Plant Modeling for an Autonomous Vehicle

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Objective and Contributions

Objective
- Provide accurate plant models of each autonomous vehicle subsystem to be used for designing controllers

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

- Conducted a literature review to look for existing solutions
- System Architecture

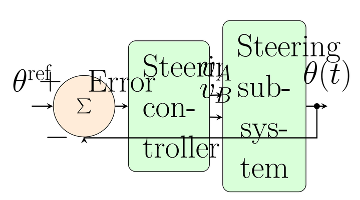

Figure 1:Steering subsystem block diagram.

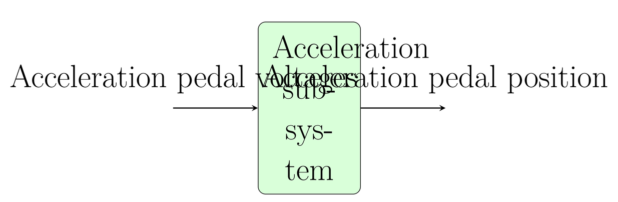

Figure 2:Acceleration subsystem block diagram

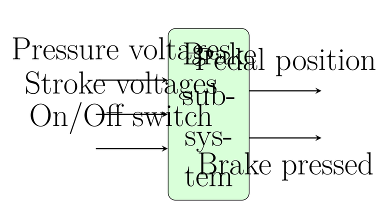

Figure 3:Brake subsystem block diagram

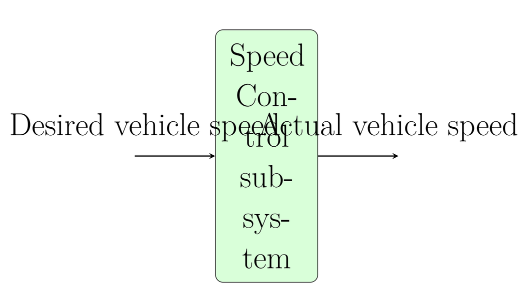

Figure 4:Speed Control subsystem block diagram

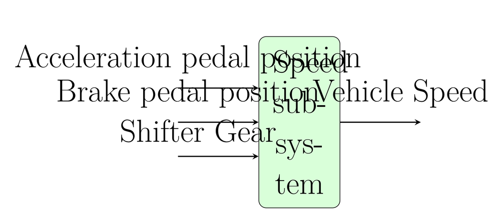

Figure 5:Speed subsystem block diagram

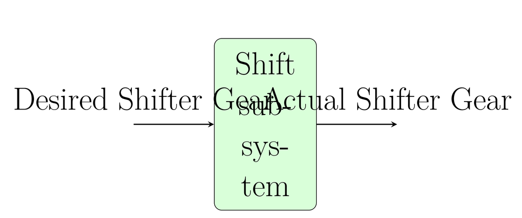

Figure 6:Shift subsystem block diagram

- Data Collection Setup
- Lexus RX450H vehicle platform
- Laptop
- PACMod ECU
- CANCase
- CAN Bus

Transfer Function Modeling

Figure 7: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:
$$\dot{\mathbf{x}} = \mathbf{A}\mathbf{x} + \mathbf{B}\mathbf{u}$$
2. Use state feedback law
$$\mathbf{u} = -\mathbf{K}\mathbf{x}$$
to minimize the quadratic cost function:
$$J(\mathbf{u}) = \int_0^{\infty} (\mathbf{x}^T\mathbf{Q}\mathbf{x} + \mathbf{u}^T\mathbf{R}\mathbf{u} + 2\mathbf{x}^T\mathbf{N}\mathbf{u})\mathrm{d}t$$
3. Find the solution $\mathbf{S}$ to the Riccati equation
$$\mathbf{A}^T\mathbf{S} + \mathbf{S}\mathbf{A} - (\mathbf{S}\mathbf{B} + \mathbf{N})\mathbf{R}^{-1}(\mathbf{B}^T\mathbf{S} + \mathbf{N}^T) + \mathbf{Q} = 0$$
4. Calculate gain, $\mathbf{K}$
$$\mathbf{K} = \mathbf{R}^{-1}(\mathbf{B}^T\mathbf{S} + \mathbf{N}^T)$$

Neural Network Modeling

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

Figure 8:Noise resistant 2-DOF helicopter model.

Neural Network Algorithm

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

Figure 9:ADP Neural Network

Experimental Results

Figure 10:Experimental Setup

(a)(b)

Figure 11:ADP experimental results for (a) the main rotor and (b) the tail rotor given a step input

(a)(b)

Figure 12: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 13:(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