Communication and Interaction between Automated Vehicles and other Road Users

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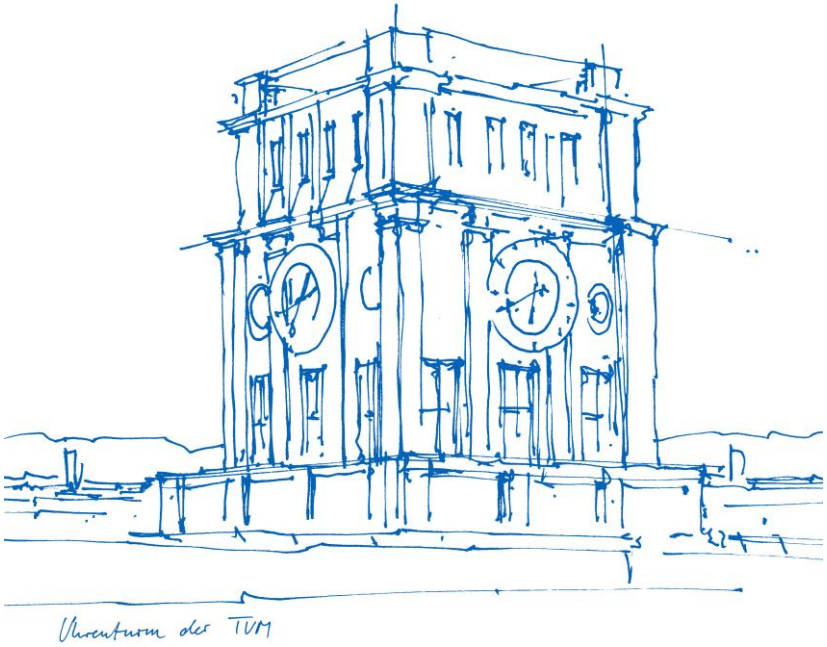
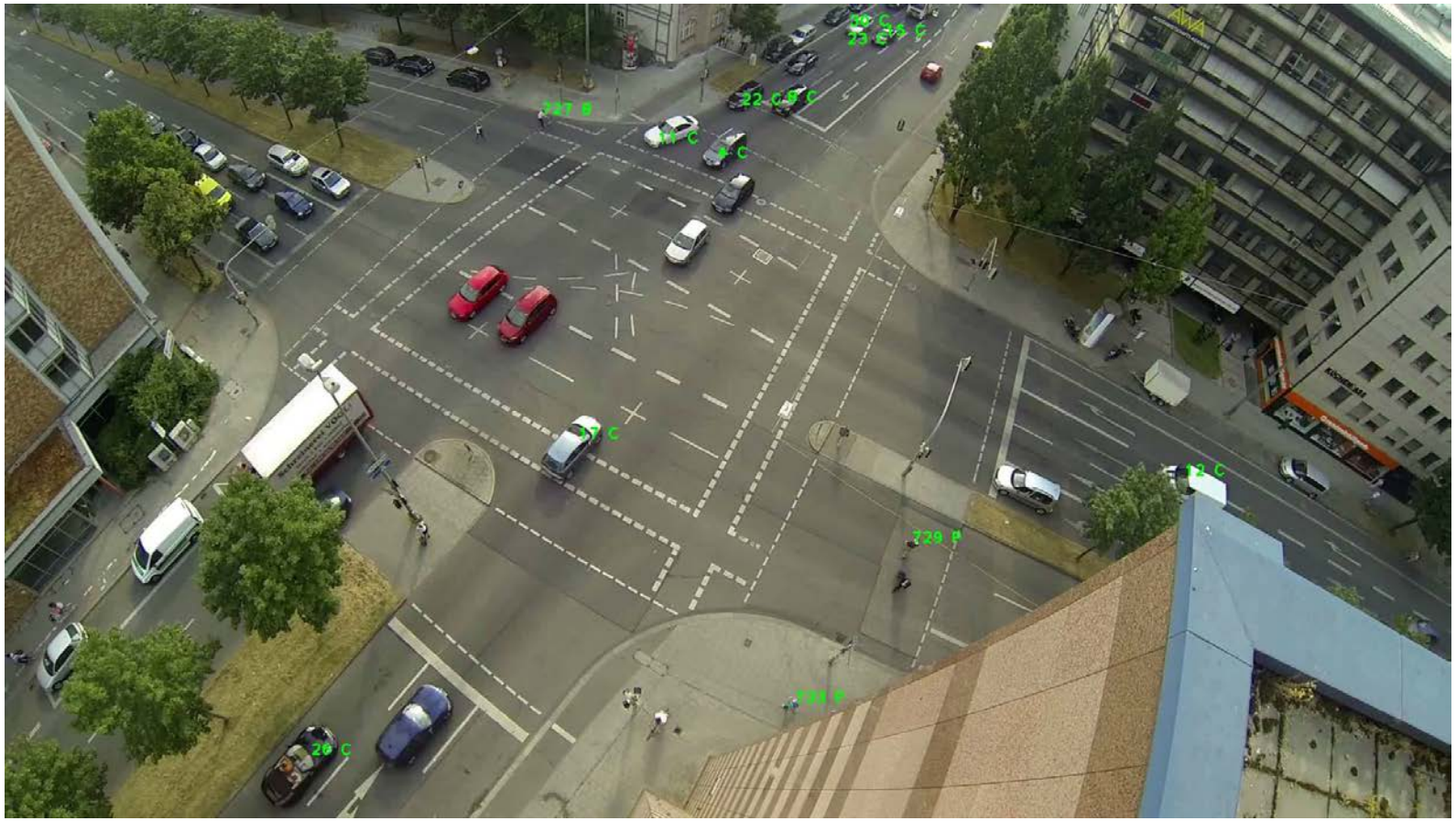
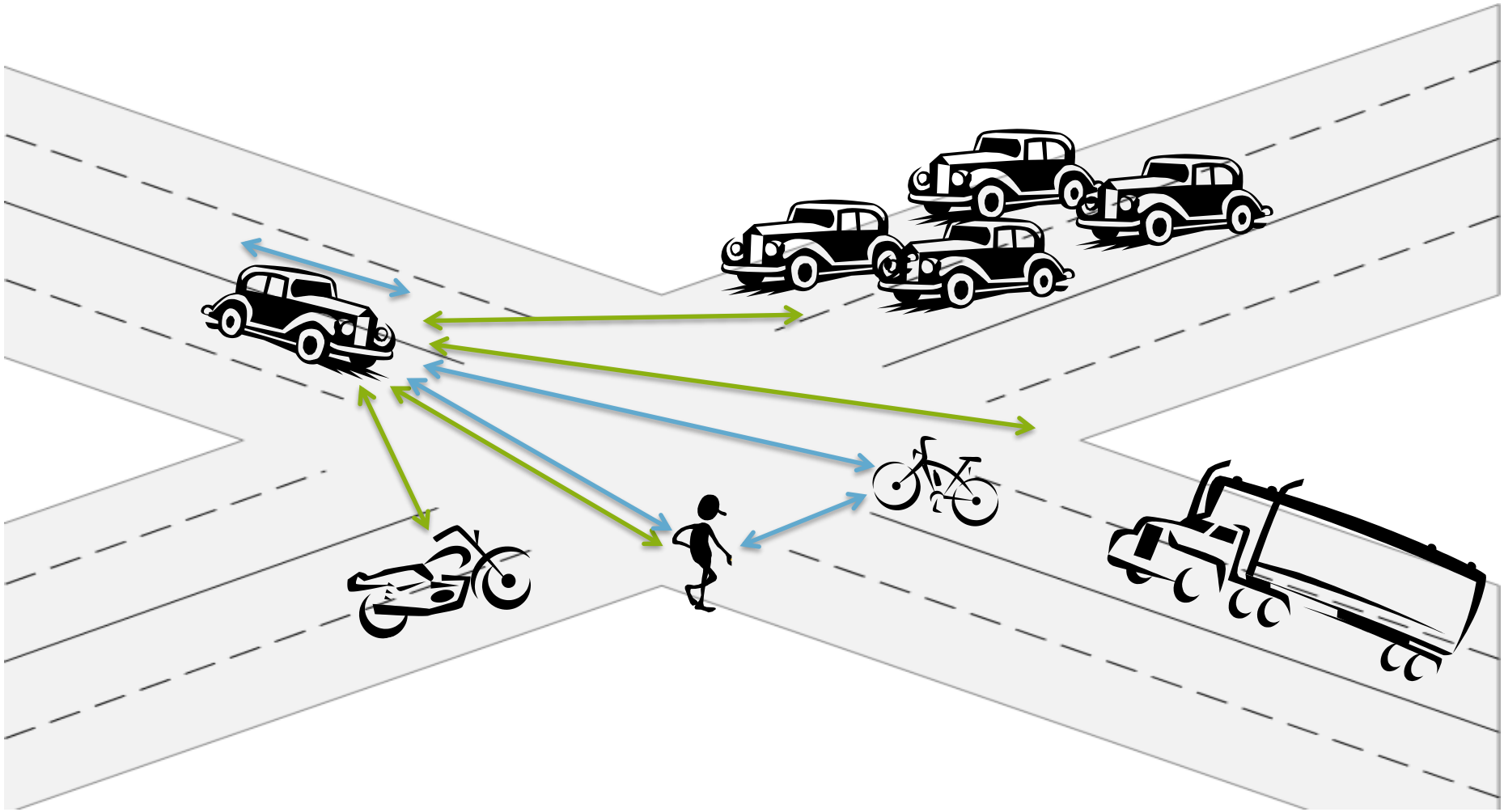
Chair of Ergonomics

