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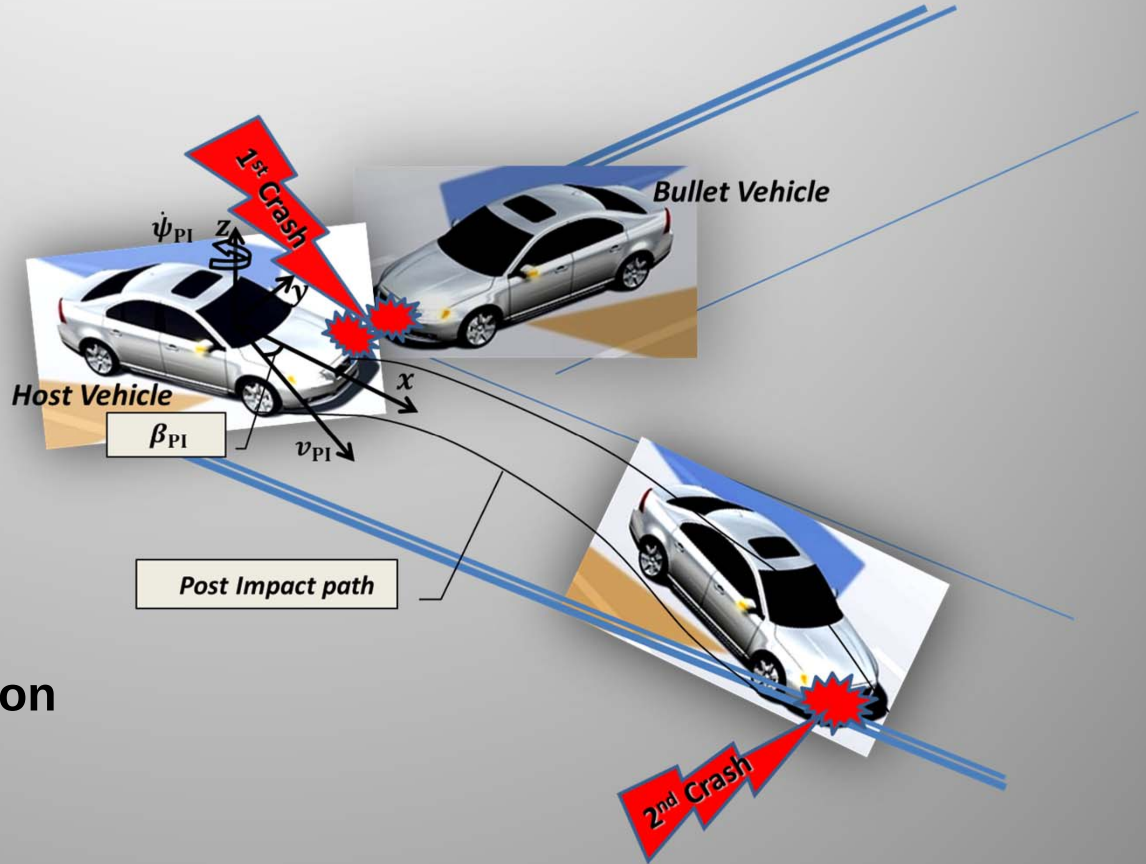
Post Impact Stability Control

Derong Yang

Vehicle Dynamics Functions, Volvo Cars

Vehicle Dynamics, Chalmers



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Advisor: **Bengt Jacobson**

VOLVO

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Real-world Accidents

Introduction

- Multiple Event Accidents (MEAs)
  - Approx. 1/4 of all car accidents
  - Human injury levels higher than in single-event accidents
  - 50% have severer injuries in *subsequent* impacts

- Research motivation: *Vehicles and humans are subjected to more than one harmful event in the traffic accidents.*

Introduction

- Electronic Stability Control (ESC)
  - Effective for following driver's intended yaw rate, assuming driver is correct
  - During impact, sensor saturated, ESC deactivated
  - ESC not designed for stabilizing violent spinning and skidding motions
  - ESC designed neither for controlling vehicle path nor orientation

