Study on the application of intelligent optimization algorithm in the optimization of passive positioning network layout

Song Binbin[1]
Naval aviation university
Yantai, China
751357347@qq.com

Wang Chengmin[2]
Army unit 32103
Weifang, China

Zhu Jing[3]
Naval aviation university
Yantai, China

Sun Chao[4]
Naval aviation university
Yantai, China

Abstract: **With the development of intelligent optimization algorithms, more and more optimization algorithms are applied to solve the optimization problems in real production and life. In a certain background environment, the positioning accuracy of the multi-station passive positioning system largely depends on the specific distribution of the stations in the system. Therefore, by analyzing the constraint conditions and reasonably establishing the model, the optimization problem of passive positioning network distribution station can be transformed into an optimization problem and solved by intelligent optimization algorithm. The GDOP direction finding cross location algorithm formula was deduced, the analysis is established under the condition of certain multistation disposition optimization model of passive location system is proposed using genetic algorithm and particle swarm optimization (pso), artificial fish algorithm of embattling method for solving optimization problem, through the comparison and analysis it is concluded that the particle swarm algorithm is more suitable for more rapid network cloth station station passive location system.**

Keywords:Intelligent optimization algorithm, passive positioning, optimization station

I. INTRODUCTION

In recent years, passive positioning technology, as a supplement to active positioning, has been widely used in military reconnaissance, civil navigation and reconnaissance and detection. Due to its advantages such as good concealment, long positioning distance and more positioning methods and means [1], it is receiving more and more attention.

Literature [2] shows that the layout form of passive positioning system has a great influence on the positioning accuracy. Therefore, how to improve the positioning accuracy of the system by optimizing the position of passive positioning system stations has become the research direction of many scholars. Literature [3][4] studies the general conditions of the optimal distribution station under the multi-station direction finding and cross-positioning system, and gives the optimal distribution station form under this criterion in combination with the double-station or three-station. Literature [5][6] choose average GDOP reference indexes, studied the several typical disposition form positioning accuracy, the simulation analysis and optimal embattling by some qualitative conclusions. In literature [7], the concept of objective function was introduced, and the GDOP formula of the time difference localization algorithm in two-dimensional condition was used as the optimization function to solve the optimal station solution. However, the modeling environment was too ideal to be applied in practice; Literature [8] proposed a layout optimization algorithm based on simulated annealing algorithm, but its convergence speed was too slow and it was not suitable for large-scale search. Therefore, it is of great significance to establish a reasonable station layout optimization model and adopt an appropriate intelligent optimization algorithm to study the station layout optimization of a multi-station passive positioning system.

II. PRINCIPLE AND FORMULA DERIVATION OF MULTI-STATION DIRECTION FINDING CROSSOVER ALGORITHM

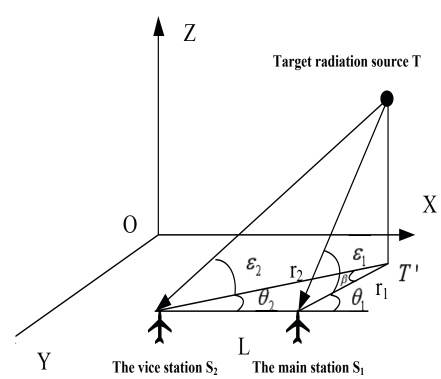

Figure 1. 3d geometric model of direction finding and cross positioning of two stations

The two-station passive direction finding and cross-positioning system is taken as the model [9], as shown in figure 1, the coordinates of the target radiation source is $T(x, y, z)$. The coordinates of the primary and secondary

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stations are (x_1, y_1, z_1) and (x_2, y_2, z_2) respectively. The main station measured the pitch Angle and direction Angle are ε_1 and θ_1 respectively, the vice station for ε_2 and θ_2, Projection onto the x-y plane, r_1, r_2 are respectively the distance of target radiation source T' to main and vice stations, β is the plane intersection angle, and the spacing between the primary and secondary stations is L. From the geometric relation, the positioning equation can be written as:

$$x = \frac{-x_1 \tan\theta_1 + x_2 \tan\theta_2}{\tan\theta_2 - \tan\theta_1} \tag{1}$$

$$y = \frac{y_1 \tan\theta_2 - y_2 \tan\theta_1 - (x_1 - x_2)\tan\theta_1 \tan\theta_2}{\tan\theta_2 - \tan\theta_1} \tag{2}$$

$$z = L\frac{\tan\varepsilon_1 \sin\theta_2}{\sin\beta} \tag{3}$$

The derivation of x, y, z according to ε_1, θ_1 and θ_2 can be obtained as follows:

$$\begin{pmatrix} dx \\ dy \\ dz \end{pmatrix} = \frac{L}{\sin^2\beta} \times \begin{pmatrix} -\sin\theta_2\cos\theta_2 & \sin\theta_1\cos\theta_1 & 0 \\ -\sin^2\theta_2 & \sin^2\theta_1 & 0 \\ -\sin\theta_2\cos\beta\tan\varepsilon_1 & \sin\theta_1\tan\varepsilon_1 & \dfrac{\sin\theta_2\sin\beta}{\cos^2\varepsilon_1} \end{pmatrix} \begin{pmatrix} d\theta_1 \\ d\theta_2 \\ d\varepsilon_1 \end{pmatrix} \tag{4}$$

