Helicopter Yaw Control System Simulation

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1 Objective

The objective of this simulation is to design and analyze a proportional feedback control system for a helicopter's yaw control using Ptolemy II. The system aims to regulate the helicopter's yaw rate by applying control torque proportional to the discrepancy between desired and actual yaw rates.

2 Mathematical Model

The helicopter's yaw dynamics are modeled as a second-order rotational system with the following parameters:

- **Moment of Inertia:** $I_{yy} = 3800\ kg \cdot m^2$
- **Control Gain:** $K = 850$
- **Initial Conditions:** $\theta(0) = 0$, $\dot{\theta}(0) = 0$ rad/s

The governing equations are:

$$e(t) = \psi(t) - \dot{\theta}(t) \tag{1}$$

$$T_y(t) = K \cdot e(t) \tag{2}$$

$$\dot{\theta}(t) = \dot{\theta}(0) + \frac{1}{I_{yy}} \int_0^t T_y(\tau) d\tau \tag{3}$$

3 Model Setup in Ptolemy II

3.1 Main Graph Configuration

- **Continuous Director:** Runs for 100 seconds.
- **Actors Used:**
  - **CurrentTime:** Provides the current simulation time.
  - **MonitorTime:** Displays the simulation time.

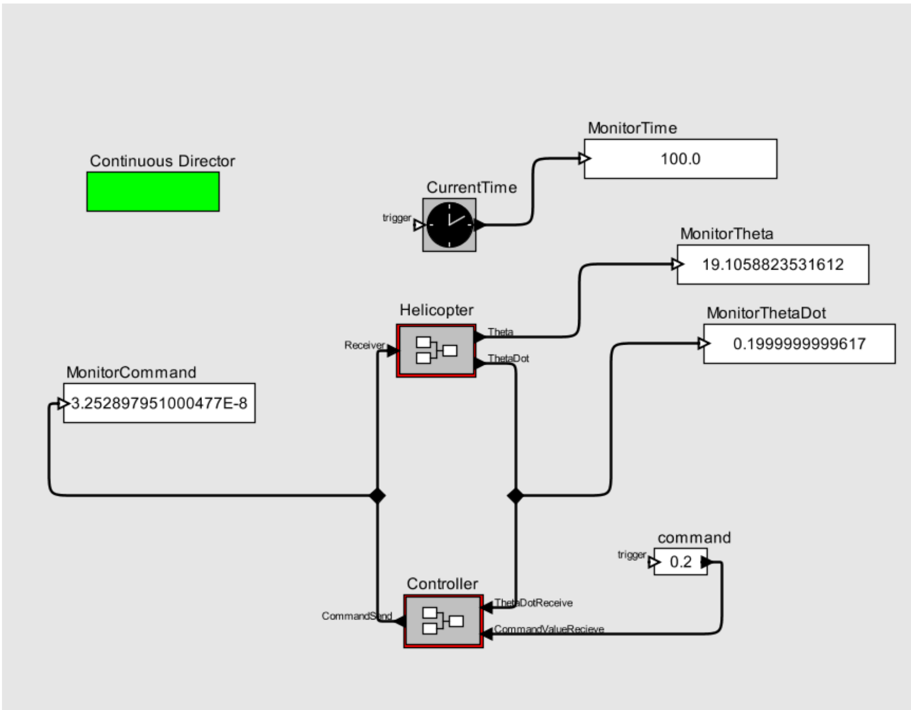

Figure 1: Main Graph Configuration

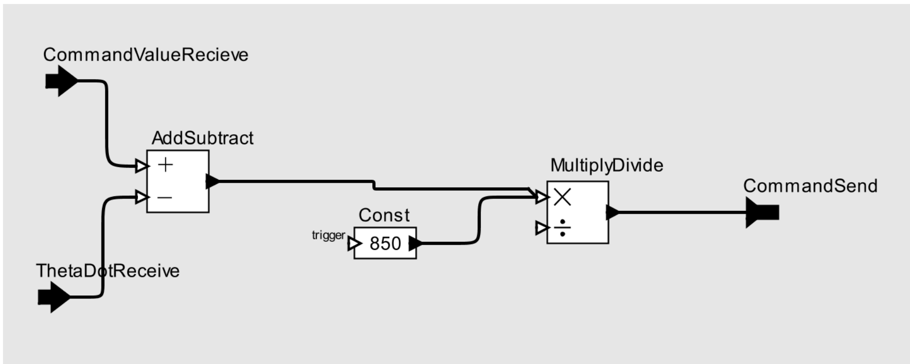

Figure 2: Controller Composite Actor

- **Helicopter Actor:** Processes the control input and outputs yaw angle (θ) and yaw rate ($\dot{\theta}$).
- **Controller Actor:** Computes the required control signal.
- **Constant:** Provides the command signal $\psi = 0.2$.
- **Monitor Actors:** Used to display values of θ, $\dot{\theta}$, and control command.

