

Evaluation of the Effects of Communication Latency in Remote-Connected Driving and Cycling Simulators

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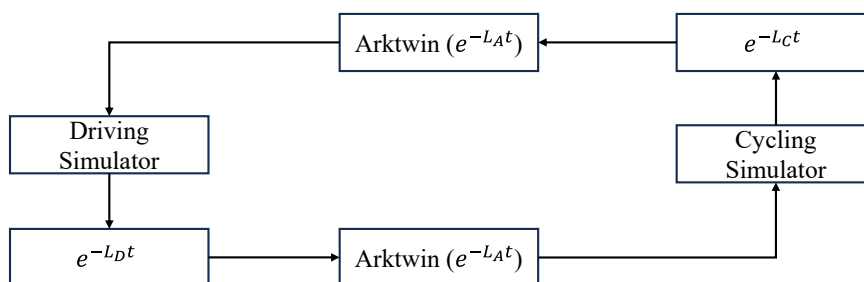


Fig. 1 Block diagram including communication delay

The development of advanced driver assistance systems (ADAS) and autonomous driving technologies has increased the demand for large-scale datasets that include realistic interactions among road users. Coupled simulators, in which multiple human participants operate different simulators within a shared virtual environment, provide an effective approach for collecting such interaction data. Recently, remote connection technologies have enabled geographically distributed simulators to be integrated through the Internet. However, communication latency introduced by network transmission may influence participants' perception, decision making, and interaction behavior. The effects of communication latency on interactions between drivers and cyclists have not yet been sufficiently investigated.

This study evaluates the influence of communication latency in a remotely connected driving simulator (DS) and cycling simulator (CS). The two simulators were connected through a distributed messaging framework over the Internet. Participants performed a passing task on a narrow residential road containing a parked vehicle that partially blocked visibility. In this scenario, drivers and cyclists were required to negotiate right-of-way while avoiding a collision. The measured one-way communication latency of the experimental environment was approximately 55 ms. Additional artificial delays of 0 ms, 333 ms, and 667 ms were introduced to investigate latency effects systematically (Fig. 1).

Experiments were conducted with two participant groups, each consisting of one driver and one cyclist. Vehicle trajectories, speeds, and minimum passing distances were recorded, and subjective evaluations were collected using questionnaires regarding communication quality, naturalness of the opponent's behavior, and perceived safety.

The results showed that all participants successfully completed the task without collisions under all latency conditions. However, increased latency tended to induce more conservative behavior, including lower traveling speeds and occasional hesitation before passing. Significant differences in average speed were observed for some participants, indicating that communication latency affected interaction strategies. In contrast, subjective evaluations remained relatively stable when the additional latency was 333 ms or less, suggesting that moderate delays did not substantially degrade the perceived quality of interaction.

These findings indicate that remotely connected driving and cycling simulators can maintain realistic interactions under moderate communication delays. The results also provide practical guidance for the design and operation of distributed simulation environments used for collecting interaction data for autonomous driving research.