Vehicle Steering Control with Human-in-the-Loop

Mengzhe Huang, Weinan Gao,
Zhong-Ping Jiang(IEEE/IFAC Fellow)
Email: {m.huang, weinan.gao, zjiang}@nyu.edu

Control and Networks Lab, Department of Electrical and Computer Engineering, Tandon School of Engineering, NYU
URL: http://engineering.nyu.edu/people/zhong-ping-jiang

November 15, 2016

Overview

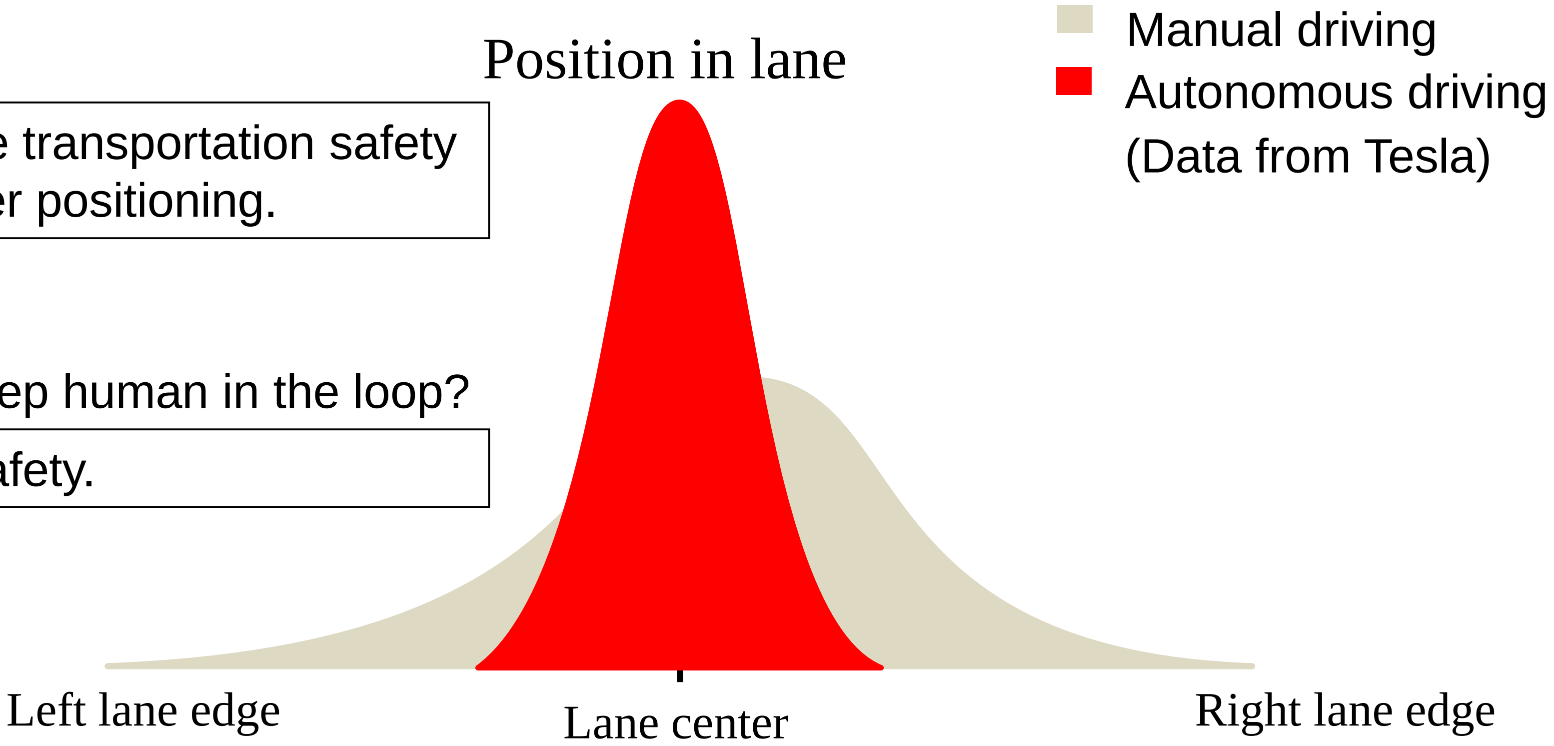
- Introduction
  - Vehicle Steering Control and Lane Keeping
  - Human in the Loop
- Problem Formulation and Proposed Solution
  - Human-in-the-loop Control Framework
  - A Data-driven Method for Vehicle Steering Control with Human in the Loop
- Simulation

Motivation:

Improve transportation safety by better positioning.

