BMW Motorrad

WHY AUTOMATIZATION IS THE FUTURE OF MOTORCYCLE SAFETY.

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FROM AUTOMATIZATION TO ASSISTANCE – INTERVENE BEFORE A CRITICAL SITUATION.

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October 1st 2018
12th International Motorcycle Conference

BMW GROUP THE NEXT 100 YEARS

TECHNISCHE UNIVERSITÄT DRESDEN

MOTIVATION – WHY IS MOTORCYCLE SAFETY SO IMPORTANT?

Between 1990 and 2017…

… car-related fatalities decreased by

77%

… motorcycle-related fatalities decreased by

45%

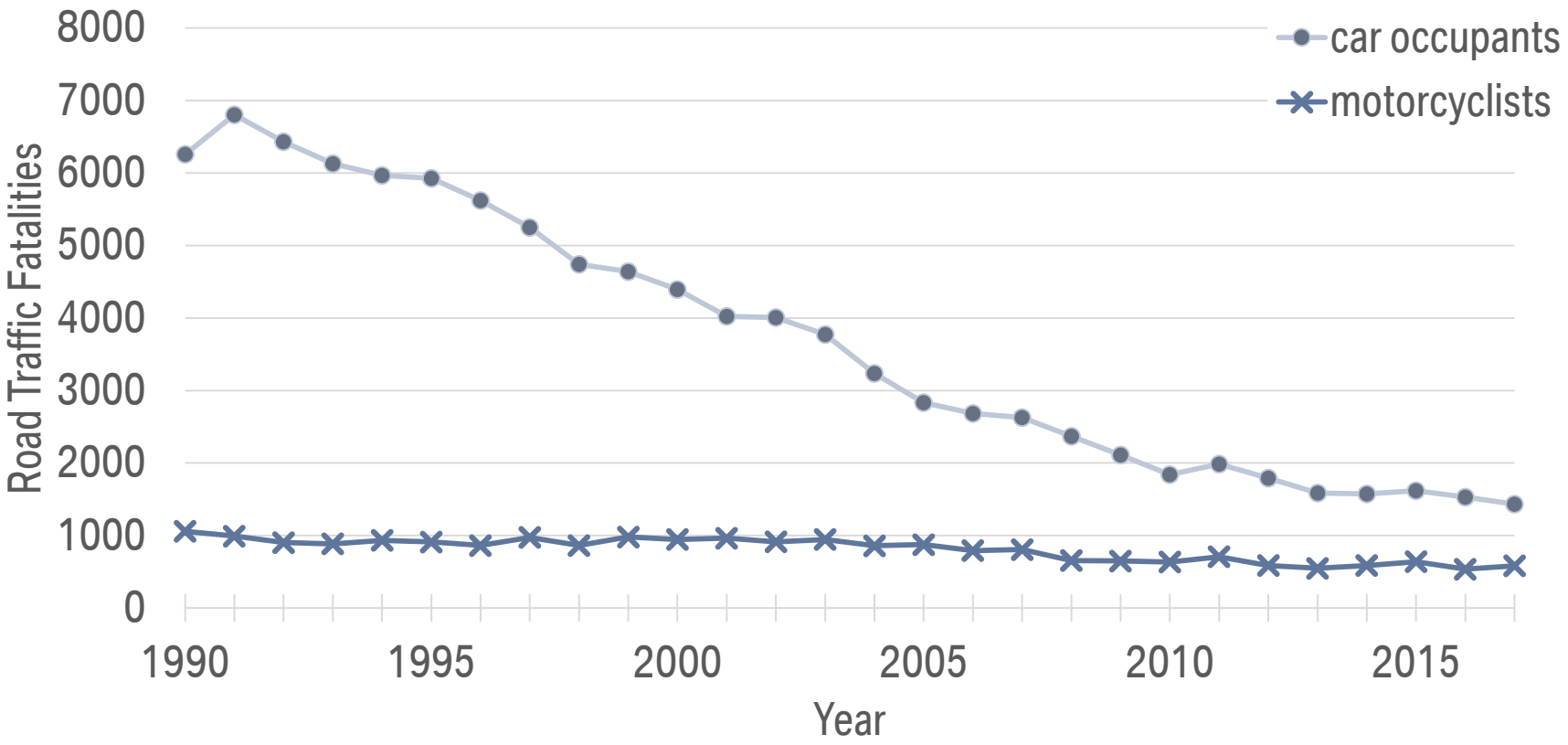
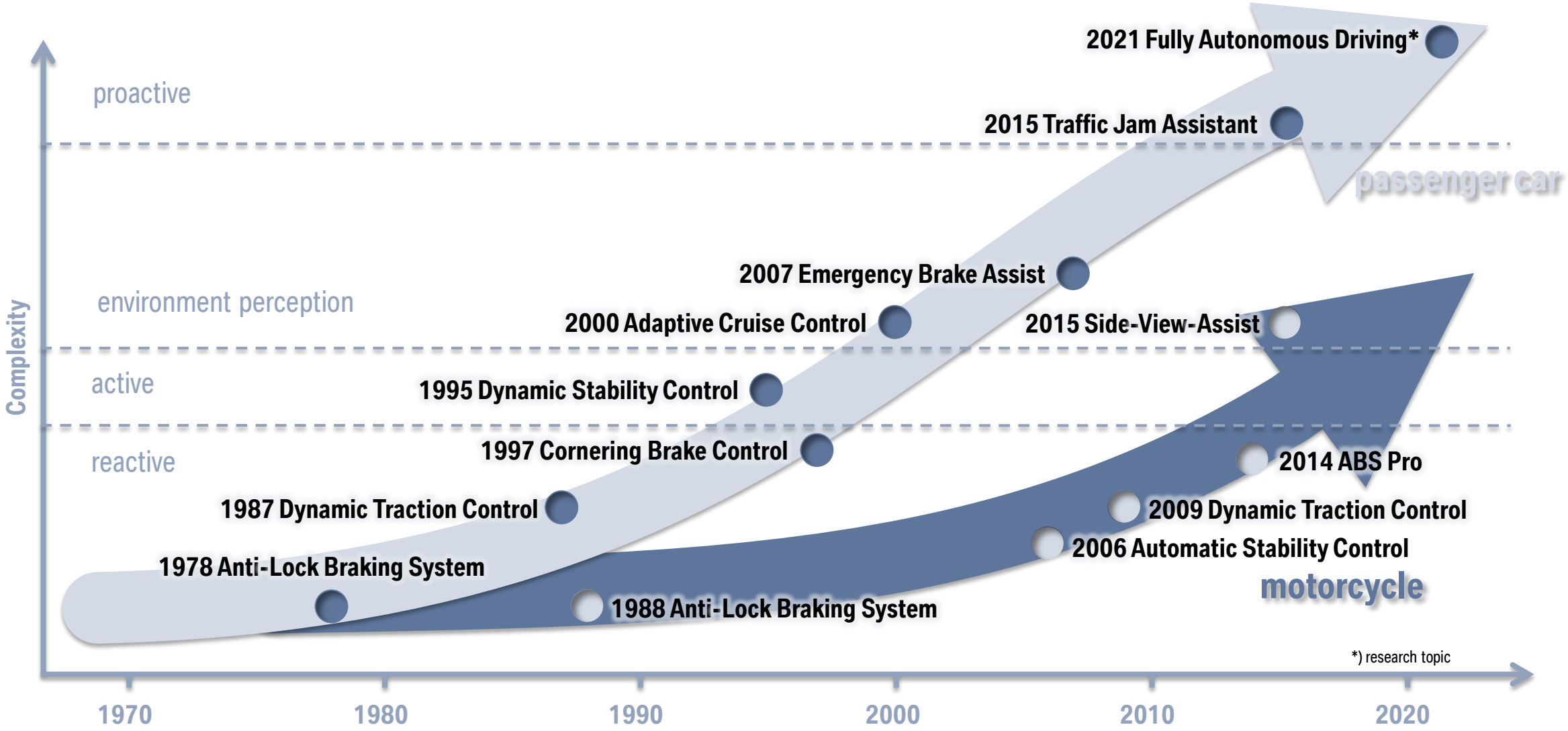


Figure 1: Car occupants and motorcycle rider fatalities in Germany from 1990 to 2017. (Source: DESTATIS)

DEVELOPMENT OF DRIVER-/RIDER-ASSISTANT-SYSTEMS.



