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The Analysis on Comprehensive Optimization of Performance of a Certain UUV and Research on Optimization Algorithm

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Abstract

Taking the comprehensive performance of a certain flat unmanned unmanned vehicle (UUV) including its rapidity, maneuverability and energy system into consideration, this paper selected 35 parameters as design variables, constructed the total objective function in the form of weighted sum, and finally established a comprehensive optimization mathematical model of UUV, based on constraint conditions. Through the usage of genetic algorithm of growth mechanism and particle swarm optimization (PSO) algorithm, combined with external hierarchical and parallel strategy, optimization algorithm was designed, and then comprehensive optimization software was compiled to analyze the relevant calculation. The results indicated that these two algorithms would have the best results in the optimization of the 4000th generation, both of which had good effect; hierarchical and parallel strategy could improve the optimization effect of algorithm; rapidity optimization system had greater influence on the total optimization system; and what's more, some parameters of the two kinds of algorithms and some optimal values of key variables including speed were obtained in this research.

Keywords: *Underwater unmanned vehicle, Comprehensive optimization, Genetic algorithm of growth mechanism, Particle Swarm Optimization, Key Variables.*

1. Introduction

With the increasing amount of global energy usage, the land resources are gradually exhausted. All the countries are starting to invest large amounts of money and manpower to explore the ocean and develop marine technology. As one of an essential tool for deep sea exploration, UUV has attracted more and more attention from researchers in various countries[1]. In the military field, UUV can be used as the carrier of submarine for self-defense and attack, due to its small volume, flexible use mode, long duration, high performance and the variety appearance and arrangement, etc. In the civilian field, UUV has some functionalities, such as the research and development of deep sea, marine biology, physics, chemistry and geology investigation, exploration samples of undersea resources, laying and installing underwater pipeline, detection and removal of fault of underwater instruments and equipment.

The design system of the UUV involves many disciplines and its design process is more complicated. The traditional design method is carried out step by step. This lead to low efficiency and high cost, and because without considering the coupling relationship between different disciplines, the overall performance of the UUV designed is not necessarily optimal. For the UUV design, multidisciplinary design optimization (MDO) is the most representative method, which is used to design such a complex system[2-4]. MDO method fully considers the coupling effect among different disciplines, and then the integrated optimal solutions of complex system can be obtained easily and efficiently. And because MDO is a concurrent design of multiple disciplines, the design cycle is greatly shortened, and the design cost is reduced significantly.

This paper selects a flat type of UUV as research object, then established a comprehensive optimization mathematical model. Through the usage of genetic algorithm of growth mechanism and particle swarm optimization algorithm, combined with optimization ideas of external hierarchical and parallel strategy, the research of optimization algorithm and analysis of multidisciplinary optimization of the UUV was realized. On the one hand, this paper offers some reference for the analysis of the advantages and disadvantages of different optimization algorithms; on the other hand, this will provide a basis for future research on comprehensive performance of UUV.

2. Introduction of optimization algorithm

2.1 Genetic algorithm of growth mechanism

The basic idea of genetic algorithm is based on Darwin's theory of evolution, Weizmann's theory of species selection and Mendel's theory of population genetics. It is a algorithm that process to search the optimal solution by simulating the biological genetic mechanism and evolution in nature. Genetic algorithm can find the global optimal solution in a very high probability, and it does not need the gradient information of the objective function and the constraint condition, which is suitable for engineering optimization design. The global search ability of genetic algorithm is strong, and can be close to the global optimum at a faster rate. But its local search ability is poor, to find the global optimum, a large number of the fitness value of the objective function is needed, and the amount of calculation increased significantly.

The general genetic algorithm uses roulette mechanism, the main characteristics of the roulette mechanism are the large probability of the large individual's fitness value is chosen to be the next generation. Such mechanisms tend to result in a large number of repeat individuals in the next generation (individuals with large fitness values), so that the population in the process of evolution has lost the diversity. Taking into account the above reasons, the carrier mechanism was used in genetic algorithm, the improvement idea is, when the initial population is generated, the worst parts individuals of the next generation are randomly generated according to the characteristics of the several best individuals in the last generation in the neighborhood. This can not only ensure the evolution of the population towards the best individual, but also ensure that the population preserve the original features of individuals of the last generation. Of course, the accomplish of the improved algorithm involves three parameters: according to the characteristics of the number of individuals to produce a new individual, the range of the neighborhood and the number of the next generation of individuals to be eliminated. Because each generation of computing, the population is updated with the optimal direction and every generation is growing up, therefore, the definition of this kind of genetic algorithm for the genetic algorithm of growth mechanism.

