Advanced evaluation of information fusion for perceptive driver assistance systems based on an environment and driving simulation

Marcus Strand, Marco Ziegenmeyer, Tobias Bär,
Dennis Nienhüser, Thomas Schamm, Thomas Gumpp,
J. Marius Zöllner
FZI Forschungszentrum Informatik

Josef Henning, Bernhard Schick
IPG Automotive GmbH

Outline

1. Introduction
2. Systems and Techniques for Environment Perception
3. Benefit and Challenge of Information Fusion
4. Requirements for a Simulation Environment
5. Simulation Method for Visual Sensors
6. Global Vehicle Integration to realize Virtual Test Driving
7. Applications and Use Cases
8. Conclusion and Outlook

Introduction - Trends

- Environment perception for advanced driver assistance systems increasing
  - Safety
  - Comfort
  - Economic driving

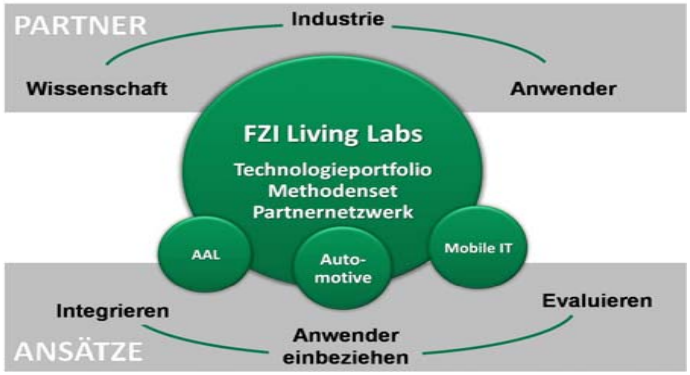
- Visual sensor technologies will be introduced more and more
- Sensor data fusion will play an important role to gain further progress of overall system performance and customer benefits
- System integration will lead to new driver assistance functionalities
- Environment perception will be used for pre-view driving strategies to reduce fuel consumption
- The complexity of integrated systems leads at least to a significant increase of development and validation effort

Science to make your business stronger

- Industry-oriented research institute for innovative products and services based on informatics and IT
- R&D partners for companies and public institutions
- The mission is the technology and knowledge transfer to mid size companies in
- Industry sectors:
  - Information services and software development
  - Automotive
  - Health Care
  - Manufacturing and Logistics
- FZI Living Labs offers an open platform for research and development suited for its partners and customers.

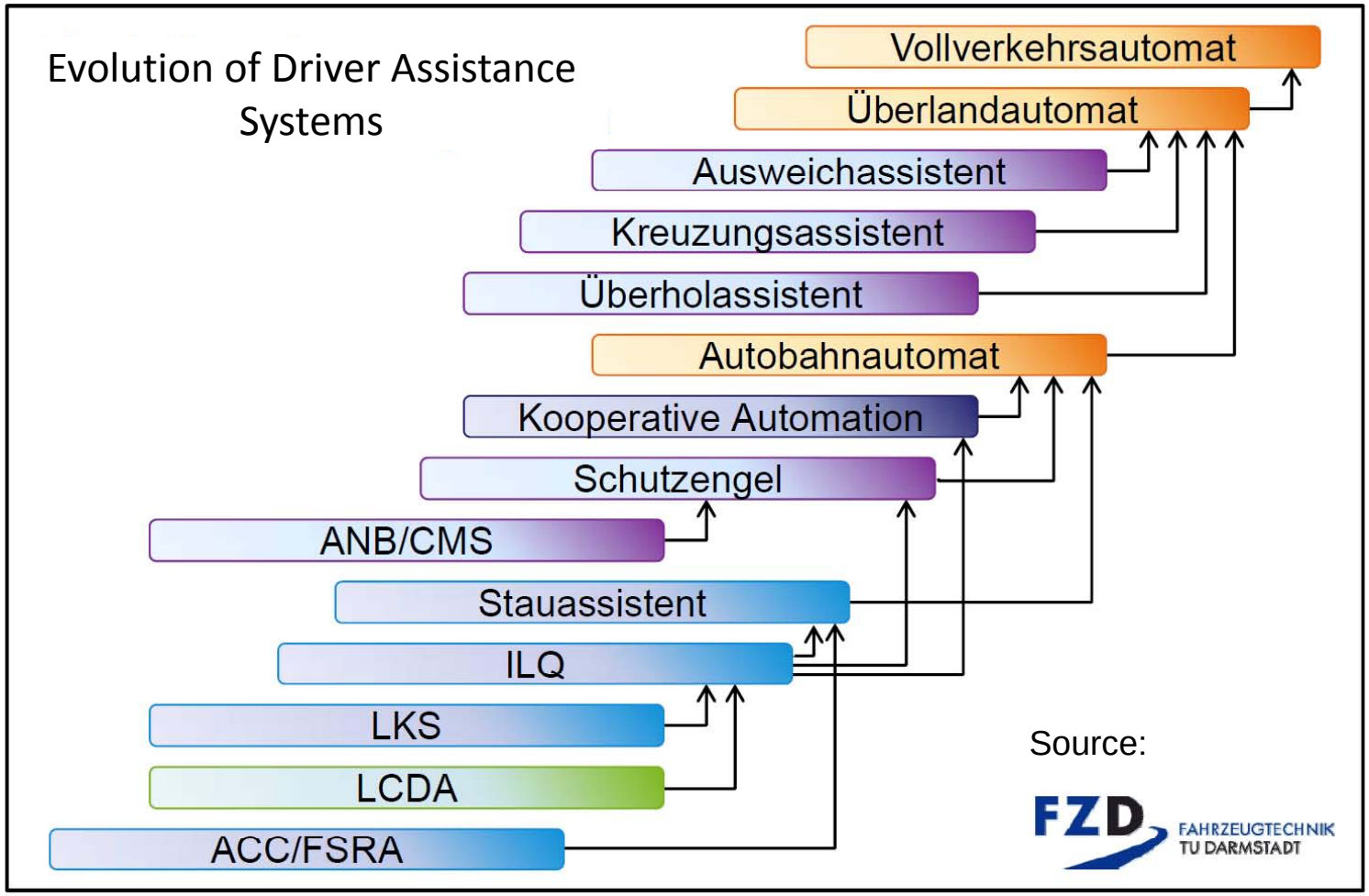
FZI Livings Labs

- FZI Living Lab AAL, Automotive and Mobile IT help to improve speed and efficiency of the innovation process.
- FZI Livings Labs can be used by our partners as platform for
  - Technology – Integration – Evaluation - Open innovation network