PROJECT OVERVIEW.

Increasing motorcycle safety by active interventions in the vehicle dynamics!

Fully-automated test ride
(without rider)

TrackMoto

Human command signals

- Engine torque
- Brake pressure
- Steering angle

Rider

Human Machine Interface

– Need and acceptance of assistance
– Kinesthetic feedback
– Intuitive systems

Theory

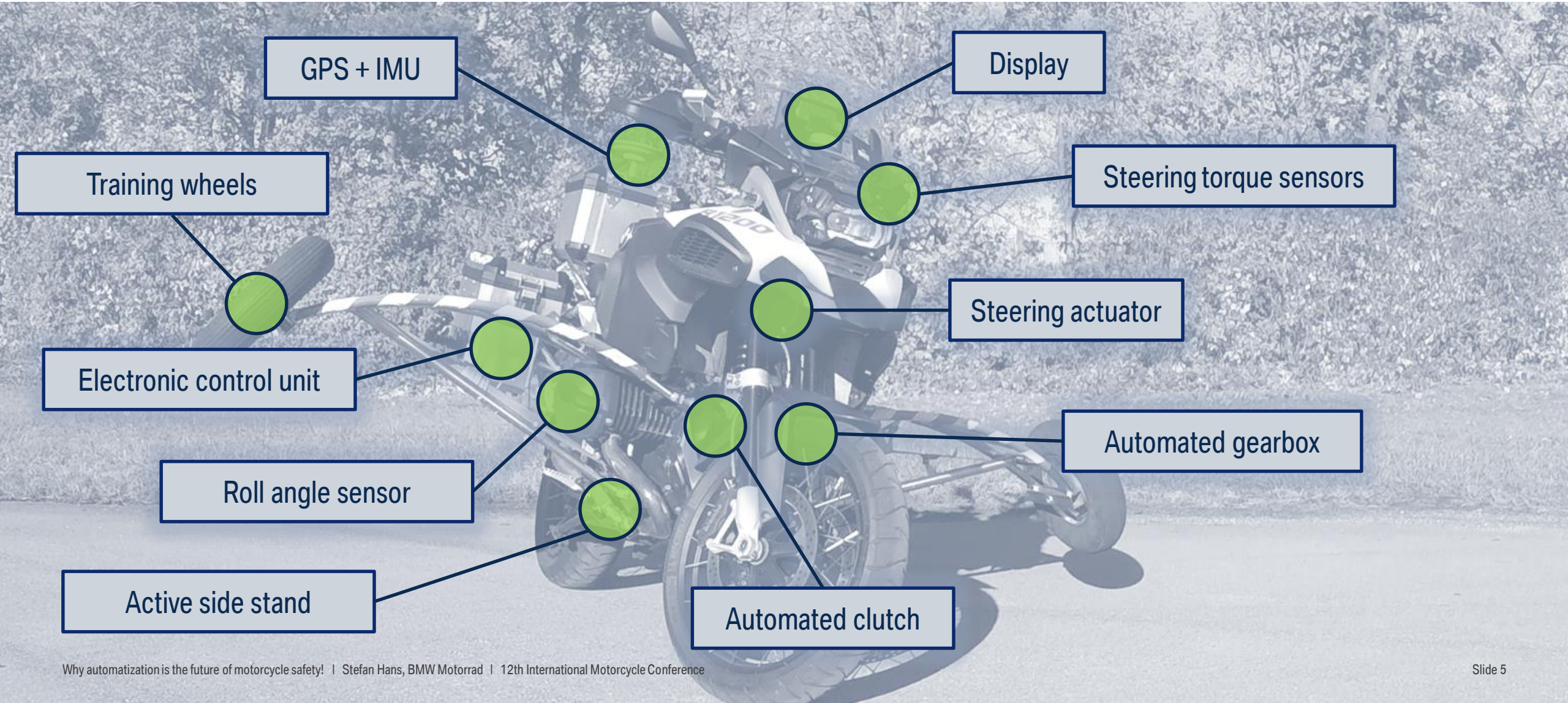
– Motorcycle dynamics model
– Simulation results

Validation

Measurements on the test track

– Prototype equipped with sensors and actuator
– Measurements of test rides

COMPONENTS OF THE PROTOTYPE.



CASCADED MULTILEVEL APPROACH.

Navigation

- **What‘s the best route from A to B?**
- Controller: Dynamic programming

Connected Motorcycle Consortium

Guidance

- **What‘s the best trajectory around the obstacle?**
- Controller: Model-Predictive Control

Stabilization

- **What steering angle do we need to stabilize the roll dynamics?**
- Controller: Sliding-Mode Control

ABS ABS
STANDARD ON ALL MODELS.

MODEL-PREDICTIVE-CONTROL.

Predicting the future trajectory by minimizing:

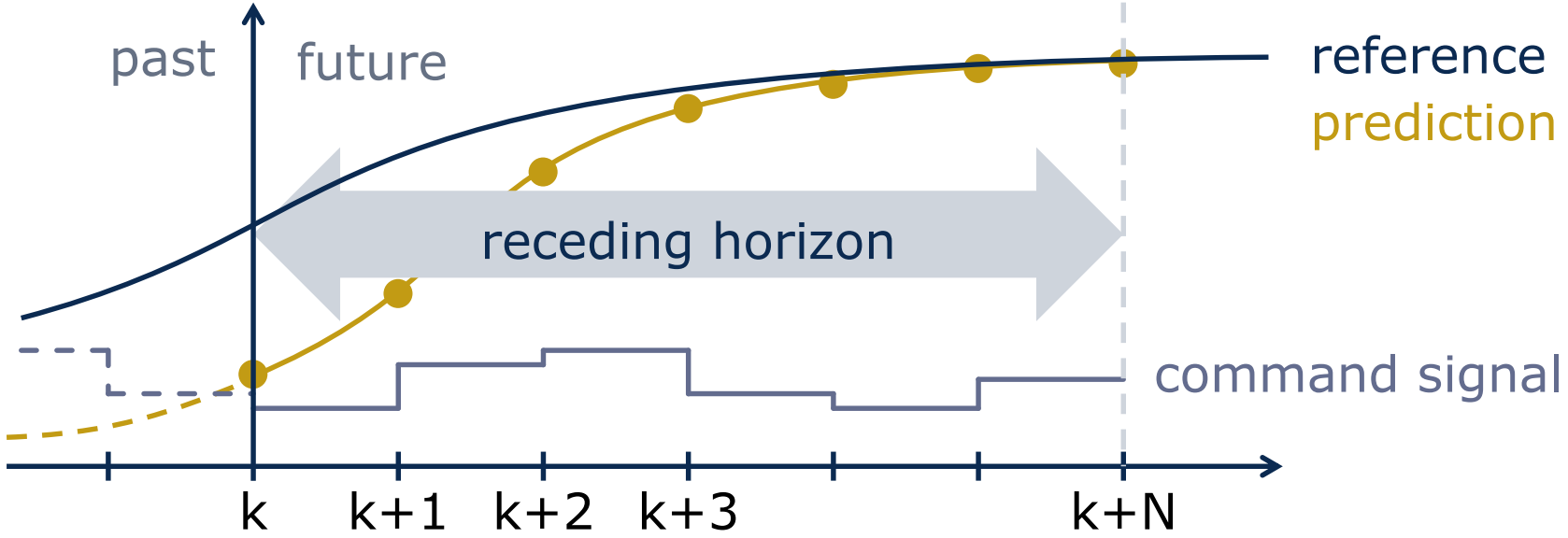
–Distance to the centerline

–Roll angle & roll rate

–Longitudinal jerk

–…

Human-like behavior (i.e. cutting curves)



SIMPLIFIED DYNAMIC MODEL OF THE MOTORCYCLE.

