Hybrid Testing:

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 723016.

Dr. Selim Solmaz
Lead Researcher | Control Systems
GSVF2020 | 01.09.2020
Presentation Outline

- Inframix project introduction, methods, scenarios & results
- Hybrid Testing concept and components
- Hybrid Testing experiments description
- Result from onramp-merge scenario
- Results from main flow scenario with IVIM speed advice
- KPI Analysis
- Conclusions & outlook
Project Overview: Inframix

Duration: 1 June 2017-31 May 2020

EC Funding: 5M €

Coordinator: AustriaTech

Consortium: AustriaTech, ICCS, Asfinag, Fraunhofer, Siemens Mobility, Virtual Vehicle, Autopistas, Enide, Technical University of Crete, TomTom, BMW

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Observations & Objectives: Inframix

Avoiding decrease of safety/efficiency by infrastructure support

- Mixed traffic situations will increase
- Mixed traffic situations will decrease efficiency and safety
- Infrastructure support can increase efficiency and safety

Support from infrastructure at different levels

- **Support perception capability of AVs**
  - extend e-horizon (e.g. road works with lane deviations or incidents ahead) including information on detailed lane layout in road work zones

- **Improve conditions for AV manoeuvres**
  - Lane change advice before an on-ramp creating more space for merging (automated) vehicles

- **Support drivers of conv. vehicles**
  - New lane markings for AD lanes

- **Improve traffic situation**
  - Provide recommendations to connected and automated vehicles to increase efficiency (e.g. gap advice in bottlenecks)

‘The main objective of INFRAMIX is to prepare the road infrastructure with specific affordable adaptations and to support it with new models and tools, to accommodate for the step-wise introduction of automated vehicles.’
3 Scenarios – 3 key areas of Inframix

Dynamic lane assignment to automated driving

Roadworks zone

Bottlenecks

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## Approach and Highlights: Inframix

### Solutions
- Traffic control strategies
- Estimation algorithms
- Digital infra elements
- Physical infra elements

### Evaluation
- Simulation – microscopic
- Simulation – submicroscopic
- Real world implementation
- Hybrid – simulation and real world

### Recommendation
- Infrastructure classification
- Safety parameters
- Roadmap
- Exploitation plans
Hybrid Testing Concept

Real vehicle driving automatically on enclosed proving Ground

Virtual Environment

Real Environment

Driving Function

Dynamic Data
ITS-G5
DENM, IVIM, MAPEM

Vehicle Sensor

Traffic

Static Environment

RSU
ITS-G5
OBU
Hardware Components of Hybrid Testing

MicroAutobox
- ADAS MWC
- CAN

real vehicle
- Mondeo ADAS KIT
- dGPS

Hardware Components
- CAN
- UDP

OBU
- Sensor C++
- Static Environment
- Dynamic Data
- Dynamic Env. Sumo/Traffic
- GPS2UTM C++

Model Connect

Virtual Vehicle
Connecting RT and non-RT Systems

Advanced, cross-domain co-simulation platform for multidisciplinary engineering

Co-Simulation Platform
Model.CONNECT™

Simulink Control System

CAN Bus 1 Mbit/s

HiL Systems ETAS, dSPACE

Hybrid Control Unit

Driveline, E-Motor, Li-Ion Battery, Cooling System

Off-line co-simulation

Model.CONNECT™

Simulation PC #1 Windows

Simulation PC #2 Windows

Testbed.CONNECT™ Engine Testbed

PUMA Automation RT Hardware

HiL Systems ETAS, dSPACE

CAN, Flex, D-IO...

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ViF-Automated Drive (AD) Demonstrator

- **Drive by wire:**
  
  DataSpeed ADAS Kit:
  drive, brake, steer, visualize by wire

- **Sensors:**
  
  Cameras, ultrasonic sensors, inertial sensors, GPS, Radars, Lidar(s), ToF...