Introduction

- Post Impact Braking (PIB)
  - New to market: Bosch SCM, VW GolfMK7/Audi Multi Collision Brake, BMW iBrake®
  - Triggered by airbag deploy signals
  - Open-loop max brake request with closed-loop ABS control

  - Reduces displacements and speed
  - Increases yaw angle
  - Degrades steerability, less benefits for active drivers

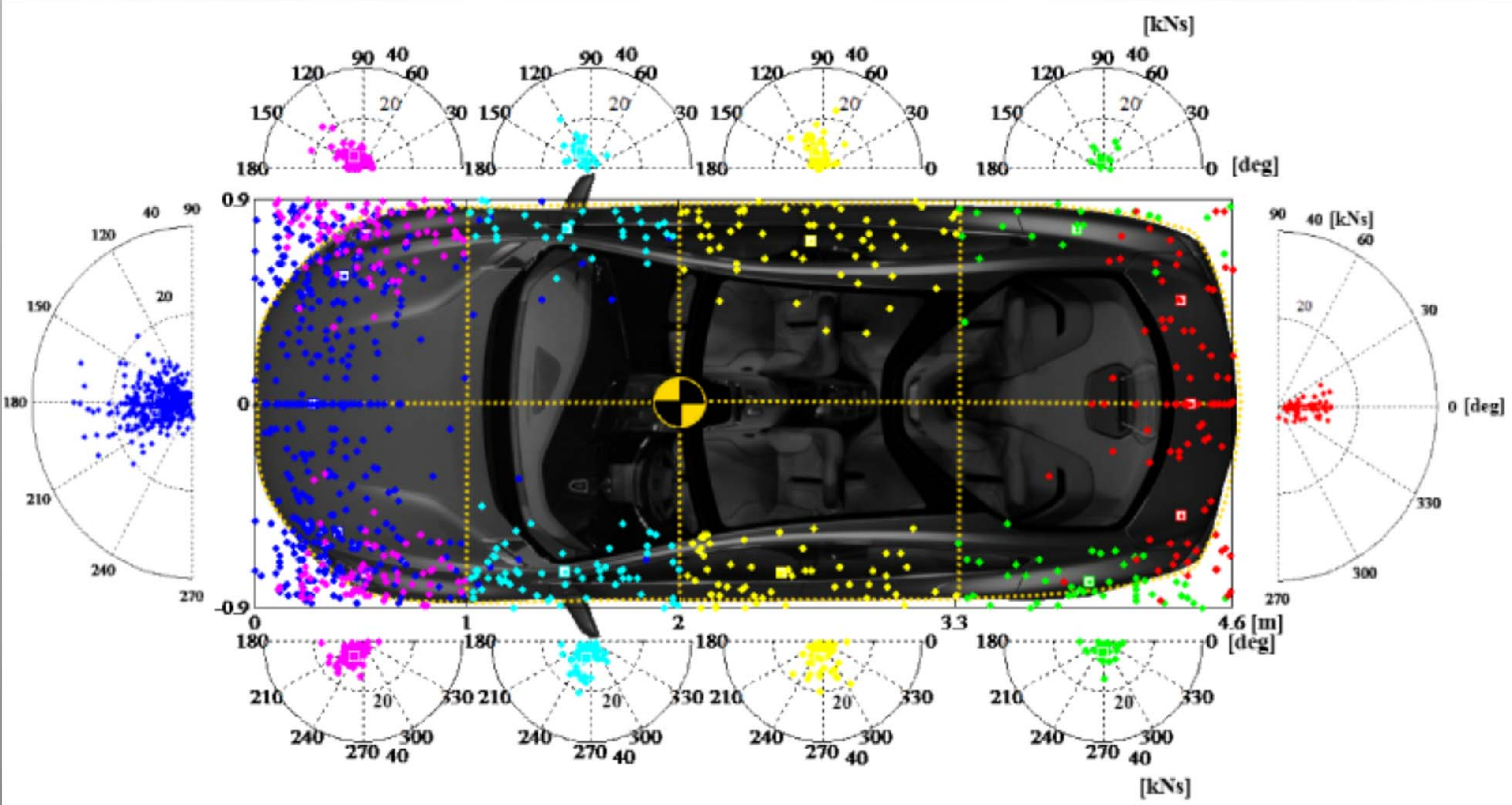
Research Question

- When driver and vehicle are disturbed by sudden impacts, how can the post impact vehicle motion control function be designed, in order to avoid or mitigate the secondary events in MEAs?

