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Research on Multiple Cell Linear Parameter Varying Model Predictive Control

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Abstract

To improve the accuracy of model predictive control, this paper presents an improved multiple cell linear parameter varying model predictive control method for carrier-based aircraft. After establishing the lateral dynamic model of carrier-based aircraft for multiple cell predictive controller, the output-feedback linear parameter varying control based on states observation should be implemented. The model simulation results indicate the better performance of the new method in comparison with the traditional controller with more accuracy and practicability.

Keywords*: Multiple Cell; Linear Parameter Varying; Model Predictive Control; Carrier-Based Aircraft*

1. Introduction

For the difficulty of lateral dynamic control of carrier-based aircraft, there are a lot of improve control method should be impressed, including fuzzy control, neural network control, robust control [1-9]. Linear parameter varying model predictive control is the better one for lateral coupling of force and moment with carrier-based aircraft, and it has been widely applied [10-12].

It's circumscribed of traditional linear parameter varying model predictive control with the difficulty to forecast, and we wish to design a universe forecasting way for predictive precision in accordance with demand, and it's the work this article will accomplish.

The rest of this paper is structured as follows: next section we first model the structure of Lateral dynamic modeling of carrier-based aircraft. Section 3 designs the output-feedback LPV control way based on states observation. The simulation results reflecting the comparison between new method and the traditional one will be discussed in Section 4.

2. Lateral Dynamic Modeling of Carrier-Based Aircraft

With the research object of F/A 18 carrier-based aircraft, we suppose that the aircraft is balanced in longitudinal direction, the angle of pitching is 4.9°, and landing on -3.5° ideal glideslope [13-16]. The dynamic modeling of carrier-based aircraft is shown as (1).

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$$\begin{cases} \dot{y}_g = v \\ \dot{v} = \dfrac{1}{m}\{g_1(\psi) f_1(\beta,\delta_{ail},\delta_{rud}) + g_2(\phi,\psi) f_2(\beta,\delta_{ail},\delta_{rud}) + g_3(\phi,\psi) f_3(\beta,\delta_{ail},\delta_{rud})\} \\ \dot{\phi} = p + (q\sin\phi + r\cos\phi)\tan\theta \\ \dot{\psi} = (q\sin\phi + r\cos\phi)/\cos\theta \\ \dot{p} = I_{zz}l + I_{xz}n - \{I_{xz}(I_{yy} - I_{xx} - I_{zz})p + \\ \quad [I_{xz}^2 + I_{zz}(I_{zz} - I_{yy})]r\} q/(I_{xx}I_{zz} - I_{xz}^2) \\ \dot{r} = I_{xz}l + I_{xx}n - \{I_{xz}(I_{yy} - I_{xx} - I_{zz})r + \\ \quad [I_{xz}^2 + I_{xx}(I_{xx} - I_{yy})]p\} q/(I_{xx}I_{zz} - I_{xz}^2) \end{cases} \tag{1}$$

$$\begin{cases} g_1(\psi) = \cos\theta\sin\psi, \\ g_2(\phi,\psi) = \sin\phi\sin\theta\sin\psi + \cos\phi\cos\psi, \\ g_3(\phi,\psi) = \cos\phi\sin\theta\sin\psi - \sin\phi\cos\psi. \end{cases} \tag{2}$$

$$\begin{cases} f_1(\beta,\delta_{ail},\delta_{rud}) = T - D\cos\beta\cos\alpha + L\sin\alpha - Y\sin\beta\cos\alpha, \\ f_2(\beta,\delta_{ail},\delta_{rud}) = -D\sin\beta + Y\cos\beta, \\ f_3(\beta,\delta_{ail},\delta_{rud}) = -D\cos\beta\sin\alpha - L\cos\alpha - Y\sin\beta\sin\alpha. \end{cases} \tag{3}$$

Where β is the angle of sideslip, I_{xx} is the rotational inertia of roll axis; I_{yy} is the rotational inertia of pitching axis; I_{zz} is the rotational inertia of yaw axis; I_{xz} is the inertia product of y axis; l is the rolling moment; n is the yawing moment.

