AutoMate:

rEvolution in vehicle automation

Driver State Modelling

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690705

Description

The Driver Monitoring System (DMS) estimates driver physiological and behavioural states including drowsiness and visual distraction. It is a vision-based system which uses a camera integrated in the cockpit observing the driver's face. The system detects, tracks the driver's face and computes features as eye closure, eye/head gaze, head pose required to model the different driver states. DMS is fully automatic, works in real time by night and day conditions. The Automate Human Machine Interaction (HMI) module makes use of the state estimation to adapt the takeover strategies and warnings. The following basic use case illustrates this interaction: when the vehicle is in automation mode the HMI shall not give back the control of the vehicle to an inattentive or sleepy driver.

Demonstrators where it is integrated

VED vehicle demonstrator

ULM simulator demonstrator

REL simulator demonstrator

CRF vehicle demonstrator

OFFIS broadbit Continental CRF DLR Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center HUMATECTS PSA GROUPE RE:Lab ulm university universität ulm VEDECOM

Project Coordinator:
Dr. Andreas Luedtke
E-Mail:
luedtke@offis.de

Dissemination Manager:
Serena Fruttaldo
E-Mail:
serena.fruttaldo@re-lab.it

AutoMate:

rEvolution in vehicle automation

V2X

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690705

Description

Vehicle-to-Everything (V2X) communication is one of the key enablers of future transport systems. Although it is well standardized, it is still in emerging phase. V2X promises more efficient traffic and reduced accident rate by utilizing the cooperation of vehicles (V2V communication) and the infrastructure (V2I communication). From other point of view V2X can be considered as another sensor of the vehicle, which provides input data, but it perceives objects, obstacles and traffic situations in a different manner. The information gained from V2X communication is used for notifying the driver and for improving the decision making process. In AutoMate the infrastructure informs the vehicle and its driver about an oncoming dangerous roadwork that requires attention from the driver.

Demonstrators where it is integrated

VED vehicle demonstrator

Project Coordinator:
Dr. Andreas Luedtke
E-Mail:
luedtke@offis.de

Dissemination Manager:
Serena Fruttaldo
E-Mail:
serena.fruttaldo@re-lab.it

AutoMate:

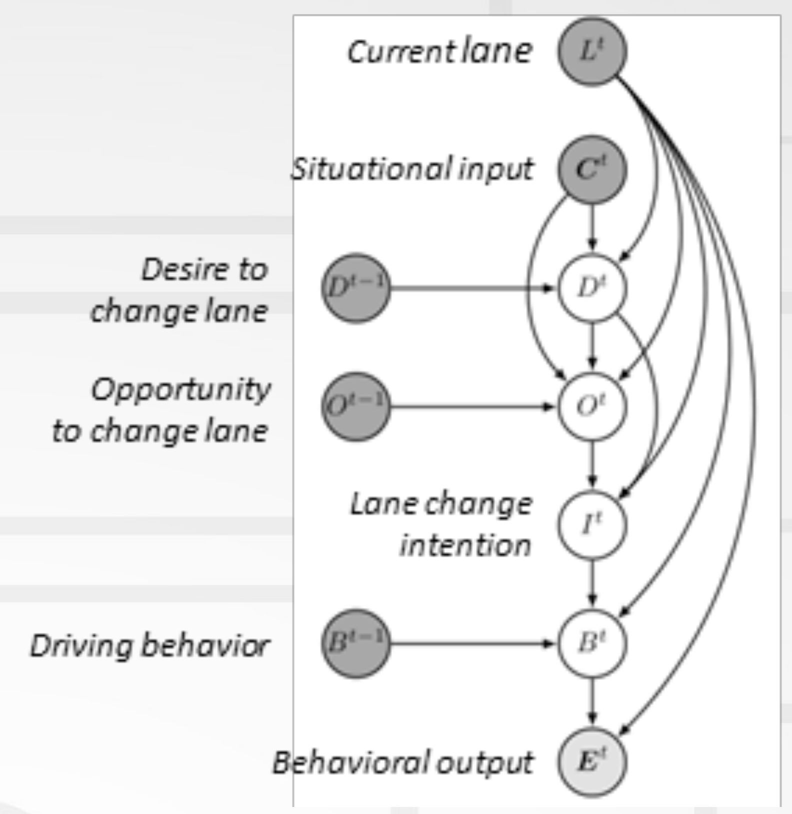
rEvolution in vehicle automation

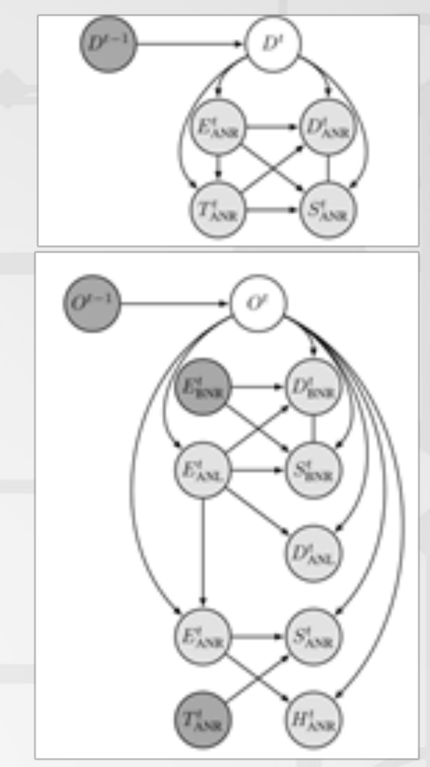
Driver intention Recognition

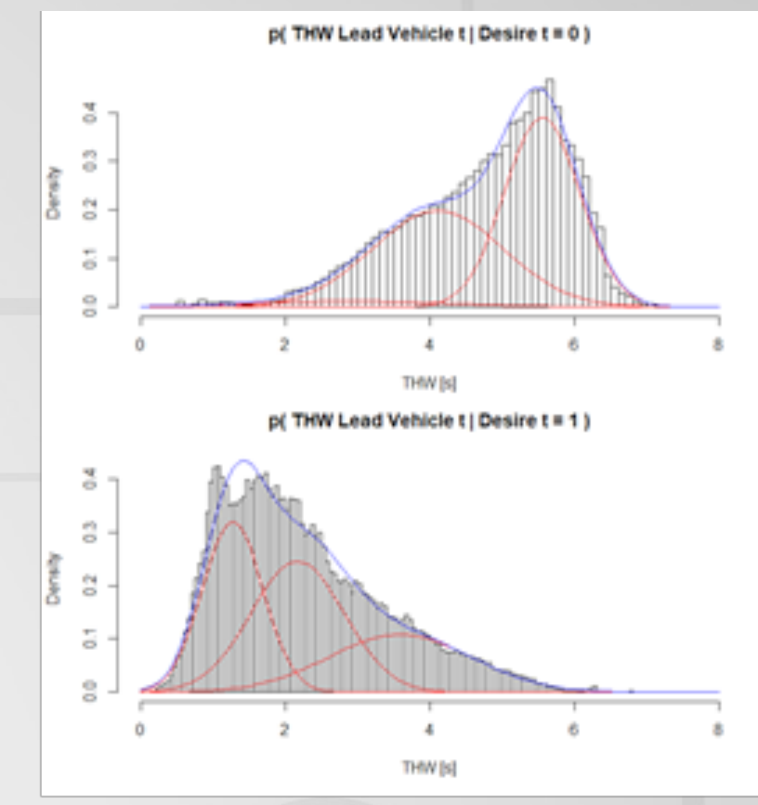
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690705

Description

To develop a shared understanding between the driver and the automation, the TeamMate car requires knowledge about the current manoeuvre intentions of the driver. When the driver is in control, such knowledge can be used to assess the safety of intended maneuvers and provide adequate information and warnings. If the automation is in control, it can be used to trigger intention-compliant behavior of the automation or to detect and communicate mismatches between the driver's intention and the TeamMate car's behavior. For this, the TeamMate vehicle uses probabilistic models for recognizing and predicting maneuver intentions in rural road and roundabout scenarios. The models are designed as (conditional) Dynamic Bayesian Networks that are learnt by machine-learning methods from annotated time-series of human driving behavior.







