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23322: Open Fusion Platform for Automated Driving Cars Based on Nvidia DPX2

Open Fusion Platform

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Associated Partners:

Agenda

- Motivation
- Overview of the *Open Fusion Platform* (OFP) Project
- Functional Architecture
- Interface Specification
- Joint Semantic Segmentation and Detection
- Intention Prediction, Risk Assessment and Decision Making for Vehicle Guidance
- Conclusion and Outlook

Motivation

- Fully automated driving prototypes available but no serial production
  - High development cost on sensors, hardware and algorithm
- Advanced driver assistance systems cover only predefined situations
- Integration issues due to heterogeneous sensors and interfaces
- Actual standardization initiatives for automated driving
  - OpenDRIVE: Format specification for road networks and infrastructure
  - OpenSCENARIO: Description of dynamic contents in driving simulation applications
  - Adaptive AUTOSAR: New AUTOSAR Platform for complex fusion systems
  - EB Robinos
    - Architecture specification in environmental fusion models
    - Software for development and embedded prototyping
    - SW Modules inside environmental model and situation analysis

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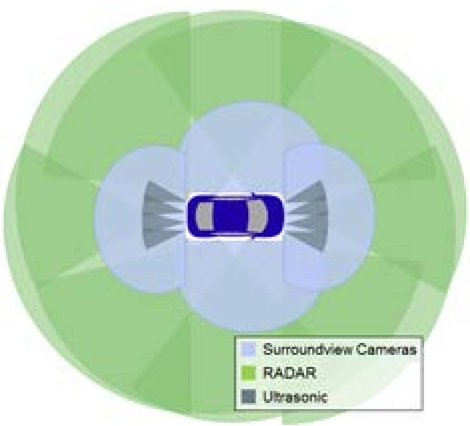
Overview of OFP

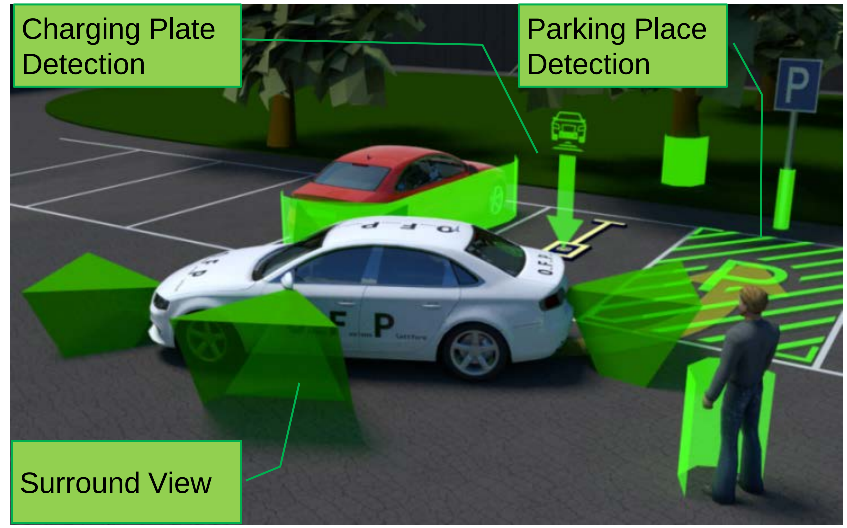
Project Objective:

- **Create a near series fusion platform** with open interfaces, that allows a cost efficient implementation of highly and fully automated driving functions.

Sensor Configuration



Project Timeframe: Jan 2016 – Dec 2018



Use Case:

“An **e-car autonomously parks and positions** itself directly on **top off a parking space with a wireless charging plate**. When car is charged, it drives itself to another parking space without a charging plate.“

DLR · HELLA · Hella Aglaia · TWT GmbH Science & Innovation · RWTH AACHEN UNIVERSITY · Elektrobit · streetscooter research · Hochschule Reutlingen Reutlingen University · InnoSenT Innovative Sensor Technology · infineon

