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Research on Quick Decision Technology of Liquid Cargo Supply's Program

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Abstract: The liquid cargo replenishment decision based on ship's stability, strength and the floating state is a multi-objective optimization problem. The mathematical model of multi-objective is built in this paper. Aiming to obtain the feasible solution, the adaptive step ergodic of permutation and combination is applied in terms of the cargo oil tank and the water ballast tank. particle swarm optimization (PSO) algorithm is applied into the project. On the basis of constraint conditions, the multi-objective optimization function is proved and take it into real operating mode for calculation and analysis. Improved objective function that is built based on multi-objective mathematical model. Taking real calculation example to verify the effectiveness of improved function and PSO algorithm. The result is good and the time complexity and mathematical precision are both improved effectively.

1. INTRODUCTION

In the whole replenishment process, Ship's own liquid volume changes greatly, these changes will have a great impact on the state of the ship itself, so to ensure stability of replenishment ship moderate during the replenishment. How to solve this problem above is important for the driver's request, the captain should choose which cargo tanks and ballast tanks for supplying liquid based on his own work experience. Decision-making often refer to the ship's loading manual, ship design specifications, and this whole process is very time-consuming. In order to reduce labor intensity of manual operation and accurately calculate state parameters of ship, appropriate quick decisions procedures are needed to develop to safeguard replenishment speed and safety of ship.

Decision-making problem is the process of finding the best option from all of the feasible alternatives. In almost all such problems the multiplicity of criteria for judging the alternatives is pervasive. That is, for such problems, the decision maker wants to solve multi-objective problem (MOP). In this paper, the MOP is changed into single-objective problem (SOP) for solving problem more easily [3]. Particle Swarm Optimization algorithm is introduced into the SOP under ship's strength and stability constrains and a new improved multi-objective function is proposed.

PSO is a global optimization algorithm based on the theory of swarm intelligence, Kennedy and Eberhart inspired by the foraging behavior of birds, created the original particle swarm optimization in 1995 [1-3]. There are a plurality of constraints inside the liquid cargo replenishment decision problem, we need to search for the optimal supply plan and the decision to meet the various constraints in conditions. In this paper, PSO algorithm is used on the liquid cargo replenishment decision-making problem based on ship's stability, strength and the floating state constraints. In PSO algorithm, multiple targets can be processed simultaneously so the most reliable, and fastest replenishment schemes will be got quickly.

2. THE MATHEMATICAL MODEL OF LIQUID CARGO REPLENISHMENT SCHEMES DECISION

The decision problem needs to dispense fuel from different liquid cargos, it will have an effect on ship's stability.

So some strength and stability constrains are shown as follows:

(1) The absolute value of heeling angel is less than 0.50;

(2) $\overline{GM}$ GM>0.75 m;

(3) Trim angel is less than <0.4%L (ship length), and as big as better. In this paper the value range from -0.9 m-0 m.

We changed MOP model to SOP model, and weighted method is used to establish the objective function, set three weight w1, w2, w3, for three constraints above.

The mathematic model is as follows:

$$\min_i \quad F(f_i) = w_1 f_i(\alpha) + w_2 f_i(t) + w_3 f_i(GM)$$

$$\text{subject to} \quad \begin{cases} |\alpha| < 0.5^\circ \\ -0.9m \le t \le 0m \\ GM > 0.75m \end{cases} \tag{1}$$

$$f(t) = \frac{|t|}{\max\{|t|\} - \min\{|t|\}} \tag{2}$$

$$f(\alpha)=\frac{|\alpha|}{\max\{|\alpha|\}-\min\{|\alpha|\}} \tag{3}$$

$$f(GM)=\frac{GM_{\max}-GM_{\min}}{GM} \tag{4}$$

$F(f)$——objective function;

GM——initial stability height of replenishment ship;

α——heeling angle of replenishment ship;

t——trim angle of replenishment ship;

w_1——weight value of objective function's heeling angle;

w_2——Weight value of objective function's trim angle;

w_3——Weight value of objective function's initial stability height;

