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IMPROVED ARTIFICIAL FISH SWARM ALGORITHM AND ITS APPLICATION IN OPTIMAL DESIGN OF TRUSS STRUCTURE

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ABSTRACT

To overcome the defects of Artificial Fish-Swarm Algorithm, an adaptive particle swarm optimization was proposed. The new algorithm employs the inertia weight adjustment strategy to dynamically adjust the idea of artificial fish's visual and step on the basic artificial fish. The chaotic early initialization was employed to improve the quality of group solutions of artificial fish. Then, it was applied to the optimal design of truss structures in size. Engineering practice and comparison with the other optimization algorithms show that the algorithm has good convergence and stability.

Keywords: *Artificial Fish-Swarm Algorithm, Adaptive, Truss, Structure Optimization, Chaos*

1 INTRODUCTION

With the advancement in engineering structures design technologies, optimal design of truss structures becomes more and more important. Yet, traditional optimization methods usually require that the objective function should have good continuity[1-2]. So, it is difficult to solve the multi-peak optimization problems, namely the discrete variables problems. This situation has signified the study of the related methods.

In recent years, biomimetic optimization algorithms have been widely used in various fields of scientific research and optimization [3-6]. Artificial Fish-Swarm Algorithm is a bionic random optimization algorithm with global search capability and less demanding on the sensitivity of various parameters. And the algorithm is easy to implement. At present, the algorithm has been applied in many fields, and achieved good results. But the algorithm is not well coordinated balance between exploration and development capacity, and there is a big run late blindness in search behavior. With the disadvantage of low optimization accuracy and the slow speed optimization, the quality and efficiency of the algorithm are affected [5].

To overcome these shortcomings, the particle swarm optimization inertia weight adjustment strategy was employed to dynamically adjust the artificial fish's vision and step on the basic algorithm, and then it was applied to optimal design of truss structures in size. Comparison results with the traditional particle swarm optimization algorithm and other algorithms show that the algorithm has good convergence and stability and can effectively optimize the design of truss structure size.

2 IMPROVED ARTIFICIAL FISH-SWARM ALGORITHM

2.1 Introduction to the basic Artificial Fish Swarm Algorithm (AFSA)

With the advancement in networking and multimedia technologies enables the distribution and sharing of multimedia content widely.

AFSA [7-8] is a simulation of fish behavior based on random search optimization algorithm, mainly through the individual fish in the artificial feeding of fish, clusters, and rear-end behavior of local search, so that the global optimum value in the group is easy to see.The state of artificial fish can be expressed as individual $X=\left(x_1,x_2,\cdots,x_n\right)$ as the optimization variables, the current location of the artificial fish food concentration is expressed as $Y=f\left(x\right)$. Where Y and X are the corresponding objective function values. $d_{ij}=\left\|x_i-x_j\right\|$ is the artificial fish's distance between the artificial fish with visual horizons. δ is the congestion factor, which is to

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limit artificial fish-scale gathering. The number of fish scale is N_p.

2.2 Adaptive Artificial Fish School Algorithm

2.2.1 Degree of premature convergence of artificial fish

In the algorithm, set the number of fish scale is N_p, if Y_{avg} artificial fish is for all the current average value of the objective function, then

$$Y_{avg} = \frac{1}{N}\sum_{i=1}^{n} Y_i \quad (1)$$

Where, Y_i is the artificial fish in the current iteration when the objective function value. Let the optimal objective function value of artificial fish Y_g, and the objective function value of the objective function value is better than Y_{avg}, defined

$$\varphi = \left|Y_g - Y_{avg}^*\right| \quad (2)$$

Where, φ can be used to evaluate the extent of premature convergence of artificial fish, and the smaller shows the groups tend to premature convergence.

2.2.2 Adaptive strategy

In the artificial fish swarm algorithm, when the optimal objective function value does not change for a long time, the fish should be based on the extent of premature convergence adaptively adjust the step size.

The objective function value of Yi in the artificial fish step size adjustment method is as follows:

(1) When Y_i is better than Y_{avg}^*,

$$Step = Step - (Step - Step_{\min}) \cdot \left|\frac{Y_i - Y^*}{Y_g - Yavg^*}\right| \quad (3)$$

(2) When Y_i is better than Y_{avg} but inferior Y_{avg}^*,

$$Step = Step_{\min} + (Step_{\max} - Step_{\min}) \times \frac{1 + \cos((iter - 1)\pi(MaxStep - 1))}{2} \quad (4)$$

At beginning $Step_{\max}$ is the largest step of search, $Step_{\min}$ is the smallest step at the end of search, $iter$ is the iteration steps carried out, $MaxStep$ is the maximum number of iterations which is allowed.

(3) Y_i is equal to Y_{avg}

Meeting this condition, the artificial fish is worse fish in the artificial fish, the adjustment of step [9] is:

$$Step = 1.5 - \frac{1}{1 + K_1 \cdot \exp(-K_2 \cdot \varphi)} \quad (5)$$

Where $k_1 = 1.5$, $k_2 = 5$.

Field of view of artificial fish is:

$$Visual = 8Step \quad (6)$$

2.3 Obtain Of The Initial Solution Of Group

Obtaining a better initial solution group, we will enhance the quality of reconciliation solution efficiently and we will get the initial solutions of good quality group by the use of chaotic initialization [10].