Therefore, the covariance matrix of radiation source target estimation can be expressed as:

$$E\left\{(dx \quad dy \quad dz)^T (dx \quad dy \quad dz)\right\} = \begin{pmatrix} \sigma_x^{\ 2} & \sigma_{xy} & \sigma_{xz} \\ \sigma_{yx} & \sigma_y^{\ 2} & \sigma_{yz} \\ \sigma_{zx} & \sigma_{zy} & \sigma_z^{\ 2} \end{pmatrix} \tag{5}$$

GDOP formula can be expressed as:

$$GDOP = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2} \tag{6}$$

Assuming that the measurement errors in the system are independent of each other, the following conditions are met:

$$\sigma^2{}_{\theta_1} = \sigma^2{}_{\theta_2} = \sigma^2{}_{\varepsilon_1} = \sigma^2 \tag{7}$$

Sorting out:

$$GDOP = L\sigma\sqrt{\omega} \tag{8}$$

Among them:

$$\omega = \frac{1}{\sin^4\beta}\left[\sin^2\theta_1 + \sin^2\theta_2 + \tan^2\varepsilon_1 \times \left(\sin^2\theta_2\cos^2\beta + \sin^2\theta_1\right)\right] + \frac{\sin^2\theta_2}{\sin^2\beta\cos^4\varepsilon_1} \tag{9}$$

III. The Establishment and Analysis of the Passive Positioning Station Optimization Model Based on Intelligent Optimization Algorithm

The generation of intelligent optimization algorithm is based on the development of optimization technology, optimization technology is based on mathematics, used to solve a variety of engineering problems optimization solution application technology, with the development of recent years, intelligent optimization algorithm is widely used in system control, artificial intelligence, communication system design and other fields. The typical intelligent optimization algorithms developed in recent years include genetic algorithm, simulated annealing algorithm, particle swarm optimization algorithm and tabu algorithm.

A. Intelligent optimization algorithm introduction

1) Introduction to genetic algorithm

Genetic Algorithms (GA) is a relatively complete theory and method developed by John Holland of the university of Michigan and his colleagues and students [10]. Genetic Algorithms (GA) is based on the principle of genetic evolution in each generation of organisms in the natural environment, in which variation, selection and inheritance are generated to ensure the continuation of the advantages of the population itself. After theoretical research and experiments, it is optimized to establish an artificial system model.

2) Artificial fish swarm algorithm is introduced

Artificial Fish School Algorithm (AFSA)is a new global optimization algorithm of bionic group intelligence first proposed by domestic scholar Dr. Li xiaolei in 2002[11]. According to the adaptability, autonomy, blindness, emergence and parallelism of animal behavior, a new intelligent optimization method is proposed. Artificial fish swarm algorithm has the advantages of good global extremum, strong robustness, simplicity and easy implementation.

3) Particle swarm optimization is introduced

Particle Swarm optimization (PSO), an effective global optimization algorithm, was first proposed by Kennedy and Eberhart in 1951 [12]. It is an optimization algorithm based on the theory of swarm intelligence, which is guided by swarm intelligence generated by the cooperation and competition among particles in the swarm. Particle swarm optimization (pso) has the characteristics of evolutionary computation and swarm intelligence. It can search the optimal solution in complex space through the cooperation and competition among individuals.

B. Establishment of optimization model for passive positioning station

To establish the optimization problem model, it is necessary to reasonably determine the decision variables, select the objective function and set the constraint conditions.

1) Determine decision variables

The position coordinates of each observation station are the most direct and the most influential factors on the distribution results, so it is feasible to select the position coordinates as the decision variables. In general, three-dimensional coordinate system includes rectangular coordinate system, spherical coordinate system and polar coordinate system. In order to simplify calculation, the model chooses rectangular coordinate system and determines that the global decision variable is defined as the position coordinate of each observation station.

2) Select the objective function

In the model, the objective function should select the index function that can reflect the positioning accuracy of the multi-station passive positioning system. GDOP model taken as objective function, the objective function of the value source target in different spatial location, its corresponding position of the positioning error of the theoretical value.