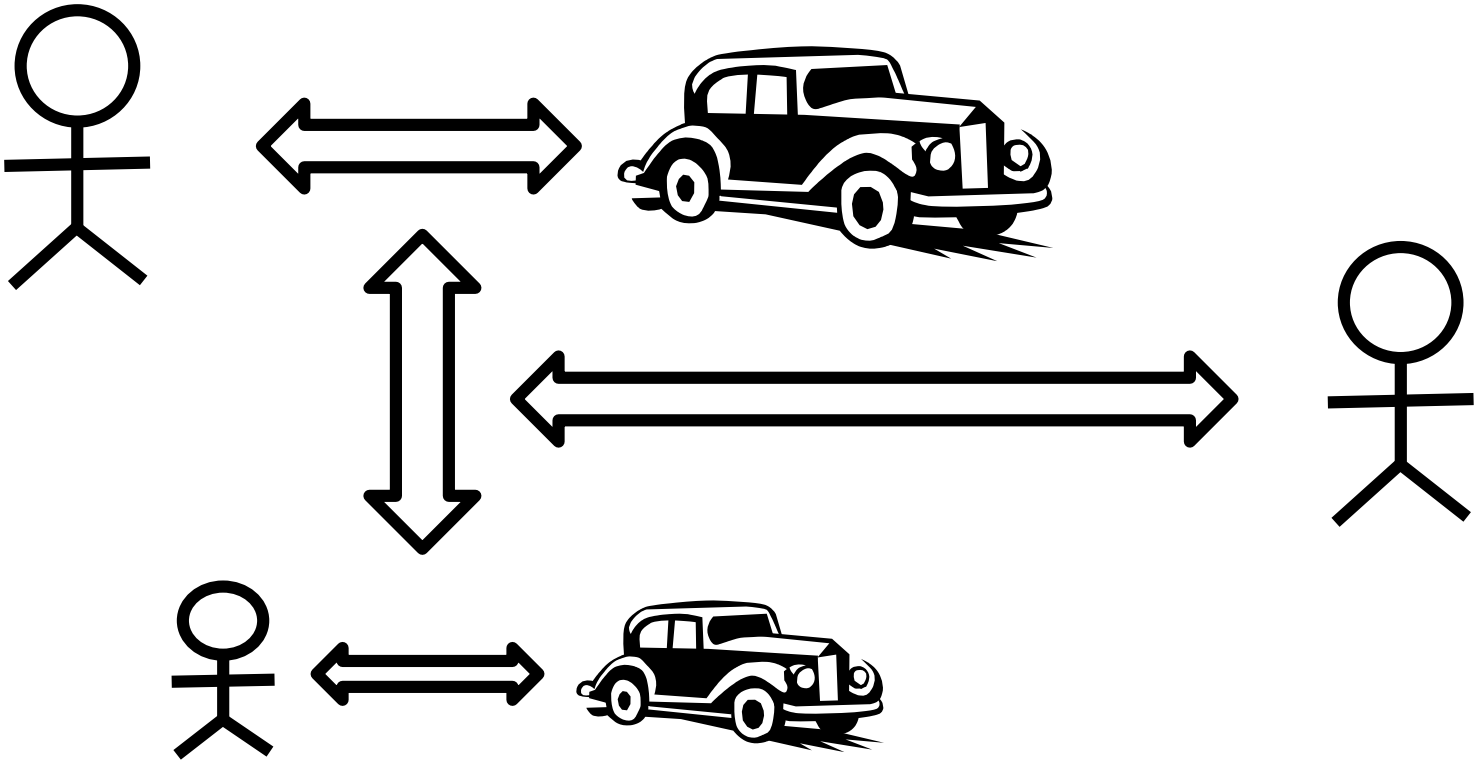
with contributions of J.Schmidtler, J.Reinhart, C.Gold, D.Damböck, M.Kienle, D.Bortot