The yawing force and moment of carrier-based aircraft is represented as (4).

$$\begin{cases} Y = \bar{q}SC_Y(\alpha,\beta,\delta_{ail},\delta_{rud}) \\ l = \bar{q}SbC_l(\alpha,\beta,\delta_{ail},\delta_{rud},p,r,V) \\ n = \bar{q}SbC_n(\alpha,\beta,\delta_{ail},\delta_{rud},p,r,V) \end{cases} \tag{4}$$

Where $\bar{q}$ is the air dynamic pressure, S is the area of wing, b is the wingspan, $C_Y(\alpha,\beta,\delta_{ail},\delta_{rud})$, $C_l(\alpha,\beta,\delta_{ail},\delta_{rud},p,r,V)$and $C_n(\alpha,\beta,\delta_{ail},\delta_{rud},p,r,V)$ are the coefficients of lateral force, rolling force and yawing force respectively. δ_{ail} is the input of aileron, and δ_{rud} is the input of rudder.

The aerodynamic coefficient should be described in polynomial form as shown in (5):

$$\begin{cases} C_Y(\alpha,\beta,\delta_{ail},\delta_{rud}) = C_{Y_\beta}(\alpha)\beta + C_{Y_{\delta_{ail}}}(\alpha)\delta_{ail} + C_{Y_{\delta_{rud}}}(\alpha)\delta_{rud} \\ C_l(\alpha,\beta,\delta_{ail},\delta_{rud},p,r,V) = C_{l_\beta}(\alpha)\beta + C_{l_{\delta_{ail}}}(\alpha)\delta_{ail} + C_{l_{\delta_{rud}}}(\alpha)\delta_{rud} \\ \qquad + \dfrac{b}{2V}C_{l_p}(\alpha)p + \dfrac{b}{2V}C_{l_r}(\alpha)r \\ C_n(\alpha,\beta,\delta_{ail},\delta_{rud},p,r,V) = C_{n_\beta}(\alpha)\beta + C_{n_{\delta_{ail}}}(\alpha)\delta_{ail} + C_{n_{\delta_{rud}}}(\alpha)\delta_{rud} \\ \qquad + \dfrac{b}{2V}C_{n_p}(\alpha)p + \dfrac{b}{2V}C_{n_r}(\alpha)r \end{cases} \tag{5}$$

Where $C_{*_\beta}(\alpha)$, $C_{*_{\delta_{ail}}}(\alpha)$, $C_{*_{\delta_{rud}}}$, $C_{*_p}(\alpha)$ and $C_{*_r}(\alpha)$ are the polynomial functions of angle of attack α .

Nonlinear dynamic function based on error states is:

$$\begin{cases}\dot{e}_y = e_v \\ \dot{e}_v = \dfrac{1}{m}\{g_1(e_\psi) f_1(\beta, e_{\delta_{ail}}, e_{\delta_{rud}}) + g_2(e_\phi, e_\psi) f_2(\beta, e_{\delta_{ail}}, e_{\delta_{rud}}) + g_3(e_\phi, e_\psi) f_3(\beta, e_{\delta_{ail}}, e_{\delta_{rud}})\} - \dot{v}_d \\ \dot{e}_\phi = (e_p + p_d) + (q\sin(e_\phi + \phi_d) + (e_r + r_d)\cos(e_\phi + \phi_d))\tan\theta - p_d \\ \dot{e}_\psi = (q\sin(e_\phi + \phi_d) + (e_r + r_d)\cos(e_\phi + \phi_d)) / \cos\theta - r_d \\ \dot{e}_p = I_{zz} l + I_{xz} n - \left\{ I_{xz}(I_{yy} - I_{xx} - I_{zz})(e_p + p_d) + \right. \\ \quad \left. \left[I_{xz}^2 + I_{zz}(I_{zz} - I_{yy}) \right](e_r + r_d) \right\} q / (I_{xx} I_{zz} - I_{xz}^2) - \dot{p}_d \\ \dot{e}_r = I_{xz} l + I_{xx} n - \left\{ I_{xz}(I_{yy} - I_{xx} - I_{zz})(e_r + r_d) + \right. \\ \quad \left. \left[I_{xz}^2 + I_{xx}(I_{xx} - I_{yy}) \right](e_p + p_d) \right\} q / (I_{xx} I_{zz} - I_{xz}^2) - \dot{r}_d \end{cases}$$

