Evaluation of Display Methods
for Teleoperation of Road Vehicles

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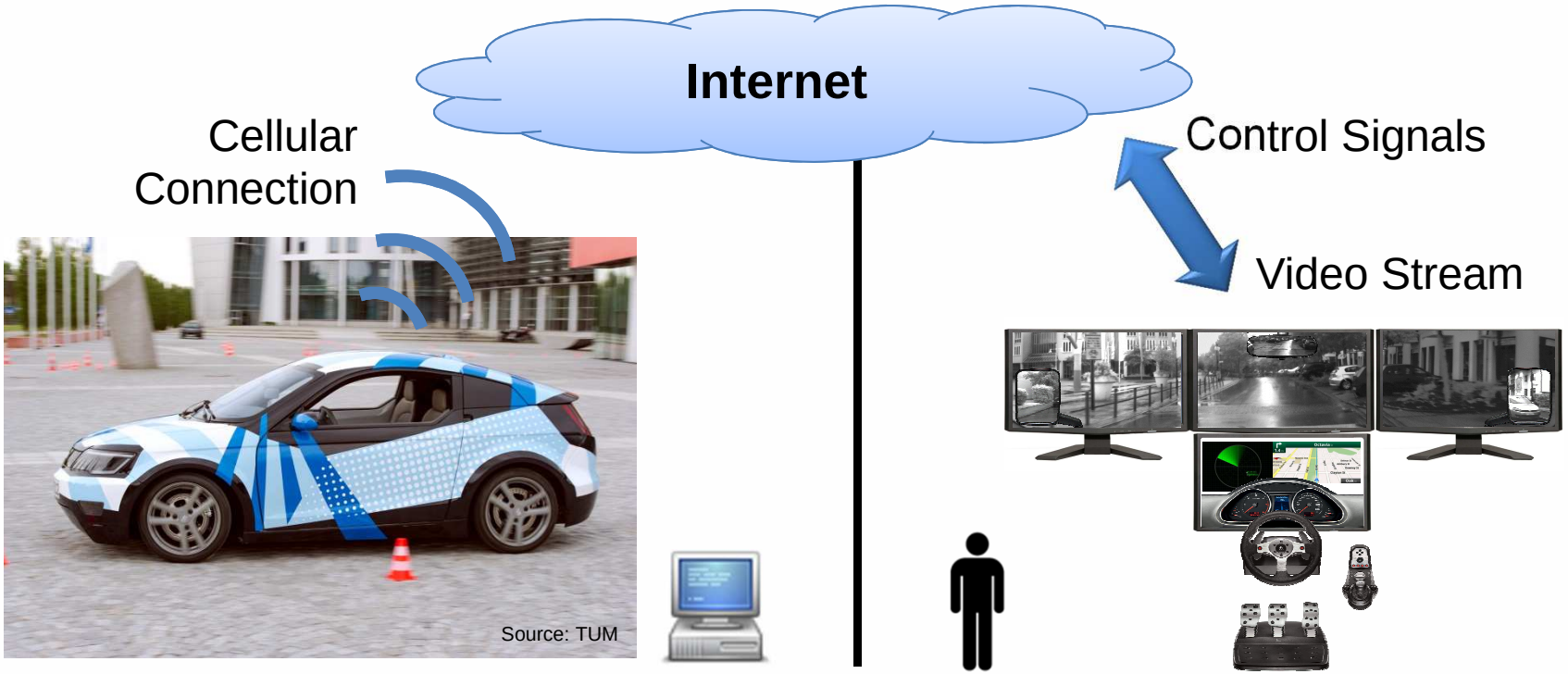
Introduction

- Driverless vehicle delivery (car-sharing or charging)
- Control via live video feed



