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Research Article

Improved Clonal Selection Algorithm (ICLONALG)

Nidhi Rai†* and Archana Singh†

†CSE Dept., Sam Higginbottom institute of Agriculture, Technology and Sciences, Allahabad, U.P., India

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Abstract

Natural immune system uses clonal selection algorithm to define the basic features of an immune response to an antigenic stimulus. It establishes the idea that only those cells that recognize the antigens are selected to proliferate. The selected cells are subjected to an affinity maturation process, which improves their affinity to the selective antigen. In this paper, we propose a computational implementation of the clonal selection principle that explicitly takes into account the affinity maturation of the immune response. The general algorithm, named CLONALG, is primarily derived to solve optimization problems, emphasizing multimodal and combinatorial optimization. In this paper there is some modification in the selection and reproduction process to maximize the optimized result.

Keywords: *Artificial immune system, clonal selection theory, clonal selection algorithm, CLONALG, optimization.*

1. Introduction

Artificial Immune System (AIS), a new branch in computational intelligence inspired by the immunological principles. In the last decades, the study of artificial immune system has been rapid increasing interest to the large number of its possible applications available in the field of science and engineering. The AIS aim at using ideas from immunology in order to develop systems capable of performing different tasks in various area of research.

Based on the learning and evolutionary principle in the adaptive immune response, De Castro developed CLONal selection ALGorithm (CLONALG), which uses individual mutation to perform greedy search and uses random search to explore the whole solution space. CLONALG emphasizes proportion selection and clone, which can hold the optimal solutions by set a memory cel. The essence of the clonal operator is producing a variation population around the parents according to their affinity, and then the searching area is enlarged. In brief, the principle of theory is that the antigen (the foreign molecule that the immune system is defending against) selects those lymphocytes (B-Cells or white blood cells that detect and stop antigens) with receptors capable of reacting with a part of antigen. Selection results in the rapid proliferation of the selected cell to combat the invasion (clonal expansion and production of antibodies). During this cell duplication process coping errors occur (somatic hypermutation) which may result in an improved affinity of the progeny cells receptors for triggering antigens. In this paper, we improved the selection scheme and production process, which gives better result. It gives maximized optimized result.

We do not need to make exactly the same phenomenon, but to show that some basic immune principles can helps as not only to better understand the immune system itself, but also to solve complex engineering task.

Rest of the paper describes our work to modify and analyze clonal selection algorithm and the results we have found during our research. In Section II we will discuss about artificial immune system. Section III we will be listing previous researches related to CLONALG. In section IV we will discuss about clonal selection theory and algorithm. In Section V will be describing our model. In section VI, discussion about experimental results of our model and finally Section VII will conclude the paper providing emphasis on future directions

2. Artificial Immune System

Artificial Immune System(AIS) are computational systems inspired by the principles and processes of the vertebrate immune system .The field of Artificial immune system (AIS) is mainly concerned with the structure and functions of the immune system to computational system, and investigate the application of this system towards solving computational problems from mathematics, engineering, and information technology. Basically an immune system has some properties i.e. detection, diversity, learning, tolerance, uniqueness and recognition of foreigners

*Corresponding author **Nidhi Rai** is a PG Scholar and **Archana Singh** is working as Assistant Professor

1) Detection : Identification takes place in an immune system when the infective fragment and sensory receptor on lymph cell surface is bonded chemically
2) Diversity: identification in an immune system is related to non-self bodies of the organism, thus the immune system has number of sensory receptor, out of which some of lymph cell will react with the foreign organism.
3) Learning: an immune system has the capability of detecting an eliminating the foreign organism as soon as possible from the human body.
4) Tolerance: the particles which are mark themselves as self bodies are contain in the chromosomal section.
5) Uniqueness: each individual process its own immune system, with its particular vulnerabilities and capabilities.
6) Recognition: of foreigners: the (harmful) molecules that are not native to the body are recognized and eliminated by the immune system.

3. Clonal Selection Mechanism

3.1 Clonal Selection Theory

Artificial immune system uses the Clonal selection theory which is a theory postulated by Burnet, Jerne, Talmadge, used to describe the functioning of acquired immunity, specifically a theory to define the basic features of an immune response to an antigenic stimulus. Clonal selection is a form of natural selection. Main idea of clonal selection organism that only those immune cells that recognize the antigens are selected to proliferate, thus being selected against those that do not.

