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Genetic Algorithm and its Application in Optimal Sensor Layout

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Abstract: This paper aims at the problem of multi sensor station distribution, based on multi-sensor systems of different types as the research object, in the analysis of various types of sensors with different application background, different indicators of demand, based on the different constraints, for all kinds of multi sensor station is studied, the application of genetic algorithms as a tool for the objective function of the models optimization, then the optimal various types of multi sensor station distribution plan, improve the performance of the system, and achieved good military effect. In the field of application of sensor radar, track measuring instrument, the satellite, passive positioning equipment of various types, specific problem, use care indicators and station arrangement between the mathematical model of geometry, using genetic algorithm to get the optimization results station distribution, to solve a variety of practical problems provides useful help, but also reflects the improved genetic algorithm in electronic weapon system based on multi sensor station distribution on the applicability and effectiveness of the optimization; finally the genetic algorithm for integrated optimization of multi sensor station distribution using the good to the training exercise tasks based on actual in, and have achieved good military effect. *Copyright © 2015 IFSA Publishing, S. L.*

Keywords: Sensor placement, Genetic Algorithm, Multi-sensor, Damage detection.

1. Introduction

Multi sensor is an important part of weapon system, play an important role in the modern war with information as the leading factor of [1]. On the digitized battlefield and environmental monitoring, very much in need of distributed real-time sensor, sensor station or distribution is of primary concern. The number of sensors, type, location and layout density determines the layout scheme of a multi sensor, especially in the number of sensors, limited by the geographical position and other factors, the overall performance of the system is often associated with each sensor station layout were closely related, study and optimization of multi sensor station layout will contribute to the electronic weapon system to achieve the desired performance optimization [2-3].

With the progress of science and technology, the development of modern industry and human needs in the future, modern space structure is toward large, complex direction [4]. Some large aircraft and spacecraft, nuclear engineering and bridge, and the modern high-rise buildings and other structures are possible in the use of the process will have a local damage, these local damage although does not lead to the destruction of the whole structure immediately, but it to the safety of whole structure constitutes a potential hazard [5]. Influence of stress concentration, fatigue and other factors can cause local damage continues to expand and increase, resulting in a decline in bearing capacity of whole structure, even cause the destruction of the whole structure [6].

The result is that not only shorten the service life of the structure, but also a threat to the security of life and property [7]. Therefore, in order to ensure the safety of structure, need to establish a method for detecting structural damage, which can quickly detect the damage appear and the damage position. Accurate detection of structural damage location and extent can help people to timely repair or change the structure of the operation of structure using the method in order to reduce the accumulation of structural damage degree, reduce the occurrence of sudden destruction.

The electronic equipment test training, from the performance testing, equipment to improve the test data accuracy, to tactical training, confrontation training daily, are the need for sensor station distribution research. Further study of multiple sensor station distribution and optimization scheme of electronic weapon system test, not only can effectively use and save test resources, speed up the completion of the test time and improve test quality and efficiency, and to improve the comprehensive ability of army scientific research test, to provide decision support to have the extremely vital significance [8].

This paper aims at the problem of multi sensor station arrangement, with different types of sensors as the object of study, in the analysis of various types of sensors with different application background, different indicators of demand, based on the different constraints, for all kinds of multi sensor station of mathematical modeling; through the algorithm research and improvement, with genetic algorithm as a tool of objective function on the model of optimization, then the optimal station distribution plan, reflect the good effect of military application. Station cloth overall optimization of multi sensor based on GA. Based on a practical training exercise tasks as the background, based on the actual training requirements and sensor distribution principle, based on considering all constraints, studies and discusses the comprehensive optimization of radar station cloth, ground battlefield sensor, has provided the powerful support for the efficient task completion and achieved good economic and military benefit.

