Designing interaction of automated vehicles for mixed traffic environment: development, integration and evaluation of the interACT system

Virtual, 9 -10 September

SUMMER SCHOOL 2020

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Agenda

- Introduction
- Interaction Strategies Methodology
- Project Demonstrators
- Evaluation Methodologies and main Results
- Conclusions

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Project Overview

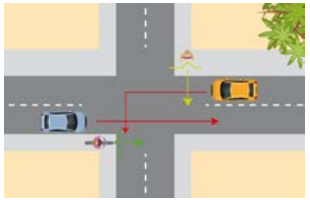
The challenge

5th Objective
Methodology for assessing the quality of interaction

1st Objective
Psychological models

Achieve a safe, highly accepted and efficient integration of Automated Vehicles in mixed traffic environment

4th Objective
Novel HMI elements



2nd Objective
Intention recognition & behavioural predictions

3rd Objective
CCPU & safety layer

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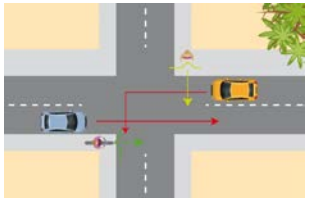

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Human-human Interaction in real Traffic

- **Observe** the interaction in urban human traffic encounters.
- **Model** the observed behavior to derive recommendations for automated vehicles.
- **Predict** the behavior of traffic participants.

Interaction Strategies for Automated Vehicles #1

- HMI-concepts were developed in a user-centred design process, taking into account human interaction strategies derived from observational studies.
- The eHMI design solutions were developed in an iterative process incorporating user feedback.
- **Intention-based**, consisting of an LED light-band wrapped around the body of the vehicle (communicating the intentions of the AV, such as giving way or starting to move).

Intention based

Interaction Strategies for Automated Vehicles #2

- A variant of the light-band, where specific segments were illuminated, was used to communicate the **perception** of (another) traffic participant.

Perception based

- A **combination** of a single lamp and the light-band were used to communicate both AV intention and perception at the same time.

Combined

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Features of interACT Demonstrators

	CRF	BMW
CCPU	Fully integrated and functional CCPU	No CCPU (just parts of it for eHMI control)
Sensors	Completely integrated sensors	No additional sensors
eHMI	eHMI elements (LED stripe)	Fully integrated and functional eHMI – LED stripe and directed single lamp
Demo Use Case	Use cases on parking lot	Use case on urban intersection
Evaluation	Evaluation on test track	Wizard of Oz evaluation in real traffic
Main responsible evaluation partner	ITS	TUM

Final BMW Demo (exterior and interior)

Side view (360° light band)

(DGPS System)

Front view (360° light band & signal lamp)

Rear view (360° light band)

Trunk lid (eHMI ECU, PC, camera unit)

Passenger compartment (eHMI control panel, signal lamp, front camera) lamp

Seat cover

Final CRF Demo (exterior and interior)

Three frontal Laser-scanner sensors

eHMI solution

Antenna for DGPS

External camera

Trunk of CRF vehicle (including Lidar ECU, CCPU and E/E components)

Internal Display
(for data monitoring and
for on-board iHMI)

Three rear Laser-scanner sensors

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Teams and Tools

www.interact-roadautomation.

UNIVERSITY OF LEEDS

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

BOSCH
Invented for life

Technical University of Munich

HELLA

CRF

ICCS

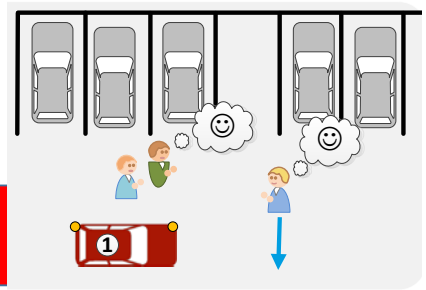
This project has received funding from the European Union's programme under g reflec

Evaluation of interACT Solutions: example of the eHMI

Intention-Based eHMI:
Slow Pulsing Light Band in cyan, presented at 0.4Hz (SPLB).
'I am giving way'

Perception-Based eHMI
Directed Light Band in cyan.
'I detected you'

Sequence Diagram



Agents

Sequence of Events

Environmental Perception
(from sensorial system)

Environment

Non-motorized TP

TP Passes

Pedestrian detected

eHMI

Cooperation Capability
AV gives way

Next Maneuver
(AV starts moving)

Vehicle

Driving

Deceleration (until full stop)