(6)

Simplifying:

$$\begin{cases}\dot{\boldsymbol{e}}_x = f(\boldsymbol{e}_x, \boldsymbol{e}_u) \\ \boldsymbol{e}_u = \begin{bmatrix} e_{\delta_{ail}} & e_{\delta_{rud}} \end{bmatrix}^{\mathrm{T}} = \begin{bmatrix} \delta_{ail} - \delta_{ail0} & \delta_{rud} - \delta_{rud0} \end{bmatrix}^{\mathrm{T}} \end{cases} \tag{7}$$

Where the lateral moment, rolling moment and yawing moment are expressed as (8).

$$\begin{cases} Y = \bar{q}S(C_{Y_\beta}(\alpha)\beta + C_{Y_{\delta_{ail}}}(\alpha)\delta_{ail} + C_{Y_{\delta_{rud}}}(\alpha)\delta_{rud}) \\ l = \bar{q}SbC_l(\alpha, \beta, \delta_{ail}, \delta_{rud}, p, r, V) = \bar{q}Sb(C_{l0}(\alpha, \beta, p, r, V) + C_{l_{\delta_{ail}}}(\alpha)\delta_{ail} + C_{Y_{\delta_{rud}}}(\alpha)\delta_{rud})) \\ n = \bar{q}SbC_n(\alpha, \beta, \delta_{ail}, \delta_{rud}, p, r, V) = \bar{q}Sb(C_{n0}(\alpha, \beta, p, r, V) + C_{n_{\delta_{ail}}}(\alpha)\delta_{ail} + C_{n_{\delta_{rud}}}(\alpha)\delta_{rud})) \\ C_{l0}(\alpha, \beta, p, r, V) = C_{l_\beta}(\alpha)\beta + \dfrac{b}{2V} C_{l_p}(\alpha) p + \dfrac{b}{2V} C_{l_r}(\alpha) r \\ C_{n0}(\alpha, \beta, p, r, V) = C_{n_\beta}(\alpha)\beta + \dfrac{b}{2V} C_{n_p}(\alpha) p + \dfrac{b}{2V} C_{n_r}(\alpha) r \end{cases}$$

(8)

Where $C_{n_p}(\alpha)$ is the coefficient of sympathetic moment.

Using triangle functions, we will get the functions as shown in (9).

$$\begin{cases} -\cos\theta \le v_{1\psi} \le \cos\theta \\ v_{2\psi} = (\dfrac{\sin\theta}{2} - \dfrac{1}{2})\sin(\phi_d + \psi_d) + (\dfrac{\sin\theta}{2} + \dfrac{1}{2})\sin(\phi_d - \psi_d) \\ v_{3\psi} = (\dfrac{\sin\theta}{2} - \dfrac{1}{2})\cos(\phi_d + \psi_d) + (\dfrac{\sin\theta}{2} + \dfrac{1}{2})\cos(\phi_d - \psi_d) \\ -1 \le v_{2\psi} \le 1, -1 \le v_{3\psi} \le 1 \end{cases} \tag{9}$$

The conditions of function are shown as (10)-(11).