- IPG developing simulation technologies for “Virtual Test Driving
  - Vehicle Dynamics & Controls – ADAS – Energy Management
- FZI & IPG established a corporate research partnership
  - Simulation methods for visual sensors and information fusion

Motivation I
Evolution of Driver Assistance Systems



Motivation II
Necessity for Information Fusion

- Different techniques for environment perception are widely used:
  - Ultra Sonic (e.g. Parking)
  - Radar, Lidar (e.g. ACC)
  - 2D-Vision (e.g. Lane Tracking)
  - 3D-Vision (e.g. Pedestrian Detection)

- Data and Information Fusion for driver and environment perception is a tendency due to several reasons:
  - No technological breakthrough for sensors is expected
  - Further progress in current technologies (3D-sensors, positioning systems, IR-Cam etc.) will be introduced
  - Priority in development of cost-saving sensors
  - Current state of environment perception is a patchwork of sensors
  - Higher complexity of upcoming tasks for driver assistance
  - …

Systems and Techniques for Environment Perception I

- Example I: Vision Based Lane Detection:

Systems and Techniques for Environment Perception II

- Example II: Vision Based Detection of warning beacons in contruction sites

Systems and Techniques for Environment Perception III

- Example III: 3D vision based vehicle detection (alternativ auch pedestrian detection möglich)

Systems and Techniques for Environment Perception IV

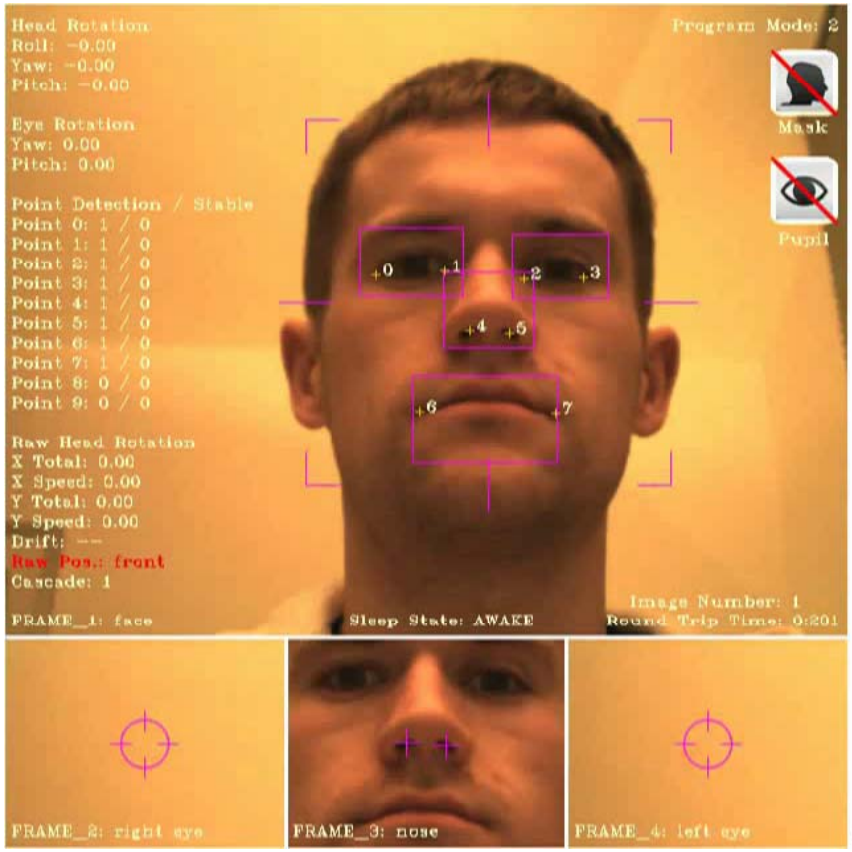
- Example IV: Vision based weather detection and removal of weather effects

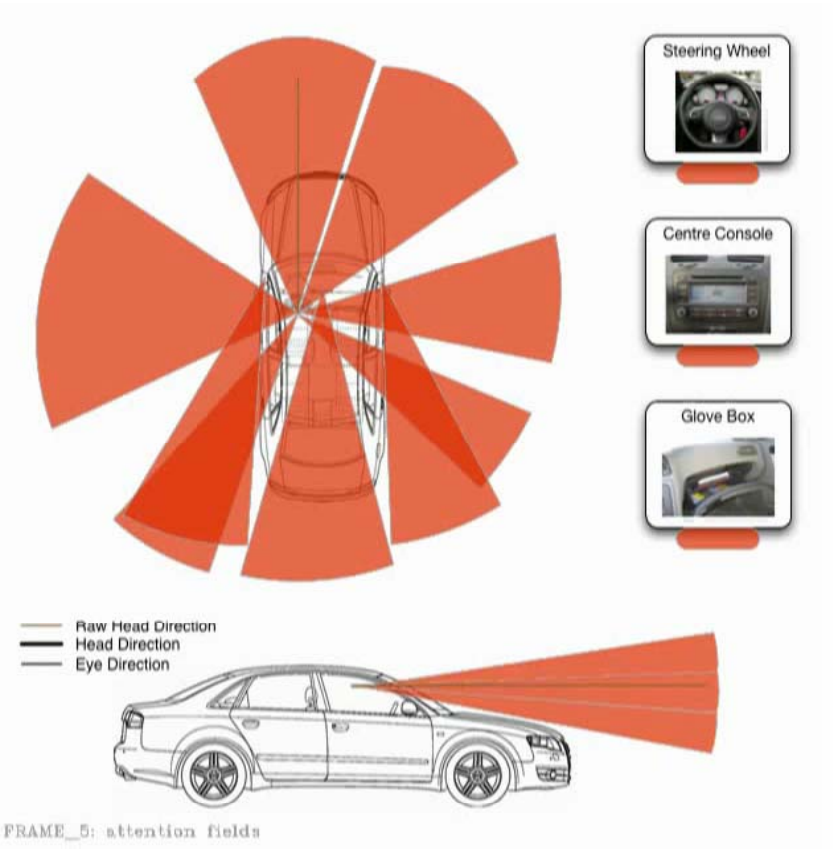
Systems and Techniques for Environment Perception IV