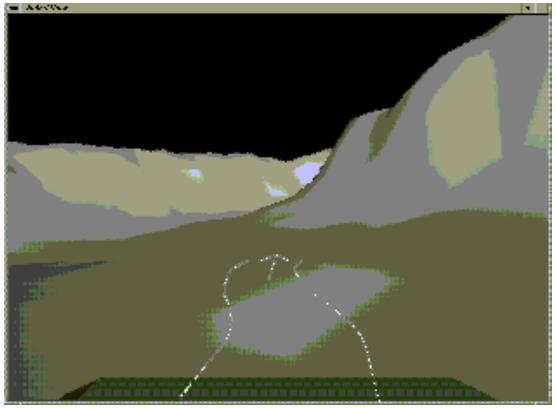
Press event at TUM

Time delays in signal chain decrease driving performance

Predictive Display

- Mitigate time delay effects
- Additional information

Finding the best display method

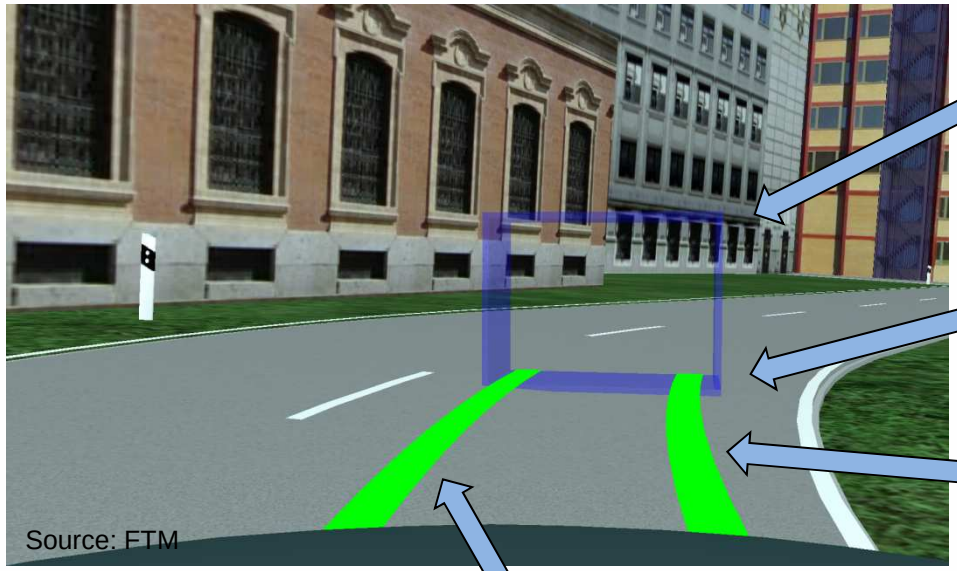


Source: Arnold 1963

Source: http://www.mitre.org/news/digest/defense_intelligence/12_09/feedback.html

Source: Davis 2009

Frame Prediction Method



Size of frame indicates vehicle boundaries

Frame position indicates predicted vehicle front position

Length of Trackmarks indicates velocity

Trackmarks indicate trajectory

Display Methods

3 Methods

Delayed Display (DD)

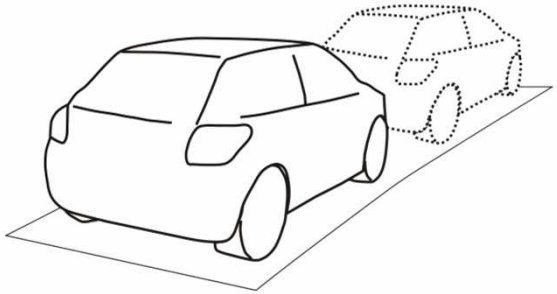
- Delayed visual feedback

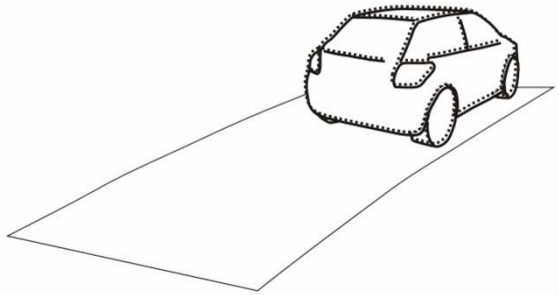
Perfect Prediction (PP)

