

Plant Modeling for an Autonomous Vehicle

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Objective and Contribution

Objective

- Create models for the subsystems of an autonomous vehicle

Contribution

- Determine if System Identification or Neural Network modeling produces better models

- Non-linearity modeling

Applications

- Use in testing to help develop more accurate vehicle controllers
- Create a guide for modeling future vehicle subsystems

Problem Setup

Figure 1:High level architecture of the proposed system.

Figure 2:2-DOF helicopter (Quanser Aero).

- State-space representation of 2-DOF helicopter

$$\begin{bmatrix} \dot{\theta} \\ \dot{\psi} \\ \ddot{\theta} \\ \ddot{\psi} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & -K_{sp}/J_p & -D_p/J_p & 0 \\ 0 & 0 & 1 & -D_y/J_y \end{bmatrix} \begin{bmatrix} \theta \\ \psi \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ K_{pp}/J_p & K_{py}/J_p \\ K_{yp}/J_y & K_{yy}/J_y \end{bmatrix} \begin{bmatrix} V_p \\ V_y \end{bmatrix}$$

Motion (Trajectory) Control Algorithm

Figure 3:A desired orientation is given by a user. The difference between this input and the actual position is calculated. The controller the calculates the proper amount of voltage to apply to the DC motors.

- 1 Employ state-space representation of 2-DOF helicopter:

$$\dot{\mathbf{x}} = \mathbf{Ax} + \mathbf{Bu}$$

- 2 Use state feedback law

$$\mathbf{u} = -\mathbf{Kx}$$

to minimize the quadratic cost function:

$$J(\mathbf{u}) = \int_0^\infty (\mathbf{x}^T \mathbf{Q} \mathbf{x} + \mathbf{u}^T \mathbf{R} \mathbf{u} + 2\mathbf{x}^T \mathbf{N} \mathbf{u}) dt$$

- 3 Find the solution \mathbf{S} to the Riccati equation

$$\mathbf{A}^T \mathbf{S} + \mathbf{SA} - (\mathbf{SB} + \mathbf{N}) \mathbf{R}^{-1} (\mathbf{B}^T \mathbf{S} + \mathbf{N}^T) + \mathbf{Q} = 0$$

- 4 Calculate gain, \mathbf{K}

$$\mathbf{K} = \mathbf{R}^{-1} (\mathbf{B}^T \mathbf{S} + \mathbf{N}^T)$$

Optimal Noise Resistant Control

Algorithm

- Utilizes gain calculated in LQR
- Added Kalman filter to reduce external disturbances to the system

Figure 4:Noise resistant 2-DOF helicopter model.

Reinforcement Learning Algorithm

- Uses neural network based on difference between desired and actual orientation to determine optimal gain

Figure 5:ADP Neural Network

Simulation Results

(a)(b)(c)(d)

Figure 6:A comparison between LQG and LQR control for a step input is shown for (a) the main rotor and (b) the tail rotor and the corresponding voltages in (c) and (d)

Experimental Results

Figure 7:Experimental Setup

(a)(b)

Figure 8:ADP experimental results for (a) the main rotor and (b) the tail rotor given a step input

(a)(b)

Figure 9:Comparison between P and PI control for a step input is shown for (a) the main rotor and (b) the tail rotor

(a)(b)

Figure 10:(a) Time = 0 and (b) Time = 10

Conclusion and Future Work

- Using Neural Networks produced more accurate models than System Identification
- Test models using Hardware-in-the-Loop
- Create new vehicle controllers