Vision

- A new vehicle dynamics control function: Post Impact Stability Control (PISC)
- Triggering: sensor signals for passive safety systems, e.g. air bags
- Actuators: individual wheel brakes, front axle steering
- Sensors: IMU, GPS, traffic environment sensing e.g. camera, radar, lidar

1st Impact Characteristics



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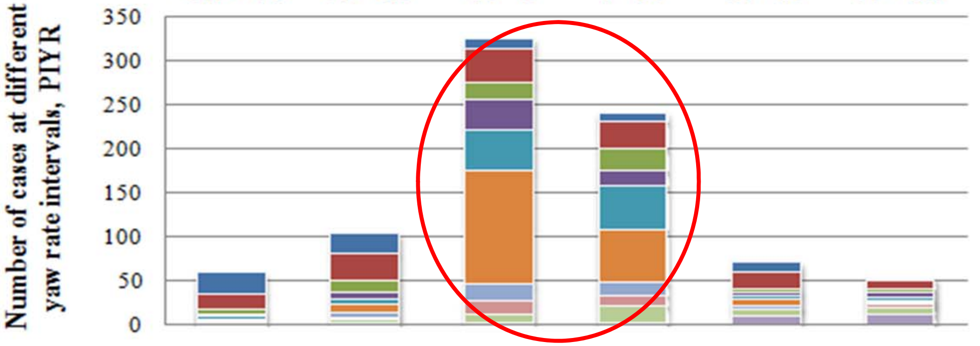
Post 1st Impact Quantities



	PISSA [deg]: -180→-90	PISSA [deg]: -90→-30	PISSA [deg]: -30→0	PISSA [deg]: 0→30	PISSA [deg]: 30→90	PISSA [deg]: 90→180		
PIYR: 180→500	24	22	12	11	11	2	82	10 %
PIYR: 90→180	17	32	39	31	19	10	148	17 %
PIYR: 60→90	7	13	18	25	4	4	71	8 %
PIYR: 30→60	1	8	34	17	3	6	69	8 %
PIYR: 0→30	4	6	47	50	5	3	115	13 %
PIYR: -30→0	3	9	129	60	7	3	211	25 %
PIYR: -60→0	1	6	20	14	3	2	46	5 %
PIYR: -90→-60	2	2	15	12	1	3	35	4 %
PIYR: -180→-90	0	4	9	19	8	8	48	6 %
PIYR: -550→-180	1	2	3	3	10	12	31	4 %
[deg/s]	60	104	326	242	71	53	**856**	100 %
	7 %	12 %	38 %	28 %	8 %	6 %		

