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Infrastructure Based Approach to Increase Cycling Safety in case of Turning Motorists Interacting with Crossing Cyclists at an Urban Intersection

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Kay Gimm, Marek Junghans, Hagen Saul, Mandy Dotzauer

Content

- Introduction and challenges
- Object detection, classification and tracking
- Infrastructural situation- and risk assessment
- Cooperative system approach / Warning the drivers
- Conclusions and future prospects

Initial situation (Germany)

- 25% of people involved in accidents are cyclists
- Dangerous: conflicts between turning motorists and cyclists going straight
- This type of crash is mainly caused by motorists and leads to (severe) injuries in 80% of all cases
- Problems:
  - Infrastructure: e.g. cycle paths with less than 2m or more than 4m distance to the street
  - Visibility conditions: Cyclist perception due to missing line-of-sight, ignoring and missing actions (e.g. look over the shoulder)
- Solutions:
  - Improved (and understandable) infrastructure
  - Advanced Driver Assistance Systems (ADAS) with cyclist detection and **increased driver's situation awareness → XCYCLE**

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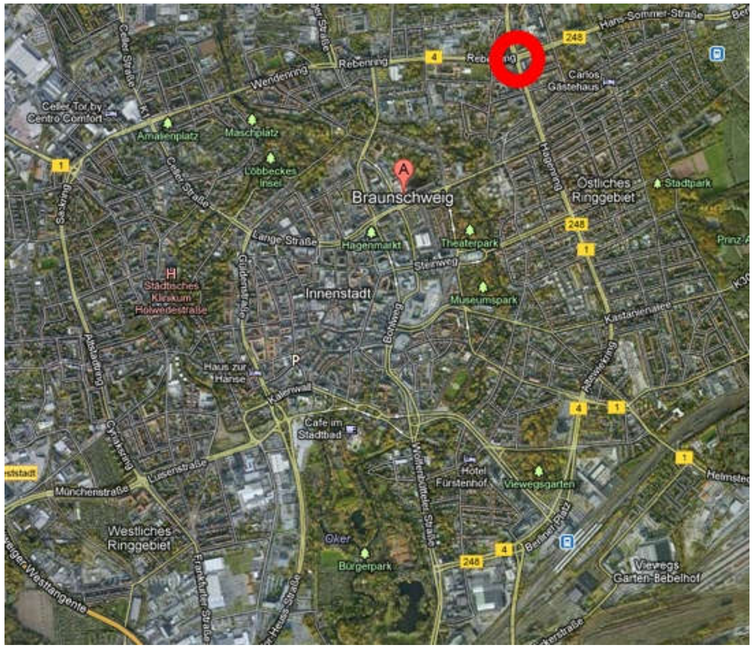
XCYCLE – What is it?

- XCYCLE = EU project challenging to reduce cyclists‘ fatalities and increase comfort in the interaction with motorized vehicles
- Project period: 06/2015 – 12/2018 (42 months)
- Funding volume: 5.0 Mio. Euro
- Website: http://www.xcycle-h2020.eu/
- Consortium

Object detection, classification and tracking

- Application platform Intelligent Mobility AIM
- large-scale research infrastructure in Braunschweig, Germany: the entire city as a platform for application-focused science, research, and development
- AIM Research Intersection



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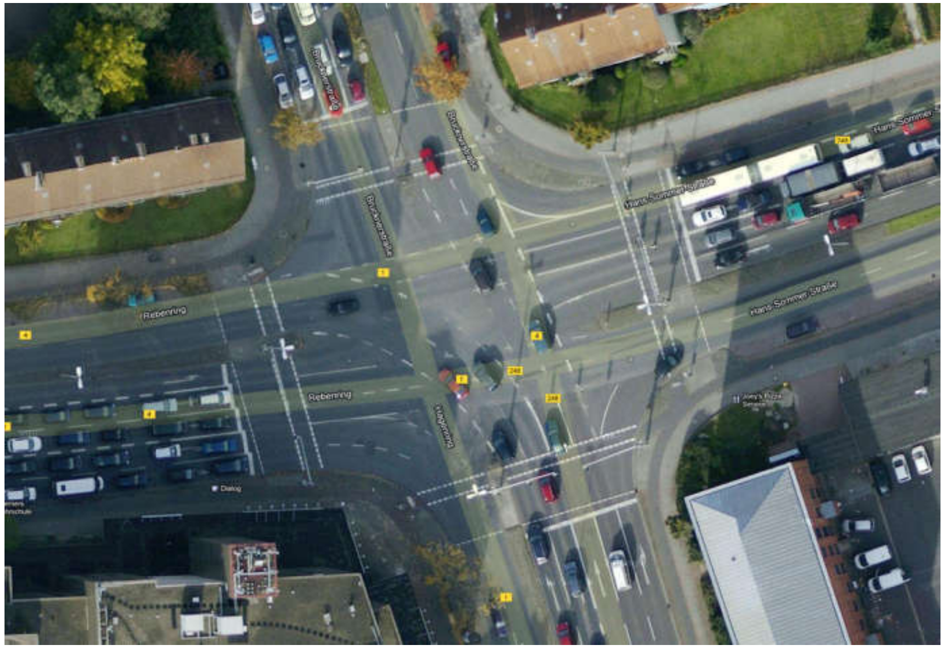


