

Artificial Immune System Approach for Multi Objective Optimization

Ms GARIMA SINGH

M.tech Software Engineering, Student, Babu Banarasi Das University, Lucknow, India.
garima_singh2108@yahoo.com

Dr. SUNITA BANSAL

I.T Department, Babu Banarasi Das University, Lucknow, India.
bansalbbd@gmail.com

Abstract

This paper presents a modified Artificial Immune System based approach to solve multi objective optimization problems. The main objective of the solution of multi objective optimization problem is to help a human decision maker in taking his/her decision for finding the most preferred solution as the final result. This artificial immune system algorithm makes use of mechanism inspired by vertebrate immune system and clonal selection principle. In the present model crossover mechanism is integrated into traditional artificial immune system algorithm based on clonal selection theory. The Algorithm is proposed with real parameters value not binary coded parameters. Only non dominated individual and feasible best antibodies will add to the memory set. This algorithm will be used to solve various real life engineering multi-objective optimization problems. The attraction for choosing the artificial immune system to develop algorithm was that if an adaptive pool of antibodies can produce 'intelligent' behavior, we can use this power of computation to tackle the problem of multi objective optimization.

Keywords: Artificial Immune System, Clonal Selection Theory, Multi Objective Optimization, Pareto Optimal.

INTRODUCTION

Artificial immune system is a new area of research, it takes ideas from human immune system. Artificial immune system approach can be applied to solve complex scientific and engineering multi objective optimization problems. Artificial immune systems are parallel and distributed systems in terms of information processing. In classification and recognition process artificial immune system is capable of retrieving information. The Artificial Immune Systems is a system developed on the basis of the current understanding of the immune system. It consist of various properties such as diversity, error tolerance, distributed computation, self-monitoring and dynamic learning. Artificial Immune System is inspired by immune functions, immunology and observed principles and models, which can be applied to complex problem domains. Artificial immune system is capable of learning and it can make use of memory when ever required. A number of properties and features of artificial immune system have attracted developers and researchers to try to implement it in the engineering field.

The Multi-objective Immune System Algorithm can be considered as the first real proposal of MOAIS in literature. Coello Coello and N. Cruz Corte's, Proposes a MOIS algorithm, in this MOIS authors follow the clonal selection principle very closely. Limitation was that the memory set is updated by the no dominated feasible individuals and limited in size. hen the algorithm performances have been improved in a successive version. [2]. Leandro N. de Castro and Fernando J. Von Zuben, proposes a paper on the topic learning and Optimization Using artificial immune system. Their paper proposes a computational implementation of the clonal selection principle. Nervous and Genetic system have already been applied to many engineering fields by modeling as neural networks and genetic algorithms and they have been widely used in various fields. [12] Gong, Shang and Jiao proposed the concept of differential degree of immune system for calculating the affinity measure of antibody and antigen interaction. Indexing is done to reduce the number of antibodies in the memory cell before the clonal selection process. This is basically a pattern recognizing problem solving algorithm. Another approach proposed by L. Nunes de Castro - The algorithm does not use explicitly a scalar index to define the avidity of a solution but some rules are defined for choosing the set of antibodies to be cloned. Ranking scheme of the system is based on the following criteria: 1) First feasible and no dominated individuals, then, 2) Infeasible no dominated individuals, finally, 3) Infeasible and dominated. Limitation was this was a time taking process. [10]

A novel artificial immune system algorithm is proposed in this paper. The idea of algorithm is adopted and derived from biological immune system. The attraction for choosing the artificial immune system to develop algorithm was that if an adaptive pool of antibodies can produce 'intelligent' behavior, we can use this power of computation to tackle the problem of multi objective optimization. This artificial immune system algorithm makes use of mechanism inspired by vertebrate immune system and clonal selection principle. In the present model crossover mechanism is integrated into traditional artificial immune system algorithm based on clonal selection theory. The Algorithm is proposed with real parameters value not binary coded parameters. Only non dominated

individual and feasible best antibodies will add to the memory set. All individuals in the memory set will be cloned. The proposed algorithm is then used to solve a real life engineering multi objective optimization problem of fuel cell component design system. Not just one solution but, a preferred set of solutions near the reference point are found. We can maximize or/and minimize complex multi objective optimization problems and get the Pareto front where both the objectives best meet and none of the objective dominate other objective. The algorithm will guide the search towards global Pareto optimal front and maintain the solution diversity in the Pareto front.

Clone selection technique is used with artificial immune system. The clonal selection theory basically deals with immune response to an antigenic stimulus. The basic idea is that only those antibodies that can recognize the antigen are selected and further expanded and go for proliferate process against those that do not. The field of Artificial Immune System is rapidly progressing as a branch of computational artificial Intelligence. Immune System has many interesting features that attract researchers to apply it to many engineering fields. Strong mimicking, imitating, robustness, self-adaptability, memory, tolerance, recognition and so on. Researchers are taking interest in developing various computational models based on various immunological principles.