The main features of clonal selection theory are:

1) The newly cells are replica of their parents (clone) which are submitted to a chromosomal mutation chemical mechanism.
2) Evacuation of newly distinguished lymph cell carrying self-reactive sensory receptor.
3) Development and differentiation on contact of mature cells with antigens.

When an antibody is strongly matches to an antigen, some sub population of its bone marrow derived cells (B lymphocytes) respond by producing anti bodies (Ab). Each cells secrets only one kind of antibody, which is relatively specific for the antigen. Antibody recognizes the antigen with certain affinity (degree of match), the B lymphocytes will be stimulated to proliferate (divide) and eventually mature into terminal (non-dividing) antibody secreting cells, called plasma cell. Proliferation of the B lymphocytes is a mitotic process whereby the cells divide themselves, creating a set of clones identical to the parent cell. The proliferation rate is directly proportional to the affinity level, i.e. the higher affinity levels of B lymphocyte, the more of them will be readily selected for cloning and cloned in large numbers. In addition to proliferating and maturing into plasma cells, the immune cells can differentiate into long-lived memory cell. Memory cells circulate through the blood, lymph and tissues and when exposed too second antigenic stimulus they commence into large immune cells (lymphocyte) capable of producing high affinity antibody specific antigen that once stimulated the primary response.

The main role of immune system is to protect our body from the foreign being. The immune system has capability to distinguish between the own constituents of our being and foreign being which can damage us. This foreign being is known as antigen. The main role played by the immune system is the antibodies. When an antigen noticed in our body then those antibodies which can distinguish the antigen will multiply by cloning. This procedure is termed as Clonal Selection Theory. The mechanism of clonal selection process is shown in fig 1.

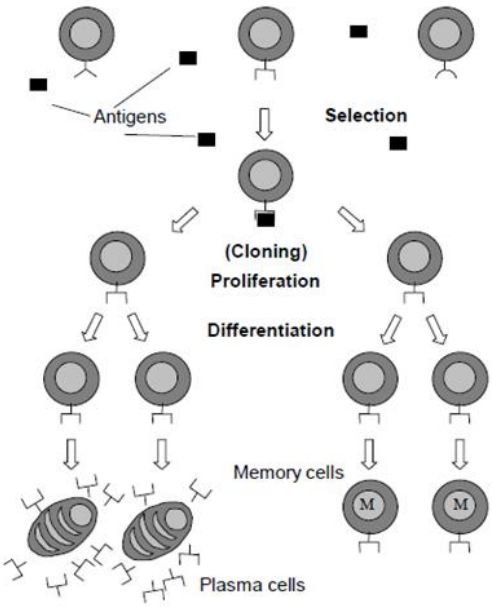

Figure 1 Clonal Selection Principle

3.2 Clonal Selection Algorithm

Definition 1.0: A clonal selection algorithm is primarily focused on mimicking the clonal selection principle which is composed of the mechanism; clonal selection, clonal expansion, and affinity maturation via somatic hypermutation.

The clonal selection algorithm, originally called CSA, and now renamed to CLONALG is developed on the concept of clonal selection theory of the immune system. In all run of algorithm, the stopping criterion is a predefined maximum number of generations. The goal of algorithm is to develop a memory pool of antibodies that represents a solution to an engineering problem. Where, an antibody represents an element of a solution or a single solution to a problem, and an antigens represents an element of the problem space.

The CLONALG proposed by De Castro can be described as follows:

1) Randomly choose an antigen and present it to all antibodies in the repertoire, and calculate the affinity of each antibody;
2) Select the n highest affinity antibodies to compose a new set;
3) Clone the n selected antibodies independently and proportionally to their antigenic affinities, generate a repertoire set of clones;
4) Submit the repertoire set to an affinity maturation process, maturation is inversely proportional to the antigenic affinity. A matured antibody population generated;
5) Re-select the highest affinity one from this set of mature clones to be a candidate to enter the set of memory antibodies set;
6) Finally, replace the d lowest affinity antibodies by some random ones.

De Castro and Timmis also suggest the two key features of clonal selection algorithms are the mutation and cloning properties. They also suggest that selection plays important and critical role in both the strong selective pressure during affinity maturation, and in the selection of long lived memory cells.

Principles 1.0: The proliferation rate of each immune cell is proportional to its affinity with the selective antigen (higher the relative affinity, the more progeny).
Principles 1.1: The mutation suffered by each immune cell during reproduction is inversely proportional to affinity of the cell receptor with the antigen (higher the relative affinity, the lower the mutation).

