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Comparison of safety and kinematic patterns of automated vehicles turning left in interaction with oncoming manually driven vehicles

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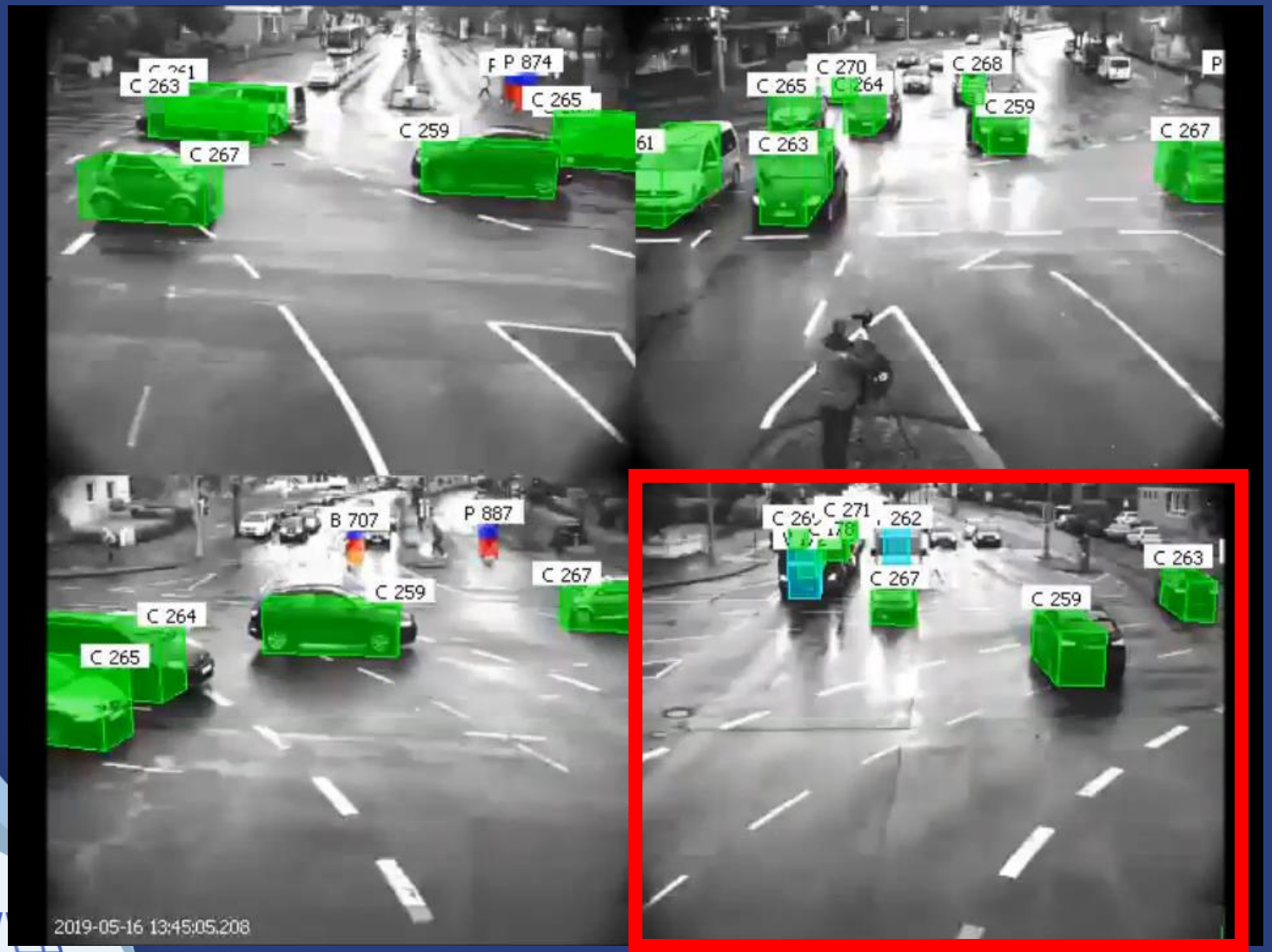
What are the differences between automated vehicles and human drivers turning left?



- Turning left is one of the most crucial tasks for automated vehicles
- What comes into your mind first watching this video?
- Conditionally tolerable left turns require proper comprehension of complex, time-critical situations and safe decision making

Research question and hypotheses

"What are the differences in conditionally tolerable left turns in oncoming traffic between an automated vehicle (AV) and manually driven vehicles (MV)?"