- Example V: Pedestrian detection

Systems and Techniques for Environment Perception V

- Example VI: Driver condition observation

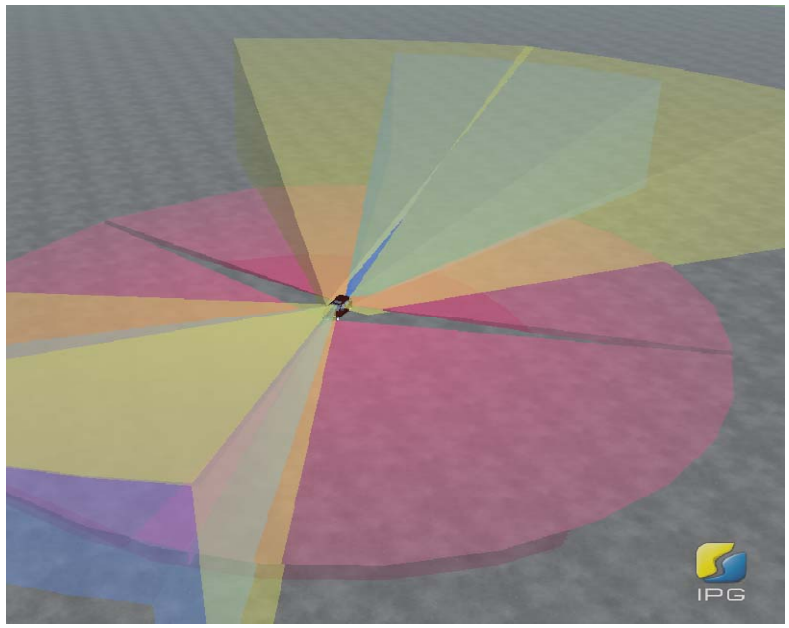


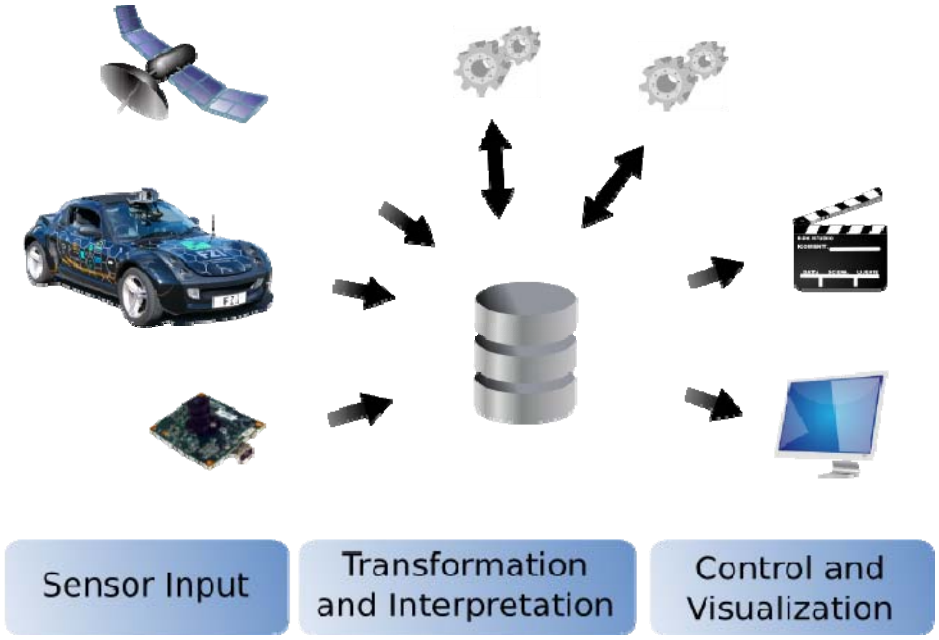


Benefit and Challenge of Information Fusion

- Fusion techniques
  - Complementary fusion (e.g. 3x Lidar)
  - concurrent fusion (e.g. PMD (3D) and cameras)
  - cooperative fusion (e.g. Radar and camera)

- Data fusion, feature fusion, decision fusion -> which level to choose?

