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Artificial Bee Colony Algorithm Optimization for Human-machine Interface Layout of Cabin Driver's Desk

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Artificial bee colony algorithm (ABC) is an effective and practical of swarm intelligence algorithm, on the basis of the basic principle and calculation process of this algorithm, the artificial bee colony algorithm is applied to the Cabin driver's control desk interface layout optimization. Based on the people-oriented design concept, firstly, based on the artificial bee colony algorithm, the multi-objective optimization calculation is presented and established a consider ergonomics design principles of constraint of Cabin driver's control desk layout optimization mathematical model to solve the problem. In the example, the artificial bee colony algorithm is applied to solve the problem of human-machine interface layout optimization for Cabin driver's control desk. The results of experimental comparison with the literature results, can be seen that the artificial bee colony algorithm is an effective and practical method for this kind of optimization problem.

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1.Introduction

In the complex product system, it should be focused on interface layout of the driver's desk for man-machine interactive operation, of which the scientific and reasonable equipment layout will affect the safety and operation efficiency about operation of the whole product's system. The driver's Desk interface is mainly composed of display and control devices, the layout optimization is important for improving the man-machine devices performance in the cabin, which has to be repeatedly iterated and gradually optimized and thus belongs to the constraint satisfaction problem. The layout of the driver's Desk interface should be considered under the design principle of importance, use frequency, function grouping and use sequence of the objects under different driving situations [1].

The layout issue belongs to NP-complete issue, While the man-machine interactive layout can be regarded as the shape-based Block Layout, SBL. This issue is a typical NP-Hard problem with high complexity, and widely used in aviation, aerospace, shipbuilding, transportation and other industries. Under classical mathematical requirements, there is not enough exaction and efficient solving algorithm. So, finding a more efficient and accurate algorithm to solve this issue is of great significance [2]. Heuristic algorithms were commonly used, such as the improved genetic algorithm (GA), the particle swarm optimization (PSO) and the ant colony algorithm (AC).

The advantage of GA highlights its fast convergence speed and strong commonality, but the defect is easy to premature convergence and slow convergence speed in the late iterations. And the advantage of PSO is rapid convergence and fewer set parameters, faults are difficult to maintain the population diversity in the late iterations and fall into local optimal solution easily; When the problem size increases, the algorithm efficiency decreases obviously. The ant algorithm through the pheromone shared between individuals making the implementation of positive feedback mechanism, improving the efficiency of global optimization. But as the pheromone update ability limitations, the algorithm is easy to fall into local optimal solution, stagnant phenomenon, appearing the stagnant phenomenon;When the problem size increases, the algorithm efficiency decreases obviously.

In recent years, the artificial bee colony algorithm (ABC), as a new intelligent optimization algorithm based on the bee self-organization model and the swarm intelligence, has become a hot spot in the field of optimization research. The research shows that the artificial bee colony algorithm highlights sound adaptability and robustness in solving the optimization problem of multi parameter and multi peak value. At present, the research results is applied to path planning [3], scheduling problem and solution of the constrained optimization problems [4-5].

Although GA, PSO and AC has longer history of development, the research and application is more mature. But as indicated by the research results, ABC algorithm has division of labor and cooperation mechanism, the algorithm is more flexible, more widely more applicable, and easy to combine with other technologies so as to improve the original algorithm, solve continuous optimization problems, in the other hand, solve the combinatorial optimization problem as well. For the purpose of this study involved inmultiple constraint combinatorial optimization problems, on the basis of the behavior of ABC algorithm, it can use the bee optimization between positive feedback mechanism, accelerate the process of global optimization effectively.

This paper attempts to apply the artificial bee colony algorithm to the solution of the driver's Desk layout optimization of the cabin with ergonomics, and quantify the importance of objects into weight value, as the honey content of food source in artificial bee colony algorithm （fitness value), propose the optimization scheme of human-machine interface layout, according to the calculation results, and compare the result with the calculation results of other algorithms.