Why keep human in the loop?

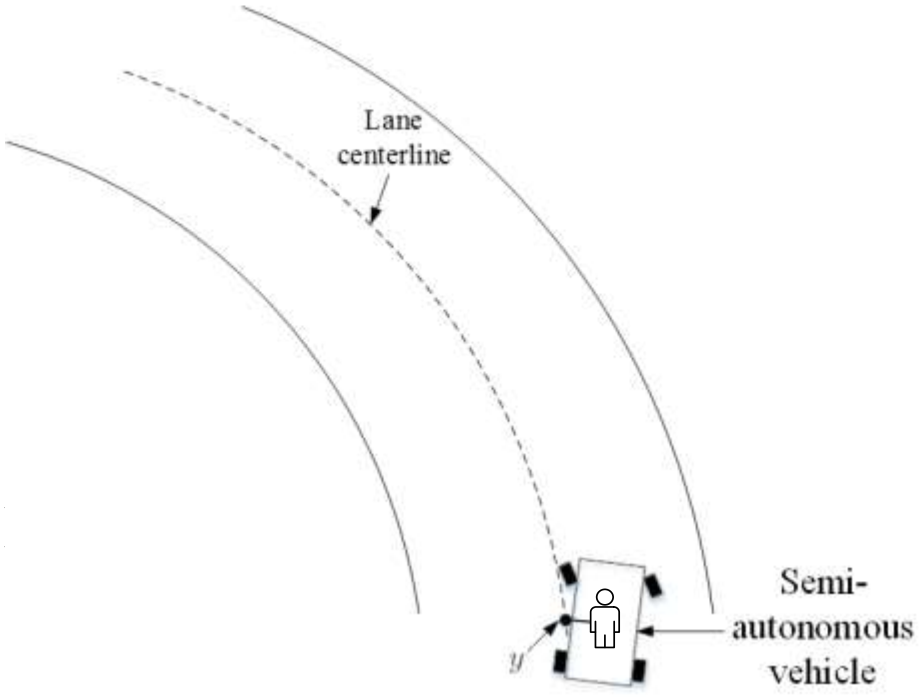
More safety.



