FEEDBACK CONTROL SYSTEMS FINAL REPORT
CARAVAN CONTROL

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ABSTRACT. This is the project abstract.

1. SCENARIO

You are an engineer in charge of designing and implementing an estimation and control system for a fleet of self-driving semi-trucks. Due to government regulation, the truck fleet can only operate in the self-driving mode when they are on long, straight stretches of highway between cities. In order to reduce costs and conserve fuel, the trucks drive very closely together at a pre-determined speed in 'caravan formation'. By driving very closely together, the trucks can draft off of one another, reduce drag, and save fuel by upwards of 21% [1].

For the system you are designing, only three trucks will be in the caravan. The caravan is equipped with the following sensor suite:

(1) The lead truck is equipped with a GPS receiver that measures its position at 1 Hz.
(2) The two following trucks are equipped with range sensors that measure the relative position between themselves and the truck in front of them at 10 Hz.
(3) All three trucks are equipped with an IMU that measures respective acceleration at 100 Hz.

Each truck may be independently controlled and may be instructed to either accelerate or decelerate.

2. SYSTEM DESCRIPTION

Define the system state.

$$\vec{x} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ v_1 \\ v_2 \\ v_3 \end{bmatrix} \tag{1}$$

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Define the reference states.

$$\vec{x_r} = \begin{bmatrix} \Delta x_{12_r} \\ \Delta x_{23_r} \\ v_{1_r} \\ \Delta v_{12_r} \\ \Delta v_{23_r} \end{bmatrix} \tag{2}$$

Define the input vector.

$$\vec{u} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} \tag{3}$$

Define the error state and stack it on top of the reference signal.

$$\vec{e} = \begin{bmatrix} x_1 \\ \Delta x_{12} \\ \Delta x_{23} \\ v_1 \\ \Delta v_{12} \\ \Delta v_{23} \\ \Delta x_{12_r} \\ \Delta x_{23_r} \\ v_{1_r} \\ \Delta v_{12_r} \\ \Delta v_{23_r} \end{bmatrix} \tag{4}$$

Define the error state dynamics.

$$\dot{\vec{e}} = \begin{bmatrix} v_1 \\ \Delta v_{12} \\ \Delta v_{23} \\ a_1 \\ \Delta a_{12} \\ \Delta a_{23} \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} = \underbrace{\begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}}_{A} \vec{e} + \underbrace{\begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \\ 1 & -1 & 0 \\ 0 & 1 & -1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}}_{B} \vec{u} \tag{5}$$

Define the error state observer equations.

$$\vec{y} = \begin{bmatrix} x_1 \\ \Delta x_{12} \\ \Delta x_{23} \\ a_1 \\ a_2 \\ a_3 \\ \Delta x_{12_r} \\ \Delta x_{23_r} \\ v_{1_r} \\ \Delta v_{12_r} \\ \Delta v_{23_r} \end{bmatrix} = \underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}}_{C} \vec{e} + \underbrace{\begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}}_{D} \vec{u} \tag{6}$$

3. Analysis

4. Simulation

5. Results

References

[1] C. Bonnet and H. Fritz, "Fuel consumption reduction in a platoon: Experimental results with two electronically coupled trucks at close spacing," tech. rep., SAE Technical Paper, 2000.

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