A study on the control method of lateral displacement and yaw angle in severely curved driving of IRWs system

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Introduction

This paper proposes an optimal control algorithm through lateral displacement and yaw angle in curved road of shallow-depth subway systems.

In the case of the surface transportation, which has recently been introduced, severe curved driving performance is required for the downtown.

The existing researches are the main research theme of the lateral displacement restoration control, but there is a limit to smooth operation when the curve is run only by receiving the lateral information. However, when the yaw angle information is obtained, it is possible to consider the turning angle of the vehicle while the vehicle is driving in a curved road. However, it is difficult to control because the change of yaw angle is more sensitive than lateral drift.

Therefore, this paper suggests an algorithm that uses both lateral displacement control and yaw control. The proposed method will be verified with the Matlab/Simulink model and the effectiveness of the proposed method will be verified through small-scale bogie system.

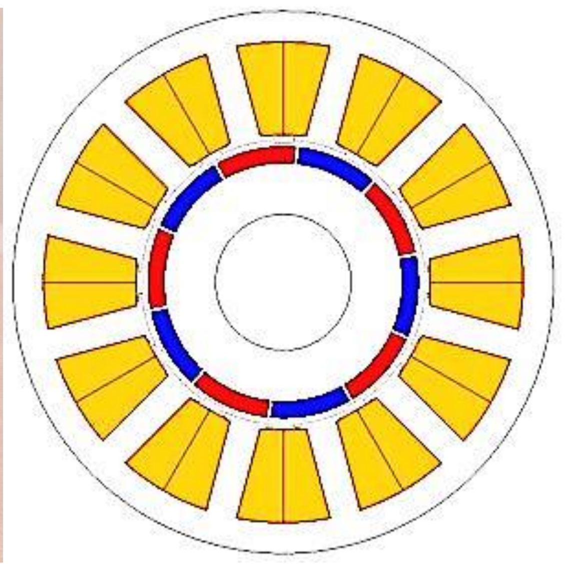
Conclusion

- For the permanent magnetic synchronous motor, the torque ripple is smaller compared to the induction motor. Also, with the advantage of high torque density, it is receiving spotlight as the future traction motor. and also applied 1/5 scale for the small-scale bogie to verify the later recovering control algorism.
- When disturbance occurs in the small-scale bogie, centering can be maintained, which demonstrated the superiority of algorism.
- Based on the lateral recovering algorism proposed through the small-scale bogie, it is considered that the algorism can be applied to the actual train system.
- When the lateral distance restoring control is performed, the restoring time is required to be about 1.2 seconds, and it is necessary to reduce the restoring time.
- The front wheels receive the sensor in the other direction to control the front wheel acting as the steering wheel, and the rear wheel controls the lateral distance

Methods

Large size Co-Extrusion

SPMSM



The model of the SPMSM of independently rotating wheelsets

The motor of independently rotating wheelsets selected model in accordance to performance of control to independently control 4 motors. Magnetic torque and reluctance torque are the two torques that exist in the motor. In the case of reluctance torque, it occurs due to interaction of d-axis and q-axis currents. The controllability reduces compared to the magnetic torque that only uses d-axis current. Thus, the motor was designed with SPMSM(Surface Permanent Magnet Synchronous Motor)using only the magnetic torque.

Mathematical Equation

$$e_y = y - y_c$$

$$\dot{e}_y = \dot{y} - \dot{y}_c = -V_y - V_x e_\psi = -\frac{l_r}{l_{fr}} V_x \tan\delta_f - V_x e_\psi \approx -\frac{l_r}{l_{fr}} V_x \delta - V_x e_\psi$$

$$\frac{e_y(k+1) - e_y(k)}{T} \approx \dot{e}_y(k) = -\frac{l_r}{l_{fr}} V(k)\delta(k) - V_x(k) - e_\psi(k)$$

