Non-Static error tracking control for near space airship loading platform

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Abstract. A control scheme based on internal model with non-static error is presented against the uncertainty of the near space airship loading platform system. The uncertainty in the tracking table is represented as interval variations in stability and control derivatives. By formulating the tracking problem of the uncertainty system as a robust state feedback stabilization problem of an augmented system, sufficient condition for the existence of robust tracking controller is derived in the form of linear matrix inequality (LMI). Finally, simulation results show that the new method not only has better anti-jamming performance, but also improves the dynamic performance of the high-order systems.

1. Introduction

Near space area is the most quite a while in the atmosphere, not affected by the weather, and almost never wet, has the stable weather conditions and good electromagnetic characteristic, in recent years, the world powers to try to take advantage of near space airship platform carry pay loadings in empty for a long time observation and communication. Air loading platform is installed in the attitude control device on the aircraft movement such as carrier, effective instruments to carry such as image sensor, the infrared camera, synthetic aperture radar, etc., on the ground or air targets to achieve automatic tracking control. The wind resistance moment, attitude Angle change or vibration of the aircraft during flight will cause the detection device on the platform to deviate from the axis, thus affecting the tracking control precision.

At present, many researches have been carried out on the tracking control algorithm of vehicle loading platform in China. Literature [1] the fuzzy controller based on genetic algorithm is used to design fuzzy -PID composite controller with fuzzy control adjustment weighting factor. Because of the complexity of the tracking control of the loading platform, the fuzzy membership has many classes, and the convergence and consistency of the intelligent algorithm are difficult to guarantee. Literature [2] adopts the position ring and speed loop control structure to improve the performance of anti-interference of the platform. However, due to the limitation of the system, there is no static difference between the angular velocity and the Angle output when interfering with input. Literature [3] realizes control loop design of sampled digital system after sampling the original system, but it is necessary to consider the proper selection of sampling interval to avoid the occurrence of leakage and aliasing. Literature [4] [5] designed the delay advance correction control, improved the system open loop gain, thereby inhibiting the interference moment. Literature [6] for rate stable loop correction link in the design of the bad anti-jamming ability of lead lag correction of defects, and puts forward the higher-order correction and high-order correction calibration in advance two kinds of control method, not only has good anti-jamming performance, and improved the dynamic performance of high order system. For a certain type of pre-research near space airship loading platform tracking control system, this paper proposes a tracking control scheme based on internal model control method with non-static error, and verify the effectiveness of the proposed method through simulation examples.

2. Description of the Loading platform control problem

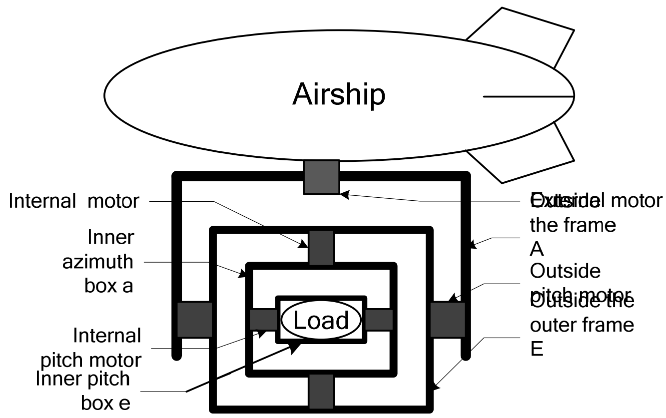

Fig. 1 airship loading platform structure

The near space airship loading platform consists of frame component, angular rate gyro, coder, motor, amplifier and controller. The frame components include outer side, pitch, inner and inner pitch. Define the outer space box frame, the external pitching frame is the frame, the inner azimuth frame is the frame, the inner frame is the frame. The top of the pitch frame is loaded with loading and gyro, and the gyroscope is used to measure the interference motion and the real Angle movement of the direction of the direction and pitch axis. When the airship movement interference Angle motion resulting from the airship will be through the shaft coupling between, from the foreign box, pitch frame, bearing box inside the outside and inside pitch box seriatim delivered to the loading on the optical axis, thus affecting the stability of the optical axis. When rate gyro felt the interference will be sensitive to the signal within the control loop to pitch bearing box and inside casing torque motor, drive the movement, the interference with the rate of equal size and opposite direction Angle motion compensation, thus cancellation rate, guarantee the stability of the optical axis tracking. At the same time, the Angle sensor on the shaft axis frame and box of the casing outside the two frame relative angular deviation of the signal, the control circuit to the casing outside the two respectively on the servo motor, so as to control the effect of exterior orientation and pitch boxes outside.