Google

Infrastructure at AIM Research Intersection

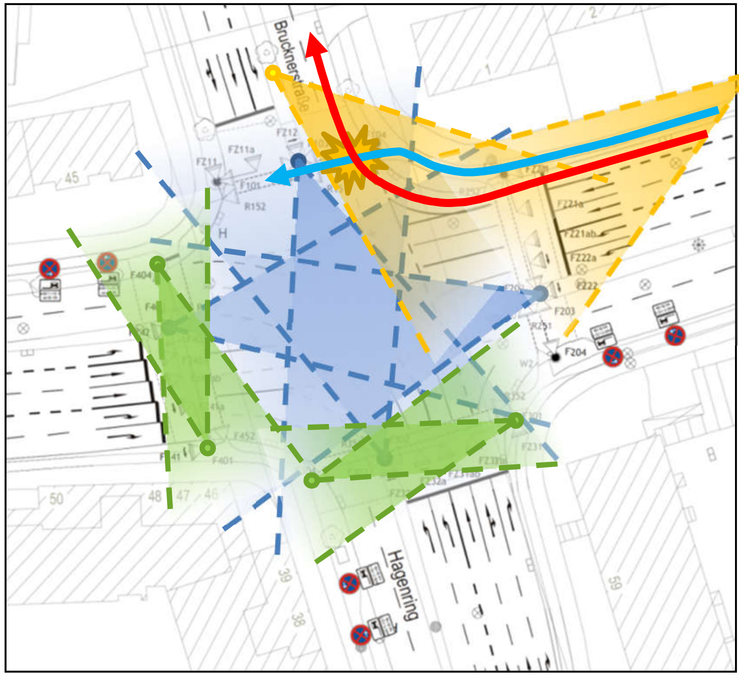
mmunication

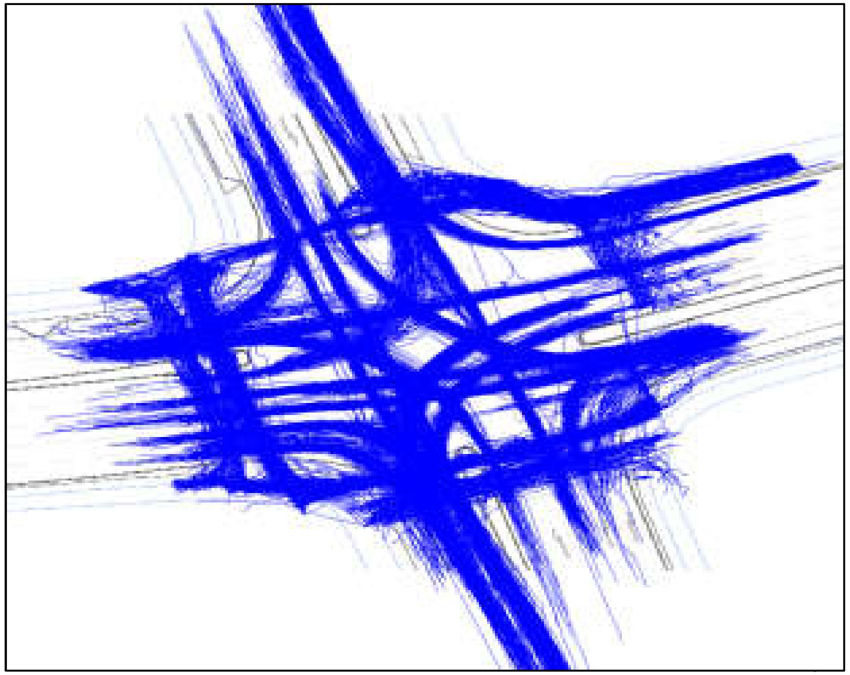
module

Infrastructure at AIM Research Intersection

Resulting data:

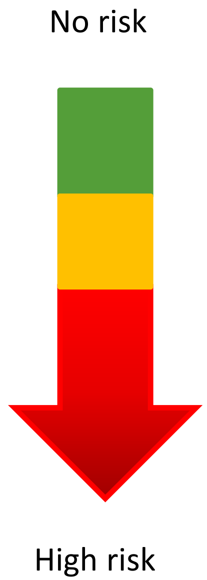
- 25 Hz trajectories (space-time curves) of all traffic participants (time, position, speed, acceleration, object size and classification)
- Communication: V2X (Vehicle-to-X) and I2V (Infrastructure-to-Vehicle)