The three weight values of w_1,w_2,w_3 can be determined by analytic hierarchy process. According to user feedback and expert system the decision making judgment matrix is [4]:

$$A=\begin{Bmatrix} 1 & 2 & 2 \\ 1/2 & 1 & 1 \\ 1/2 & 1 & 1 \end{Bmatrix} \tag{5}$$

By calculating eigenvalues and eigenvector of the judgment matrix and normalized the matrix, three weight value is $w=(w_1,w_2,w_3)=(0.5,0.25,0.25)$, so function (1) can be changed into (6) as follows:

$$F(f_i)=0.5f_i(\alpha)+0.25f_i(t)+0.25f_i(GM)$$
$$\text{subject to}\quad \begin{cases} |\alpha|<0.5^\circ \\ -0.9m\le t\le 0m \\ GM>0.75m \end{cases} \tag{6}$$

3. LIQUID CARGO DECISION PROBLEM BASED ON PSO ALGORITHM

3.1. Standard PSO

Particle Swarm Optimization (PSO), also known as fine grain swarm optimization, had been developed into evolutionary computation technique by Kennedy and Ebehtart, and so on in 1995, which comes from simulation of a simplified social model. The mathematical description is:

Assume search space of each particle is D, and the total number of particle is n, position of i-particle is expressed as vector $x_i=(x_{i1},x_{i2},...x_{iD})$; The optimal location of i-particle is $p_i=(p_{i1},p_{i2},...p_{iD})$ can be noted pBest and the optimal location of whole particle swarm is $p_g=(p_{g1},p_{gi2},...p_{gD})$ noted gBest. Particle velocity of each dimension and position in the evolutionary process changes as follows:

$$v_{id}(t+1)=wv_{id}(t)+c_1rand()\cdot[p_{id}(t)-x_{id}(t)]+c_2rand()\cdot[p_{gd}(t)-x_{id}(t)] \tag{7}$$

$$x_{id}(t+1)=x_{id}(t)+v_{id}(t+1)\qquad 1\le i\le n,1\le d\le D \tag{8}$$

While *c1* and *c2* called as cognitive and social parameters are non-negative constant; *rand()* are the random numbers between [0, 1]; and w is inertia weight which reflects the choices of algorithm between global search and local search. Usually a range for each dimension of particle position and velocity needs to set, if exceeding this range, a boundary value must be set. Initial location and velocity of particle swarm generate randomly.

Definition of PSO algorithm is relatively clear and easy to understand [5], easy to operate, it is an in-depth study method belongs to the field of intelligent optimization algorithms and suitable for Scientific computing and engineering applications.

3.2. Mathematical Model of the Replenishment Scheme Decision Based on PSO

This chapter uses particle swarm intelligence algorithm [6, 7] for iterative solver. And then from a mathematical point of view of intelligent algorithms to solve practical problems. through repeated iterations finally able to get the global optimal solution needed.

The dimensions of the search is set to 6, so one particle $X_i=(x_{i1},x_{i2},x_{i3},x_{i4},x_{i5},x_{i6})$, fitness function of each particle on the use of multi-objective optimization problem's objective function (6) [8, 9]. Update the speed and position according to the formula (7). Select acceleration factor of 1.8. The position value of each particle is the fuel volume to be assigned for each tank, according to calculation formula of ship's stability, we can get. angle of heel, trim values, high initial stability GM values. Then linear combination of these three values get fitness function. Assume the fitness function is as follows [10]:

$$f(x_1,x_2,x_3)=0.5x_1+0.25x_2+0.25x_3 \tag{9}$$

Iterative fitness function until the error value between each of the obtained within a fixed value. The algorithm iteration time is short, the result of high accuracy, both to meet the time requirements of the project, but also to the mathematical precision.

4. EXAMPLE OF CALCULATION AND ANALYSIS USING PSO

The initial state of example is shown in Table **1**.

Table 1. The initial state of ship.

