

# Image Noise Cancellation Using a Hybrid Clonal Selection Algorithm and Cellular Neural Network

Chiao-Yu Chuang

Department of Electronic  
Engineering, National  
Kaohsiung University of  
Applied Sciences, Kaohsiung,  
Taiwan 807, R.O.C.

ps3joe@pchome.com.tw

Te-Jen Su

Department of Electronic  
Engineering, National  
Kaohsiung University of  
Applied Sciences, Kaohsiung,  
Taiwan 807, R.O.C.

sutj@cc.kuas.edu.tw

Hsiao-Ching Lin

Department of Electronic  
Engineering, National  
Kaohsiung University of  
Applied Sciences, Kaohsiung,  
Taiwan 807, R.O.C.

1093320110@cc.kuas.edu.tw

## ABSTRACT

In this paper, a new method for image noise cancellation by designing the templates of cellular neural network (CNN) is introduced. The discrete-time cellular neural network (DTCNN) with uncertainties using clonal selection algorithm approach is employed to investigate the problem. Based on clonal selection algorithm, the templates of CNN are optimized to reduce noise interference in contaminated image e.g. Tainted medical computed tomography (CT). Some examples are provided to illustrate the effectiveness of the proposed methodology.

## Categories and Subject Descriptors

G.1.6 Optimization

## General Terms

Algorithms

## Keywords

Clonal Selection Algorithm,  
Cellular Neural Network,  
Image Noise Cancellation.

## 1. INTRODUCTION

Immune system is a complex of cells, molecules and organs. It learns about the antigen, thus protecting the body against any further invasion from this antigen. The learning mechanism creates the immune system's memory, which causes rapid response next similar invasion. By using this mechanism, immune algorithm shows a good performance as an optimization algorithm. Clonal selection algorithm (CSA) inspired from the artificial immune system (AIS) is used to define the basic features of an immune response to an antigenic stimulus, and reach the optimization performances for many engineering problems. In this paper, we present CSA for the engineering optimization of cellular neural network (CNN).

In a cellular neural network circuit, the data always suffer from various kinds of noises. The sources of noise may be external interferences, e.g. atmospheric noise, man-made noise, that causes the perturbations to the system. These perturbations can produce the wrong judgment in system operation. Consequently, the CNN's configuration should determine along with the templates optimization to reduce the noise interference. A CSA-CNN algorithm proposed for templates optimization in this paper.

In the next section the artificial immune system and clonal selection algorithm are described. The CNN is presented in Section 3, and our proposed algorithm is introduced in Section 4. In Section 5, the simulation results are proposed to exhibit results. Finally, the conclusion is given in Section 6.

## 2. HEURISTIC ALGORITHM

### 2.1 Artificial Immune System (AIS)

The human immune system (IS) is a complex system of cells, molecules and organs that represent an identification mechanism capable of perceiving and combating dysfunction from our own cells and the action of exogenous infectious microorganisms. The human immune system protects our bodies from infectious agents such as viruses, bacteria, fungi and other parasites. Any molecule that can be recognized by the adaptive immune system is known as antigen. The basic component of the immune system is the lymphocytes or the white blood cells.

Lymphocytes exist in two forms, B cells and T cells. These two types of cells are rather similar, but differ with relation to how they recognize antigens and by their functional roles, B cells are capable of recognizing antigens free in solution, while T cells require antigens to be presented by other accessory cells. Each of this has distinct chemical structures and produces many shaped antibodies form its surfaces to kill the antigens. Antibodies are molecules attached primarily to the surface of B cells whose aim is to recognize and bind to antigens.

The immune system possesses several properties such as self/nonself discrimination immunological memory, positive/negative selection, immunological network, clonal selection and learning which performs complex task.

Artificial Immune System (AIS) is a set of advanced techniques, which attempt to algorithmically imitate natural the behavior of immune system and utilize the natural immune system as a metaphor for solving computational problems. AIS is the beneficial mechanisms extracted or gleaned from the immune system that can be used to solve particular problems, e.g. misbehavior detection, identification, robotics, control, and optimization problems, etc.

An immune algorithm, which was proposed by Fukuda et al. [1], modeled mathematically the immune diversity, network theory and clonal selection as a multi-modal function optimization problem. The guide of diversity and multiple solution vectors instituted are kept as memory of the system.

### 2.2 Clonal Selection Algorithm (CSA)

The main goal of the immune system is to protect the human body from the attack of foreign (harmful) organisms. The immune system is capable of distinguishing between the normal components of our organism and the foreign material that can cause us harm. These foreign organisms are called antigens. The molecules called antibodies play the main role on the immune system response. The immune response is specific to a certain foreign organism (antigen). When an antigen is detected, those antibodies that best recognize an antigen will proliferate by cloning. This process is called clonal selection theory.

