



Camera Behavior Models for ADAS and AD functions with Open Simulation Interface and Functional Mockup Interface

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Prof. Dr. Stefan-Alexander Schneider,
PhD.C. –Eng.Kmeid Saad

Advanced driver assistance systems (ADAS) – ADAS Sensors

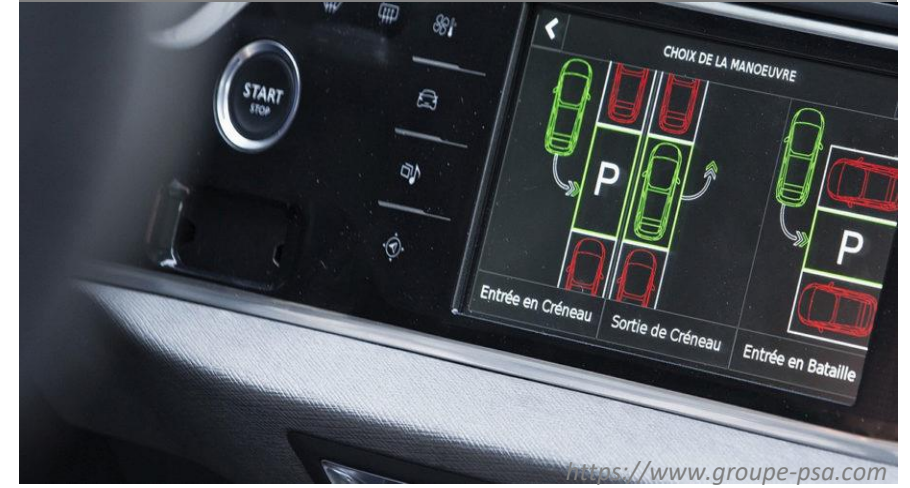
Adaptive cruise control



Lane Keeping Assist



Automatic Parking



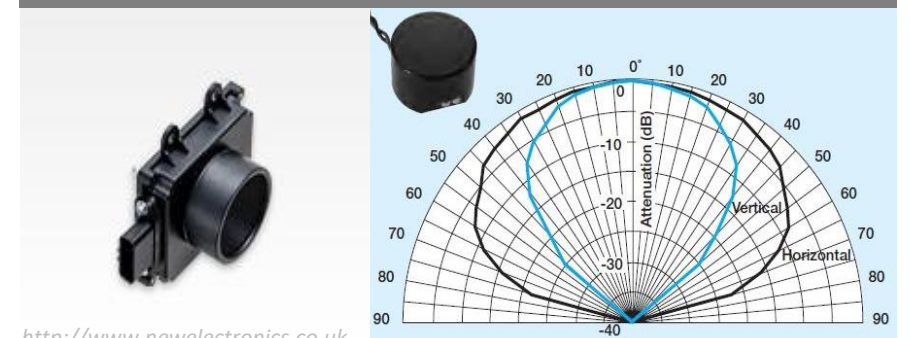
Radar



Camera



Ultrasonic Sensor



Challenges: Defining ADAS requirements

In the context of **ADAS** requirements are mainly derived from the following groups:

Vehicle users (especially the driver)