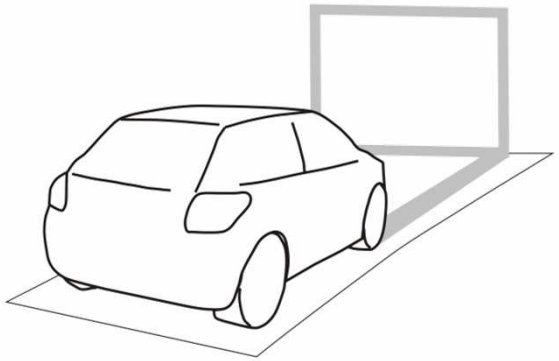
- Video images altered to show no delay

Frame Prediction (FP)

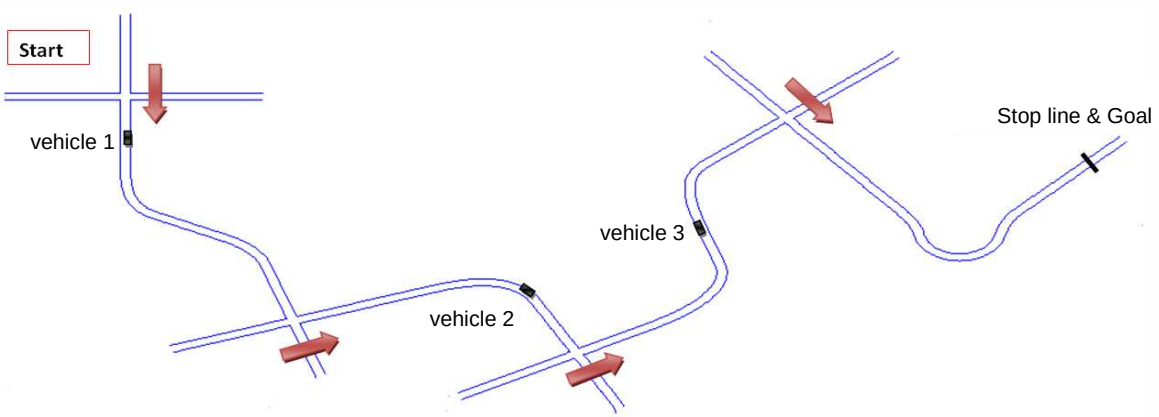
- Frame displayed at predicted position

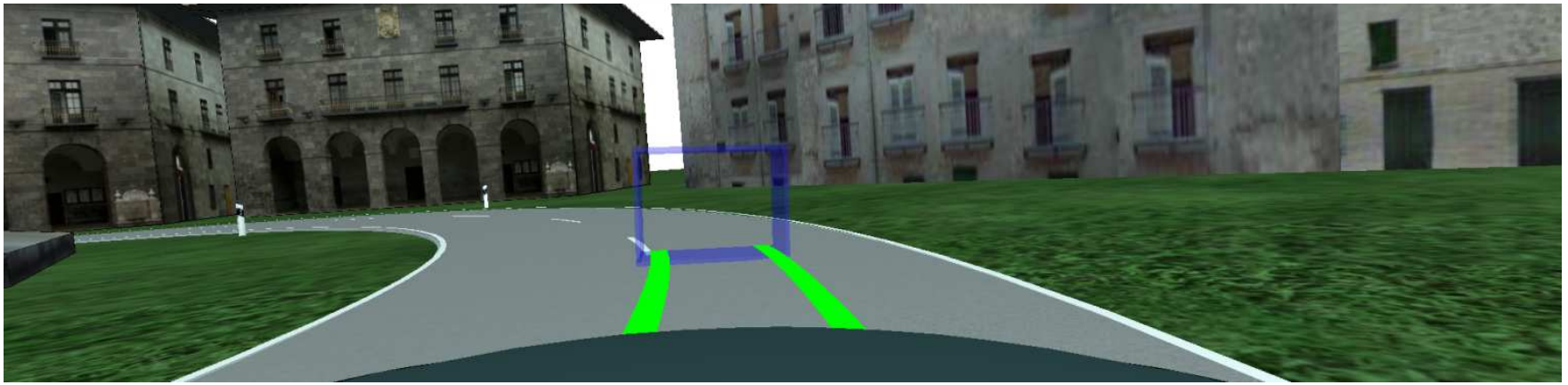






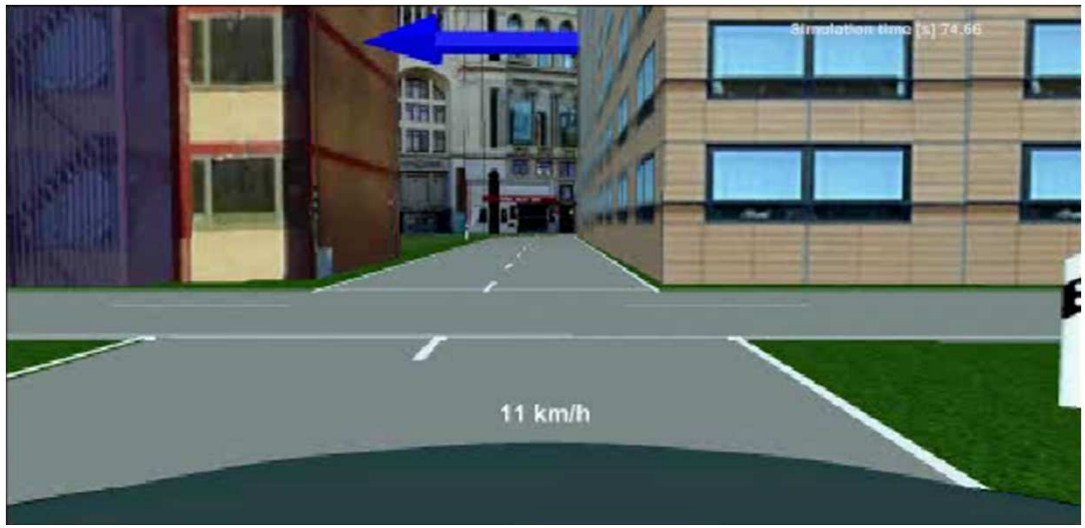
User Study With Driving Simulator