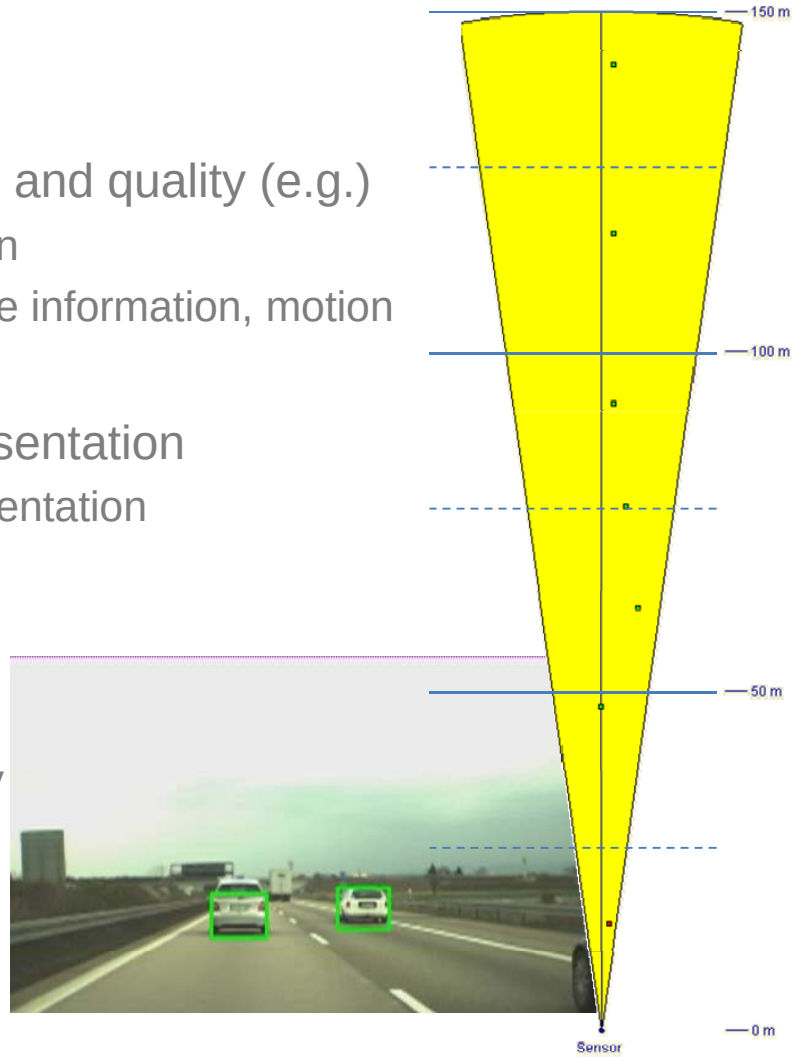




Benefit and Challenge of Information Fusion

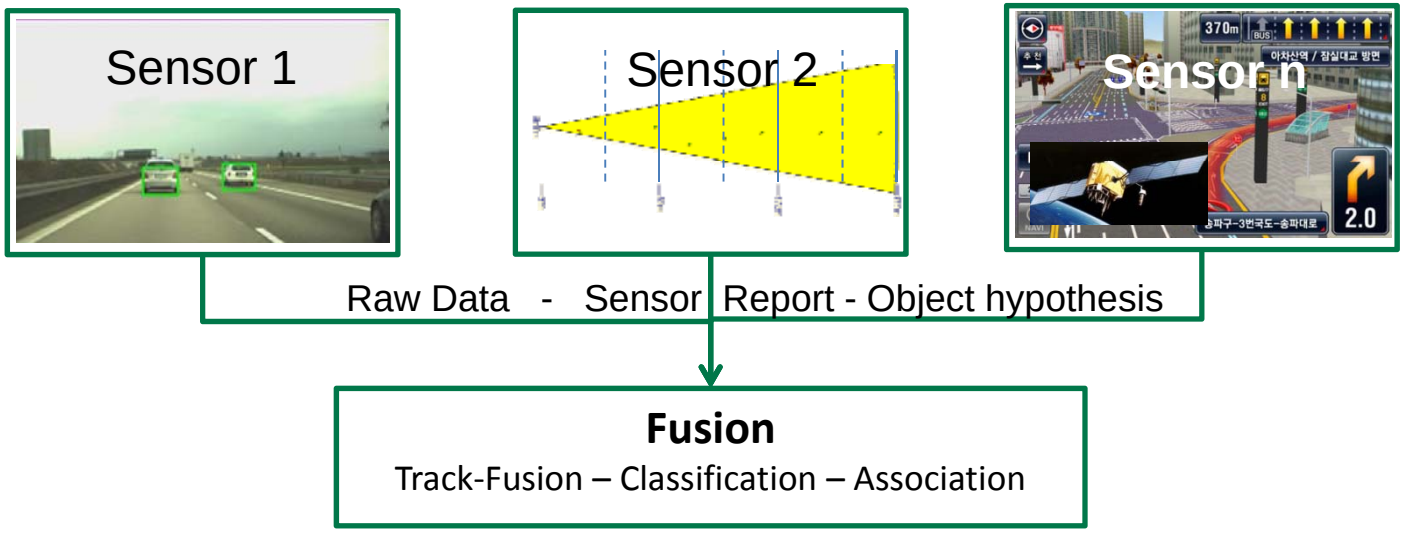
Example: Radar and Camera

- High diversity by means
  - Big win of complementary information and quality (e.g.)
    - Radar: longitudinal precision
    - Camera: lateral precision, size information, motion
  - Few information redundancy
  - Complex common environment representation
    - Radar: object based representation
    - Camera: occupation grid
- Fusion combines the strengths
  - Field of view and data quality
  - Overlapped information for plausibility
- Variants
  - Low cost radar with stereo camera
  - High end radar with mono camera



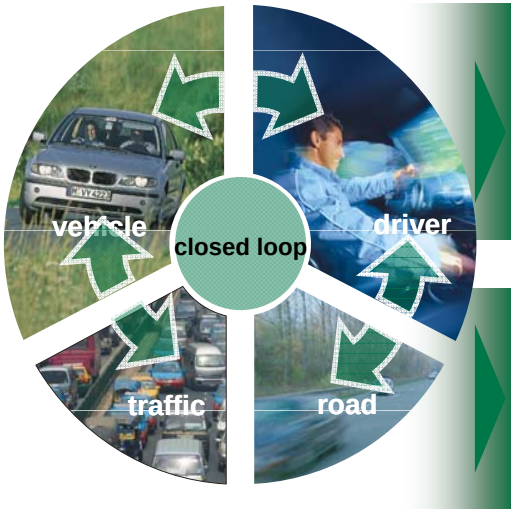
Requirements for a Simulation environment

Why closed loop simulation in a total vehicle environment?