2. Related Theory Sensor Optimization

2.1. Classification of Multi Sensor

According to the technical approach to classification, sensors can be classified as radar, signals intelligence sensors, radiometer, photoelectric sensors, remote sensors, sensor, ground battlefield sensor acoustic detection [9]. These sensors can be deployed in the ground, coastal, surface and underwater or mounted on a single soldier, ships, submarines, balloons, aircraft, satellite motion platform. As shown in Fig. 1:

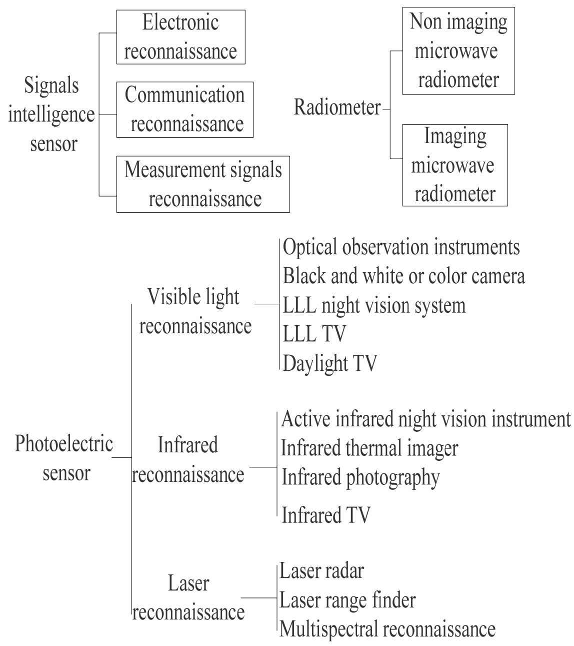

Fig. 1. Sensors deployed in the ground, coastal, surface and underwater.

2.2. Research Status of Optimization Technology of Sensor Station Distribution

Optimization of technology directly originated from the military practice of sensor stations cloth branching linear programming, search theory, network and data processing statistics. Among them, the linear programming is Dr. Dantzig served as the U.S. air force audit mathematics consultant in complete United States Air Force proposed 'optimal planning of scientific computing' project started in 1947; search theory originated in the Second World War the American scientist Koopman [10] and his colleagues in antisubmarine operations team work; network originated in 1956 the United States DuPont Co trial "critical path method" and in 1958 the United States Navy Special Planning Bureau in the program evaluation and review technique Polaris missile development for the first time in the data processing statistics; directly originated from the two tactical warfare evaluation and improvement of military application.

The U.S. military in multi sensor station layout and Optimization Research of methods have been developed by theoretical study and experimental phase gradually transition to the practical application stage, and by optimizing the sensor station distribution improves the overall efficiency of the sensor network in actual combat. About the construction of American sensor equipment material is more, but because the secret reason about U.S. in layout and optimization method of multi sensor system research results and detailed information is currently unable to obtain. Other foreign multi sensor station distribution of test and training data optimization technology is also very limited. Although not refer to these specific data, but the current situation shows that the theory and method of American use of optimization techniques for multi-sensor cloth on joint operations, digitized force, information operations, such as C4ISR research station of theory and practice, in the military field is still in the leading position, and play a very important effect.

3. Genetic Algorithm and its Improvement

3.1. The Principle of Genetic Algorithms

1) Determine the composition and length of individual;

2) The initial evolution algebra t-> 0, setting the need to implement the maximum evolution algebra T, random (or initialization) to generate m individuals, the formation of the initial population of M(0), each individual is a potential solution to the problem;

3) On individual evaluation, get each individual population M(t) the fitness value of U(m), and all were evaluated;

4) The implementation of genetic operation, through the process of individual C(t) produce offspring, were evaluated the operation continues offspring parent and offspring, choose show individual components of new group M(t+1);

5) Termination conditions, the algorithm converges, find a solution. T< t, returned 1, continue with step (3) and (4); if the maximum generation set is t>T, is that in the calculation of the maximum fitness value of individual is the optimal solution.