The initial solution equation can be obtained from:

$$X_{k+1} = \mu X_k (1 - X_k) \quad (7)$$

The purpose of optimization is to minimize the weight of the structure. And the objective function can be expressed as:

$$\min w = \sum_{i=1}^{n} \rho A_i l_i \quad (8)$$

A_i is the sectional area of bar; l_i is the length of bar; ρ is the material density; and i is the number of design variables.

The bar must meet the constraints of strength, stiffness, stability and the requirements of section size. The constraints can be expressed as

$$\begin{cases} \frac{\sigma_i}{[\sigma]} - 1 \le 0 \\ \frac{u_j}{u_{\max}} - 1 \le 0 \\ \frac{Y_i}{[Y]} - 1 \le 0 \\ A_{\min} \le A_i \le A_{\max} \end{cases} \quad (9)$$

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Where: σ is the first i poles the axial normal stress, $[\sigma]$ is the allowable stress of the material, u_j is the displacement of node j. A_{min}, A_{max} are for the rod cross-sectional area of the upper and lower limits respectively.

The framework of the improved algorithm is shown in Figure 1.

3 ENGINEERING PRACTICE

In order to verify the effectiveness of the algorithm we proposed, we used it to the 25 space truss optimization and compared the performance with other algorithms. The 25 space truss structure is shown in Fig.2. The structure of the two load cases considered and the specific conditions are shown in Table I. The material density is 0.1l b/in3 and the modulus is 107 psi. Because of structural symmetry, 25 are divided into 8 categories, classification, and the allowable stress of the rods is shown in Table II. The optimized results of displacement point in all directions d ≤ 0.35in, the rod cross-section in2 are shown in TableIII.

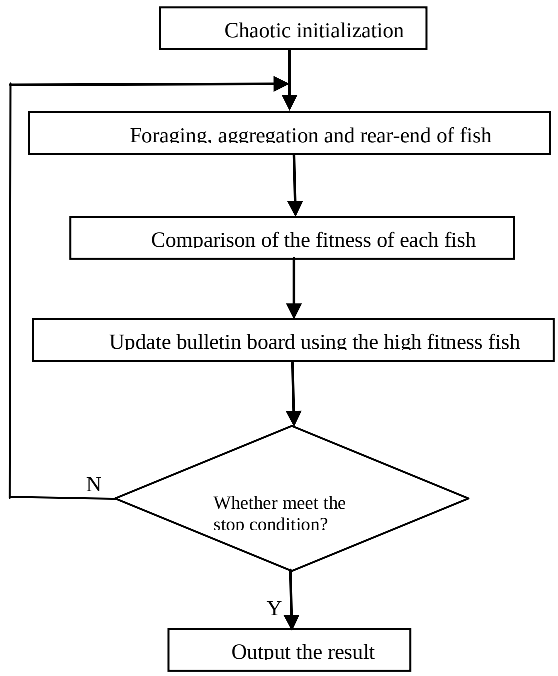

Figure 1: Framework Of The Improved Algorithm

Table 1: Load Cases Of 25-Bar Spatial Truss Structure

Node	Conditions 1			Conditions 2		
	Px/kips	Py/kips	Pz/kips	Px/kips	Py/kips	Pz/kips
1	1.0	10.0	-5.0	0	20.0	-5.0
2	0	10.0	-5.0	0	-20.0	-5.0
3	0.5	0	0			
4	0.5	0	0			

Table 2: The Classification And Member Stress Limitations Of 25-Bar Spatial Truss Structure

Lever type	1	2	3	4	5	6	7	8
Number	1-2	1-4,2-3,1-5,2-6	2-5,2-4,1-3,1-6	3-4,5-6	3-6,4-5	3-10,6-7,4-9,5-8	3-8,4-7,6-9,5-10	3-7,4-8,5-9,6-10
Allowed tensile stress (ksi)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Allowed compressive stress (ksi)	35.092	11.590	17.305	35.092	35.902	6.759	6.959	11.802

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Table 3: Comparison Of Optimal Designs For 25-Bar Spatial Truss Structure

Lever type	1	2	3	5	6	7	8	Weight (lbs)
Cross-sectional area (in^2)	A1	A2	A3	A5	A6	A7	A8	
GA[10]	0.019	1.787	3.007	0.01	0.693	1.884	2.597	547.754
SA[11]	0.016	2.044	2.831	0.01	0.669	1.714	2.72	545.940
HPSO[12]	0.01	1.942	2.966	0.01	0.704	1.734	2.632	545.618
CLPSO[13]	0.01	1.988	2.901	0.01	0.698	1.726	2.659	545.705
SGSO[14]	0.01	1.9339	3.0652	0.01	0.70124	1.6891	2.619	545.290
Algorithm we proposed	0.012	1.926	2.974	0.01	0.696	1.712	2.622	545.126

As can be seen from the table, the improved artificial fish swarm algorithm we proposed overcomes the disadvantages of basic AFSA, and can realize the optimization effectively.

4 CONCLUSION

Artificial Fish-Swarm Algorithm is a promising bionic random optimization algorithm. We proposed an improved algorithm and introduced it to optimize the design of truss structures after the establishment of the corresponding optimization model. The comparison results verified the efficiency and the feasibility of the method in solving practical optimization problems.

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