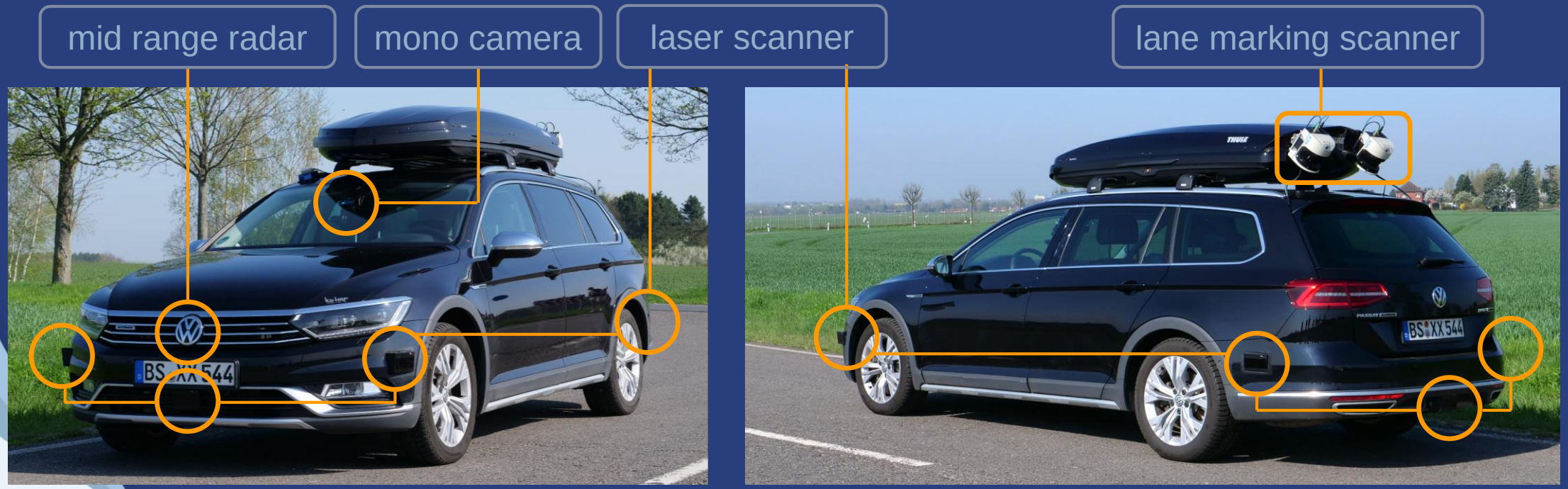
- H1: speed of AV lower than MV during approaching, passing and leaving intersection
- H2: acceleration/deceleration of AV less intensive than MV
- H4: PET distribution of AV has more uncritical PET (post encroachment time) values than MV

Junghans, M., Krauns, F., Sonka, A., Böhm, M., Dotzauer, M. (2021). Comparison of safety and kinematic patterns of automated vehicles turning left in interaction with oncoming manually driven vehicles. Transactions on Transport Sciences (TOTS), Vol. 2/2021, pp. 1-12, Palacký University Olomouc. DOI: 10.5507/tots.2021.003, https://tots.upol.cz/corproof.php?tartkey=tot-000000-0123

Material and apparatus

TEASY 3 (Testing and Engineering of Automated Driving SYstems)

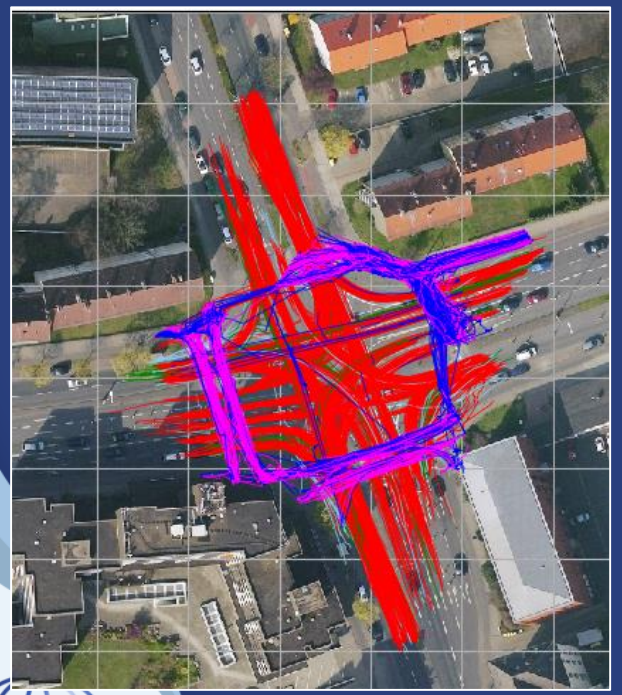
- SAE L3 vehicle developed by Technische Universität Braunschweig
- Environment sensor setting: mid-range radar, mono camera, laser scanner, Inertial Measurement Unit (IMU)
- V2X communication