- Data must be spatiotemporal concurrent (time, position)
- Complex scenarios must be applicable
- Tests must be repeatable and reproducible
- Technologies must be replaceable rapidly
- Test shall be possible in the early development phase and continuously
- Vehicle tests are costly, limited repeatable and late in the development

Requirements for a Simulation environment



- Excellent Driver - Vehicle – Road – Traffic models
- Detailed 3D vehicle model for realistic vehicle dynamics behavior
- Comprehensive maneuver and traffic control to reconstruct complex test scenarios (event driven)
- Capability to integrate extensive control system and ADAS sensors in the total vehicle
- Capability to integrate “Virtual Visual Sensors”
- Model platform for controls (MATLAB/SIMULINK)
- C-Code interfaces for models and program devices
- Network communication service
- Powerful visualization (online and real-time)
- Applicable for office, hardware-in-the-loop simulation and in simulators

CarMaker are used as Virtual Test Driving Platform

Simulation Method for Visual Sensors Visualization

Drawing of 2D Pictures

Drawing of 2D Pictures

Screen Signal

Graphic Board

OPEN GL commands
3D Object lists

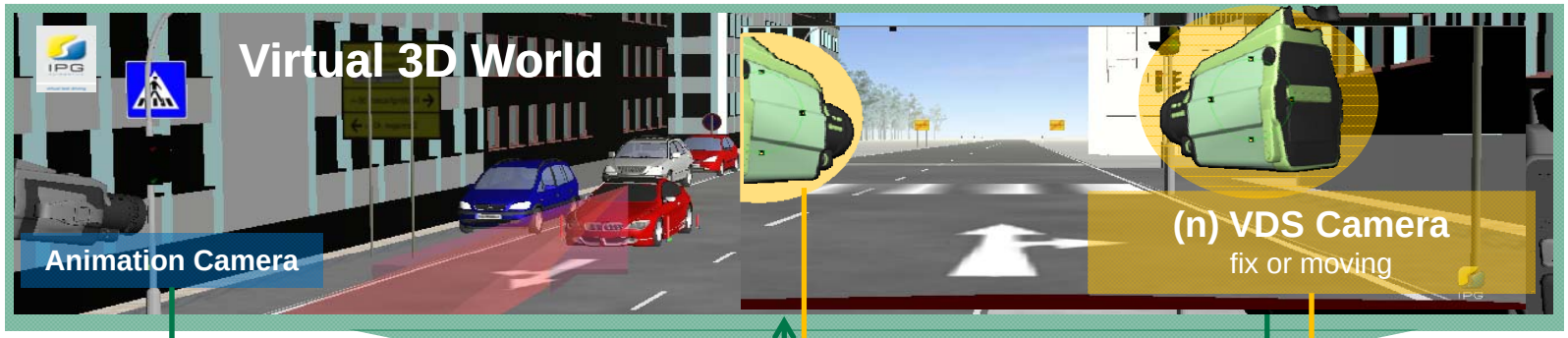
IPGMovie

Dynamic motion data
Object allocation

CarMaker
Driver – Vehicle - Environment

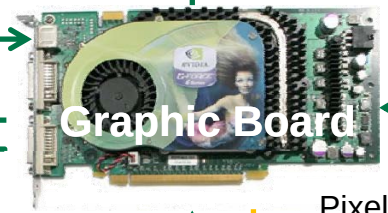
Video Export
(avi, mpg...)

Simulation Method for Visual Sensors “VDS – VideoDataStream in real-time”



Drawing of 2D Pictures

Screen Signal



Independent configurable
- position and direction
- frame rate [25Hz]
- resolution [640x480]
- picture type [mono]
- sensor properties
- optic