Standstill

Acceleration and go straight on

CCPU

Decision to Yield

Decision to Move on

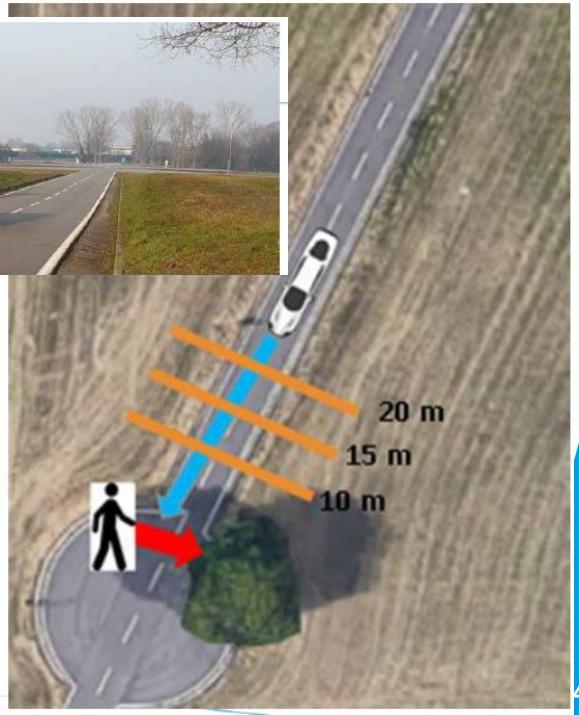
Maneuver finished

iHMI

Driver

Evaluation on CRF Test-track: interaction between pedestrian and AV

- **CRF demonstrator manipulations: ~12km/h**
  - *eHMI*: no eHMI, Directed Light Band, Slow Pulsing Light Band
  - *Distances*: (10, 15, 20)m
- **Task:** Raise your hand if:
  - deceleration perceived
  - eHMI perceived
  - crossing decision / confidence, safety
- **Assessment:**
  - System Usability Scale
  - Acceptance scale (van der Laanet al., 1997)
  - Learnability and Effectiveness (Janderet al., 2012)
  - Comfort and Safety



Video

- Video 1 (ext. From test)
- Video 2 (ext. For online event)
- Video 3 (int.)

Results and Open-points

- Pedestrians generally felt safe and comfortable interacting with the demonstrator in a test-track setting.
- Both eHMI solutions were generally well received, with high ratings of usability, acceptance and learnability for both.
- The Perception-Based eHMI was perceived more quickly than the Intention-Based eHMI, and led to better ratings of AV speed and stopping behaviours compared to no eHMI conditions.
- However, the results suggest that in naturalistic lighting conditions neither of the eHMI solutions impact on pedestrian crossing decisions or ability to detect AV yielding behaviour, with AV speed and distance having a much greater effect.
- When the eHMI was absent, participants used vehicle kinematics to infer intention.

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Key-findings

- Our observation studies in conventional traffic situations showed that explicit communication rarely happens, interactions are mainly is resolved by implicit communication: human road users are able to make decisions based on the implicit communication of AVs.
- eHMIs might be beneficial for the interaction with AVs in urban traffic, but the effects are highly depending on the underlying scenario.
- However, it is important to ensure the high visibility of eHMI, as it might have the potential to encourage early crossings.
- Ensuring consistency between eHMI message and vehicle behavior is important.
- Misleading eHMI could potentially cause collisions.

Next Steps, Lessons Learnt and Recommendations

- More studies should be developed, to understand interactions in more complex scenarios (e.g. more than one to one interactions) and across different situations as well as to understand long-term effects and behavioral adaptation.
- Extension of the covered scenarios from the Perception Platform point of view.
- The AV either needs to perceive all surrounding traffic participants in close proximity or should not communicate otherwise.
- The consequences of misleading eHMI are severe, and therefore public guidance around eHMI capability will be required. The public should be educated about the risk of eHMI failures.
- The results of the CRF study suggest that the interACT eHMI solutions may not impact on road users crossing decisions, but the *Perception-Based* design, in particular may lead to greater confidence and comfort in the AV behaviour (so increasing the visibility or contrast of a *light-based eHMI* can be relevant).

For more information

- ***interACT* project web-site**: www.interact-roadautomation.eu

- **Final event of the project** (online): https://www.interact-roadautomation.eu/final-event-overview/

interACT
Designing cooperative interaction of automated vehicles with other road users in mixed traffic environments

L3Pilot
Driving Automation

Thank you for your kind attention.

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723051.