2.Artificial Bee Colony (ABC)

The artificial bee colony algorithm is a swarm intelligence optimization algorithm to find the optimal solution inspired by gathering nectar of bees, which was put forward by Karaboga Dervis, a Turkey scholar, in 2005. With the advantages of few parameters, fast convergence speed and no easiness of falling into local optimum. the bees are a type of social life, which can collect nectar in a complex environment with high efficiency. The research results showed[6] that the bees were divided into three types according to the role in the process of gathering nectar: scouter, leader and follower. And they gathered honey by exchanging information through a variety of ways, such as swing dance and smelling.

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ABC algorithm generates the initial population of NP solutions (food sources). Firstly, in each solution $X_i(i=1,2,...,NP)$ is D-dimensional vector; then the leader bees are led separately to search the food source (solutions) and compare the nectar quality (fitness) to decide whether to replace the old food by the new or not. All the leader bees fly back to the dance area and convey the information of nectar quality to the follower bees by means of swing dancing after searching, then the follower bees choose the food source according to the following probability Pi, in which the food with more nectar will attract more follower bees to improve the ability of searching for local optimal food source of the swarm. After the local food source collection, the leader bees continue to search for better food sources, in which some leader bees are always unable of searching for better food sources after the searching of limited times, they will become the scouter bees and discard the current region to randomly fly to other places so as to search for better food sources to improve the ability of searching for the global optimal food source of the swarm. Swarm can obtain the best food source in a certain search space with higher efficiency through such a division of the collaborative search process.

In the process of iteration, the bees search for food source by these rules [7]:

1) Both the leader bees and follower bees have half of the swarm;

2) The amount of leader bees and the food sources correspond to each other;

3) The leader bees share the food source information to follower bees , the follower bees select the best food sources and then search for the collection in the neighborhood.

The location of food source in the algorithm is the possible solution to the optimization problem, and the honey content of food source is the fitness value of optimization problem.

The corresponding relationship between the behavior of nectar collecting and the optimization problem include: the nectar source position is corresponding to the feasible solutions to the optimization problems; the nectar content of the food source is corresponding to the fitness; the speed of searching and collecting is corresponding to the optimal solution speed;the food source with highest nectar content is corresponding to the optimal solution of optimization problem. The ABC algorithm process is shown in Fig1.

3.Construction of Cabin Driver's Desk Layout Optimization Model based on ABC

3.1 Project Description

In this real project, the object operation area in front of the driver, and the driver's desk region range is 1200mm*740mm. The desk is the control center of the deep-sea manned submersible, which is used to complete all kinds of operation tasks including starting, diving, floating, mechanical arm operation, camera equipment control by the operators.The problem of device layout with ergonomic design principles can be described as How to place the object to make the smallest plane area in the layout plane dimension. Two common types of man-machine interface device and function grouping are summarized by this research through survey of domestic existing manned submersible and field study combination with interview as follows [8]. The first type is the control device including power switch, mechanical arm, mobile camera control board, intercom, lighting controller, automatic control switch group, of which the layout are required to try to focus on the front of the manned cabin, around the front observation window. The cabin driver's desk interface layout element is shown in Fig 2.

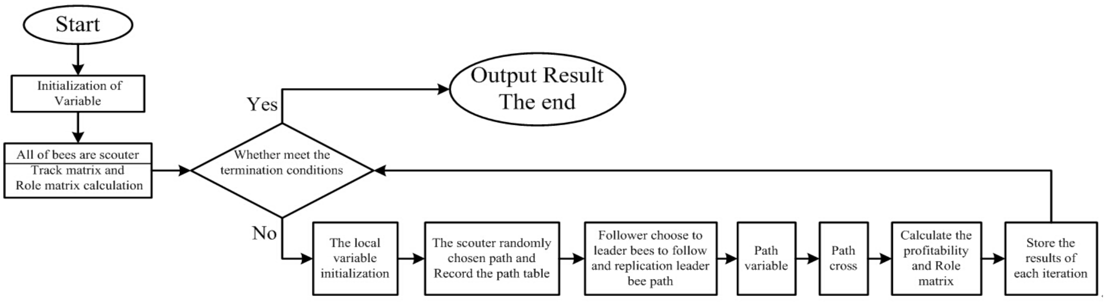

Figure 1: Optimal Layout of Convergence Curves

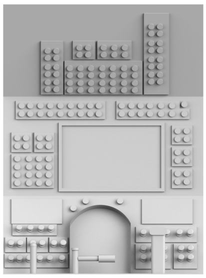

Figure 2: Cabin Driver's Desk Interface Layout Element

The layout of driver's desk in cabin has a high demand of the man-machine characteristic, the quality of the overall layout in the cabin is determined by the comfort, accessibility, the field of vision, and the operation characteristic of man-machine.