Associated Partners: NVIDIA · Continental

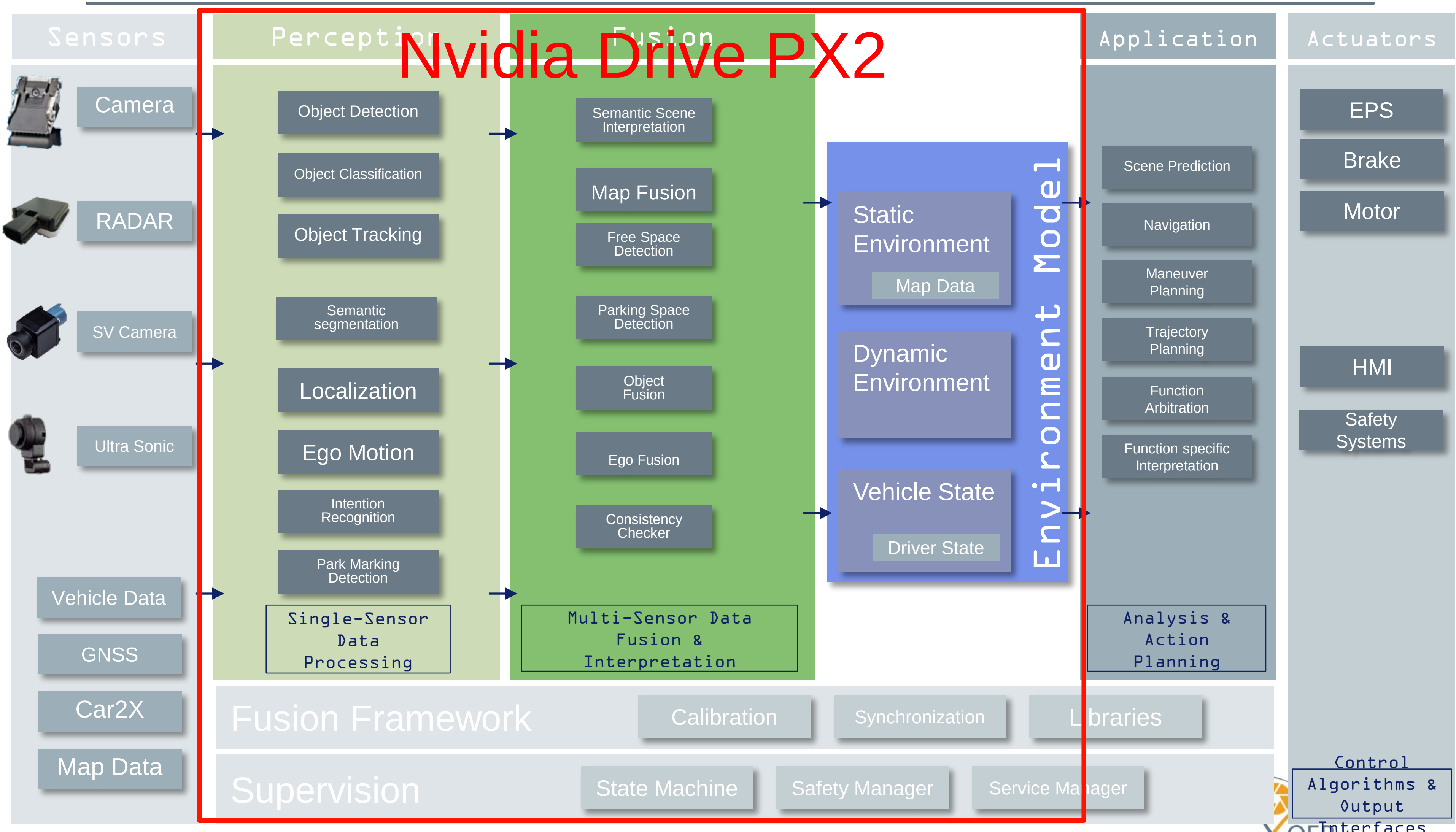
Car Platforms used in OFP

e.GO life (Electric)

Passat GTE (Plug-in Hybrid)

