals corresponding to data of subregions extracted from the original picture are fed to the input layer and these signals propagate forward to the output layer. Next, the connecting coefficients (i.e. synapse efficacies) are adjusted backward so as to decrease the squared error between output signals and teaching signals.

The second process is a recognition phase(or reminding or reasoning phase) for which the already trained network is applied. Input signals to be classified are fed to the input layer, then appropriate output cell fires correspondingly to a class of input signals. In this study, the nonliner function of sigmoid-type

$$F(x) = 1/(1 + exp(-x)) \quad (1)$$

is used for the characteristic of each neuron cell. A neuron cell is considered to be fired if its output value is greater than 0.5.

4 Results for Pattern Recognition

4.1 Effect of the number of hidden layer cells

The number of input layer cells is 144. We assigned here one output layer cell so that the firing of the output cell means "spermatozoon" and the non-firing "not-spermatozoon". The effect of the number of hidden layer cells is investigated by simulation studies in relation to the goodness of recognition rate, defined by

$$\text{goodness of recognition rate} = \frac{\text{the number of firing cells(or non-firing)}}{\text{the number of specimens of spermatozoa (or other substances)}} \quad (2)$$

For the training phase of the neural network, 50 specimens of spermatozoa and 50 specimens of other substances were used. For the recognition phase, 40 spermatozoa and 20 other substances, which were different from the training ones, were used. In Fig.5, two examples of spermatozoon and other substance patterns are given with the states of hidden layer cells and output layer cells.

number of hidden-layer cells	5	7	10	20	30	40	50	70
recognition rate of spermatozoa (%)	55	40	80	75	80	80	87	80
recognition rate of others (%)	30	35	65	70	60	75	75	65

Table 1 Experimental results

The results are summarized in Table 1.

From these results, we may conclude that at least 10 hidden layer cells are required for this problem. When the number of hidden layer cells is less than 10, the recognition rate decreased even if the error in the training phase took small values. Also, the efficiency of training process in such a case was poor and the trappings of up-dating of coefficients, probably in local minima of the squared error function, have been observed.

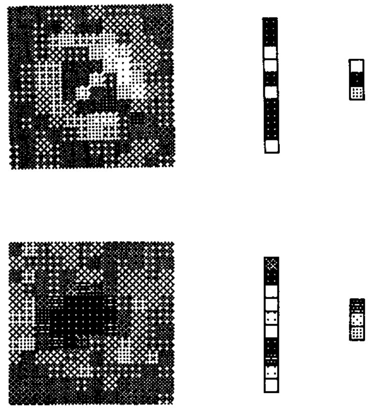

Fig. 5 12x12 pixels patterns, hidden layer cells and output layer cells. (above: spermatozoon, below:other substance)

4.2 Effects of the number of output layer cells

It is expected to improve the goodness of recognition rate by increasing the number of output layer cells. Two cases are studied below. The first case is a network with two output layer cells; the one is for spermatozoa and the another is for other substances. For the second case, we added a third output cell corresponding to the data of averaged concentration of a picture. The results are given in Tables 2 and 3. Apparently, no improvement is not observed in Table 2, while satisfactory improvement in Table 3. In our experience, the mask matching technique using three kinds of template gave about 70% recognition rate[1]. The result in Table 3 exceeds this value and will be enough for clinical appications. It seems that the training process was enhanced by adding inhomogeneous information like an averaged concentration of the picture and this yielded better generalization of the acquired knowledge

number of hidden-layer cells	10	20	30	40	50
recognition rate of spermatozoa (%)	65	52	55	55	57
recognition rate of others (%)	45	50	65	55	55

Table 2 The case of two output layer cells

number of hidden-layer cells	10	20	30	40	50
recognition rate of spermatozoa (%)	95	90	90	95	97
recognition rate of others (%)	90	95	95	95	95

Table 3 The case of three output layer cells

for the classification problem of relevant patterns.

4.3 Discussion

The training of neural network depends much on initial values of connecting coefficients. Normally, such initial values are given by random numbers. However, if the firing of some hidden layer cells has meaning for corresponding recognition procecss of specified patterns., we may assign pre-determined values for the connecting coefficients. We have observed such a tendency for some connecting coefficients between the input layer cells and the hidden layer cells. So, we were able to reduce the iteration number of training by such a pre-wiring method. It seemed to us that a part of hidden layer cells can represent specified characteristics included in the given input figure, of which details, however, could not be clayfied in this study. Also, we should note that the effectiveness of the back propagation algorithm much depends on the scheme to avoid the falling of algorithm in local minima. The results in Table 3 shows such an example, where the algorithm was activated by a third output layer cell which could promote a global convergence.

5 Parallel Processing by Multi-Processors

Although the computation scheme for neural networks is generally not complex, the size of network will become large for pratical applications. We expect also the possibility of parallel processing for such a network as long as we presume a use of digital architecture. We have studied the load sharing problems of computation required for the training of the neural network in Fig.3 in parallel processing. The multi-layered neural network takes in principle a densely connected structure. This characteristic can not be neglected for the training phase when we assign random initial values for connecting coefficients. Therefore, we may say that there will be no effective solutions for parallelizing the learning algorithm. The Transputers used in our experiment have sparse connection structure as a multi-processor system[6]. Therefore, the problem in their application to the neural network simulation is focussed on the method how to divide the network structure and how to allocate obtained sub-networks to each processor. As a result, the network should be vertically divided so as to reduce the communication rates between prosessors and load should be equally allocated to each processor. In Table 5, the time for 50 iterations of learning phase and the throughput rates are given in comparison with other architectures. The Transputer system seems to provide a reasonable facility for neuro-computing from the viewpoint of cost/performance.

	sec/50 learnings	CPS
PC-286VE (80286+287)	20.00	3,682
SUN3 (68020+68881)	8.50	8,981
TRANSPUTER (× 5)	0.45	164,942

(CPS:connections per second)

Table 4 Comparison of computing speed

6 Conclusion

A three layered neural network was applied for pattern recognition problems of human sperms under the microscopic image. The effects of the number of hidden layer cells and of output layer cells in the network were investigated from the viewpoint of recognition rate. The knowledge acquired on the connection of the neural network could be much generalized by taking an adequate network structure and it gave a better recognition rate than conventional tenplate matching techniques. The parallel processing for the training algorithm of the network was implemented for the multi-Transputer systems. Such a multi-processor structure seems to provide a reasonable tool for practical application of neural network techniques.

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