講演番号	059

文献番号	20226059

A nonlinear model predictive control for self-driving trucks achieving a reduced computational cost by hierarchical structure

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KEY WORDS: **Vehicle dynamics, heavy duty, Motion control, Driving stability,** Nonlinear model predictive control [B1]

Trucks play a central role in the logistics industry. In recent years, the demand for logistics demand has grown, but the shortage of drivers is becoming more serious. For this reason, research on automated truck driving has been conducted intensively. Among them, MPC has attracted prominent attention because it can explicitly take constraints into account and make model-based predictions.

This study proposes a control system that improves tracking performance during turning under large variations in vehicle characteristics such as vehicle weight and deviation of gravity center. The nonlinear track model is hierarchically divided into a kinematic model for path planning and a kinematic model for trajectory tracking to reduce the computational complexity. Then, a hierarchical controller was constructed by applying NMPC to the nonlinear kinematic model and feedforward gain-scheduling control concerning velocity to the dynamic model. They suppress uncertainties in road surface characteristics and loading while reducing the dimension of the computationally intensive NMPC. The configuration of the controller is shown in Fig. 1. The upper-level NMPC controller generates the trajectory by calculating the reference velocity V_x and angular velocity ω, then, the lower-level dynamics controller calculates the actual control inputs a and δ to follow the reference signals. The lower-level dynamics controller calculates the control inputs a and δ that follow the references, V_x and ω. The NMPC controller can explicitly consider the constraint conditions and generates a trajectory that is feasible for the truck. In addition, byincluding a deceleration term in the evaluation function that suppresses the magnitude of the centripetal acceleration, it is realized to suppress the tire force saturation without explicitly considering the tire model.

Figure 2 shows the simulation results when the proposed hierarchical controller is applied to a truck loading a large mass. With the weight of the deceleration term set to be 0 $(W_\rho = 0)$ the car went off the course, but with the weight of deceleration set to be $9\,(W_\rho = 9)$, the car succeeded to run through the course. This confirms that suppression of centripetal acceleration by deceleration suppresses the saturation of tire force and improves tracking performance. In addition, the control input is less than the upper and lower limits indicated by the dashed lines confirms that the system can generate a trajectory that the truck can follow. Thus, the proposed controller successfully achieved safe driving under large variation of loaded weight.

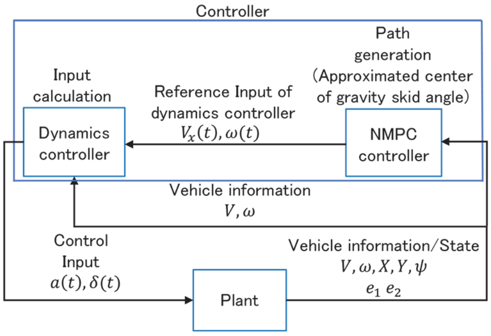

Fig.1 Control system configuration

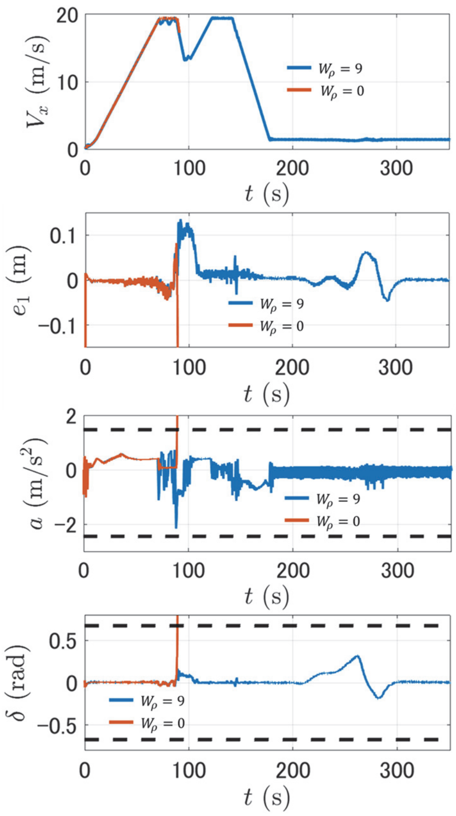

Fig.2 Load capacity 4000 kg at 70 km/h, center of gravity 1 m in front

2022 JSAE Congress (Autumn) - Summarized Paper
Issued on October 7, 2022