AUDI A6

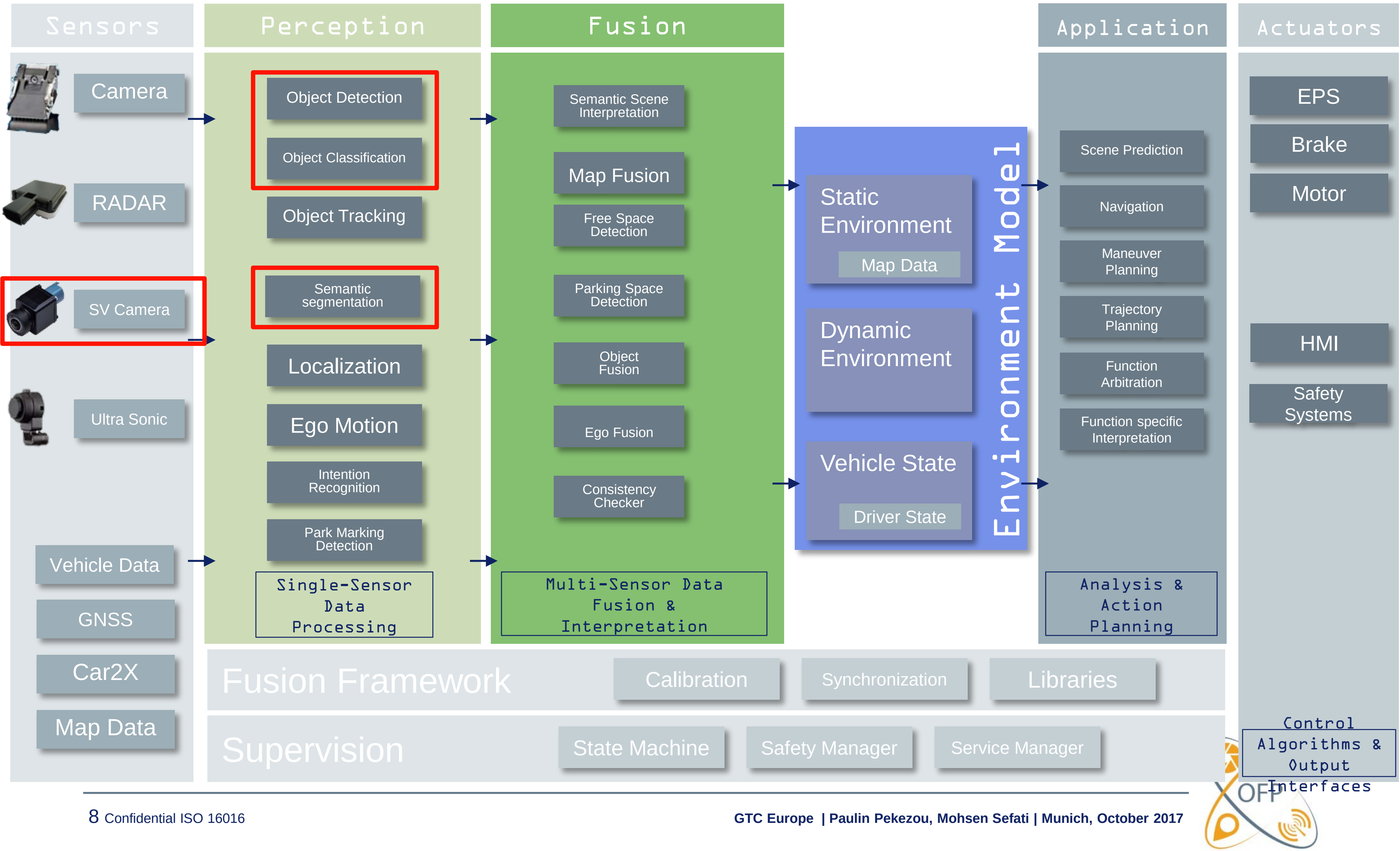
Functional Architecture



Interface Specification

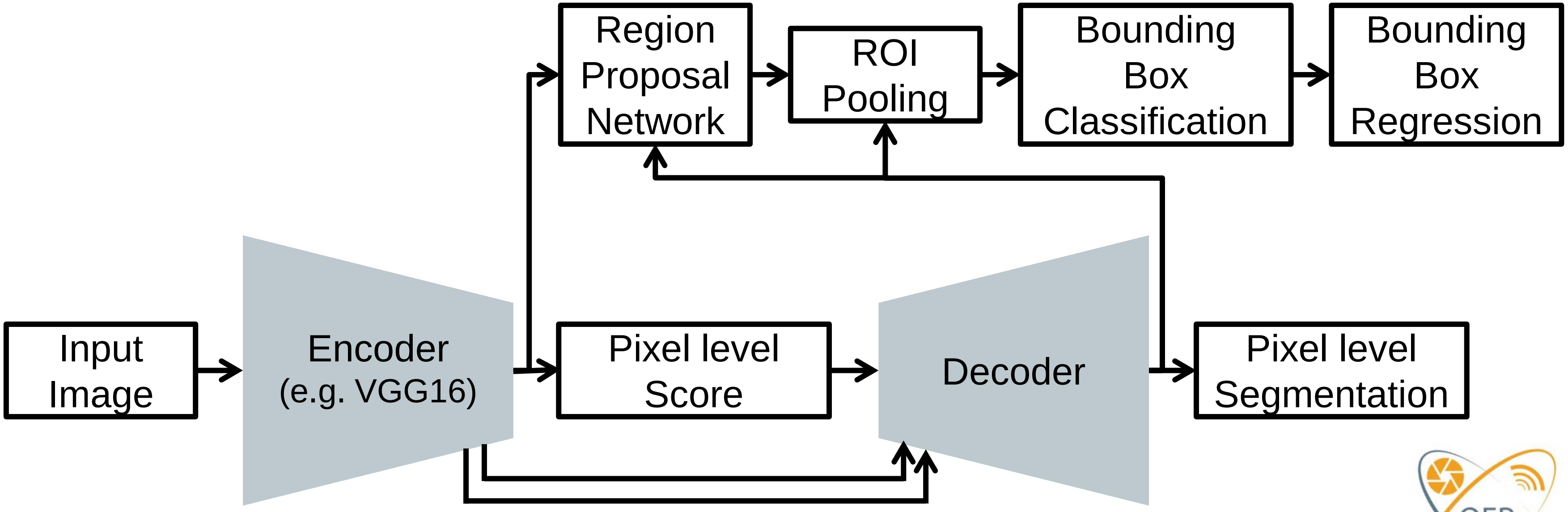
- Hardware Interface
  - Use available standards as CAN, LVDS, etc.
- Basic Software
  - Elektrobit AdaptiveCore: Adaptive AUTOSAR implementation from Elektrobit
- Data- and timing-driven communication
- Definition of generic data types. E.g. object, ego pose and motion, image, etc.
- Software interface
  - Description of inputs and outputs using module manifest
  - Specification of a module manifest template
  - Layer specific module manifest implements the manifest template
- Interface specification available soon on the project homepage http://www.ofp-projekt.de/ofp-project/de/Oeffentliche-Dokumente-305.html

Joint Semantic Segmentation and Object Detection
Overview



Joint Semantic Segmentation and Object Detection
Model

- Sharing of features between Faster R-CNN [1] and FCN [2]
- Extension of Faster R-CNN ROI Poling with FCN score map
- Advantages
  - Reduce feed forward computation time and memory consumption
  - Improve detection while keeping the segmentation unchanged



Joint Semantic Segmentation and Object Detection