3.2 Connections in the Main Graph

- $\dot{\theta}$ from Helicopter $\rightarrow$ $\dot{\theta}_{receive}$ in Controller.
- Constant Command (0.2) $\rightarrow$ $CommandValueReceive$ in Controller.
- $CommandSend$ from Controller $\rightarrow$ Receiver in Helicopter.
- $CommandSend$ from Controller $\rightarrow$ MonitorCommand.

4 Controller Composite Actor Setup

The controller calculates the error between the command and actual yaw rate, then applies proportional control:

- **AddSubtract Block:**
  - Input 1 (Add): $CommandValueReceive$ (desired yaw rate)
  - Input 2 (Subtract): $ThetaDotReceive$ (actual yaw rate)
  - Output: Error $e(t)$
- **MultiplyDivide Block:**
  - Input 1 (Multiply): Error $e(t)$

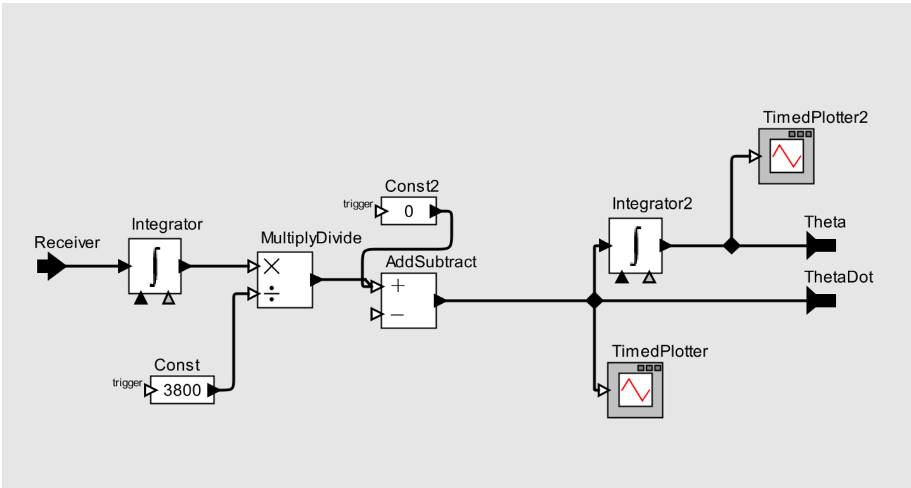

Figure 3: Helicopter Composite Actor

- Input 2 (Multiply): Constant 850 (Gain K)
- Output: Control Signal $T_y(t)$

- **Control Signal Output:** Sent to the helicopter's receiver.

5 Helicopter Composite Actor Setup

The helicopter processes the control signal to determine yaw dynamics:

- **Integrator Block:** Converts control torque into angular acceleration.
- **MultiplyDivide Block:**
  - Input 1 (Multiply): Integrated torque (from Integrator)
  - Input 2 (Divide): Constant 3800 (Moment of Inertia I_{yy})
  - Output: Angular velocity $\dot{\theta}$
- **Second Integrator Block:** Converts $\dot{\theta}$ to yaw angle θ.
- **Outputs:** θ and $\dot{\theta}$ displayed using monitor blocks.

6 Simulation Results

The simulation results for 100 seconds show:

- **Final Yaw Angle (θ):** 19.105 rad
- **Final Yaw Rate ($\dot{\theta}$):** 0.199999 rad/s
- **Final Control Command:** 3.25289E-8

6.1 Performance Analysis

- The system achieves a steady-state yaw rate of **0.2 rad/s**, matching the reference input.
- The yaw angle follows a linear increase, as expected in a proportional control system.
- The control system exhibits minimal error at steady-state.

7 Conclusion

This simulation successfully demonstrates a proportional feedback control system for a helicopter's yaw dynamics using Ptolemy II. The results validate the effectiveness of the control model in achieving the desired yaw rate while maintaining stability.