$$\begin{cases} \left|a_{1\psi}\right| \le \left|D\cos\alpha + \bar{q}S(C_{Y_{rud}}\delta_{rud0} + C_{Y_{ail}}\delta_{ail0}) + D\sin\alpha\right| \le \\ \left|D\cos\alpha + D\sin\alpha\right| + \left|\bar{q}S(C_{Y_{rud}}\delta_{rud0} + C_{Y_{ail}}\delta_{ail0})\right| \le \\ \le \left|D\cos\alpha + D\sin\alpha\right| + \bar{q}S\left|(C_{Y_{rud}}\max(\delta_{rud0}) + C_{Y_{ail}}\max(\delta_{ail0}))\right| \\ \left|b_{1\psi}\right| \le \left|\cos\alpha\bar{q}S(C_{Y_{rud}}\delta_{rud0} + C_{Y_{ail}}\delta_{ail0}) + D + (C_{Y_{rud}}\delta_{rud0} + C_{Y_{ail}}\delta_{ail0})\sin\alpha\bar{q}S\right| \le \\ \left|D\right| + \left|\cos\alpha\bar{q}S + \sin\alpha\bar{q}S\right|\left|C_{Y_{rud}}\max(\delta_{rud0}) + C_{Y_{ail}}\max(\delta_{ail0})\right| \\ a_{1\psi\max} = \left|D\cos\alpha + D\sin\alpha\right| + \bar{q}S\left|(C_{Y_{rud}}\max(\delta_{rud0}) + C_{Y_{ail}}\max(\delta_{ail0}))\right| \\ b_{1\psi\max} = \left|D\right| + \left|\cos\alpha\bar{q}S + \sin\alpha\bar{q}S\right|\left|C_{Y_{rud}}\max(\delta_{rud0}) + C_{Y_{ail}}\max(\delta_{ail0})\right| \end{cases} \quad (10)$$

$$\begin{cases} \left|a_{2\psi}\right| \le \frac{1}{2}\cos\alpha\bar{q}SC_{Y_\beta} + \frac{1}{2}\sin\alpha\bar{q}SC_{Y_\beta} \\ \left|b_{2\psi}\right| \le \frac{1}{2}\bar{q}SC_{Y_\beta} \\ \left|a_{3\psi}\right| \le \left|\frac{1}{2}(\cos\alpha\bar{q}SC_{Y_\beta} + \sin\alpha\bar{q}SC_{Y_\beta}) + T + L\sin\alpha + L\cos\alpha\right| \\ a_{2\psi\max} = \frac{1}{2}\cos\alpha\bar{q}S + \frac{1}{2}\sin\alpha\bar{q}SC_{Y_\beta} \\ b_{2\psi\max} = \frac{1}{2}\bar{q}SC_{Y_\beta} \\ a_{3\psi\max} = \frac{1}{2}(\cos\alpha\bar{q}SC_{Y_\beta} + \sin\alpha\bar{q}SC_{Y_\beta}) + T + L\sin\alpha + L\cos\alpha \end{cases} \quad (11)$$

Where

$$\begin{cases} c_{1\psi} = \sqrt{a_{1\psi\max}^2 + b_{1\psi\max}^2} \\ c_{2\psi} = \sqrt{a_{2\psi\max}^2 + b_{2\psi\max}^2} \end{cases} \quad (12)$$

$$\frac{\partial(g_1 f_1 + g_2 f_2 + g_3 f_3)}{\partial e_\psi} = \sigma_\psi \in \left[-c_{1\psi} - c_{2\psi} - a_{3\psi\max}, c_{1\psi} + c_{2\psi} + a_{3\psi\max}\right] \quad (13)$$