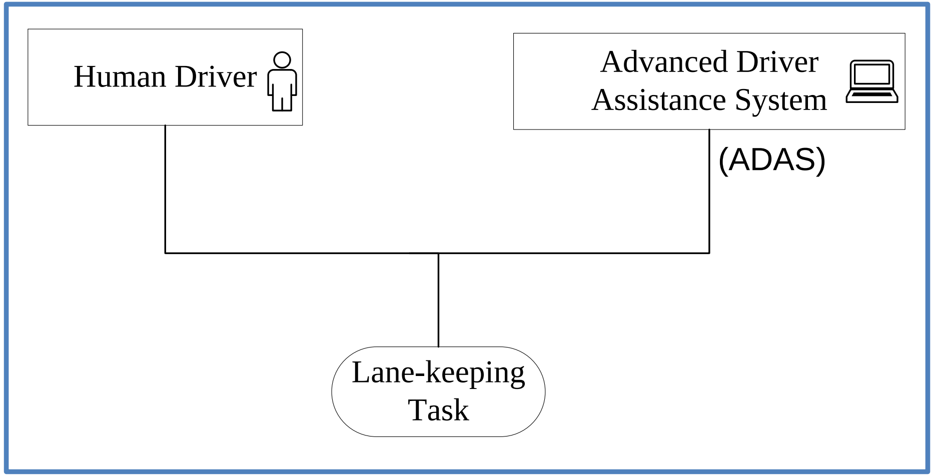
Problem description

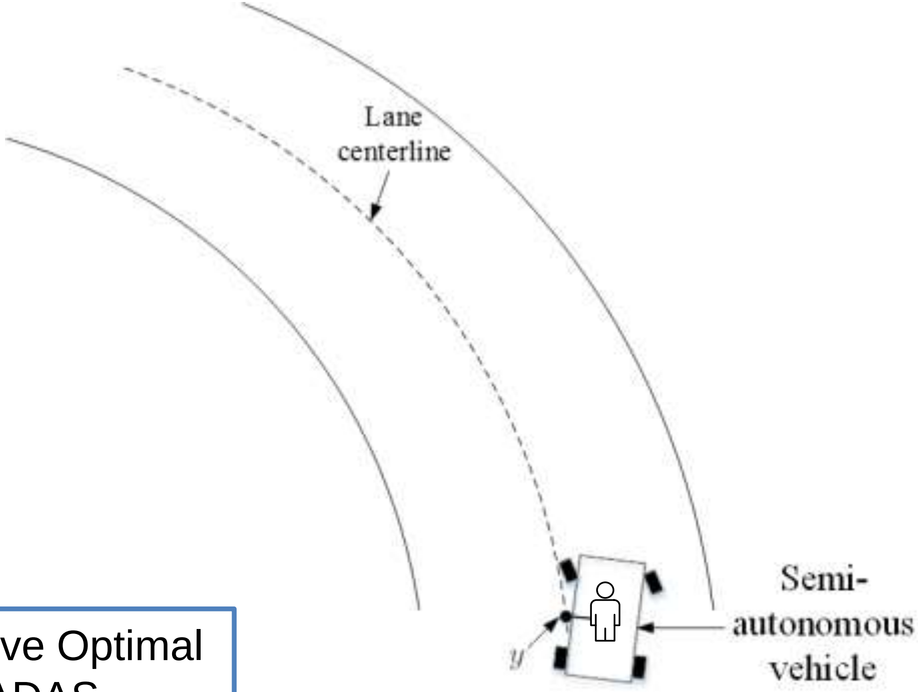
- Semi-autonomous vehicle:
  To incorporate human driver into the design procedure

- The goal of our study:
  To achieve lane keeping on the curving lane with human in the loop (the driver collaborates with the designed controller



