Analysis and Research on Fuzzy Control and Vibration Intelligent Control of "Dumbbell" Spacecraft Based on Particle Swarm Optimization

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Abstract: Dumbbell spacecraft as an important content of technology research and development design, in the development of social economy and science and technology innovation, the independent attitude control for demand is higher and higher, although widely used in various types of unmanned space missions, showed a very broad application prospects, but from the perspective of stability analysis found that the actual design does not meet the requirements of multiple performance indicators, The response speed, input constraint and disturbance suppression of system operation are not studied comprehensively. Therefore, this article on the basis of the understanding of dumbbell spacecraft attitude motion model, according to the related theory knowledge, the fuzzy controller design based on particle swarm optimization, in-depth studies are the final results show that the proposed algorithm has certain adaptability and effectiveness, the dumbbell spacecraft fuzzy controller has the advantage of actual design.

Keywords: Particle swarm optimization; The spacecraft; Fuzzy control; The attitude.

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1. Motion model of dumbbell spacecraft

The kinematics equation of spacecraft is the basic content of the accurate attitude of "dumbbell" spacecraft. Because the attitude of orbital spacecraft is clear, the parameters included can be converted to each other. The actual common parameters are divided into the following contents:

First, Euler Angle. The main use of three parameters to show the attitude of the spacecraft, can intuitively show the corresponding geometric significance, at the same time, this parameter can be obtained by the spacecraft attitude sensor, does not need to change the parameters, so it is very suitable for the performance of the spacecraft motion attitude. Combined with Euler's theorem analysis, the total number of rigid body around the fixed point can be expressed into the cylinder for multiple rotation according to the algorithm to complete the conversion. In this process, the coordinates of the dumbbell spacecraft can be obtained by rotating reference coordinates. The actual rotation Angle is the Euler Angle, in which the yaw Angle refers to ψ, the roll Angle refers to φ, and the pitch Angle refers to θ. The euler Angle is used to show the attitude transformation matrix as follows[1]:

$$R_{312}(\Psi,\varphi,\theta)=R_y(\theta)R_x(\varphi)R_z(\psi)$$

$$=\begin{bmatrix} \cos\psi\cos\theta-\sin\psi\sin\theta\sin\varphi \quad \cos\theta\sin\psi+\cos\psi\sin\theta\sin\varphi-\sin\theta\cos\varphi \\ -\cos\varphi\sin\psi \quad \cos\varphi\cos\psi \quad \sin\varphi \\ \sin\theta\cos\psi+\sin\psi\cos\theta\sin \quad \sin\psi\sin\theta-\cos\psi\cos\theta\sin\varphi \quad \cos\varphi\cos\theta \end{bmatrix}$$

The rotation order is 3-1-2. The relation between euler Angle and attitude matrix transformation elements is shown as follows:

$$\psi=\arctan\left(-R_{yx}/R_{yy}\right),\varphi=\arcsin\left(R_{yx}\right),\theta=\arctan\left(-R_{xz}/R_{zz}\right)$$

In combination with the above formulas, it is found that the euler rotation will produce singular phenomena under the condition φ=π/2, and any rotation order will produce singular phenomena.

First, quaternion. This parameter describes the rotation of a vector or coordinate system with respect to a coordinate system, defined as follows:

$$q=\begin{bmatrix} q_0 \\ q_1 \\ q_2 \\ q_3 \end{bmatrix}=\begin{bmatrix} \cos\left(\frac{\varphi}{2}\right) \\ e_x\sin\left(\frac{\varphi}{2}\right) \\ e_y\sin\left(\frac{\varphi}{2}\right) \\ e_z\sin\left(\frac{\varphi}{2}\right) \end{bmatrix}=\begin{bmatrix} \cos\left(\frac{\varphi}{2}\right) \\ e\sin\left(\frac{\varphi}{2}\right) \end{bmatrix}$$

In the above formula, $e=\left[e_x,e_y,e_z\right]^T$ represents the euler rotation axis, φ represents the rotation Angle about the Euler axis, and meets the following conditions:

$$q_0^2+q_1^2+q_2^2+q_3^2=1$$

The quaternion Qv formed by four parameters is defined as follows:

$$q_v\equiv q_0+iq_1+jq_2+kq_3\equiv\left[q_0q_2q_2q_3\right]^T\equiv\left[q_0q\right]$$

In the above formula, q0 represents the scalar part of the quaternion, Q represents the vector part of the quaternion, and I, j, and K refer to imaginary units.