- Dominant Post Impact Velocity (PIV): 20-80 km/h

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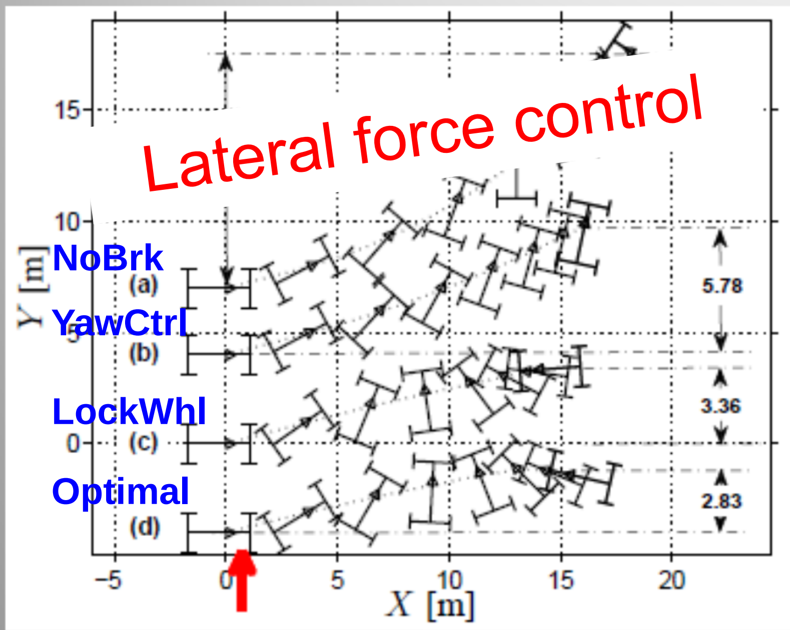
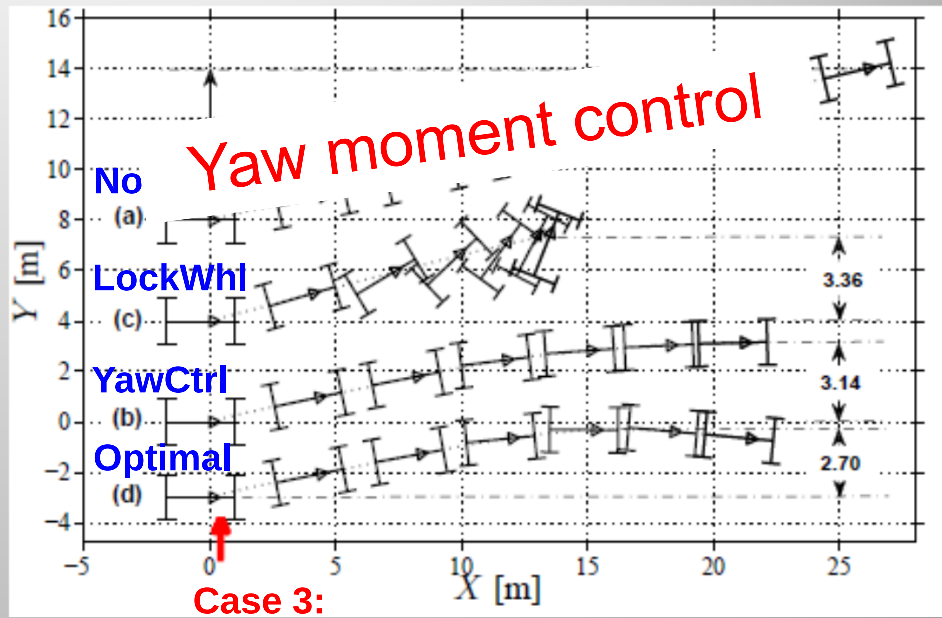
Accident Analysis

- Database: **Germany In-depth Accident Study (GIDAS)**
  - **14600** passenger cars motion **reconstructed**
  - **25.3%** of 14600 cars in GIDAS involved in MEAs
  - **7.3%** are PISC-relevant cars which have potential to gain benefits from PISC, e.g. where detection and actuation is possible
  - Reduction of kinetic energy and lateral displacement is beneficial for most cases.

