Fixed-Wing Autonomous Aircraft Simulation with Cessna 172

Design Summary

The goal of this project was to develop and simulate an autonomous aircraft guidance system using MATLAB and Simulink.

The first step was dynamics modeling, involving selecting a realistic aircraft and identifying key parameters such as mass, moments of inertia, and aerodynamic coefficients to create a state-space model with A, B, C, and D matrices. I also linearized and simulated longitudinal dynamics such as pitch, altitude, and airspeed and created simulation plots for each one. Furthermore, I explored open-loop behavior with elevator and throttle inputs.

Next, I focused on lateral-directional dynamics such as roll, yaw, and sideslip and integrated this into a full 6-DoF state-space model within Simulink. I also included actuator dynamics and saturation logic for realism.

Afterwards, I designed an LQR controller for longitudinal and lateral-directional control and simulated step responses and trajectory-following performance. Within this, I tuned Q and R matrices to balance tracking vs control effort and created closed-loop simulation plots to verify the overshoot, settling time, and response quality of the controller.

The next step was to use a discrete Kalman filter to model a realistic sensor suite. I ensured to include sensor noise models for increased realism and replaced direct state measurements in the controller with filter outputs. From here, I was able to compare the closed-loop performance with and without estimation.

The final implementation was a waypoint guidance system to simulate realistic forward-motion 2D aircraft kinematics with heading control. To do this, used a PID heading controller with error filtering and anti-windup, as well as L1 Guidance law for nonlinear path tracking. With this, I created an animation to visualize the aircraft flying a closed loop path.