Legal parties, legislative authorities



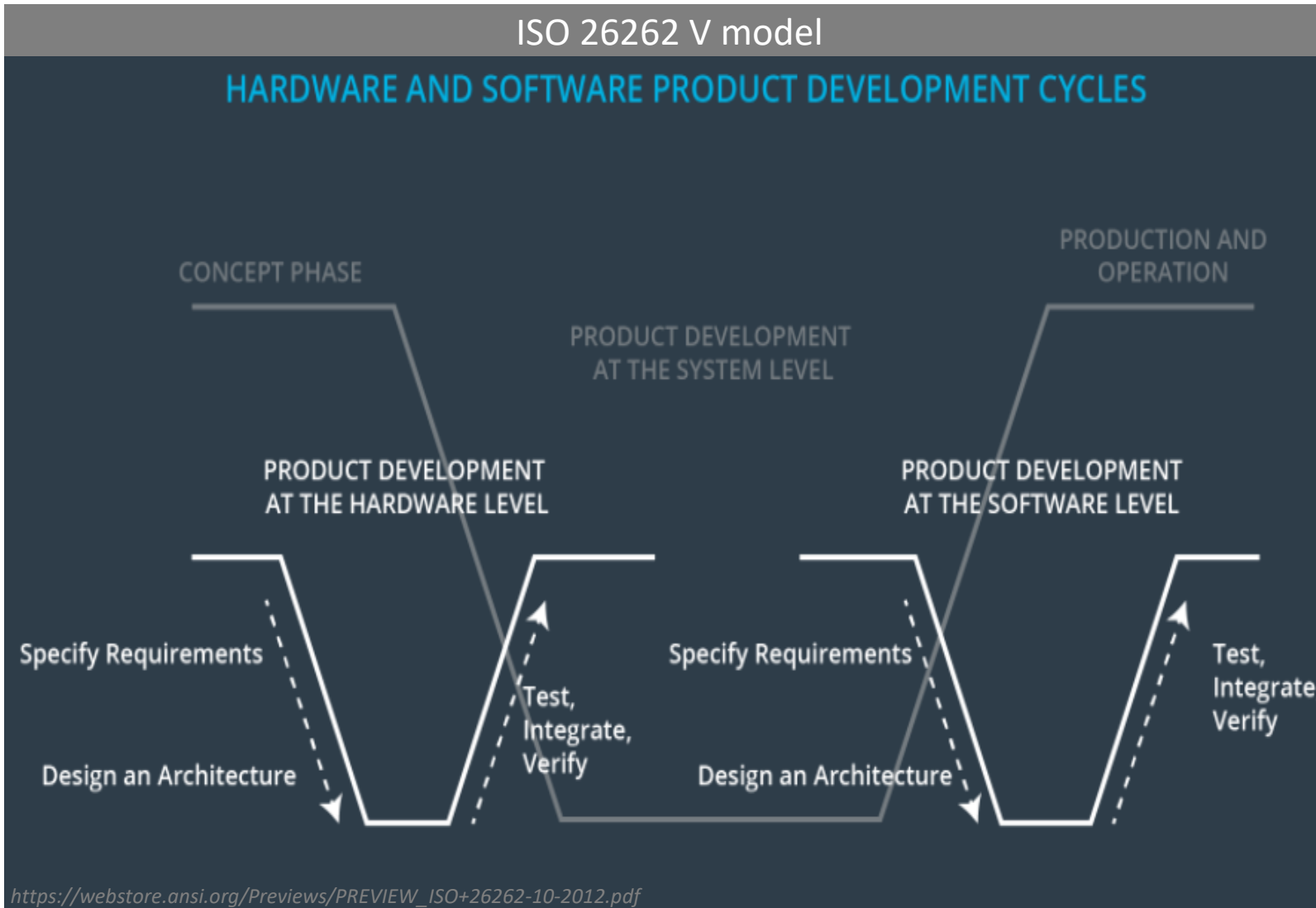
Car manufacturer



And others, ...



Including Functional Safety Requirements...

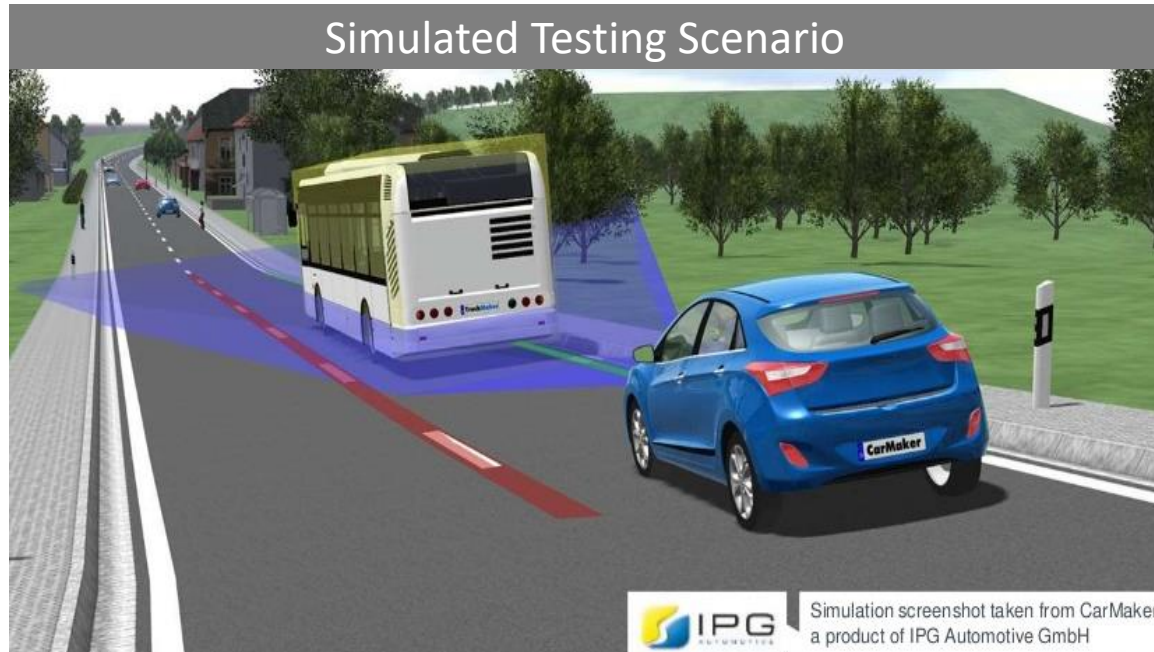


- › Where some ADAS cases require up to about 200 million km of real drive testing for qualification.

Handbook of Driver Assistance Systems, Editors: Winner, H., Hakuli, S., Lotz, F., Singer, C.

Challenges

- › Introduction of a hybrid strategy of virtual and real testing is of an essence:



Which raises the need of ADAS Sensor Models!