$$\begin{cases} \frac{\partial(g_1 f_1 + g_2 f_2 + g_3 f_3)}{\partial e_{\delta_{ail}}}\Big|_{\boldsymbol{e}_x=0,\boldsymbol{e}_u=0} = \bar{q}SC_{Y_{ail}}\sqrt{a_{\delta_{ail}}^2 + b_{\delta_{ail}}^2}\sin(\beta + \eta_{\delta_{ail}}) \\ a_{\delta_{ail}} = -\cos\theta\cos\alpha\sin\psi_d + \frac{\sin\alpha}{2}[(1-\sin\theta)\sin(\phi_d + \psi_d) + (1+\sin\theta)\sin(\phi_d - \psi_d)] \\ b_{\delta_{ail}} = (\frac{1}{2} - \frac{1}{2}\sin\theta)\cos(\phi_d + \psi_d) + (\frac{1}{2} + \frac{1}{2}\sin\theta)\cos(\phi_d - \psi_d) \\ \eta_{\delta_{ail}} = \arctan(b_{\delta_{ail}} / a_{\delta_{ail}}) \end{cases}$$

(14)

$$\begin{cases} \dfrac{\partial(g_1 f_1 + g_2 f_2 + g_3 f_3)}{\partial e_{\delta_{rud}}}|_{\boldsymbol{e}_x=0,\boldsymbol{e}_u=0} = \bar{q}SC_{Y_{rud}}\sqrt{a_{\delta_{rud}}^2 + b_{\delta_{rud}}^2}\sin(\beta+\eta_{\delta_{rud}}) \\ a_{\delta_{rud}} = -\cos\theta\cos\alpha\sin\psi_d + \dfrac{\sin\alpha}{2}[(1-\sin\theta)\sin(\phi_d+\psi_d)+(1+\sin\theta)\sin(\phi_d-\psi_d)] \\ b_{\delta_{rud}} = (\dfrac{1}{2}-\dfrac{1}{2}\sin\theta)\cos(\phi_d+\psi_d)+(\dfrac{1}{2}+\dfrac{1}{2}\sin\theta)\cos(\phi_d-\psi_d) \\ \eta_{\delta_{rud}} = \arctan(b_{\delta_{rud}}/a_{\delta_{rud}}) \end{cases} \tag{15}$$

$$\begin{cases} a_{\delta_{\max}} = \cos\theta\cos\alpha + \sin\alpha \\ b_{\delta_{\max}} = 1 \\ c_\delta = \bar{q}S\sqrt{a_{\delta_{\max}}^2 + b_{\delta_{\max}}^2} \\ \dfrac{\partial(g_1 f_1 + g_2 f_2 + g_3 f_3)}{\partial e_{\delta_{ail}}}|_{\boldsymbol{e}_x=0,\boldsymbol{e}_u=0} = \sigma_{ail} \in \left[-C_{Y_{ail}}c_\delta, C_{Y_{ail}}c_\delta\right] \\ \dfrac{\partial(g_1 f_1 + g_2 f_2 + g_3 f_3)}{\partial e_{\delta_{rud}}}|_{\boldsymbol{e}_x=0,\boldsymbol{e}_u=0} = \sigma_{rud} \in \left[-C_{Y_{rud}}c_\delta, C_{Y_{rud}}c_\delta\right] \end{cases} \tag{16}$$

We utilize yawing angle β as output, and obtain the linear matrix of output function as shown in (17).

$$\begin{aligned} v_{a.yb} = V_{k.xg}(\sin\phi\sin\theta\cos\psi - \cos\phi\sin\psi) + \\ v(\sin\phi\sin\theta\sin\psi + \cos\phi\cos\psi) + V_{k.zg}\cos\theta\sin\phi \end{aligned} \tag{17}$$

$$\beta \approx \sin\beta = \begin{bmatrix} 0 & \beta_v & \beta_\phi & \beta_\psi & 0 & 0 \end{bmatrix} \begin{bmatrix} e_y \\ e_v \\ e_\phi \\ e_\psi \\ e_p \\ e_r \end{bmatrix} \tag{18}$$