The dumbbell-shaped spacecraft attitude kinematics equation represented by quaternion is shown as follows:

$$\dot{q}_v=\frac{1}{2}\Xi(q_v)\omega$$

$$\Xi(q_v)=\begin{bmatrix} -q^T \\ \left[q^{\times}+q_0I_3\right] \end{bmatrix}$$

In the above formula, $\omega = [\omega_1 \omega_2 \omega_3]^T \in R^3$ represents the component of the relative rotational angular velocity, and $q_v = \{q_0, q\}$ represents the unit quaternion. In this paper, Qx is defined as the differential matrix, and the corresponding rotation matrix is described as:

$$R = (q_0^2 - q^T q)I_3 + 2qq^T - 2q_0[q^\times]$$

First, Rodrigue and his correction parameters. This parameter is derived from the unit quaternion and is defined as follows:

$$\rho = \bar{e}\tan\frac{\Phi}{2}$$

In the above formula, $\rho = [\rho_1 \rho_2 \rho_3]$ represents the Rodrigue parameter, and the singularity appears in the ±π region. The corresponding formula to present the rotation matrix using relevant parameters is:

$$R^\rho = 1 + \frac{(1-\rho^T \rho) + 2qq^T - 2q_0[q^\times]}{1+\rho^T \rho}$$

According to Rodrigo parameters, the attitude kinematics equation of dumbbell spacecraft is:

$$\dot{\rho} = H(\rho)\omega$$

The above formula meets the following conditions:

$$H(\rho) = \frac{1}{2}\left(I_3 + [\rho^\times] + \rho\rho^T\right)$$

The rodrigue parameters after correction are defined as follows:

$$\sigma = \bar{e}\tan\frac{\Phi}{4}$$

In the above formula, $\sigma = [\sigma_1 \sigma_2 \sigma_3]$ represents the modified Rodrigue parameter, and a strange phenomenon appears in the ±2π region. According to the modified Rodrigues parameters, the attitude kinematics equation of dumbbell spacecraft is shown as follows:

$$R^\sigma = I_3 - \frac{4(1-\sigma^T \sigma)}{(1+\sigma^T \sigma)^2}[\sigma^\times] + \frac{8}{(1+\sigma^T \sigma)^2}[\sigma^\times]^2$$

The kinematics equation based on Rodrigue parameters is shown as follows[2,3]:

$$\dot{\sigma} = G(\sigma)\omega$$

The above formula meets the following conditions:

$$G(\sigma) = \frac{1}{2}\left(\frac{1-\sigma^T \sigma}{2} I_3 + [\sigma^\times + \sigma\sigma^T]\right)$$

From the perspective of dynamics equation, if dumbbell-shaped spacecraft acts as a rigid body, it can provide three actuators with perpendicular torques to each other for driving, and the corresponding dynamics model is shown as follows:

$$J\dot{\omega}(t) + \Phi(\omega(t))J\omega(t) = u(t)$$

In the above formula, $J \in R^{3\times 3}$ represents positive definite and symmetric spacecraft inertia matrix, and meets the condition of $J = J^{-1} > 0$; $\omega \in R^3$ represents the angular velocity of the spacecraft; $u(t) \in R^3$ represents the control vector acting on the spacecraft, and $\Phi(\omega(t)) \in R^{3\times 3}$ represents the 3×3 antisymmetric matrix, as shown below:

$$\Phi(\omega(t)) = \begin{bmatrix} 0 & \omega_3(t) & -\omega_2(t) \\ -\omega_3(t) & 0 & \omega_1(t) \\ \omega_2(t) & -\omega_1(t) & 0 \end{bmatrix}$$

T-s fuzzy model is a common content of the practical discussion of researchers, and the final results show that many control problems can be regarded as T-S fuzzy systems. As one of the nonlinear models, this model is easier to present complex dynamic characteristics of the system. The specific description is as follows:

If Z1 (t) is Mi1 and Z2 (t) is Mi2 and... And Zi (t) is M1n, it can be obtained:

$$\dot{x}(t) = A_i x(t) + B_i u(t)$$
$$y(t) = C_i x(t) \quad i = 1,\ldots,r$$

In the above formula, M_{ij} represents the fuzzy set, R represents the number of fuzzy rules, $x(t) \in R^n$ represents the state vector, Zn (t) represents the antecent variable, $u(t) \in R^n$ represents the control input vector, and (Ai, Bi) represents the dimension matrix corresponding to the ith subsystem. After x (t) and u (t) are defined, the output of the fuzzy system represents the weighted average of the output of the subsystem, and the specific formula is as follows:

$$\begin{cases} \dot{x}(t) = \sum_{i=1}^{r} h_i(z(t))(A_i x(t) + B_i u(t)) \\ y(t) = Cx(t) \end{cases}$$

The above formula meets the following conditions:

$$w_i(z(t)) = \prod_{j=1}^{p} M_{ij}(z(t))$$

$$h_i(z(t)) = w_i(z(t)) / \sum_{i=1}^{r} w_i(z(t)), i = 1,\ldots,r$$

Where, M_{ij} (z (t)) represents the membership function belonging to zj (t) fuzzy set, and meets the following conditions:

$$w_i(z(t)) \geq 0, \sum_{i=1}^{r} w_i(z(t)) > 0, i = 1,2,\ldots,r$$

$$h_i(z(t)) \geq 0, \sum_{i=1}^{r} h_i(z(t)) = 1, i = 1,2,\ldots,r$$

When the system is under control, the real controller and the system have the same prospect by using the fuzzy parallel distributed compensation strategy. Fuzzy state feedback control law is shown as follows:

If Z1 (t) is Mi1 and Z2 (t) is Mi2 and... And Zi (t) is M1n, it can be obtained:

$$u(t) = -K_i x(t), i = 1, \ldots, r$$

In the above formula, Ki represents the dispute matrix of the state feedback controller. At this time, the controller can input and output according to the following formula:

$$u(t) = -\sum_{i=1}^{r} h_i(z(t)) K_i x(t)$$

Combined with the above formula, the weighted average formula of fuzzy system subsystem output is analyzed, and the closed-loop formula of nominal system can be obtained, as shown below:

$$\dot{x}(t) = \sum_{i=1}^{r} \sum_{j=1}^{r} h_i(z(t)) h_j(z(t)) (A_i - B_i K_j) x(t)$$

In order to further discuss the application characteristics of fuzzy system, three aspects should be analyzed comprehensively:

First, if there is a positive definite matrix P, then the linear matrix inequality is shown as follows:

$$G_{ii}^T P + P G_{ii} < 0, i = 1, 2, \ldots, r$$

$$\left(\frac{G_{ij} + G_{ji}}{2}\right)^T P + P\left(\frac{G_{ij} + G_{ji}}{2}\right) < 0, i < j < r$$

If the above formula is true, it means that the closed-loop system is stable and progressive, and meets the condition of $G_{ij} = A_i - B_i K_j$.

Secondly, if the rule of the fuzzy system constructed at any time t is 1< S ≤r, then it is assumed that the positive definite matrix P and Q exist at the same time, if the following formula is met:

$$G_{ii}^T P + P G_{ii} + (s-1)Q < 0, i = 1, 2, \ldots, r$$

$$\left(\frac{G_{ij} + G_{ji}}{2}\right)^T P + P\left(\frac{G_{ij} + G_{ji}}{2}\right) - Q < 0, i < j$$

Then it means that the fuzzy system is globally asymptotically stable to the equilibrium point.

Finally, it is assumed that there exists a positive definite matrix P and a series of symmetric matrices Xij, and the specific inequalities are shown as follows:

$$\Lambda_{ii}^T P + P\Lambda_{ii} + X_{ii} < 0$$

$$\Lambda_{ij}^T P + P\Lambda_{ij} + X_{ij}, < 0$$

$$X = \begin{bmatrix} X_{11} X_{12} \ldots X_{1N} \\ X_{12} X_{22} \ldots X_{2N} \\ \vdots \quad \vdots \quad \vdots \\ X_{1N} X_{2N} \ldots X_{NN} \end{bmatrix}$$

Then fuzzy control system is in line with the condition

$$\Lambda_{ii} = G_{ii} \quad \Lambda_{ij} = \left(G_{ij} + G_{ji}\right)/2$$

.