- **Interfaces:**
  
  HMI touch display, CAN, 
  ROS (Robot operating System) Kinetic 
  Nvidia Drive PX/2 (Ubuntu 16.04) 
  dSPACE MicroAutoBox II 
  PC (Win/Linux)

- **Applications:**
  - Measurement (sensor data acquisition, sensor fusion)
  - Development and test (ADAS/AD)
  - Energy management (hybrid car)
  - Proving ground platform
- Open drive map format (.xodr) file of the ÖAMTC Lang-Lebring proving ground near Graz
- A straight road section with approximate usable length of ~250 m and width of at least 10 m across the main testing zone
- 3 virtual lanes with a width of 3.5m each + additional maneuver space as buffer zone
Hybrid Testing Experiments and Scenarios

Experiment Stack-I Onramp – Merge into the main road

- Without traffic
- With low traffic density
- With high traffic density

Experiment Stack-II Main road – speed recommendation (IVIM)

- Main road – without traffic
- Main road – without traffic & speed recommendation (IVIM)
- Main road – speed recommendation (IVIM) with vehicle in front & MWC overtakes
- Main road – speed recommendation (IVIM) with vehicle in front MWC adapts speed
Onramp Scenario: Merge into the main road

Merge into main road w/o traffic

• VuT starts at the rightmost lane & accelerates to 30 km/h

• When the VuT reaches 20 km/h (parameter) it starts the lane change manoeuvre to merge into the main lanes (lane 2 and 3 from the right)

• No interfering traffic
Onramp Scenario: Merge into the main road

Merge into main road w/o traffic

• Data Sample

• Post-Processing

• Longitudinal Dynamics

• Lateral Dynamics

• Ego-vehicle track
Onramp Scenario: Merge into the main road with Traffic

Merge into main road with low traffic density

- VuT starts at the rightmost lane & accelerates to 30 km/h
- When the VuT reaches 20 km/h (parameter) it starts the lane change manoeuvre to merge into the main lanes (lane 2 and 3 from the right).
- Three vehicles on the main road
Onramp Scenario: Merge into the main road with Traffic

Merge into main road with high traffic density

• Lane Change not possible, MWC performs a safety stop
Main road Scenario:
max speed (IVIM) with vehicle in front, MWC adapts speed

- No Message vs. with ITS-G5 (IVIM) Message
Main road Scenario:  
max speed (IVIM) with vehicle in front, MWC adapts speed

With max speed (IVIM), vehicles in front and MWC adapts speed

- The VuT starts on the left side of the track on the middle lane (lane-2), accelerates from standstill to 30 km/h and changes the lane before the lane ends

- After ~100m from the start, the VuT receives an IVIM via its OBU with a new max. speed of 50 km/h and accelerates to this speed

- A slower vehicle in front of the VuT hinders the VuT reaching the new max speed without overtaking forcing the VuT to follow behind it
Main road Scenario:
max speed (IVIM) with vehicle in front, MWC adapts speed
Main road Scenario:
max speed (IVIM) with vehicle in front, MWC overtakes

With max speed (IVIM), vehicles in front and MWC overtakes

- The VuT starts on the left of the track on the middle lane (lane-2), accelerates from stand still to 30 km/h and changes to the side lane before the lane ends

- After ~100m from the start, the VuT receives an IVIM via its OBU with a new max. speed of recommendation of 50 km/h and accelerates to this speed but a slower vehicle in front of the VuT hinders the VuT reaching the new max speed without overtaking

- The VuT performs a lane change manoeuvre to overtake
# Experiment (Stack-II) KPI Results

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<th>Scenario/Testday/Testrun</th>
<th>IVI send</th>
<th>IVI received</th>
<th>IVI Speed</th>
<th>VuT has adapted the speed</th>
<th>mean Speed VuT</th>
<th>mean speed VuT in rel. zone</th>
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Hybrid Testing Promotion Video
Conclusion & Outlook

- Repeatable and stable real-world proof of concept runs were demonstrated on the ÖAMTC Lang-Lebring Proving Ground
- Data Collected & proof-of-concept shown
- Comparison between sub-microscopic simulations were made
- Methodology particularly suitable to evaluate ADAS functions in various and randomized traffic scenarios
- Another potential utilization is for testing the effect of C-ITS messages on mixed traffic scenarios
- Potential extensions are possible and is planned for follow-up research activities:
  - Sensor modelling
  - 3D visualization integration
  - Integration of vehicular sensors to the co-simulation framework
  - Digital twin calibration
THANK YOU

selim.solmaz@v2c2.at

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Lead Researcher | Control Systems

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www.v2c2.at