Then, Grade the modules by using frequency, operation mode, operation sequence [9], functional importance combined with the comprehensive influence of ergonomics theory for human vision and the range of reachable domain, to make the operation to be simple and easy, reduce the mistake operation, reduce discomfort of the body caused by long time working. The man-machine constraint level target tree of objects should be established and evaluated by the expert group to establish the multiple judgment matrixes corresponding to the level of the man-machine constraint hierarchy of the console so as to calculate the sort weights of computing matrix, in which the project team of man-machine performance in various object modules has been summed up in the paper [10]. And the result is the operation power controller > automatic driving controller > submarine attitude controller > communication transmission controller >= internal environment controller > mechanical arm controller >= signal and information monitor > emergency alarm controller > lighting controller > auxiliary controller.

3.2 Mathematical Model

Based on the above description of the problem, the interface layout objective function can be defined to maximize meet the geometry matching degree about module. The layout problem with man-machine constraint for driver's desk can be described as: a number of things which are placed in a container (rectangular) non-overlapping under the constraint of ergonomic importance degree and how to minimize the area of the container.

The constraint condition includes:

(1) the objects which do not interfere with each other; (2) the objects which should not exceed the boundary of the desk; (3) the same components which can basically meet the principle of symmetry; (4)the component position which can meet the sort requirements of the corresponding human-machine ergonomics.

The mathematical modeling of this problem is shown as follows: in the plane rectangular coordinate system *Oxy*, the length and width of the container are *L* and *W*. The result of layout optimization design is a position parameter of the device, the set of objects to be arranged in a rectangular container is expressed as $X=\{(x_1,y_1),(x_2,y_2),\ldots,(x_n,y_n)\}$, and the position parameter of the $i(i\in X)$ object is x_i,y_i, then the satisfied constraint condition can be expressed as:

(1) Objects which do not interfere with each other, can be expressed as:

$$\begin{cases} S_1=\frac{K_i+K_j}{2}-|x_i-x_j|\le 0 \\ S_2=\frac{T_i+T_j}{2}-|y_i-y_j|\le 0 \end{cases} \tag{3.1}$$

Explaination: *x* and *y* refers to object location parameters; *K* and *T* refer to x of the object *x*, *y* direction size.

(2) the objects which should not exceed the boundary of the desk, can be expressed as:

$$\begin{cases} S_3 = x_i + \frac{K_i}{2} - L \le 0 \\ S_4 = y_i + \frac{T_i}{2} - W \le 0 \end{cases} \tag{3.2}$$

$$\begin{cases} S_5 = x_i - \frac{K_i}{2} \ge 0 \\ S_6 = y_i - \frac{T_i}{2} \ge 0 \end{cases} \tag{3.3}$$

(3)the same components which can basically meet the principle of symmetry;

(4) the component position which can meet the sort requirements of the corresponding man-machine ergonomics [11];

To minimize the objective function,which can be expressed as:

$$\min F(X_i) = \max\begin{Bmatrix} \sqrt{x_i^2+x_j^2}+K_i \\ \sqrt{y_i^2+y_j^2}+T_i \end{Bmatrix} \tag{3.4}$$

In the above formula, *i, j= 1,2,…,n.*

This layout problem reduction constraints the optimization problem into a single objective. Penalty function method can be used to deal with this problem [12]; and it will be easy to solve,the constraint conditions multiplied by the punish coefficient and the constrained optimization problem changinge into nonconstrained problem. The layout scheme of the objective function can be represented as:

$\min f_i=\min F(X_i)+\sum_{j=1}^{6}\lambda_j s_j$, among them $\lambda_i(i=1,2,3,4,5,6)$,

Stand for the constraint conditions of penalty coefficient;

S_j (j = 1,2,3,4,5,6) as the constraint condition of the expression,

The Values: $S_j=\begin{cases} S_j, S_j>0 \\ 0, S_j\le 0 \end{cases}$

3.3 Calculation Process

In the process of artificial bee colony algorithm, the initial population of *n* solutions is initialized, firstly. And then, the follower will produce a new position of food source around the position in the memory , as shown in the Formula (5).

$$\upsilon_{ij}=x_{ij}+\varphi_{ij}(x_{ij}-x_{kj}) \tag{3.5}$$

Among them, $k\in\{1,2,...,n\}$ and $k\neq i$, $k\in NP$, $j\in\{1,2,...,m\}$, stand for a component in m dimensional vector $\varphi_{ij}\in[-1,1]$.

In the process of iteration, the optimal solution is remembered by Leader and adopts the principle of greed, in comparison with the optimal solution and the other solutions which have already been found. If the new food with honey is higher than the old food source, it will give up the old optimal solution, save the new optimal solution, otherwise it will remain unchanged. When all the Leader search to the source of information, then share information with Follower.

After the acquisition of the food source, the follower will choose to collect the food source with certain probability, as shown in the Formula (6).

$$p_j = \frac{fitness_j}{\sum_{i=1}^{n} fitness_i} \tag{3.6}$$

$$x_i^j = x_{\min}^j + rand()(x_{\max}^j - x_{\min}^j) \tag{3.7}$$

In which,the $fitness_j$ stand for the amount of honey at the food source j.

In the algorithm, if the bees find a food source in the iteration of certain limited times, its $fitness_j$ value will not change and the bees should give up to continue mining,the leader changes into scouter, to research for new food sources. ABC algorithm will use the following Formula (7) to search for new food sources.

Among them, X stands for the food source which will give up, $j\in\{1,2,...,m\}$, Using the artificial bee colony algorithm, the local optimal food source can be searched by the collecting bees and judged bees, which will research the global best food source. This algorithm can achieve the optimal solution development ability and balance the exploration ability of the entire search space.Using Artificial Bee Colony algorithm to achieve the layout optimization for the man-machine interface as follows:

Step1: initialization of artificial bee population , generate populations with *n* solutions;

Step 2: calculate the fitness value of each food source, take the fitness (weight value) of the largest object, place in the area of the largest human machine constraint;

Step 3: the scouter finding the new position around the food source, Leader chooses the food source and the follower gather honey;

Step 4: according to gather in front of the content information, the leader finished the choice and localization for m times, and record the location coordinates and honey content information, Follower abandons the food source;

Step 5: repeat Step3,4,until finish all objects;

Step 6: repeat Step 2 and compare the honey content information the layout twice.If the containing honey value is greater than the previous value, replace the original coordinate; Otherwise, retain the original coordinate;

Step 7: under the same situation,repeat Step 4;

Step 8: iterative n times, determine whether to reach the termination conditions or not, until there is no honey content information to replace, then, in the end of the algorithm; otherwise do Step 2.

4.Example Practice

In order to test the ABC algorithm performance in the project practice, choosing the parameter of length(K/mm), width (T/mm), Interference quantity ($\Delta S/mm^{2)}$ and computing time(t/s) as evaluation index of algorithm performance. In comparing with other algorithms, adduce numerical examples from other documents. The examples are cited in a paper [12],there are 26 objects, including 22 control device, 4 Indicator light, driver's desk as the research object, the size is 1200 mm x 740 mm.

ABC algorithm is to solve man-machine interface layout problem by using Matlab programming calculate. Experiments running in PC:2.40 GHz CPU, RAM 8 GB. The example randomly runs 100 times. In ABC algorithm, the population size of NP = 10, parametric dimension D = 14, the largest number of search limit = 500, 500 iterations. Experimental results express,the application of ABC algorithm to calculate the fitness value of convergence curve is shown in Fig 3and the optimal layout results are shown in Figure 4.