2.2 Algorithm of particle swarm optimization

The basic idea of particle swarm optimization algorithm is derived from the migration and clustering characteristics of birds foraging. It is similar to other evolutionary algorithms, and also has the concept of "population" and "evolution". Search for the optimal solution of complex space by the behavior of cooperation and competition among individuals. But particle swarm optimization algorithm does not exist the crossover, mutation, selection and other evolutionary operations. It takes a particle of no mass and no volume as an individual in a population and the particle is moving at a certain speed in the search space. In the course of the movement the particle has the individual extreme value and the global extreme value. Individual extreme value is the optimal solution in the search process of the particle, and the global extreme value is the optimal solution in the whole population history. According to the information of these two extreme values, the particle can update the speed and position of its own flight to the best position. The algorithm has strong global search capability and is easy to be realized. It has been widely used in the fields of science and engineering.

The particle swarm optimization algorithm is characterized by the particle in the population fly to its own historical best position and the best location of the group's history. The algorithm is easy to fall into local extreme value and premature convergence. In addition, the performance of the particle swarm optimization algorithm is dependent on the setting of algorithm parameters, the parameters mainly have the maximum speed, the two acceleration constants and the inertia constant The setting of parameter values greatly affects the search ability of the algorithm. Because the trajectory of the particle position update formula is not controllable, this makes the particle cycle beat in the solution space, so the maximum speed is used to limit the speed. Increase the maximum speed is conducive to global search, reduce the maximum speed is conducive to local development. But the maximum speed is too high, the particle motion may cross the optimal solution in the location, leading to the algorithm is difficult to converge; on the contrary, the maximum speed is too small, the algorithm may fall into local extreme value. The choice of maximum speed is usually given by experience, and is generally set to the 10-20% of the problem space. Particle swarm optimization algorithm has been proved to be a simple and effective algorithm in the study of single objective optimization and multi-objective optimization, which has been developed rapidly in recent years.

3. Establish the optimization mathematical model of unmanned underwater vehicle

In this paper, the optimization of unmanned underwater vehicle including rapidity, maneuverability and energy system. Firstly, 35 parameters are selected as optimization design variables. Then, the total objective function is established in the form of weighted sum of three sub objective functions and combining the penalty function to get the fitness function. Finally, constraints of equality and inequality constraints are constructed.

3.1 Design variable

The research object of this paper is a flat unmanned underwater vehicle with cross rudder, as shown in figure 1.

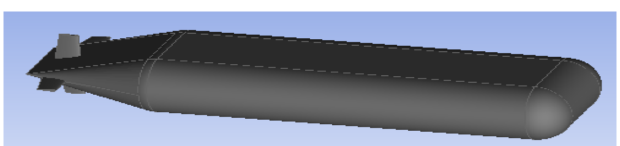

Fig. 1 Geometry model of flat unmanned underwater vehicle with cross rudder.

There are many factors affecting the rapidity, maneuverability and energy system of unmanned underwater vehicle. Considering all kinds of factors that affect the performance of the hull, the paper selected the following 35 design variables:

Table 1: The range of design variable

NO.	Design variable	Unit	Upper and lower limit
1	The length of bow(L_h)	m	0.5013~0.6127
2	The length of middle hull(L_m)	m	5.4819~6.7001
3	The length of stern(L_a)	m	1.9368~2.3672
4	The width of the hull(B)	m	2.0772~2.5388
5	The height of the hull(H)	m	1.014~1.114
6	The longitudinal position of barycenter(X_g)	m	-0.04~-0.03
7	Longitudinal coordinate of forward looking sonar(X_h)	m	3.7~3.72
8	Longitudinal coordinate of communication sonar(X_e)	m	3.3~3.32
9	Longitudinal coordinate of lifting GPS(X_{Gps})	m	0.567~0.577
10	Longitudinal coordinate of communication antenna(X_l)	m	0.115~0.118
11	Longitudinal coordinate of emergency communication sonar(X_y)	m	-1.31~-1.3
12	Longitudinal coordinate of front rings(X_{d1})	m	3~3.08
13	Longitudinal coordinate of back-end rings(X_{d2})	m	-1.535~-1.515
14	The longitudinal position of buoyant center(X_f)	m	-0.23~-0.21
15	Propeller diameter(D_p)	m	0.36~0.55