Algorithm process:

Begin

$t \leftarrow 0$

Initialization $M(t)$

Evaluation $M(t)$

While (Non termination condition) **do**

Begin

Recombination $M(t)$

Generation $C(t)$

Choose $M(t+1)$ from $M(t)$ and $C(t)$

$t \leftarrow t+1$

End

End

3.2. An Improved Adaptive Genetic Algorithm

Use the following formula to describe the coordination coefficient is introduced:

$$F(f) = \frac{2}{1+e^{\frac{f-f_0}{f_{\max}-f_0+m}}} \tag{1}$$

The coefficient will be around the average fitness values of the reference adaptive coordination of the operator, when the value of individual fitness and average fitness values are consistent, keep invariant operator.

Among them, f, f_a, f_{max} represents the value of individual fitness and population average fitness value of maximum and group fitness value; m is the positive real number is relatively small, to avoid the model the denominator hours operation error. For each individual, the crossover probability and mutation probability into the actual crossover and mutation probability given values were multiplied by the coordination coefficient:

$$p_c' = p_c \cdot F(f), \quad p_m' = p_m \cdot F(f) \tag{2}$$

Several commonly used test functions are selected with single peak or multi peak. The test functions are selected as follows:

$$f(x) = \sum_{i=1}^{n} \frac{x_i^2}{4000} - \prod_{i=1}^{n} \cos\frac{x_i}{\sqrt{i}} + 1 \quad x_i \in [-600, 600] \tag{3}$$

$$f(x) = (\sum_{i=1}^{n} x_i^2)^{1/4} \cdot [\sin^2(50(\sum_{i=1}^{n} x_i^2)^{1/10}) + 1] \quad x_i \in [-32.767, 32.767] \tag{4}$$

$$f(x) = \sum_{i=1}^{n} (100(x_{i+1} - x_i^2)^2 + (x_i - 1)^2 \quad x_i \in [-100, 100] \tag{5}$$

In the test, the basic genetic algorithm SGA, the conventional adaptive genetic algorithm AGA, the improved adaptive genetic algorithm IAGA parameter was set 30: population size, crossover probability Pc =0.65, mutation probability Pm =0.01. All the algorithms were run 30 times, the calculation results shown in Table 1.

Table 1. Average evolution generation of variety genetic algorithm.

Optimization value of function	SGA	AGA	IAGA
99.0	4.1	2.7	1.5
99.5	7.3	4.6	2.2
99.9	26.2	8.1	2.8
99.95	57.6	11.6	5.6
99.99	135.8	37.1	9.3
99.995	165.7	46.2	15.1
99.999	/	51.1	18.2
99.9995	/	53.8	22.3

3.3. Positioning Netting Optimization Mathematical Model

The number of track measuring instrument in the test set is 3 sets, coordinate O - XYZ cartesian coordinate system (Fig. 2).

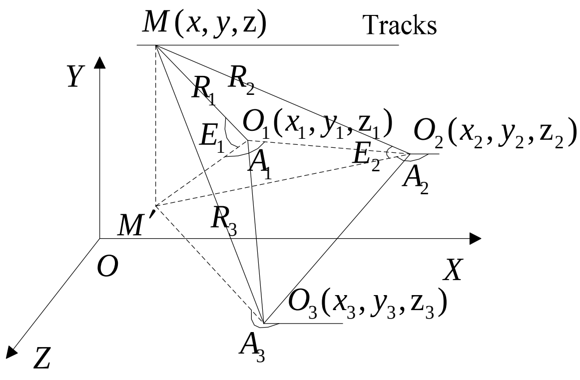

Fig. 2. The coordinate O-XYZ cartesian coordinate system.