In multi objective optimization processes two or more conflicting objectives optimized simultaneously subject to certain constraints. In the presence of trade off between more than one objectives, optimal decisions needed to be taken. The main objective of the solution of multi objective optimization problem is to help a human decision maker in taking his/her decision for finding the most preferred solution as the final result. Set of most preferred solutions is represented by Pareto front of two or more conflicting objectives. It gives an idea about the points where all the objectives best optimized (maximized or minimized)

ARTIFICIAL IMMUNE SYSTEM

Artificial immune system is a new research field as artificial intelligent system. The main function of the Immune system is to protect the body from foreign and harmful entities. The biological immune system is characterized by its strong robustness and self-adaptability even when encountering amounts of disturbances and uncertain conditions. Cell level, immunology concerns mainly in T lymphocytes and B-lymphocytes, focusing primarily on their interactions. Modern immunology shows that there are different cells with various functions in immune system, for instance, antibodies attach on the B lymphocyte surface. Each antibody has idiotope which acts as antigen, paratope which recognizes other antibodies and antigens, and epitope which can be recognized by other antibodies and antigens. Artificial immune system imitates the natural immune system that has sophisticated methodologies and capabilities to build computational algorithms that solves engineering problems efficiently. It is interesting to observe that the process of recognition, identification and post processing involve several mechanisms such as the pattern recognition, learning, communication, adaptation, self organization, memory and distributed control by which the body attains immunity. The human immune system has motivated scientists and engineers for finding powerful information processing algorithms that has solved complex engineering tasks. They are useful in constructing novel computer algorithms to solve complex engineering problems.

Clonal Selection Theory

Clonal selection is a technique used with artificial immune system. The immune system is an organ used to protect an organism from foreign material that is potentially harmful to the organism (pathogens), such as bacteria, viruses, pollen grains, incompatible blood cells and man made molecules. In artificial immune system, antigen usually means the problem and its constraints. Antibodies represent candidates of the problem. The antibody population is split into the population of the Non dominated anti- bodies and that of the Dominated antibodies. The Non-dominated antibodies are allowed to survive and to clone. Clonal selection works on idea that cells that will recognize the antigens will go for proliferation process and rest will not. Most triggered cells are selected as memory cells for further pathogen attacks and rest mature into plasma cells.

Algorithms based on clonal selection principle are motivated by the clonal selection theory of biological immune system that explains about B and T lymphocytes improving their responses to antigens over time called affinity maturation. Clonal selection algorithms focus on the Darwinian's theory in which selection is motivated by the antigen affinity and antibody interactions, variation is inspired by somatic hyper mutation and reproduction is inspired by cell division. These algorithms are many applied to optimization and pattern recognition problems, some of which resembles genetic algorithm without the recombination operator. The primary task of the immune system can be summarized as distinguishing between itself and non-self. Clonal selection algorithms is also called clever algorithm.

MULTI OBJECTIVE OPTIMIZATION

Multi-objective optimization is a process of simultaneously optimizing more than one objective conflicting with each other subject to certain constraints. We have to take a decisions that is optimal in the presence of trade-

offs between more than one conflicting objectives. One cannot identify a single point of solutions to optimize each objective simultaneously. Multi objective problem has no single solution that can optimize performance across all objectives. A range of solution is obtained according to the specified optimization criteria, each with a unique trade-off. Multi objective optimization methods will be used when there is a problem that incorporates objectives that conflicts and hence requires a trade off in the solution. When searching for the solutions, we reach to certain points such that, when we attempt to improve an objective further, another objective will suffer as a result. We can use a tentative method to find solution of various Multi Objective Optimization problems called non-dominated solution, or Pareto optimal.

Multi-Objective Optimization Problem:

The multi-objective programming problem is represented as:

$$\text{Minimize } f(x) = \{f_1(x), f_2(x), f_3(x), \dots, f_m(x)\}$$

$$D \in x$$

Where $x = (x_1, x_2, x_3, \dots, x_n)$ is a variable vector in a real and n-dimensional space, D is the feasible solution space, and $f_i(x), i = 1, 2, \dots, m$ specify the objective functions. The decision variable vector 'x' or solution is comprised of a number, 'm' parameters that are adjustable in nature

$$x = [x_1, x_2, x_3, \dots, x_m]$$

One solution's cost over the other can be assessed by an objective function, which in the multi objective problem case will consist of 'n' functions; each is related to a particular single objective.

$$f(x) = [f_1(x^{(1)}), f_2(x^{(2)}), f_3(x^{(3)}), \dots, f_n(x^{(n)})]$$

where $x^{(j)} \subseteq x$ for $j = 1, 2, \dots, n$;

Each objective will be dependent on a subset of the full range of decision variables. The objective of the multi objective optimization is to find a complete set of decision variables that minimizes and/or maximizes according to some criteria. This is done by comparing solutions in terms of Pareto optimality. A set of solution is said to be a part of Pareto optimal set if and only if, it is non-dominated and not dominated by any other solution in terms of one or more objectives.