16	Propeller solidity ratio(A_e/A_0)		0.62~0.7
17	Propeller rotational speed(N)	r/min	340~360
18	Pitch ratio(γ)		0.85~1.05
19	Design speed(V_s)	kn	2.9~3.1
20	The outer end length of the horizontal rudder(d_{oh})	m	0.2~0.4
21	The inner end length of the horizontal rudder(d_{ih})	m	0.3~0.43
22	The height of the horizontal rudder(Z_h)	m	0.6~0.72
23	The outer end length of the vertical rudder(d_{ov})	m	0.2~0.4
24	The inner end length of the vertical rudder(d_{iv})	m	0.3~0.43
25	The inner end length of the vertical rudder(Z_v)	m	0.5~0.75
26	Longitudinal position of the rudder(X_r)	m	-4.05~-4
27	The sailing time of design speed(x)	h	150~250
28	Propeller rotational speed at the speed of V_1(N_1)	r/min	100~500
29	Propeller rotational speed at the speed of V_2(N_2)	r/min	500~1000
30	The reduction coefficient of height(β)		0.7~0.8
31	The ratio of the length of energy tank and the length of middle hull(ζ)		0.35~0.5
32	The number of battery box in the direction of coxswain(m)		5~9
33	The number of battery box in the direction of the wide of boat(n)		2~5
34	The number of battery cassette in the battery box(v)		7~11
35	The number of battery in the battery cassette(u)		2~6

3.2 Objective function

In this system, there are three speed: design speed Vs, balance speed V1 and balance speed V2. V1 was 2 kn and V2 was 5 kn. The ratio of the V1 navigation time and Vs navigation time is k1, the ratio of the V2 navigation time and Vs navigation time is k2, here k1, k2 are taken 0.1. In this paper, the unmanned underwater vehicle has three sub objective functions of rapidity, maneuverability and energy system. The total objective function of the optimization mathematical model is composed of three sub objective functions in the form of weighted sum, and combining the penalty function to get the final fitness function.

3.2.1 Objective function of rapidity

The Navy coefficient includes all aspects of the ship resistance and propulsion performance and it can be used for evaluation of ship rapid performance. In this paper, the Navy coefficient is used to measure the rapid performance index of unmanned underwater vehicle.

The formula of Navy coefficient is:

$$C_{sp}=\frac{V^2\Delta^{2/3}(\eta_R\eta_0\eta_s\eta_H)}{R_t}$$

(1)

The rapidity objective function is as follows:

$$C_S=\frac{1}{1+k_1+k_2}C_{sp1}+\frac{k_1}{1+k_1+k_2}C_{sp2}+\frac{k_2}{1+k_1+k_2}C_{sp3}$$

(2)

Where C_{sp1}、C_{sp2}、C_{sp3} respectively are navy coefficient of design speed V_s, balance speed V_1 and balance speed V_2; V is the speed; Δ is the displacement; R_t is the total resistance; η_0 is the propeller open water efficiency; η_H is the hull efficiency; η_R is the relative rotation efficiency; η_S is the shafting transfer efficiency.

3.2.2 Objective function of maneuverability

The maneuverability of the unmanned underwater vehicle should be considered from the horizontal and vertical movement. In this paper, 6 sub-objective functions are selected to form the performance index of maneuverability, and the specific composition by the way of weighted sum with each index.

1.Static stability coefficient index of incidence angle (Lalfa)

$$Lalfa = l'_\alpha = \frac{l_\alpha}{L} = -\frac{M'_w}{Z'_w} \tag{3}$$

Where M'_w is the derivative of the longitudinal moment on the heave speed; Z'_w is the derivative of the vertical force on the heave speed.

2.Criterion numeral index of vertical dynamic stability (*Cv*)

$$Cv = \left[1 - \frac{M_w(m'+Z'_q)}{M'_q Z'_w}\right] > 0 \tag{4}$$

Where m' is the dimensionless value of quality; $m' = \frac{m}{0.5\rho L^3} = 2C_B \frac{B}{L}\cdot\frac{H}{L} = 2\frac{\nabla}{L^3}$; M'_q is the derivative of the pitching moment on the pitch angular velocity; Z'_q is the derivative of the vertical force on the pitch angular velocity.