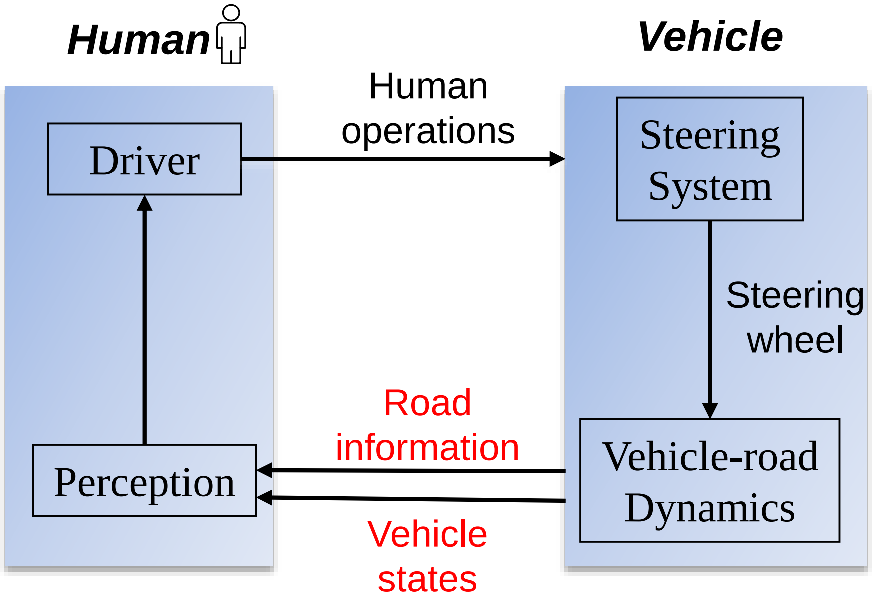
Human-in-the-loop Design Procedure

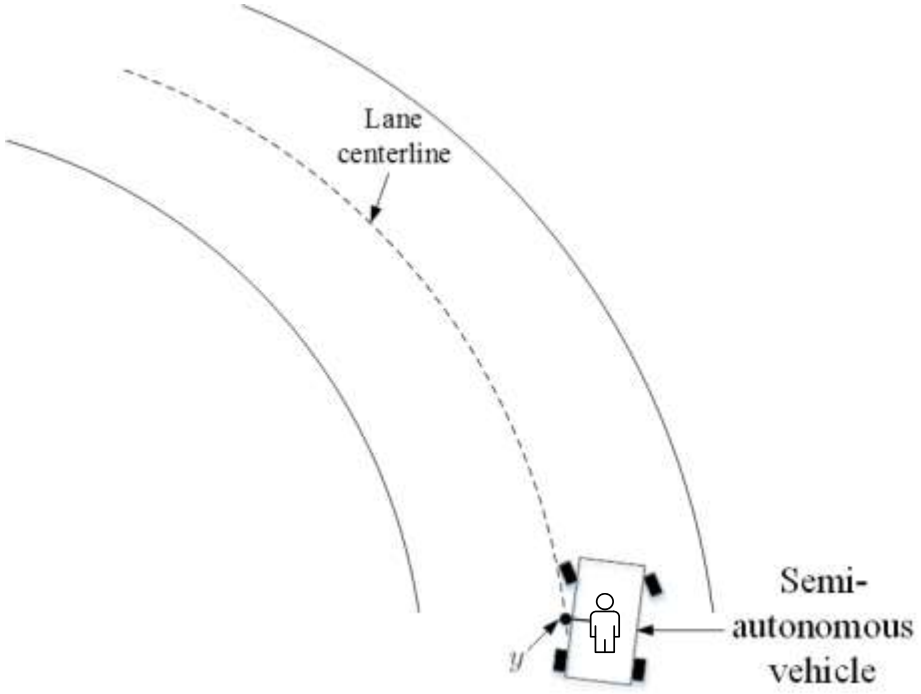




Adaptive Optimal Control Problem → Adaptive Optimal ADAS

Human Vehicle Interaction

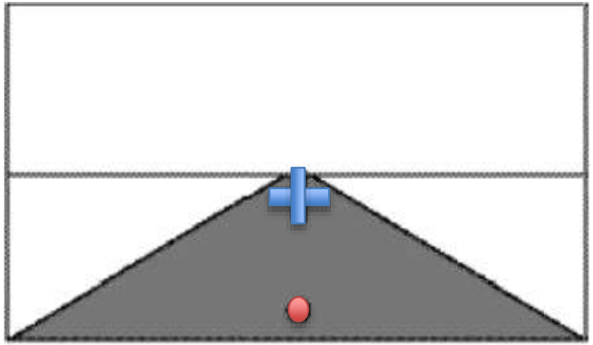




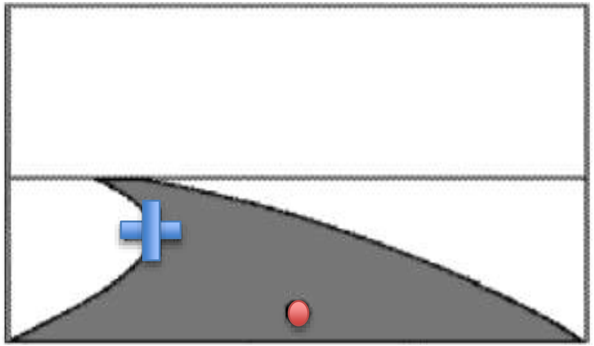
Human driver model

A human driver model represents the process by which a driver transforms perceived information about the driving situation into an action on the vehicle's actuators.

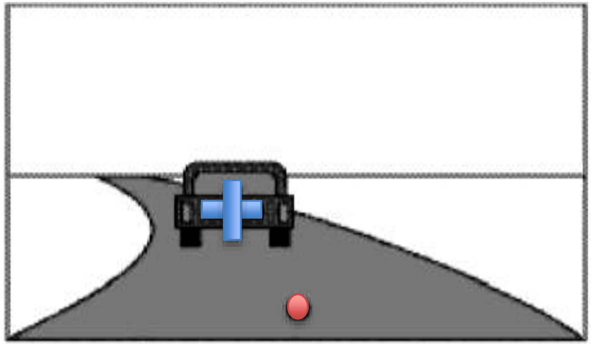
Two-point visual model [D. Salvucci, 2004]