Open Simulation Interface (OSI) in ADAS Sensor Modeling

Open Simulation Interface

- Consists of two individual interfaces (entry points) for object data.
- Implementation based on protocol buffers library.



osi::GroundTruth

- Generic object output of the simulation framework.
- World / global reference frame.
- Comprehensive description of the virtual environment including all relevant object data required by statistical sensor models.

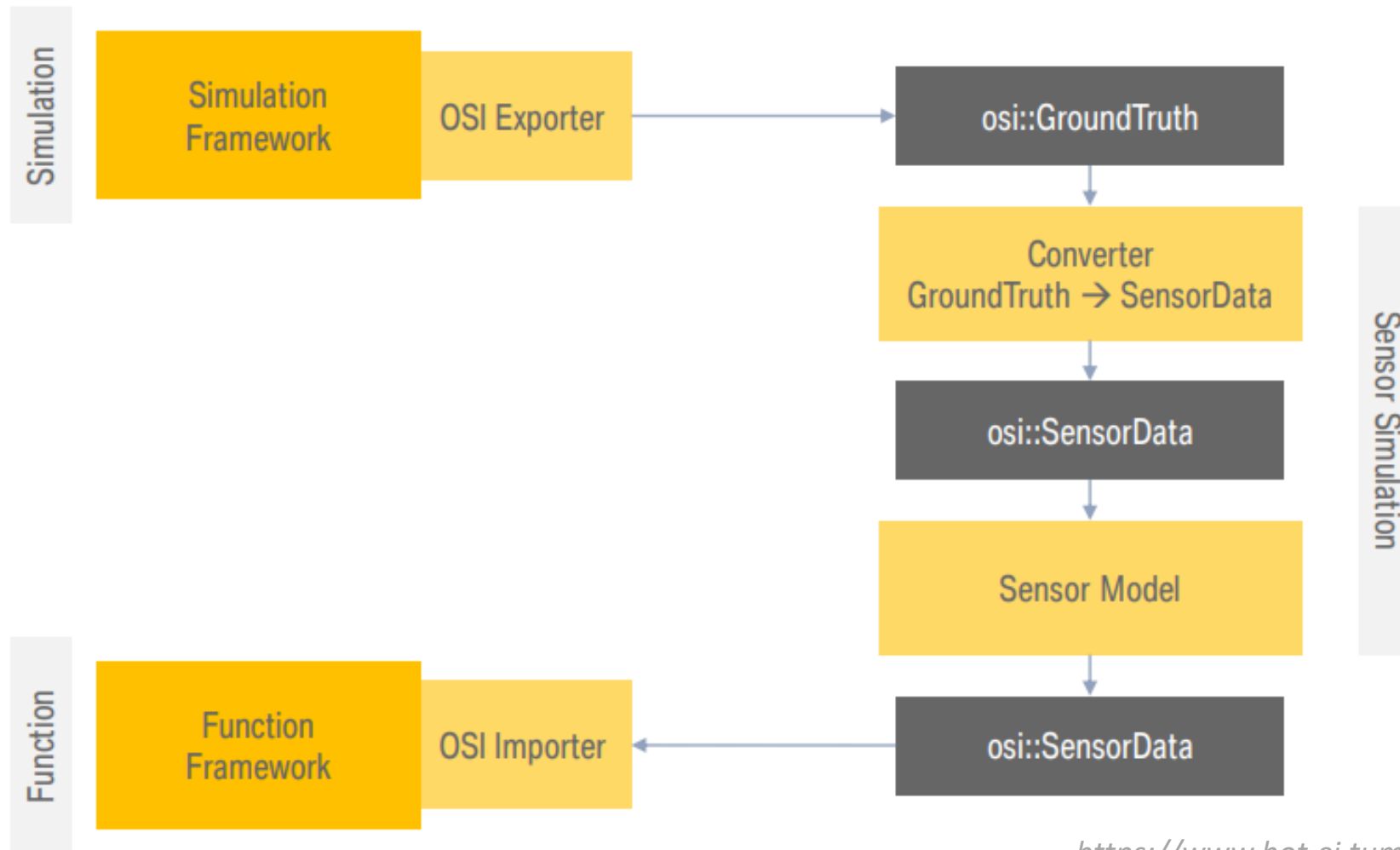


osi::SensorData

- Direct input and output of statistical sensor model(s).
- Input for the environment model.
- Sensor reference frame.
- Description of the sensor output including uncertainties.