3.Index of rise rate (Rra)

$$Rra = \frac{\partial V_{x'}}{\partial \delta_h} = -\frac{V^3}{m'gh}\left[\frac{M'_{\delta_h}}{Z'_{\delta_h}} - \frac{M'_w}{Z'_w} - \frac{M'_\theta}{Z'_w}\right]Z'_{\delta_h} \tag{5}$$

Where M'_{δ_h} is the derivative of the longitudinal moment on the rudder angle of the horizontal rudder; Z'_{δ_h} is the derivative of the vertical force on the rudder angle of the horizontal rudder; M'_θ is the derivative of the longitudinal moment on the trim angle.

4.Static stability index of drift angle (Lbelta)

$$Lbelta = l'_\beta = \frac{l_\beta}{L} = \frac{N'_v}{Y'_v} \tag{6}$$

Where N'_v is the derivative of yawing moment on the sway speed; Y'_v is the derivative of drifting force on the sway speed.

5.Weight dimensionless number index of horizontal line stability (CH)

$$C_H = 1 + \frac{N'_v(m'-Y'_r)}{N'_r Y'_v} > 0 \tag{7}$$

Where N'_r is the derivative of yawing moment on the heave speed; Y'_r is the derivative of drifting force on the heave speed.

6.Rudder effect index of horizontal steady turning (VarT)

$$VarT = K' = \frac{Y'_{\delta_v} N'_v - N'_{\delta_v} Y'_v}{N'_r Y'_v + N'_v(m'-Y'_r)} \tag{8}$$

Where Y'_{δ_v} is the derivative of the horizontal force on the rudder angle of the vertical rudder; N'_{δ_v} is the derivative of the yaw moment on the rudder angle of the vertical rudder.

In summary, the objective function of maneuverability is as follows:

$$C_M = \text{Lalfa}*\alpha_1 + \text{Cv}*\alpha_2 + \text{Rra}*\alpha_3 + Lbelta*\alpha_4 + \text{C}H*\alpha_5 + VarT*\alpha_6 \tag{9}$$

Where $\alpha 1$、$\alpha 2$、$\alpha 3$、$\alpha 4$、$\alpha 5$、$\alpha 6$ respectively are weight of each sub-objective function, $\alpha 1$、$\alpha 2$、$\alpha 3$、$\alpha 4$、$\alpha 5$、$\alpha 6$ are greater than 0, and $\alpha_1+\alpha_2+\alpha_3+\alpha_4+\alpha_5+\alpha_6=1$, their values respectively are 0.1, 0.2, 0.2, 0.1, 0.2, 0.2.

3.2.3 Objective function of energy system

Taking into account the performance of the energy tank is determined by the power supplied by the unit weight, and need to have a high circuit efficiency. So the selection of power circuit efficiency, equipment circuit efficiency and energy weight ratio as 3 sub-objective function, and then the distribution of weight, using the way of weighted sum with each index to obtain the objective function of energy system.

1.Power circuit efficiency (η_M)

$$\eta_M = \frac{P_E}{P_t} = \frac{(E-Ir)I}{EI} = \frac{U}{E} = \frac{145}{3.2uvw_1}$$

(10)

Where w_1 is the number of battery box that provide power circuit.

2.Equipment circuit efficiency (η_E)

$$\eta_E = \frac{P_E}{P_t} = \frac{(E-Ir)I}{EI} = \frac{U}{E} = \frac{24}{3.2uvw_2}$$

(11)

Where w_2 is the number of battery box that provide equipment circuit.

3.Energy weight ratio (μ)

$$\mu = \frac{0.16uv}{1.5uv + 0.2v + 0.3}$$

(12)

In summary, the objective function of energy system is as follows:

$$C_N = \eta_M * \beta_1 + \eta_N * \beta_2 + \mu * \beta_3$$

(13)

Where $\beta 1$、$\beta 2$、$\beta 3$ respectively are weight of each sub-objective function, $\beta 1$、$\beta 2$、$\beta 3$ are greater than 0, and $\beta_1 + \beta_2 + \beta_3 = 1$, their values respectively are 0.4、0.4、0.2.