Optimized Path Lateral Control – examples



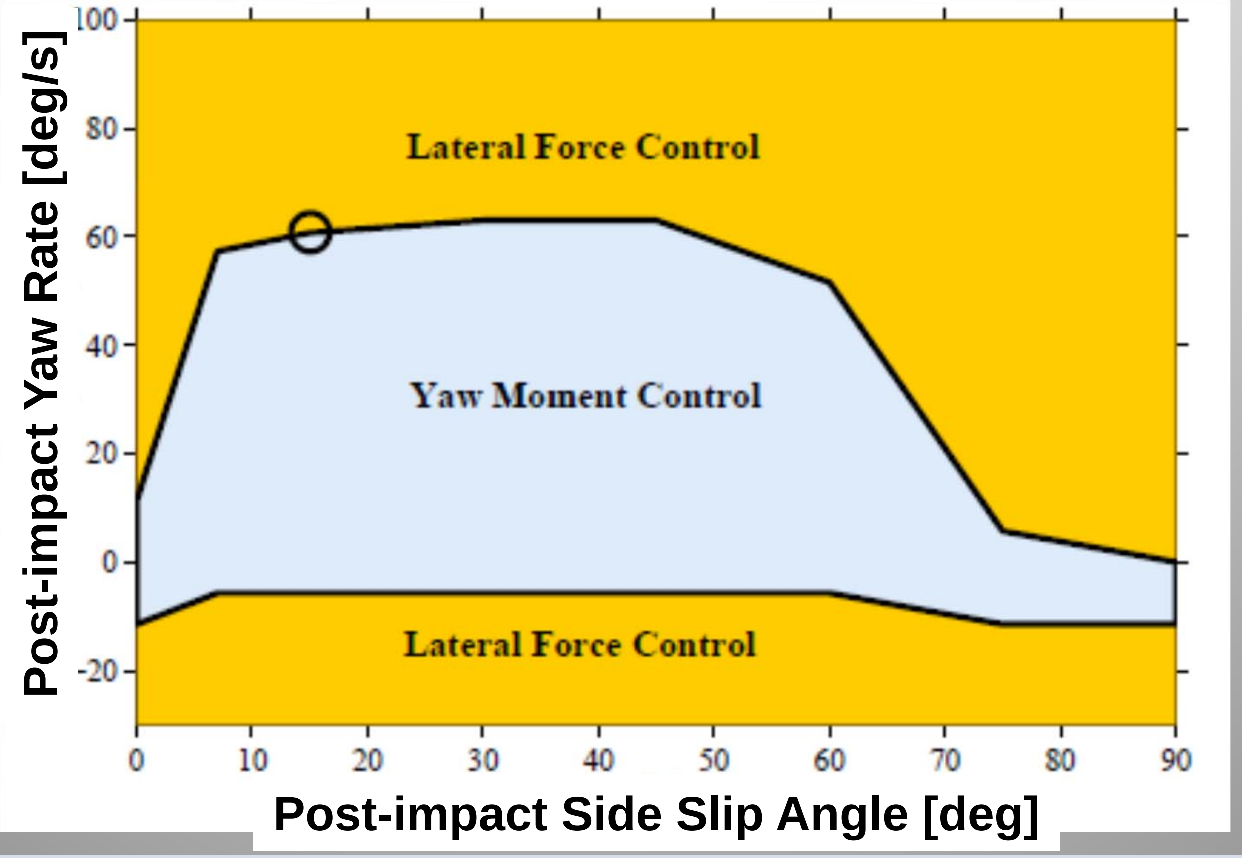
Case 1:
FrontAxleSlides



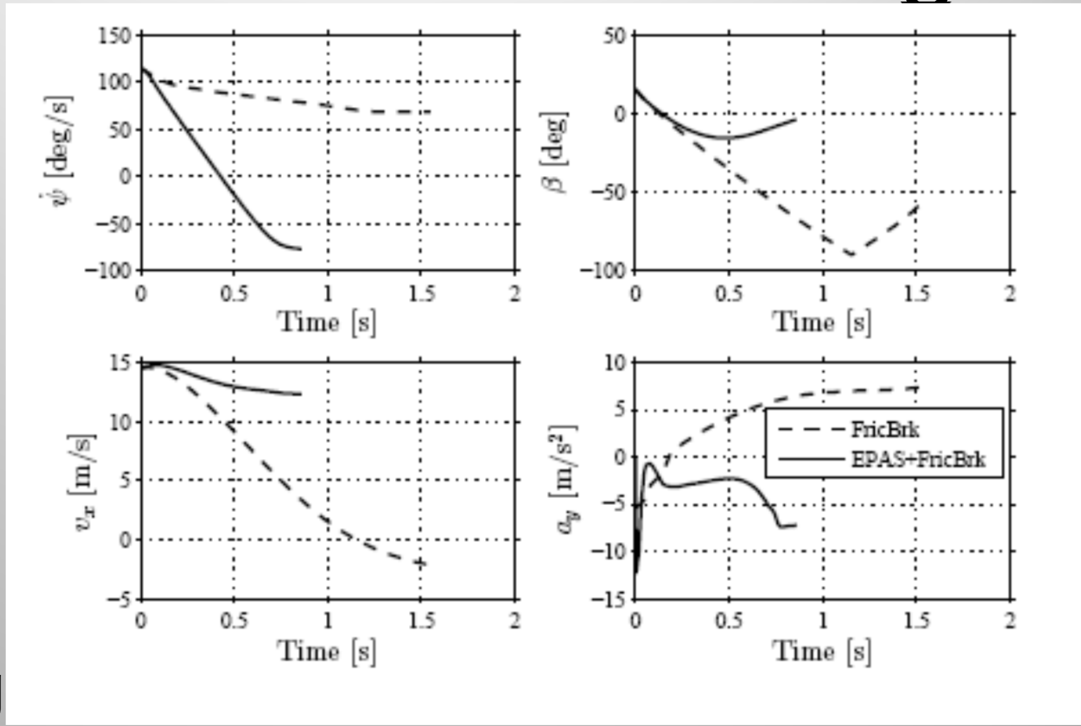
Case 3:
BothAxlesSlideInSameDir
(Lighter yaw disturbance)

