

Vehicle Lateral Control Based on Data-Driven ADRC

Shuichi Yahagi ¹⁾ Itsuro Kajiwara ²⁾

1) Tokyo City University, Department of Mechanical Engineering,
1-28-1 Tamazutsumi, Setagaya-ku, Tokyo, 158-8557, Japan (E-mail: yahagis@tcu.ac.jp)
2) Hokkaido University, Division of Mechanical and Aerospace Engineering,
N13, W8, Kita-ku, Sapporo, 060-8628, Japan

KEY WORDS: Vehicle dynamics, Steering system, Motion control, Controller design (B1)

This work introduces a data-driven design of the active disturbance rejection control (ADRC) for vehicle lateral control. This control method is effective for industrial systems with nonlinear and/or time-varying characteristics. However, its performance heavily depends on the choice of design parameters. The proposed method incorporates a one-shot data-driven design approach to optimize ADRC parameters directly from a set of data without repeated experiments. The effectiveness of the proposed method is demonstrated using a vehicle simulator, and the results confirm that it achieves good tracking performance.

The control law of the ADRC, which consists of an extended state observer (ESO) and an I-P controller, is given by

$$u = \frac{1}{b} \left\{ \frac{K_i}{s} (r - \hat{y}) - K_p \hat{y} - \hat{F} \right\}$$

where r , y , u , and F denote the target value, system output, control input, and disturbance including modeling error, respectively; s is the Laplace operator; and K_p and K_i are the proportional and integral gains, respectively. The unknown disturbance F is estimated by the ESO, which is given by

$$\begin{cases} \dot{\hat{x}} = A_c \hat{x} + B_c u + L(y - \hat{y}) \\ \hat{y} = C_c \hat{x} \end{cases}$$

where the state vector is defined as $x = [y \quad F]^\top$, and L is the observer gain.

We propose a data-driven design method for model-reference ADRC (MR-ADRC) using virtual reference feedback tuning (VRFT), which determines the optimal control parameters for achieving model-reference control from the initial input-output data $\{u_0(t), y_0(t)\}_{t=0}^N$. By introducing the virtual reference signal. By incorporating a virtual reference signal $r_v = M_d^{-1}y_0$, the optimal parameters are obtained by minimizing the following cost function:

$$J_{VR}(\rho) = \frac{1}{N} \sum_{t=1}^N (L_p u_0(t) - L_p C(\rho)(r_v(t) - y_0(t)))^2$$

where L_p denotes a pre-filter. This cost function indicates that VRFT minimizes the error between the initial control input and the virtual control input. For the proposed MR-ADRC, the VRFT-based cost function is formulated as

$$J_{VR}^*(\rho) = \frac{1}{N} \sum_{t=1}^N (d(t) - \rho^T \xi(t))^2$$

where

$$\begin{aligned} \rho &= [K_i \quad K_p]^\top, \\ d(t) &= L_p(u_0(t) - (1 - W_F)^{-1}b^{-1}W_F s y_0(t)), \\ \xi(t) &= L_p(1 - W_F)^{-1} [K_i \quad K_p] \begin{bmatrix} (M_d^{-1} - I)/p \\ -1 \end{bmatrix} y_0(t) \end{aligned}$$

Since the evaluation function is convex with respect to the control parameter vector ρ , the optimal solution ρ^* can be determined using the least-squares method.

Vehicle lateral motion systems are known to exhibit nonlinear and time-varying characteristics. The effectiveness of the proposed data-driven MR-ADRC design method is demonstrated for such systems. The results show that the proposed method achieves high-precision reference-model tracking without requiring a detailed model of the controlled system. In summary, the proposed method enables the design of an MR-ADRC from a single set of experimental data and is highly effective for lateral motion control of vehicles with nonlinear characteristics.

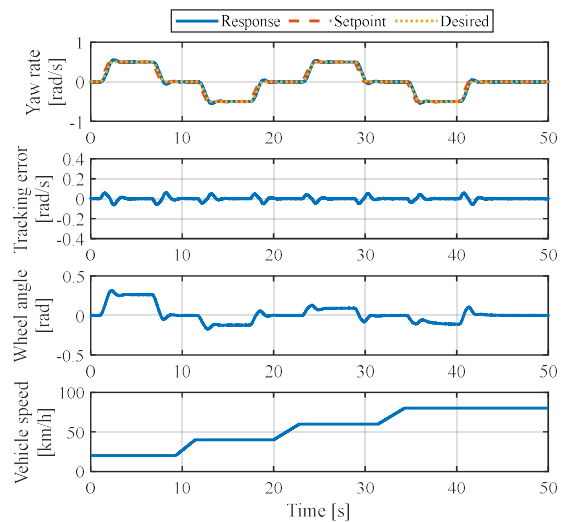


Fig.1 Results after tuning