Position three coordinate measuring instrument, the measured dynamic target coordinate location for M(x, y, Z) for plane shadow M formed in three stations (1, 2, 3) three measurement target measurement instrument M the azimuth angle (pitch for the goal of measuring the obtained angle E(1, 2, 3) for measuring instrument to the distance measured target M. Track measuring slant range, azimuth and elevation data of E_i can use the position parameter X, Y, Z in rectangular coordinates are expressed as:

$$R_i = [(X - X_i)^2 + (Y - Y_i)^2 + (Z - Z_i)^2]^{1/2} \tag{6}$$

$$A_i = \begin{cases} 0^\circ + \arcsin[(Z - Z_i)/L_i] & X - X_i \geq 0 \\ 180^\circ - \arcsin[(Z - Z_i)/L_i] & X - X_i \geq 0 \end{cases}$$
$$E_i = \arctan[(Y - Y_i)/L_i] \tag{7}$$

In the formula, X_i, Y_i and Z_i represent the i track the Cartesian coordinate measuring instrument. The nonlinear equations into linear equations after Taylor launched, position parameters are calculated using the least squares estimation of target trajectory.

$$\Delta L = A\Delta X + \xi \tag{8}$$

A measurement data track measuring instrument on the target trajectory parameters X, Y, Z of the partial derivative matrix Jacobi,

That is:

$$A^T = \begin{bmatrix} \frac{\partial R_1}{\partial X} & \frac{\partial A_1}{\partial X} & \frac{\partial E_1}{\partial X} & \frac{\partial R_2}{\partial X} & \frac{\partial A_2}{\partial X} & \frac{\partial E_2}{\partial X} & \frac{\partial R_3}{\partial X} & \frac{\partial A_3}{\partial X} & \frac{\partial E_3}{\partial X} \\ \frac{\partial R_1}{\partial Y} & \frac{\partial A_1}{\partial Y} & \frac{\partial E_1}{\partial Y} & \frac{\partial R_2}{\partial Y} & \frac{\partial A_2}{\partial Y} & \frac{\partial E_2}{\partial Y} & \frac{\partial R_3}{\partial Y} & \frac{\partial A_3}{\partial Y} & \frac{\partial E_3}{\partial Y} \\ \frac{\partial R_1}{\partial Z} & \frac{\partial A_1}{\partial Z} & \frac{\partial E_1}{\partial Z} & \frac{\partial R_2}{\partial Z} & \frac{\partial A_2}{\partial Z} & \frac{\partial E_2}{\partial Z} & \frac{\partial R_3}{\partial Z} & \frac{\partial A_3}{\partial Z} & \frac{\partial E_3}{\partial Z} \end{bmatrix} \tag{9}$$

4. The Experimental Analysis

4.1. The Optimization of Multi Station Sensors with Different Application Background Based on GA

When the optimization calculation to the evolution of maximum algebra T, or to find the optimal termination the fitness of the individual and convergence algorithm.

The algorithm flow chart shown in Fig. 3.

4.2. Algorithm Simulation and Results

To track measuring instrument (A, B, C) of cloth stood on the flat area, the range of 30 km × 20 km, the movement of the target trajectory is idealized as a straight line, the height of the target is 6000 m, the trajectory is parallel to the XOZ plane, the target trajectory equation:

$$\begin{cases} x = 200t - 200 \\ y = 6000 \qquad t \in [1,100] \\ z = 25000 \end{cases} \tag{10}$$

Set three track measuring instrument are working under the ideal condition, can satisfy the complete tracking measurement trajectory towards the target, the angle measuring accuracy and same as 23", at the same time, dividing the target trajectory spacing is 200 points, no error, calculate the trajectory measuring instrument for each point should be measured range and the pitch value of A, E, and Gauss white noise in A, E (variance of size 23") to measure the actual condition of the value simulation.

Experience the cloth before optimization and after optimization station form shown in Fig. 4, Fig. 5 (linear motion trajectories for the target to be measured in the XOZ plane projection), the Fig. 6 is cloth station positioning accuracy, through the contrast before and after optimization, optimize embattle later on target positioning accuracy overall have bigger promotion for the test, to obtain the high accuracy data of great significance.

