Virtual driving as an important component for functional tests of ContiGuard® Functions

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Introduction and Motivation

- **Our Vision: Zero Accidents**

- **This Requires Safety Solutions for all Price Segments and Situations**

- **One part of the Puzzle is the Emergency Brake Assist (EBA) City**

- **Target is to reduce accidents in the Speed Range below 30 km/h**
Introduction and Motivation

69% of accidents with injuries to persons are in city areas up to 30 kph

<table>
<thead>
<tr>
<th>Year</th>
<th>In City</th>
<th>Out of City</th>
<th>Autobahn</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>228717</td>
<td>86662</td>
<td>20466</td>
</tr>
<tr>
<td>2008</td>
<td>221306</td>
<td>81039</td>
<td>18269</td>
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</table>

Source: Statistisches Bundesamt

- Rear collision is the most frequent collision type
- Main reason is the lack of attention of the driver

“Emergency Brake Assist” from Continental was developed to support drivers in these situations
Closing Velocity Sensor – Sensor Platform for EBA City

Principle of CV - Closing Velocity Sensor for environment identification

Sensor Principle: Time of Flight of Light Pulses
Wave length: IR
Mounting Position: behind Windscreen
at interior rear view mirror

- Sensor generates 3 independent Beams
- Operation Range up to approx. 10 m
### EBA City – 3 Functionalities

<table>
<thead>
<tr>
<th>EBA City</th>
<th>PreFill</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td></td>
<td>Preconditioning of the Brake System</td>
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</table>

Obstacle
EBA City – 3 Functionalities

- **PreFill**
  - Preconditioning of the Brake System

- **Brake Assist Support**
  - Sensitivity Adjustment of Brake Assist Thresholds
EBA City – 3 Functionalities

**EBA City**

<table>
<thead>
<tr>
<th>PreFill</th>
<th>Brake Assist Support</th>
<th>Autonomous Braking</th>
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<tbody>
<tr>
<td>Preconditioning of the Brake System</td>
<td>Sensitivity Adjustment of Brake Assist Thresholds</td>
<td>Graded, Autonomous Deceleration Request</td>
</tr>
</tbody>
</table>

Obstacle
Challenges for the Development

- Development of a complex System
  - (multiple components, Sensor, Brake System etc.)

- Driver Assistant function with strong intervention into vehicle dynamics
  - Functionality has to consider physical behavior of vehicle

- consideration of complex driving scenarios

- (e.g. evasion by steering, etc.)
Requirements for a Simulation Tool

- Closed Loop Simulation
- Multiple domain Simulation (sensoric, brake systems, vehicle dynamics)
- Possibility to perform rapid testing of algorithms
- Realistic and adaptable vehicle models
- Simulate complex scenarios → driver model + maneuver control
- Realistic brake hydraulic model
- Real time capability for HIL
- Interface between simulated environment and sensor model
CarMaker simulation platform was used for vehicle – driver – road – traffic

Field of applications for ADAS (samples)

- Adaptive Cruise Control
- Parking Assistance
- Collision Avoidance
- Lane Keeping Assistance
Simulation environment for “EBA City”

Real system

- Test vehicle
- CV-Sensor
- CV Sensor with EBA City

Virtual environment

- Vehicle Dynamics Model
- DA Sensor Model
- SIMULINK Model
Simulation environment for “EBA City”

Key models have been integrated into CarMaker model platform

- **Brake System**
- **Vehicle Data**
  - e.g. Speed, Yaw Rate, Long. Acceleration etc.
- **Sensor ECU**
  - Function on Target HW
  - relevant Object
  - Sensorics
- **Real World**
- **Vehicle Dynamics Model**
- **3D Environment Model**
- **3D Envir**
- **Vehicle Data**
- **ECU Function SIMULINK**
- **Sensor Behavioral Model**
- **Object List**
- **3D Sensor Mask Model**

**Vehicle Data**

- **Measurement Error**
- **all Objects with ideal properties within detection range**

**CarMaker**

**Continental**
A vehicle control module allow the interaction of driver and ADAS systems

- Driver model is embedded in a drive maneuver control module
  - Driving tasks management and event driven operations
  - Monitoring and analysis of all quantities

- HMI for drivers wish + vehicle control interface for cooperative functions
  - Steering wheel, pedal (brake, accel., clutch), shift, cockpit switches etc.
  - Acc/Dec interface and steer angle /torque interface for system requests
Simulation environment for “EBA City”