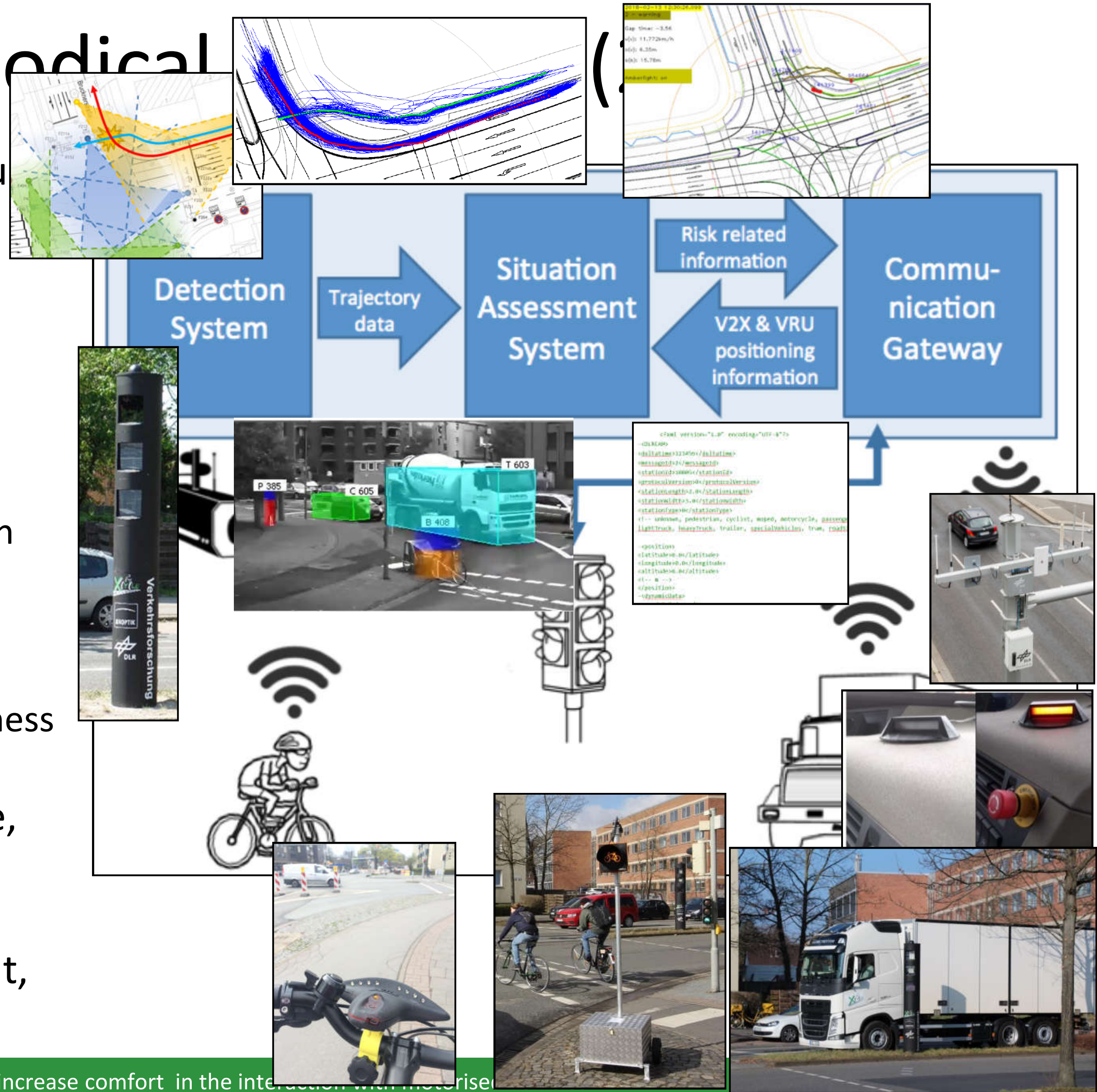
Methodical approach (1)

1. Detection and prediction of critical encounter situations by situation and risk assessment
   - Risk Level 0 (RL 0) – no cyclist present
   - Risk Level 1 (RL 1) – cyclist present
   - Risk Level 2 (RL 2) – cyclist is on collision course, but at a certain distance before the conflict zone
   - Risk level 3 (RL 3) – cyclist is on collision course, and immediate assistance of the driver required by ADAS
   - Risk Level 4 (RL 4) – collision is imminent, thus intervention by the ADAS
2. Warning the interacting partners
   - Sending out warnings to the motorist (and also receive warnings by the motorist)
   - Sending out warnings to the cyclist
   - Sending out warnings to a certain infrastructure road element



Methodical

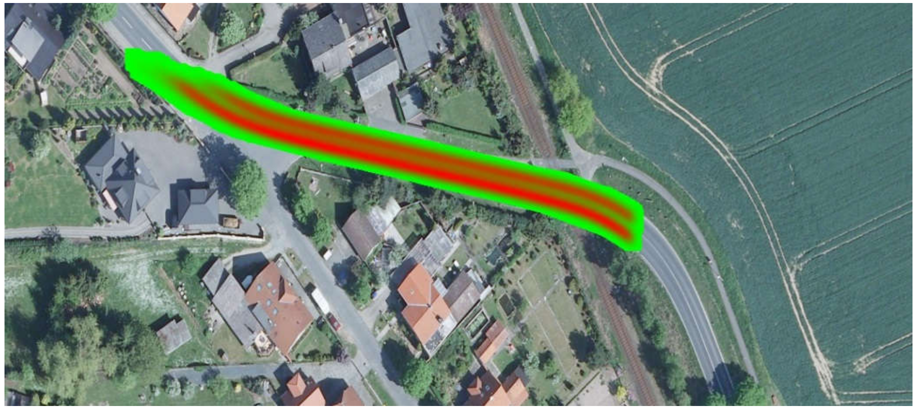
- Transmission of infrastructu information
- Enrichment of in-vehicle and infrastructural situation assessment
- bidirectional information exchange with motorist
  - SOM: Sensory Observation message
  - RISK: Risk related warning message
  - CAM: Cooperative awareness message
- Send out warning to bicycle, called On-bike tag
- Send our warning to infrastructural road element, called Amber Light