Where

$$\begin{cases} \beta_v = (\sin\phi_d\sin\theta\sin\psi_d + \cos\phi_d\sin\psi_d)/V_a \\ \beta_\phi = ((\sin\theta\cos\phi_d\cos\psi_d + \sin\psi_d\sin\phi_d)V_{k.xg} + V_{k.zg}\cos\theta\cos\psi_d + \\ \qquad v_d(\sin\theta\cos\phi_d\sin\psi_d - \sin\phi_d\cos\psi_d))/V_a \\ \beta_\psi = ((-\sin\theta\sin\phi_d\sin\psi_d - \cos\psi_d\cos\phi_d)V_{k.xg} + \\ \qquad v_d(\sin\theta\sin\phi_d\cos\psi_d - \cos\phi_d\sin\psi_d))/V_a \end{cases} \tag{19}$$

Finally, the affinity form of factor $\boldsymbol{\sigma}$ should be obtained:

$$\begin{cases} \boldsymbol{e}_x(k+1) = f(\boldsymbol{e}(k), \boldsymbol{e}_u(k)) := \boldsymbol{A}(\boldsymbol{\sigma}(k))\boldsymbol{e}_x(k) + \boldsymbol{B}(\boldsymbol{\sigma}(k))\boldsymbol{e}_u(k) \\ \boldsymbol{e}_y(k) = \boldsymbol{C}(\boldsymbol{\sigma}(k))\boldsymbol{e}_x(k) \\ \boldsymbol{\sigma}(k) = \begin{bmatrix} \sigma_\phi(k) & \sigma_\psi(k) & \phi_d(k) & \sigma_{ail}(k) & \beta_\phi(k) \end{bmatrix} \end{cases} \tag{20}$$

Where $\boldsymbol{\lambda}(k)$ is the function of $\boldsymbol{\sigma}$.

3. Output-Feedback LPV Control Based on States Observation

The conditions of multiple-constraints LPV control based on variable weight matrix is that suppose some moment t_k, the lateral position and velocity are $y_d(t_k)$ and $v_d(t_k)$, the roll angle and yawing velocity are p_d and r_d respectively.

With a known of $y_d(t_k)$, $v_d(t_k)$, $\psi_d(t_k)$, $p_d(t_k)$ and $r_d(t_k)$, $\phi_d(t_k)$, $\delta_{\text{rud\_trim}}(t_k)$ and $\delta_{\text{ail\_trim}}(t_k)$ are iterative solving with balancing function trim of Matlab.

$$\min \ \dot{\boldsymbol{x}} = f(\boldsymbol{x}, \boldsymbol{u}) \tag{21}$$

(21) expresses the relationship between actual input and ideal input:

$$\begin{cases} \boldsymbol{x}(k+1) - \boldsymbol{x}_d(k+1) = \boldsymbol{A}(\boldsymbol{\lambda}(k))(\boldsymbol{x}(k) - \boldsymbol{z}(k)) + \boldsymbol{B}(\boldsymbol{\lambda}(k))(\boldsymbol{u}(k) - \boldsymbol{v}(k)) \\ \boldsymbol{x}_d(k) = \begin{bmatrix} y_d(k) & v_d(k) & \phi_d(k) & \psi_d(k) & p_d(k) & r_d(k) \end{bmatrix}^{\mathrm{T}} \\ \boldsymbol{v}(k) = \begin{bmatrix} \delta_{ail\_trim} & \delta_{rud\_trim} \end{bmatrix}^{\mathrm{T}} \end{cases} \tag{22}$$

$$\boldsymbol{x}(k+1) = \boldsymbol{A}(\boldsymbol{\lambda}(k))\boldsymbol{x}(k) + \boldsymbol{B}(\boldsymbol{\lambda}(k))\boldsymbol{u}(k) \tag{23}$$

$$\boldsymbol{x}_d(k+1) = \boldsymbol{A}(\boldsymbol{\lambda}(k))\boldsymbol{x}_d(k) + \boldsymbol{B}(\boldsymbol{\lambda}(k))\boldsymbol{v}(k) \tag{24}$$

Where $\boldsymbol{x_d}(k)$ is the ideal state, aircraft's state function at k moment is expressed in (23), the state function of ideal following aircraft is expressed in (24).