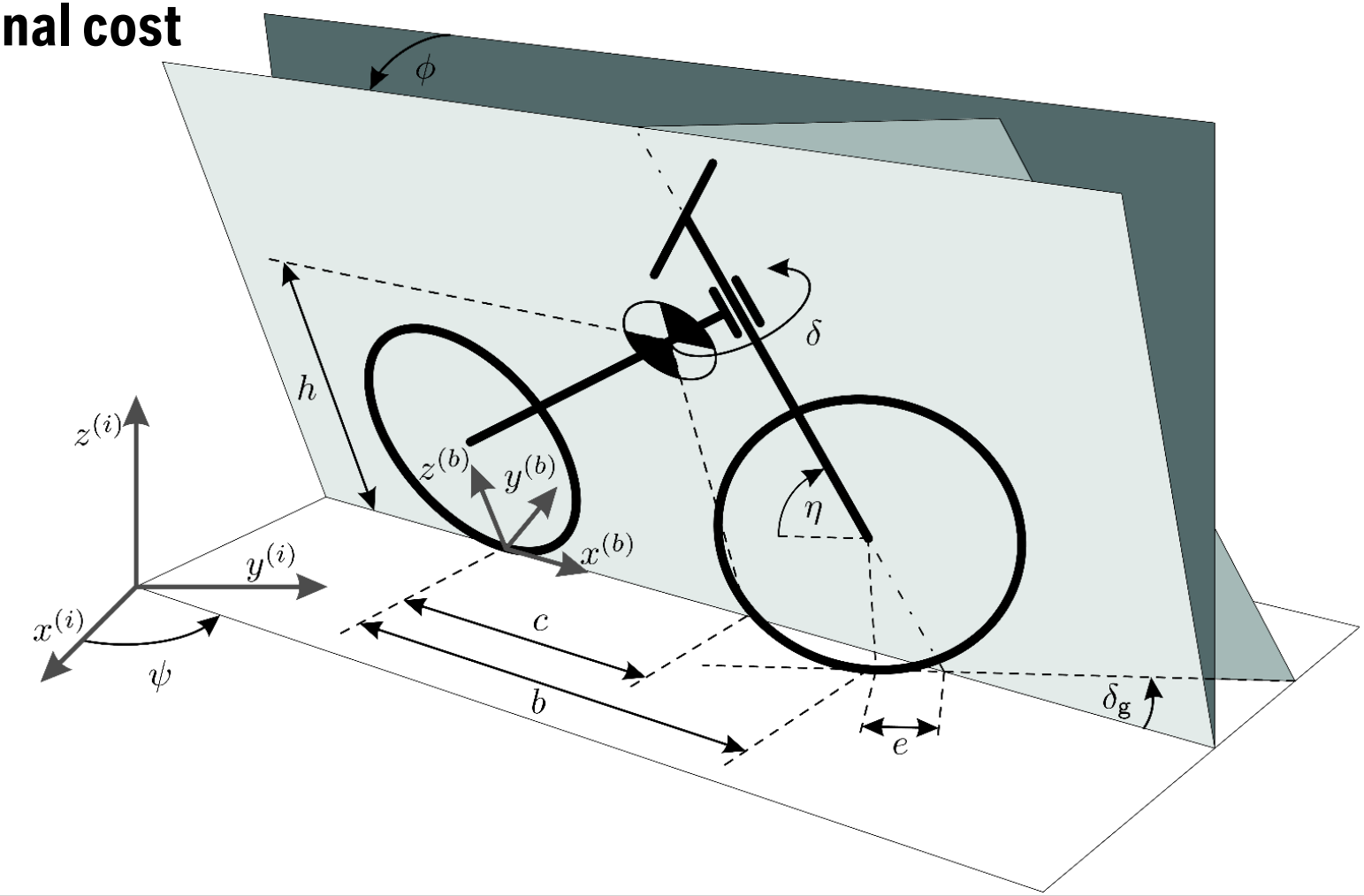
Trade-off: accuracy ⇔ computational cost

