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# Multi-source image fusion algorithm based on cellular neural networks with genetic algorithm

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ABSTRACT

Multi-source image fusion is a technology that can make a single image to include more information by fusing two or more source images which are obtained by different sensors from the same scene. How to keep the detail and edge information of the original images is the key to multi-source image fusion. To address this problem, we propose a new approach which base on cellular neural networks and genetic algorithms. In this approach, the source images are inputted to the work which has determined the parameters using genetic algorithms and then we can get the fused image. Compared with other fusion algorithms, the proposed approach could fuse multi-source images adaptively and maintain the edges and details information effectively.



## 1. Introduction

With the rapid development of image processing technology, different kinds of imaging sensors are able to offer a variety of information that is extracted from the same scene. Overall analysis of these information would be beneficial to improving the utilization rate of image information. Multi-source image fusion [1] provides an effective mean to combine all information from same scene but different sensors and produce a single fused image containing an enhanced description of the scene. The fused image is more useful for visional perception and computer operators. There are various fusion algorithms to achieve this goal, some classical algorithms such as the algorithm based on principal component analysis (PCA) [2], Laplacian pyramid (LP) [3], discrete wavelet transform (DWT) [4], shearlet transform (ST) [5], pulse coupled neural network (PCNN) [6,7] and so on. More recently, some more sophisticated algorithms has been successfully applied to image fusion and achieved excellent performance, e.g. algorithm based on random walks [8], non-negative matrix factorization and difference images [9], nonsubsampled contourlet transform [10], etc. All those methods have achieved good results in application, but most of their fusion results are lack of edges and details information. Thus, how to improve edges and detail information has become a hot topic.

Cellular neural networks (CNN) [11,12], which was first proposed by Chua and Yang, is a novelty dynamical neural network combine the structure of cellular automata and Hopfield neural network. Compared with traditional neural network, the CNN involves a more attractive parallel computation structure so that the calculation would not increase more when the amount of data of mathematical model grows exponentially. Due to its efficient computing, CNN is generally employed in many aspects especially in image processing applications, such as image feature extraction, image edge detection, image encoding, image hole filling, character recognition, robot vision and so on. When confirmed the template parameter, traditional CNN always rely on past experience value which is not available for a specific template issues in most cases. We have to repeated tests on the experience of the template in order to get targeted at specific problem templates. Through the establishment of the objective function associated with the template and the optimization algorithm can effectively solve the optimization problem.

As a nonlinear optimization, genetic algorithm (GA) has been widely used in solving nonlinear objective function for its accuracy and efficiency. Genetic algorithm is an adaptive probabilistic search algorithm for global optimization which simulates biological genetic and evolution in Darwin's theory [13]. When we solve a problem, genetic algorithm map the solution space to the creaturely genetic space and then we achieve global optimization through biological genetic and evolution. Therefore, genetic algorithm can be applied to solve the optimal solution to the objective function related to the template parameters, adaptively obtain template parameters to specific issues.

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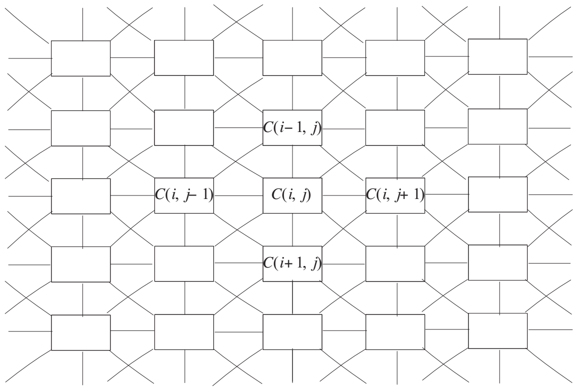


**Fig. 1.** A two-dimensional model of CNN.

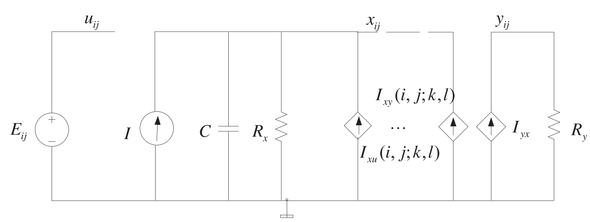


**Fig. 2.** An example of a cell circuit.

Based on the above analysis, we will present a novel multi-source image fusion algorithm based on cellular neural networks with genetic algorithm (GACNN) in this paper. Experiments show that proposed approach could fuse multifocus images adaptively and maintain the edges and details information effectively.