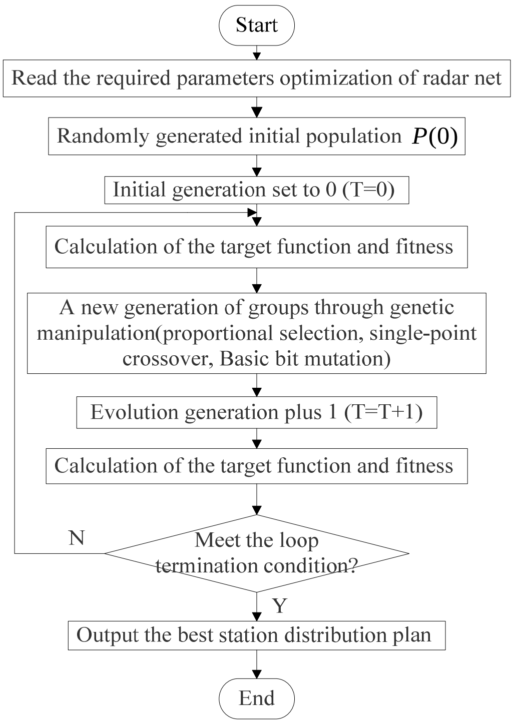

Fig. 3. The algorithm flow chart shown in.

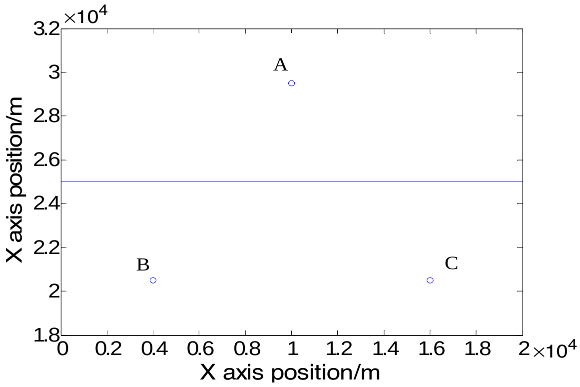

Fig. 4. Experience the cloth before optimization and after optimization station.

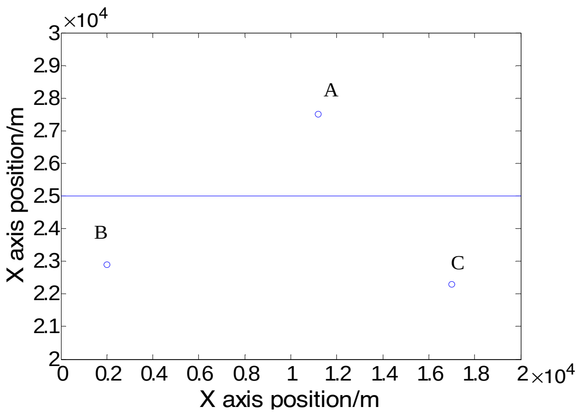

Fig. 5. Linear motion trajectories for the target to be measured in the XOZ plane projection.

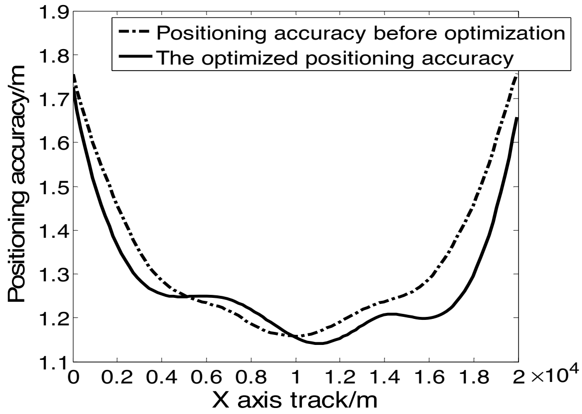

Fig. 6. The cloth station positioning accuracy.