Thus, the mathematical model of the near space airship loading platform can be described as:

$$\begin{cases} \dot{x}(t) = A_\Delta x(t) + B_\Delta u(t) + B_w w(t) \\ y(t) = Cx(t) \end{cases} \tag{1}$$

System (1) , state variables $x = [\theta_e, \dot{\theta}_e, \theta_a, \dot{\theta}_a, \theta_E, \dot{\theta}_E, \theta_A, \dot{\theta}_A]^{\mathrm{T}}$,each element corresponds to the Angle and Angle change rate of the four frames; Control input $u = [U_e, U_a, U_E, U_A]^{\mathrm{T}}$, The elements in u correspond to the control input of the four frames; Y is the system quantity measurement output for external interference. A_Δ , B_Δ represents the matrix with uncertainty. There is $A_\Delta = A + \Delta A$, $B_\Delta = B + \Delta B$, ΔA, ΔB_2 representation of the uncertainty of the system and the conditions.

$$\Delta A = E_1 \Sigma_1 F_1 A \, , \, \Delta B = E_2 \Sigma_2 F_2 B \tag{2}$$

System (2) , E_1 , E_2 , F_1 , F_2 , representing the appropriate dimension, Σ_1 , Σ_2 represents the uncertainty matrix and $\Sigma_1^T\Sigma_1 \le I$, $\Sigma_2^T\Sigma_2 \le I$ is satisfied. Behind will not sure to restrict, the structure of the article will point out that if loading platform in the model parameters in a limited range change, can through certain technical method makes the uncertainty as described in the form of (2).

3. The internal mode based on control tracking algorithm

3.1. The method of internal mode control

As shown in fig.2, the internal model has no static control system, and the structure is a feedback system with compensator. The function of servo compensator is to make the system realize asymptotic tracking and perturbation inhibition, which is actually a dynamic system. The function of the stabilization compensator is to calm the whole system and is a constant state feedback.

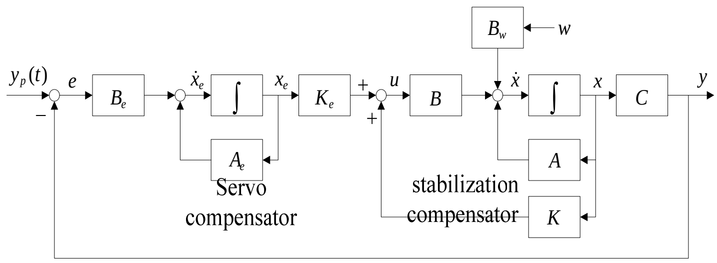

Fig. 2 structure block diagram of internal model control system

The servo compensator is

$$\begin{cases} \dot{x}_e(t) = A_e x_e(t) + B_e e(t) \\ y_e(t) = K_e x_e(t) \end{cases} \tag{3}$$

The stabilization compensator is a state feedback

$$u(t) = \begin{bmatrix} K & K_e \end{bmatrix} \begin{bmatrix} x(t) \\ x_e(t) \end{bmatrix} \tag{4}$$

Therefore, the closed-loop system equations of uncertain systems are obtained

$$\begin{cases} \dot{\hat{x}}(t) = \tilde{A}\hat{x}(t) + \hat{B}\hat{w}(t) \\ \hat{y}(t) = \hat{C}\hat{x}(t) \end{cases} \tag{5}$$