Pixel Pictures (rgb, mono)
Z-buffer

IPGMovie

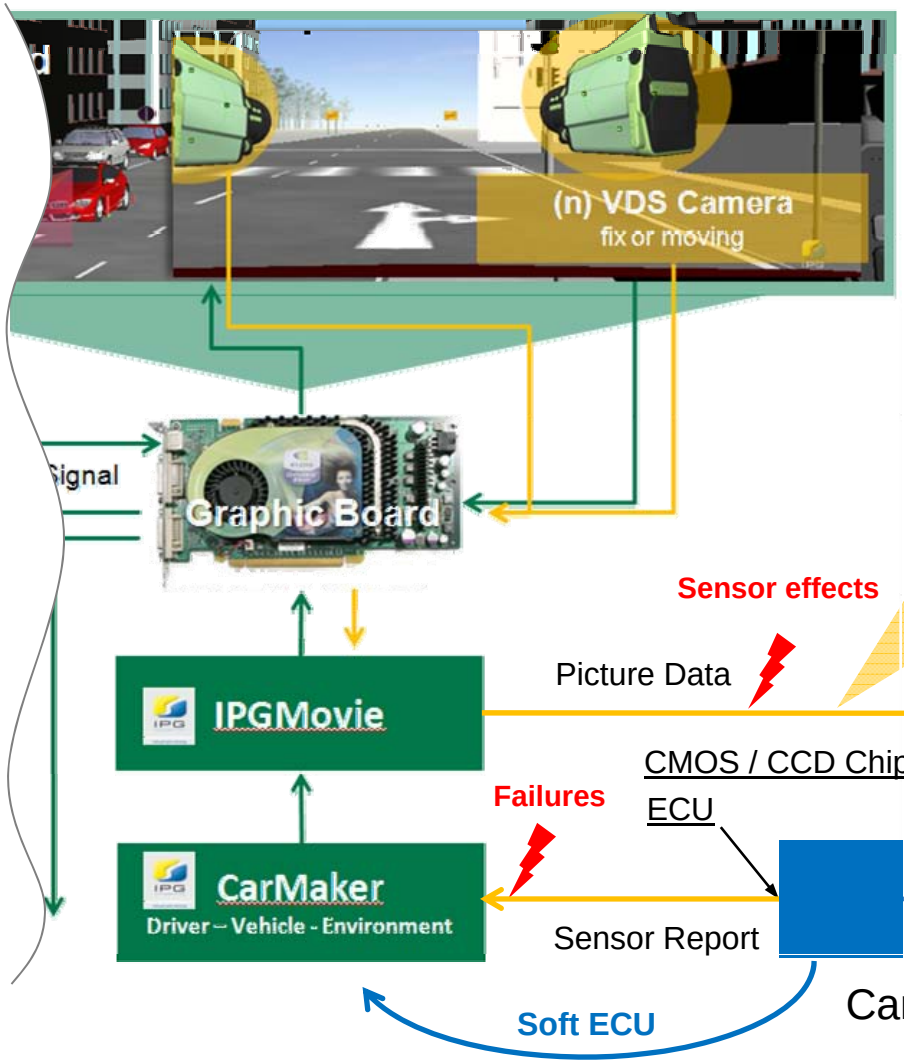
TCP/IP Socket

Image Data
- Color (PPM)
- Grey Scale (PGM)
- Deepness Maps (PGM)

Video Export
(avi, mpg...)

CarMaker
Driver – Vehicle - Environment

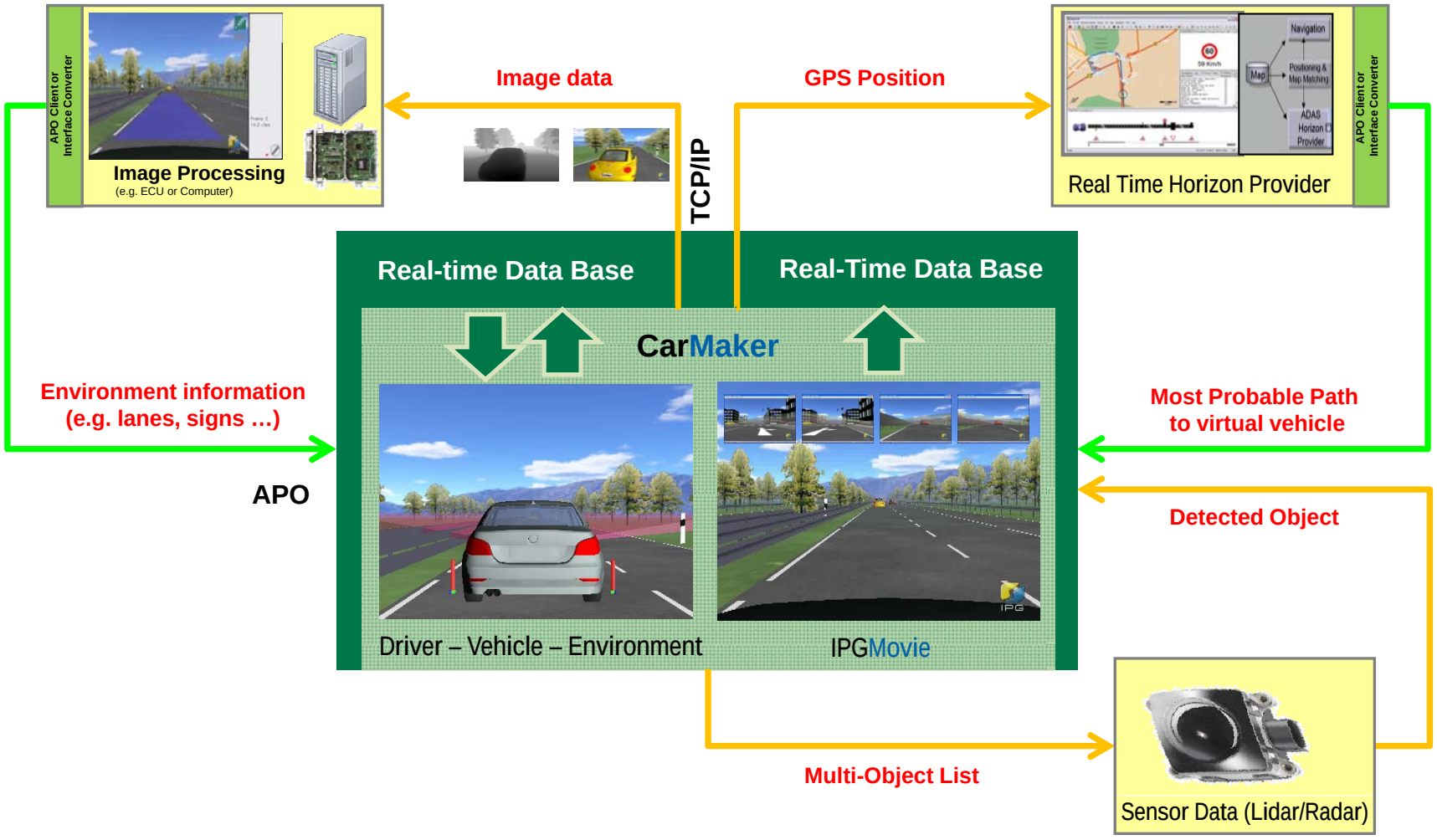
Simulation Method for Visual Sensors “VDS – VideoDataStream in real-time”



