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

Virtual, 9 -10 September

Fabio Tango
Centro Ricerche Fiat (CRF)
Agenda

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

• Introduction
• Interaction Strategies Methodology
• Project Demonstrators
• Evaluation Methodologies and main Results
• Conclusions
The challenge

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

1st Objective
Psychological models

2nd Objective
Intention recognition & behavioural predictions

3rd Objective
CCPU & safety layer

4th Objective
Novel HMI elements

5th Objective
Methodology for assessing the quality of interaction

Occasion of presentation 09.09.2020
The challenge

5th Objective
Methodology for assessing the quality of interaction

1st Objective
Psychological models

4th Objective
Novel HMI elements

3rd Objective
CCPU & safety layer

2nd Objective
Intention recognition & behavioural predictions
Agenda

• Introduction
• Interaction Strategies Methodology
• Project Demonstrators
• Evaluation Methodologies and main Results
• Conclusions
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).
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.

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

• Introduction
• Interaction Strategies Methodology
• Project Demonstrators
• Evaluation Methodologies and main Results
• Conclusions
## Features of interACT Demonstrators

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

- Side view (360° light band)
- Front view (360° light band & signal lamp)
- Rear view (360° light band)
- Passenger compartment (eHMI control panel, signal lamp, front camera) lamp
- Trunk lid (eHMI ECU, PC, camera unit)
- Seat cover
Final CRF Demo (exterior and interior)

- Three frontal Laser-scanner sensors
- Three rear Laser-scanner sensors
- eHMI solution
- Internal Display (for data monitoring and for on-board iHMI)
- Antenna for DGPS
- External camera
- Trunk of CRF vehicle (including Lidar ECU, CCPU and E/E components)
Agenda

• Introduction
• Interaction Strategies Methodology
• Project Demonstrators
• Evaluation Methodologies and main Results
• Conclusions
Teams and Tools

www.interact-roadautomation.

UNIVERSITY OF LEEDS

This project has received funding from the European Union’s Horizon 2020 Research and Innovation Programme under grant agreement N° 723839.
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
- Environment
- Non-motorized
- TP
- eHMI
- Vehicle
- CPU
- iHMI
- Driver

### Sequence of Events
1. **Decision to Yield**
2. **Driving**
3. **Deceleration (until full stop)**
4. **Standstill**
5. **Cooperation Capability**
   - AV gives way
6. **TP Passes**
7. **Environmental Perception** *(from sensorial system)*
8. **Pedestrian detected**
9. **Decision to Move on**
10. **Next Maneuver** *(AV starts moving)*
11. **Acceleration and go straight on**
12. **Maneuver finished**

### Occasion of presentation
- 09.09.2020
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 Laan et al., 1997)
  - Learnability and Effectiveness (Jander et 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.
Agenda

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

• Our observation studies in conventional traffic situations showed that explicit communication rarely happens, interactions are mainly 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](http://www.interact-roadautomation.eu)

• Final event of the project (online): [https://www.interact-roadautomation.eu/final-event-overview/](https://www.interact-roadautomation.eu/final-event-overview/)
Thank you for your kind attention.

Fabio Tango (CRF)
fabio.tango@crf.it
Tel (office): +39 011 9083904

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