2. Design and analysis of fuzzy controller

Because fuzzy control does not analyze the precise data of the controlled target in practical application, the system runs at a fast speed and parameter changes show a certain robustness, it has gradually become a difficult point discussed by researchers in practical design. In today's science and technology research, fuzzy controller, as a nonlinear controller type, has a very strong complexity in the practical application of the whole system, so we should pay attention to scientific adjustment of parameters. Through the integration of relevant literature in recent years, it is found that although the existing method can adjust the controller parameters in order, the actual operation speed is slow, which will directly affect the initial value, which will inevitably cause obstacles to the application of system control. The PSO algorithm studied in this paper has better performance than other algorithms, both in computational efficiency and robustness is very high, and it can find the global optimal solution for the dumbbell spacecraft fuzzy control problem. In this paper, a fuzzy controller with simple structure, convenient application, good stability and dynamic performance is proposed based on the accumulated experience of current research literature, and an improved example group optimization algorithm is proposed to solve the problem of difficult parameters[4].

2.1 Controller Design

For dumbbell spacecraft fuzzy control, the overall system design includes two fuzzy controllers, particle swarm optimizer, control objects and other contents, as shown in the figure 1 below:

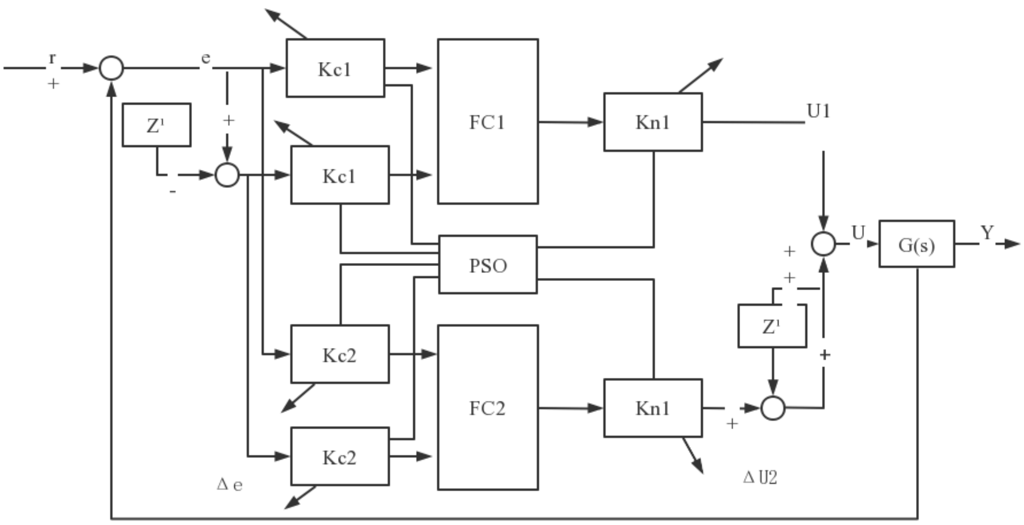

FIG. 1 System structure diagram

First, the fuzzification of input variables and output variables should be fully demonstrated. The formula for the actual input variable is as follows:

$$k_e.e(k) = k_e(r(k) - y(k))$$
$$k_{\Delta e}.\Delta e(k) = k_{\Delta e}.(e(k) - e(k-1))$$

In the above formula, Y (k) refers to the process input, r (k) refers to the set value, e (k) and e (k-1) represent the errors existing between the present stage and the last moment, and * represents 1 and 2. The actual value range of the deviation and its change rate should be controlled within the range of [-L, L] after quantitative processing. At this point, L will be valued within the range of [1,5], or it can be dynamically adjusted in combination with the change of the output set value, so as to reduce the sensitivity of the control system to the change of the set value. The fuzzy set of input language variables is defined as negative (N) and positive (P), as shown below:

The output variables of the two fuzzy controllers FC1 and FC2 used in this study are U1 (k) and △ U2 (k) during the operation, and the corresponding quantization factors are KU1 and KU2. The fuzzy set definition of the output language during the change can get negative (N), zero (Z) and positive (P), and the central values are -h, 0 and H. The specific membership function is shown in the figure 2.3below:[5,6]

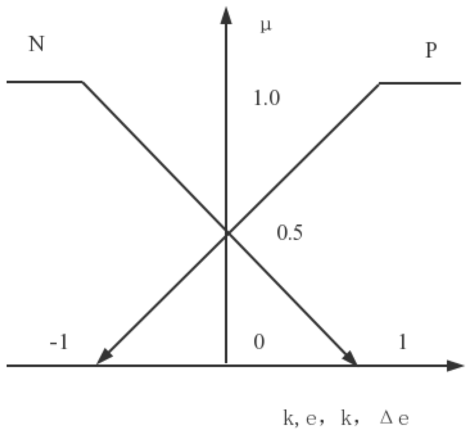

FIG. 2 $k_e e$ and $k_{\Delta e}\Delta e$

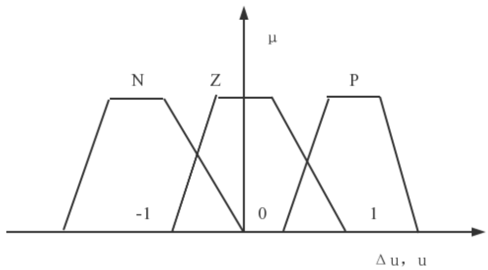

Figure 3 $k_{u1}u1$ and $k_{\Delta u2}\Delta u2$

The calculation formula of membership function is as follows:

$$\mu_{N_{e_*}} = \frac{L - k_{e_*} e}{2L}, \mu_{p_{e_*}} = \frac{L + k_{e_*} e}{2L}$$

$$k_{e_*} e \in [-L, L];$$

$$\mu_{N_{\Delta e_*}} = \frac{L - k_{\Delta e_*} \Delta e}{2L}, \mu_{P_{\Delta e_*}} = \frac{L + k_{\Delta e_*} \Delta e}{2L}$$

$$k_{\Delta e_*} \Delta e \in [-L, L]$$

Secondly, master the rules of fuzzy control. FC1 and FC2 will use the same form of fuzzy control rules, as shown below:

$$R_1; if \quad e \quad is \quad N_e \quad and \quad \Delta e \quad is \quad N_{\Delta e}, rhen \quad u \quad is \quad N$$

$$R_2; if \quad e \quad is \quad N_e \quad and \quad \Delta e \quad is \quad N_{\Delta e}, rhen \quad u \quad is \quad Z$$

$$R_3; if \quad e \quad is \quad N_e \quad and \quad \Delta e \quad is \quad N_{\Delta e}, rhen \quad u \quad is \quad Z$$

$$R_4; if \quad e \quad is \quad N_e \quad and \quad \Delta e \quad is \quad N_{\Delta e}, rhen \quad u \quad is \quad P$$

In the above formula, u stands for U1, △ U2.

Finally, fuzzy reasoning analysis. By using Larsen product reasoning, Zadeh fuzzy logic, Lukasiewicz fuzzy form and other contents to study, it can be seen that the actual output quantity should be calculated and analyzed by using the fuzzy algorithm of the barycenter solution, and the output result of the controller is as follows:

Where, the output result of fuzzy controller 1 (FC1) is:

$$K_{u_1} u_1 = k_{u_1} H \frac{S(\mu_{R_4}) - S(\mu_{R_1})}{S(\mu_{R_1}) + S(\mu_{R_2 \vee R_3}) + S(\mu_{R_4})}$$

The output result of fuzzy controller 2 (FC2) is:

$$K_{\Delta u_2} \Delta u_2 = k_{\Delta u_2} H \frac{S(\mu_{R_4}) - S(\mu_{R_1})}{S(\mu_{R_1}) + S(\mu_{R_2 \vee R_3}) + S(\mu_{R_4})}$$

And meet the above conditions:

$$S(\mu_{R_1}) = \mu_{R_1} S, S(\mu_{R_2 \vee R_3}) = \mu_{R_2 \vee R_3} S$$
$$S(\mu_{R_4}) = \mu_{R_4} S$$

In the above formula, S represents the area of the single output fuzzy set analyzed in the above figure, while $S(\mu_{R_2 \vee R_3}) and S(\mu_{R_4})$ represents the weighted area of membership degree calculated in combination with the control law.