<u>Assumptions:</u>

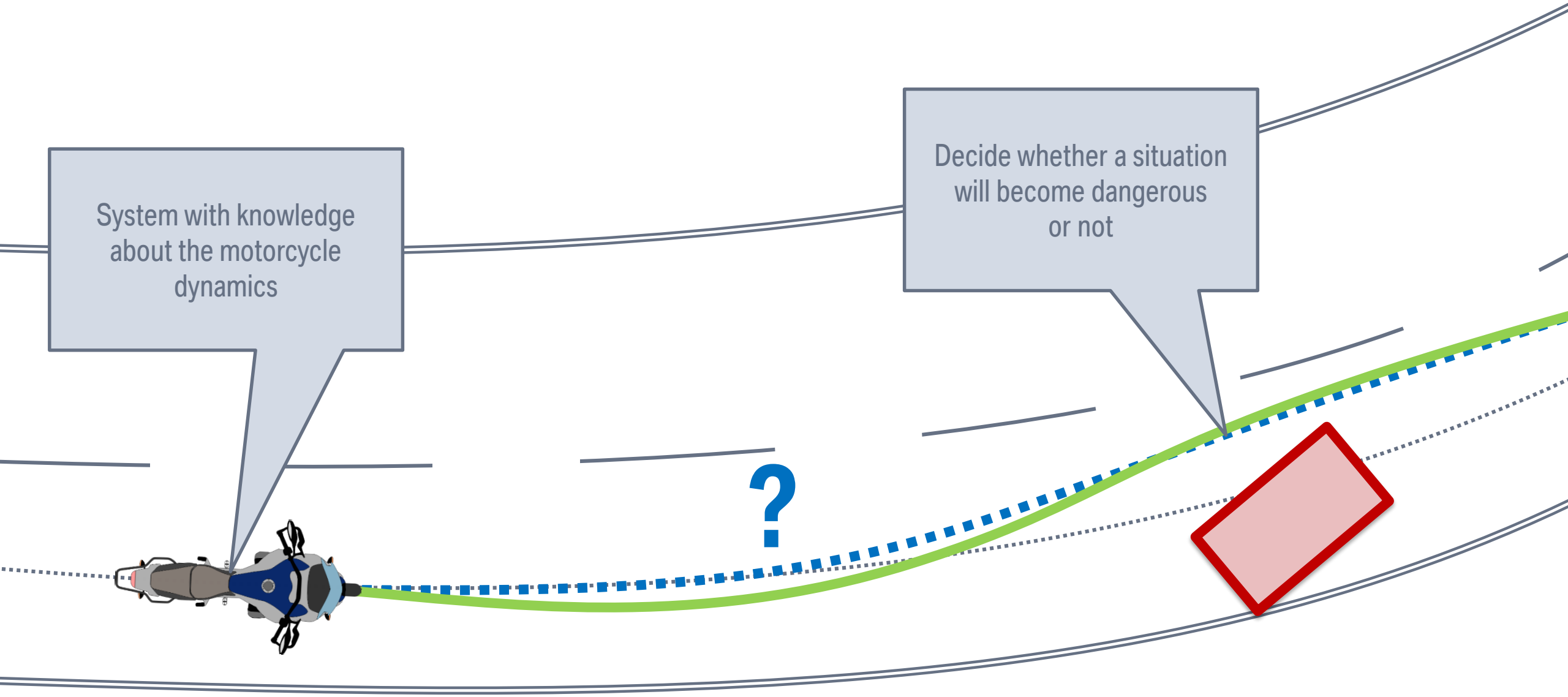
–Point-mass

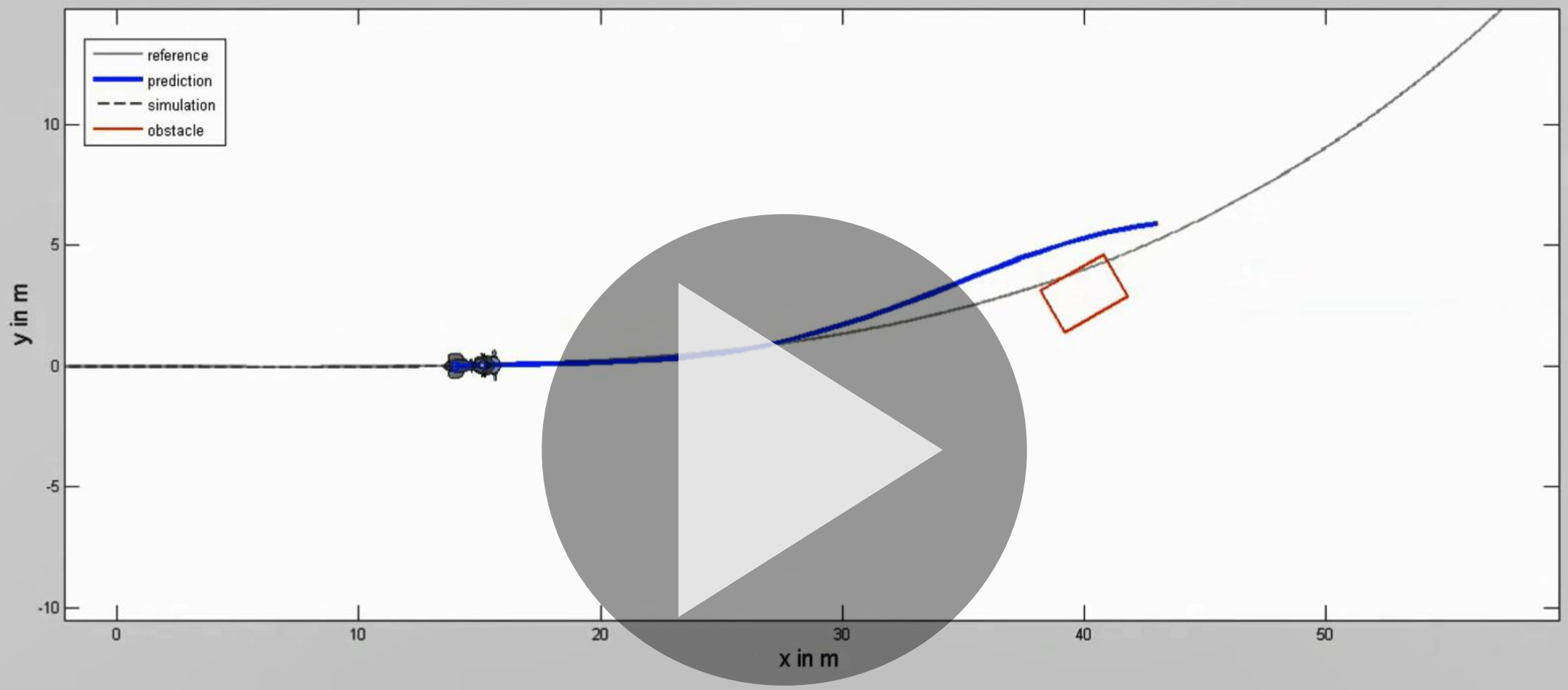
–Tire width neglected

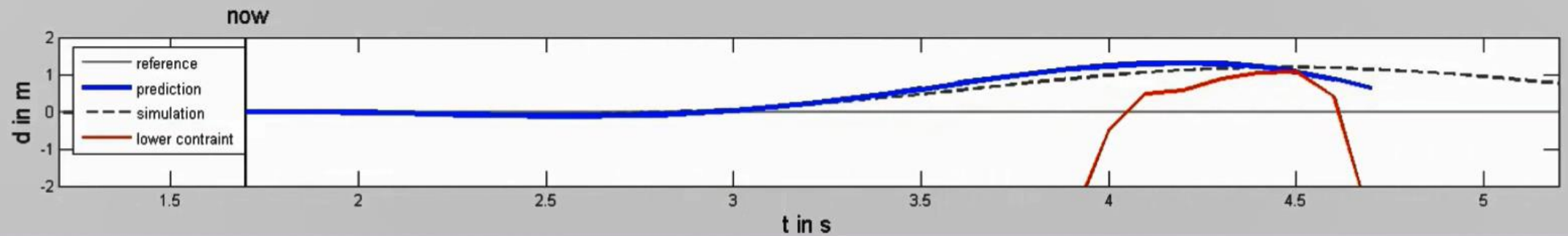
–Wheels roll without slip



GUIDANCE LEVEL: WHAT'S THE BEST TRAJECTORY AROUND THE OBSTACLE?




reference
prediction
simulation
obstacle
y in m
x in m
10
5
0
-5
-10
0
10
20
30
40
50


now
reference
prediction
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d in m
t in s
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2
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3
3.5
4
4.5
5


STOP

Motivation

“As dispensable as 40 degrees fever.”
„So entbehrlich wie 40 Grad Fieber.“

"But there is no more fun driving a Töff. I prefer to stay THE BOSS of my bike myself."
„Da bleibt aber kein Spaß mehr drauf, ein Töff zu fahren. Ich bleibe lieber selbst DER BOSS meines Bikes.“

"Things that do not need the world. That's a variant of it."
„Dinge, die die Welt nicht braucht. Das ist eine Variante davon.“

"If these things come, I give my driver's license off voluntarily.“
„Wenn die Dinger kommen, geb‘ ich meinen Schein freiwillig ab.“

"Bullshit. Keep your fingers off the motorcycles. (…) **I do not want a system that puts me in an inclined position on the brakes because it scared itself."**
„Schwachsinn. Lasst die Finger von den Motorrädern. (…) Ich will kein System, dass mir in der Schräglage in die Bremse greift, weil es sich erschrocken hat.“

Research Question

?

?

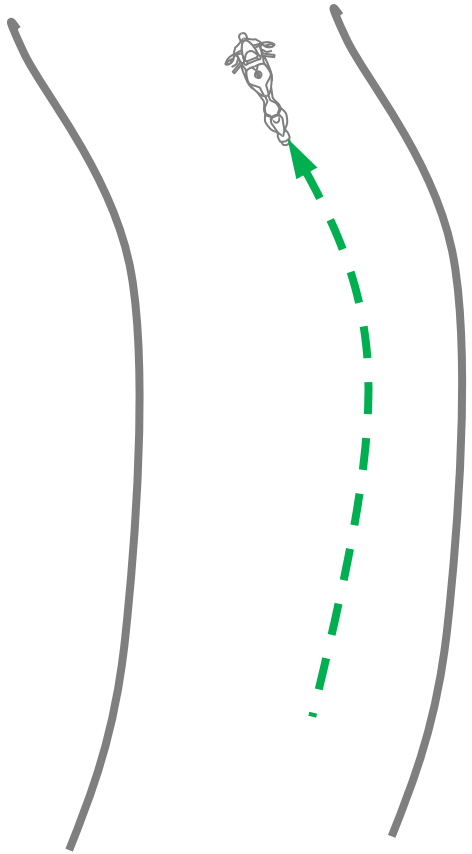
1.