Suppose the estimating error state is $\hat{\boldsymbol{e}}_x$, and

$$\hat{\boldsymbol{e}}_x(k+1) = \boldsymbol{A}(\boldsymbol{\lambda}(k))\hat{\boldsymbol{e}}_x(k) + \boldsymbol{B}(\boldsymbol{\lambda}(k))\boldsymbol{e}_u(k) + \boldsymbol{L}_p(\boldsymbol{e}_y(k) - \boldsymbol{C}(\boldsymbol{\lambda}(k))\hat{\boldsymbol{e}}_x(k)) \tag{25}$$

If $\boldsymbol{e}(k) = \boldsymbol{e}_x(k) - \hat{\boldsymbol{e}}_x(k)$, the error state at k+1 moment is:

$$\boldsymbol{e}(k+1) = (\boldsymbol{A}(\boldsymbol{\lambda}(k)) - \boldsymbol{L}_p\boldsymbol{C}(\boldsymbol{\lambda}(k)))\boldsymbol{e}(k) \tag{26}$$

For the system as shown in (27):

$$\begin{cases} \boldsymbol{e}_x(k+1) = \boldsymbol{A}(\lambda(k))\boldsymbol{e}_x(k) + \boldsymbol{B}(\lambda(k))\boldsymbol{e}_{\boldsymbol{u}}(k) \\ \boldsymbol{e}_y(k) = \boldsymbol{C}(\lambda(k))\boldsymbol{e}_x(k) \\ \lambda(k) = \begin{bmatrix} \lambda_1(k) & \lambda_2(k) & \lambda_3(k) & \lambda_4(k) & \lambda_5(k) \end{bmatrix} \\ \boldsymbol{e}_y(k) = \begin{bmatrix} e_y & e_v & e_\phi & e_\psi & e_p & e_r & \beta \end{bmatrix}^{\mathrm{T}} \end{cases} \tag{27}$$

We use (28) forecast future.

$$\hat{\boldsymbol{e}}_x(k+1+i \mid k) = \boldsymbol{A}(\boldsymbol{\lambda}(k))\hat{\boldsymbol{e}}_x(k+i \mid k) + \boldsymbol{B}(\boldsymbol{\lambda}(k))\boldsymbol{e}_{\boldsymbol{u}}(k+i \mid k), i \geq 1 \tag{28}$$

4. Model Simulation

To improve the tracking precision of aircraft's trajectory, it designs a landing control method. Figure6-10 are the response curves of flight path, height deviation, longitudinal sick, gliding angle and velocity for the improve way and traditional control patterns.

From Figure 6-10, the approximation error of system is $\varepsilon = 0.2$ m at the moment 3.8s under the asymmetric variable universe adaptive fuzzy landing control system, and it achieves the same error at the moment 12.3s under the traditional landing control system. It has the superiority complex on approximation error for the asymmetric variable universe adaptive fuzzy landing control system we designed.