$$e_y(k+1) = e_y(k) - TV_x(k)e_\psi(k) - T\frac{l_r}{l_{fr}} V(k)\delta(k)$$

$$e_\psi(k+1) = e_\psi(k) + T\dot{\psi}_c(k) - T\dot{\psi}(k)$$

y : *Lateral position of the origin of* $\{xyz\}$ *coordinate*

y_c : *Lateral position of the lane center*

V_x :*longitudinal velocity at the center of vehicle*

l_f (l_r):*longitudinal distance from the front(rear) wheel*

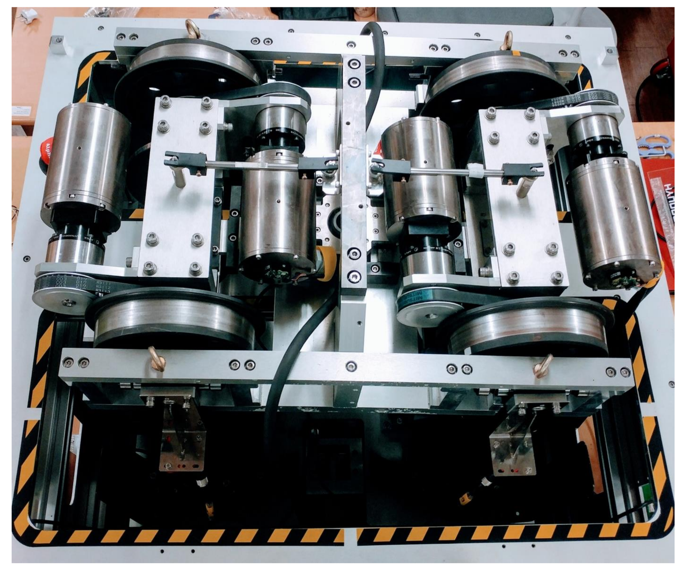
l_{fr} :$l_f + l_r$ *wheelbase*

δ (δ_f, δ_r) : (*front, rear*) *steering angle*

ψ : *yaw, angle of vehicle*

Samples

Hardware

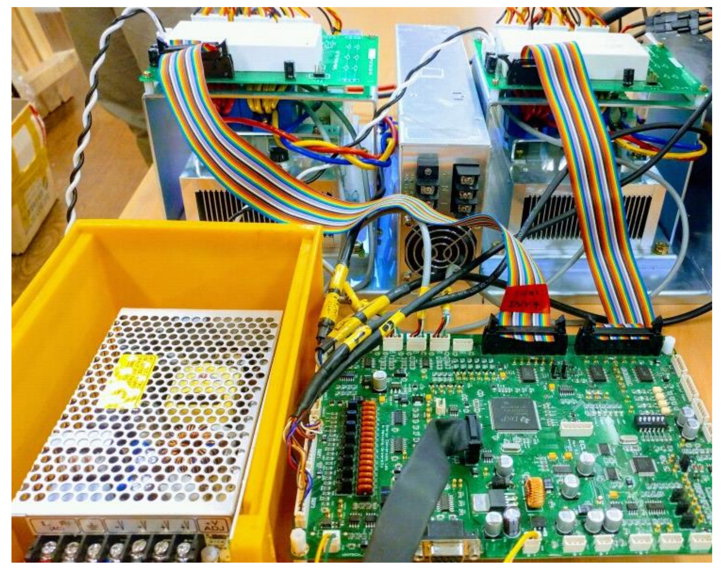


Small-scale bogie

The small-scale bogie was made as shown in Fig. by using 4 independent wheel motors. Each motor was in charge of the each bogie's wheel, and it was connected through the reducer.

The rotor position of the motor used encoder for measurement.

To recognize the lateral displacement of small-scale bogie, 4 laser sensors were fixed on the center part of the wheel.