Thus a general clonal selection algorithm possesses the following mechanism:

Table 1 CLONALG parameters

1. Randomly initialize pool of antibodies
2. Expose the pool to antigen
   a. Clonal Selection
   b. Clonal Expansion
   c. Clonal Hypermutation

CLONALG Description and Pseudocode

Table 2 CLONALG pseudo code listing

Parameter	Description
P	Antibodie's repertoire
N	The fixed antibody repertoire size.
n	The number of antibodies to select for cloning.
L	Bit string length for each antibody
Nc	Number of clone created by each selected antibody.
D	Random number of antibodies to insert at the end of each generation. Best antibodies replace the d lowest affinity antibodies in the repertoire.
Stop condition	Typically a specified number of generation or function evaluations.
Affinity	Solution evolution.
Clone	Duplication of selected bit string.
Hypermutate	Modification of a bit string where the flipping of bit(it may be single bit or multiple bit) is governed by an affinity proportionate probability distribution.

Table 3 General algorithmic model of the clonal selection principle

```
P  <- rand(N,L)
While Not Stopcondition Do
  ForEach p of P Do                  // presentation
    affinity(p)
  EndFor
  P1 <- select(P, n)                 // clonal selection
  ForEach p1 of P1 Do                // clonal expansion
   C <- clone(p1)
  EndFor
  ForEach c of C Do                  // affinity maturation
   hypermutation(c)
  EndFor
  ForEach c of C Do                  // presentation
    affinity(c)
  Endfor
  P <- insert (C, n)                 // greedy selection
  Pr <-rand (d, L)
  P <-replace (P. d. Pr)             // random replacement
EndWhile
```

4. Related Work

A short survey gives number of variants to the CLONALG algorithm, focusing on those features that may prove interesting or useful. Some of variants of CLONALG are presented here. White and Garret investigated the pattern recognition version of CLONALG and generalized the approach for the task of binary pattern classification renaming it Clonal Classification (CLONCLAS). To address concerns of algorithm efficiency, parameterization, and representation selection for continuous function optimization. Garrett proposes an updated version of CLONALG called Adaptive Clonal Selection (ACS).

Cutello, Narzisi, *et al.* proposed two modified versions called CLONALG1 and CLONALG2 with varying elitist strategies which were raced against the opt-IA algorithm. Dilettoso and Selerno treated CLONALG as a niching technique and raced it against

traditional EC niching approaches. Wang proposed a CSA based on CLONALG with a static clone sized applied to power filter design observing niching like behaviors. Cruz-Cortes, Trejo-Perez, *et al.* investigated CLONALG with binary and gray encoding schemes as well as a real-valued encoding scheme with a mutation scheme based on Gaussian and Cauchy random numbers. Another multi-objective application of CLONALG was proposed by Stevens, Das, et al.

Dong, Shi, *et al.* proposed the Immune Memory Clonal Selection Algorithm (IMCSA) applied to designing stack filters for noise suppression. This extension to CLONALG used dual-binary strings in each antibody, self- tuning mutation parameter, recombination parameters and inserted memory cells that were developed using alternative algorithms.

CLONALG has also been hybridized with many other optimization procedures, some examples include the following: Zuo and Fan proposed the Chaotic Search Immune Algorithm (CSIA) that integrated elements of the CLONLG algorithm and was applied to the tuning Radial-Basis Functions (RBF) in real time controller design.

5. Proposed Work

After discussing the clonal selection algorithm and reproduction process, the improvement of CSA is straightforward. The objective of this algorithm is to increase the affinity value of selected cells and maximized the optimized result. In this algorithm there is some modification in the reproduction procedure and selection process.

5.1 Algorithm

The algorithm overview is described as follows:

1) Randomly choose an antigen and place it to all antibodies in the repertoire, and calculate the affinity of each antibody;
2) Select the highest affinity antibodies to compose a new set
3) Clone (reproduction) the selected antibody independently and proportionally to their antigenic affinities, generate a temporary population of clone;
4) Submit the population of clones to an affinity maturation(hypermutation) process, maturation is inversely proportional to the antigenic affinity. A matured antibody population generated;
5) Now re-selection, the highest affinity from this set of mature clones;
6) Clone the selected antibodies equal to the population size and proportionally to their antigenic affinities, generate a repertoire set of clone;
7) Submit the repertoire set to an affinity maturation process;
8) For i=2 to 8 (for even times) re-select(i) the highest affinity from this set of mature clones and clone the selected antibodies equal to the population size, submit the repertoire set to an affinity maturation process;
9) New population generated
10) Merge the random population generated in step(1) and the population generated in step(13) and replace lower affinity cells; and repeat the step (2).

