Automatic Flight Control

Flight Control of a Fixed-Wing Aircraft

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Flight Control of a Fixed-Wing Aircraft

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Outline

- Flight control of a fixed wing aircraft
- Fixed wing aircraft model
- Structure of flight control system
 - Longitudinal control
 - Lateral control
 - Multiloop control
- Design of flight control system
- 5 Implementation of linear controllers for nonlinear plants
- 6 Simulink model for the fixed wing aircraft
- Simulink model for the flight control system
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 - Lateral control



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Flight Control of a Fixed-Wing Aircraf

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Flight control of a fixed wing aircraf

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Flight Control of a Fixed-Wing Aircraft

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Flight control of a fixed wing aircraft

Flight control of a fixed wing aircraft

- Let us consider the flight control of a fixed wing aircraft.
- The purpose of the controller is to allow the aircraft to flight automatically tracking the set-points in airspeed, altitude and heading.
- This controller is a basic autopilot system.
- The aircraft considered for this control application will be a general model with a simplified propulsion system.



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Fixed wing aircraft model

• The equations of motion for the fixed wing aircraft are

$$\begin{split} \dot{\mathbf{p}}_{\mathbf{e}} &= \mathbf{C_{b/e}}^T \mathbf{V_b}, \\ \dot{\Phi} &= \mathbf{H}\left(\Phi\right) \Omega_{\mathbf{b}}, \\ \dot{\mathbf{V}}_{\mathbf{b}} &= \frac{\left(\mathbf{F_{a,b}} + \mathbf{F_{t,b}}\right)}{m} + \mathbf{G_b} - \Omega_{\mathbf{b}} \times \mathbf{V_b}, \\ \dot{\Omega}_{\mathbf{b}} &= \mathbf{I_b}^{-1} \left(\mathbf{M_{a,b}} + \mathbf{M_{t,b}} - \Omega_{\mathbf{b}} \times \mathbf{I_b} \Omega_{\mathbf{b}}\right). \end{split}$$



Fixed wing aircraft model

Where

$$\mathbf{G_b} = \begin{bmatrix} -gs\theta \\ gs\phi c\theta \\ gc\phi c\theta \end{bmatrix}$$

$$\begin{split} \mathbf{G_b} &= \begin{bmatrix} -gs\theta \\ gs\phi c\theta \\ gc\phi c\theta \end{bmatrix}, \\ \mathbf{F_{a,b}} &= \mathbf{C_{b/w}F_{a,w}} = \mathbf{C_{b/w}} \begin{bmatrix} -D \\ -C \\ -L \end{bmatrix} = \mathbf{C_{b/w}} \begin{bmatrix} -\bar{q}SC_D, \\ -\bar{q}SC_C, \\ -\bar{q}SC_L, \end{bmatrix}, \end{split}$$

$$\mathbf{F_{t,b}} = \begin{bmatrix} F_t \\ 0 \\ 0 \end{bmatrix}.$$



Fixed wing aircraft model

And

$$\begin{split} \mathbf{M_{a,b}} &= \begin{bmatrix} l \\ m \\ n \end{bmatrix} = \begin{bmatrix} \bar{q}SbC_l, \\ \bar{q}ScC_m, \\ \bar{q}SbC_n, \end{bmatrix} - \Delta CG_b \times \mathbf{F_{a,b}}, \\ \mathbf{M_{t,b}} &= -\Delta CG_b \times \mathbf{F_{t,b}} \end{split}$$



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Fixed wing aircraft model

• The aerodynamic coefficients are modeled by

$$\begin{split} C_L = & C_{L,0} + C_{L,\alpha}\alpha + C_{L,\delta f}\delta_f + C_{L,\delta i}\dot{i}_h + C_{L,\delta c}\delta_e + \frac{c}{2V}\left(C_{L,\alpha}\dot{\alpha} + C_{L,q}q\right) + C_{L,M}M, \\ C_D = & C_{D,0} + \frac{\left(C_L - C_{L,min\,drog}\right)^2}{\pi ARe} + C_{D,M}M, \\ C_C = & C_{C,\beta}\beta + C_{C,\delta_c}\delta_a + C_{C,\delta_c}\delta_r + \frac{b}{2V}\left(C_{C,p}p + C_{C,r}r\right), \\ C_l = & C_{l,\beta}\beta + C_{l,\delta_a}\delta_a + C_{l,\delta_c}\delta_r + \frac{b}{2V}\left(C_{l,p}p + C_{l,r}r\right), \\ C_m = & C_{m,0} + C_{m,\alpha}\alpha + C_{m,\delta_f}\delta_f + C_{m,b}\dot{i}_h + C_{m,\delta_c}\delta_e + \frac{c}{2V}\left(C_{m,\Delta}\dot{\alpha} + C_{m,q}q\right) + C_{m,M}M, \end{split}$$