No simple control mode, e.g. yaw motion control or locked wheel braking, is optimal alone to reduce lateral deviations in all studied cases. Instead, a combination of these strategies appears as the most efficient.

Optimal Strategy to Minimize Lateral Deviation

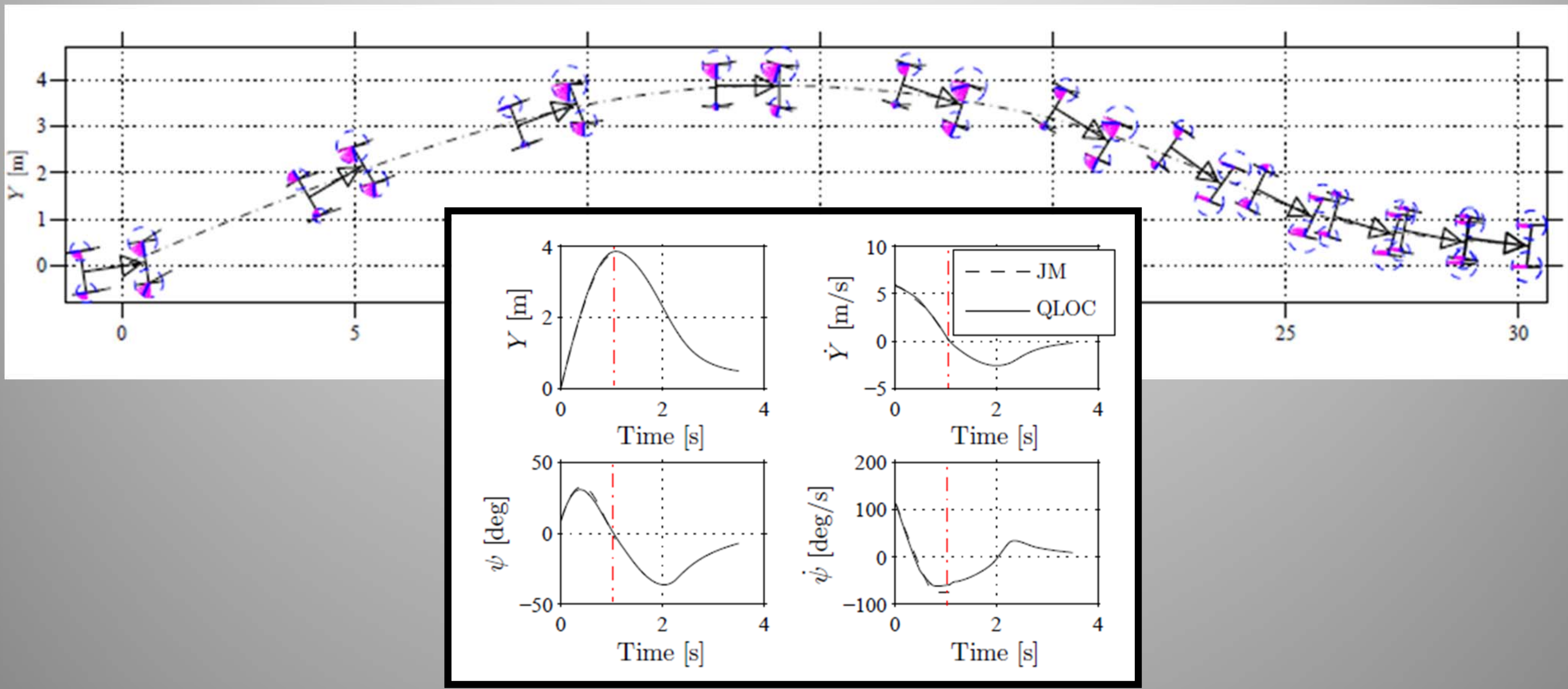


Case 1: w/o steering



- with steering
  - higher residual speed
  - overshooted yaw rate and lateral acc
  - can be efficiently suppressed by countersteer after Y_{max}

Controller vs. Optimization:
4×brakes and 1×steering

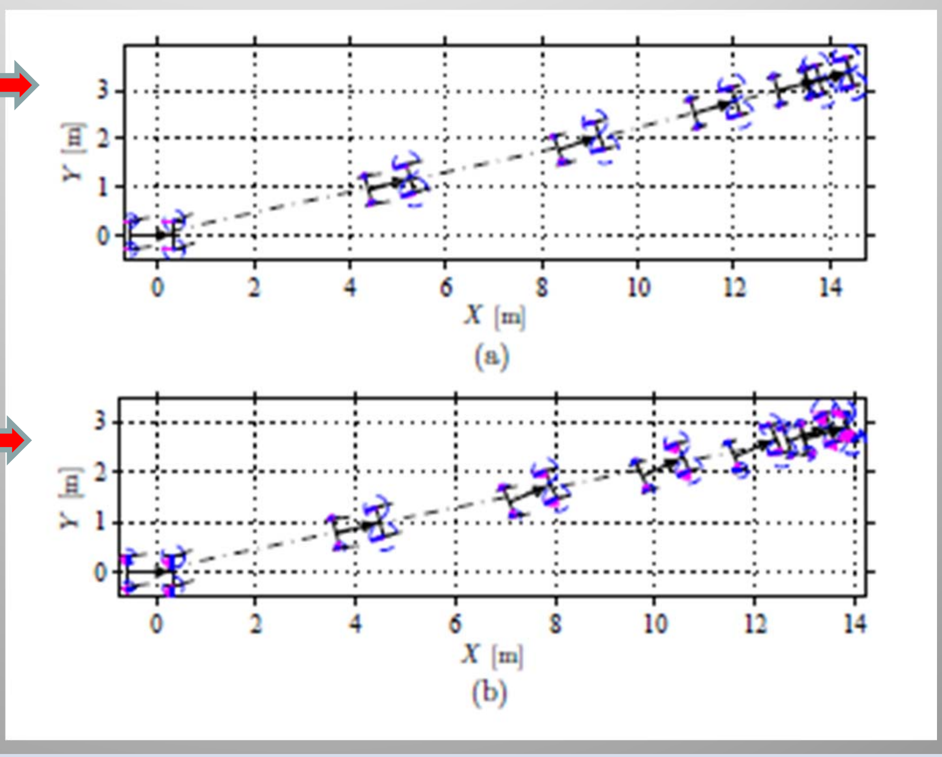


Minimize both lateral and longitudinal displacements

$$J = \sin(80°) \cdot \dot{X}(t_f) + \cos(80°) \cdot \dot{Y}(t_f), \text{where } J(t_f) = 0$$

Numerical optimization

Closed-loop controller



Function Verification

Picture : www.theautochannel.com

Picture: http://www.vti.se

Discussion & Future work

Improve controller design

- **High CG vehicle**

(control arbitration with RSC)

Improve controller design

- **Reference path depends on fixed or moving objects** (scenario identification & multi-objective criteria)
  e.g. 1st impact occurs at or near a curved road

Improve controller design

- **Driver interaction**
  (analyze the driver actions and vehicle kinematics, to decide if disengage PISC or not)

Improve controller design

- **Sensors and actuators failures**, e.g. blown tyres after 1st impact

(internal system fault detection, identification and compensation)