Demonstrators where it is integrated

VED vehicle demonstrator

ULM simulator demonstrator

REL simulator demonstrator

Project Coordinator:
Dr. Andreas Luedtke
E-Mail:
luedtke@offis.de

Dissemination Manager:
Serena Fruttaldo
E-Mail:
serena.fruttaldo@re-lab.it

AutoMate:

rEvolution in vehicle automation

Semantic Enrichment

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690705

Description

Semantic enrichment enables the TeamMate car to attach semantic information to perceived traffic participants. Semantic information such as which maneuvers other traffic participants are allowed to do next is difficult to obtain from sensor inputs alone but critical to predict future evolutions of traffic scenes. An ontology representing a taxonomy of scene elements and their relationships has been created using the Web Ontology Language (OWL). Traffic rules are made available using the Semantic Web Rule Language (SWRL). The modeled ontology captures semantic, temporal, and spatial relations between scene entities. Combining OWL and SWRL yields a complete knowledge base from which permissible maneuvers can be inferred at runtime when provided with the dynamic objects in the TeamMate car's vicinity.

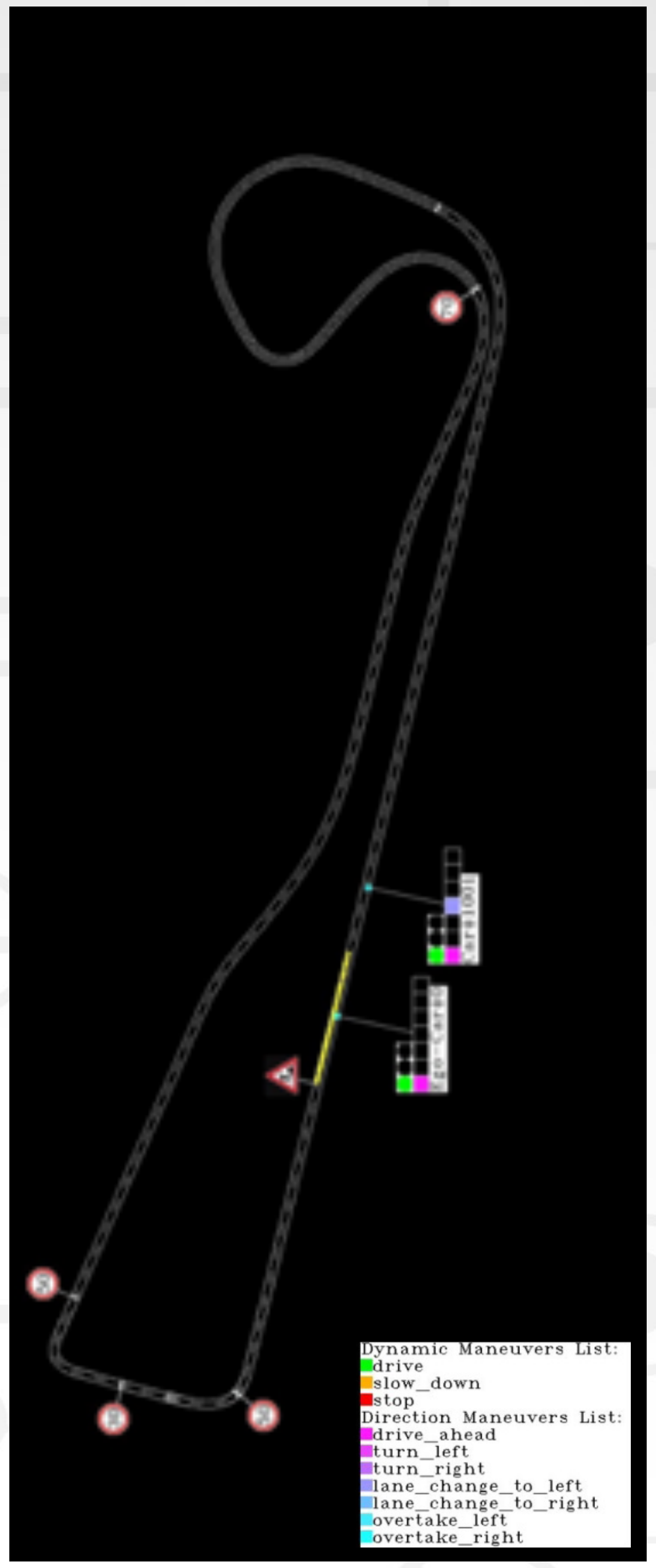
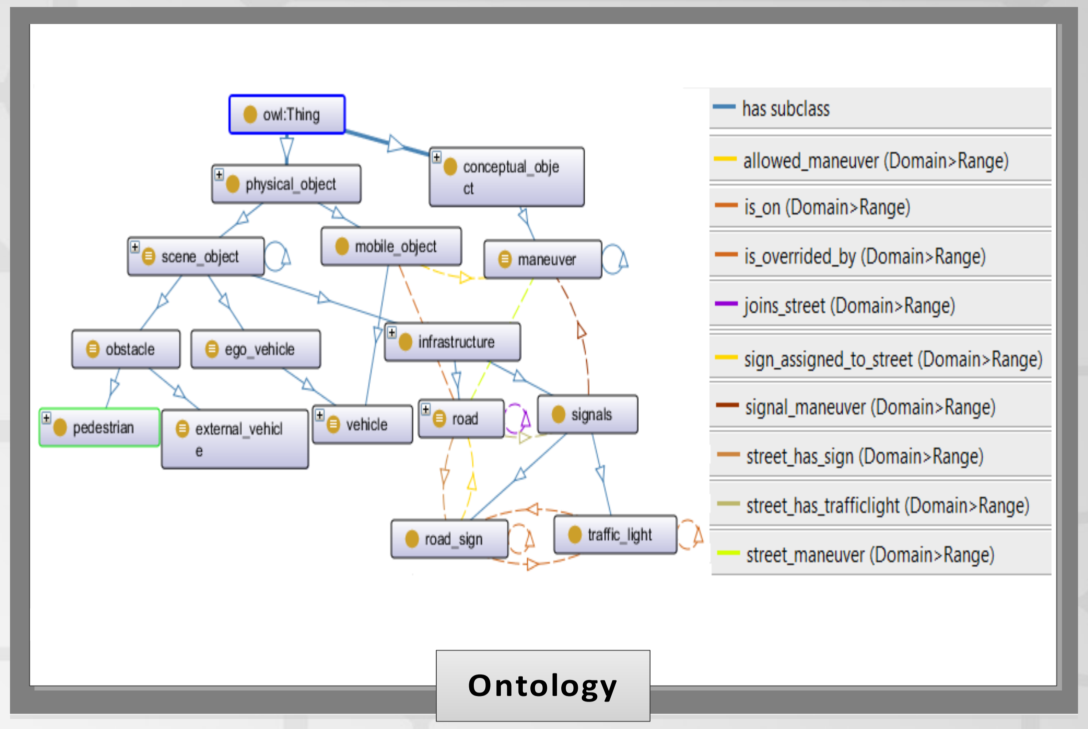


Figure 1: *Inferred permissible driving maneuvers for traffic objects within the vicinity of the TeamMate car.*



Name	Rule	Meaning
R1	stop_sign(?s) ^ maneuver(?m) ^ signal_maneuver(?s,?m) → stop(?m)	Stop sign allows stop maneuver
R2	give_way_sign(?s) ^ maneuver(?m) ^ signal_maneuver(?s,?m) → slow_down(?m)	Give way sign allows slow maneuver
R3	traffic_light(?l) ^ has_tl_state(?l,?s) ^ red_light(?s) ^ signal_maneuver(?l,?m) → stop(?m)	Red traffic light allows stop maneuver
R4	traffic_light(?l) ^ road(?r) ^ road_sign(?s) ^ trafficlight_assigned_to_street(?l,?r) ^ sign_assigned_to_street(?s,?r) ^ signal_maneuver(?s,?m) ^ signal_maneuver(?l,?m2) → street_maneuver(?r,?m2)	Traffic lights has high priority comparing to traffic signs, if both are assigned to the same road
R5	road(?r) ^ road_sign(?s) ^ sign_assigned_to_street(?s,?r) ^ no_trafficlight_assigned_to_street(?r,true) ^ signal_maneuver(?s,?m) → street_maneuver(?r,?m)	maneuver allowed on that road depend on the assigned traffic sign where there is no traffic light
R6	mobile_object(?o) ^ road(?r) ^ street_maneuver(?r,?m) ^ is_on(?o,?r) → allowed_maneuver(?o,?m)	Traffic participants allowed maneuvers depend on the road there are on
R7	road(?r) ^ road_vehicle(?o) ^ is_on(?o,?r) ^ has_max_speed_value(?r,?v) → has_max_speed_value(?o,?v)	Vehicles allowed maximal velocity depend on the road there are on