<https://www.hot.ei.tum.de>

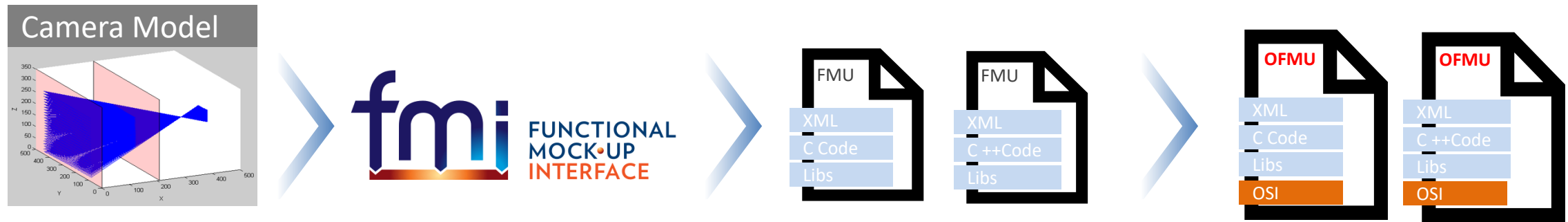
Open Simulation Interface – Data Flow



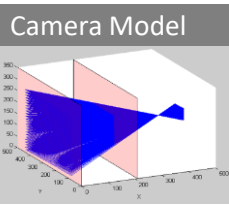
<https://www.hot.ei.tum.de>

Open Simulation Functional Mockup Unit in ADAS Sensor Modeling

OFMU

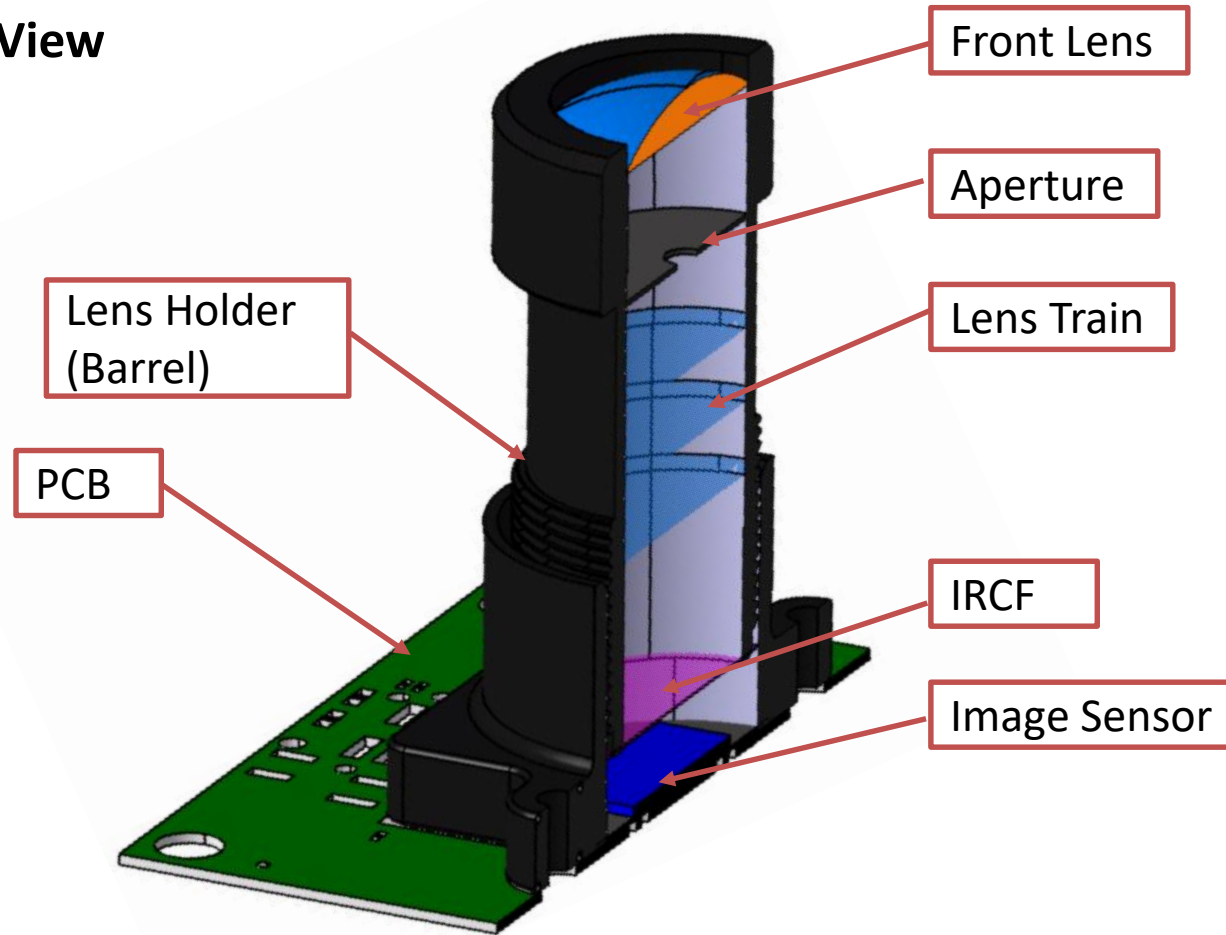


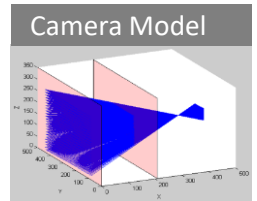
Open Simulation Interface (OSI): <https://github.com/OpenSimulationInterface/open-simulation-interface>
OSI Sensor Model Packaging: <https://github.com/OpenSimulationInterface/osi-sensor-model-packaging>