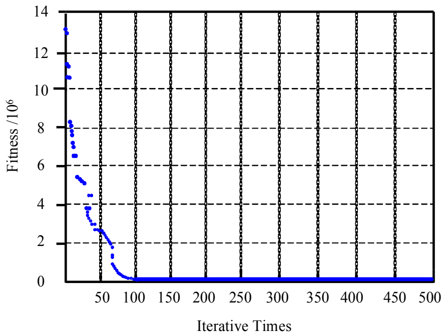

Figure 3: The optimal layout of convergence curves

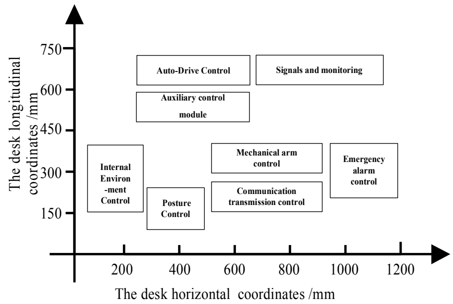

Figure 4: The optimal Layout results

Ones paper by using the particle swarm algorithm, set the particle swarm population size n = 10 [12]. The computing speed can be controlled in an acceptable range. Learning factor c 1 =c 2=2, the maximum number of iterations t = 100. The total number of iterations matching degree curve as shown in Fig 5. Table 1 display the performance comparison between ABC algorithm and the algorithm proposed by Chen Dejun[12].

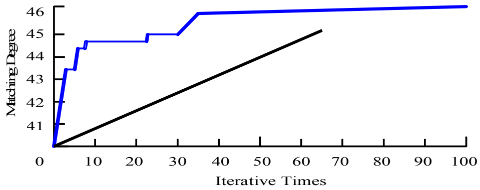

Figure 5: Total Number of Iterations Matching Degree Curve

Calculation method	Object Length (*K/mm*)	Object width (*T/mm*)	Interference quantity ($\Delta S/mm^2$)	Computation time (*t/s*)
Chen Dejun proposed	≤50.246	≤32.676	0	267
ABC	≤50.967	≤32.551	0	185

Table 1: Performance of the optimal Layout

The example optimal solution by using ABC algorithm compared with the algorithm proposed by Chen Dejun[12], although the object maximum length larger than the algorithm proposed by Chen Dejun[12], but the computing time reduces (267-185) / 267 = 30.7%. It can be seen that ABC algorithm for solving the two-dimensional layout problem with performance constraints has high convergence speed and precision. At the same time the conclusion from Fig.1 also shows that, the numerical example given the iterations number is 500 times, and the program runs to 100 ~ 150 times that it has reached a quite high accuracy, but the convergence speed slows significantly after 150 times, which indicate that the ABC algorithm search speed will slow down when the near optimal solution is even trapped in local optimal solution.

5. Conclusion

The calculation results show that the modules of submarine attitude control, mechanical arm control, communication transmission control with high importance and high use frequency should be arranged in the best control area. The mechanical arm controller is at the upper right side of the submarine attitude controller and above of the communication transmission controller, while the emergency alarm controller module is arranged at the right side of the communication transmission controller, in order to meet the requirements by the using sequence among the module, all the position relations between the submarine attitude controller and the mechanical arm controller, automatic driving controller and mechanical arm controller, automatic driving controller and signal and information monitor, internal environment controller and auxiliary operation controller can meet the requirements of the operation space compatibility; the distance between the modules match the definition of Expression (4) according to the distance check by the coordinate system in figure.

In this case, calculate by 100 times.The optimal solution total matching degree is 46.1374, the ratio of optimal solution obtained is 91.6%, and the average number of iterations is 28.7642, which all indicate the model has a high efficiency in the use of artificial bee colony algorithm, and prove the parameter setting in this layout example, whichis reasonable.A layout result with relatively high satisfaction can be obtained by the application of the layout model and algorithm in this paper. It indicates the validity and practicability of solving this kind of problems by this method, which can make contribution to solvine all kinds of man-machine interface layout optimization problem.

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