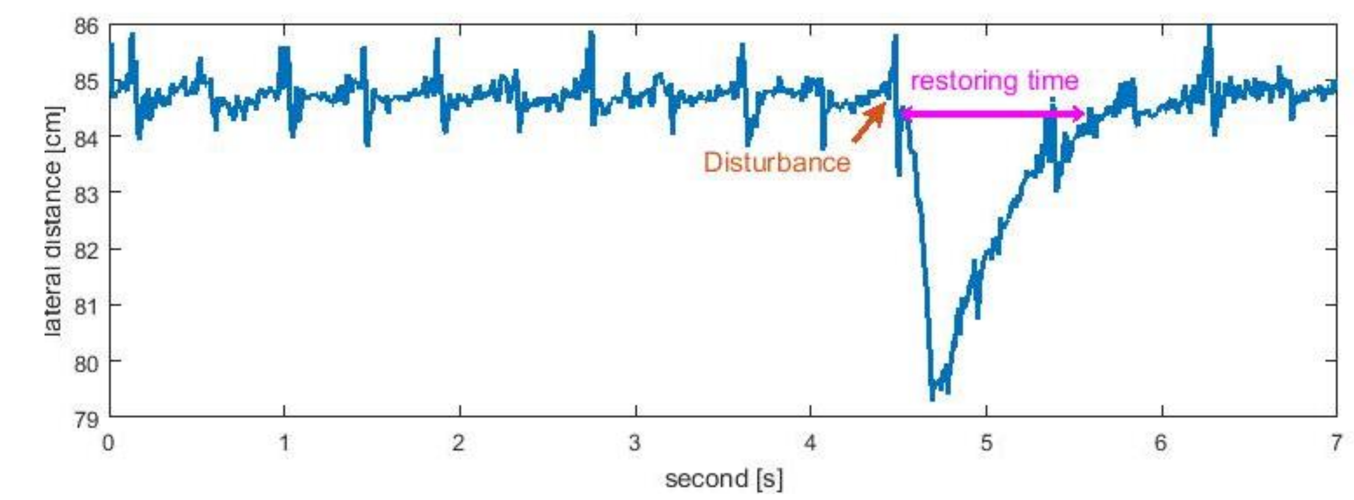


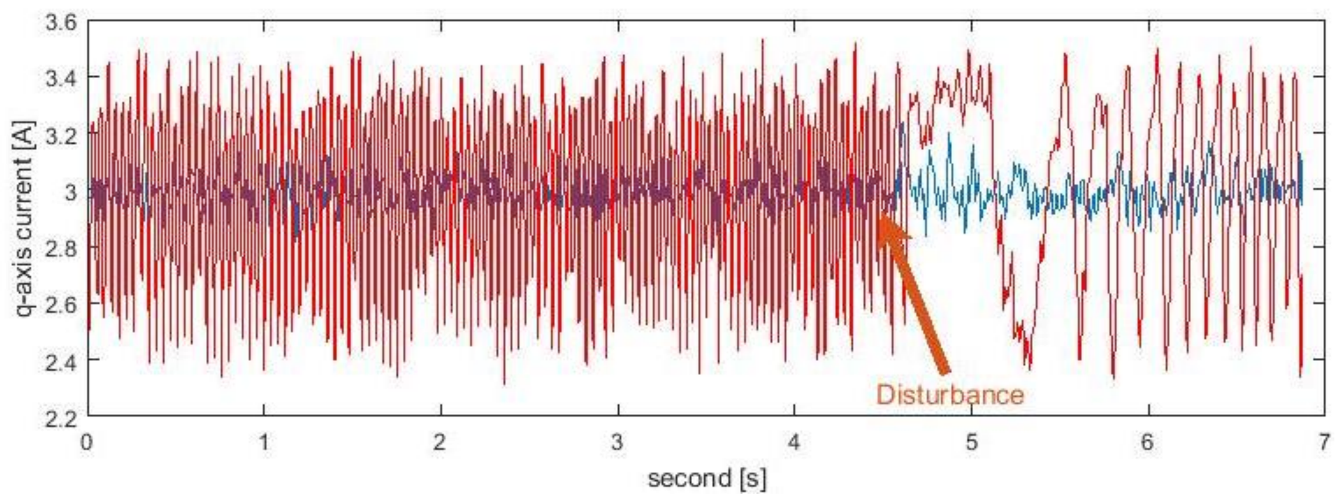
DSP and inverters

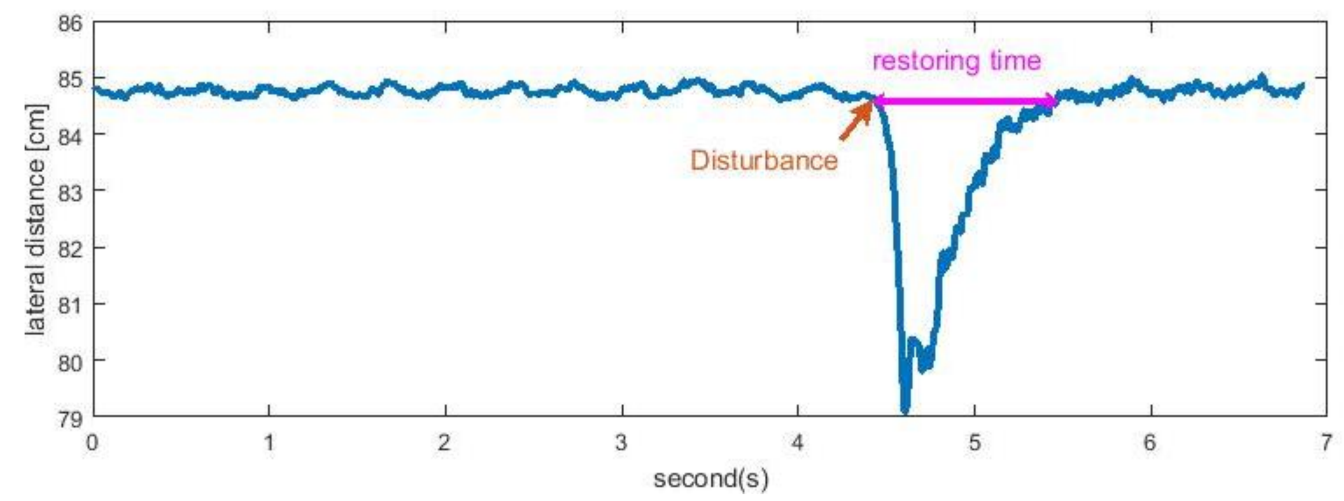
Fig. used independent wheel motor to show the later recovering control test inverter and controller.