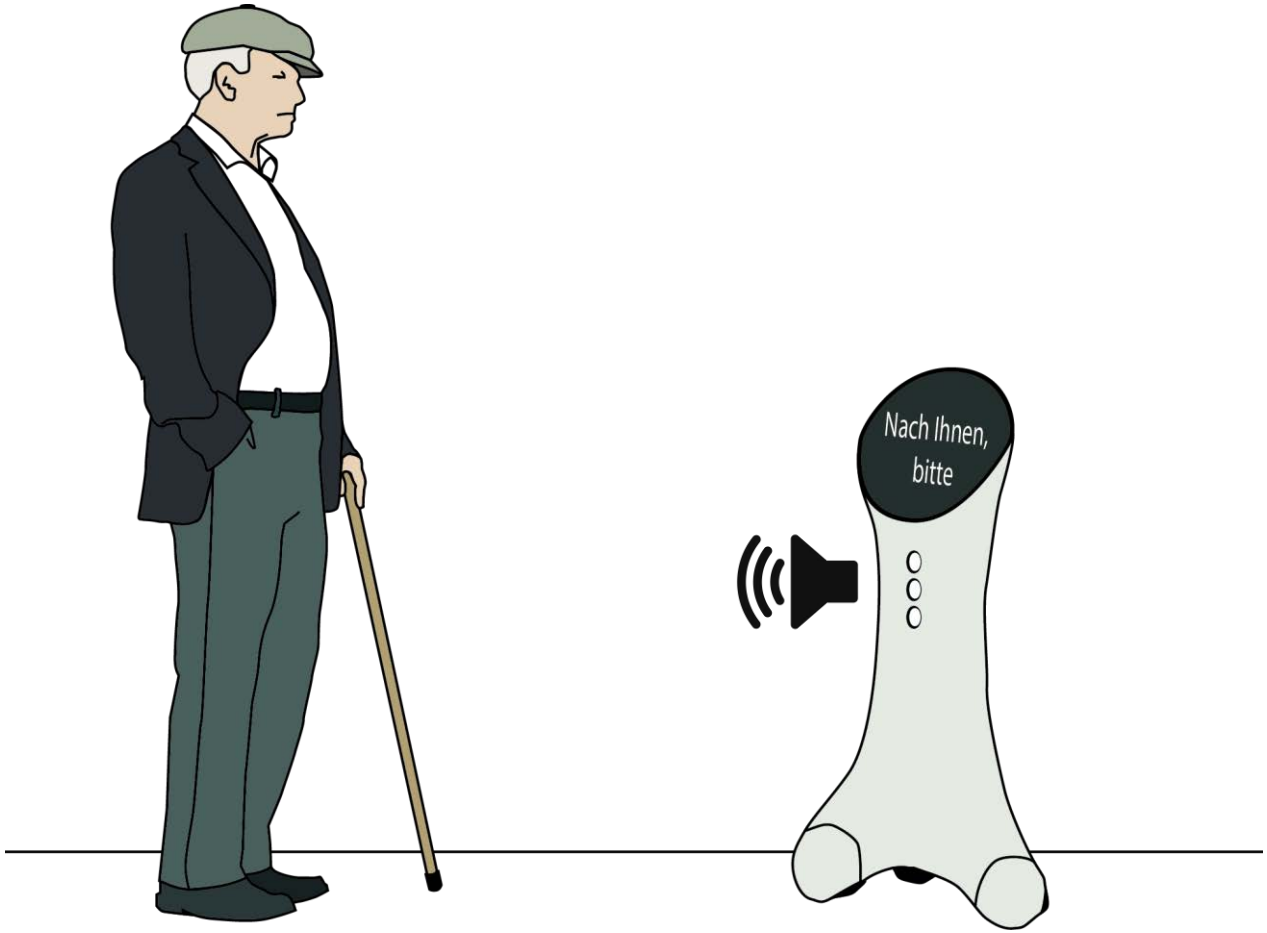
We are able to do this – Why change



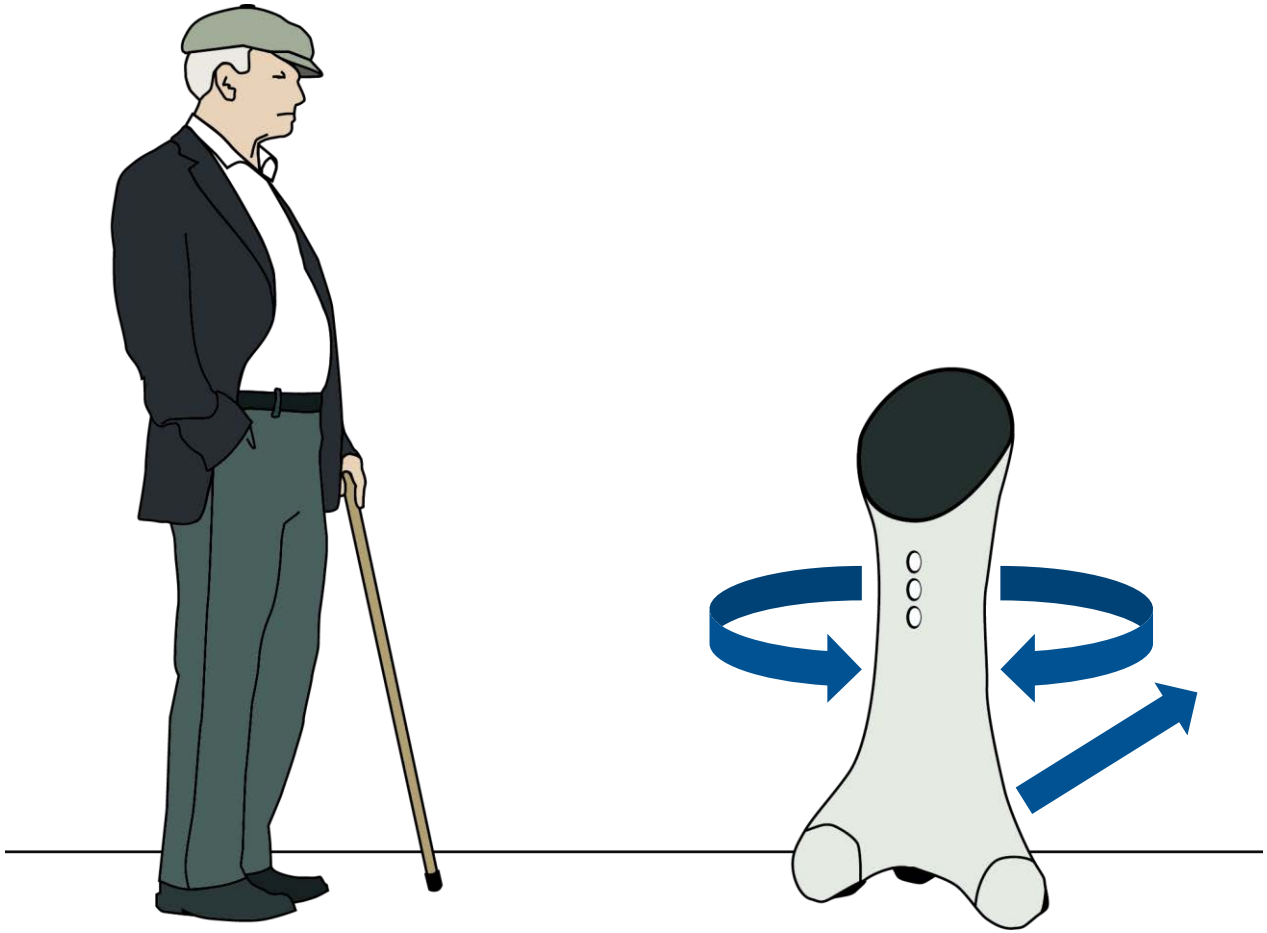




Explicit Communication



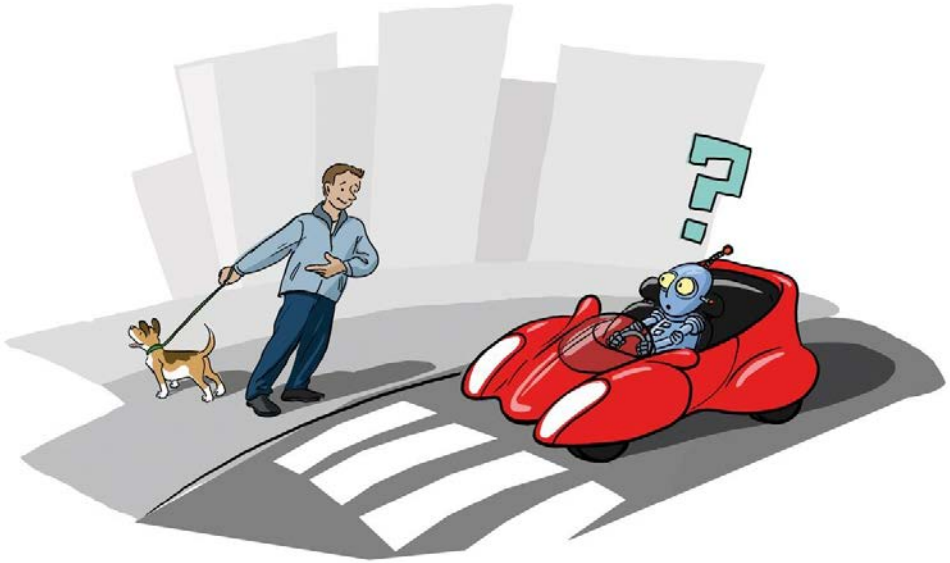
Implicit Communication



Legible Movements of automated mobile Systems

Communication of Intentions, Actions and system states

- Explicitly via displays etc.