Traffic Rules using SWRL

Figure 2: *The Knowledge Base with domain knowledge modeled with OWL and traffic rules modeled with SWRL.*

Demonstrators where it is integrated

VED vehicle demonstrator

Project Coordinator:
Dr. Andreas Luedtke
E-Mail:
luedtke@offis.de

Dissemination Manager:
Serena Fruttaldo
E-Mail:
serena.fruttaldo@re-lab.it

AutoMate:

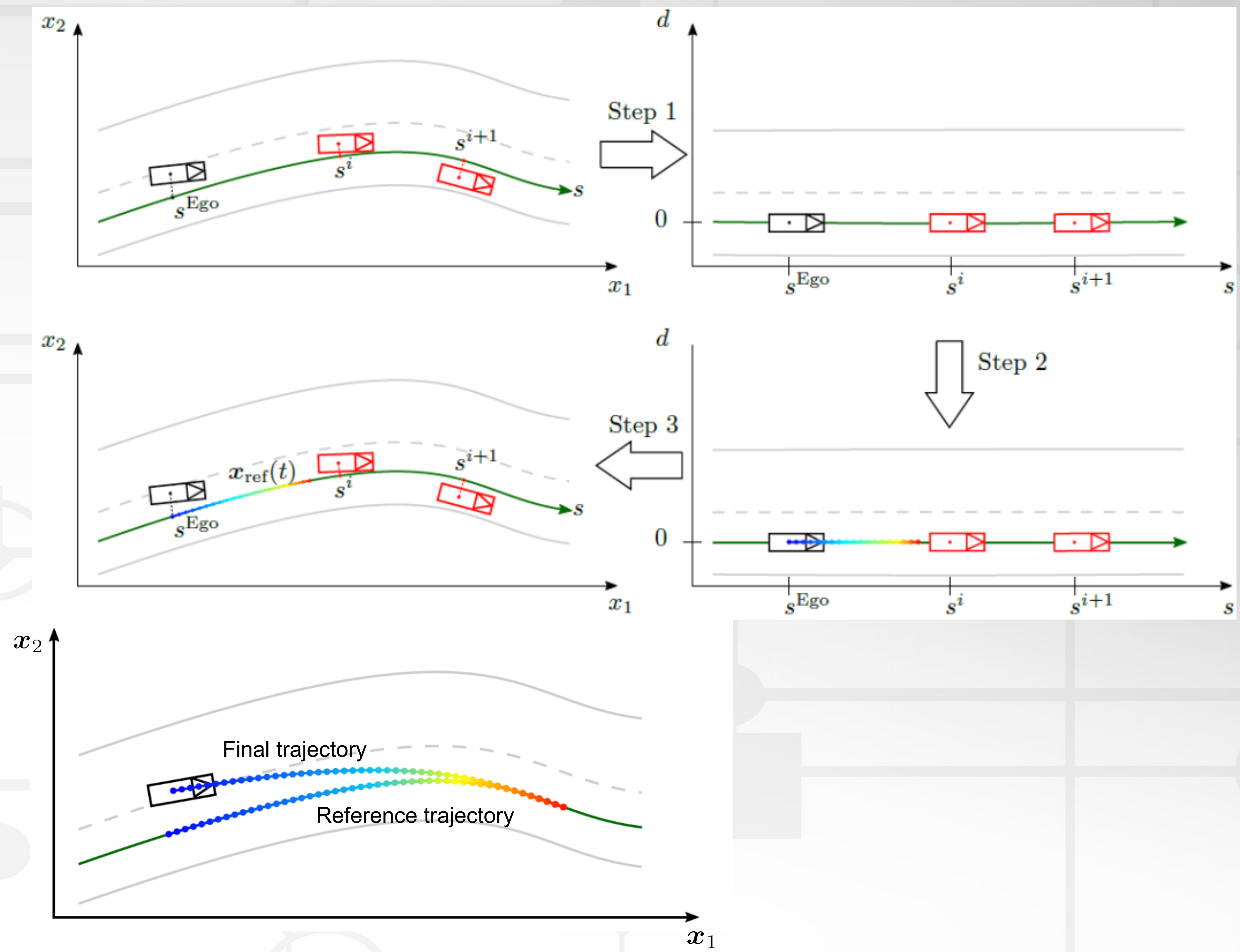
rEvolution in vehicle automation

Planning and execution of safe maneuver

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690705

Description

Based on the environmental model, trajectory planning has to be performed to guide the vehicle safe and comfortable through the environment. The trajectory planning algorithm used within the TeamMate concept was designed for on road driving. Necessary inputs for the planner are a pre-recorded digital map for having the road infra structure information. The ego vehicle state, which is identical to the start state of the trajectory to be planned, vehicle tracks to keep safe distances from and the information input from the driver. Based on this information, the first step is to project the vehicle on the center line of the one road the planner aims to guide the vehicle towards. A driver model is integrated over the planning horizon to obtain a "reference"-trajectory. This reference is then included into the cost functional of an optimal control problem.



Demonstrators where it is integrated

VED vehicle demonstrator

ULM vehicle demonstrator

Project Coordinator:
Dr. Andreas Luedtke
E-Mail:
luedtke@offis.de

Dissemination Manager:
Serena Fruttaldo
E-Mail:
serena.fruttaldo@re-lab.it

AutoMate:

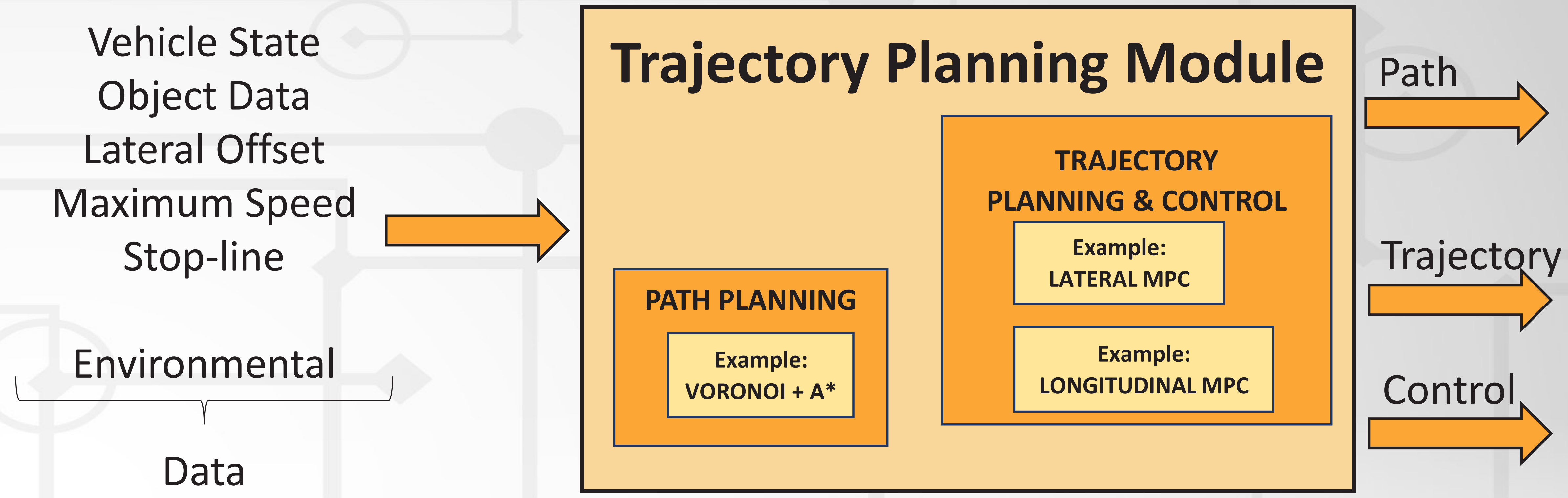
rEvolution in vehicle automation

Planning and execution of safe maneuver

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690705

Description

Trajectory planning and execution are two basic requirements for autonomous driving and must be present in every automatically controlled vehicle. In AutoMate, we focused on aspects of decision-making, motion planning and control for self-driving cars.This module takes as inputs the driver's state and the environment situation. Based on this data, potential strategic maneuvers are identified and planned up to a concrete action sequence at operational level. The aim of control is to follow longitudinal speed and distance references defined by the driver or by road camera information available. The aim of lateral control is to minimize lateral deviation and heading angle errors, ensuring the vehicle stability. The resulting plans include a suitable task distribution plan between driver and automation.