Training and Evaluation on Daimler Cityscapes dataset

- Training and evaluation on Daimler Cityscapes dataset [3] using GTX 1080ti GPU
- Evaluation results: Intersection Of Union (IOU) for segmentation and mean Average Precision (mAP) for detection

FCN Model	Average IOU
Single	**0,579**
Joint Model	0,572

FR-CNN Model	AVG mAP	Overall mAP
Single	0,32	0,327
Joint Model	**0,325**	**0,358**

- Complexity on GTX 1080ti, image size: 2048x1024
  - The joint-Model uses **33%** less memory and is **1,3x** slower than both single models running in parallel

Model	#Params	Runtime	Memory
Single FCN	134,5M	320ms	5,63GB
Single Faster R-CNN	136,9M	250ms	4,47GB
Joint-Model	256,9M	430ms	6,71GB

Joint Semantic Segmentation and Object Detection
Fine Tuning on OFP Surround View Camera Data

- Fine tuning of the model trained on Daimler Cityscapes with OFP surround view camera data

- Complexity on GTX 1080ti, image size: 1024x440
  - The joint-Model uses **23%** less memory and is **1,08x** slower than both single models running in parallel

Model	Runtime	Memory
Single FCN	180ms	2,22GB
Single Faster R-CNN	112ms	1,98GB
Joint-Model	195ms	3,22GB