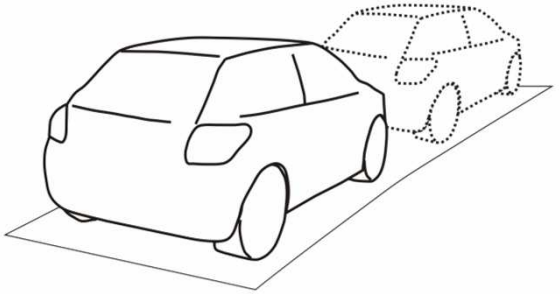


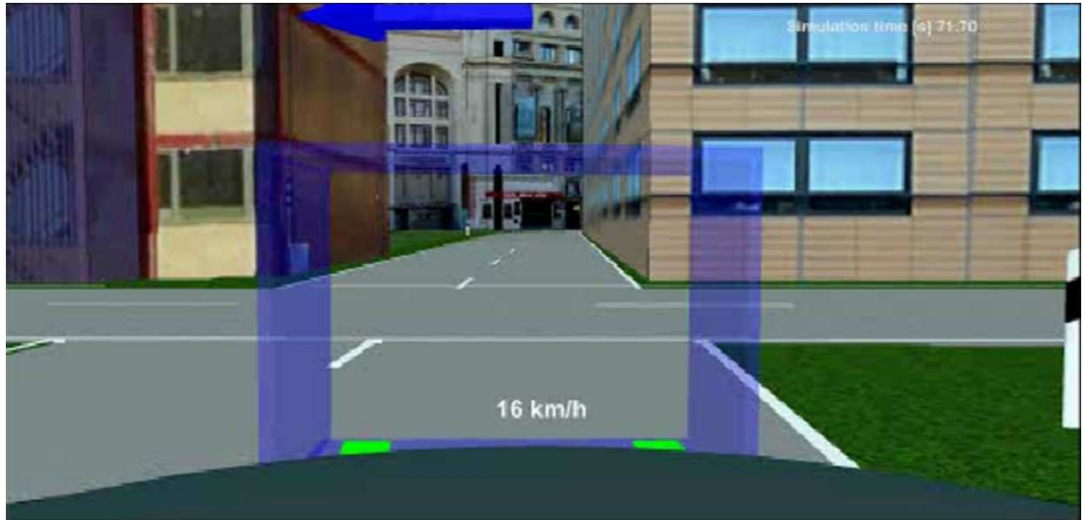


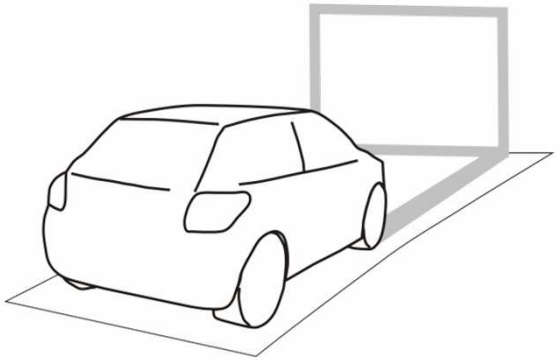
Participants

- Students and employees of TUM
- ♀: 1 ♂: 21
- Age: 21 to 35 (average 24.91) years
- Experience with driving simulators: 4
- Good or very good experience with computer games: 15