ADAS Sensor Model – Camera Model

› 3D Model – Section View

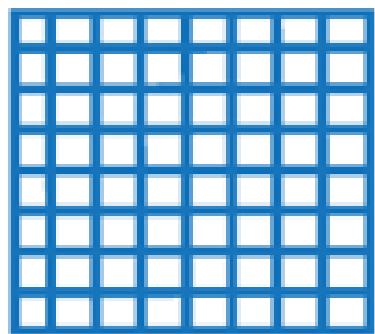




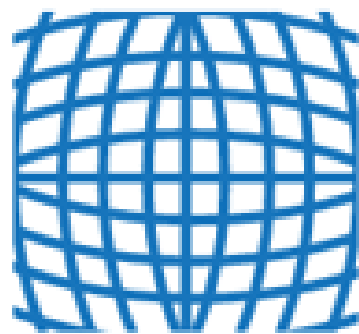
ADAS Sensor Model – Camera Model

› Image Distortions:

Radial distortion occurs when light rays bend more near the edges of a lens than they do at its optical center.

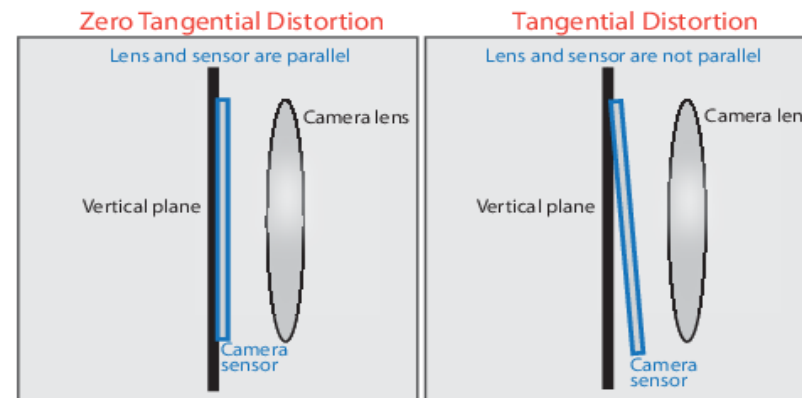


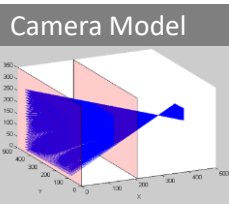
No distortion



Positive radial distortion
"barrel"

Tangential distortion occurs when the lens and the image plane are not parallel.





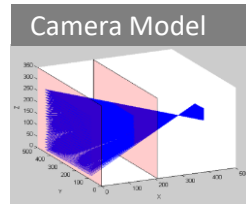
ADAS Sensor Model – Camera Model

› Results:

Observe the unsymmetrical distortion

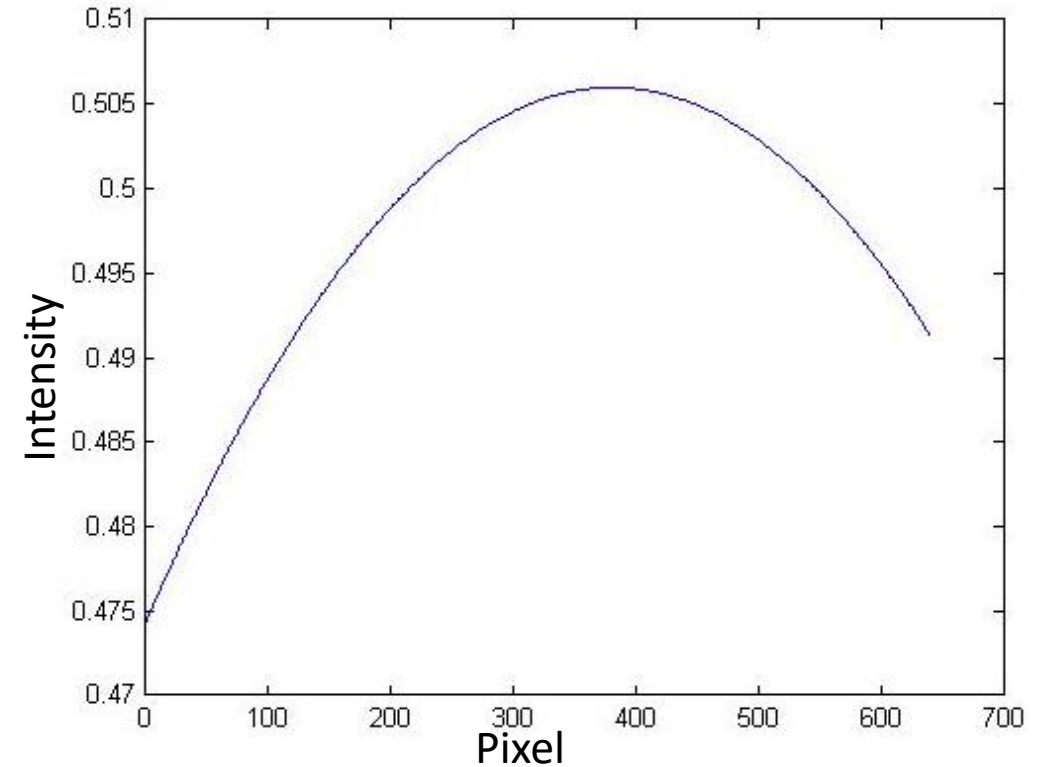
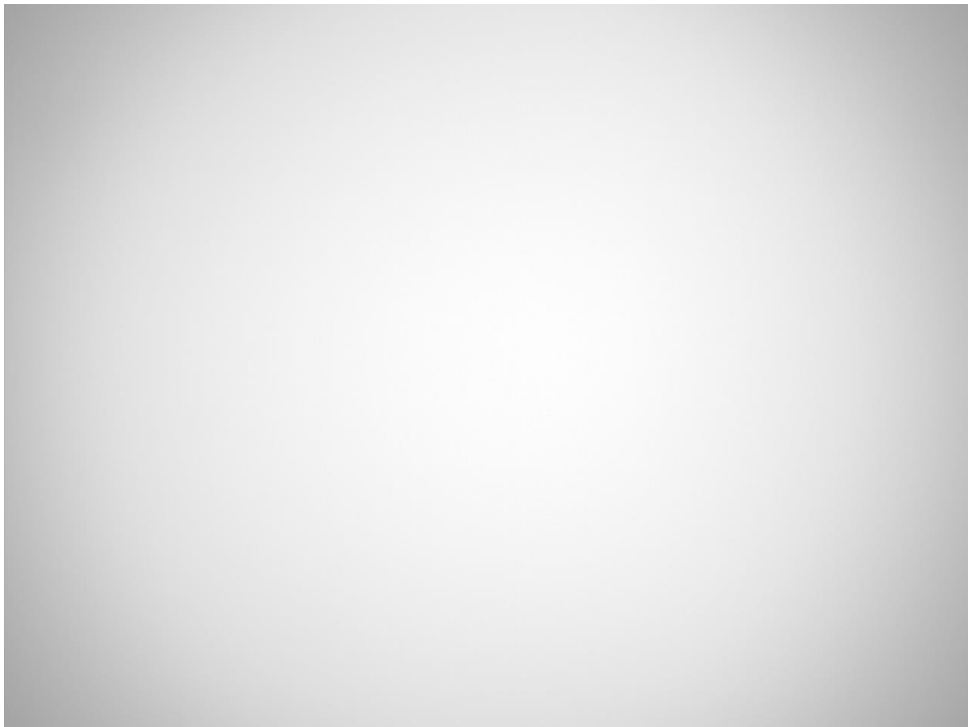


ADAS Sensor Model – Camera Model

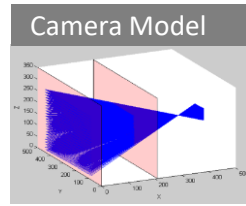


› Vignetting:

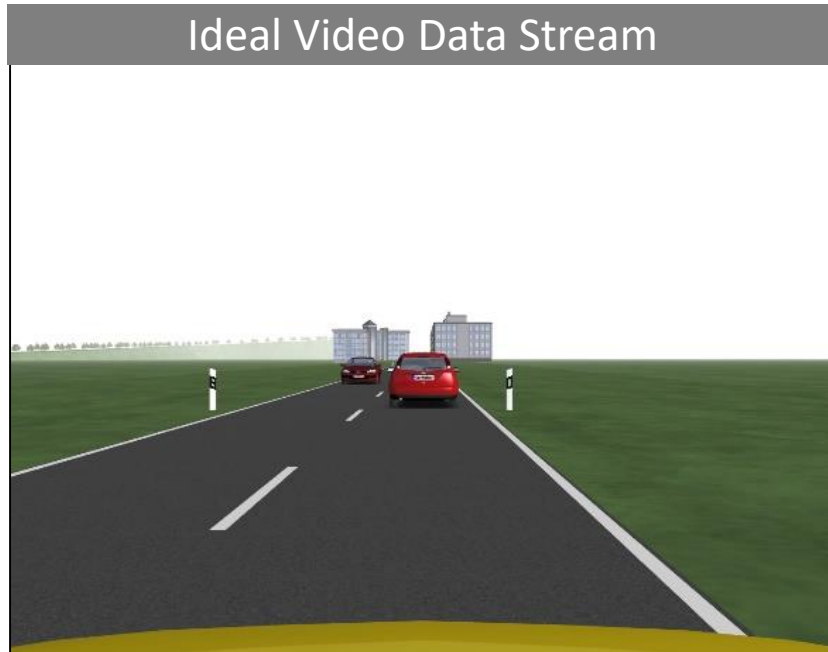
The effect of the vignetting may be described as the reduction of an image's brightness the periphery compared to the image center.