3.2.4 Total optimization objective function

The index of unmanned underwater vehicle rapidity, maneuverability and energy system are combined, using the way of weighted sum with each index to obtain the total optimization objective function.

The total optimization objective function is as follows:

$$C = C_S * \gamma_1 + C_M * \gamma_2 + C_N * \gamma_3$$

(14)

Where $\gamma 1$、$\gamma 2$、$\gamma 3$ respectively are weight of rapidity, maneuverability and energy system, $\gamma 1$、$\gamma 2$、$\gamma 3$ are greater than 0, and $\gamma_1 + \gamma_2 + \gamma_3 = 1$, their values respectively are 0.4、0.4、0.2.

3.2.5 Optimization fitness function

The optimization fitness function is the product of the optimization of the total objective function and the penalty function, and the penalty function is the product of the penalty value of equality constraints and inequality constraints.

The fitness function is as follows:

$$S = C * P(x)$$

(15)

Where $P(x)$ is penalty function. In this paper, all the constraint satisfaction degree of the optimization system is more than 99.99%, that is, $P(x) = 1$.

3.3 Constraints conditions

3.3.1 Equation constraints

1) Meet the buoyancy constraints, balance between optimized displacement and designed displacement: $\rho V = \Delta_0$;

2) Meet the force balance constraints: $T_E = R_t$;

3) Meet the torque balance constraints: $\frac{\eta_R \eta_S P_s}{2\pi N} = K_Q \rho N^2 D_p^5$;

4) Meet the power supply constraints of energy tank, W_M and W_E respectively are the power consumption of power circuit and equipment circuit: $W = W_M + W_E = 0.16 * u * v * m * n * 0.95$.

3.3.2 Inequality constraints

1) Ranges of values of 35 design variables;

2) Meet the trim angle constraints of depth-keeping

linear with balance navigation: the trim angle must be less than 10°;

3) Meet the rudder angle constraints of depth-keeping linear with balance navigation: the balance rudder angle control within the range of ±5°;

4) Meet the length constraint of energy tank: $L_E = 0.284m + 0.05(m-1) < \varsigma L_m$;

5) Meet the width constraint of energy tank: $B_E = 0.21n + 0.05(n-1) < B - 2b$;

6) Meet the height constraint of energy tank: $h = (0.015u + 0.003)v + 0.065 < \beta H$.

4. Optimum calculation and analysis

4.1 Genetic algorithm of growth mechanism optimization calculation

4.1.1 Comparing the influence of different genetic factors

Parameter setting : the population size was 200, the genetic times was 1000, and the crossover and mutation were selected. The crossover probability was 0.75, mutation probability was 0.15, variable carrier probability was 0.0001-0.01, evolutionary weights was 0.7. The following 6 groups of genetic factors were selected to calculate.

Table 2: The calculation results of different genetic factors

Genetic factors	0.02	0.04	0.06	0.08	0.1	0.12
Fitness function value	0.68976	0.7107	0.70598	0.67668	0.66275	0.65659

From the data in Table 2, with the change of genetic factors, the fitness function value is also changing, there is an optimal genetic factor. For the mathematical model of this paper, the best genetic factor is 0.04.

4.1.2 Compare the effects of different evolutionary weights

Parameter setting : genetic factor was 0.04, other parameter settings are the same as the 4.1.1. Evolutionary weights were calculated in the following 6 groups.

Table 3: The calculation results of different evolutionary weight

Evolutionary weight	0.1	0.3	0.5	0.7	0.9
Fitness function value	0.65797	0.67842	0.67141	0.71316	0.67603

As shown in Table 3, with the change of evolutionary weight, there is an optimal evolutionary weight. For the mathematical model of this paper, the evolutionary weight is 0.7, which has better calculation results ,and the larger evolutionary weights are better.

4.2 A comparative analysis of the different probability of maximum particle flight speed and interval in particle swarm optimization algorithm

Parameter setting : the population size was 200, the genetic times was 1000, variable weight take 0.9~0.4, among which the initial weight is 0.9, the final weight is 0.4, the probability of maximum particle flight speed and interval are calculated respectively in the following 6 groups.