(a) Straight lane



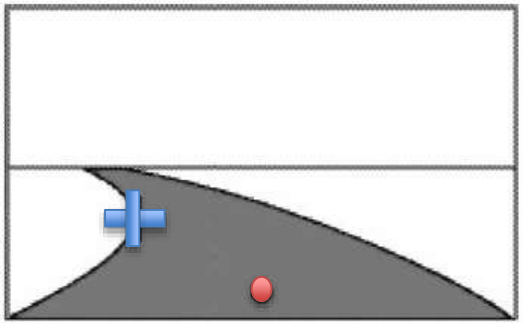
(b) Curving lane

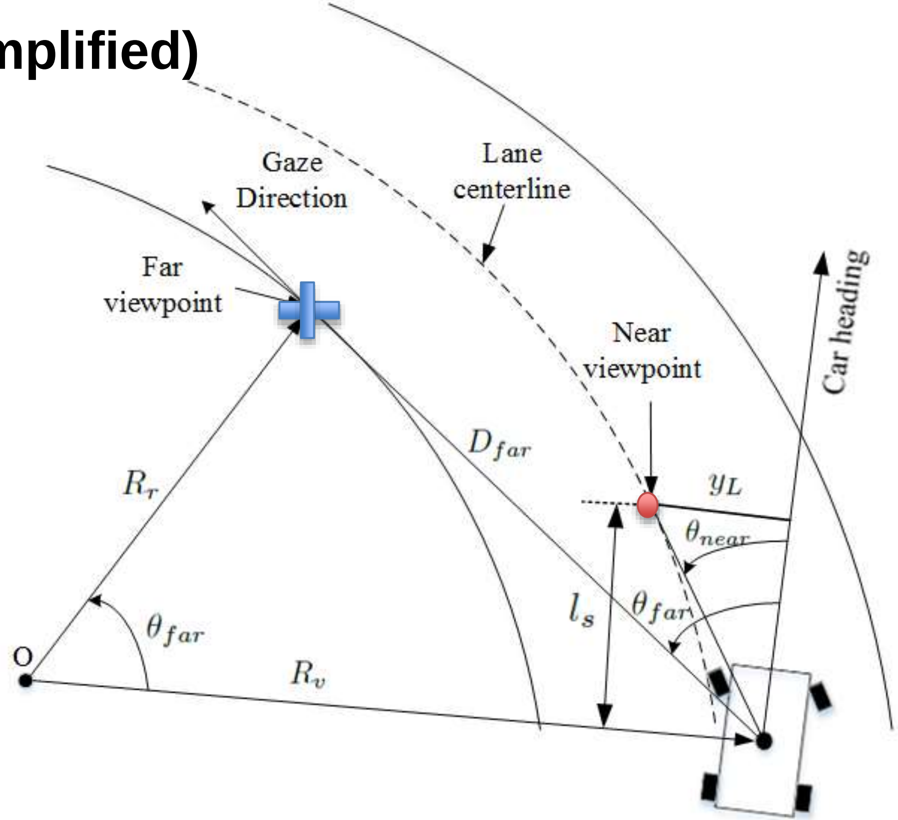


(c) With a leading vehicle

Near and far points

Mathematical modeling for a driver (simplified)





The information from the two viewpoints can be approximated by **two visual angles** θ_{near} and θ_{far} [Saleh, 2013].

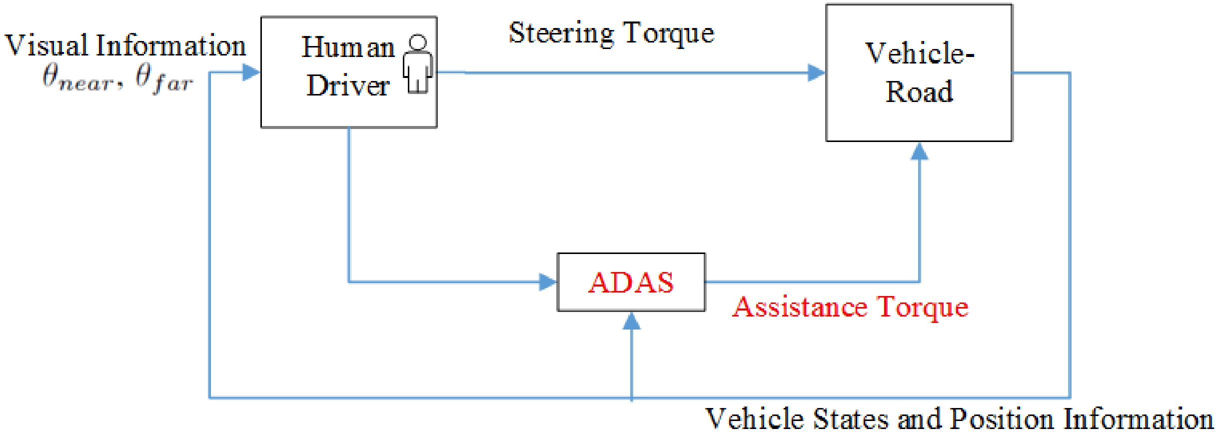
$$T_d = K_{near}\theta_{near} + K_{far}\theta_{far}$$

