# 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

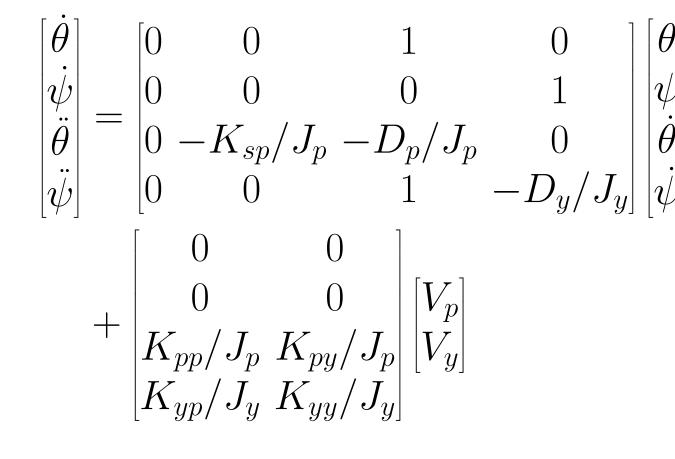
### Applications

- 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



# 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.

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

$$\dot{\mathbf{x}} = \mathbf{A}\mathbf{x} + \mathbf{B}\mathbf{u}$$

Use state feedback law to minimize the quadratic cost function:  $\mathbf{u} = -\mathbf{K}\mathbf{x}$ 

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

3 Find the solution S to the Riccati equation

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

• Calculate gain, **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

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