Table 4: The calculation results of different probability of maximum particle flight speed and interval

Probability of maximum particle flight speed and interval	0.14	0.15	0.16	0.17	0.18	0.19
Fitness function value	0.68883	0.70487	0.7192	0.72976	0.68847	0.68371

The speed of particle flight is limited to the range of maximum flight speed. As shown in Table 4, with the increase of the probability of maximum particle flight speed and interval, the fitness function value is changed. In these changing processes, there is an optimal probability of flight speed and interval, when it is 0.17, the fitness function value is the highest, and the optimal calculation result is the best.

4.3 Analysis of different calculation times of the two algorithms

For genetic algorithm of growth mechanism, the parameter setting: genetic factor was 0.04, evolutionary weights was 0.7, other parameter settings are the same as the 4.1.1. The calculation times to take 5 groups, and the results of each objective function value are shown in figure 2.

For particle swarm optimization algorithm, the parameter setting: the probability of maximum particle flight speed and interval is 0.17, other parameter settings are the same as the 4.2. The calculation times to take 5 groups, and the results of each objective function value are shown in figure 3.

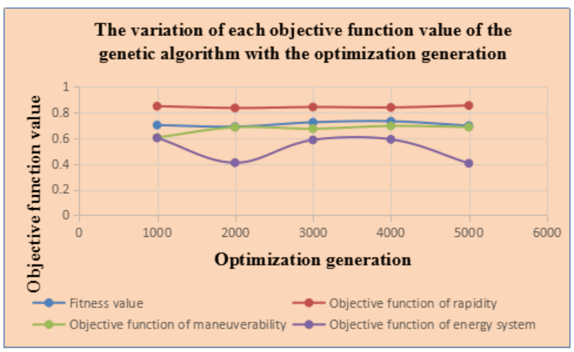

Fig. 2 The calculation of different generation on genetic algorithm.

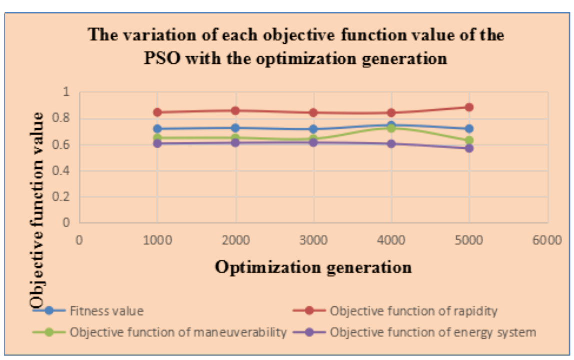

Fig. 3 The calculation of different generation on PSO.

As can be seen from Figure 2 and figure 3, with the change of the optimized generation, the results indicated that these two algorithms would have the best results in the optimization of the 4000th generation, both of which had stable effect. The maximum fitness value of the two algorithms are basically the same, both in about 0.74, so the optimization results of the two algorithms had a good effect. And the change trend of the rapid objective function value is closest to the fitness function value, so it can be concluded that the rapid optimization system have a large impact for the overall optimization system.

Design variables optimization values of two algorithms are shown in Table 5, comparison each design variable with table 1 ,we can be found that the optimal value of each design variable is close to the middle value of the upper and lower limits. so both the genetic algorithm of growth mechanism and particle swarm optimization algorithm had better optimization effect.

Table 5: Design variable optimal values of the two algorithm

Design variable	Genetic algorithm	PSO
Lh	0.553	0.61
Lm	5.834	5.732
La	1.993	1.937
B	2.309	2.334
H	1.075	1.061
Xg	-0.034	-0.038
Xh	3.706	3.714
Xe	3.31	3.308
XGps	0.573	0.574
Xl	0.116	0.116
Xy	-1.307	-1.306
Xd1	3.052	3.013
Xd2	-1.532	-1.528
Xf	-0.22	-0.224
Dp	0.391	0.39
Ae/A0	0.649	0.685
N	347.433	344.206

γ	0.963	0.959
Vs	3.029	2.977
doh	0.33	0.309
dih	0.381	0.345
Zh	0.693	0.686
dov	0.341	0.398
div	0.373	0.392
Zv	0.716	0.744
Xr	-4.025	-4.038
x	185.457	189.052
N1	254.978	289.803
N2	803.025	748.122
β	0.776	0.728
ζ	0.461	0.472
m	8	8
n	4	4
v	9	9
u	5	5

4.4 Discuss the effects of parallel and hierarchical strategies on the algorithm

For particle swarm optimization algorithm, calculation times is 4000, the probability of maximum particle flight speed and interval was 0.17, other parameter settings are the same as the 4.2. For Genetic algorithm of growth mechanism, calculation times is 4000, genetic factor was 0.04, evolutionary weights was 0.7, other parameter settings are the same as the 4.1.1. Carrier probability was 0.005, parallel computing times was one (the length of the bow), the calculation results of the hierarchical and parallel strategies are shown in the following table.