Formula

$$\hat{x}(t) = \begin{bmatrix} x(t) \\ x_e(t) \end{bmatrix},\ \hat{w}(t) = \begin{bmatrix} w(t) \\ y_p(t) \end{bmatrix},\ \tilde{A} = \hat{A} + \Delta\hat{A}$$

$$\hat{A} = \begin{bmatrix} A + BK & BK_e \\ -B_e C & A_e \end{bmatrix},\ \hat{B} = \begin{bmatrix} B_w & \\ & B_e \end{bmatrix},\ \hat{C} = \begin{bmatrix} C & 0 \end{bmatrix}$$

$$\Delta\hat{A}=\begin{bmatrix}\Delta A+\Delta BK & \Delta BK_e\\ 0 & 0\end{bmatrix}=\begin{bmatrix}E_1\\ 0\end{bmatrix}\Sigma_1\begin{bmatrix}F_1A & 0\end{bmatrix}+\begin{bmatrix}E_2\\ 0\end{bmatrix}\Sigma_2\begin{bmatrix}F_2BK & F_2BK_e\end{bmatrix}=\hat{E}_1\Sigma_1\hat{F}_1+\hat{E}_2\Sigma_2\hat{F}_2$$

3.2. Reference to the mathematical description of the signal and interference

In order to study the tracking control problem of load platform, it is necessary to understand the motion characteristics of its command signal and interference, and establish the corresponding signal model to study the asymptotic tracking and interference suppression of the system. In the analysis and simulation of the load platform, the instruction input is the unit slope function, then the Laplace transform is $1/s^2$; the airship movement is regarded as external disturbance, the motion function is expressed as the sine function, then the Laplace transform is $A\omega/\left(s^2+\omega^2\right)$. Therefore, $y_p(t)$ and $w(t)$ can be expressed as:

$$\begin{cases} y_p(s)=n_y(s)/d_y(s)\\ w(s)=n_w(s)/d_w(s)\end{cases} \tag{6}$$

Because of the known signal structure of the function, the polynomials $d_y(s)$ and $d_w(s)$ are known to ensure that $y_p(t)$ and $w(t)$ are strictly unique components that are unique to $n_y(s)$ and $n_w(s)$. From the realization theory of the transfer function, we can see that the time domain functions $y_p(t)$ and $w(t)$ corresponding to the formula (6) are generated by the state space model under the respective initial conditions $x_p(0)$ and $x_w(0)$ respectively.

$$\begin{cases} \dot{x}_p=A_px_p \quad y_p(t)=c_px_p\\ \dot{x}_w=A_wx_w \quad w(t)=c_wx_w\end{cases} \tag{7}$$

The smallest polynomials of A_p and A_w are $d_y(s)$ and $d_w(s)$, respectively. Let $f_p(s)$ and $f_w(s)$ be the smallest polynomial of A_p and A_w respectively, then in the tracking control problem, only consider the part of $y_p(t)$ and $w(t)$ that does not tend to zero when $t\to\infty$, that is, $f_p(s)$ and $f_w(s)$ are located in the right half plane root. The active polynomial represents the minimum multipurpose of $f_p(s)$ and $f_w(s)$ on the right half of the plane.

$$f_g(s)=s^r+a_1s^{r-1}+\cdots+a_{r-1}s+a_r$$

Then the root of the $f_g(s)=0$ has a non-negative real part. The $f_g^{-1}(s)I_q$ can be derived from the $y_p(t)$ and $w(t)$ when $t\to\infty$ does not tend to zero part of the common model, and it is in series with the controlled system, that is, the input into a tracking error,

$$\dot{x}_e(t)=A_ex_e(t)+B_ee(t) \quad y_e(t)=x_e(t) \tag{8}$$

Where,

$$A_e=\mathrm{diag}\underbrace{\left[\Gamma,\Gamma,\cdots,\Gamma\right]}_{q}\ ,B_e=\mathrm{diag}\underbrace{\left[\beta,\beta,\cdots,\beta\right]}_{q}$$

$$\Gamma = \left[\begin{array}{c|ccc} 0 & & & \\ \vdots & & I_{r-1} & \\ 0 & & & \\ \hline -a_r & -a_{r-1} & \cdots & -a_1 \end{array}\right], \ \beta = \left[\begin{array}{c} 0 \\ \vdots \\ 0 \\ \hline 1 \end{array}\right]$$

Equation (8) is to study the dynamic system tracking problem in the $y_p(t)$ and $w(t)$ established by the signal model. Which can be obtained without static tracking control theorem?

4. Applications

Aiming at the small-perturbation linearization model of load control platform, this paper designs a controller with no static tracking control scheme proposed in this paper. Uncertainty takes 10% of the maximum perturbation of all parameters in the spatial equation and transforms the parameter uncertainty into the corresponding structure.

