Keyframe Selection, Communication, and Prediction for Teleoperated Driving Systems

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I. Introduction

Autonomous driving systems face significant challenges, where human intervention is still needed when the situation becomes so complicated and beyond the autonomous vehicle's (AV) capability. Thus, teleoperated driving is important to free the AVs – human operators remotely control AVs via wireless networks.

However, good communication performance cannot always be guaranteed in all situations. Limited radio bandwidth and dynamic time delay are two major challenges in teleoperated driving. In [1], a novel rate-quality model has been proposed to dynamically change the bitrates and resolution of the video streaming according to the dynamic bandwidth. In [2], a latency visualization method was developed to mitigate the effect of dynamic time delay on teleoperated driving.

In this poster, we propose a new framework to mitigate the effects of both limited bandwidth and dynamic time delay using a keyframe selector, based on AV designed by [3], and a video predictor. We evaluate our methodology in simulated scenarios using CARLA [4].

II. Methods

Fig. 1 shows the proposed framework. We propose a keyframe selector at an AV to select keyframes to be sent to the teleoperator rather than a complete video streaming with every single image frame. This is because under limited bandwidth, sending every frame is less efficient than only sending key images, which contain critical information for teleoperated driving. The keyframe selector utilizes changes of current vehicle states, changes of AV-generated control commands, and semantic information of images to identify keyframes. In our experiment, we utilise vehicle states available on real platforms, including speed, steering angle, throttle input, and brake input.

In fact, the keyframes may not be consistent with each other because of unequal time intervals among them. It is difficult for the teleoperator to control AV according to the raw keyframe sequence. In that case, we propose a predictor to reconstruct a full video sequence based on keyframes only. This predictor aims to improve the consistency of the video and reduce the influence of delay.

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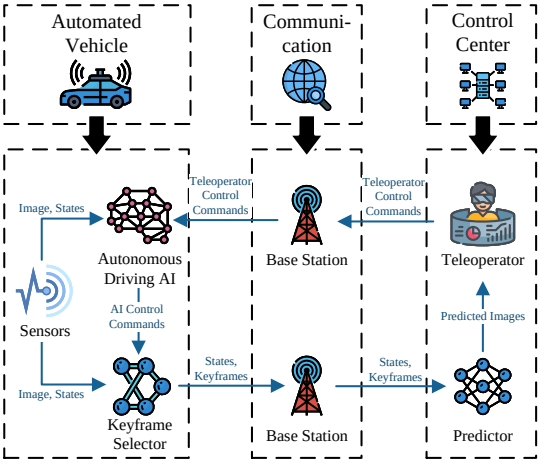

Fig. 1. Proposed framework for teleoperated driving, with keyframe selection, communication, and prediction. (In this work, we focus on uplink communication from AV to teleoperator.)

III. Evaluation

In the preliminary study and validation, we developed and tested the keyframe selector based on changes in the AV state and AV-generated control commands[1]. The default frame rate and the image sending rate are set to 20 Hz. At the current stage, we use the AI driving program developed in [3] as a teleoperator to control the AV. The result shows that our method can reduce the image sending rate to about 2 Hz on average, while keeping a similar driving performance to the 20 Hz image sending rate. As a comparison, if we reduce the image sending rate to 2 Hz uniformly (without keyframe selection), the control performance decreases dramatically. This shows that the keyframe selector can reduce about 90% of the communication load in our preliminary experiment in CARLA while maintaining good teleoperation performance.

References

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[1]The preliminary demo link: https://youtu.be/gdpMfr9GJrQ