Situation and Risk Assessment (1)

Trajectory/path prediction

- Determine the main traffic path of all motorists and cyclists
  - Trajectory accumulation to create a 2D probability density function of the trajectories

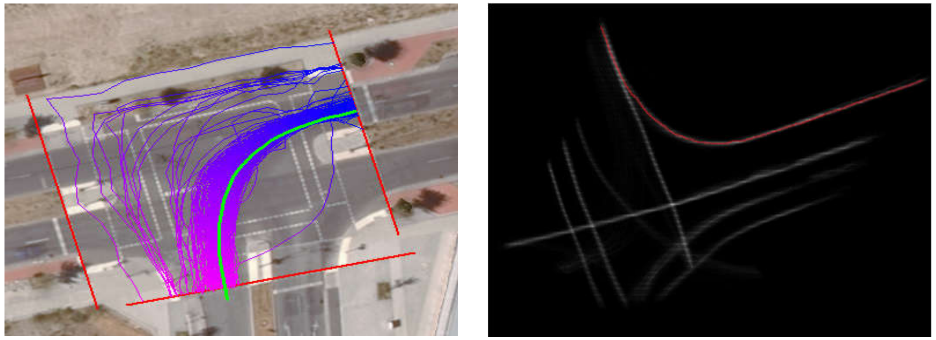


2D probability density map of accumulated trajectories

  - Non-maximum suppression (NMS):

$$T(x,y)_{NMS} = \arg\max_{x,y} P\big(T(x,y)\big)$$

T – Trajectory
P – Probability density function



Non-maximum suppression

Situation and Risk Assessment (2)

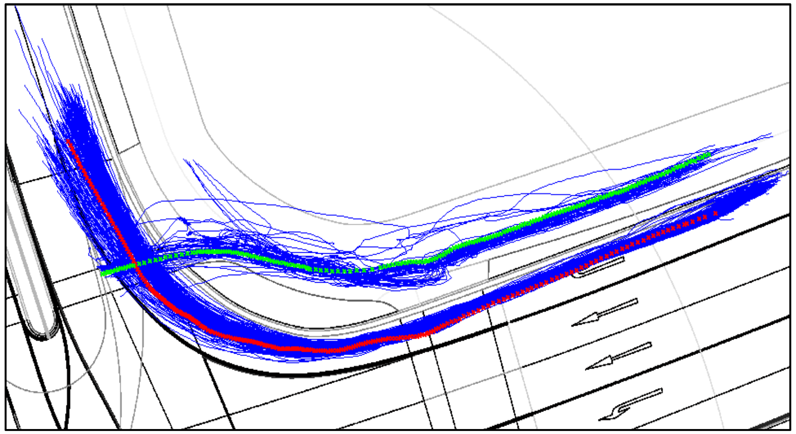
Trajectory/path prediction

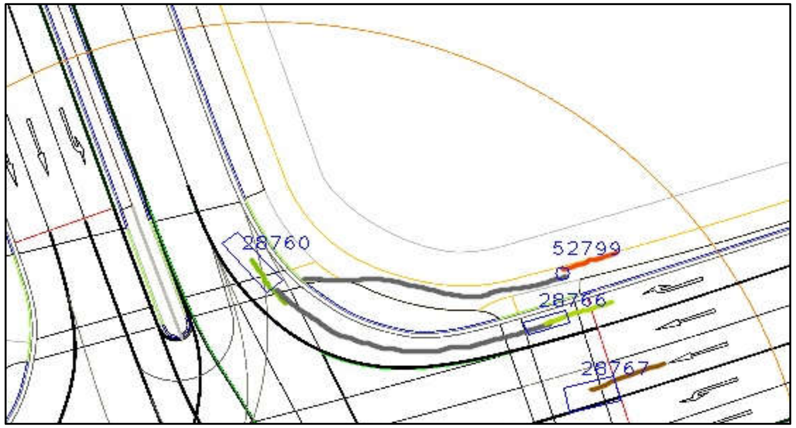
- Estimate the <u>future path</u> of all interacting motorists and cyclists
  - Predict the behavior of each interacting pair to conflict point