5.2 Flow Chart

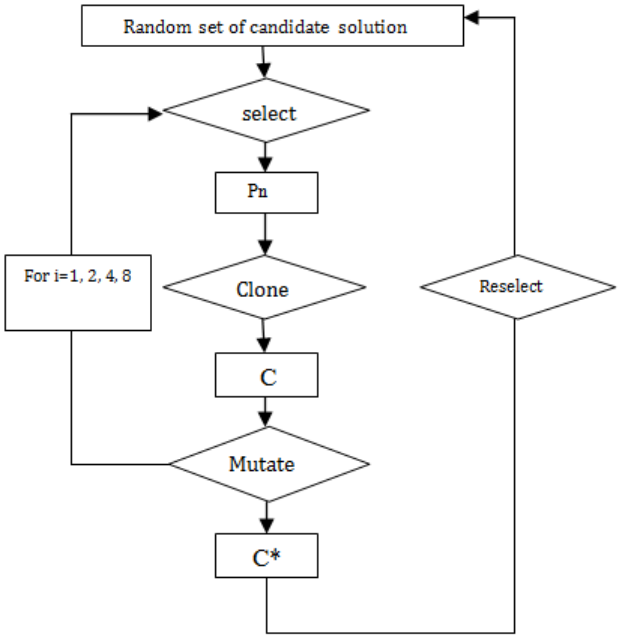

Figure 2 Flow Chart of proposed algorithm

By comparing the proposed algorithm with CLONAG, we can notice that proposed algorithm reach a diverse set of local optima solutions as compare to CLONAG. Essentially, their coding schemes and evaluation functions are not different, but their evolutionary production and selection schemes are different.

6. Results

6.1 Experimental Result

A deep analysis of the proposed algorithm has been done on the basis of coding result. It is also maximization problem as compare to CLONALG. Table shows iteration vise function evaluation and give average value and maximal value of function.
Parameters are as follows:
Number of generations: 25
Population size: 50
Hypermutation probability (pm): 0.010
function used to maximized: function f(x, y) = x.sin (2.pi.x)-y.sin (2.pi.y+pi) +1,

Table 4 Function evaluation at each iteration

Iterations	Pm	Value of x	Value of y	Average value	f(x,y)
1	0.0100	-0.71	-0.54	0.80	1.602
2	0.0100	-0.71	-0.60	1.02	1.936
3	0.0100	-0.63	-0.70	1.11	2.039
4	0.0100	-0.63	-0.70	1.16	2.039

5	0.0100	-0.63	-0.70	1.23	2.039
6	0.0100	-0.63	-0.70	1.23	2.039
7	0.0100	-0.63	-0.70	1.33	2.039
8	0.0100	-0.63	-0.70	1.51	2.039
9	0.0100	-0.69	-0.60	1.56	2.049
10	0.0100	-0.69	-0.60	1.57	2.049
11	0.0100	-0.69	-0.60	1.51	2.049
12	0.0100	-0.69	-0.70	1.61	2.064
13	0.0100	-0.64	0.65	1.66	2.240
14	0.0100	-0.64	0.65	1.70	2.240
15	0.0100	-0.64	0.65	1.74	2.241
16	0.0100	-0.64	0.65	1.72	2.241
17	0.0100	-0.64	0.65	1.76	2.241
18	0.0100	-0.63	-0.62	1.79	2.250
19	0.0100	-0.63	-0.62	1.82	2.250
20	0.0100	-0.63	-0.62	1.84	2.250
21	0.0100	-0.63	-0.62	1.78	2.250
22	0.0100	-0.63	-0.62	1.85	2.250
23	0.0100	-0.63	-0.62	1.93	2.250
24	0.0800	-0.63	-0.62	1.89	2.250
25	0.0800	-0.63	-0.62	1.95	2.250

Maximum found [x, y, f(x,y)]: [-0.63, -0.62, 2.25]

6.2 Multi-Modal Optimization

The individuals are reproduces by clonal selection algorithm that has higher affinity and selects their improved maturated progenies. This scheme suggest that the algorithm perform the greedy search, where single members will be locally optimized (exploitation of the surrounding space), and the newer yield a broader exploration of the search space. Because of this characteristic of CSA, it is suitable for solving modal optimization task, and as illustration, consider the case of maximizing the function f(x, y) = x.sin (2.pi.x)-y.sin (2.pi.y+pi) +1, shown in figure 3. This function is composed of many local optima and single global optimum.