Demonstrators where it is integrated

CRF vehicle demonstrator

Project Coordinator:
Dr. Andreas Luedtke
E-Mail:
luedtke@offis.de

Dissemination Manager:
Serena Fruttaldo
E-Mail:
serena.fruttaldo@re-lab.it

AutoMate:

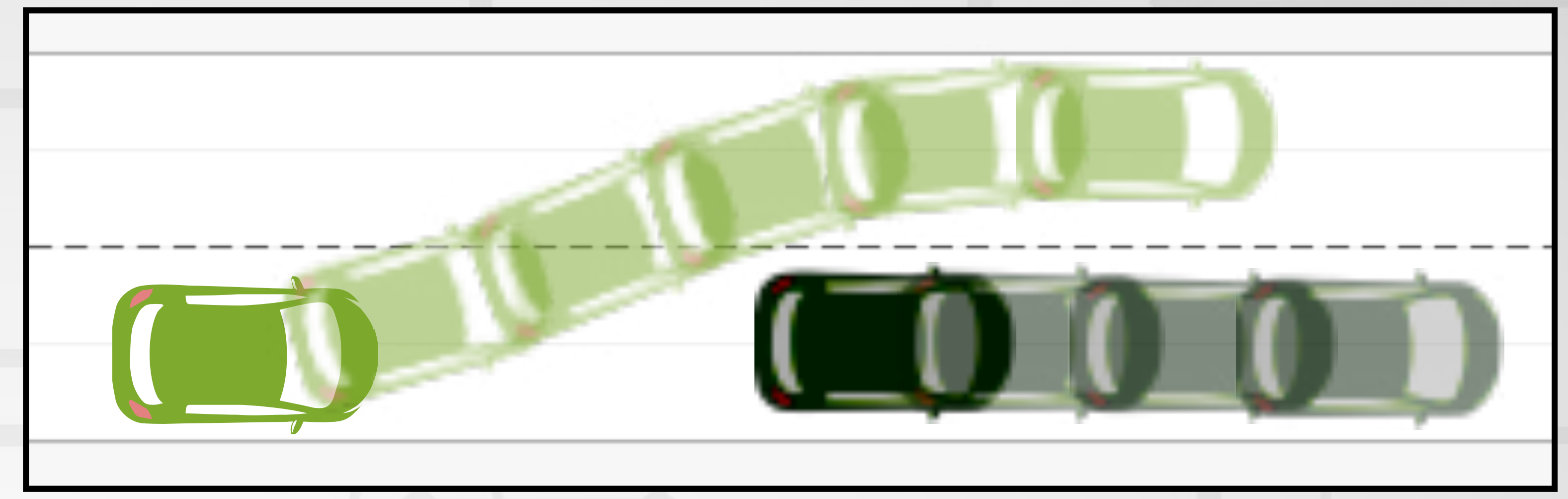
rEvolution in vehicle automation

Online Learning

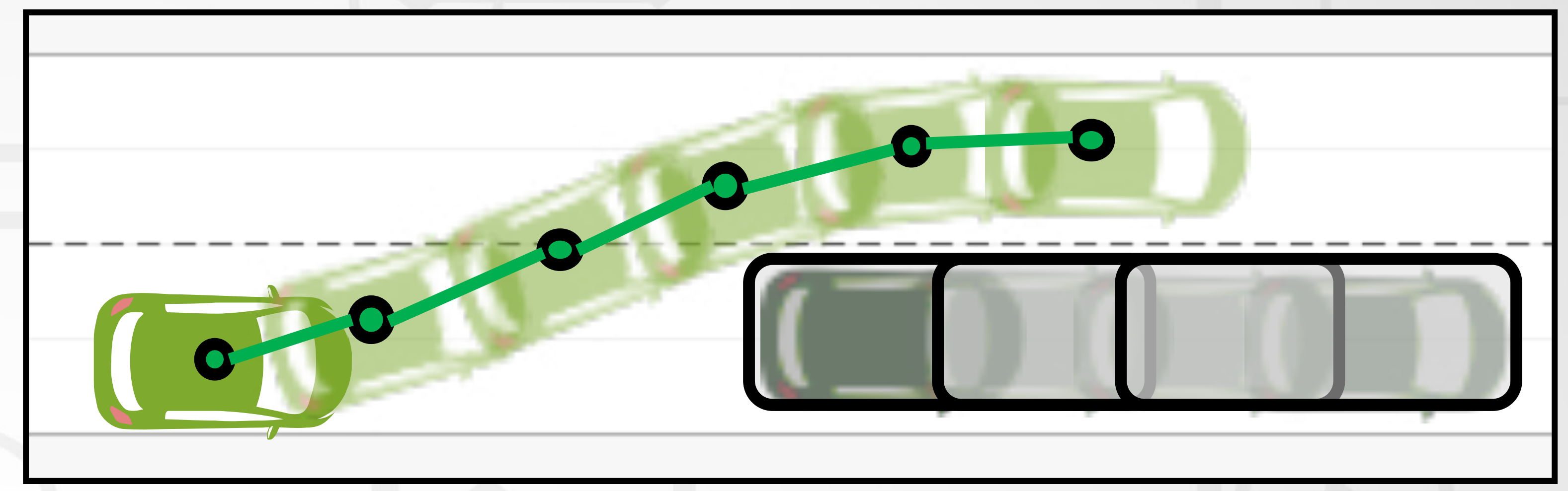
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690705

Description

The Online Learning of Intention from the Driver updates the Driver Intention Recognition model while driving to fit the individual driver. This shall improve cooperation due to reduced false alarms for the lane change intention recognition and the adaptation of the automation behavior to the driver's preferences. Via Bayesian parameter learning and the usage of hyper-parameters the distribution parameters of the underlying Dynamic Bayesian Network are recalibrated. The hyper-parameters describe probability distributions over the model parameters and are updated as new evidence becomes available through observations while driving. To create a complete training data set the required labels are generated in the process via smoothing or with rules to interpret the driver feedback provided via the HMI.

