WHY AUTOMATIZATION IS THE FUTURE OF MOTORCYCLE SAFETY.
STEFAN HANS, BMW MOTORRAD

FROM AUTOMATIZATION TO ASSISTANCE – INTERVENE BEFORE A CRITICAL SITUATION.
MARKUS KÖBE, 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.

- 1978 Anti-Lock Braking System
- 1987 Dynamic Traction Control
- 1988 Anti-Lock Braking System
- 1997 Cornering Brake Control
- 1995 Dynamic Stability Control
- 2000 Adaptive Cruise Control
- 2007 Emergency Brake Assist
- 2006 Automatic Stability Control
- 2009 Dynamic Traction Control
- 2007 Emergency Brake Assist
- 2015 Side-View-Assist
- 2014 ABS Pro
- 2015 Traffic Jam Assistant
- 2015 Traffic Jam Assistant
- 2021 Fully Autonomous Driving

Why automatization is the future of motorcycle safety! | Stefan Hans, BMW Motorrad | 12th International Motorcycle Conference
Increasing motorcycle safety by active interventions in the vehicle dynamics!

- **Rider**
  - Need and acceptance of assistance
  - Kinesthetic feedback
  - Intuitive systems

- **Human Machine Interface**

- **TrackMoto**
  - Fully-automated test ride (without rider)

- **Human command signals**
  - Engine torque
  - Brake pressure
  - Steering angle

- **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.

- Electronic control unit
- GPS + IMU
- Steering torque sensors
- Display
- Steering actuator
- Automated gearbox
- Training wheels
- Roll angle sensor
- Active side stand
- Automated clutch
CASCaded Multilevel Approach.

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

**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

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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

Assumptions:
- Point-mass
- Tire width neglected
- Wheels roll without slip
GUIDANCE LEVEL: WHAT'S THE BEST TRAJECTORY AROUND THE OBSTACLE?

- System with knowledge about the motorcycle dynamics
- Decide whether a situation will become dangerous or not
Why automatization is the future of motorcycle safety!

Stefan Hans, BMW Motorrad

12th International Motorcycle Conference
“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.“
Intervene before a critical situation – Markus Köbe
1. Traffic Accidents of Powered-Two Wheelers
Accident Research
Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of Control</td>
<td>24 %</td>
</tr>
<tr>
<td>Turning Off</td>
<td>19 %</td>
</tr>
<tr>
<td>Turning In Crossing</td>
<td>25 %</td>
</tr>
<tr>
<td>Longitudinal Traffic</td>
<td>19 %</td>
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</tbody>
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Intervene before a critical situation – Markus Köbe

Loss of Control

Accident Research

Speed 114 kph

Radius 78 m

Needed Angle 53°
Intervene before a critical situation – Markus Köbe

Accident Research
Loss of Control

Slide 17
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- Speed 114 kph
- Radius 78 m
- Needed Angle 53°
- Emergency Braking with ABS-Intervention
- Putting up of Motorcycle
Intervene before a critical situation – Markus Köbe
Intervene before a critical situation – Markus Köbe
2.

Identification of Assistance Functions
Motorcycle Rider
Rider Types

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Intervene before a critical situation – Markus Köbe

**Rider Tasks**

**Primary:** Vehicle Guidance

**Secondary:** Setting Operation Points

**Tertiary:** Setting Ambience

---

**Scenarios**

- Normal Driving
- Warning
- Danger

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**NAVIGATION**

**GUIDANCE**

**STABILIZATION**

- Switching Gears, domes, operating the turn signal, switching lights

- Radio settings, temperature control, telephony, infotainment
Intervene before a critical situation – Markus Köbe

**Scenarios**

- Normal Driving
- Warning
- Danger

**Rider Tasks**

**Primary:** Vehicle Guidance

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**Tertiary:** Setting Ambience

**Assistance Functions**
<table>
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<tr>
<th>Primary Rider Task</th>
<th>Normal Driving</th>
<th>Critical Situation</th>
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<tbody>
<tr>
<td>Planning Curvature</td>
<td>Driving on Curves</td>
<td>Curvature for speed too high</td>
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<td>Steering torque to the ideal line</td>
<td>Steering torque to the ideal line or for greater curvature</td>
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<tr>
<td>Planning Speed</td>
<td>Driving on Curves</td>
<td>Speed for curvature too high</td>
</tr>
<tr>
<td>Limiting the speed</td>
<td>Reduction of drive torque / braking intervention on the rear wheel for cornering yaw moment</td>
<td></td>
</tr>
<tr>
<td>Stabilization</td>
<td>Driving /w cruise control</td>
<td>Curve Braking</td>
</tr>
<tr>
<td>Limiting the speed</td>
<td>Compensation of the steering torque</td>
<td></td>
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</table>

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3.

Implementation of Assistance Systems
Vehicle Dynamics Model

- Roll Angle Speed Controller
- Model Predictive Controller

Gas konstant
Assistenz bremst ab auf Kurvengeschwindigkeit
**DGPS, Road Data**

- Projection on track coordinates

**6-DOF-Sensor, Speed, Handlebar Angle**

- Kinematic controller (Lyponov stability)
- target curvature / target roll angle
- PID-Controller

**Steering Torque**

**Steering torque to the ideal line or for greater curvature**

**Rolling angle difference to handlebar angle**

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Ausweichen ohne Fahrerlenkmoment
Cooperative
Intelligent
Transport Systems

Intervening ARAS

Stability Control

Point of no return

$t_{\text{critical (I)}}$

$t_{\text{critical (II)}}$

$t_{\text{critical (III)}}$

$t_{\text{PONR}}$

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Thank you very much!

Please feel free to ask questions.

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