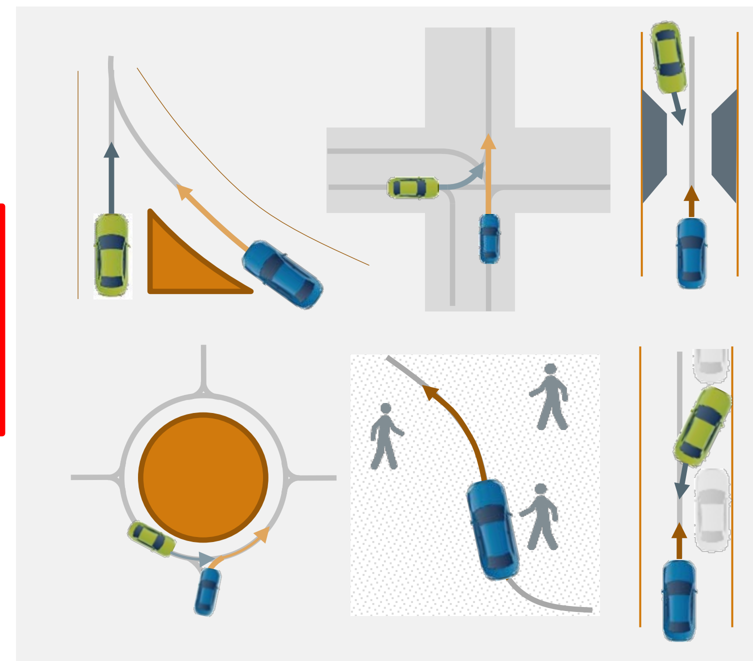
- Video

An Abstract Functional Architecture for Automated Driving

For an automated vehicle guidance, the model and understanding about the current scene and it‘s context are required

		Task of Perception	Task of Driving
Marco Scale	Street Level	**Road Level Env. Modelling** Road Network Traffic Flow	**Navigation** Route Planning
Miso Scale	Lane Level	**Context Understanding** Ego Vehicle State Scene/Scenary Modelling	**Guidance** Situation Assessment Decision Making
Micro Scale	Feature Level	**Feature Extraction** Obj. Detection & Tracking Free Space Detection Lane Tracking	**Stabilization** Trajectory Planning Trajectory Tracking Vehicle Dynamics Control

Addressing Scenarios

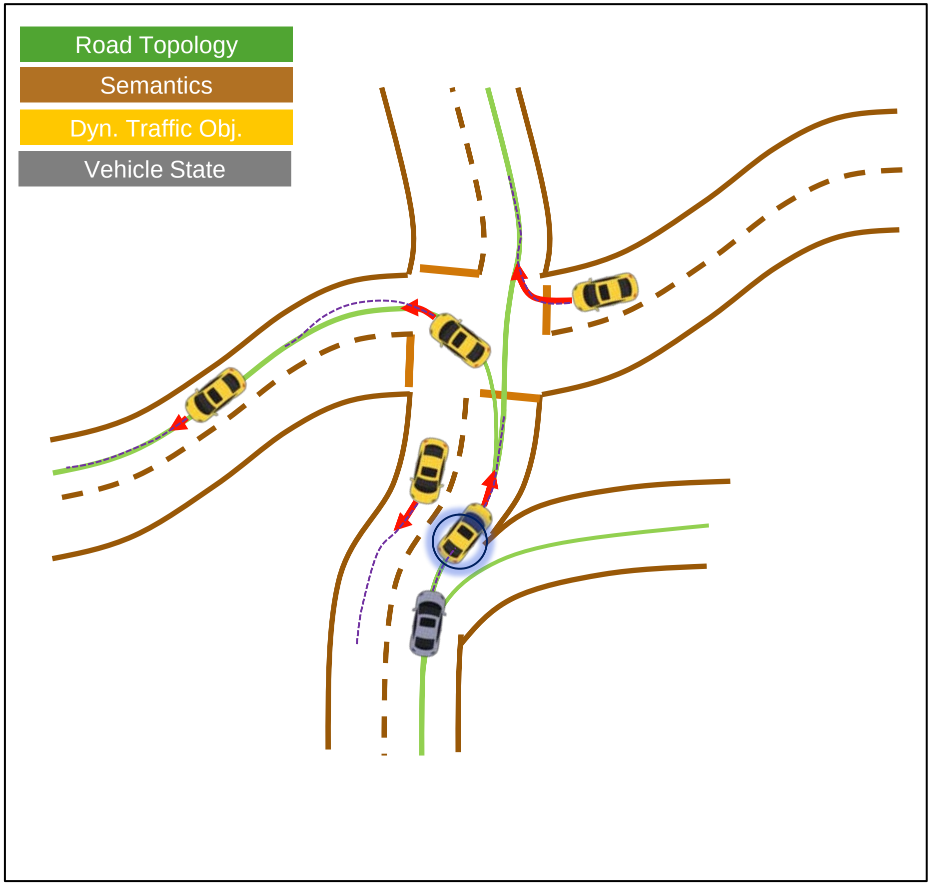


OFP-Platform Provides us with Required Information about the Current Scene with different APIs