3) Set constraints

In order to ensure the feasibility and safety of the model, the actual situation of passive positioning of multiple stations was analyzed comprehensively. In order to ensure that each station can obtain radiation signal, communication and transmission between stations, and the security of carrier platform, the stations should be limited to a certain three-dimensional rectangular space.

C. Intelligent optimization algorithm parameter setting

1) Genetic algorithm parameter setting

The population size of the genetic algorithm was set as 20, and the main parameters were variable factor P_m=0.08 and cross factor P_x=0.1.

2) Parameter setting of artificial fish swarm algorithm

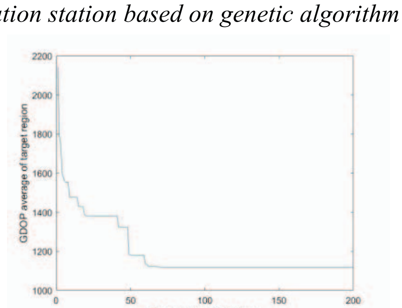
The population size of artificial fish swarm algorithm is selected as 20, and the main parameters are set as T_n=3, visual field V=15, and step length S=0.01.

3) particle swarm optimization algorithm parameter setting

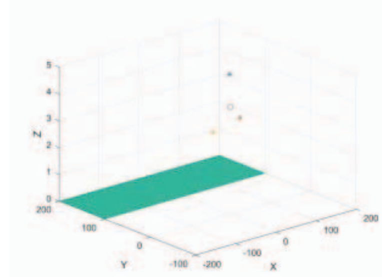
Selection particle swarm size 20, is conducive to the algorithm convergence, and selection of weight coefficient ω = 0.7298, η_1= 2, η_2 = 2.

IV. SIMULATION AND RESULT ANALYSIS

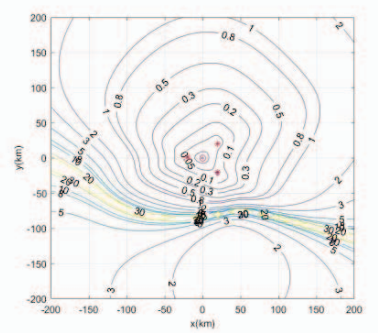
A. Simulation analysis of space 4 station passive location optimization station based on genetic algorithm



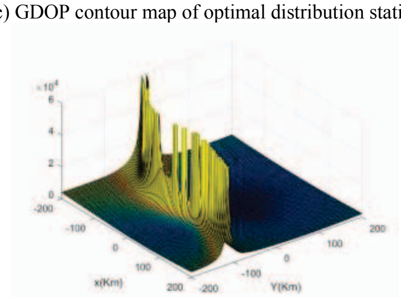
(a) relation diagram of the number of iterations of the genetic algorithm



(b) schematic diagram of the distribution stations and target areas of the genetic algorithm



(c) GDOP contour map of optimal distribution station

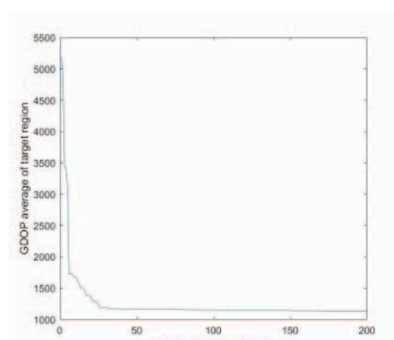


(d) GDOP three-dimensional map of optimal distribution station

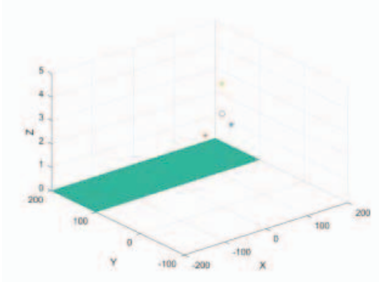
Figure. 2 simulation diagram of space 4-station passive positioning optimization distribution station based on genetic algorithm

Based on genetic algorithm, the coordinates of each optimal distribution station are S_0= (0,0,4) km, S_1= (20,20,5) km, S_2= (1.6706,-20,3.7095) km, S_3= (-20,20,3) km, and the minimum GDOP mean of the target area is 1119.