Considering the linear model of the control system of a spacecraft near the spacecraft, the closed-loop system is established based on the uncertainty model. Using Matlab,

$$S_1 = \begin{bmatrix} -0.0095 & -0.0079 & 0.0434 & -0.0048 & -0.0024 & -0.0008 & 0.0013 & -0.0008 \\ 1.2898 & -0.0147 & 0.0804 & -0.0291 & 0.1819 & 0.0562 & -0.0714 & 0.2612 \\ -0.1591 & -0.2162 & -0.0164 & 0.0172 & -0.0818 & -0.0045 & 0.2806 & 0.0060 \\ 0.2256 & 0.1501 & 0.0711 & -0.0541 & -0.0645 & 0.3013 & -0.0303 & -0.0561 \end{bmatrix}$$

$$X_1 = \begin{bmatrix} -0.0053 & -0.0019 & 0.0002 & -1.3940 & 0.2364 & -0.0809 & -0.0342 & -0.9337 \\ -0.0019 & -0.0006 & 0.0016 & -0.0161 & -1.2562 & -0.0924 & -0.7419 & 0.0851 \\ 0.0002 & 0.0016 & 0.0005 & -0.0967 & -0.0608 & -0.0110 & -0.0679 & -0.0173 \\ -1.3940 & -0.0161 & -0.0967 & -0.0275 & 0.7445 & 0.0152 & -3.8235 & 0.4173 \\ 0.2364 & -1.2562 & -0.0608 & 0.7445 & -0.1442 & -0.4500 & -0.3754 & -3.8479 \\ -0.0809 & -0.0924 & -0.0110 & 0.0152 & -0.4500 & -0.0442 & -0.6402 & -0.3357 \\ -0.0342 & -0.7419 & -0.0679 & -3.8235 & -0.3754 & -0.6402 & 0.1403 & 0.0811 \\ -0.9337 & 0.0851 & -0.0173 & 0.4173 & -3.8479 & -0.3357 & 0.0811 & -0.4155 \end{bmatrix}$$

$$S_2 = \begin{bmatrix} -0.0410 & -0.0133 & 0.5654 & 0.0006 \\ 4.6584 & -0.1379 & 0.2847 & 0.0413 \\ -0.8127 & 0.0552 & -0.0233 & 0.3063 \\ -0.0724 & -1.9764 & 0.0165 & 0.1309 \end{bmatrix}, X_2 = \begin{bmatrix} 0.0020 & -0.1654 & 0.0237 & 0.3191 \\ -0.1654 & 0.0030 & 0.2626 & 4.0414 \\ 0.0237 & 0.2626 & -0.0030 & -0.0579 \\ 0.3191 & 4.0414 & -0.0579 & -0.2642 \end{bmatrix}$$

The controller is:

$$K = \begin{bmatrix} -4.0675 & -7.1102 & 76.5933 & -0.4099 & 0.1473 & 2.6843 & -0.3272 & 0.4948 \\ -1.4203 & 0.2440 & 31.0774 & -0.3785 & 0.2851 & -1.4335 & -0.2742 & -0.5948 \\ -1.7272 & -4.1004 & 17.5778 & -0.4112 & -0.2792 & 5.2393 & 0.1973 & 0.2749 \\ -5.4746 & -12.2341 & 94.8908 & -1.2857 & -0.6472 & 12.5011 & -0.3490 & 0.5224 \end{bmatrix}$$

$$K_e = \begin{bmatrix} -9.4408 & 2.4464 & 171.4408 & -11.5299 \\ 167.7102 & -12.5932 & 18.9654 & 5.6072 \\ -28.9634 & 2.2703 & -1.5454 & -1.0730 \\ 3.2437 & -0.2951 & -4.7742 & -0.0459 \end{bmatrix}$$

In order to test the performance of the static tracking controller, the perturbation performance of the perturbation system is investigated by using the slope command in the range of 10% uncertainty. The stability of the system (1) under the action of the internal model controller is verified. In the absence of external input, the system's autonomous capacity is shown in Fig.