Table 6: The influence of parallel and hierarchical strategy on algorithm

Optimization strategy	Single PSO	Hierarchical: PSO and PSO	Parallel: PSO
Fitness value	0.723 91	0.72649	0.73907
Optimization strategy	Hierarchical: PSO and Genetic algorithm of growth mechanism		Hierarchical and Parallel: PSO and PSO
Fitness value	0.72676		0.74251

As shown in Table 6, with the change of the optimization strategy, the fitness value is changing. And the optimization effect is as follows, hierarchical parallel is better than parallel; parallel is better than hierarchical; hierarchical is better than simple algorithms. It thus can be seen that parallel and hierarchical strategy can improve the optimization effect of the algorithm, and its optimization effect is the best by using hierarchical and parallel strategies together.

4.5 Analysis of the influence of key variables on Optimization System

The particle swarm optimization algorithm is used to conduct optimized calculation of several key design variables, such as speed and propeller rotational speed, the changes of their fitness values are obtained respectively, as shown in the following figure.

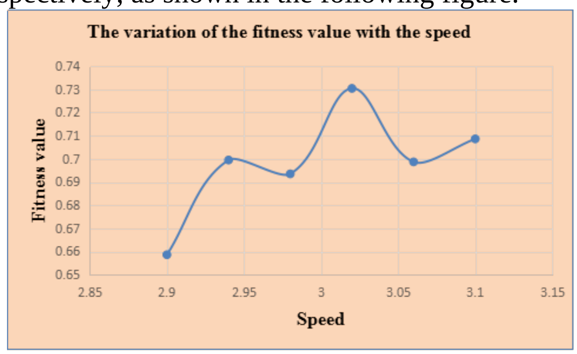

Fig. 4 The variation of the fitness value with the speed.

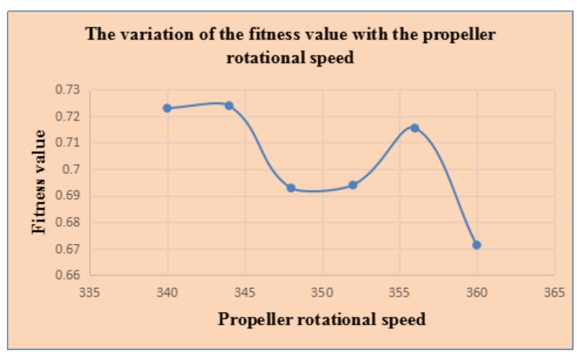

Fig. 5 The variation of the fitness value with the propeller rotational speed.

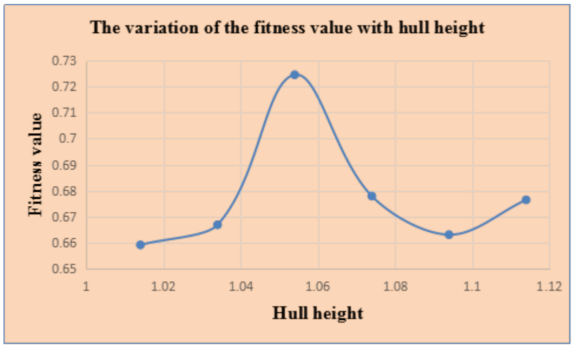

Fig. 6 The variation of the fitness value with hull height.

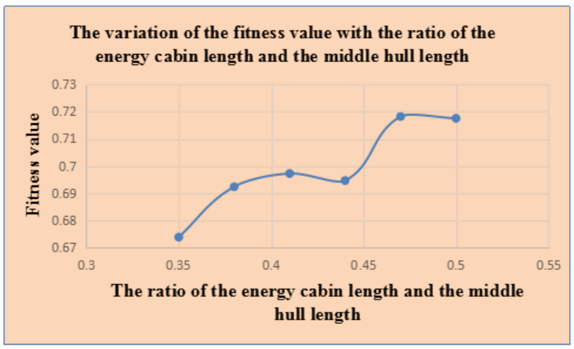

Fig. 7 The variation of the fitness value with the ratio of the energy cabin length and the middle.

