An Experimental Study on Modeling Accuracy of Digital Twin for Cloud-Based Remote Vehicle Path Tracking Control

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1. Introduction

Path tracking control is essential for various applications of autonomous vehicle. Remote control scheme, in which control functions are located in a cloud server, has several advantages such as small cost of vehicle itself and easy informantion sharing at the server [1]. However, this scheme has a problem that transmission delay in the Internet deteriorates control accuracy. Predictive control with digital twin computing (DTC) is expected to solve this problem [2]. Based on a predictive model (PM) using DTC, before one-way transmission delay time, control server can make an adequate control signal for a controlled vehicle [2]. Accurate predictive control requires PM that accurately models a real vehicle. We defined modeling error (ME) as the discrepancy between PM and real vehicle's behavior. In practice, it is impossible to make ME zero, so cyclic Feedback signals from the actual vehicle is necessary to correct PM's state. In this paper, we present results of an experimental evaluation of the dependence of path tracking control accuracy on ME and Feedback cycle.

2. Implemented system

We implemented an experimental system of remote autonomous path tracking control with small four-wheeled vehicle (UV) (Fig. 1). Control Server (CS) uses PM to predict future position and direction of the UV. CS generates a control signal (UDP packet) and sends it to UV every 10 ms so that UV follows the target path. This signal includes travel speed and steering angle of front wheels. Position Detector (PD) detects position of UV every 100ms based on images captured by the camera. PD sends a status signal (UDP packet) to CS in every 100 ms. This signal contains position of UV and time. This signal is used to correct the state of the PM to match the real state.

3. Evaluation and Discussion

Fig. 2 shows the target path and an example of the UV trajectory obtained by an experiment. The maximum lateral displacement from the target path (MLD) is used as a measure of control accuracy; the smaller the MLD, the more accurate the control. Fig. 3 shows characteristics of MLD. To investigate the dependence on ME, we intentionally

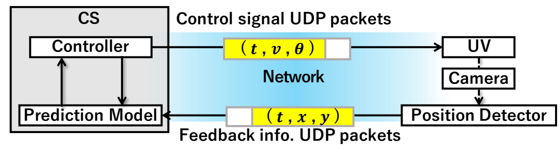

Fig. 1 Remote Vehicle Control System Using DTC

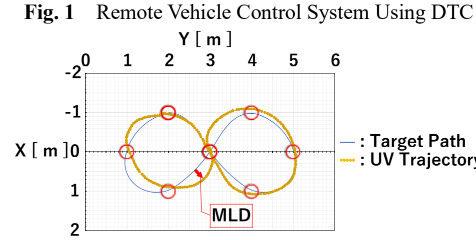

Fig. 2 Tracking Path and UV Trajectory

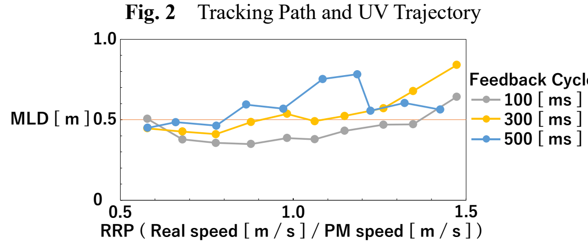

Fig. 3 MLD for each Feedback Cycle model

changed peed setting in PM's prediction process. The real UV speed setting was fixed at 0.55 m/s. The ratio of real UV speed to PM speed (RRP) represents ME. Feedback cycle was set to 100 ms, 200 ms, and 300 ms. Fig. 3 shows that MLD < 0.5 m was achieved when 0.6 < RRP < 1.4 and Feedback cycle was 100 ms.

4. Conclusion

In this study, we implemented remote path tracking control system with DTC and experimentally elucidated control accuracy depending on ME and Feedback cycle. It is not difficult to implement DT so that 0.6 < RPR < 1.3 and the Feedback cycle is less than 100 ms. We will clarify requirements for vehicles running at higher speeds, in our future work.

References

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[2] Y. Yoshimoto et al, "Effect of Buffering Time on Tracking Control Accuracy in Remote Vehicle Control with Digital Twin Computing," International Conference on Emerging Technologies for Communications 2021, P3-4, Dec. 2021.

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