- Implicitly via movements



Legibility – “Robot behavior is legibile if:

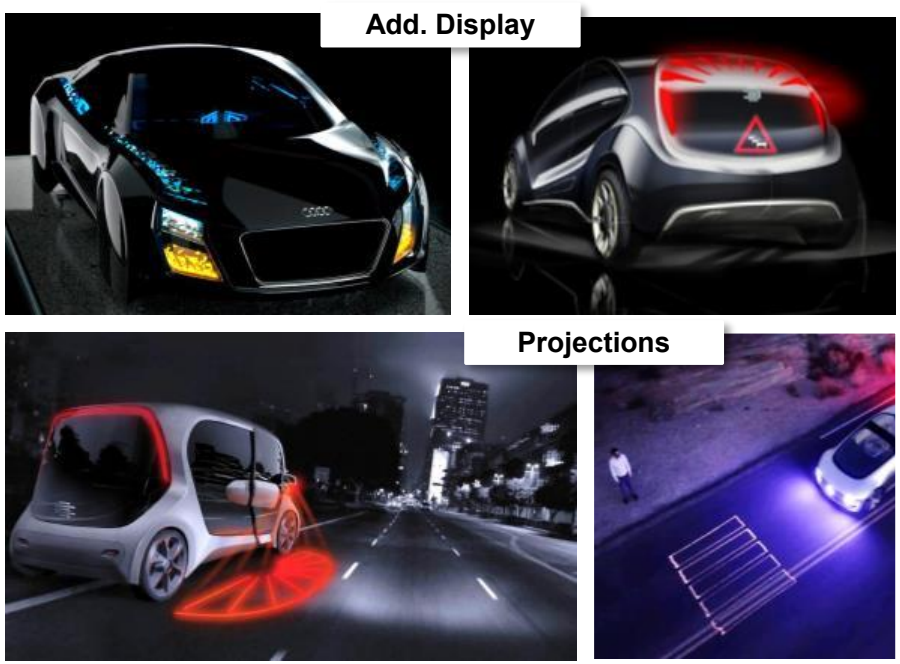
- (factor 1) a human observer or interactor is able to understand its intentions, and
- (factor 2) the behavior met the expectations of the human observer or interactor.”
  (Lichtenthäler & Kirsch, 2016)

