Development of a Vehicle Occupant Body Control Model Using Multibody Dynamics and Deep Learning

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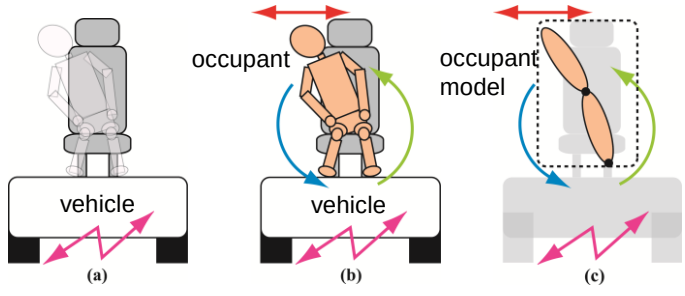
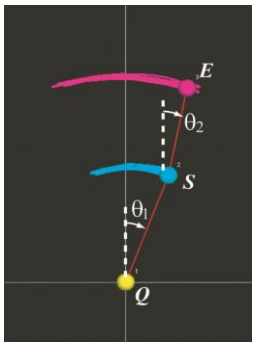
1. Background & objective

(a) At the design stage of a automobile, the behavior of the occupants is often ignored.
(b) Since the mass of the occupant is not so small that it can be ignored compared to the mass of the automobile body, it is required to establish a vehicle design method considering the interaction between the occupant and the automobile body.
(c) We propose a simple mechanical control model that can simulate the physical behavior of the occupant.

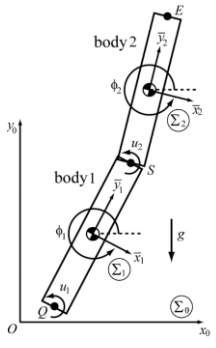


2. Vibration test of occupant



Sine excitation at various frequencies around the roll axis. Measure the movement of 3 points Q, S, E with a motion capture system.

3. Dynamics model



$\boldsymbol{\theta} = \begin{bmatrix} \theta_1 \\ \theta_2 \end{bmatrix}$:tilt angle

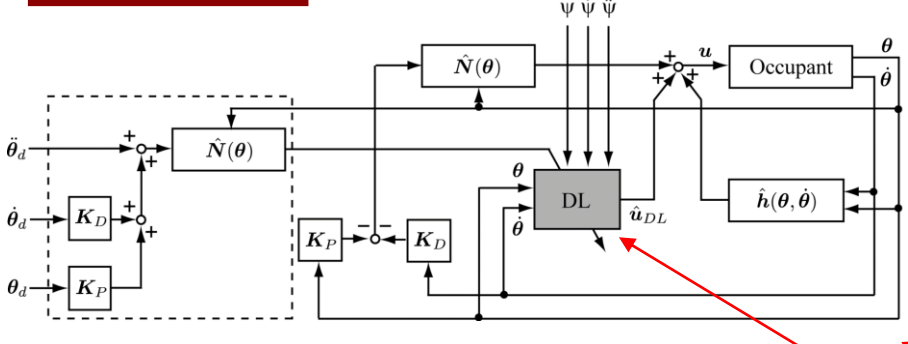
$\boldsymbol{\theta}_d = \begin{bmatrix} \theta_{1d} \\ \theta_{2d} \end{bmatrix}$:measured tilt angle

$\boldsymbol{u} = \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$:driving trque

Modeled as a 2-link system where point Q is excited.
Derivation of equations of motion using multibody dynamics.

$$\boldsymbol{N}(\boldsymbol{\theta})\ddot{\boldsymbol{\theta}} + \boldsymbol{h}(\boldsymbol{\theta}, \dot{\boldsymbol{\theta}}) = \boldsymbol{u}$$

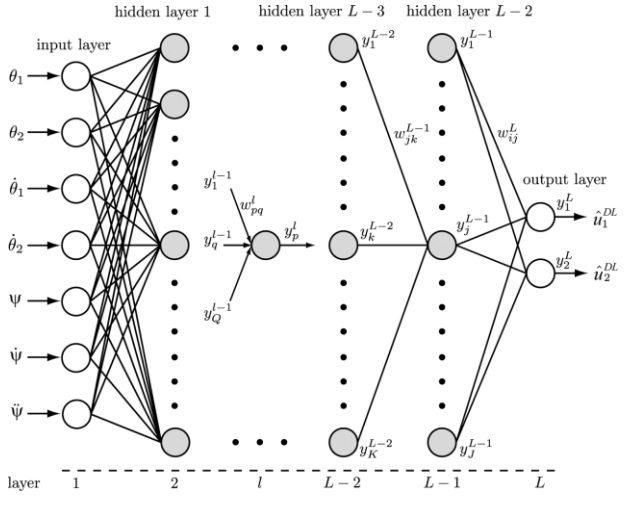
4. Control model



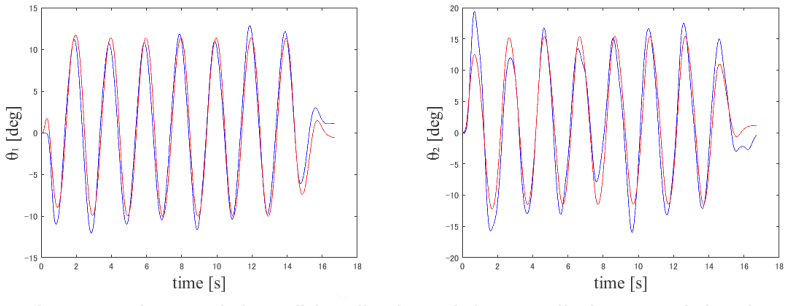
Combine two types of control inputs $\boldsymbol{u} = \boldsymbol{u}_{PD} + \boldsymbol{u}_{DL}$

$\boldsymbol{u}_{PD} = \hat{\boldsymbol{N}}(-\boldsymbol{K}_D\dot{\boldsymbol{\theta}} - \boldsymbol{K}_P\boldsymbol{\theta}) + \hat{\boldsymbol{h}}$: Non-linear PD control

$\boldsymbol{u}_{DL} = \hat{\boldsymbol{N}}(\ddot{\boldsymbol{\theta}}_d + \boldsymbol{K}_D\dot{\boldsymbol{\theta}}_d + \boldsymbol{K}_P\boldsymbol{\theta}_d)$: Estimated by deep learning



5. Validation of the model



The experimental data (blue line) and the prediction result by the proposed model (red line) are almost in agreement.

6. Summary

- Proposed occupant body control model using multibody dynamics and deep learning
- Confirmed that the physical behavior of the occupant is predictable by the proposed model
- In future research, we would like to improve the accuracy of the model by introducing a recurrent neural network and DQN that are advantageous for estimating time series data.