4.3. Optimization of Cloth Minimum Passive Location Sensor Station

In this paper, another angle to lower Carmelo precision positioning error was the object of study. We using TDOA/AOA (time difference of arrival / angle of arrival) passive location sensor system mode of the station layout optimization. By making the CRLB to the target location accuracy error, we find the location sensor optimal station distribution mode.

Fig. 7 shows the evolutionary computation after 10000 generations, optimal station distribution position of passive location sensor, wherein the green star mark corresponding to the main passive locating the position of the sensor. Fig. 8 shows the situation for the station layout optimization process CRLB changes with the evolution algebra.

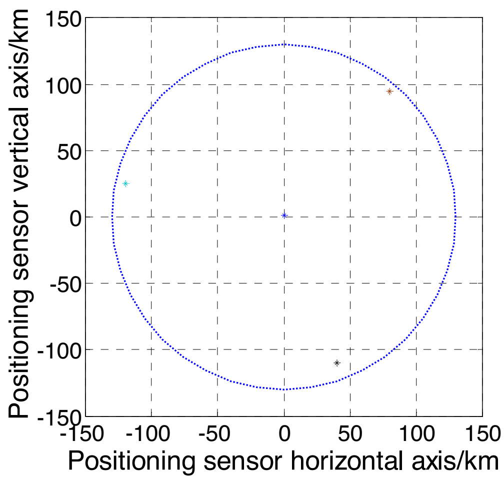

Fig. 7. The evolutionary computation after 10000 generations.

The number of passive positioning sensor invariant, station distribution range unchanged, the operation parameters of genetic algorithm are set the same, different is, the location of the target from the space of a point target into a three-dimensional space of the region, namely:

$$Z_2 : \{x \in [50,100], y \in [50,100], z \in [10,20]\} \quad (11)$$

Fig. 8 shows the evolution of 10000 generations, passive location sensor station distribution of optimal location, blue star standard corresponding is the main passive locating the position of the sensor. Fig. 8 shows the situation during the process of optimization CRLB change with the evolving algebra for cloth station.

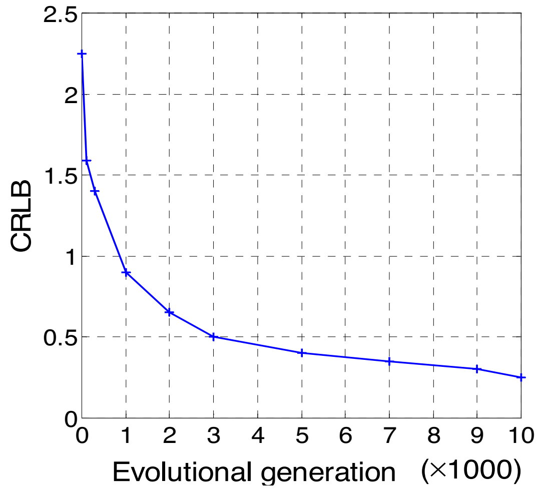

Fig. 8. The situation for the station layout optimization process CRLB.

Optimize embattle results show that the routine use of position and test task of the sensor in the "ten" word or diamond such as cloth station geometry is different, showing the irregular form of station distribution, in this case, the average CRLB positioning error of the system is minimal, precision helps test to maximize access data location, reduce the error.

5. Conclusions

The overall performance of electronic weapon system composed of multiple sensors are often associated with each sensor station layout were closely related, study and optimization of multi sensor station layout, will contribute to the electronic weapon system to achieve the expected performance of the optimal. From the performance test, the test equipment to improve the accuracy of the data, to the tactical training, confrontation training daily, are the need for sensor station distribution research. Further study of multiple sensor station layout and optimization scheme of weapon system test, not only can effectively use and save test resources, speed up the completion of the test time and improve test quality and efficiency, but also has extremely important significance to improve the comprehensive ability of army scientific research test.

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