A Clonal Selection Algorithm (CSA), which considered the affinity maturation of the immune response, presented by De Castro & Von Zuben [2,3,4], in behalf of solving complicated problems, like multi-model optimization and learning.

The main characteristics of the clonal selection are expressed as following:

- (1) Generation of new random genetic changes, subsequently expressed as diverse antibody pattern by a form of accelerated somatic mutation;
- (2) Phenotypic restriction and retention of one pattern to one differentiated cell (clone);
- (3) Proliferation and differentiation on contact of cells with antigens.

## 3. CELLULAR NEURAL NETWORK

Cellular neural network is a brilliant alternative to conventional computers for image processing. In this paper, the modal of discrete-time cellular neural network (DTCNN) is considered. Chua et al. [5,6] have shown the dynamics of each cell described by the following equations:

$$x_{ij}(k+1) = \sum_{c(g,l) \in N_c(i,j)} A_{ij:gl} y_{gl}(k) + \sum_{c(g,l) \in N_c(i,j)} B_{ij:gl} u_{gl}(k) + I \quad (1)$$

$$\begin{aligned}
y_{ij}(k) &= f(x_{ij}(k)) \\
&= \begin{cases} 1 & \text{if } x_{ij}(k) > 0 \\ -1 & \text{if } x_{ij}(k) < 0 \end{cases} \quad (2) \\
i &= 1, \dots, \bar{M}; \quad j = 1, \dots, \bar{N}
\end{aligned}$$

where  $x_{ij}$ ,  $u_{ij}$  and  $y_{ij}$  denote the state, input, and output of a cell, respectively. The parameters  $A_{ij:gl}$  represent the feedback operators which described the interaction between the cell  $C(i,j)$  and the output  $y_{gl}$  of each cell  $C(g,l)$  that belongs to the neighborhood  $N_y(i,j)$ . Similarly,  $B_{ij:gl}$  represent the control operators and the parameter  $I$  represents bias item. These describe the interaction between the cell  $C(i,j)$  and the input  $u_{gl}$  of each cell  $C(g,l)$  within the neighborhood  $N_u(i,j)$ .

Then, eqs. (1) and (2) can be written in vector form by re-numbering the cells from 1 to  $n$ , with  $n = \bar{M} \times \bar{N}$ . Therefore, the model of DTCNN can be described as follows:

$$\begin{aligned}
\mathbf{x}(k+1) &= \mathbf{A} \mathbf{y}(k) + \mathbf{B} \mathbf{u}(k) + \mathbf{I} \quad (3) \\
\mathbf{y}(k) &= \mathbf{f}(\mathbf{x}(k))
\end{aligned}$$

where  $\mathbf{x}(k) = [x_1(k), \dots, x_n(k)]^T$  is the state vector,  $\mathbf{y}(k) = [y_1(k), \dots, y_n(k)]^T$  is the output vector,  $\mathbf{u} = [u_1, \dots, u_n]^T$  is a constant input vector and  $\mathbf{f} = [f(x_1), \dots, f(x_n)]^T$  is the output functions, whereas the matrices  $\mathbf{A} \in \mathfrak{R}^{n \times n}$  and  $\mathbf{B} \in \mathfrak{R}^{n \times n}$  are known constant feedback matrix and control matrix.

## 4. CSA -CNN TEMPLATES OPTIMIZATION

In the past years, the templates of CNN were obtained by complicated mathematical calculations, like Linear Matrix Inequality (LMI), etc. At present, heuristic algorithms are applied to solve these arduous problems. Genetic Algorithm (GA) is a popular intelligence tool, which is often employed for engineering optimization; but GA has two main disadvantages: the one is lack of the local search ability and the other is the premature convergence. In order to overcome these drawbacks, several

researchers have studied new optimization methods based on the immune system; Clonal Selection Algorithm is superior one of these methods.

In this section, we used Clonal Selection Algorithm (CSA) for the automatic templates optimization of DTCNN for solving image noise cancellation. Operations performed by an asymptotically stable CNN can be described by a triplet of signal arrays, e.g., for images: the input, initial state, and settled output of the network mapped into scale values of pixels. According to Section 3, the templates of DTCNN distinguished into three parameters: the feedback matrix  $A$ , the control matrix  $B$  and the bias term  $I$ . The problem of optimization is to find optimal templates triplet —  $A$ ,  $B$  and  $I$ . These were designed as following pattern structures:

$$A_{ij:gl} = \begin{bmatrix} a_2 & a_1 & a_2 \\ a_1 & a_0 & a_1 \\ a_2 & a_1 & a_2 \end{bmatrix}, \quad B_{ij:gl} = \begin{bmatrix} b_2 & b_1 & b_2 \\ b_1 & b_0 & b_1 \\ b_2 & b_1 & b_2 \end{bmatrix}, \quad I = i$$

where  $a_0, a_1, a_2$  are components of matrix  $A$ , the rest may be deduced by analogy for  $B$  and  $I$ . Therefore, the solutions of problem represented as string forms – antibodies, constructs of  $A$ ,  $B$  and  $I$ . The training sample consists of the pair input image/desired output shown in Figure. 1. The input image is contaminated by uniform random noise and the desired output image is clearly.