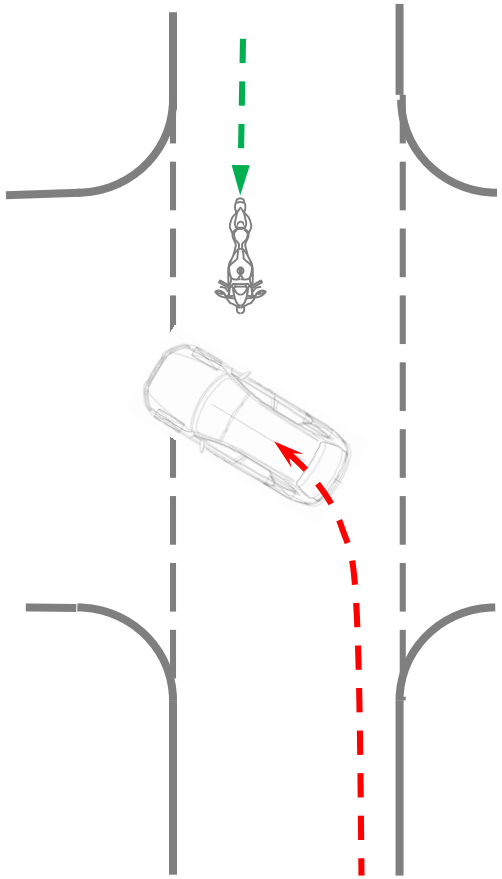
Traffic Accidents of Powered-Two Wheelers

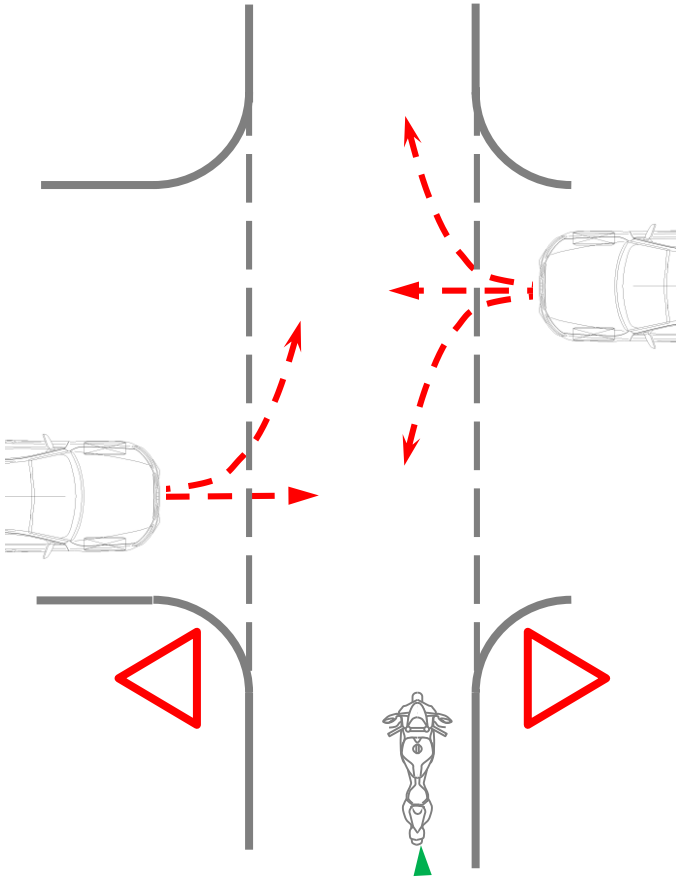
Accident Research

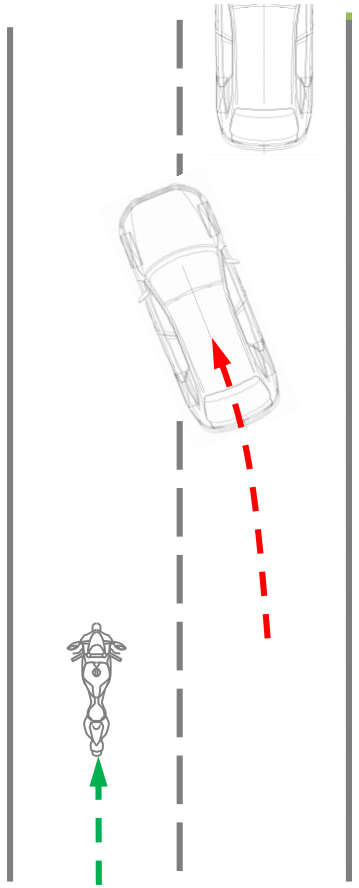
Scenarios

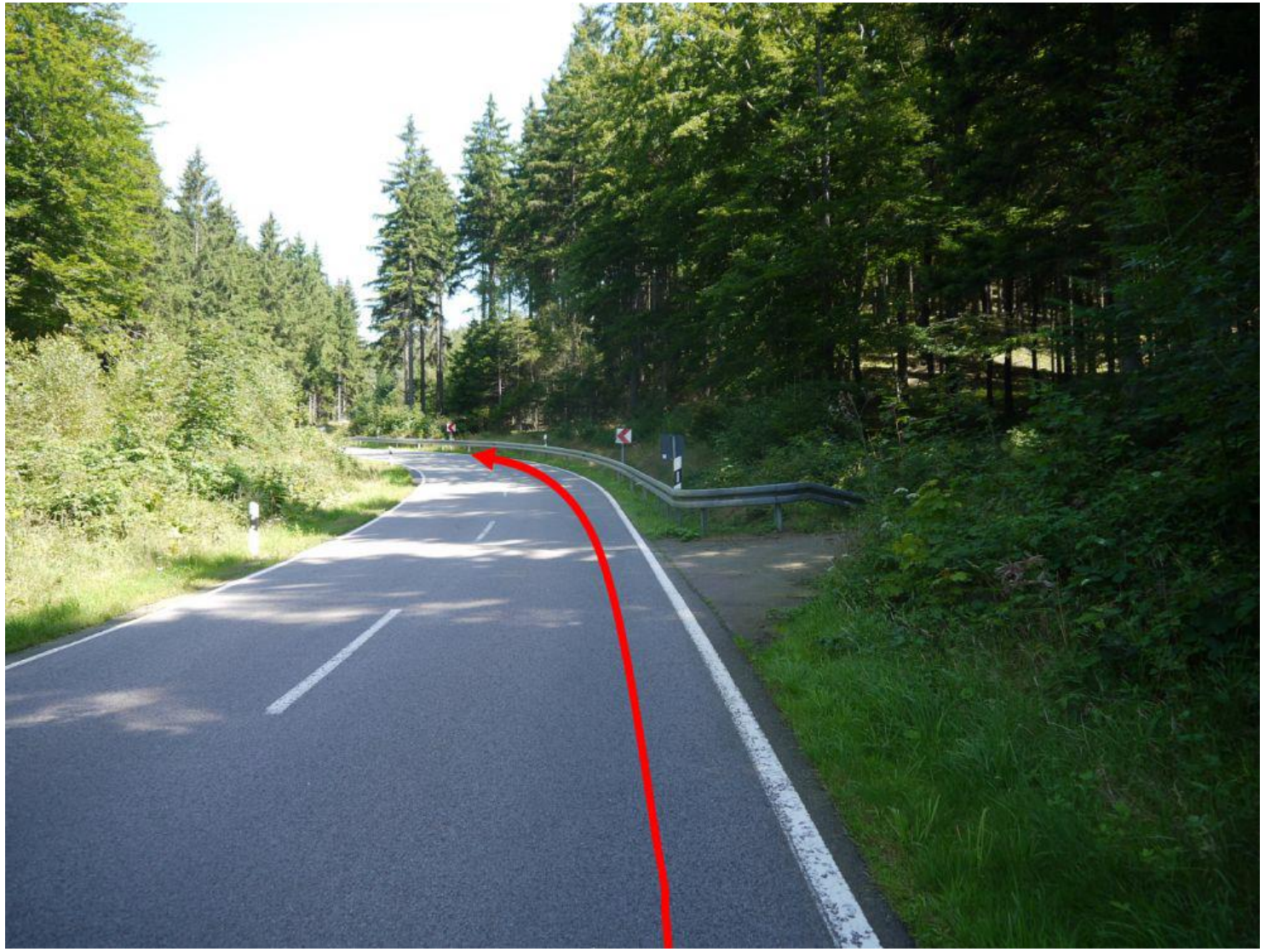
Loss of Control	Turning Off	Turning In Crossing	Longtidudinal Traffic
24 %	19 %	25 %	19 %