Displacement (t)	Aft Draft (m)	Fore Draft (m)
48000	10.516	11.023
α (^{0})	t (m)	GM (m)
-0.18	-0.507	1.553

We set there is only one kind liquid cargo need to supply and the amount of liquid supply is 100t.

Firstly, the amount of oil tank is divided into 10 parts and every part is set to be a fixed step length for supplying. So there are 11 kinds of oil tank residual quantity state: 0t; 10t; 20t…; 100t, 0t represents amount of oil is empty and 100t represents amount of oil is not needed to supply.

In the second search, the search step lengths is 1t and continue searching with the supply's quantity is already determined in first search above. Searching will not stop until find a better solution.

According to PSO algorithm, first initialize discharge amount of each tank. The calculation result is shown in Table **2**: C1 to C6 Correspond discharge amount of tank 1 to tank6, F is value of the fitness function.

In Table **2** when precision error of fitness function F is 10-3 and the number of iteration is 5, function values achieved within the accuracy. The discharge amount of each tank are 38.06t , 0.62t , 0t , 0.54t , 1.97t , 58.81t. After supplying based on replenishment scheme above, the angle of heel is 0 degree, trim value is -0.55 m and GM is 1.59 m. These calculation results verified method be researched in this paper is effective. The unit of oil is ton in scheme above and precision error is 10-3, the precision is within the Precision range and meet the needs of the project. In order to improve the precision range of mathematical sense, the precision error can be reduced to 10-5. The result is shown in Table **3**.

When the precision error is 10-5, 40 size of the particles iterated 11 times, the result is : angle of heel is 0 degree, trim value is -0.5465 m and GM is 1.604 m. It is better than result in Table **2**.

Examples of calculations can get the conclusion: when set to a fixed Precision, particles can always find the ideal location to make fitness function to obtain a minimum value within a certain range. So the problem in this paper, always can search a best replenishment scheme to meet the require of project.

5. IMPROVED MULTI-OBJECTIVE DECISION-MAKING FUNCTION

In the actual process of replenishment, floating state and the ship's stability has a goal state, according to the end of the state to be close to the target value [10]. We improved the multi-objective decision-making function, it is shown as follows:

$$Object[i] = \frac{1}{Y_a[i]+1} + \frac{Max - Min}{Max\_ - Min\_ + |GM[i]| - GM\_} + \frac{Max - Min}{Max - Min + |t[i] - t\_|} \qquad (10)$$

$Ya[i]$ ——the number of ballast tanks used in ith program;

$Max\_$ ——GM maximum value in all Feasible programs;

$Min\_$ ——minimum GM value in all Feasible programs;

Table 2. Calculation results.

Iterations	C1 (t)	C2 (t)	C3 (t)	C4 (t)	C5 (t)	C6 (t)	F	α (^{0})	t (m)	GM (m)
1	10.35	0	0	0	7.88	81.77	4.61	0.34	-0.53	1.6
2	37.69	0.59	0	0.8	1.97	58.94	2.96	0.01	-0.55	1.59
3	37.69	0.59	0	0.8	1.97	58.94	2.96	0.01	-0.55	1.59
4	38.06	0.62	0	0.54	1.97	58.81	2.93	0	-0.55	1.59
5	38.06	0.62	0	0.54	1.97	58.81	2.93	0	-0.55	1.59

Table 3. Calculation results for Accuracy of 10-5.

Iterations	C1	C2	C3	C4	C5	C6	F		t	GM
1	10.3478	0	0	0	7.8838	81.7684	4.6089	0.34	-0.5477	1.608
2	37.6935	0.5916	0	0.8018	1.9702	58.9428	2.9641	0.01	-0.5475	1.606
3	37.6935	0.5916	0	0.8018	1.9702	58.9428	2.9641	0.01	-0.5475	1.606
4	38.0589	0.6183	0	0.5409	1.9722	58.8098	2.9345	0.01	-0.5475	1.605
5	38.0589	0.6183	0	0.5409	1.9722	58.8098	2.9345	0	-0.5475	1.605
6	38.0589	0.6183	0	0.5409	1.9722	58.8098	2.9345	0	-0.5475	1.605
7	38.0589	0.6183	0	0.5409	1.9722	58.8098	2.9345	0	-0.5473	1.605
8	38.069	0.6162	0	0	1.9461	59.3686	2.9343	0	-0.5472	1.605
9	38.0181	0.5946	0	0.0404	1.9792	59.3678	2.9341	0	-0.5471	1.605
10	37.9817	0.5971	0	0	2.0339	59.3873	2.934	0	-0.5470	1.605
11	37.9817	0.5971	0	0	2.0339	59.3873	2.934	0	-0.5465	1.604