Next, our proposed method for designing the templates is introduced as the following steps:

**Step1)** Generating a set (P) of candidate solutions --- Antibodies, composed of the subset of memory cells (M) added to the remaining (Pr) population (P = M + Pr); and antibodies were indicated that constituents of the templates;

**Step2)** Determining (Selecting) the n best individuals of the population (Pn), based on an affinity measure, the affinity function is as following equation presented by Lopez et al. [7]:

$$error^c = (y^c(k_{end}) - y_d^c)^2$$

where  $y^c(k_{end})$  is the output of cell  $c$  which depends on the size of templates is reached at time interval  $k_{end}$  and  $y_d^c$  is the desired output value. The total error will be computed over all the cells of the network.

- Step3)** Reproducing (Clone) these  $n$  best individuals of the population, giving rise to a temporary population of clones (C). The clone size is an increasing function of the affinity with the antigen.
- Step4)** Submitting the population of clones to a hypermutation scheme, where the hypermutation is proportional to the affinity of the antibody with the antigen. A matured antibody population is generated (C\*);
- Step5)** Re-selecting the improved individuals from C\* to compose the memory set M. Some members of P can be replaced by other improved members of C\*;
- Step6)** Replacing  $d$  antibodies by novel ones (diversity introduction). The lower affinity cells have higher probabilities of being replaced.
- Step7)** It is circulating from step1. to step6. until the solutions have satisfied certain conditions in the memory cells.

## 5. SIMULATION RESULTS

In this section, using CNN with CSA approach for image noise cancellation for the 180\*180 and 240\*240 bipolar Computed Tomography (CT) images interfered by the salt and pepper noise is considered.

### Example1: Femur Computed Tomography (CT) image

Computed Tomography (CT) is familiar diagnosis in medical field, and it is often tainted by outside interference. Given the Femur image in Figure 2, it is coded such that +1 corresponds to black pixels and -1 to white ones. This image was the network input with noise for the discrete-time CNN, through computer simulating using GA and CSA-CNN, the results for the final output image obtained in Figure 3.

Using GA and our proposed CSA-CNN algorithm, initially, we defined the parameters of each algorithm as following Table 1.

### Example 2: Knee Computed Tomography (CT) image

Furthermore, in order to contrast with each status according to above parameters, the knee bipolar image depicted in Figure 4 interfered by the salt and pepper noise with different noise density, and simulated by GA and CSA-CNN. Therefore, the corresponding elements of approximated optimal templates  $A$ ,  $B$  and bias item  $I$  for respective conditions were received at Table 2. By combining the above templates, the clearness of the results for the final output images were obtained in Figure 5 and Figure 6. Comparing with these consequences, our proposed CSA-CNN algorithm could restrain from noise of the contaminated image effectively. CSA-CNN algorithm is serviceable tool for image noise cancellation.

## 6. CONCLUSION

In this paper, a new hybrid algorithm for image noise cancellation is described. Discrete-Time Cellular Neural Network (DTCNN) with Clonal Selection Algorithm (CSA) is presented. CSA inspired from the artificial immune system (AIS) is an effectual tool in behalf of solving complicated problems. The optimum corresponding templates of DTCNN has been developed through consecutive generation of CSA.

The noise of bipolar contaminated image is retrained effectively using this method. Computer simulations show the advantage of the proposed CSA-CNN algorithm for image noise cancellation. Moreover, we will research the technique for gray or color image noise cancellation, and enhance the quality of handled image by modified hybrid algorithm in future.

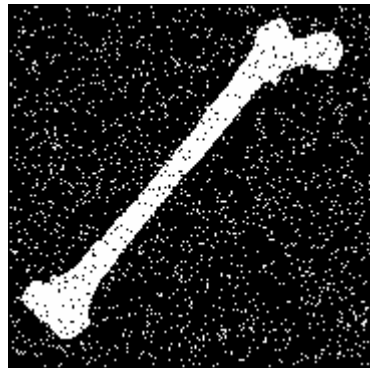
## 7. REFERENCES

- [1] Fukuda, T., Mori, K. & Tsukiama, M. *Parallel Search for Multi-Modal Function Optimization with Diversity and Learning of Immune Algorithm*. In (Ed.) D. Dasgupta, *Artificial Immune Systems and Their Applications*, Springer-Verlag, pp. 210-220, 1999.