It can be seen from Fig. 3 that when the system is subjected to the initial energy, only the angle changes of each frame react quickly, and the state vectors in the formula (5) are rapidly stabilized in a short time, indicating that the system after designing the internal model controller has Stability, can work steadily. The following test system tracking performance, tracking instructions input for the slope function, airship sine movement.

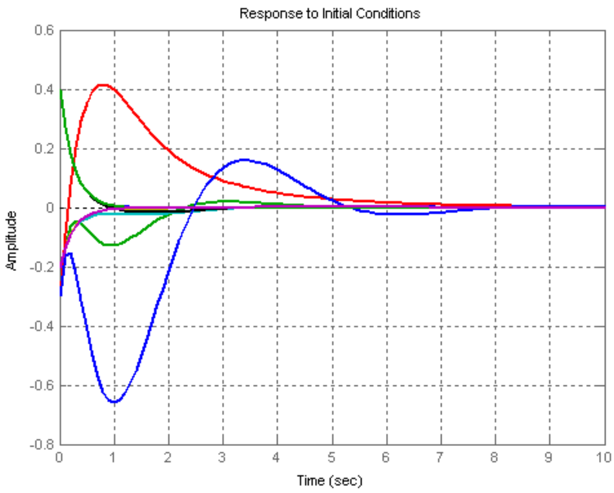

Fig. 3. The system's zero-input response

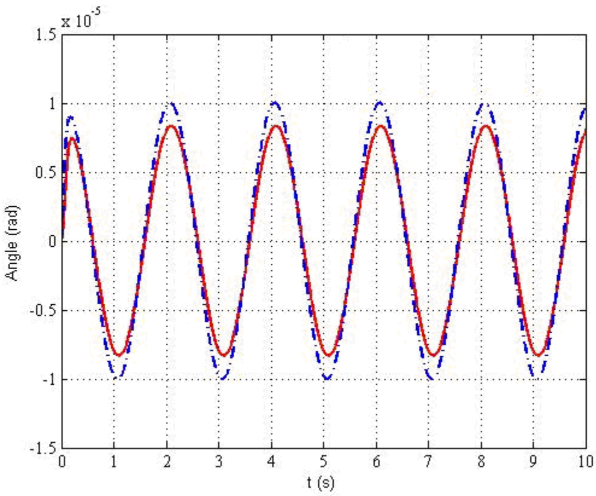

Fig. 4. The angular response of the inner and outer frames in the presence of sinusoidal disturbances

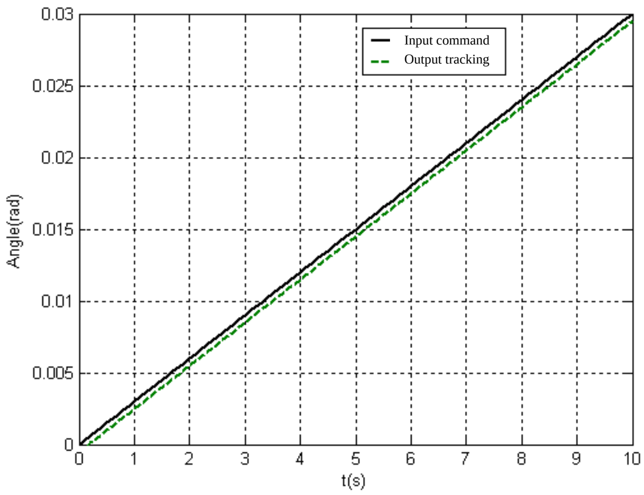

Fig. 5. Visual axis instruction tracking response

The simulation shows that the amplitude of the outer frame is greatly reduced in the load platform under the interference of the external moment when the sinusoidal motion of the uncertain perturbation system and the airship is made under the action of the static tracking controller. To a certain extent, the external interference from the shielding effect, in order to provide accurate conditions for the shaft to track, Figure 5 shows that the output signal can be better to track the input command, and the output angle fluctuation is only 24 μrad, than the ordinary PI The calibration method is better. This shows that no static tracking control method is relatively easy to achieve in the project.

5. Conclusion

The important reasons for the tracking performance of the loading platform are the uncertainty of the model and the jamming of the airship. With attention paid to the above two aspects of control system requirement, the controller based on internal model control method is designed with the combination of the reasonable use of control structure and the advanced control technology. The effectiveness of this method is verified by simulation.

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