$GM[i]$ ——GM value in ith program;

$GM\_$ ——GM target value;

Max ——Trim maximum value in all Feasible programs;

Min ——Trim minimum value in all Feasible programs;

$t[i]$ ——Trim value in ith program;

$t\_$ ——Trim target value;

When Ya[i], GM, t_ are close enough to their own target values, each sub-formula is more close to 1. So that the value of Object[i] is greater. We can choose the biggest result as a relative optimum scheme.

In order to verify the correctness of the function (9), Simulation calculated according to 5 kinds supply conditions in Table **4**, the amount of fuel generated randomly. Each data takes two-out program to compare with.

Assume target value in Table **5**. After calculation, the calculation results are shown in Table **6**.

Table 4. Supply request data form.

	Fuel Oil (t)	Diesel Oil (t)	Fresh Water (t)	Jet Fuel (t)
Condition 1	800t	600t	100t	200t
Condition 2	800t	600t	150t	250t
Condition 3	1000t	800t	200t	300t
Condition 4	1200t	1000t	300t	300t
Condition 5	1400t	1000t	400t	400t

Table 5. Target values.

Target	*GM*	*t*
Values	1.5	-0.6

From Figs. (**1**, **2**), the result of GM shows a good performance, While the first two cases the value of the trim

Table 6. Improved algorithm results comparison.

	Selected Scheme		Phase-Out Program 1		Phase-Out Program 2	
	GM (m)	*t (m)*	*GM (m)*	*t (m)*	*GM (m)*	*t (m)*
Condition 1	1.585	-0.825	1.677	-0.582	1.602	-0.780
Condition 2	1.570	-0.865	1.597	-0.618	1.586	-0.511
Condition 3	1.595	-0.575	1.620	-0.579	1.548	-0.735
Condition 4	1.524	-0.572	1.524	-0.572	1.536	-0.585
Condition 5	1.504	-0.593	1.504	-0.593	1.525	-0.551