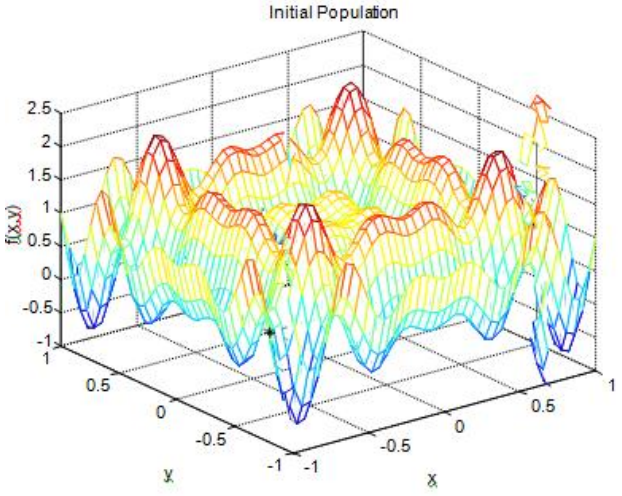

Figure 3 Function to be maximized by the CSA

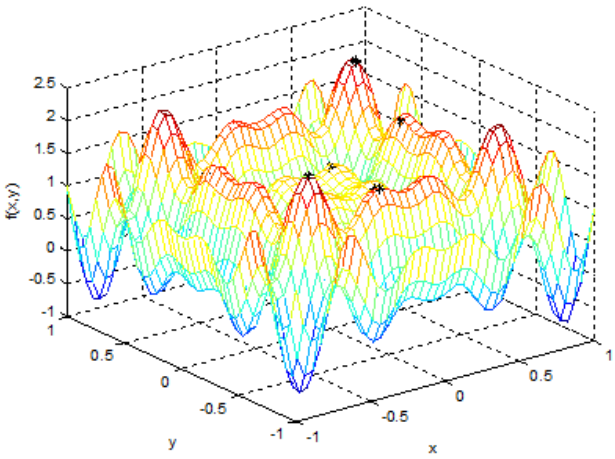

Figure 4 Optimized population after cell generation

The affinity measure related to the evaluation of the function f(x,y) after decoding the value of x and y, figure 4 presents the optimized population after defined generation. The solutions cover most of the peaks, including the global optimum.

Table 5 Comparison Table

Avg,f(x,y) / Algo	Avg	f(x,y)
CLONALG	1.92	2.02
ICLONALG	1.95	2.25

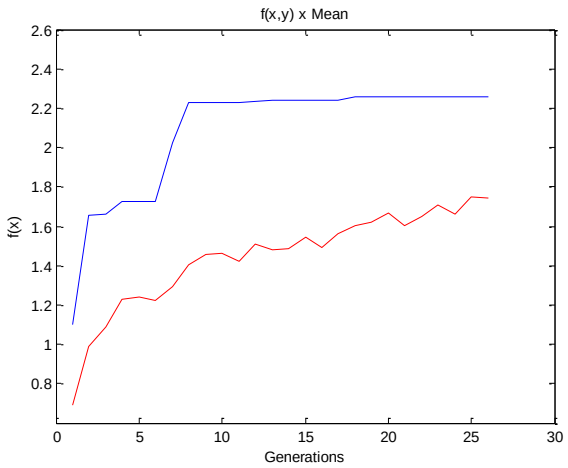

Figure 5 Best and average fitness function determined by CSA (simple evaluation function)

Conclusions

In this paper, we proposed a general-purpose algorithm inspired in clonal selection principle. There is modification in the reproduction process which improves the performance and results also. The algorithm is capable to solve complex problems, like multi-modal optimization. The algorithm introduced constitutes a version of the clonal selection principle.

By comparing the proposed algorithm with CLONAG, we can notice that proposed algorithm reach a diverse set of local optima solutions as compare to CLONAG. Essentially, their coding schemes and evaluation functions are not different, but their evolutionary production and selection processes are different. We do not advocate this algorithm performs better than CLONALG, but it gives better result in maximization problems. Instead, we demonstrate that the proposed algorithm is derived from the CLONALG, which performs learning and multimodal search, and presents a fine tractability in terms of computational cost.

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