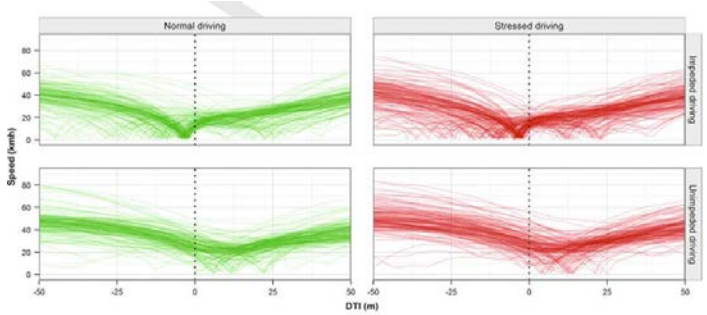
Reading:

Lichtenthäler, C., & Kirsch, A. (2016). **Legibility of Robot Behavior : A Literature Review**. Retrieved from https://hal.archives-ouvertes.fr/hal-01306977/

https://nemo-responsive-image.live.cf.public.springer.com/v1/resize/width/%7Bwidth%7D/%7Bpixel_ratio%7D/url/http:/resource-cms.springer.com/springer-cms/rest/v1/img/6509180/v3/4by3

Current OEM Concepts





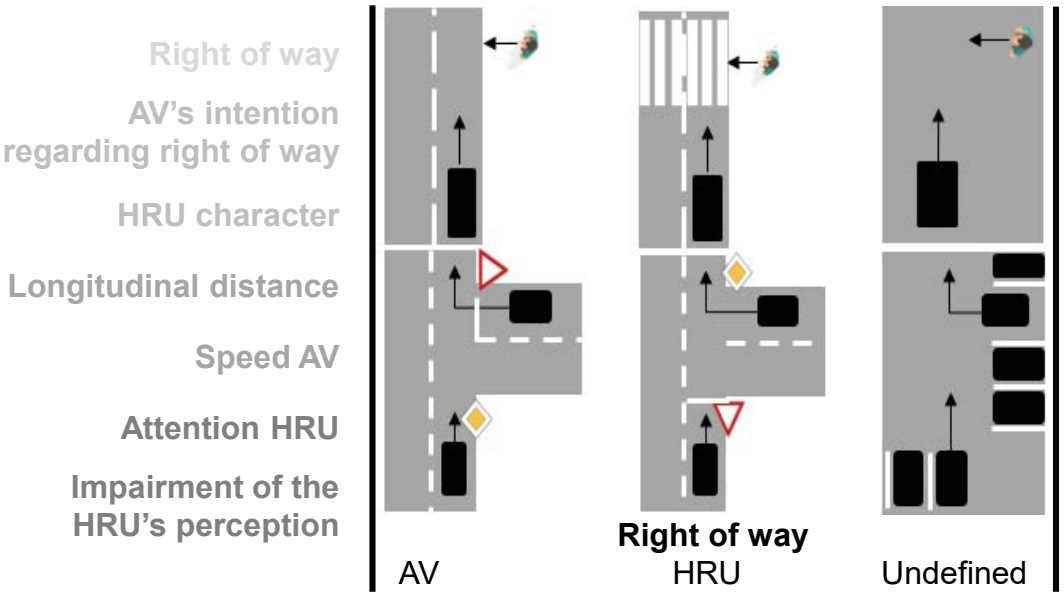
- **Focused on explicit, external messages**
- **Based on and embedded into a running system**