Driver's control torque

Driver's control torque

$$T_d = K_{near}\theta_{near} + K_{far}\theta_{far}$$

Vary from person to person



Block Diagram

Adaptive ADAS provide more personalized service

Minimal intrusiveness and good performance

→ Adaptive optimal control problem → Data-driven method

[1] W. Gao, Z. P. Jiang and K. Ozbay. "Data-driven adaptive optimal control of connected vehicles." *IEEE Transactions on ITS* (2016).
[2] Z. P. Jiang and Y. Jiang. "Robust adaptive dynamic programming for linear and nonlinear systems: An overview." *European Journal of Control* 19.5 (2013): 417-425.

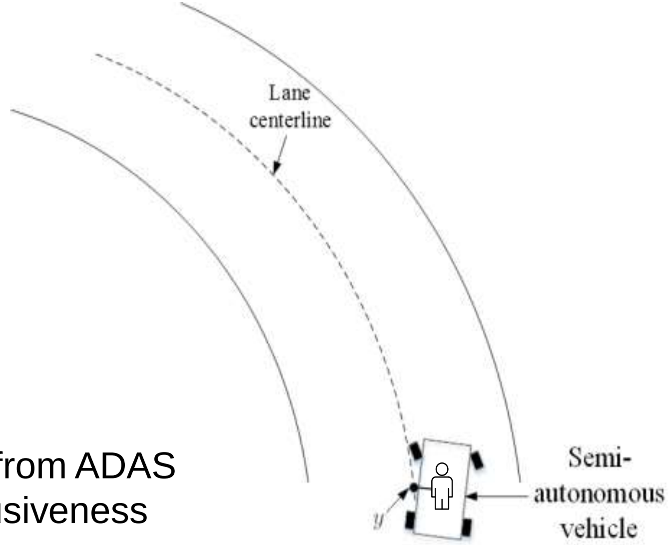
Data-driven Formulation for Vehicle Steering Control with Human in the Loop

Find an adaptive optimal ADAS (controller) to solve following optimization problem

$$\min_{u} J = \sum_{k=0}^{\infty} [q y^2(k) + r u^2(k)]$$

Lateral deviation from lane centerline

Assistance torque from ADAS with minimal intrusiveness



s.t. $x(k+1) = Ax(k) + B(\mathbf{u(k)} + \boldsymbol{T_d}) + Dw(k)$

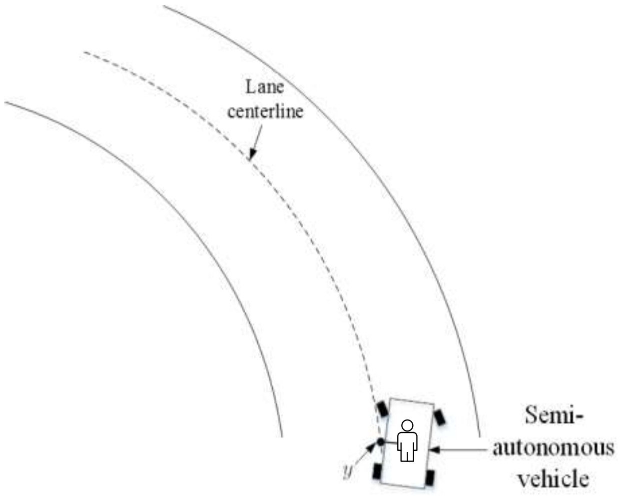
(Vehicle-road dynamics with human in the loop)

Road information (curvature)

Note: Vehicle and human parameters are unknown.