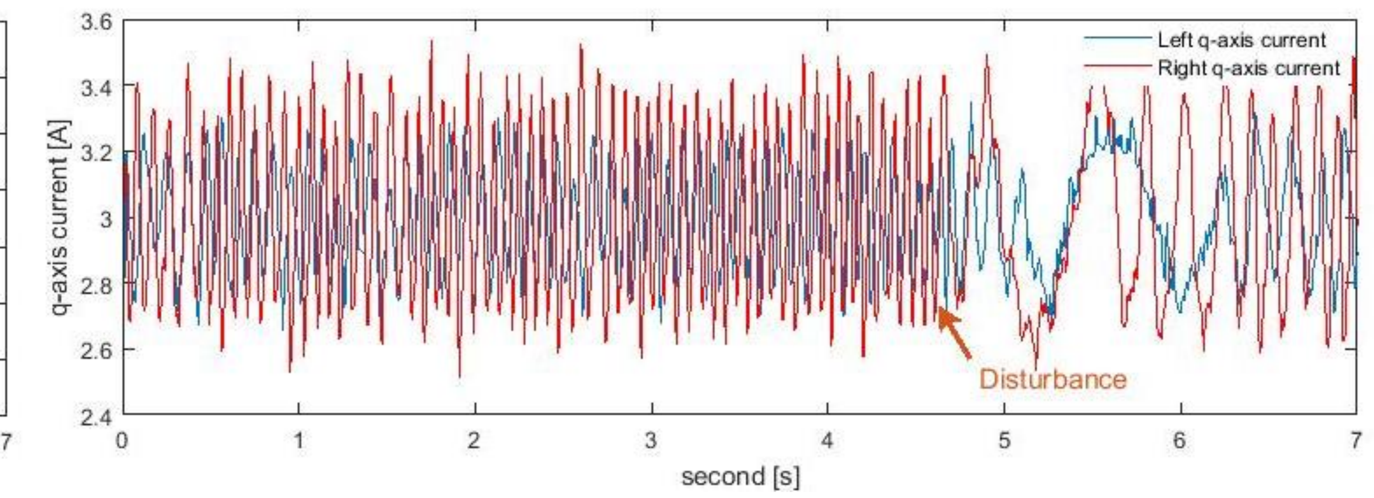
Because of the 1C2M system, there are 4 motors. DSP used TI28335, and because 12 switching signals can be created per 1 DSP, a total of 2 DSPs were used.