$$x(t+\Delta t) = \frac{a(t)}{2}\Delta t^2 + v(t)\Delta t + x(t)$$

$$v(t+\Delta t) = a(t)\Delta t + v(t)$$

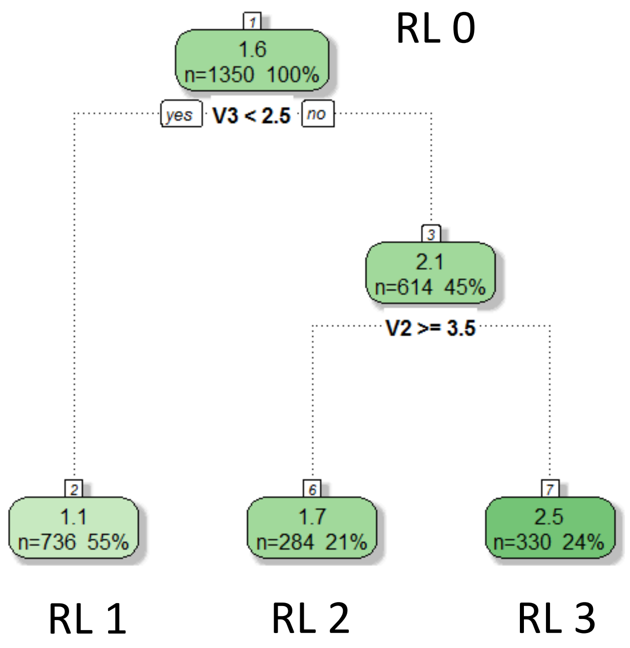
x – distance
v – speed
a – acceleration
t – time
Δt – time delta





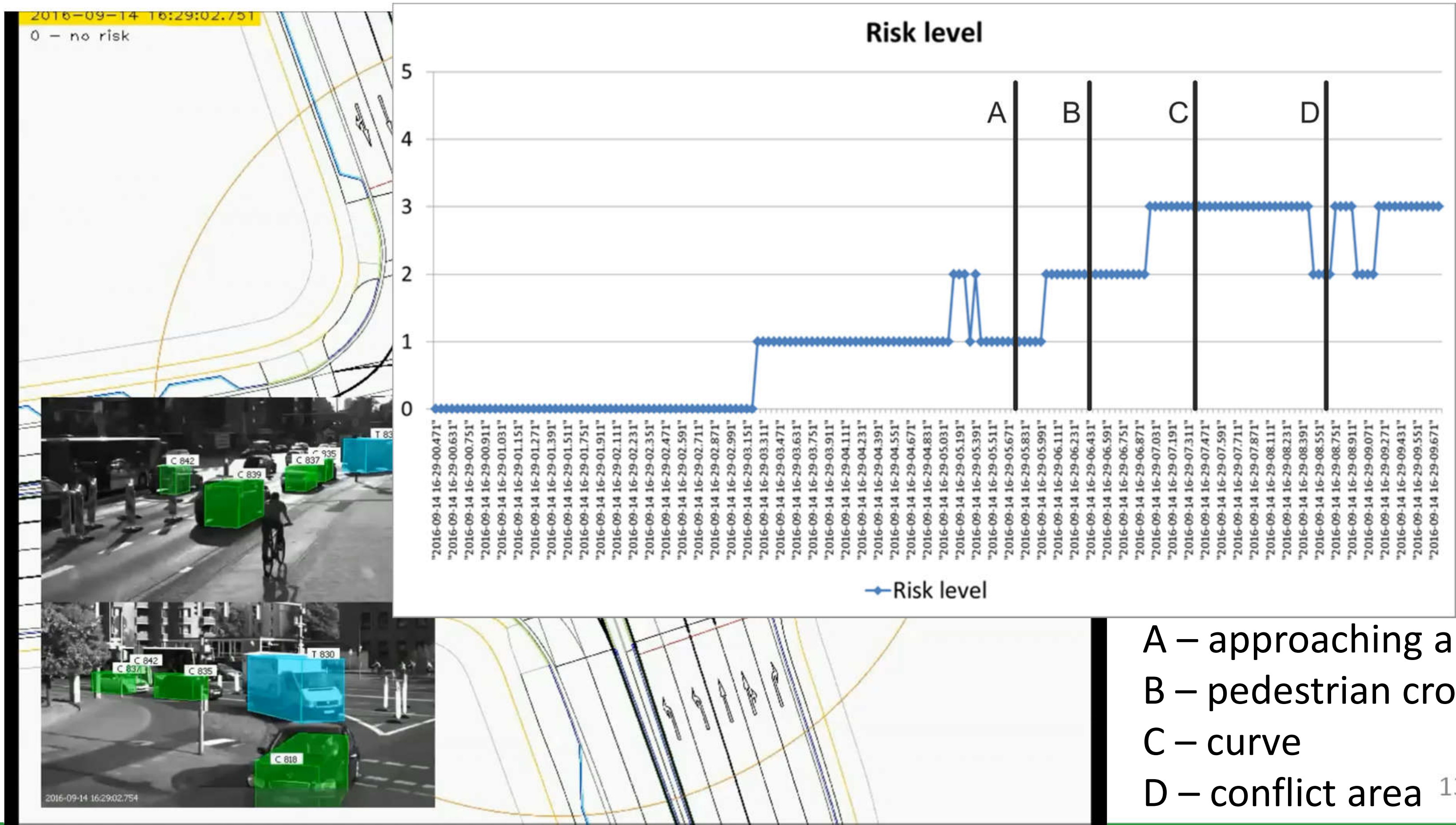
Situation and Risk Assessment (3)