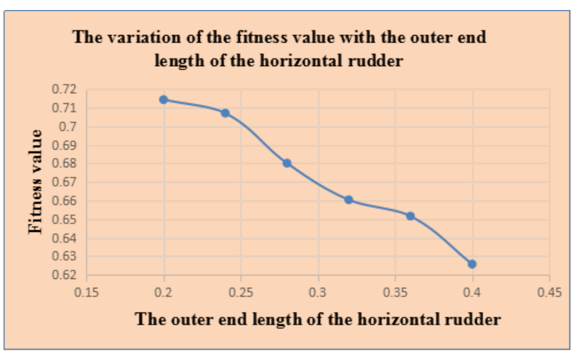

Fig. 8 The variation of the fitness value with the outer end length of the horizontal rudder.

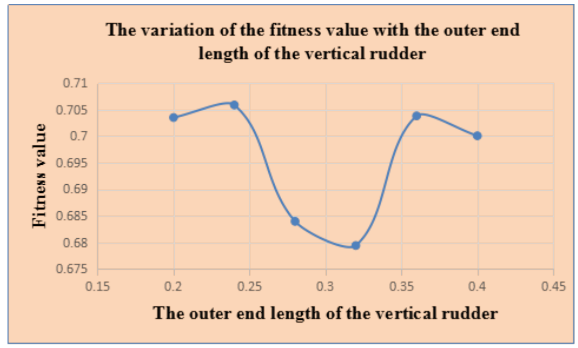

Fig. 9 The variation of the fitness value with the outer end length of the vertical rudder.

As can be seen in the above 6 figures, the fitness value of several key design variables, such as speed, have been changed evidently. It shows that both of them are sensitive to the total optimization system.

Figure 4 and figure 5 represent the fast system parameters, the changing tendency of the fitness value is that with the speed are increased first, then decreased, then increased, and then decreased, and finally increased, the best speed was 3.02kn. With the propeller rotational speed are increased first, then decreased, then increased, and finally decreased, the best propeller rotational speed was 344r/min.

Figure 6 and figure 7 represent the energy system parameters. The changing tendency of their fitness value is basically consistent, which are increased with the hull height and the ratio of the energy cabin length and the middle hull length, then decreased, and finally increased. The best hull height was 1.054, and the best ratio of the energy cabin length and the middle hull length was 0.47.

Figure 8 and figure 9 represent the maneuvering system parameters, the changing tendency of the fitness value had been decreased with the outer end length of horizontal rudder, the best outer end length of horizontal rudder was 0.2m. And with the outer end length of the vertical rudder it increased first, then decreased, then increased, and finally decreased, the best outer end length of the vertical rudder was 0.24m.

5. Conclusion

To summarize, this paper selects a flat type of UUV as research object, then established a comprehensive optimization mathematical model. Through the usage of genetic algorithm of growth mechanism and particle swarm optimization algorithm, combined with external hierarchical and parallel strategy, optimization algorithm was designed, and then comprehensive optimization software was compiled to analyze the relevant calculation. Finally, this paper has got some conclusions as follows:

(1) For the mathematical model of this paper, the calculation results of the genetic algorithm of growth mechanism is best when genetic factor is 0.04 and evolutionary weights is 0.7.

(2) For the mathematical model of this paper, the calculation results of PSO is best when the probability of maximum particle flight speed and interval is 0.17.

(3) Genetic algorithm of growth mechanism and particle swarm optimization algorithm would have the best results in the optimization of the 4000th generation, both of which had good effect.

(4) For the mathematical model of this paper, rapidity optimization system had greater influence on the total optimization system.

(5) Parallel and hierarchical strategy can improve the optimization effect of the algorithm, and its optimization effect is the best by using hierarchical and parallel strategies together.

(6) Several key design variables, such as speed, are sensitive to the total optimization system. Some conclusions are as follows: the best speed was 3.02kn; the best propeller rotational speed is 344r/min; the best hull height was 1.054; the best ratio of the energy cabin length and the middle hull length was 0.47; the best outer end length of horizontal rudder was 0.2m; and the best outer end length of the vertical rudder was 0.24m.

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