The output of both is as follows:

$$U_1 = \frac{k_{u_1} H}{4L - 2\max(k_{e_1}|e|, k_{\Delta e_1}|\Delta e|)} \times (k_{e_1} e + k_{\Delta e_1} \Delta e)$$

$$\Delta U_2 = \frac{k_{\Delta u_2} H}{4L - 2\max(k_{e2}|e|, k_{\Delta e_2}|\Delta e|)} \times (k_{e_2} e + k_{\Delta e_2} \Delta e)$$

The output result of the overall fuzzy controller is:

$$U = U_1 + \sum_0^k \Delta U_2 =$$
$$\frac{k_{u_1} H\left(k_{e_1} e + k_{\Delta e_1} \Delta e\right)}{4L - 2\max\left(k_{e_1}|e|, k_{\Delta e_1}|\Delta e|\right)} \times$$
$$\left(k_{e_1} e + k_{\Delta e_1} \Delta e\right)$$
$$\sum_0^k \frac{k_{\Delta u_2} H\left(k_{e_2} e + k_{\Delta e_2} \Delta e\right)}{4L - 2\max\left(k_{e2}|e|, k_{\Delta e_2}|\Delta e|\right)}$$

The controller contains six control parameters, and the corresponding values can be determined by using particle swarm optimization (PSO) algorithm.

2.2 Parameter optimization

PSO algorithm can obtain a large number of random particles during initialization, but during actual iteration, all particles can be innovated after tracking the optimal solution, and finally obtain the optimal solution based on searching the whole space. Where, the position and speed formula of iteration I is:

$$X_i(k) = \left(X_{i_1}(k), X_{i_2}(k), \ldots, X_{i_N}(k)\right)$$
$$V_i(k) = \left(V_{i_1}(k), V_{i_2}(k), \ldots, V_{i_N}(N)\right)$$

In actual iterative analysis, the example can scientifically adjust its position speed based on mastering the mechanism:

On the one hand, what the particle obtains is the optimal solution, which is the individual extreme value pBest.

On the other hand, the optimal solution obtained by the population is the global extreme value gBest, and the specific formula is as follows:

$$P_i(k) = \left(P_{i_1}(k), P_{i_2}(k), \ldots, P_{i_N}(k)\right)$$
$$P_g(k) = \left(P_{g_1}(k), P_{g_2}(k), \ldots, P_{g_N}(N)\right)$$

When calculating the k+1 iteration, the particle will adjust its velocity and position in combination with the law shown below:

$$V_{i_n}(k+1) =$$
$$\omega V_{i_n}(k) + c_1 r_1\left(P_{i_n}(k) - X_{i_n}(k)\right) +$$
$$c_2 r_2\left(P_{g_n}(k) - X_{i_n}(k)\right)$$
$$X_{i_n}(k+1) = X_{i_n}(k) + V_{i_n}(k+1)$$

In the above formula, W stands for inertia weight. Scientific adjustment of relevant data can clarify more flight speed and effective search range. C1 and c2 represent learning factors, r1 and r2 represent two independent random numbers within the interval [0,1], n=1,2... ,N represents the dimensional vector value of the particle, Xin (k) and Vin (k) represent the velocity and position of the particle's NTH dimensional vector.

A new numerical w adjustment algorithm for inertia weight is proposed in this paper, and the specific formula is shown as follows:

$$\omega(k)=\omega_{\max}-(\omega_{\max}-\omega_{\min})\times\left(1-\frac{|J_{opt}-J_{mean}|}{\max(J_{opt},J_{mean})}\right)$$

In the above formula, W (k) represents the inertia weight, wmax represents the maximum weight, wmin represents the minimum weight, Jopt represents the fitness function of the current global optimal particle, Jmean represents the average value of the fitness function of all particles, and K represents the actual number of iterations.