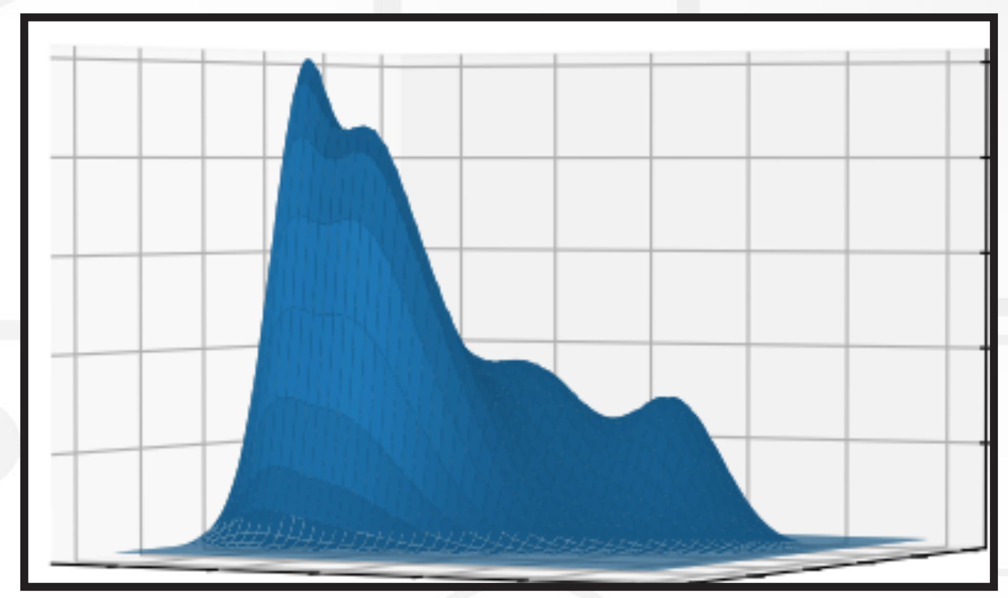


Get Evidence via Observation

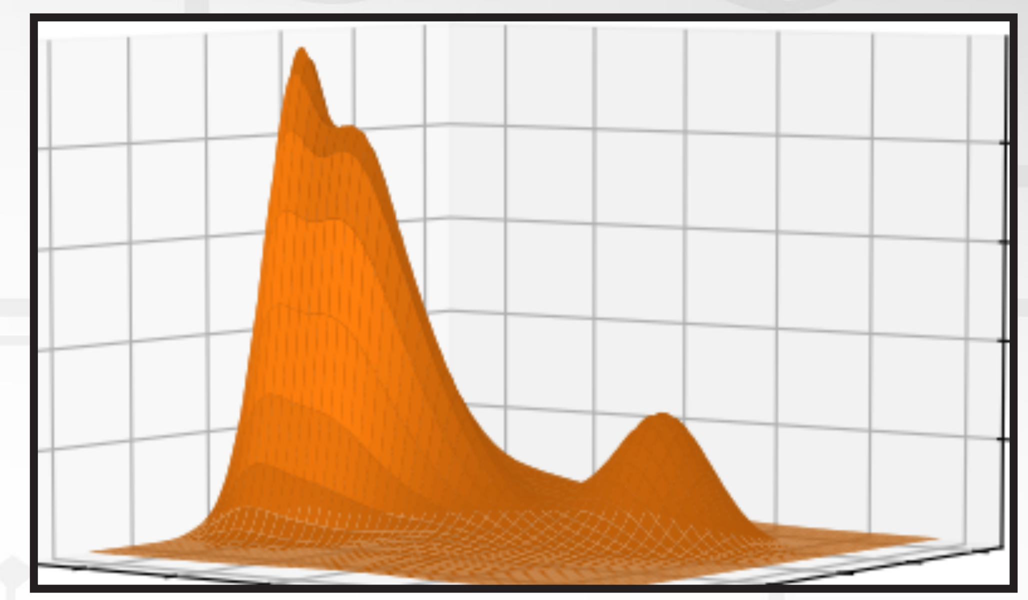


Labelling via Smoothing/Rules

Bayesian Parameter Update



Example Distribution from initial Model



Updated Distribution

Demonstrators where it is integrated

VED vehicle demonstrator

ULM simulator demonstrator

Project Coordinator:
Dr. Andreas Luedtke
E-Mail:
luedtke@offis.de

Dissemination Manager:
Serena Fruttaldo
E-Mail:
serena.fruttaldo@re-lab.it

AutoMate:

rEvolution in vehicle automation

Online Risk Assessment

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690705

Description

Calculating safe and feasible trajectories for the TeamMate car requires a safety corridor which needs to be within the boundaries of the road and free from dynamic objects. Using satellite navigation allows localizing a car on a map, but the location retrieved will be inaccurate due to blocked or distorted satellite signals. The uncertainty information associated with the satellite navigation system can be used to estimate the corridor within the road boundaries which can still be considered safe, conditional on the current uncertainty and a user provided acceptable risk threshold. The module can then quantify the risk of trajectories planned by the TeamMate car based on the uncertainty of the localization. The risk quantification is based on the time-to-collision safety surrogate measure.

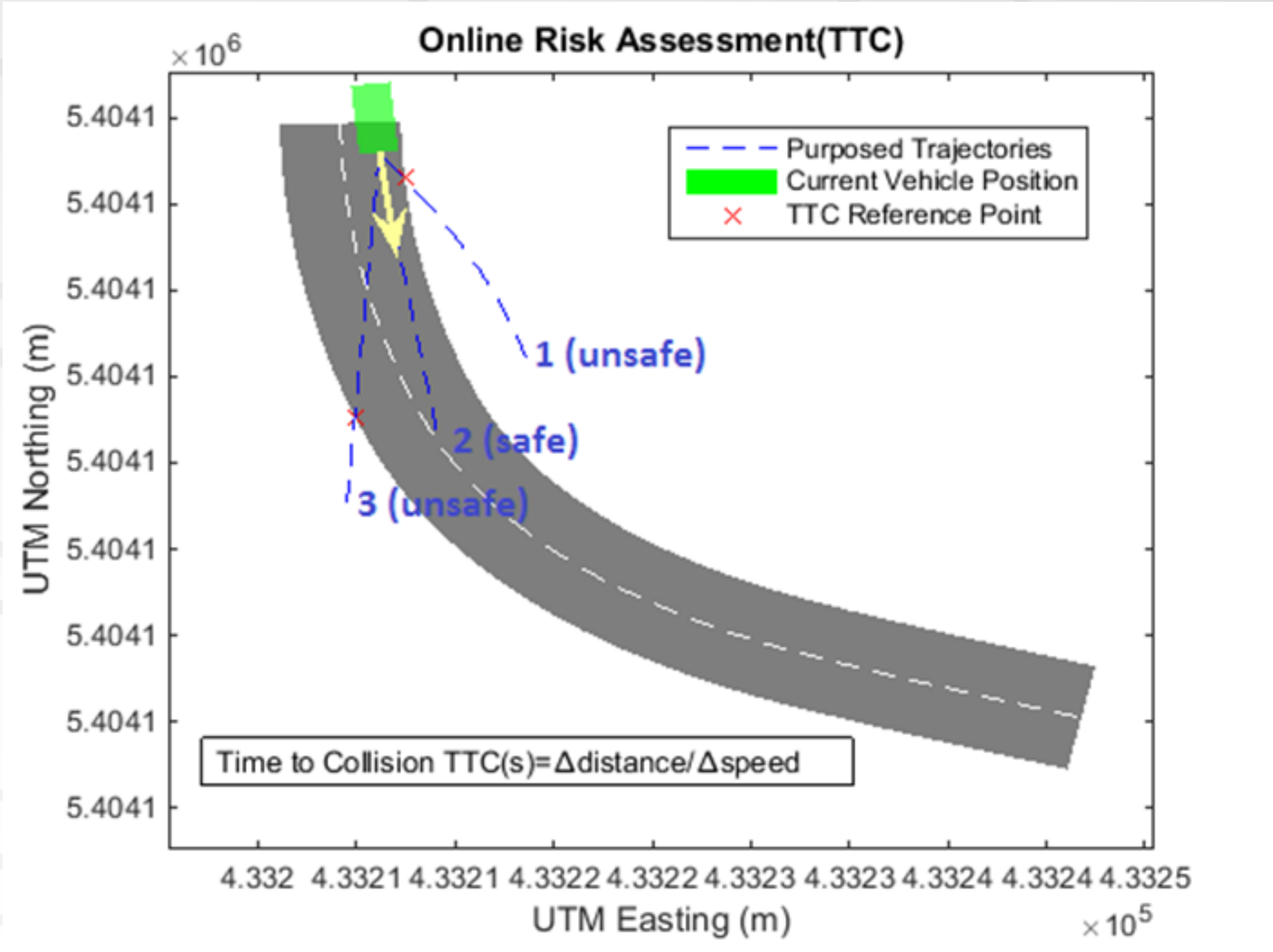


Figure 1: *Trajectory assesment within the safety corridor envelope.*

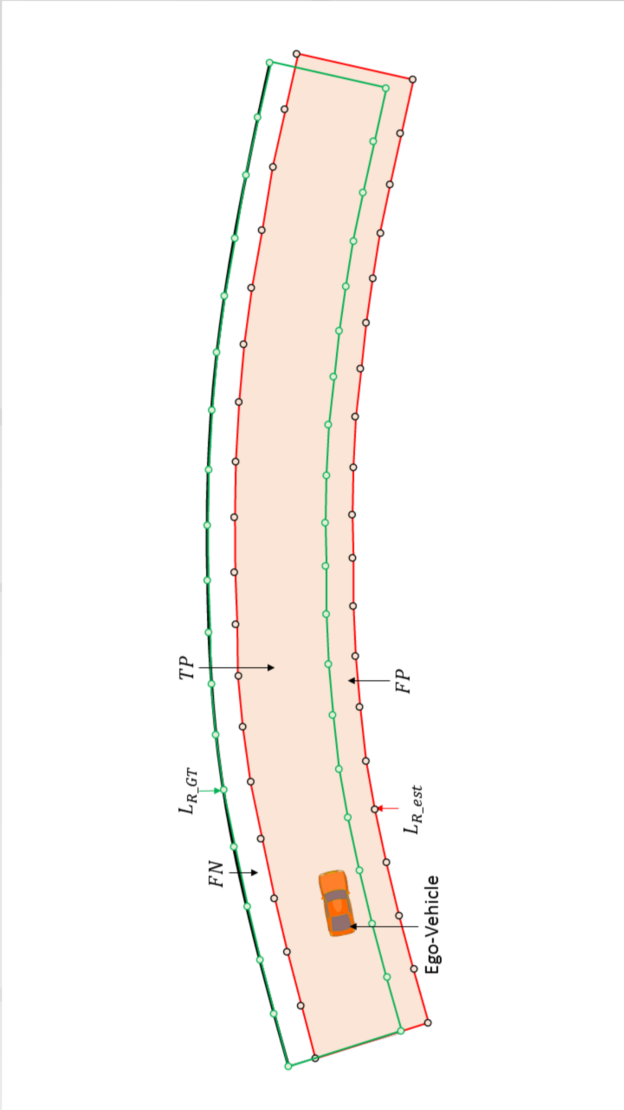


Figure 3: *Illustration of the extracted safety corridor using the user provided risk threshold and the localization uncertainty.*