A solution x^* is said to be pareto optimal if :

$$f_i(x^*) < f_i(x) \forall x \in \chi$$

where χ consist of the full set of all possible variables need to take a final decision.

Pareto Optimal

Pareto optimal is a non dominated tentative solution for multi objective optimization problems. Set of optimal solutions also known as Pareto-optimal solutions. It is named after Italian economist Vilfredo Pareto in 1906. We can use this method to find solution of various Multi Objective Optimization problems. In the presence of conflicts between more than one objectives, best decisions needed to be taken. A single solution cannot optimize each objective simultaneously. In the search for the solution, we reach certain points such that, when we attempt to improve one objective further, the other one suffers as a result. Solution of multi objective problems requires a set of points where all the objectives best optimized without sacrificing another objective. Pareto optimal solutions are also known as efficient, non inferior solutions. Their corresponding vectors are known as non dominated.

THE PROPOSED APPROACH

We propose a modified AIS approach using Clonal selection algorithm for multi objective optimization. In the present model crossover mechanism is integrated into traditional clonal selection algorithm. Only non dominated and feasible individual or best antibodies are added to the memory set. All individuals in the memory set will be cloned. The Algorithm is proposed with real parameters value not binary coded parameters. The clonal selection algorithm will focus on imitating the clonal selection principle which is composed of the mechanisms; selection, expansion, and maturation of affinity of clones via crossover mechanism.

Parameters

- N: The Fixed P i.e. Population size.
- n: Number of Abs to select for cloning.
- L: Bit string length for each antibody.

d: Number of random antibodies to insert at the end of each generation. Random antibody replace the d lowest affinity antibody in the collection.

P: Collection of Antibodies.

Abs: Antibodies

Nc : No of clones created by each selected antibody.

Where, $N_c = \text{round}(N \cdot \beta)$ and β is a user parameter.

Proposed Algorithm

input : N, β, n, L, d

output : P

$P \leftarrow \text{rand}(N, L)$;

while $\langle \rangle \text{stop_condition}()$ do

for each $P_i \in P$ do

affinity(P_i);

end for

$P_{\text{select}} \leftarrow \text{select}(P, n)$;

$P_{\text{clones}} \leftarrow 0$;

for each $P_i \in P_{\text{select}}$ do

$P_{\text{clones}} \leftarrow \text{clone}(P_i, \beta)$;

end for

for each $P_i \in P_{\text{clones}}$ do

crossover(P_i, P);

affinity(P_i);

end for

$P \leftarrow \text{select}(P, P_{\text{clones}}, N)$;

$P_{\text{rand}} \leftarrow \text{rand}(d, L)$;

replace(P, P_{rand});

end

return P ;

This algorithm is then implemented, tested and simulated using MATLAB to observe its output response, performance and to carry out various calculations related to this algorithm. We will try to solve Real Life Multi objective optimization Problems using this algorithm.

EXPERIMENTS

Test Problem: Multi-objective Optimization Problem for Fuel Cell Component Design System. To satisfy the functions we have to design the panel of fuel cell component accordingly. This problem is formulated as a Multi objective optimization problem, with h, w, and t as the 3 design variables.

Fuel cell component design system has two problems to optimize: [7].

(a). Problem 1:

$$\text{Minimize } f_1(h, w) = (w - 0.034)^2 + (h - u)^2$$

$$f_2(h, w) = (h)^2 + (w - u)^2$$

Subject to: $h - 1.6 \leq 0; 0.4 - h \leq 0; w - 5 \leq 0; 2 - w \leq 0;$

Where $u = \frac{Pwh}{2E_t \sin^2 \theta}$, $tg \theta = \frac{2h}{w}$

E is the Young's modulus of copper and P is the pressure.

The proposed algorithm will be used to optimize the above multi objective optimization problem of fuel cell component design system using MATLAB 7.12

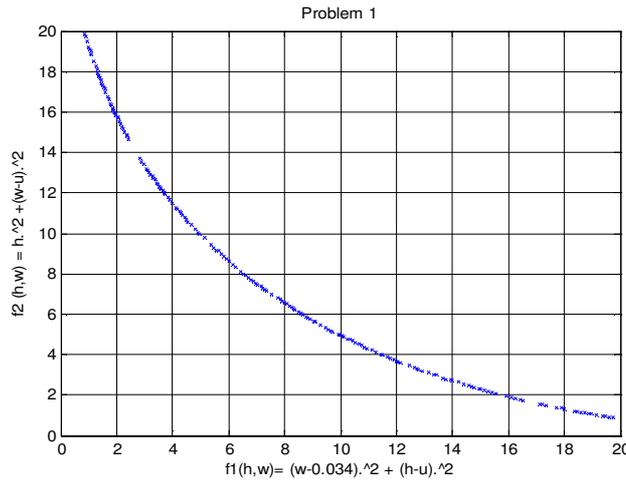


Figure 1: Pareto Front for Problem 1.