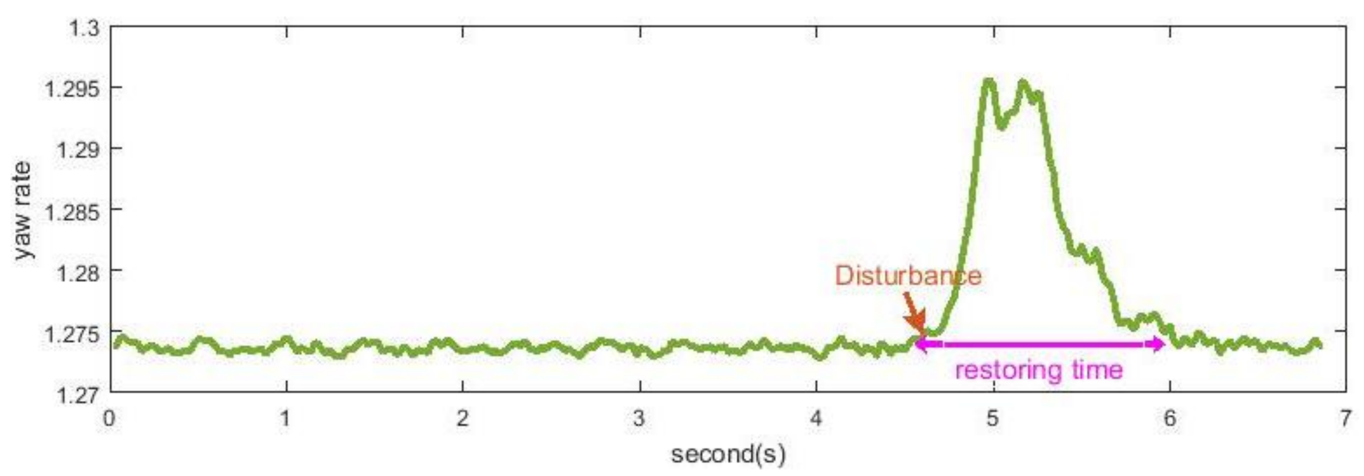
Results





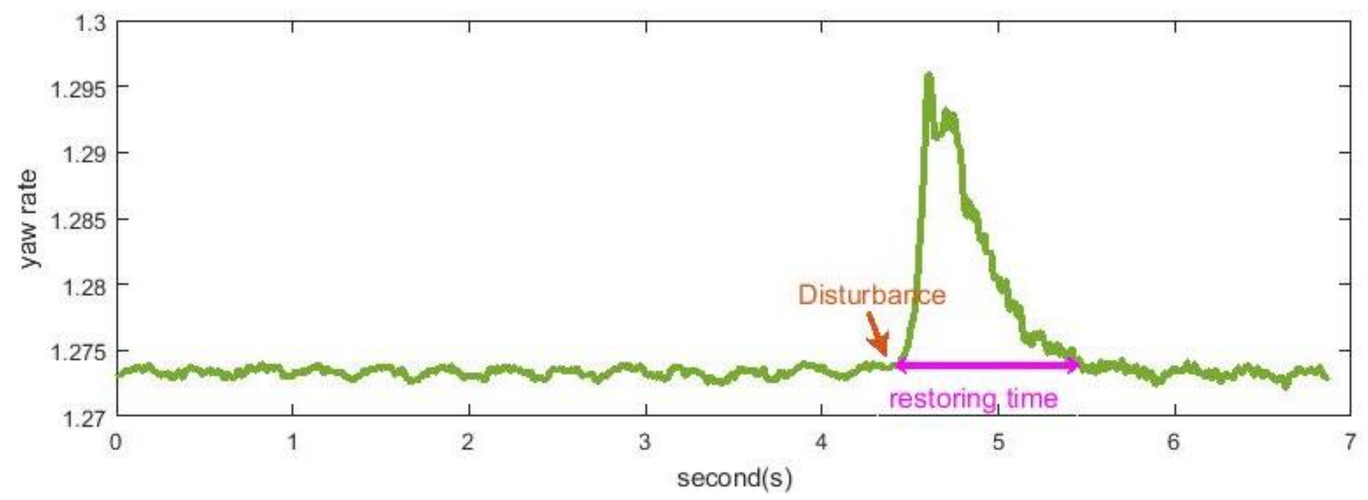






The left figure shows the result of the restoring control by controlling the lateral distance of the vehicle when the disturbance input is represented by the lateral distance, the yaw angle, and the q-axis current waveform

When the lateral distance restoring control is performed, the restoring time is required to be about 1.2 seconds, and it is necessary to reduce the restoring time.



The three images on the left are the waveforms of the newly designed lateral distance, yaw angle and q-axis current, respectively. In order to make the restoring time shorter than that of the lateral distance control, the front wheels receive the sensor in the other direction to control the front wheel acting as the steering wheel, and the rear wheel controls the lateral distance according to the conventional method. As a result, it took about 1 second restoring time when disturbance occurred than previous method.