M. Huang, W. Gao and Z. P. Jiang. "A data-based lane-keeping steering control for autonomous vehicles: A Human-in-the-loop approach." In Proceeding of Chinese Control Conference, pp. 8974-8979, July, 2016.

Data-driven Method for Vehicle Steering Control with Human in the Loop



- Collect data
  - Vehicle internal states (sideslip angle, yaw rate, steering angle, change rate of steering angle)
  - Vehicle-road position states (lateral deviation, vehicle heading angle, road curvature)
  - Driver's control torque

  Sensors: camera, line sensors and GPS.

- Use data-driven adaptive dynamic programming (ADP) to find an adaptive optimal ADAS to improve the performance of lane keeping

Remark:
ADP integrates ideas from *reinforcement learning* and *dynamic programming* to design **model-free adaptive optimal controllers**.

IEEE-Wiley book by Jiang and Jiang, 2017, to appear.

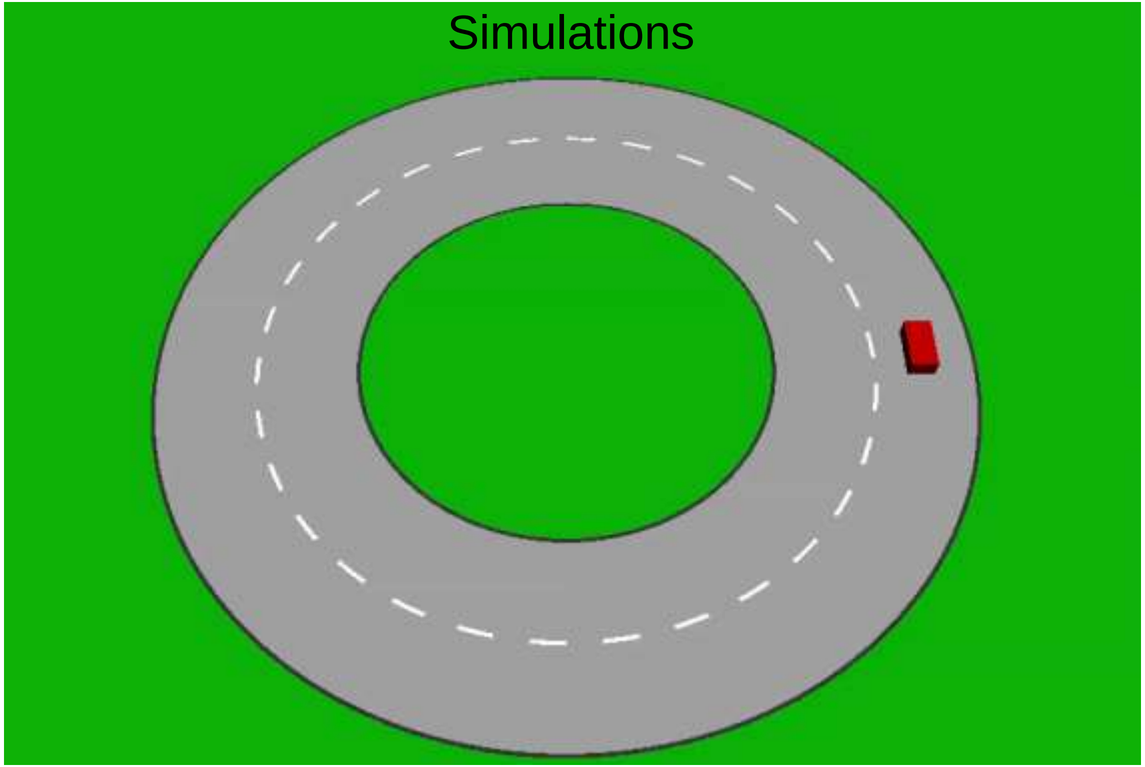
Simulations on a circle:

Red:
Human driver

Blue:
Human driver and ADAS

Performance
Red: About 20-30 cm deviation

Blue: minimized lateral deviation



Animation made by Manuel Serrano

Thank you!