Publication Fuest et al. (2017): Taxonomy of Relevant Traffic Situations

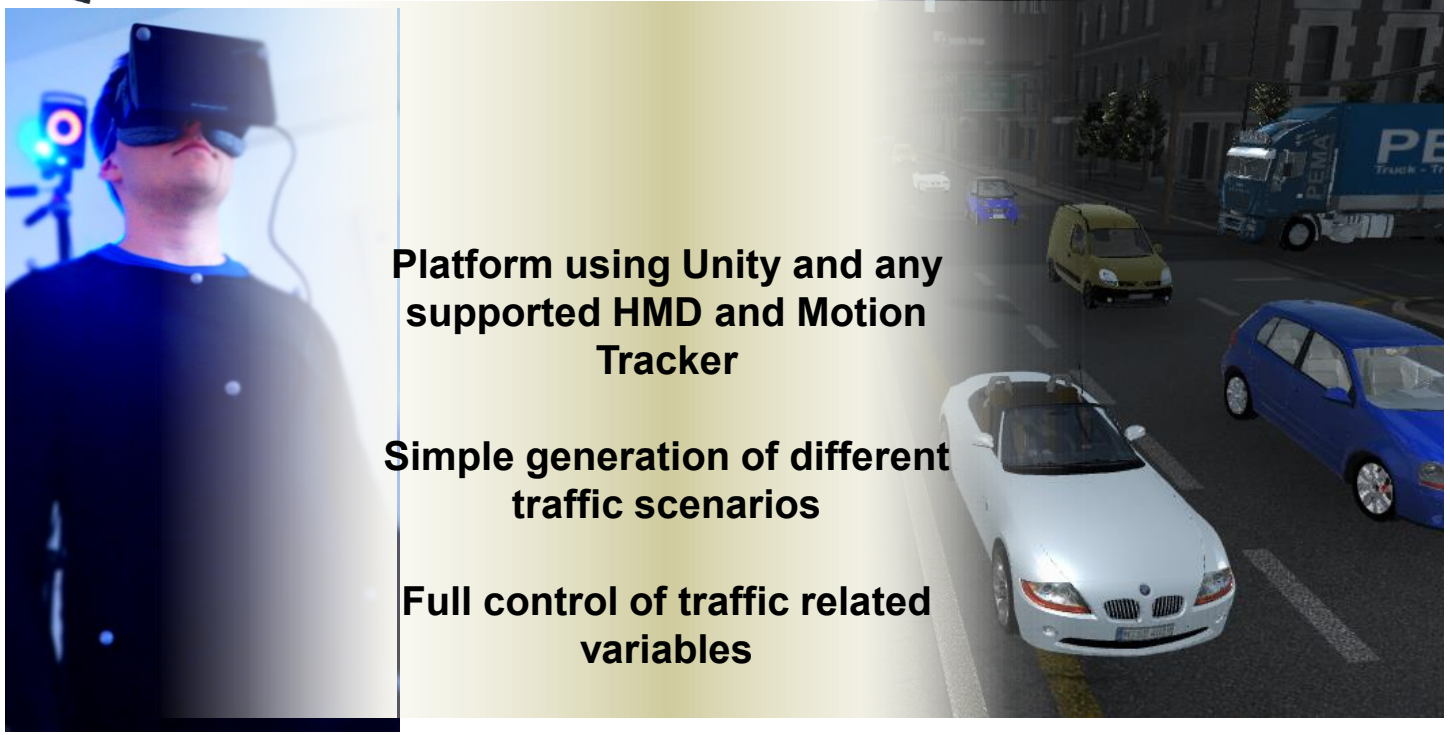
- classifies the interaction between an automated vehicle (AV) and a human road user (HRU)
- provides an overview over relevant attributes and related value facets that may influence the communication between the AV and the HRU
- can be used to choose attributes and value facets which are relevant for a specific research question

Taxonomy - Application

*"How quickly can the AV's intention regarding the **right of way** be expressed by using a **targeted design of the trajectory**?"*

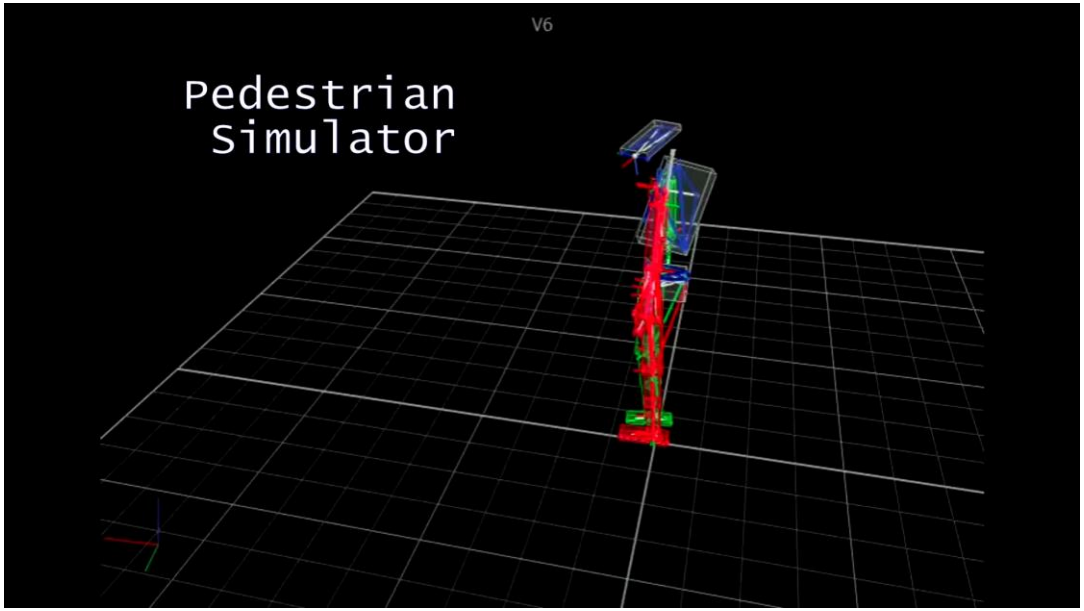


Lab Study Dietrich et al.: Pedestrian Simulator

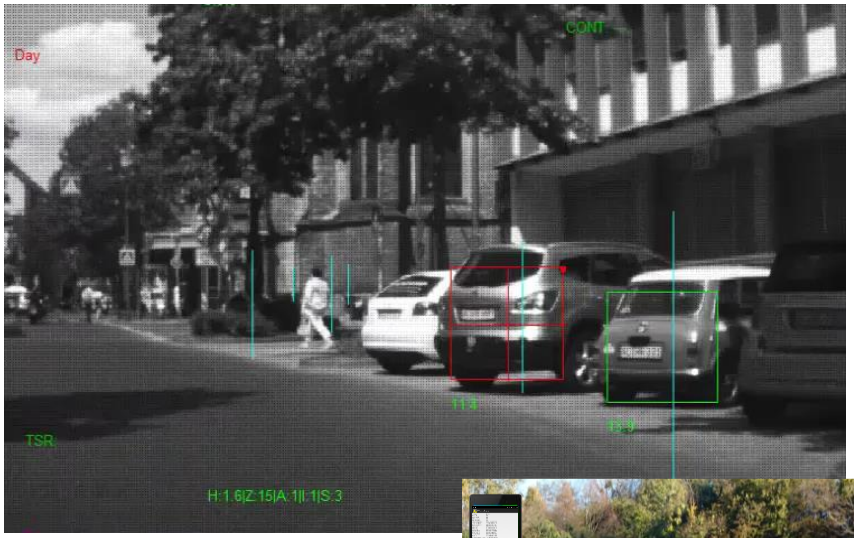


- How to implement a methodology to investigate interaction and cooperation between traffic participants? (non-assisted cars, assisted cars, VRUs)
- Definition of suitable analysis tools and metrics to quantify interaction and cooperation