The goal is to make W follow the particle swarm optimization algorithm to find the best speed, and adjust the adaptive in the change. From the practical point of view, the fuzzy controller design based on particle swarm optimization algorithm can not only improve the efficiency of the algorithm, but also solve the problems existing in the previous operation, such as local optimality.

3. Simulation analysis

In order to verify the design method proposed in this paper, a typical fuzzy control example of dumbbell spacecraft is compared and analyzed. The parameters of the actual algorithm are set as the total population is 50, the number of particles is 6, the correlation velocity is controlled within the range of [-10, 10], and the corresponding position is within the range of [0,4].

3.1 Integration delay

The corresponding model formula is as follows:

$$G(s)=\frac{1}{s(s+1)}e^{-0.2s}$$

According to the flow chart of PSO algorithm, the actual performance statistics of random simulation are shown as FIG. 4 follows:

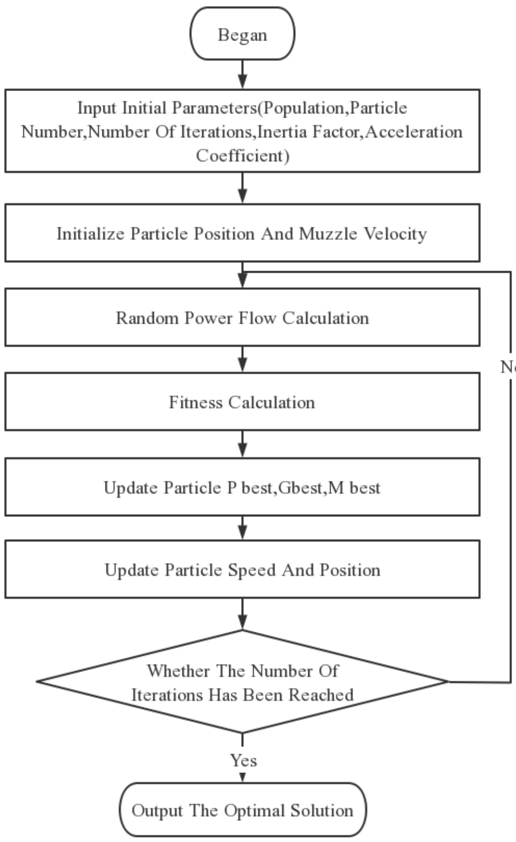

FIG. 4 Flow chart of PSO algorithm

Table 1 control performance comparison results

Performance indicators	$\delta / \%$	$U_3 / \%$	T_r	T_S	ITAE
Poulin E	33.5	-	1.10	16.52	2.71
PID(Z-N)	51.2	-	2.26	16.87	3.43
pROPOSED	11.3	-	1.80	7.51	1.62

Combined with the analysis of the above simulation results, it can be seen that the overshoot of the overall system is %, the rise time is T, and the adjustment time is Ts. Compared with the PID control set by z-N method and the control algorithm proposed by Poulin et al., different degrees of changes can be obtained. The actual adjustment amount reaches 11.3%, and the adjustment time is also effectively controlled.

3.2 Non-minimum phase system

The corresponding formula is as follows:

$$G(s)=\frac{s^2-7s+6}{s^3+6s^2+8s+6^*}$$

By comparing the performance data of the controller proposed in the existing literature and the fuzzy controller in this paper, and combining with the inference system analysis shown in the figure below, it can be seen that the step response results of the non-minimum phase system under the influence of the controller mentioned above will change to some extent. In this paper, the algorithm has been improved to some extent, and a good compromise has been achieved between fast adjustment and negative Us%.[7.8]