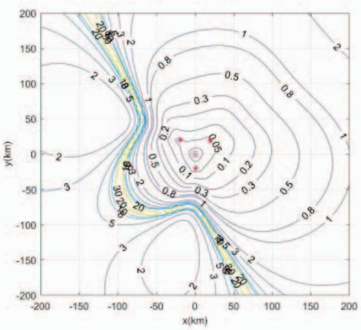
B. Simulation analysis of space 4-station passive location optimization station based on artificial fish swarm algorithm



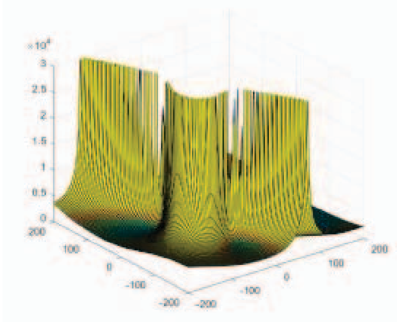
(a) GDOP contour map of typical distribution stations



(b) GDOP contour map of optimal distribution stations



(c) GDOP contour map of optimal distribution station

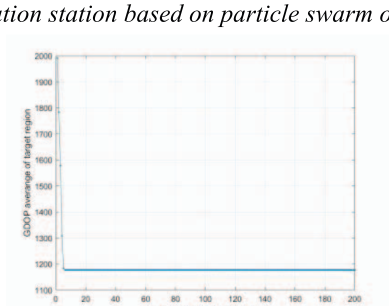


(d) GDOP three-dimensional map of optimal distribution station

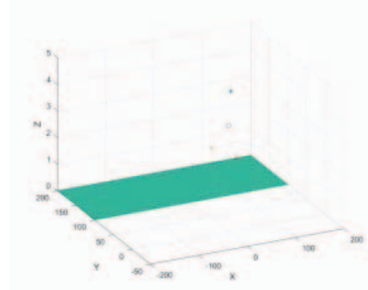
Figure. 3 simulation diagram of 4 stations of passive positioning optimization distribution based on artificial fish swarm algorithm

Based on the artificial fish swarm algorithm, the coordinates of each optimal distribution station are S_0= (0,0,4) km, S_1= (0.7806,-20,3) km, S_2= (-19.48,20,3.7095) km, S_3= (20,18.9107,5) km, and the minimum GDOP average of the target area is 1169.

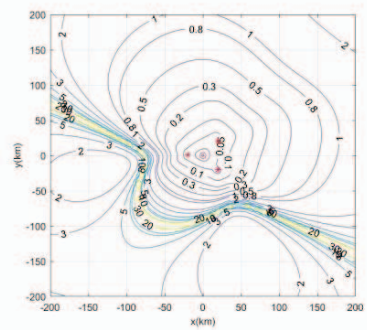
C. *Simulation analysis of space 4 station passive location optimization station based on particle swarm optimization*



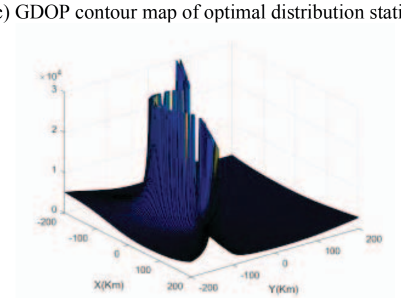
(a) relation diagram of iteration number of particle swarm optimization



(b) schematic diagram of station layout and target area of particle swarm optimization (pso)



(c) GDOP contour map of optimal distribution station



(d) GDOP three-dimensional map of optimal distribution station

Figure. 4 simulation diagram of four stations in space for passive positioning optimization based on particle swarm optimization

Based on the particle swarm optimization algorithm, the coordinates of each optimal distribution station are S_0= (0,0,4) km, S_1= (20,20,5) km, S_2= (1.0574,-20,3) km, S3= (-20,20,3) km, and the minimum GDOP mean of the target region is 1117.

D. *Results analysis*

1) The comparison of station layout results of three intelligent algorithms shows that: Under the condition of satisfying the accuracy, the three intelligent optimization algorithms can find the optimal distribution station result by iteration, and the fitness function value gradually decreases with the increase of the number of iterations, and finally can converge and stabilize at a certain fixed value, indicating that the three intelligent optimization algorithms can achieve the optimal distribution station.

2) In terms of positioning accuracy, pso is better than genetic algorithm than artificial fish swarm algorithm. For a given positioning area in the simulation, the average GDOP value of pso is the smallest.

3) By comparing the coordinates of each station, it can be seen that the optimal distribution station for target positioning within a certain space is not unique, but the positions of each station of the optimal distribution station are relatively concentrated in some fixed positions.

V. SUMMARIZES

In this paper, the optimization model of multi-station passive positioning system under a specific situation is discussed and established, and the optimization method of multi-station passive positioning based on genetic algorithm, artificial fish swarm algorithm and particle swarm algorithm is proposed, which solves the problem of optimal positioning of multi-station passive positioning system for a certain area. Through the experiment and simulation, the station coordinates of the optimal layout station for the regional target are obtained by the four stations passive positioning system based on three intelligent optimization algorithms. Compared with the other two algorithms, particle swarm optimization (pso) is simple in calculation, efficient and accurate, and converges quickly.

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