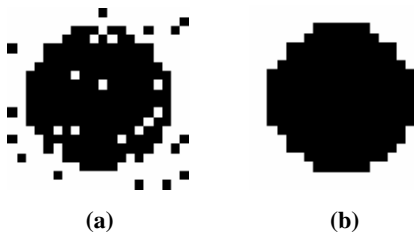
- [2] Leandro Nunes de Castro and Fernando Jose Von Zuben. *Artificial Immune System: Part I—Basic Theory and Application*. TR—DCA 01/99, 1999.
- [3] Leandro Nunes de Castro and Fernando Jose Von Zuben. *Artificial Immune System: Part II—A Survey of Application*. DCA-RT 02/00, 2000.
- [4] L. N. de Castro., & F. J. Von Zuben, “Learnig and Optimization Using the Clonal Selection Principle”, *IEEE Transactions on Evolutionary Computation*, Vol. 6, NO.3, pp.239-251, 2002.
- [5] Chua, L.O. and Yang, L., *Cellular neural networks: Theory*. IEEE Trans. Circuits Syst., vol.35, pp.1257-1272, Oct.1988.
- [6] Chua, L.O. and Yang, L., *Cellular neural networks: Applications*. IEEE Trans. Circuits Syst., vol.35, pp.1273-1290, Oct.1988.
- [7] Lopez P., Vilarino D.L. and Cabello D. *Design of Multilayer Discrete Time Cellular Neural Networks for Image Processing Tasks Based on Genetic Algorithms*. IEEE International Symposium on Circuits a System, pp. 133-136, 2000.



**Figure 2: The original Femur image**



**(a) The contaminated image with 12% noise**



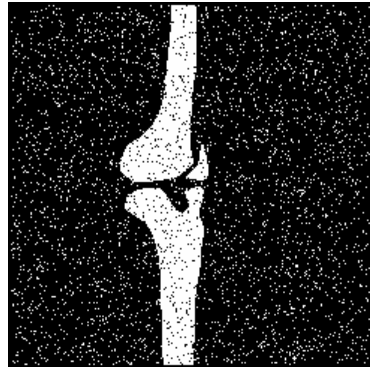
**Figure 1: The training samples with 10% noise**  
**(c) Input image (b) Desired output**



**(b) The result using GA-CNN**



(c) The result using CSA-CNN Algorithm



(a) The contaminated image with 12% noise

Figure 3: Contrasting simulations of the noise cancellation on Femur image with 12% noise



Figure 4: The original Knee image



(b) The result using GA-CNN

Figure 5: Contrasting simulations of the noise cancellation on knee image with 12% noise

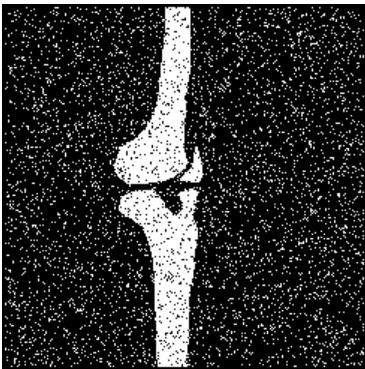


(c) The result using CSA-CNN Algorithm



(b) The result using GA-CNN Algorithm

Figure 5: Contrasting simulations of the noise cancellation on knee image with 12% noise



(a) The contaminated image with 18% noise



(c) The result using CSA-CNN Algorithm

Figure 6: Contrasting simulations of the noise cancellation on knee image with 18% noise

**Table 1. Established parameters in CSA & GA**

	CSA	GA
<b>Number of candidates generated</b>	10	20
<b>Number of generations</b>	300	300
<b>Clonal multiple</b>	1 time	×
<b>Crossover probability</b>	×	Exchanging crossover : 0.8
<b>Mutation probability</b>	Hypermutation : 0.01	One-point mutation : 0.01
<b>Percentage of random new cells each generation</b>	20%	×

**Table 2. The elements of the template  $A$ ,  $B$  and  $I$  for respective conditions using CSA-CNN**

Templates	feedback matrix $A$			control matrix $B$			bias $I$
	$a_0$	$a_1$	$a_2$	$b_0$	$b_1$	$b_2$	$i$
Noise = 12%	-6.3999	9.5426	-0.5535	8.5117	3.9921	6.0842	-0.5045
Noise = 18%	-3.7749	2.9596	1.0894	4.2053	1.0081	0.9220	0