- Identification of the relevant parameters of the interacting cyclist-motorist pair
  - How distant are them from the collision zone?
    - → Positions in relation to the collision zone
  - When will they appear to be at the collision zone?
    - → Speeds
  - Are they going to collide or are we expecting a near-miss?
    - → Gap time (predicted PET)
- Decision Tree (DT)
  - classification problem
  - Supervised training of the DT
- Results
  - Essential parameters describing and predicting critical situation could be confirmed
  - Very simple first version of DT, which satisfactorily described the situations (without RL 4)



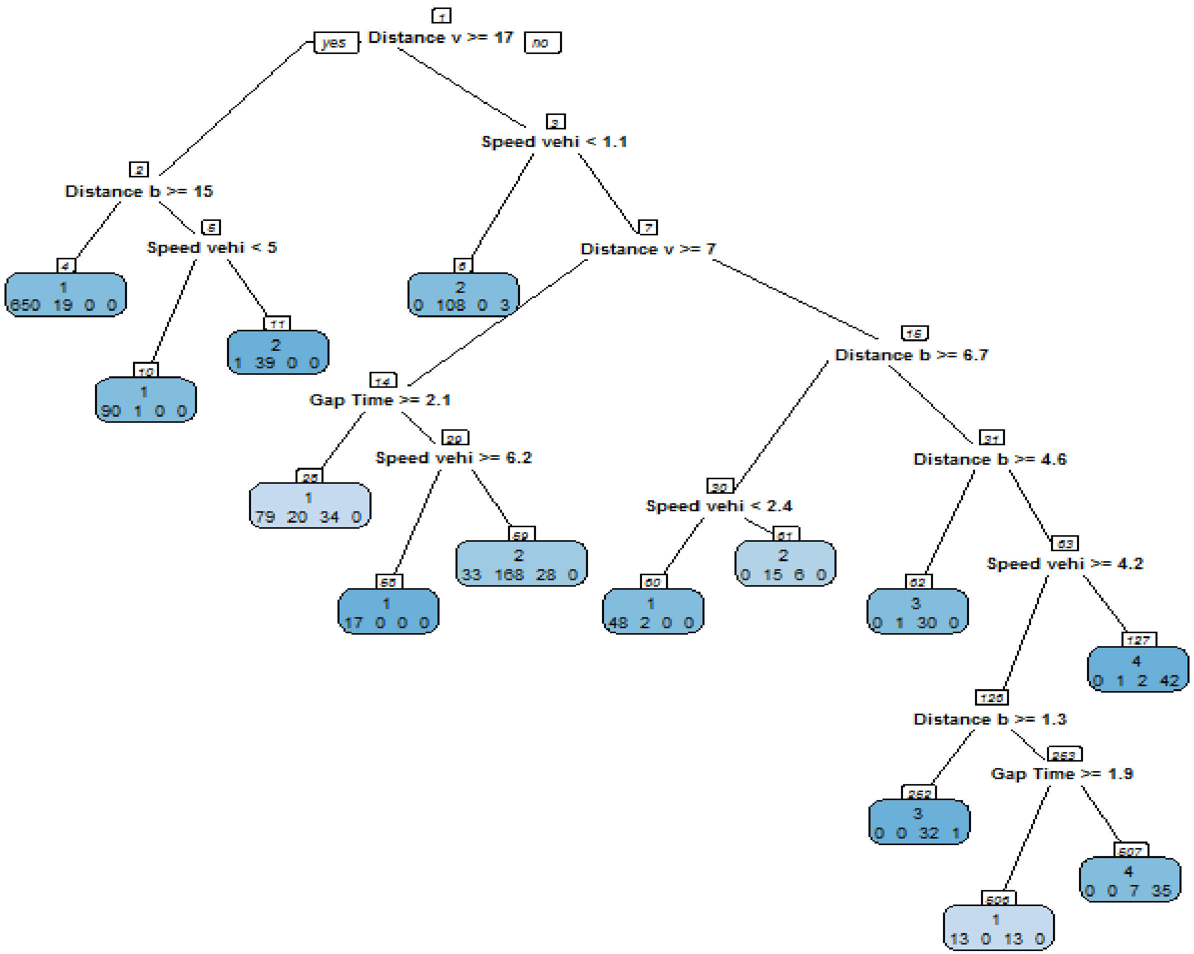
Situation and Risk Assessment (4)

- Example for risk level evolution (slow motion: ¼ speed)



A – approaching area
B – pedestrian crossing
C – curve
D – conflict area

Situation and Risk Assessment (5)



Observational studies 1 (1)

Several observational studies

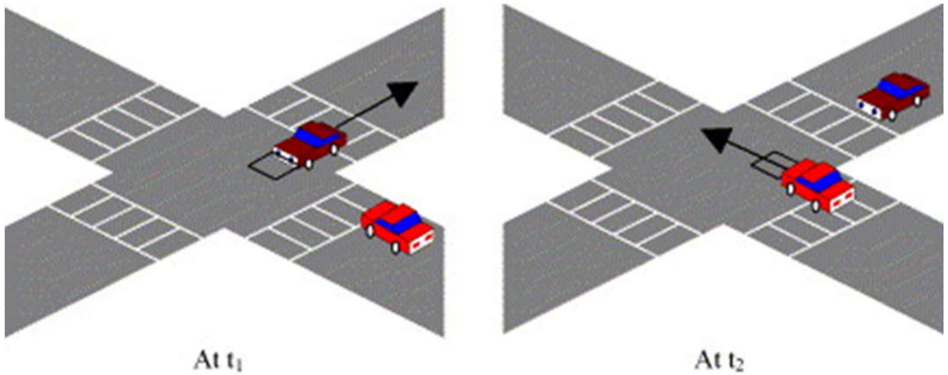
- Are there patterns in kinematic trajectory data that allows us to distinguish between critical and uncritical encounter situations between interacting motorists and cyclists?
- Are we able to predict upcoming conflicts and thus to compute the risk of collision between cyclist and motorist?
- How good can we enhance the vehicular based approaches for risk detection by infrastructure?