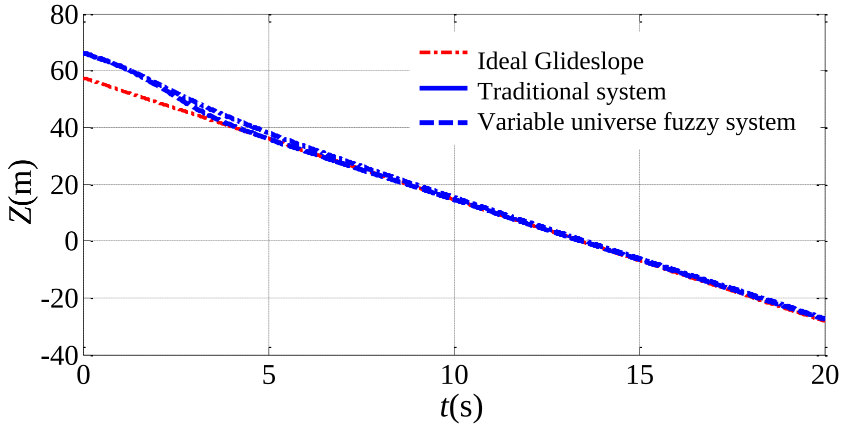

Figure 6. Response Curve of Flight Path

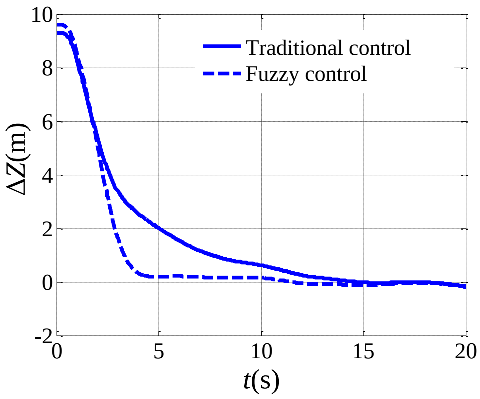

Figure 7. Response Curve of Deviation

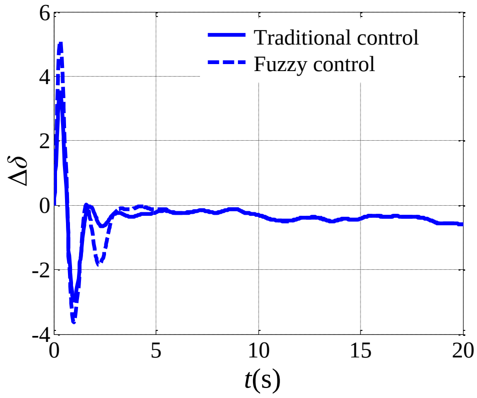

Figure 8. Response Curve of Stick

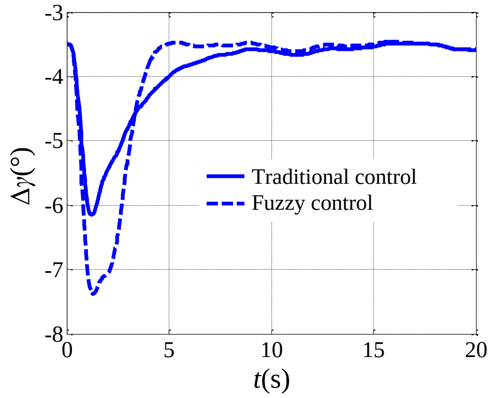

Figure 9. Response Curve of Gliding Angle

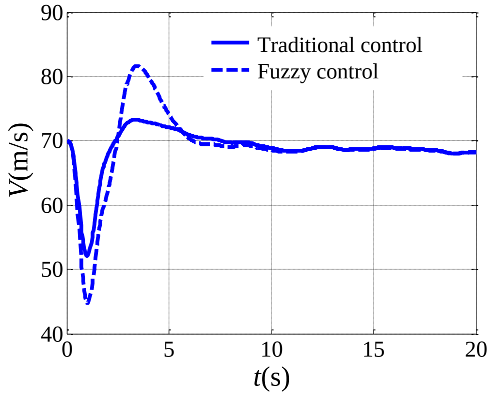

Figure 10. Response Curve of Velocity

6. Conclusion

This paper has presented an improved multiple cell linear parameter varying model predictive control manner for carrier-based aircraft. The output-feedback linear parameter varying control based on states observation should be adapted for lateral dynamic model. The simulation results show that comparing with the traditional model predictive control manner, the multiple cell LPV one has better evaluation result for pilots.

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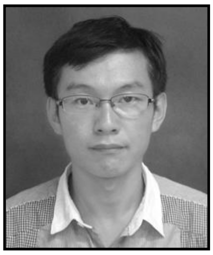

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