Research on Interactions between Vehicles and VRUs

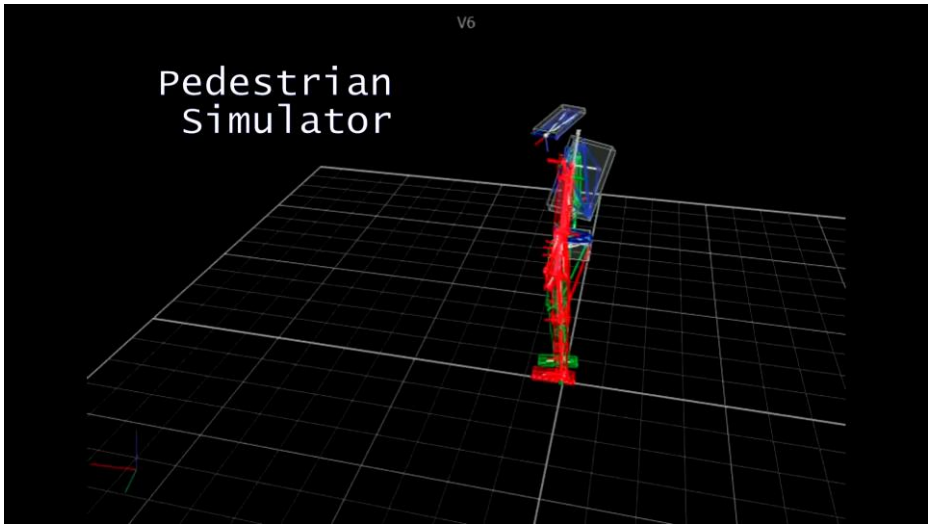


Research on Interactions between Vehicles and VRUs

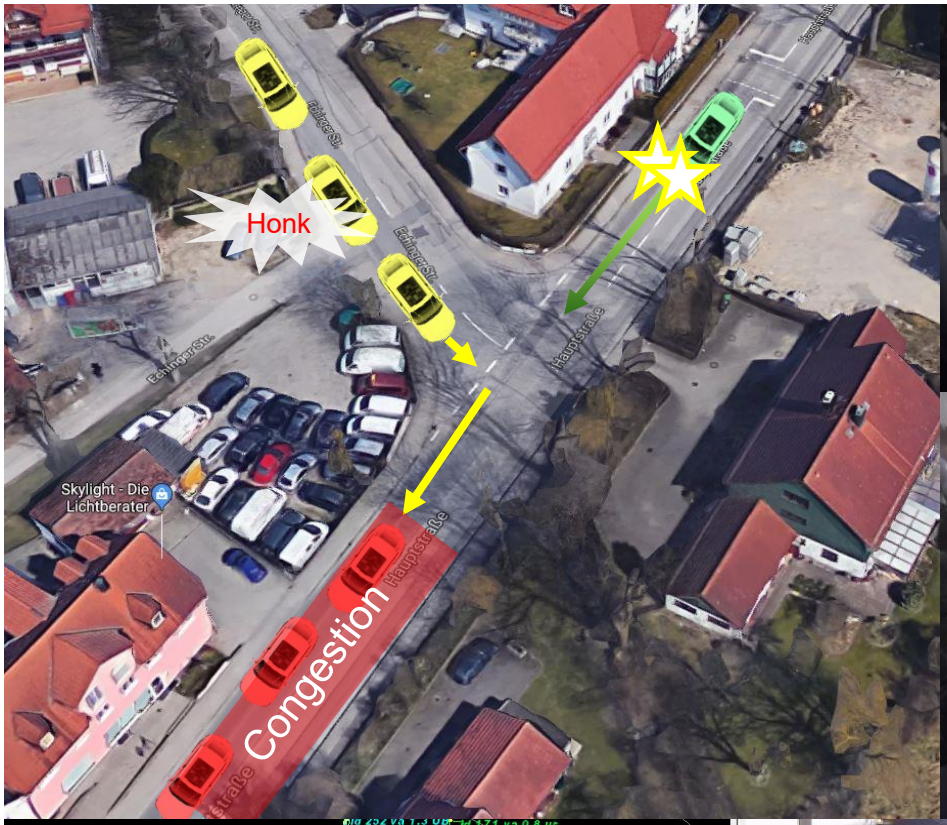


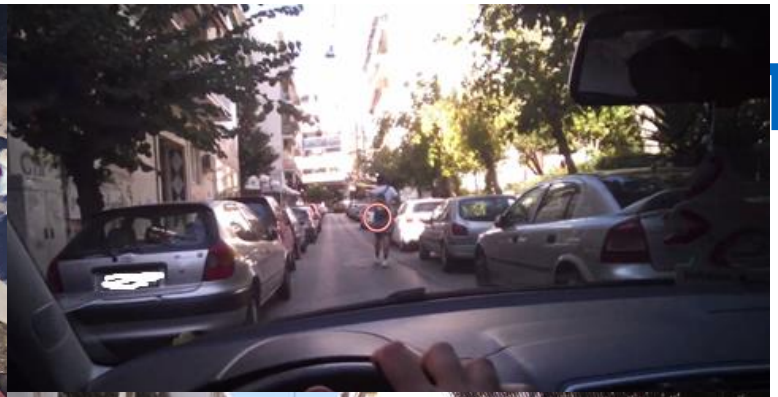
Field Data

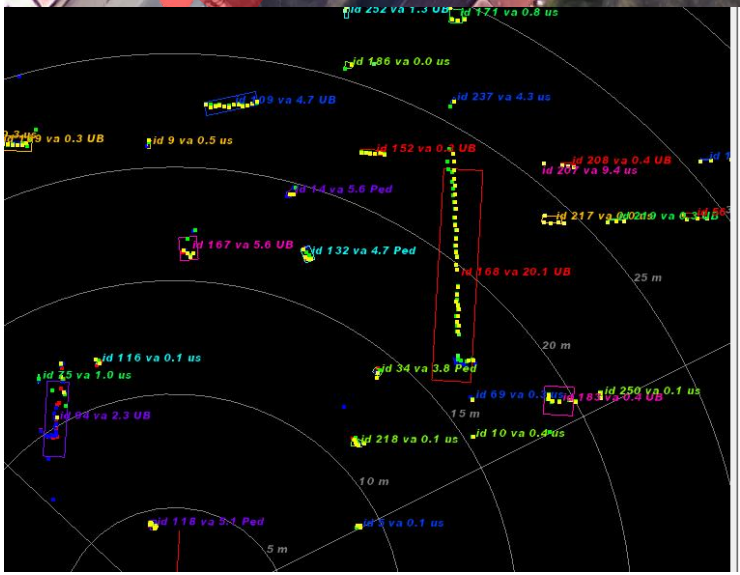
Testbed Aachen



Pedestrian Simulator TU München


Honk
Congestion
Hauptstraße
Skylight - Die Lichtberater




id 1 va 0.0 us
id 237 va 4.3 us
id 9 va 0.5 us
id 208 va 0.4 UB
id 167 va 5.6 UB
id 132 va 4.7 Ped
id 116 va 0.1 us
id 34 va 3.8 Ped
id 218 va 0.1 us
25 m
20 m
15 m
10 m
5 m

Methodology

Video:

- Birds eye view perspective of locations chosen to represent the use-cases

- Algorithmic analysis of the videos to derive positions and velocities of various traffic participants

Methodology

LiDAR:

- Stationary LiDAR giving additional information on traffic participants and increasing tracking range
- Collected data is synchronized in time enabling a holistic overview of observed interactions

WebCam

GNSS Receiver

Ibeo Lux Laser Scanner

SSD Drive

Laptop Power Bank

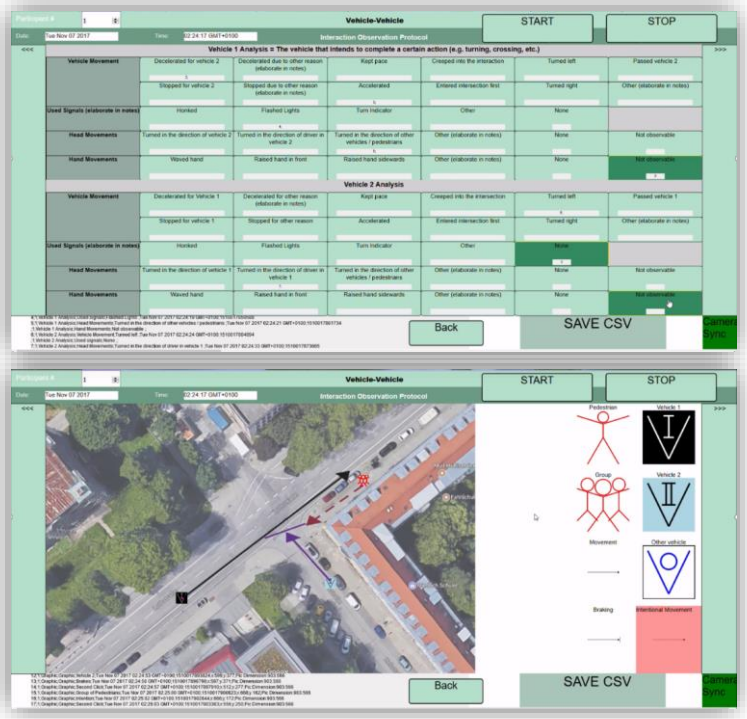
Raspberry Pi

WiFi Access Point

Methodology

Manual Observation:

- Observers protocolling individual observed interactions from the ground
- HTML based app for tablets observing pedestrian and driver behaviour, including head rotation, eye contact, etc.
- Questionnaires



Overall Findings

- Human road users seem to **avoid active communication with others** by adapting their movement behavior early
- Only in **ambiguous situations** (e.g. deadlocks) **communication** is used to let the other traffic participant go first, mostly **using gestures**
- In the rare case that pedestrians waved a driver through, the **“Thank You” hand gesture** always followed by the driver.

Results

- Most notably, interaction occurs only if the velocity of the vehicle in right of way is below a certain threshold
- At higher velocities interactions are highly unlikely
- AVs might need to adapt their behavior accordingly.
- Different driving strategies implicitly give hints to other road users about the driver’s intention.

Conclusions