Figure 1 illustrates the result of problem 1. Pareto front shows the range where both the function best optimized i.e. minimized in this case, with in the given constraints.

Output indicates that range of variables will $0.4 \leq h \leq 1.6$ and $2 \leq w \leq 5$. Some Pareto front function values from figure 1 and design variable values corresponding to them are listed in table 1.

Table 1: Function values and design variables (h,w) for Problem 1.

f1(h,w)	f2(h,w)	h	w
5.78	9.48	0.64	2.98
7.40	7.71	0.49	3.36
8.36	6.70	1.41	3.83
10.25	5.16	1.27	4.11
11.08	4.23	0.83	4.11
14.77	2.48	0.84	4.66

Problem 2:

Minimize $f_1(h, t) = (t - h + 7.5)^2 + (t + h - u)^2 / 4$

$$f_2(h, t) = (t - u)^2 / 2 + (h - 1)^2$$

$$g_1(h, t) = 2.5 - (h - 2)^3 / 2 - t \geq 0$$

Subject to: $g_2(h, t) = 3.85 + 8(t - h + 0.65)^2 - t - x \geq 0$

$$0 \leq h \leq 5; 0 \leq t \leq 3;$$

Where $u = \frac{Pwh}{2E_t \sin^2 \theta}$, $tg \theta = \frac{2h}{w}$

E is the Young's modulus of copper and P is the pressure.

The proposed algorithm will be used to optimize the above multi objective optimization problem of fuel cell component design system using MATLAB 7.12

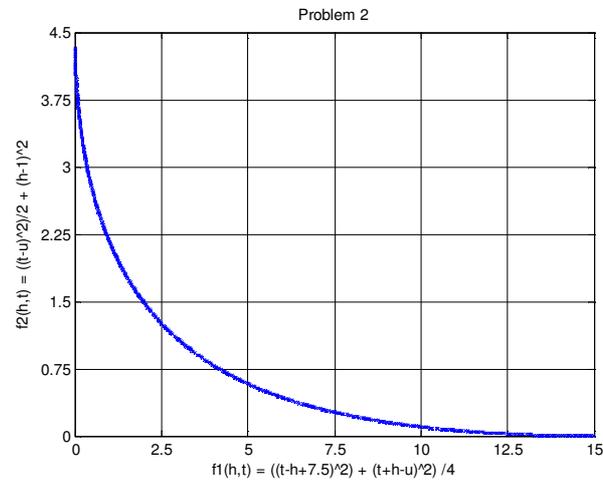


Figure 2: Pareto Front for Problem 2.

Figure 2 illustrates the result of problem 2. Pareto front shows the range where both the function best optimized i.e. minimized in this case, with in the given constrains.

Output indicates that range of variables will $0 \leq h \leq 5$ and $0 \leq t \leq 3$. Some Pareto front function values from figure 2 and design variable values corresponding to them are listed in table 2.

Table 2: Function values and design variable (h,t) for Problem 2.

f1(h,t)	f2(h,t)	h	t
0.45	3.37	4.49	2.75
1.95	2.32	3.72	3
2.5	1.42	3.54	2.74
5.116	0.64	2.82	2.96
7.125	0.52	2.50	2.98
10.22	0.25	2.04	2.91

CONCLUSION AND FUTURE SCOPE

In this paper, an artificial intelligent approach based on the clonal selection principle of Artificial Immune System is proposed. Instead of one solution, a preferred set of solutions near the reference points can be found. We can maximize and/or minimize complex multi objective optimization problems and get the Pareto front where both the objectives best meet and none of the objective dominate other objective.

It is very important to cover the gap among a theoretical system , algorithm based on that theory and then its application to solve a problem. Artificial immune system approach based algorithm and model performances can be enhance by researching further in this field. This opens the research trends to study if there are certain methodology that can be used along with artificial immune system approach to improve its performance and scope.

In future, further investigation can be conducted to evaluate and improve the biological information system inspired algorithms and approach. Various functions and features of biological immune system can be adopted to develop algorithms that can deal with more complex real world problems. Many engineering problems can be solve by using artificial immune system approach, after further investigation and research work in this field. It is a very interesting field of biological information processing system that can contribute to various complex problem solving domain.

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