11 km/h

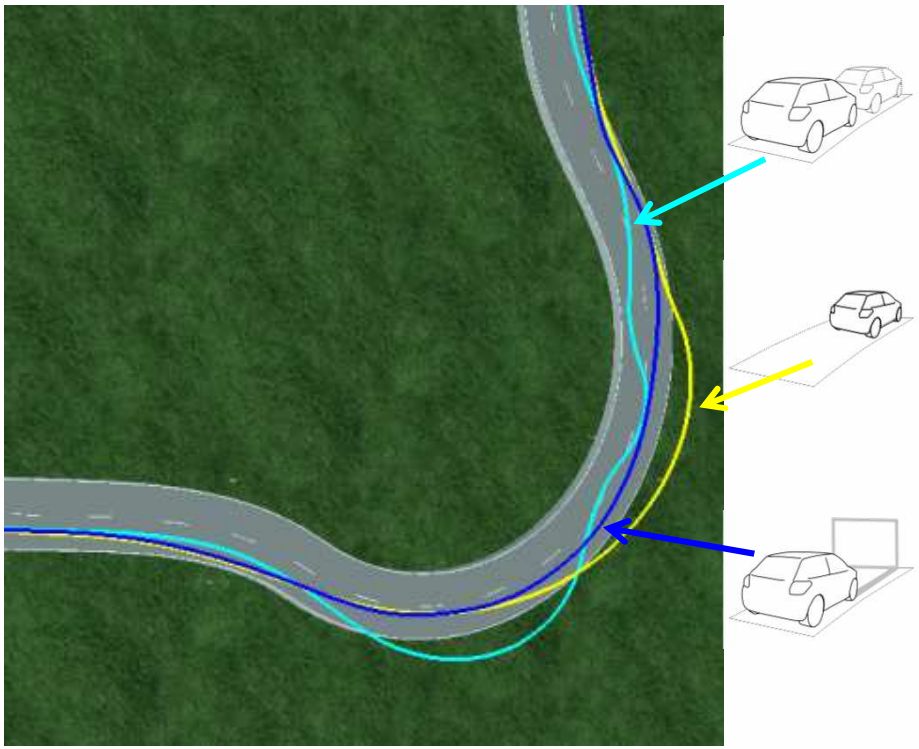


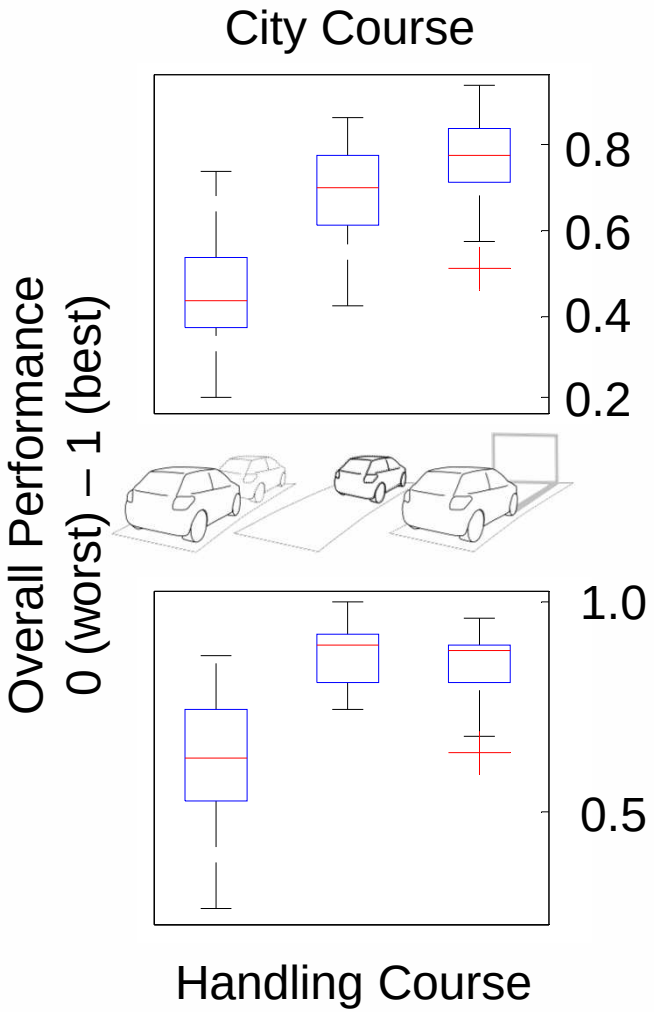

16 km/h



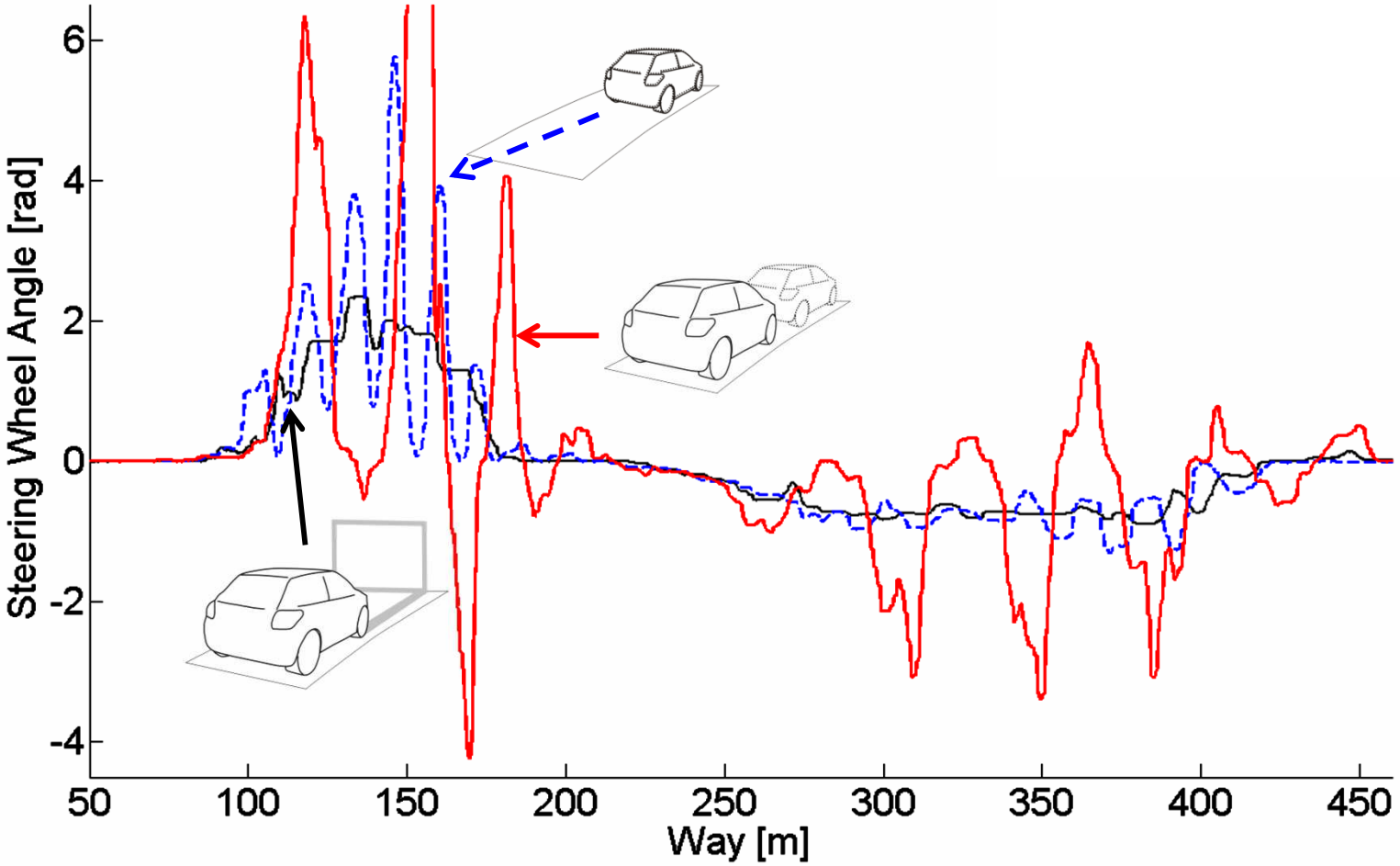
Overall performance improved

- 2/3 Lane accuracy
- 1/3 Task completion time

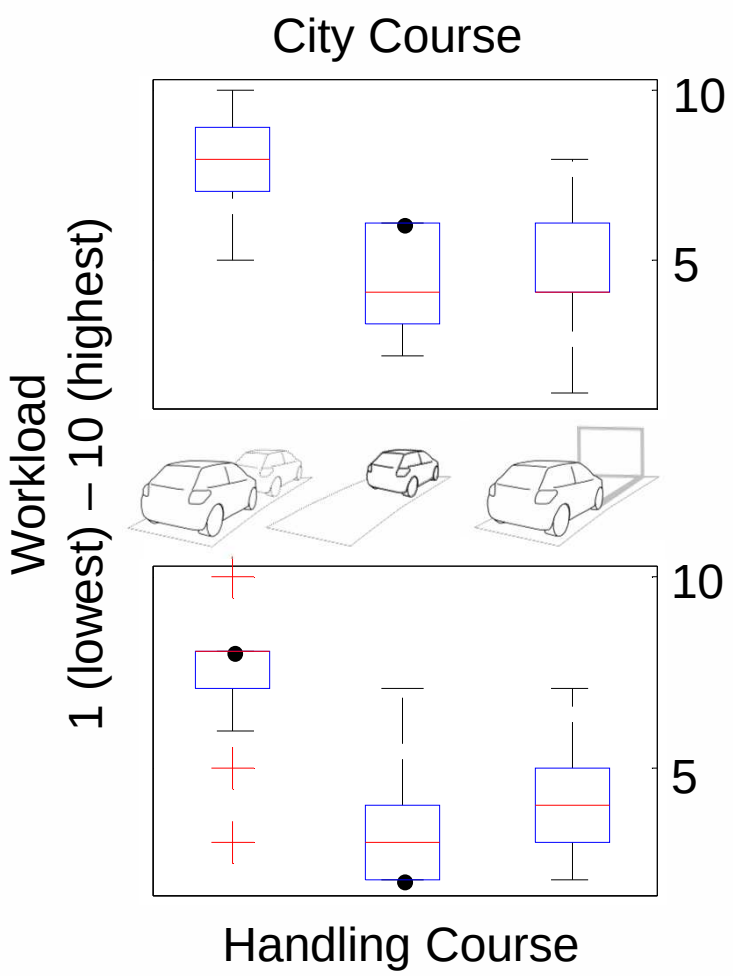


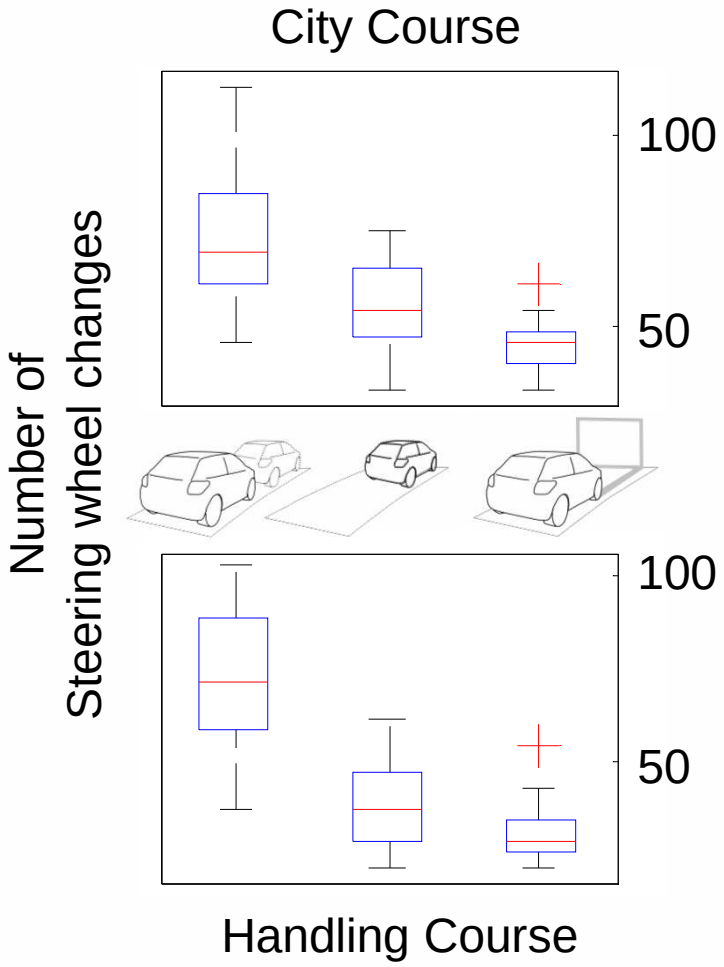


Number of steering wheel changes DD>PP>FP