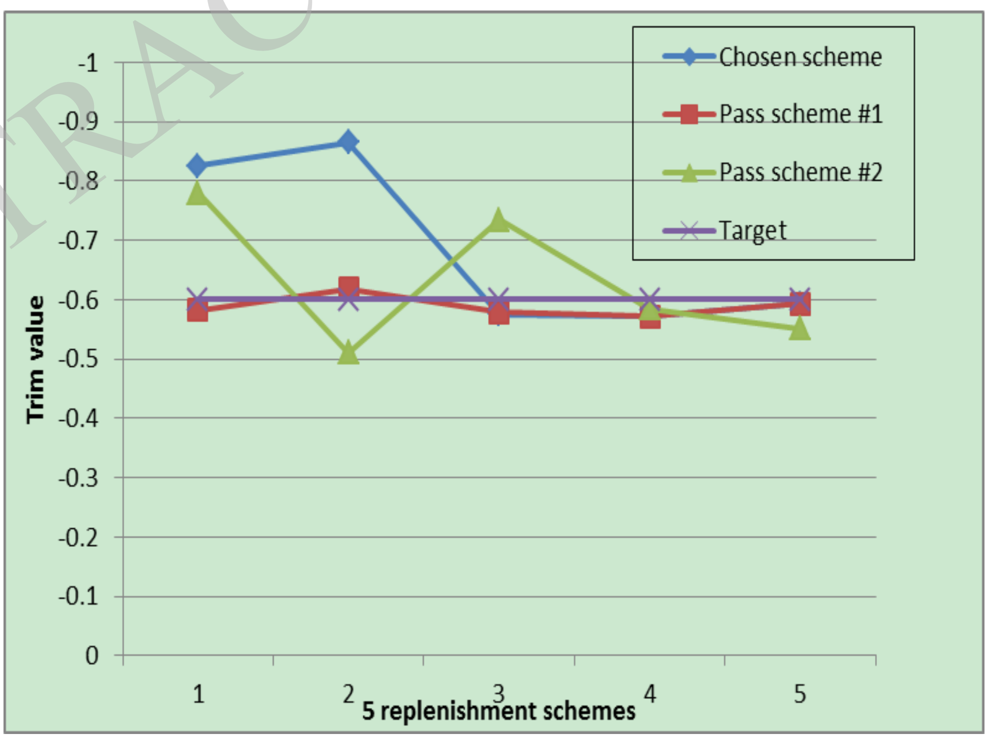

Fig. (1). Trim value. **Notes:** The trim value diagram shows the trim values after finishing supplying in 5 different replenishment schemes.

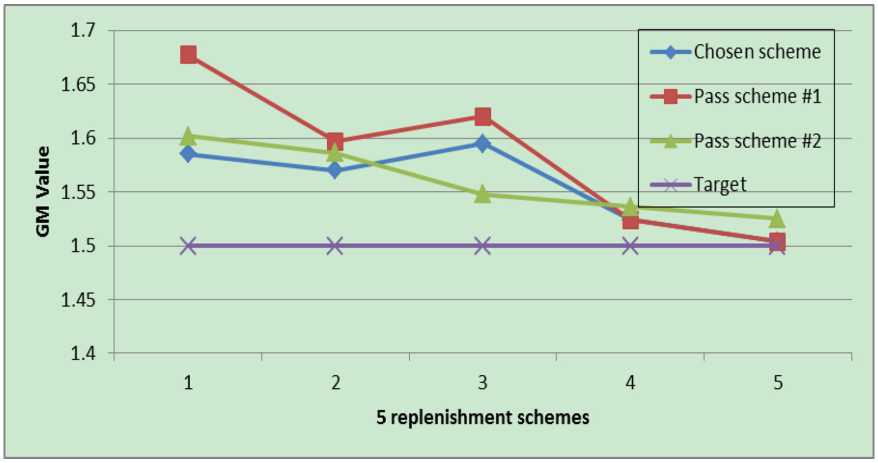

Fig. (2). GM value. **Notes:** The GM value diagram shows the GM values after finishing supplying in 5 different replenishment schemes.

is not particularly desirable, but it corresponds to the other indicators are relatively best. After the multi-objective function improved, calculation solution trend by using iterative was relatively stable. Improved equation can be considered to meet the requirements of the target value and suitable for replenishment target value theory decision problem and verify the rationality of the function (9).

For a clear analysis of ship's trim value and GM after supplying under different replenishment scheme and put the result into Figs. (**1**, **2**).

From Figs. (**1**, **2**), the result of GM shows a good performance. While the first two cases the value of the trim is not particularly desirable, but it corresponds to the other indicators are relatively best. After the multi-objective function improved, calculation solution trend by using iterative was relatively stable. Improved equation can be considered to meet the requirements of the target value and suitable for replenishment target value theory decision problem and verify the rationality of the function (9).

CONCLUSION

For liquid cargo replenishment scheme decision problem, when a supply require comes specific supply scheme should be given out. From mathematical intelligent optimization algorithms point of view, use PSO algorithm to iterative for calculating best result of fitness function. Then solve the problem from the mathematically. Thus overcoming the contradictions between the time complexity and precision of Solutions of engineering solutions. In order to increase the accuracy of calculations, the multi-objective function was improved. Through the calculations of different kinds replenishment working conditions based on improved function in section 5, and the simulation results were compared with phase-out results were better. It verified the fitness and correctness of improved function presented in this paper.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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