→ Results of one of these conducted observational studies

Observational studies 1 (2)

Patterns affecting safety

- Trajectory data of 4 weeks (August, 22nd to September, 18th 2016)
- Examination of interactions between cyclists and motorists on the basis of surrogate safety indicators (SSI): PET<2.0s
- Find relevant situations: analysis of key variables in different sections to distinguish between critical, non-critical and unaffected situations
  - relative position of cyclist and motorist
  - speed, speed difference, acceleration, space-time diagram



$PET = \Delta t_2 - \Delta t_1$

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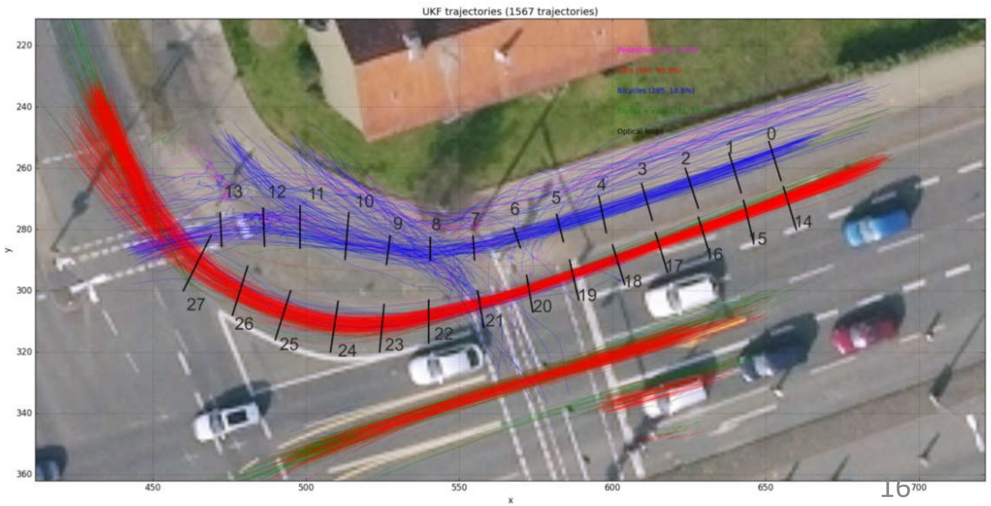
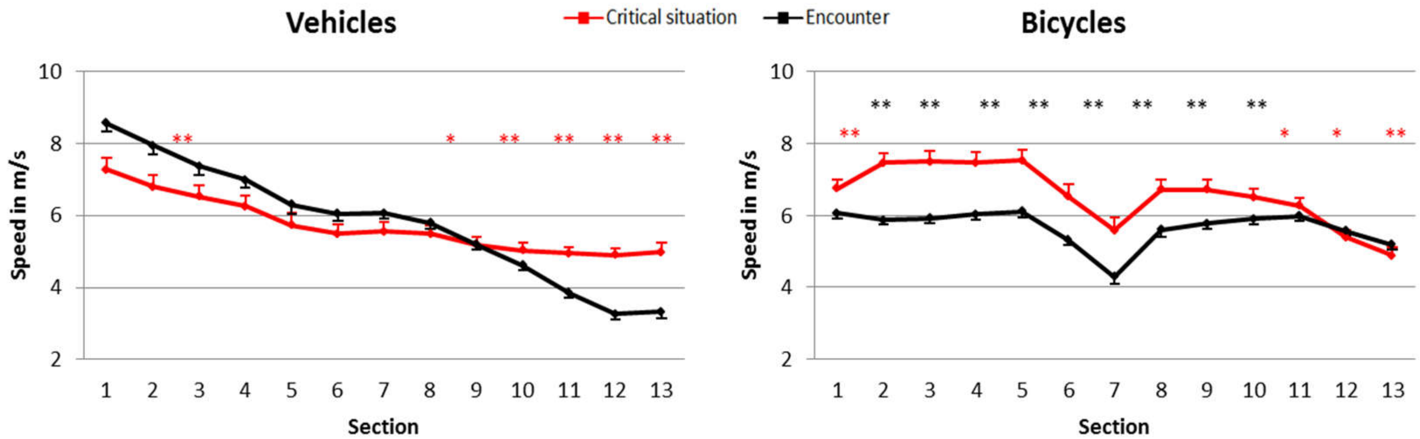