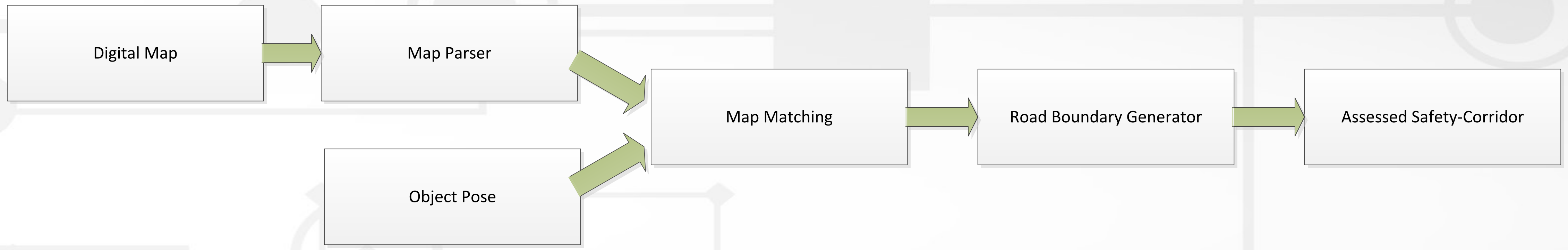


Figure 2: *Process chain depicting the realization of Online Risk Assessment using boundary corridor.*

Demonstrators where it is integrated

VED vehicle demonstrator

Project Coordinator:
Dr. Andreas Luedtke
E-Mail:
luedtke@offis.de

Dissemination Manager:
Serena Fruttaldo
E-Mail:
serena.fruttaldo@re-lab.it

AutoMate:

rEvolution in vehicle automation

Online Risk Assessment: Dynamic Objects

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690705

Description

The purpose of online risk assessment in AutoMate is the calculation of *safety corridors* that quantify the safety of the current and near-future traffic situation according to a metric of risk. A safety corridor is a geometric interpretation of the area in which the probability of the TeamMate car colliding with another object for a specific temporal interval is bounded by a user-defined threshold. The safety corridors are derived from the predicted spatial and temporal evolution of traffic participants observed in the vicinity of the TeamMate car. Once constructed, safety corridors can be used by the TeamMate car to plan safe trajectories, assess the safety of a trajectory planned by the automation, or assess the safety of a trajectory predicted for the human driver prior to its execution.

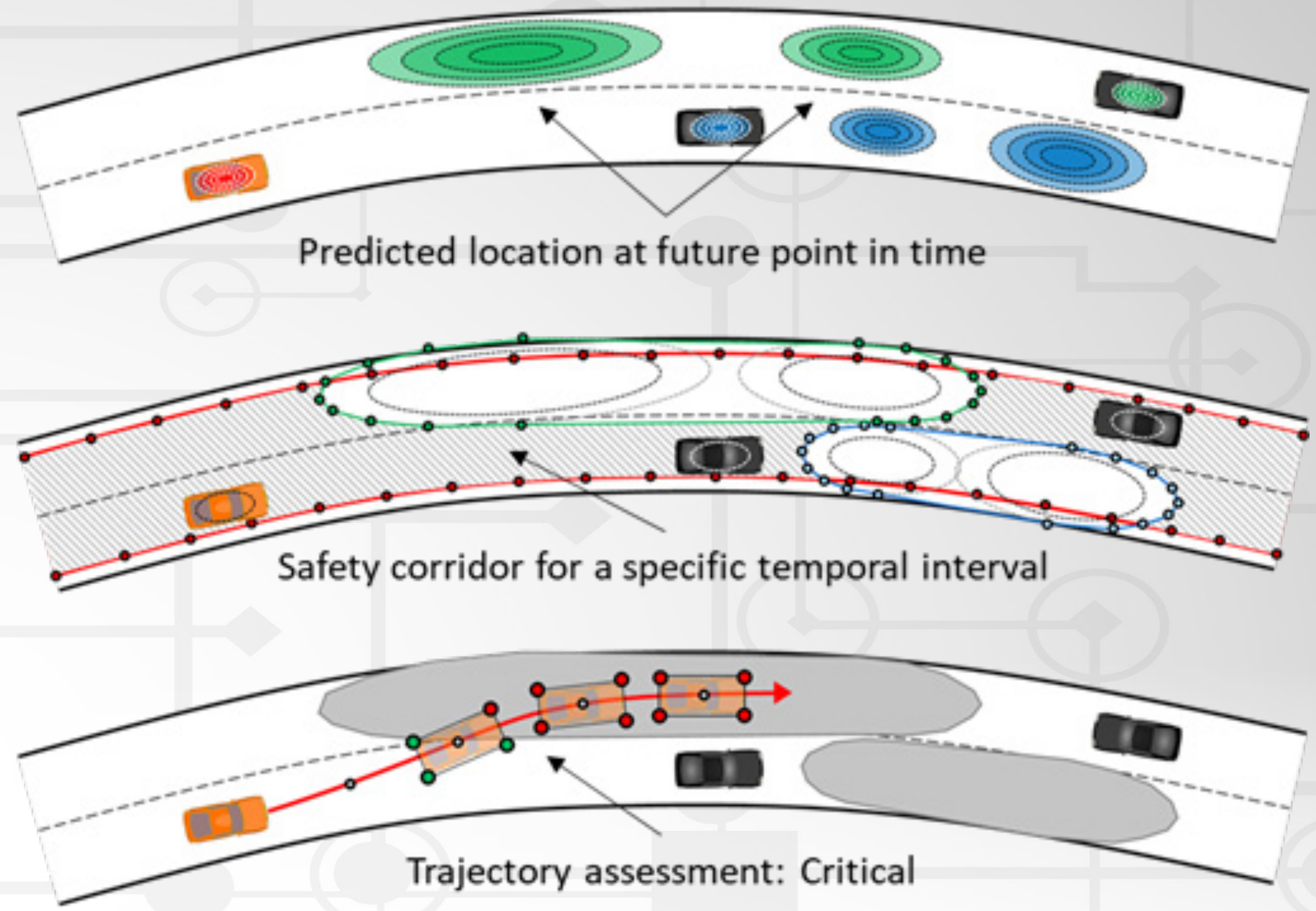


Figure: *The predicted location and pose of vehicles at consecutive points in time are combined into polygons enclosing probable locations of vehicles for a temporal interval. Together, they define a safety corridor in which the TeamMate vehicle may maneuver with bounded risk of collision. This allows a fast assessment of trajectories as safe or critical by checking, whether the TeamMate vehicle leaves the safety corridor in a specific temporal interval.*

Demonstrators where it is integrated

VED vehicle demonstrator

ULM simulator demonstrator

Project Coordinator:
Dr. Andreas Luedtke
E-Mail:
luedtke@offis.de

Dissemination Manager:
Serena Fruttaldo
E-Mail:
serena.fruttaldo@re-lab.it

AutoMate:

rEvolution in vehicle automation

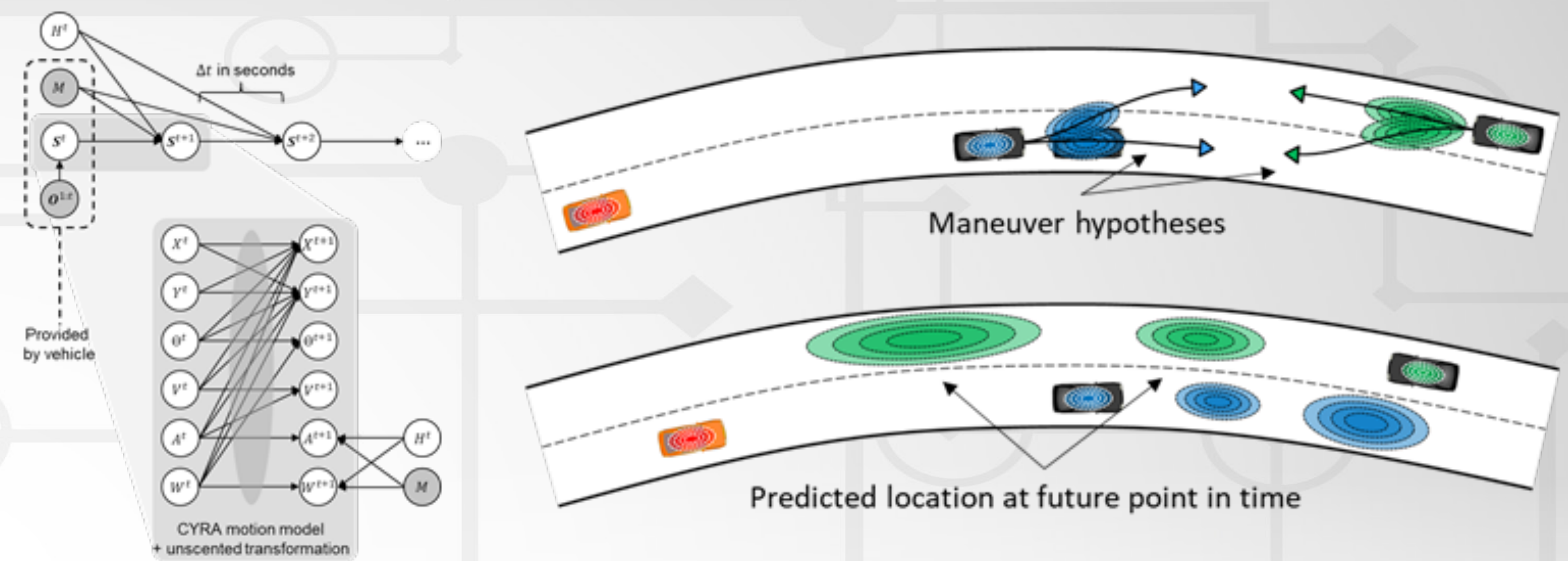
Traffic Prediction

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690705

Description

The TeamMate car requires the ability to anticipate the future evolution of the traffic scene. To achieve this goal, the traffic prediction comprises situation and vehicle models in a probabilistic model that can predict the temporal and spatial evolution of traffic participants observed in the vicinity of the TeamMate vehicle (including the TeamMate vehicle itself). In this model, a traffic participant is represented by a six-dimensional Gaussian belief state, comprising its location, yaw angle, velocity, acceleration, and yaw-rate. The dynamics of a traffic participants are modelled via the constant yaw-rate and acceleration (CYRA) motion model. A map of the environment and simple driver models are used to derive probable future control signals. Passing belief states through the non-linear system dynamics is achieved by unscented transformation.

A probabilistic model is used to predict the spatial evolution of the observed states of all vehicles. Short-term predictions are used to predict different maneuver hypotheses. New sensor observations are then used to infer the most probable maneuver and predict its long-term evolution.



Demonstrators where it is integrated

VED vehicle demonstrator

ULM simulator demonstrator

Project Coordinator:
Dr. Andreas Luedtke
E-Mail:
luedtke@offis.de

Dissemination Manager:
Serena Fruttaldo
E-Mail:
serena.fruttaldo@re-lab.it

AutoMate:

rEvolution in vehicle automation

Interaction Modality

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690705

Description

To support the cooperation between the driver and the TeamMate car in the context of highly automated driving, it is necessary to understand the impact of interfaces, especially how different interaction modalities influence the cooperation. This Enabler ("Interaction Modality") provides Guidelines to design an adequate and cooperative interaction between the driver and the TeamMate car, following the TeamMate concept. The Guidelines provide suggestions for the implementation and the particular use of other enablers to meet the requirements for a successful cooperation. Based on the empirical results of the different interaction modalities in the driving simulator and existing literature, ten guidelines which define the modality, needed feedback and restriction have been derived. A particular focus was laid on the different interaction modalities that are used for the interface.

Demonstrators where it is integrated

VED vehicle demonstrator

ULM simulator demonstrator

REL simulator demonstrator

CRF vehicle demonstrator

VED simulator demostrator

ULM vehicle demostrator

Project Coordinator:
Dr. Andreas Luedtke
E-Mail:
luedtke@offis.de

Dissemination Manager:
Serena Fruttaldo
E-Mail:
serena.fruttaldo@re-lab.it

AutoMate:

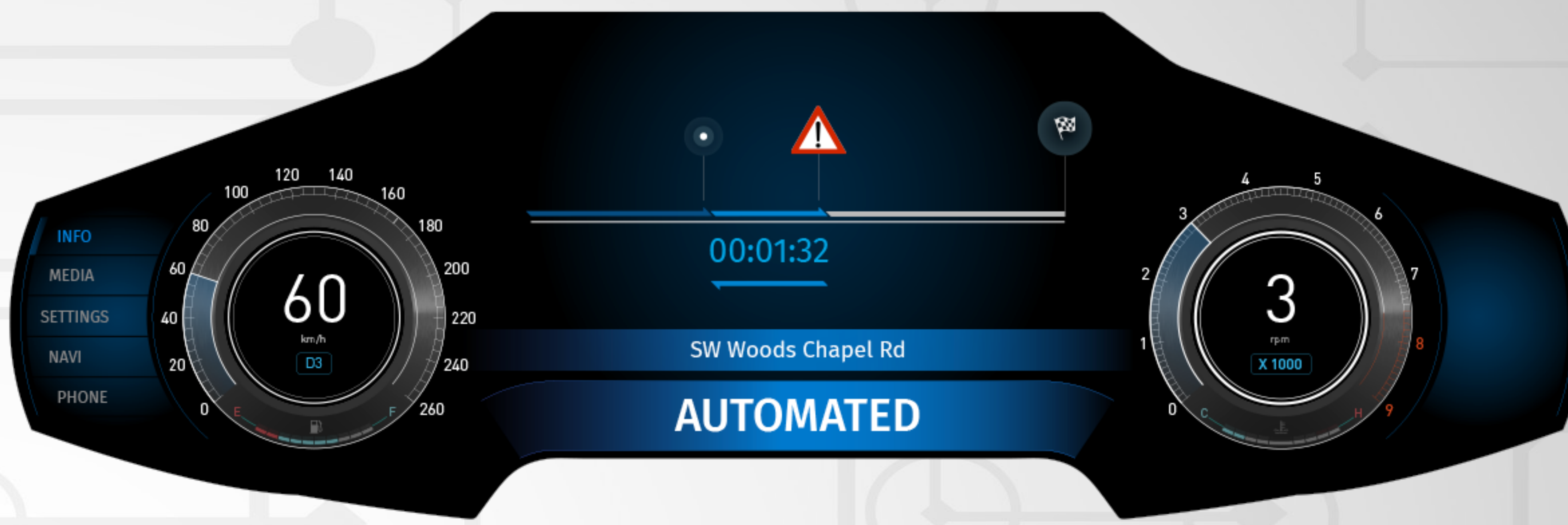
rEvolution in vehicle automation

TeamMate Multimodal HMI

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690705

Description

The TeamMate multimodal HMI aims to exploit the complementarity of humans and automation at perceptual, decisional and actuation level. The interaction developed in AutoMate consists in a dialogue between the human and the automation. It increases the system effectiveness by explaining the reason of the vehicle's limitation and the action expected from the user. The tests performed in the project show that this explanation increases the driver's awareness, the acceptance and the trust without increasing the workload. The other relevant topic related to human-automation interaction, i.e. the "driver in the loop", has been addressed developing an incremental and state-adaptive strategy, deployed with a multimodal interface, based on visual and audio messages, haptics and information provided on a nomadic device.The HMI has been developed through an iterative design process with the involvement of real users in a driving simulator.