OFP Platform

Environment Model

- Static Environment
  - Map Data
- Dynamic Environment
- Vehicle State
  - Driver State



Vehicle Guidance

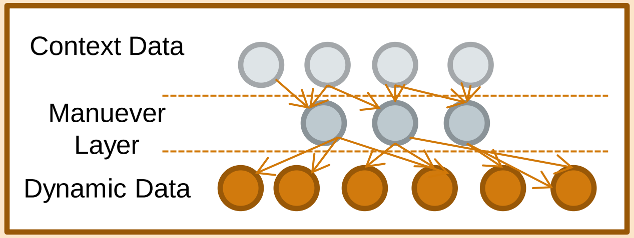
Intention Detection → Trajectory Prediction → Risk Assessment → Decision Making

Intention Detection and Prediction of Road Participants by Using Probabilistic Approaches such as Bayesian Network

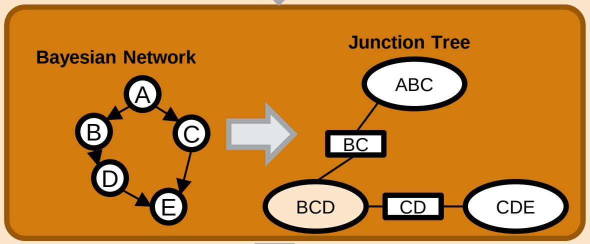
Approach:

Dynamic data: v_{lat}, v_{long} , a_{lat} , a_{long} , …

Context data: $t_{time\text{-}to.turn}$, $t_{time\text{-}to.vehicle}$, $t_{time\text{-}to\text{-}line}$,

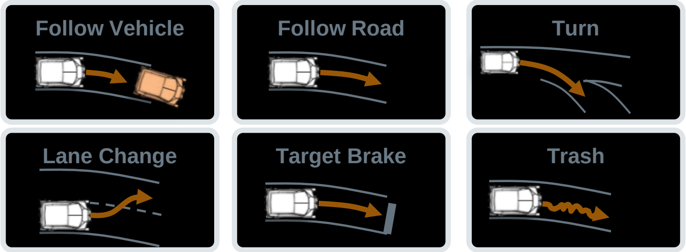


Conversion of Bayesian Network to Junction Tree for better calculation performance

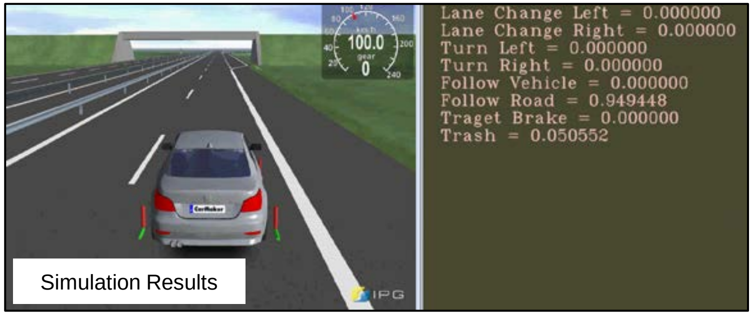


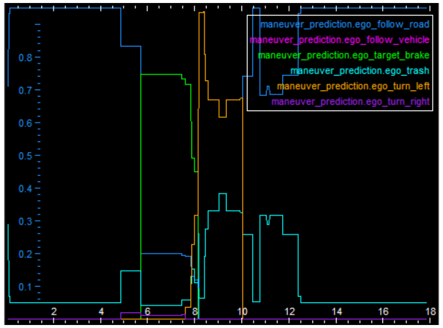
Calculation of probability of each Maneuver based using Junction Tree Algorithm

Maneuver Catalog:

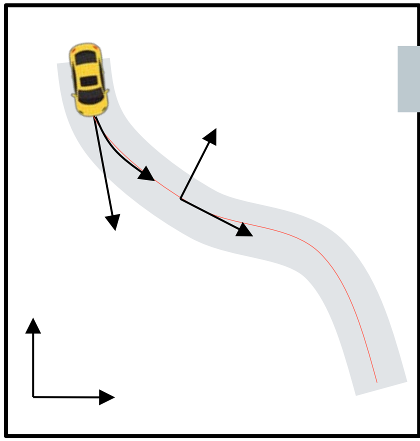
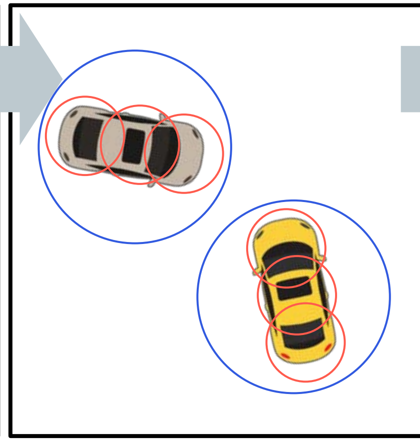
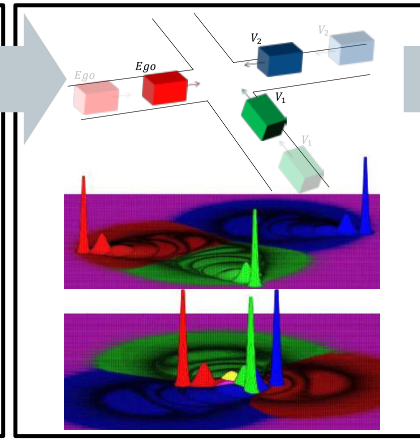
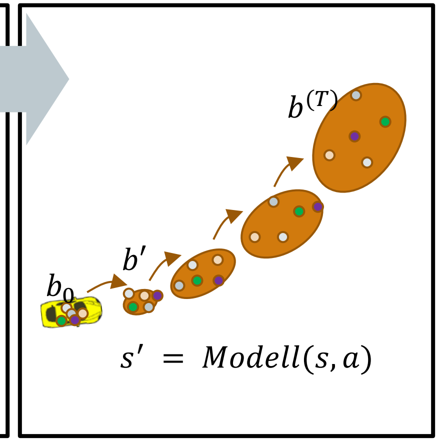


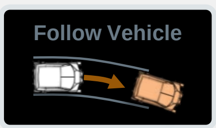
Some Results:

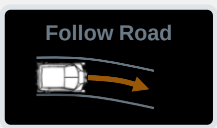


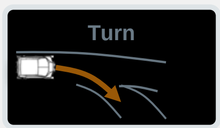


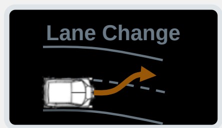
Risk Assessment of the Scene by Calculating the Predicted Trajectory and Collison Probabilities

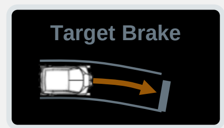
Motion Model in Road Coord. Sys.	Two Step Collision Check	Calculating the Collision Probabilities	Sampling Using Monte Carlo
			

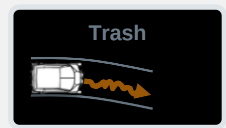












Motion Model	Gap Keeping Model	Constant Acceleration Model	Constant Radius Model: Constant Velocity Model + Constant Acceleration Model	Half Sinus Model: Constant Velocity Model	Constant Acceleration Model (Considering the Distance to Obstacle)	Constant Acceleration Model + Constant Yaw Rate Model

Decision Making under Uncertainties by Using POMDP-Approach

POMDP
Partially Observable
Markov Decision Process:

$S = \{s\} = \{x, y, v_x, v_y\}$ (States)
$A = \{a\} = \{Acc, CV, Dec\}$ (Actions)
$T = P(s'|s, a)$ (Transition)
$R = R(b, a)$ (Rewards)
$Z = \{z\}$ (Measurements)
$O = P(z|s', a)$ (Observation)
$\gamma \in]0; 1[$ (Discount factor)