Reduced workload with prediction



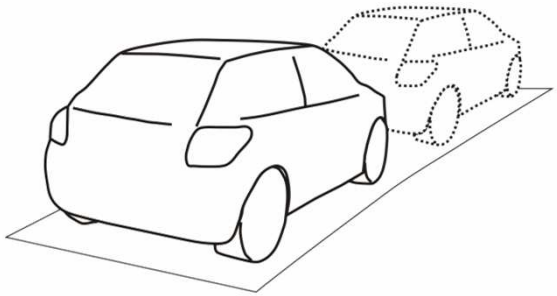


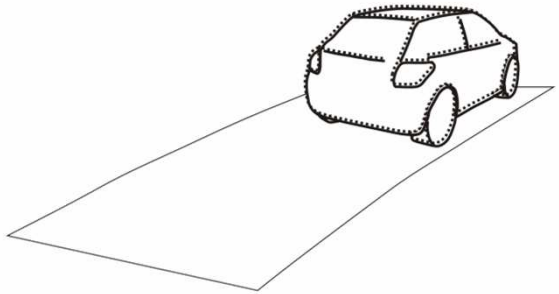
Additional measurements

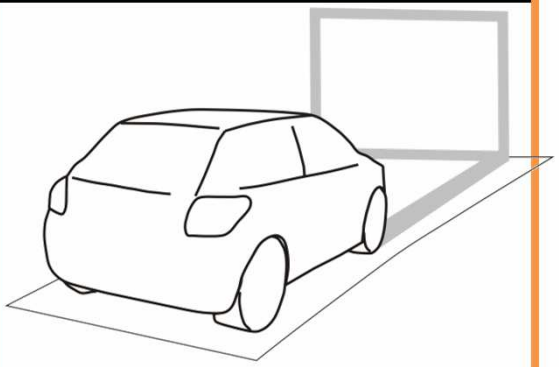
- Task Completion time reduced
- Sensation of velocities improved
- Distance to stop line reduced with FP

Comparison

Delayed Display	Perfect Prediction	Frame Prediction
+ No Implementation effort - Bad driving performance - High workload	+ Driving Performance + Workload + Higher velocities - Implementation effort	+ Driving Performance + Workload - Preview distance for higher velocities







Conclusion

- Negative influence of time delays on driving performance and operator workload
- Mitigation possible with predictive displays
- FP sometimes even better than PP
- High implementation effort for PP not necessary

Frame Prediction is the preferred method

Outlook

- Further improve FP
- Prediction of other traffic participants

Thank you!

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