Demonstrators where it is integrated

VED vehicle demonstrator

ULM vehicle demostrator

CRF vehicle demostrator

VED simulator demostrator

ULM simulator demostrator

REL simulator demostrator

Project Coordinator:
Dr. Andreas Luedtke
E-Mail:
luedtke@offis.de

Dissemination Manager:
Serena Fruttaldo
E-Mail:
serena.fruttaldo@re-lab.it

AutoMate:

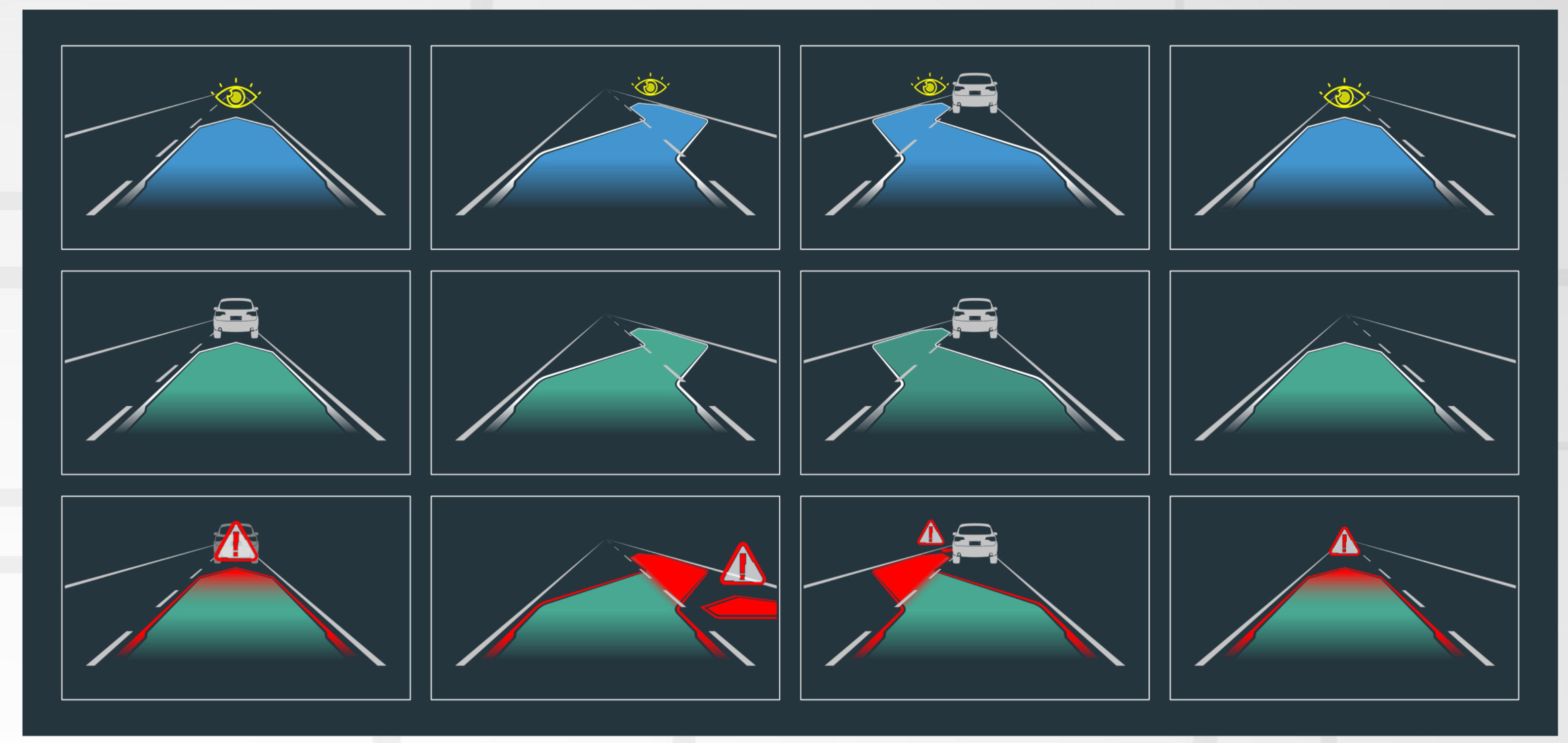
rEvolution in vehicle automation

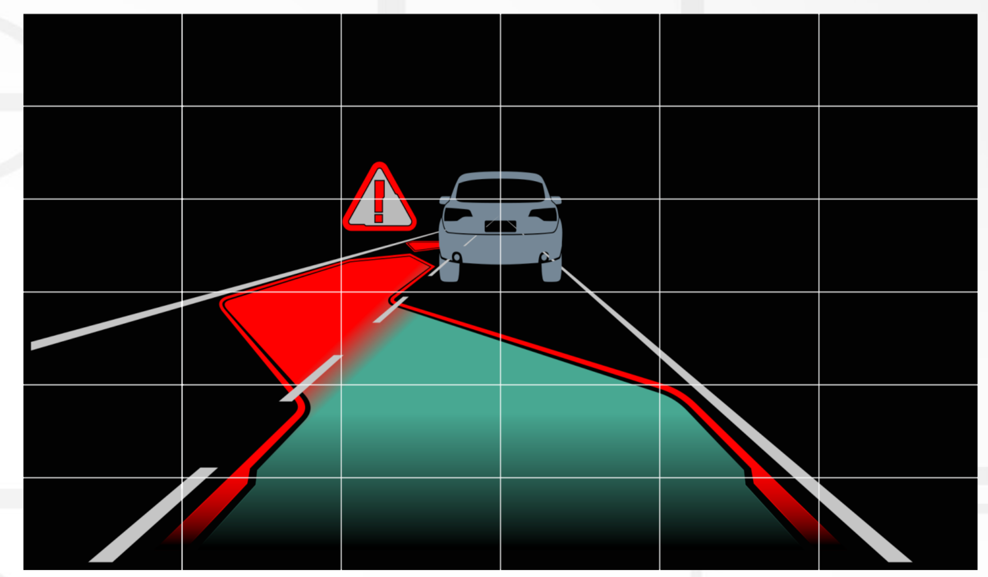
Augmented Reality HMI

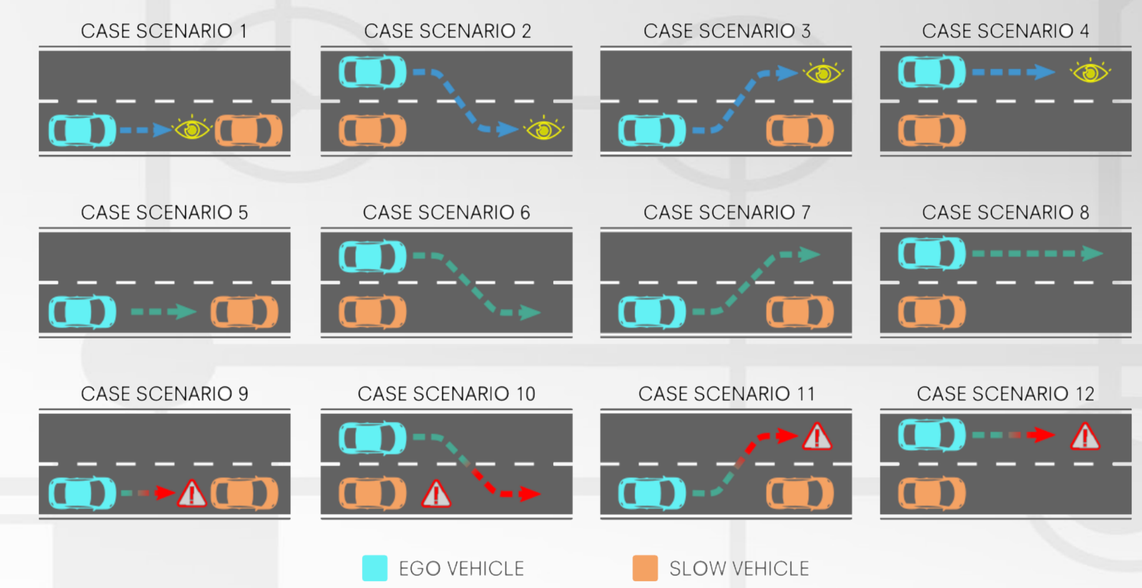
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690705

Description

To follow the TeamMate approach, it is necessary that the system provides a shared understanding of the current situation between the driver and the automation. The main objective of the Augmented Reality HMI is to improve the cooperation between the automation and the driver, this means that the Augmented Reality HMI should provide a better situation understanding to understand the behavior of the automation. In order to implement the Augmented Reality HMI in a real vehicle, at AutoMate we used the Epson Moverio BT-200 smart glasses to represent what would be shown on the vehicle's windshield as proof of concept. Due to the limitation of the AR glasses, 2D images were designed to represent the different possible scenarios to ensure the understanding of the situation of the vehicle's behaviour.







Demonstrators where it is integrated

VED vehicle demonstrator

ULM simulator demonstrator

Project Coordinator:
Dr. Andreas Luedtke
E-Mail:
luedtke@offis.de

Dissemination Manager:
Serena Fruttaldo
E-Mail:
serena.fruttaldo@re-lab.it