Camera Types

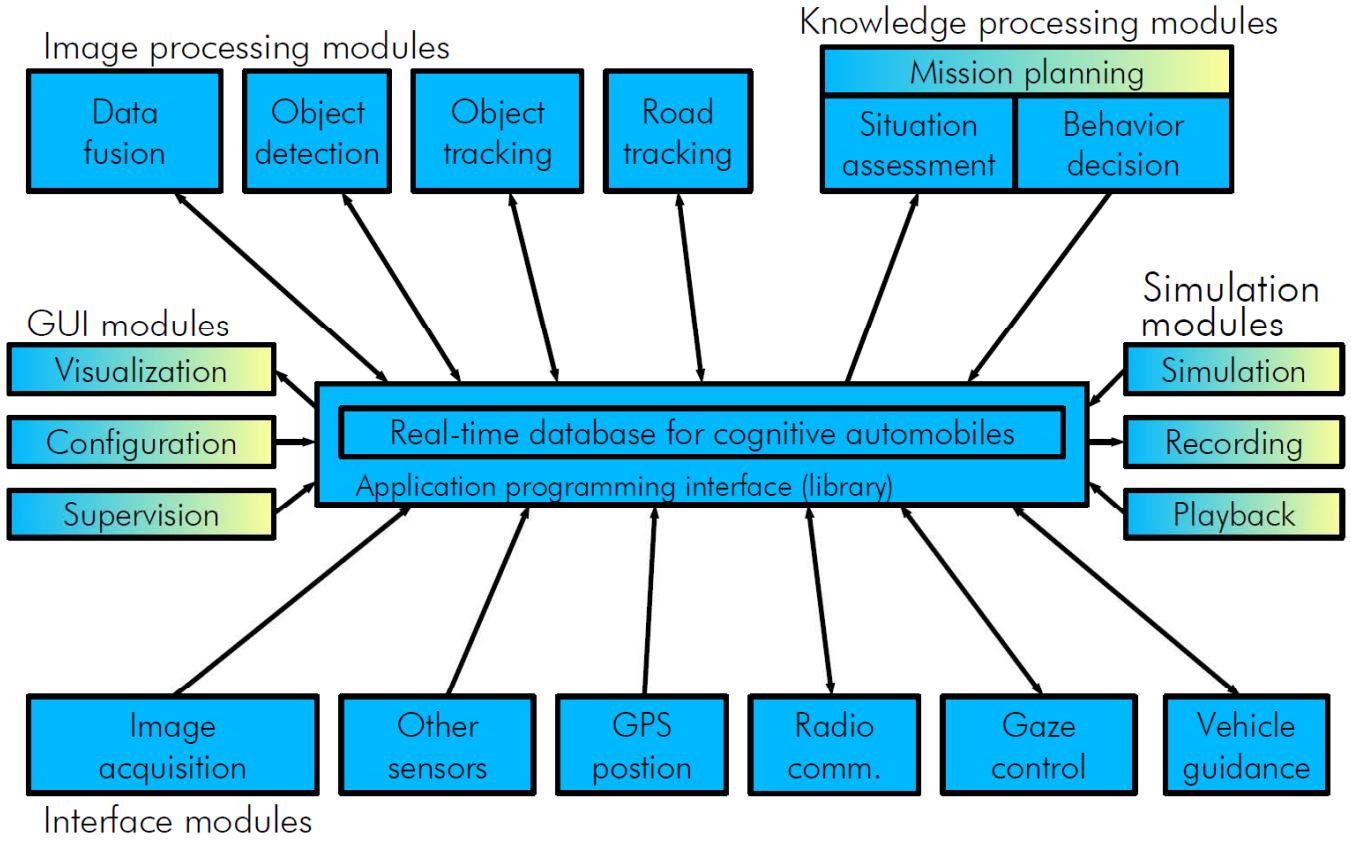
- Mono
- Stereo
- IR-CAM
- 3D - PMD-Cameras

Global Vehicle Integration to realize Virtual Test Driving



Global Vehicle Integration to realize Virtual Test Driving

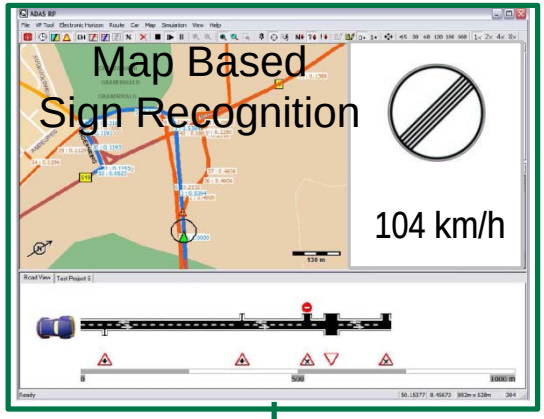
- Real Time Data Base[1]

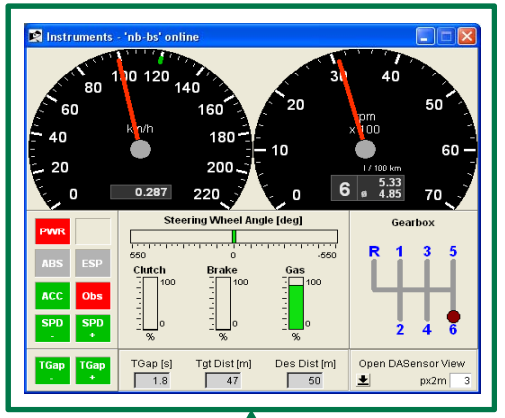


[1] Matthias Goebl; Eine realzeitfähige Architektur zur Integration kognitiver Funktionen. Dissertation, Lehrstuhl für Realzeit-Computersysteme, Technische Universität München, 2009

Applications and Use Cases I

Traffic Sign Recognition + ACC





Fusion
Classification

Functions
- Display warning
- Speed set at ACC
- ..