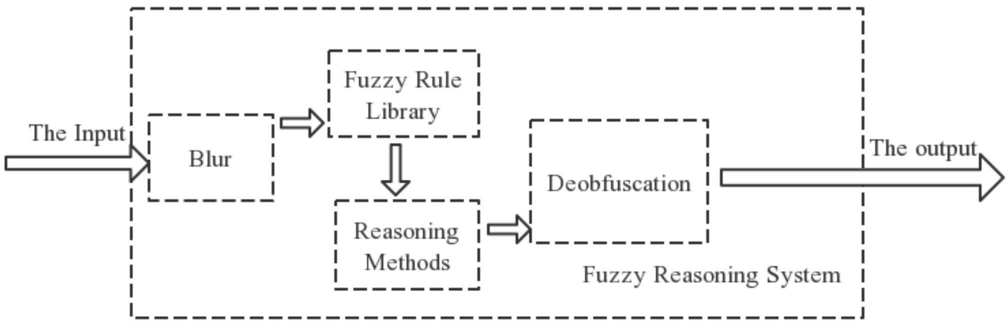

FIG. 5 Structure diagram of fuzzy inference system

3.3 Double box system

The representative water level control system model of double header box needs to be calculated and obtained according to experimental data. The actual transfer function is shown as follows:

$$G(s)=\frac{0.75e^{-8.067}}{(1+61.45s)^2}$$

By changing the design numerical output perturbation method, is applied at T = 4000 the add value is 0.2 under the condition of disturbance, the output of the simulation results prove that this algorithm has a good application performance, the numerical changes in water level set, system there are only small overshoot, the disturbance of effects on the system is low, can quickly restore the stability of the state. However, the overshoot produced by traditional PID controller is larger.[10.11]

Conclusion

To sum up, in combination with the analysis of spacecraft application experience in recent years, it is found that in order to ensure that the internal design of the system meets the work requirements of relevant fields, it is necessary to integrate relevant literature to scientifically optimize parameters, and to clarify the application advantages of PSO algorithm and fuzzy controller. In this paper, the PSO algorithm is used for comprehensive optimization, and the fuzzy controller is further discussed. The final results show that the relevant control design not only has stronger dynamic performance, but also can improve the stability accuracy. The actual results also further prove that the application algorithm has a certain effectiveness, and the designed controller has advantages.

Reference

[1] Xiaogang wu,Xudong wang,Tengwei yu, et al. Fuzzy Control Of Electromagnetic Clutch Based on Particle Swarm Optimization. China Mechanical Engineering, 2010, 021(009):1071-1077.

[2] Changjun xie, Shu Hai quan, Ling yao. Research on Regenerative Braking Control Strategy of Electric Vehicle Based on Particle Swarm Optimization Fuzzy Controller [J]. Journal of Wuhan University of Technology: Transportation Science and Engineering, 2008, 32(4):669-672.

[3] Wei yang,Lang wei,Jingyu liu. Journal of Mechanical Engineering, 2017, 53(002):115-123.

[4] Wensi ding,Kun liu,Yunke ding. Fuzzy PID Controller Based on Particle Swarm Optimization for Valve-Controlled Asymmetric Servo Cylinder [J]. Chinese Hydraulics & Pneumatics, 2017, 000(009):17-23.

[5] Yu zhang,Qun liu,Huifang liu, et al. Fuzzy Control of Hand-Holding Force of Surgical Robot Optimized by Particle Swarm Optimization [J]. Machinery Design & Manufacture, 2018(4):242-244.

[6] Ahmad, M., Beddu, S., binti Itam, Z., & Alanimi, F. B. I. (2019). State of the art compendium of macro and micro energies. *Advances in Science and Technology Research Journal*. Volume 13, Issue 1, March 2019, pages 88–109 https://doi.org/10.12913/22998624/103425

[7] Yanhua han. Dynamics Modeling and Analysis of Tethered spin Spacecraft for Artificial Gravity Technology [J]. Journal of Dynamics and Control, 2019(3).

[8]. Placement optimization of actuator and sensor and decentralized adaptive fuzzy vibration control for large space intelligent truss structure[J]. Science China(Technological Sciences),2011,54(04):853-861.

[9]LI DongXu,XU Rui. Autonomous decentralized intelligent vibration control for large split-blanket solar arrays[J]. Science China(Technological Sciences),2013,56(03):703-712.

[10]Chunmei Li.Semi-active fuzzy control for machine tool vibration[A].The International Association for Engineering and Technology Publishing.Abstracts of International Conference on Mechanics, Materials and Structural Engineering 2016[C].International Association of Engineering and Technology Publishing:, 2016:1.

[11]. Fuzzy Hybrid Control of Vibration Attitude of Full Car via Magneto-rheological Suspensions[J]. Chinese Journal of Mechanical Engineering,2010,23(01):72-79.