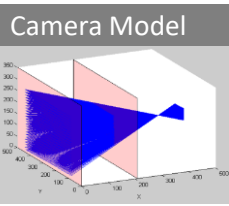


ADAS Sensor Model – Camera Model



› Results:

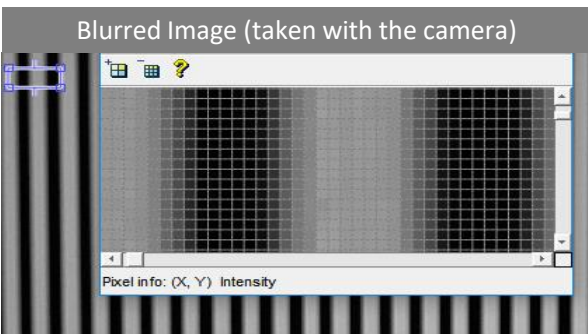
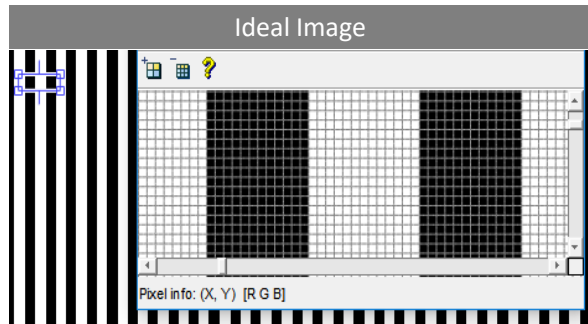




ADAS Sensor Model – Camera Model

› Lens Blur

In reality, the "image" of each object point is spread, or blurred, within the image. this places a definite limit on the amount of detail (object smallness) that can be visualized.

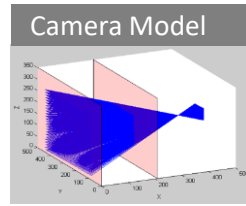


R
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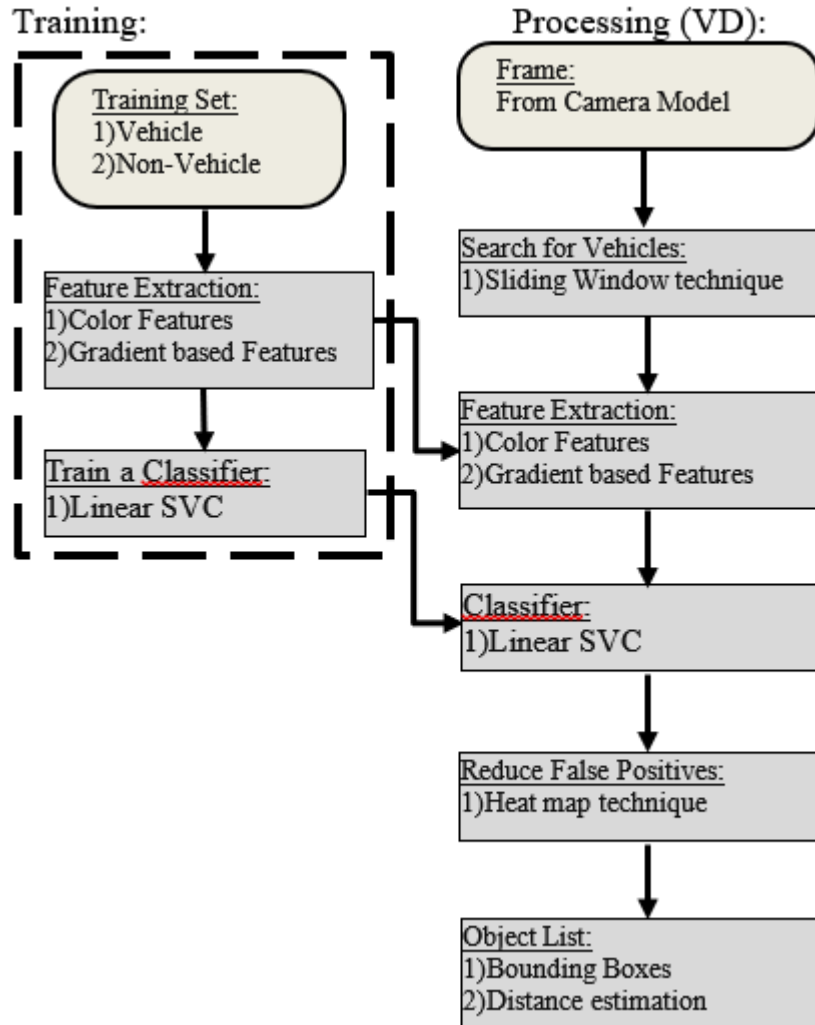
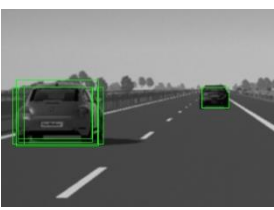
Blur Kernel							
7x7 double							
	1	2	3	4	5	6	7
1	0.0203	0.0203	0.0203	0.0203	0.0203	0.0203	0.0203
2	0.0153	0.0153	0.0153	0.0153	0.0153	0.0153	0.0153
3	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154
4	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154	0.0154
5	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143	0.0143
6	0.0157	0.0157	0.0157	0.0157	0.0157	0.0157	0.0157
7	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150