 $C_n = C_{n,\beta}\beta + C_{n,\delta_a}\delta_a + C_{n,\delta_r}\delta_r + \frac{b}{2V}\left(C_{n,p}p + C_{n,r}r\right).$



Fixed wing aircraft model

• And the propulsion system is modeled by

$$\mathbf{F_{t,b}} = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} F_{t_{max}} \delta_t.$$



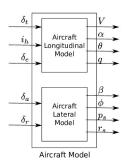
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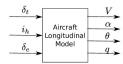
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Linearized aircraft model



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Linearized aircraft longitudinal model





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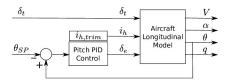
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Structure of flight control system

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Pitch control - inner loop (with elevator)





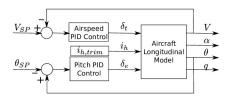
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Structure of flight control system Longitudinal control

Airspeed control loop (with elevator)





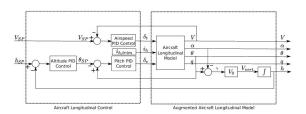
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Structure of flight control system Longitudinal control

Altitude control - outer loop (with elevator)





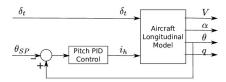
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Pitch control - inner loop (without elevator)





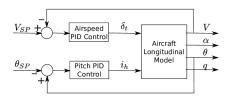
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Structure of flight control system Longi

Airspeed control loop (without elevator)





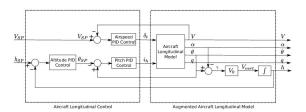
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Structure of flight control system Longitudinal control

Altitude control - outer loop (without elevator)



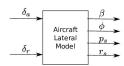


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Linearized aircraft lateral model





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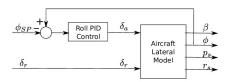
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tructure of flight control system Lateral control

Roll control - inner loop





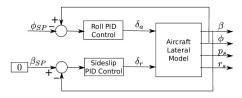
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Structure of flight control system Lateral co

Sideslip control loop





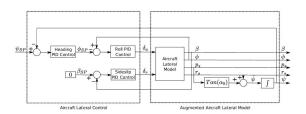
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Structure of flight control system Lateral control

Heading control - outer loop



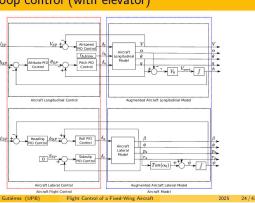


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Multiloop control (with elevator)



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Design of flight control system

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Flight Control of a Fixed-Wing Aircraft

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Design of flight control system

Design of flight control system

- Design the autopilot control loops in this order
 - Longitudinal control
 - Pitch PID.
 - Airspeed PID.
 - Altitude PID.
 - Lateral control
 - Roll PID.
 - Sideslip PID.
 - Sideslip PID.
 Heading PID.



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Implementation of linear controllers for nonlinear plants

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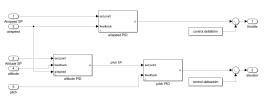
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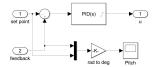
Simulink model for the flight control system Notes Outline 1 Flight control of a fixed wing aircraft Fixed wing aircraft model Structure of flight control system Longitudinal control Lateral control Multiloop control Design of flight control system 5 Implementation of linear controllers for nonlinear plants 6 Simulink model for the fixed wing aircraft Simulink model for the flight control system Longitudinal control • Lateral control Simulink model for the flight control system Notes Flight control system Aircraft position [0:0:0] Notes Flight control system Notes Longitudinal control





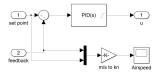
Simulink model for the flight control system | Longitudinal control

Inner loop: pitch PID



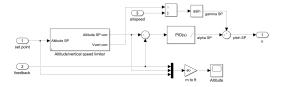


Airspeed PID





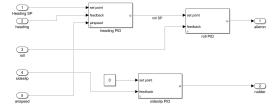
Outer loop: altitude PID





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Lateral control



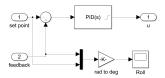


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Inner loop: roll PID





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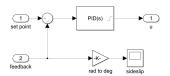
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Sideslip PID



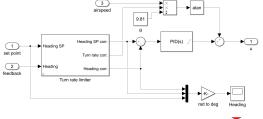


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Outer loop: heading PID



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