Action Set A

a_0: Acceleration
a_1: Deceleration
a_2: Constant Velocity

State S

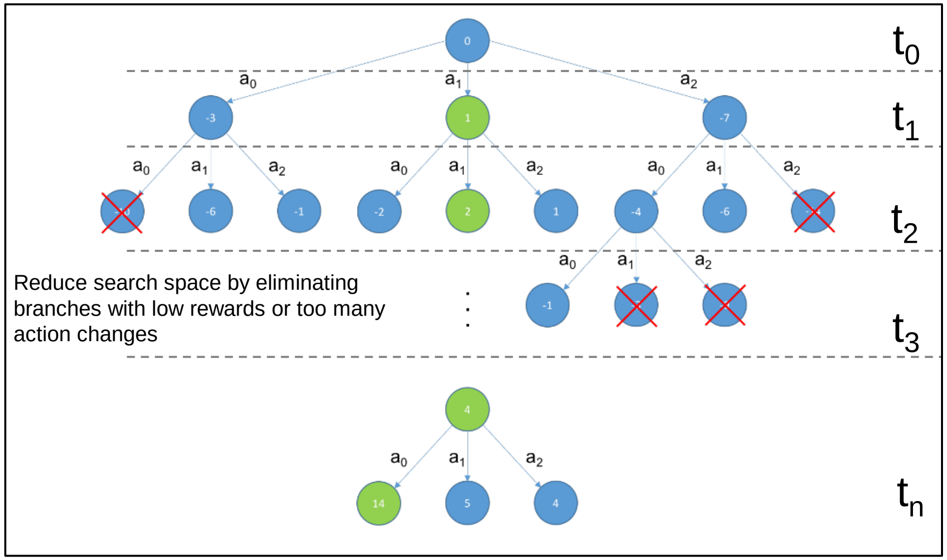
Ego Vehicle

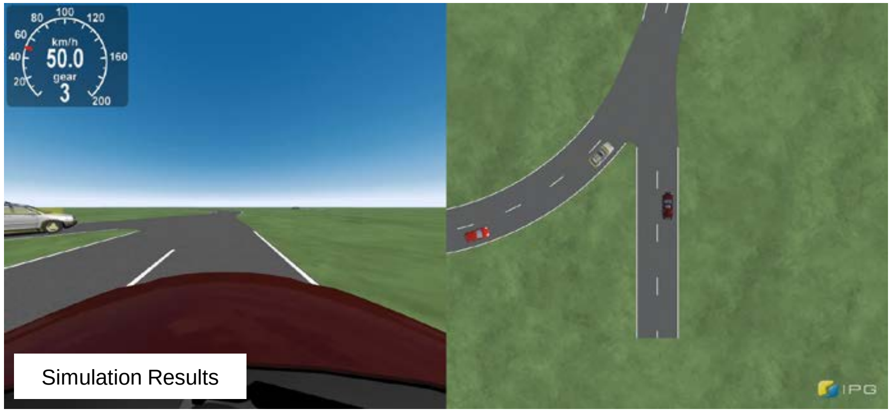
Position (x, y)
Velocity (V_x, V_y)

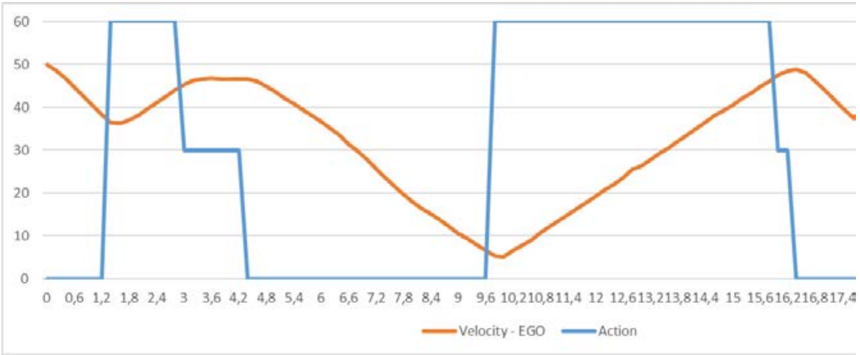
Road Participants

Position (x,y)
Velocity (v_x,v_y)
Intention Model

Evolution of the Scene in each frame







Conclusion and Outlook

- Open fusion platform based on Nvidia DPX2
- Functional architecture as a layer model
- Interface specification based on available standards and generic data types
- Joint learning of semantic segmentation and detection improves the detection
- Automated vehicle guidance using environment model from OFP platform
- Next steps
  - Integration into the DPX2 and test with live data
  - Fine tuning of the models
  - Validation of the algorithms in real scenarios

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Thank you for your Attention!

Open Fusion Platform

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Literature

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2. Evan Shelhamer, Jonathan Long, Trevor Darrell: Fully Convolutional Networks for Semantic Segmentation. CoRR abs/1605.06211 (2016)

3. Cordts, M., Omran, M., Ramos, S., Rehfeld, T., Enzweiler, M., Benenson, R., Franke, U., Roth, S., Schiele, B.: The Cityscapes Dataset for Semantic Urban Scene Understanding. In: Proc. of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR) (2016)