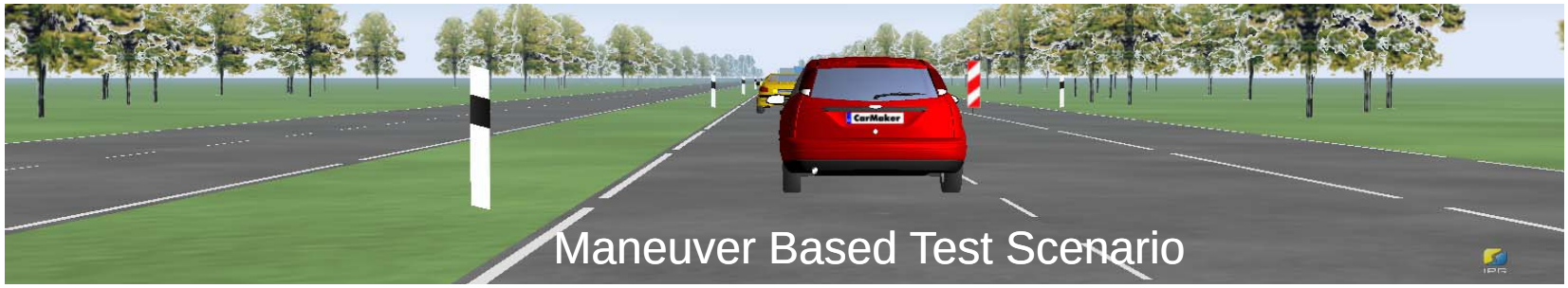
ACC

Applications and Use Cases II

Lane Keeping Assistance + Traffic Sign Recognition

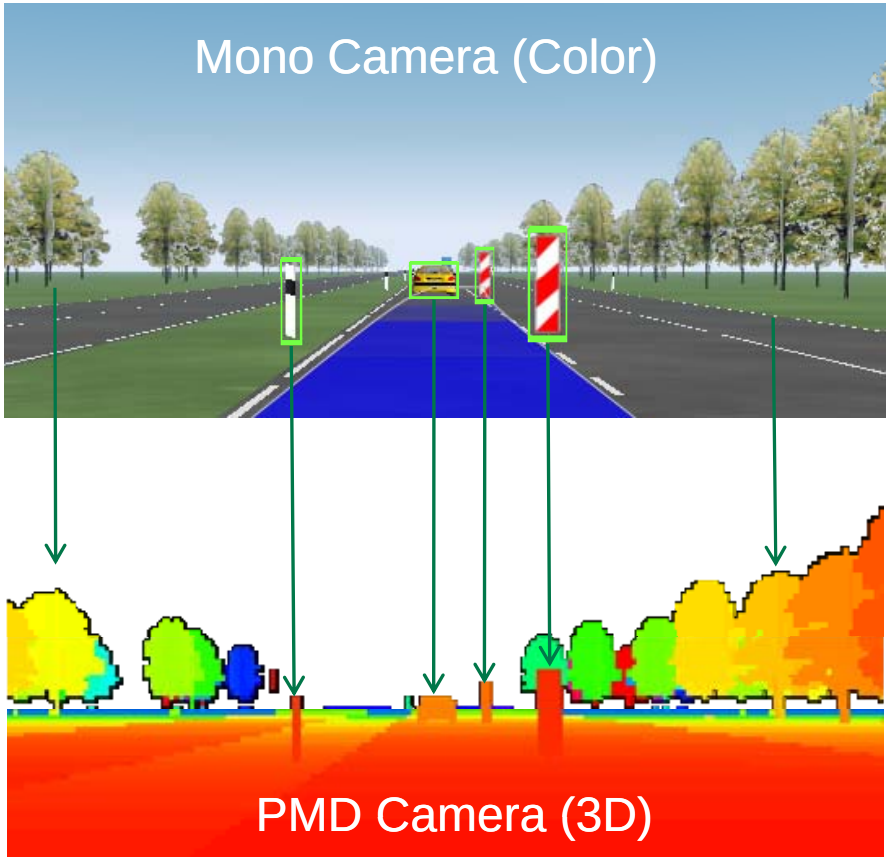
Applications and Use Cases III

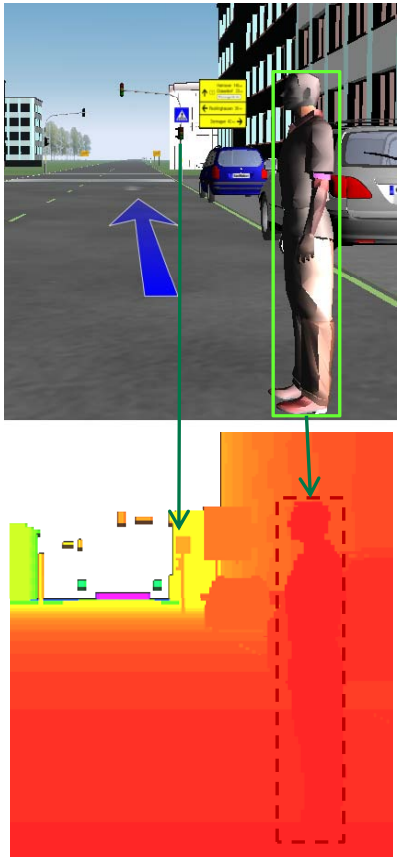
Object tracking fusion



Applications and Use Cases IV

3D - PMD camera applications





Conclusion and Outlook

The presentation have illustrate

- Systems and techniques for environment perception
- Benefit and challenge of information fusion
- Necessity for closed loop simulation in the total vehicle environment
- VDS – VideoDataStream as new method to integrate virtual sensors
- Virtual test method of environment perception and fusion algorithms

Outlook

- Advanced visual sensor models with specific sensor effects and extended visualization (e.g. weather conditions)
- Extensive traffic flow simulation to create random traffic situations
- IPGDriver with psychological behavior for follow2stop and lane change
- Road network and digital maps incl. environment infrastructure
- Fusion of virtual and real sensor data (augmented simulation)
- Research program to investigate focus of drivers attention