Observational studies 1 (4): How patterns affect safety

- ANOVA test: Which variables are the essential parameters characterizing safety



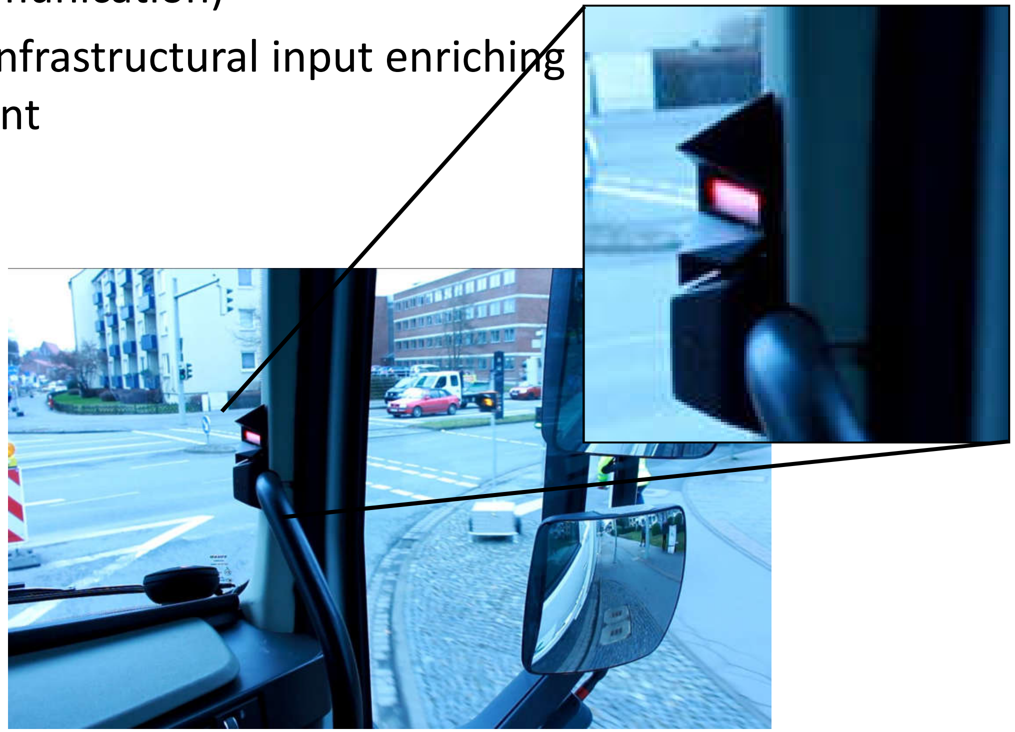
Dotzauer et al. 2017 Cycling through intersections: Patterns affecting safety

- The last 10 meters make the difference!
  – Relative position is essential for a situation to evolve into a critical or an uncritical encounter
  – Conflicts emerge within the last 10m before the conflict zone (this is the difference to uncritical encounters!)
  – Motorists decelerate 10m before the conflict point in uncritical encounters
  – Cyclists' speeds approach intersection with higher speeds in critical encounters

How to warn the drivers? (1)

Truck driver and motorists equipped with V2X

- Risk related warning to truck/motorized vehicle as RISK message by I2V (Infrastructure-to-Vehicle communication)
- In-vehicle HMI is triggered based on infrastructural input enriching in-vehicle situation and risk assessment



How to warn the drivers? (2)

Truck driver and motorists <u>without V2X</u>

- Risk related warning to truck/motorized vehicle as RISK message by I2V (Infrastructure-to-Vehicle communication) to the Amber Light
- Amber Light is triggered to light (RL 2 or 3) or flash (RL 4)

How to warn the drivers? (3)

Cyclists

- On-bike-tag was integrated in AIM Research Intersection
- Tag matched with camera-based detected object
- individual bicyclist warnings triggered by the infrastructure
- HMI: black cover and white LEDs

Conclusions & Future Prospects

Conclusions

- Developed of simple and powerful algorithms to detect and predict the risk of collision between cyclists and motorists: Path prediction + Decision Tree
- Identified kinematic patterns affecting safety allowing us to differentiate between critical and uncritical encounters
- Conducted several observational studies and technical evaluations of the cooperative system (infrastructure, vehicle w/o Amber Light, cyclist & on-bike tag) at AIM Research Intersection, Braunschweig, Germany
- Identified mainly stability and timely problems during the computation of an accurate and reliable risk level by the infrastructure

Conclusions & Future Prospects

Future work

- Improvement of the process chain by more powerful server solutions
- Improvement of software by optimized and stabilized algorithms
  - Adoption of Neuronal Networks for more reliable trajectory path prediction
  - Algorithms for stabilizing risk level estimation and thus triggering the Amber Light
  - Improvement of algorithms handling missing and erroneous data
- Collection of more trajectory data to reliably train the AI algorithms in use
- final objective and subjective evaluation of Amber Light and On-bike tags in upcoming studies
- Put the system into permanent operation, i.e. 24/7
- Generalization of the situation and risk assessment for different intersection geometries and different turning maneuvers

Thank you for your attention!

German Aerospace Center (DLR)
Institute of Transportation Systems
Marek Junghans
Rutherfordstraße 2
12489 Berlin, Germany
Phone: +49 30 67055 214
Email: marek.junghans@dlr.de