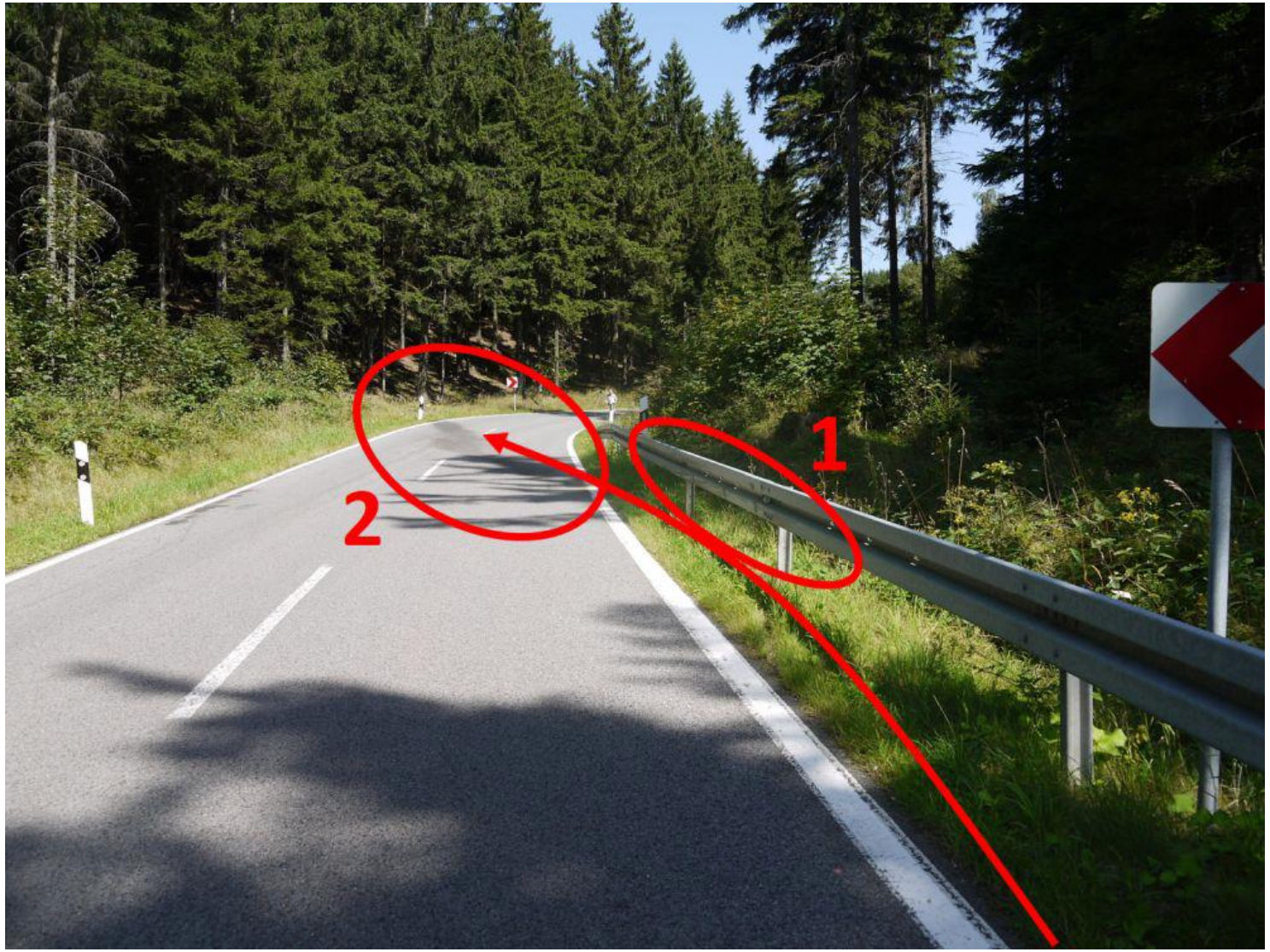
Speed 114 kph

Radius 78 m

Needed Angle 53°

Accident Research

Loss of Control



Speed 114 kph

Radius 78 m

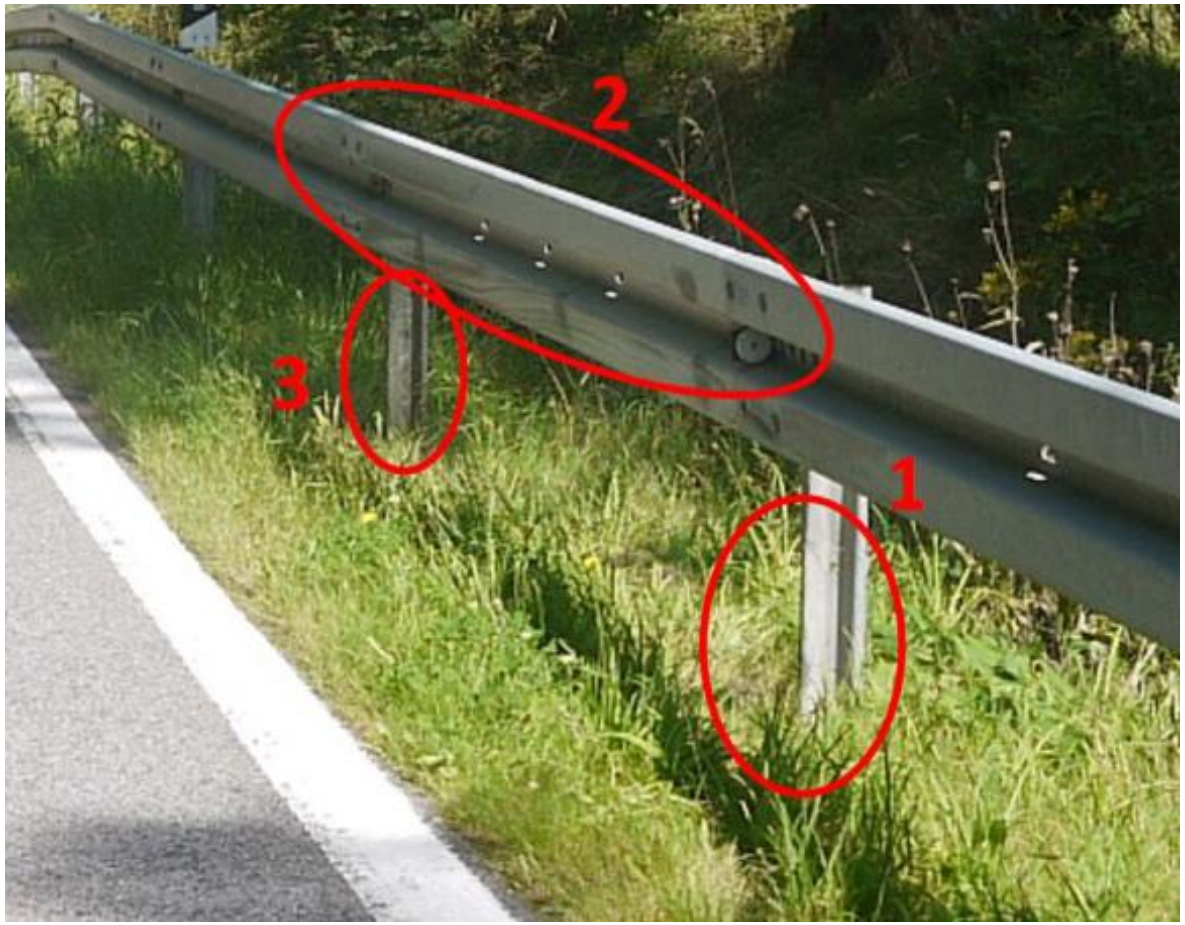
Needed Angle 53°

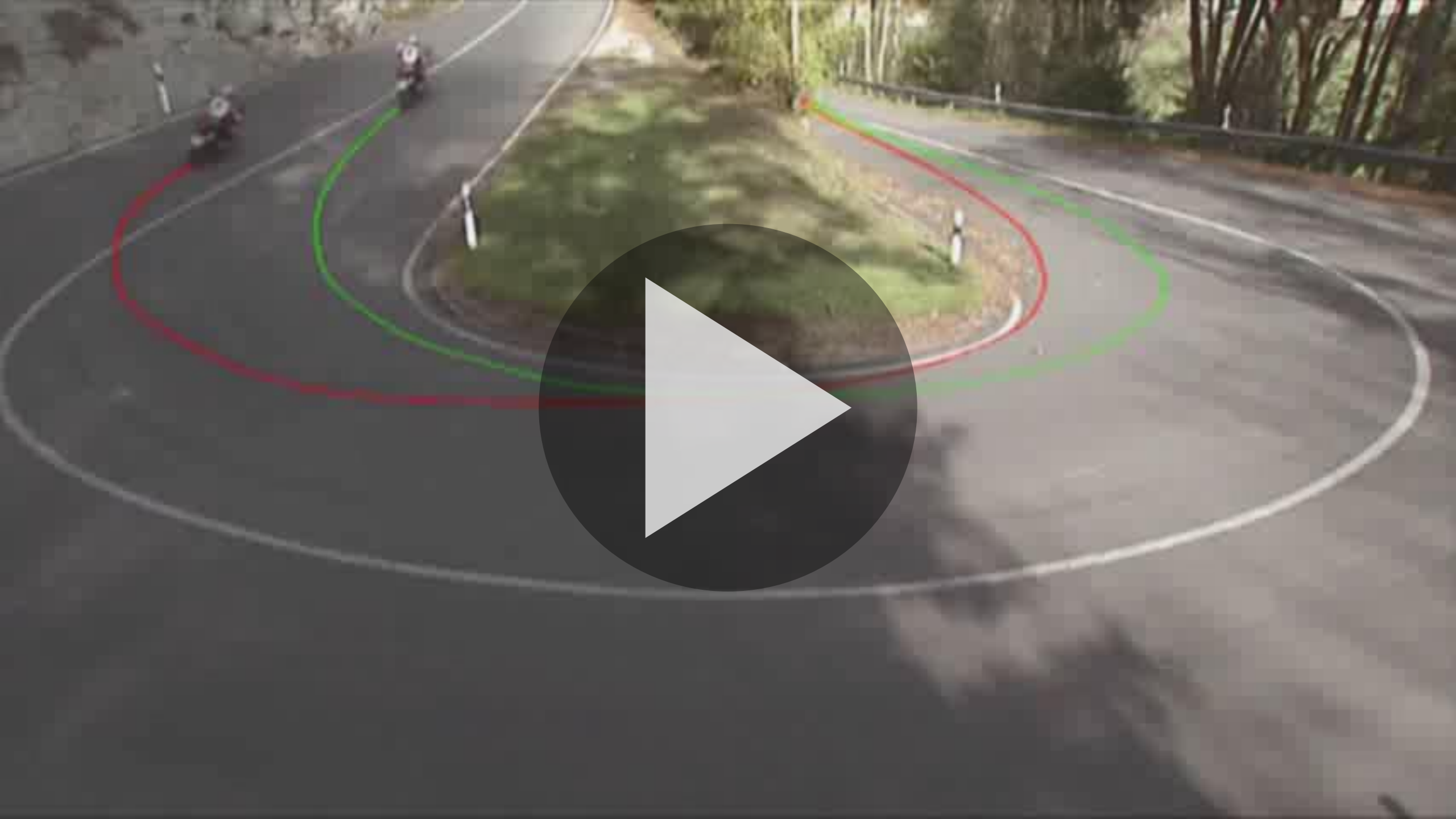
Emergency Braking with ABS-Intervention

Putting up of Motorcycle

Accident Research

Loss of Control





2.

Identification of Assistance Functions

Motorcycle Rider

Rider Types

Scenarios

Normal Driving	Warning	Danger

Rider Tasks

Primary: Vehicle Guidance	**NAVIGATION**	
	GUIDANCE	Gas, Steer, Brake
	STABILIZATION	
Secondary: Setting Operation Points	Switching Gears, domes, operating the turn signal, switching lights	
Tertiary: Setting Ambience	Radio settings, temperature control, telephony, infotainment	

Scenarios