## 2. Basic theory

### 2.1. Model and architecture of CNN

The model and structure of CNN [14,15] is similar to that found in cellular automata, belonging to unsupervised neural network. An example of a two-dimensional model of CNN is shown in Fig. 1, the basic circuit unit of CNN is called a cell (the box shown in Fig. 1), any cell in CNN is connected only to its neighbor cells. Consider an $M \times N$ CNN, having $M \times N$ cells arranged in $M$ rows and $N$ columns. The cell on the $i$th row and the $j$th column is denoted by C($i$,$j$). The $r$-neighborhood of a cell C($i$, $j$) in a CNN is defined by

$$N_r(i,j) = \left\{ C(k,l) \,|\, \max\{|k-i|, |l-j|\} \le r, \quad 1 \le k \le M; \quad 1 \le l \le N \right\} \tag{1}$$

where $N_r(i, j)$ is $r$-neighborhood with radius $r$. There are $(2r+1)^2$ cells in a $r$-neighborhood, every cell in neighborhood influence the state and output of center cell C($i$, $j$) through the unique weights.

The model of CNN achieved analog circuit in hardware as soon as it was proposed, each cell equals to a circuit, a typical example of a cell circuit of CNN is shown in Fig. 2.

Applying KCL and KVL, the circuit equations of a cell are easily derived from the cell circuit as follows:

*State equation*:

$$C\frac{dx_{ij}(t)}{dt} = -\frac{1}{R_x}x_{ij}(t) + \sum_{C(k,l)\in N_r(i,j)} A(i,j;k,l)\,y_{kl}(t) + \sum_{C(k,l)\in N_r(i,j)} B(i,j;k,l)\,u_{kl} + I \tag{2}$$

**Algorithm 1**
Genetic algorithm.

**Input:** *N, n, L,Range*
**Output:** $X_{N-1}$
1: Produce the initial population: a $n \times L$ matrix $X_0$, $-\text{Range} < X_0[k][j] < \text{Range}$.
2: $i = 0$.
3: **while** $i < N$ **do**
4: Calculate the fitness $fit_i = Fitness(X_i)$.
5: Reproduction operation $X_{i+1} = Reproduction(X_i, fit_i)$.
6: Crossover operation $X_{i+1} = Crossover(X_{i+1})$.
7: Mutation operation $X_{i+1} = Mutation(X_{i+1})$.
8: **end while**

*Output equation*:

$$y_{ij}(t) = \frac{1}{2}\left(\left|x_{ij}(t)+1\right| - \left|x_{ij}(t)-1\right|\right) = \begin{cases} 1 & x_{ij}(t) \ge 1 \\ x_{ij}(t) & x_{ij}(t) < 1 \\ -1 & x_{ij}(t) \le -1 \end{cases} \tag{3}$$

where the node voltages $x_{ij}$ and $y_{ij}$ denote the state and output of C($i$, $j$); the node voltages $u_{kl}$ and $y_{kl}$ denote the input and output of neighborhood of C($i$, $j$); $C$ is a linear capacitor, $I$ is an independent current source; $R_x$ is a linear resistor; $A(i, j; k, l)$ is called feedback operator and $B(i, j; k, l)$ is called control operator.

Each cell of same CNN has an input, an output, and a dynamic system constituted by the state in accordance with the rules of dynamics evolution. $A$, $B$ and $I$ shown at Eq. (2) are called template parameters of CNN, whose value determine the instantaneous nature, dynamic characteristics and stability of the network.

### 2.2. Template set of CNN

The network parameters for spatially invariant CNN are given in a template set, consisting of the feedback matrix $A$, control matrix $B$ and the overall network bias $I$. Those template parameters determine the function of network to achieve [16]. It's key to answer how to set the template parameters $A$, $B$ and $I$ to CNN applications.

#### 2.2.1. Template set methods

According to the available literature, the template set method is mainly divided into three categories [17]:

(1) *Empirical method*: The template of network is determined rely on past experience or analysis of a large number of experiments.
(2) *Analytical method*: This method determines the template parameters by analyzing the characteristics of the input and output of network and solving constraints with the state under local rules.
(3) *Learning method*: The template is determined by optimizing the objective function related with template parameters in this method. This method can be implemented by either local learning or global learning. Local learning means the algorithm combine prior knowledge with intermediate results while global learning is a stochastic optimization algorithm, such as simulated annealing (SA), genetic algorithm, probability relaxation and so on.

In this paper, we set template of CNN with genetic algorithm.

#### 2.2.2. Genetic algorithm

The core process of genetic algorithm to solve problem is shown in Algorithm 1 [18], where $n$ is individuals of population, $L$ is the number of wanted parameters, $N$ is iterations, *Range* is range of individual genes. At the first of GA, we need to determine the size of the population according to the number of parameters and accuracy requirements, code the parameters in a binary