Camera Model Output

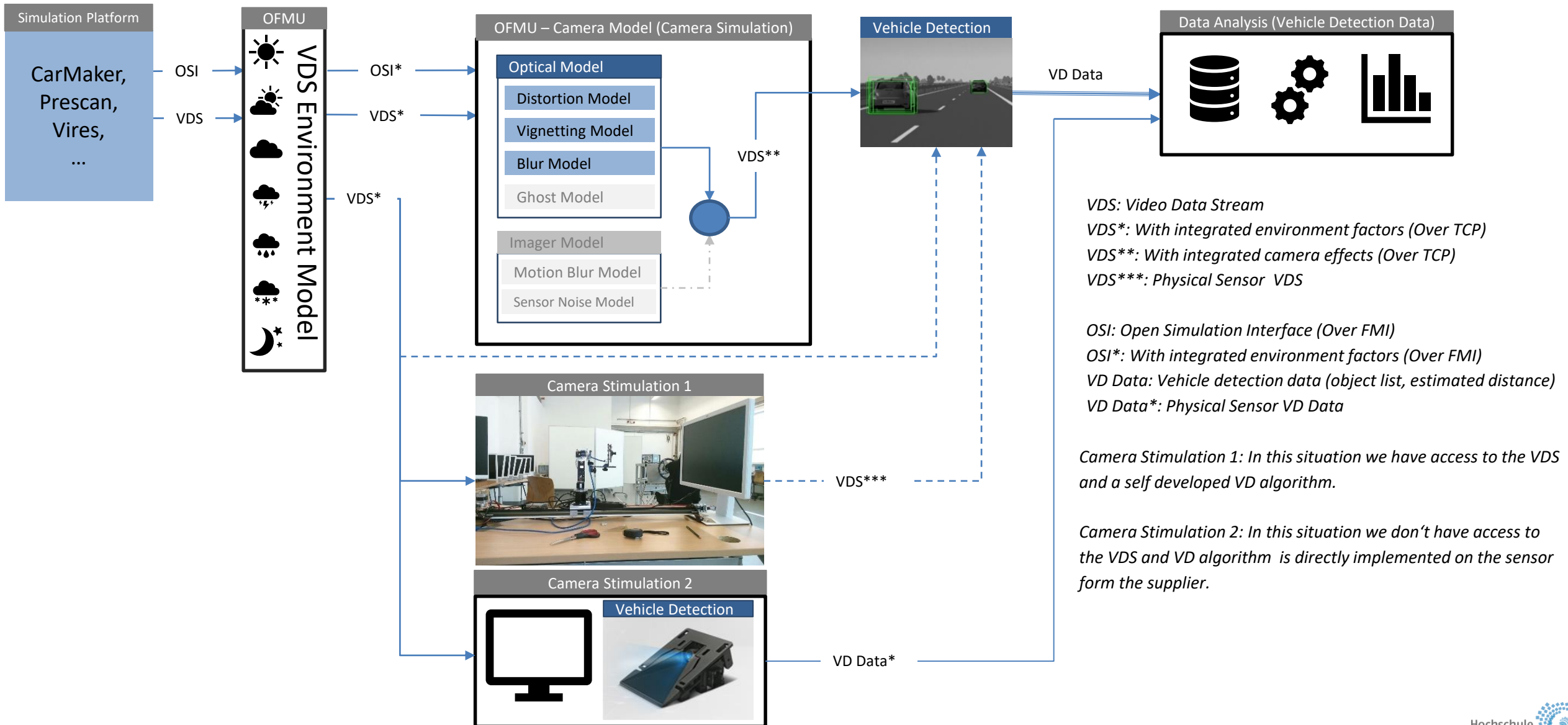


ADAS Function – Vehicle Detection

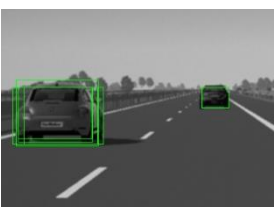


- › Based on Histogram of Oriented Gradients (**HOG**) features we trained our vehicle detection.
- › Later a sliding windows approach is implemented where overlapping tiles from each frame are then classified as vehicle or non-vehicle.
- › Heat maps to show locations of repeated detections helped in identifying detections that were found in the same location or near the same location in several subsequent frames.
- › Finally, bounding boxes around high-confidence detections were generated.

Camera Simulation / Stimulation Setup

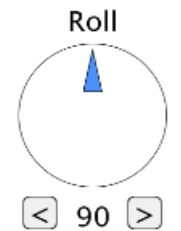
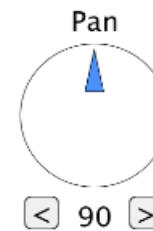


ADAS Sensor Model – Camera Model



Short look into Validation

Camera test bed Prototype, capable of controlling the camera's pitch, yaw and roll angles and one additional translation all of which are controlled by a dedicated desktop interface.



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Thank you for your attention!

Kmeid.saad@hs-Kempton.de
stefan-alexander.schneider@hs-kempton.de