Normal Driving | Warning | Danger

Rider Tasks

Primary:
Vehicle Guidance

Secondary:
Setting Operation Points

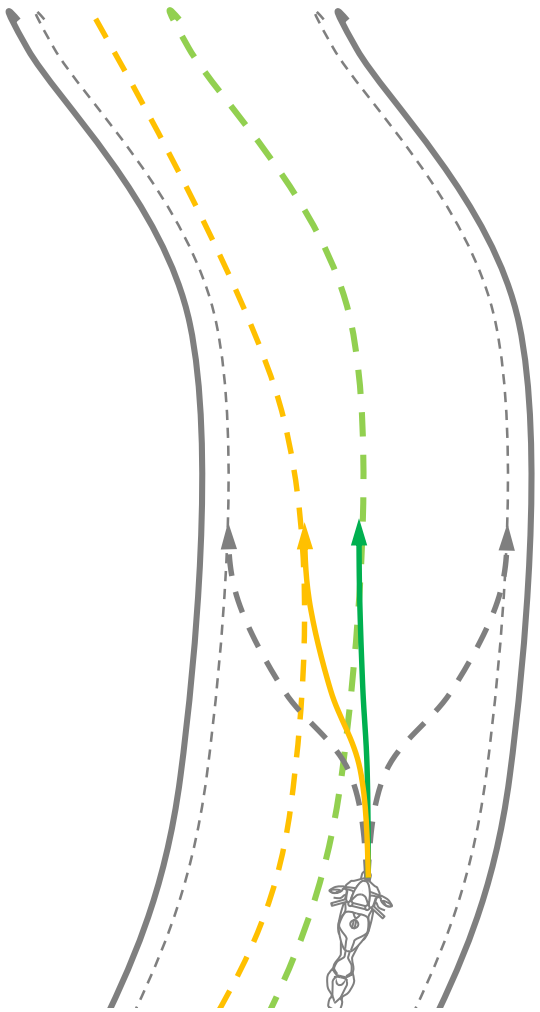
Tertiary:
Setting Ambience

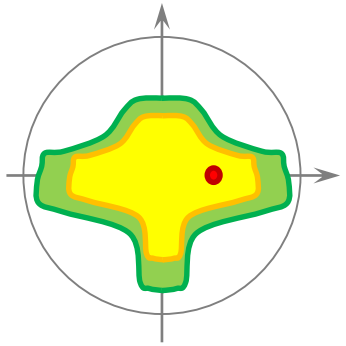
Assistance Functions

		Normal Driving	Critical Situation: Warning	Critical Situation: Danger
Primary Rider Task	**Planning Curvature**	Driving on Curves **Steering torque to the ideal line**	Curvature for speed too high **Steering torque to the ideal line or for greater curvature**	
	Planning Speed	Driving on Curves **Limiting the speed**	Speed for curvature too high **Reduction of drive torque / braking intervention on the rear wheel for cornering yaw moment**	
	Stabilization	Driving /w cruise control **Limiting the speed**	Curve Braking **Compensation of the steering torque**	

