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

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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
Infrastructure at AIM Research Intersection
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

No risk
High risk
Methodical approach:

- Transmission of infrastructural 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

- Non-maximum suppression (NMS):

\[ T(x, y)_{NMS} = \arg\max_{x,y} P(T(x, y)) \]

- \( T \) – Trajectory
- \( P \) – Probability density function
Situation and Risk Assessment (2)

Trajectory/path prediction
- Estimate the future path 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
- \(\Delta t\) – time delta
Situation and Risk Assessment (3)

• Identification of the relevant parameters of the interacting cyclist-motorist pair
  – How distant are they 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)
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

\[ \text{PET} = \Delta t_2 - \Delta t_1 \]
Observational studies 1 (4): How patterns affect safety

- ANOVA test: Which variables are the essential parameters characterizing 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

Dotzauer et al. 2017 Cycling through intersections: Patterns affecting safety
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 without V2X

- 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!

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