Following approaches and boundary conditions have been considered:

- Simulation provide first of all ideal object information e.g. position, size, speed, acceleration are exactly known.
- For comparability with real test scenarios - at least partial sensor properties (measurement errors) must be modeled.
- Quality of vehicle information on CAN (e.g. speed) suffers from measurement errors (absolute, temporary, delay's, noise etc.). This could lead to difference to real testing.
- A systematic signal manipulation within the test maneuver must be possible to investigate the failure robustness.
Customer use cases and test challenges

Simulation shall reconstruct real use cases by event triggered maneuvers

- **Pure longitudinal mission**
  - speed difference to moving or stationary objects (e.g. drive against obstacle)

- **Pure lateral mission**
  - lateral moving object (e.g. vehicle sheer in)
  - avoiding obstacle (e.g. speed breaks and chicanes in play streets)

- **Combined longitudinal and lateral mission**
  - lateral moving object with speed difference (e.g. vehicle sheer in)
  - avoiding moving obstacle with speed difference (e.g. entrance at parking area)
Customer use cases and test challenges

Event triggered maneuvers guarantee reproducibility and reusability

- Obstacle avoidance
- Real test driving
- Obstacle avoidance
- Virtual test driving

- How probable is the collision situation?
- How easy is the avoidance by steer?
Customer use cases and test challenges

Event triggered maneuvers by monitor and analyze of related quantities

- **Sample 1: Pure longitudinal maneuvers**
  - Man 2: Constant
  - Man 3: Acceleration
  - Man 2: Braking

- **Sample 2: Pure lateral maneuvers**
  - Man 1: Acceleration
  - Man 2: Constant Driving
  - Man 3: Lane Offset

- **Sample 3: Combined longitudinal and lateral maneuvers**
  - d trigger
  - d steer intervention
  - d steer intervention
A detail maneuver test catalogue have been developed based on …

- Functional Safety Assessment
- Event Tree Analysis
- Real Test Procedures
- Field Experience

<table>
<thead>
<tr>
<th>Maneuvers</th>
<th>Description</th>
<th>Maneuver parameters</th>
<th>Variations</th>
<th>Evaluation Criteria's</th>
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Maneuver and evaluation catalogue

For each maneuver test variations and default values have been defined

### Maneuver 6: Obstacle Avoidance

- **Test Variation**
  - Vehicle speed
  - Obstacles speed
  - Obstacles offset
  - Obstacles initial s-road
  - Driver steer angel / speed
  - Driver gas
  - TTC maneuver start

### Maneuver 9: Alleyway driving

- **Test Variation**
  - Vehicle velocity
  - Obstacle velocity
  - Alleyway width
  - Alleyway width curvature / curve radius
  - Accelerator position
  - Decelerator position
For each maneuver evaluation criteria’s have been created and allocated

**Maneuver 6: Obstacle Avoidance**

- ds_min [m]
- Car.ax_max [m/s²]
- Prefill [0,1]
- AutoBraking [0,1]
- TTC [s]
- Impact [0,1]
- Driver.Brake [%]
- Driver.Gas [%]
- ds Prefill [m]
- ds AutoBraking [m]
- dec.t [s]
- relspeed [m/s]
- TTC.\_avoid\_manstart [s]
- Alley_width [m]
- Reaction [s]
- Reaction\_losingdist [m]
- Impact.v [m/s]
- Impact.Angl [°]

**Maneuver 9: Alleyway driving**
A test management tool was applied with maneuver and evaluation catalogue

**Vehicle Configuration**
- Handover key values e.g. engine, tire …

**Test Group Definition**
- e.g. longitudinal, lateral maneuvers …

**Test Case 1**
- Test Case selection e.g. TestRun

**Parameter Variations**
- Variation list of any system parameter
- vehicle, road, controller,
  test execution etc of all InfoFiles!

**Test Case 2**
- Test Case selection e.g. TestRun

**CONCERTO Application**
- Automatic start of post-processing
Benefits and Conclusion

- Successful Closed Loop simulation of ADAS function with environment sensor
- Implementation of a TestManager with respects to the demands from ADAS functions

Benefits utilizing simulation for the development of ADAS functions:

- Simulation studies for “Functional Safety Assessment”
- In the Loop Algorithm tests in the development phase
- Parameter studies for integrated functions and related valid ranges
- Virtual testing of functional system behavior
- Test of “Failure Resistance” by failure imprint (maneuver driven)
- Virtual pre-tests for test matrix reduction of road tests
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