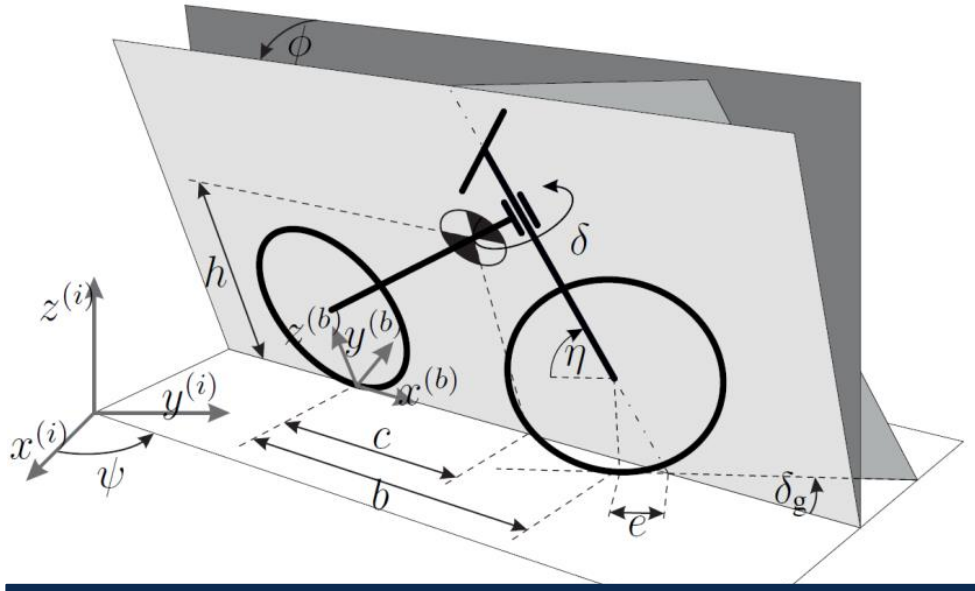
3.

Implementation of Assistance Systems





Vehicle Dynamics Model



Observer

- Roll Angle Speed Controller
- Model Predictive Controller

Getz, N. H.: Dynamic inversion of nonlinear maps with applications to nonlinear control and robotics. Ph. D. thesis, University of California at Berkeley, 1995
Hans, S., Krehel, M., Köbe, M., Prokop, G.: A Cascaded Model-Predictive Approach To Motorcycle Safety, AVEC, Munich, 2016


Gas konstant
Assistenz bremst ab auf
Kurvengeschwindigkeit

DGPS, Road Data

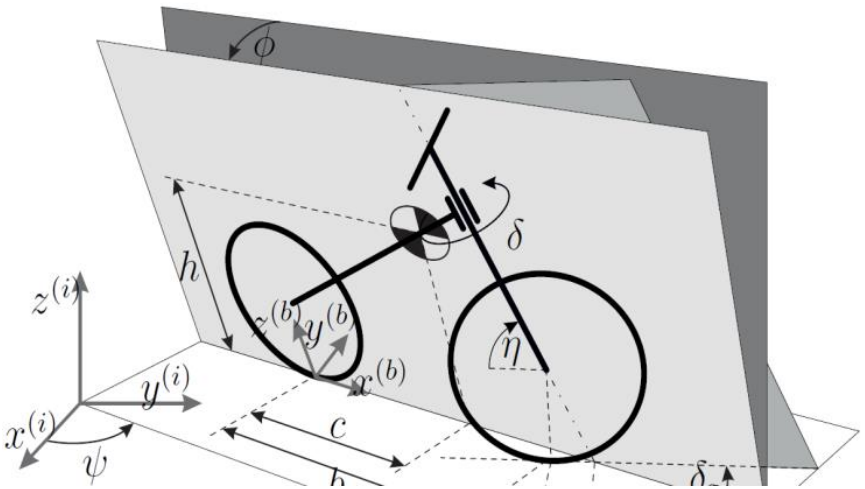
Projection on track coordinates

Steering torque to the ideal line or for greater curvature

Tracking

6-DOF-Sensor, Speed, Handlebar Angle

Kinematic controller (Lyponov stability)



target curvature / target roll angle

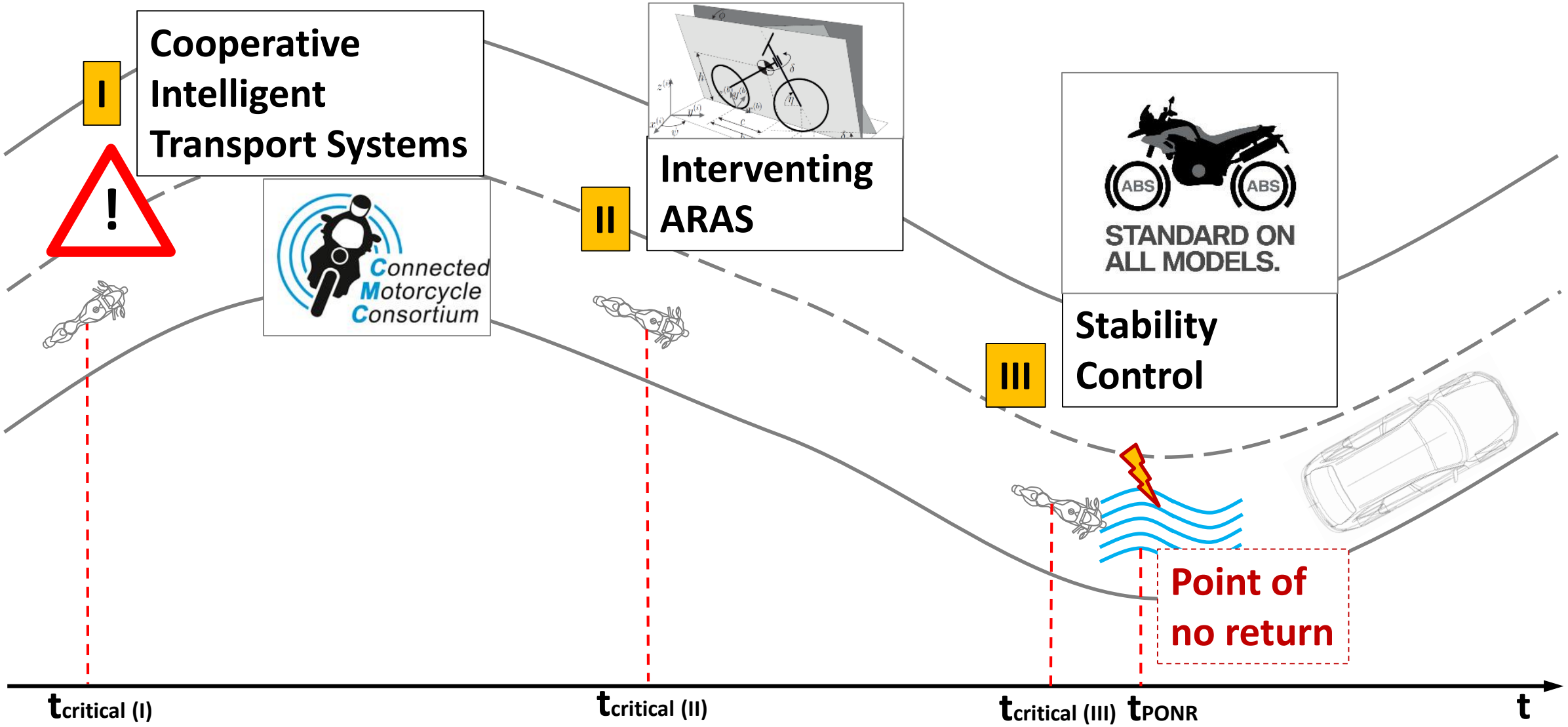
PID-Controller

Rolling angle difference to handlebar angle

Handlebar Motor

Steering Torque


Ausweichen
ohne Fahrer-
lenkmoment


I
Cooperative Intelligent Transport Systems
Connected Motorcycle Consortium
II
Interventing ARAS
ABS
ABS
STANDARD ON ALL MODELS.
III
Stability Control
Point of no return
tcritical (I)
tcritical (II)
tcritical (III)
tPONR
t

Thank you very much!

Please feel free to ask questions.

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