- Current taxonomies of AD do not take into account cooperation between traffic participants
- A systematic of methodologies is needed
- Implicit communication plays a dominant role for interaction between traffic participants
- There is a dilemma of consistency of eHMI of the near future and the existing knowledge for their design and usage
- No clear indication can be given for explicit communication
- Explicit communication should not be the remedy for insufficient realization of AV functionality

German Activities

- UR:BAN (Driver Assistance in urban areas) (2012 - 2016)
- BaSt „Kommunikation zwischen Verkehrsteilnehmern: Einfluss zunehmender Fahrzeugautomatisierung“
- IMAGINE (Cooperative Manouvers on Motorways) (2016 - 2020)
- Pedsival – Validation of Pedestrian Simulators (IFSSTAR – TUM) (2017 ->)

- inter:ACT EU-Project (Designing cooperative interaction of automated vehicles with other traffic participants in mixed traffic environments) (2017 - 2021)
- DFG SPP (2016 ->). Interaction between AV and VRU (Prof. Krems)
- Konvoy Project
- KOLA – Kooperativer Laserscheinwerfer (11/2016 - 10/2019)
- Unicaragil – Autonomous Driving
- @city – Urban Automated Driving (2018 ->)

Wizard of Oz

Second Part - Method

Dependent Variables

Intention Recognition Time (IRT):

- measures how much **time** is needed by a pedestrian to **understand the intention** of a vehicle
  (Dragan & Srinivasa, 2013; Gielniak & Thomaz, 2011)

Questionnaire

- **vehicle's assumed intention** ("Let the HRU go first" or "Go first")
- **certainty** about the vehicle's intention (very uncertain to very certain)
- **vehicle's driving behavior** (very poor to very good)
- **perceived criticality** of the situation (very critical to very uncritical)

Wizard of Oz

Discussion

Intention

- participants almost always understood the intention of the vehicle

Driving Profile

- pedestrians preferred if a vehicle yielded its right of way

Seat Cover

- pedestrians did not perceive the difference between a driver and an empty driver seat

Intentions are not only transmitted through the driver, but also through the driving behaviour of the vehicle.

References

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