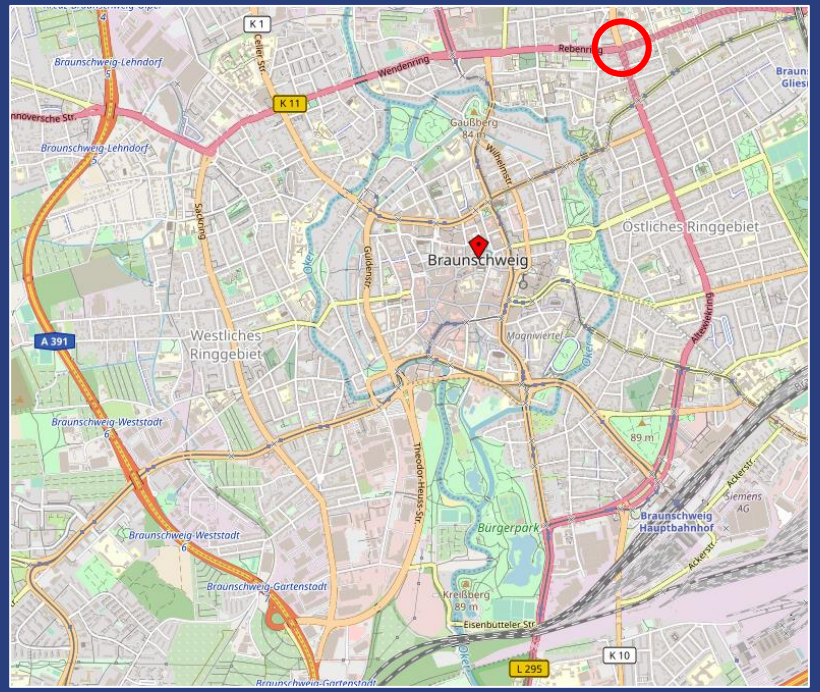
Material and apparatus

AIM Research Intersection, Braunschweig, Germany

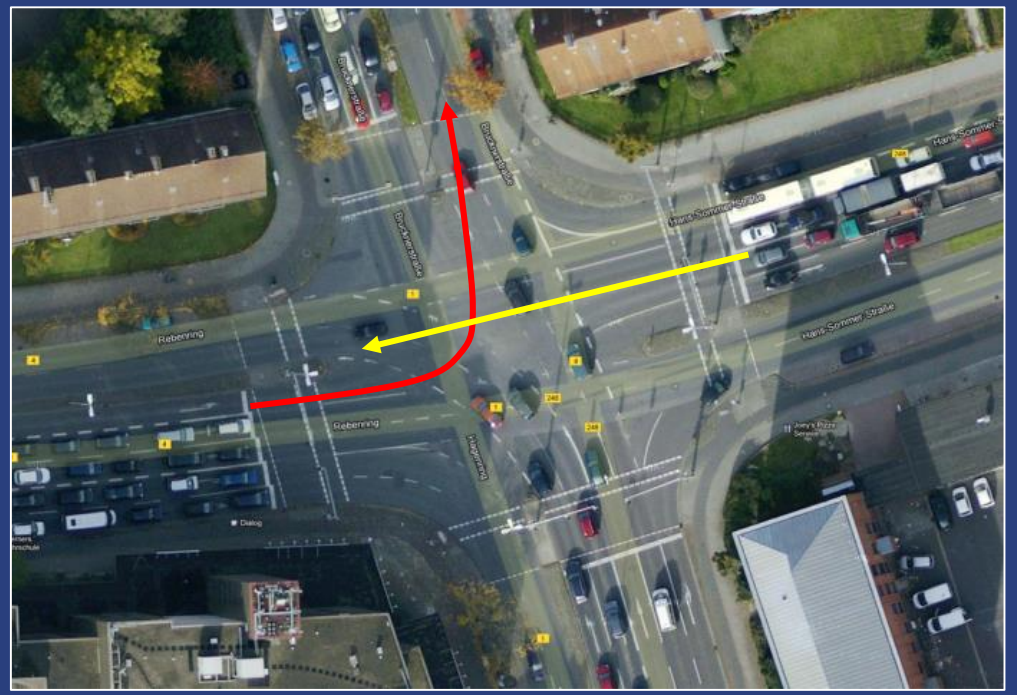
- Application platform Intelligent Mobility (24/7 operation, several stereo cameras)
- Up to 4 lanes per direction, ≈ 20.000 road users per day, 58 crashes between 2015-2019 (5 people injured) and 9 crashes in left-turn situations
- Conditionally tolerable left turning AV (W→N) interacting with oncoming traffic (E→W) and VRU in the North



Car (red), truck/van (green), cyclist (blue), pedestrian (purple)



Source: OSM



Source: Google

Data

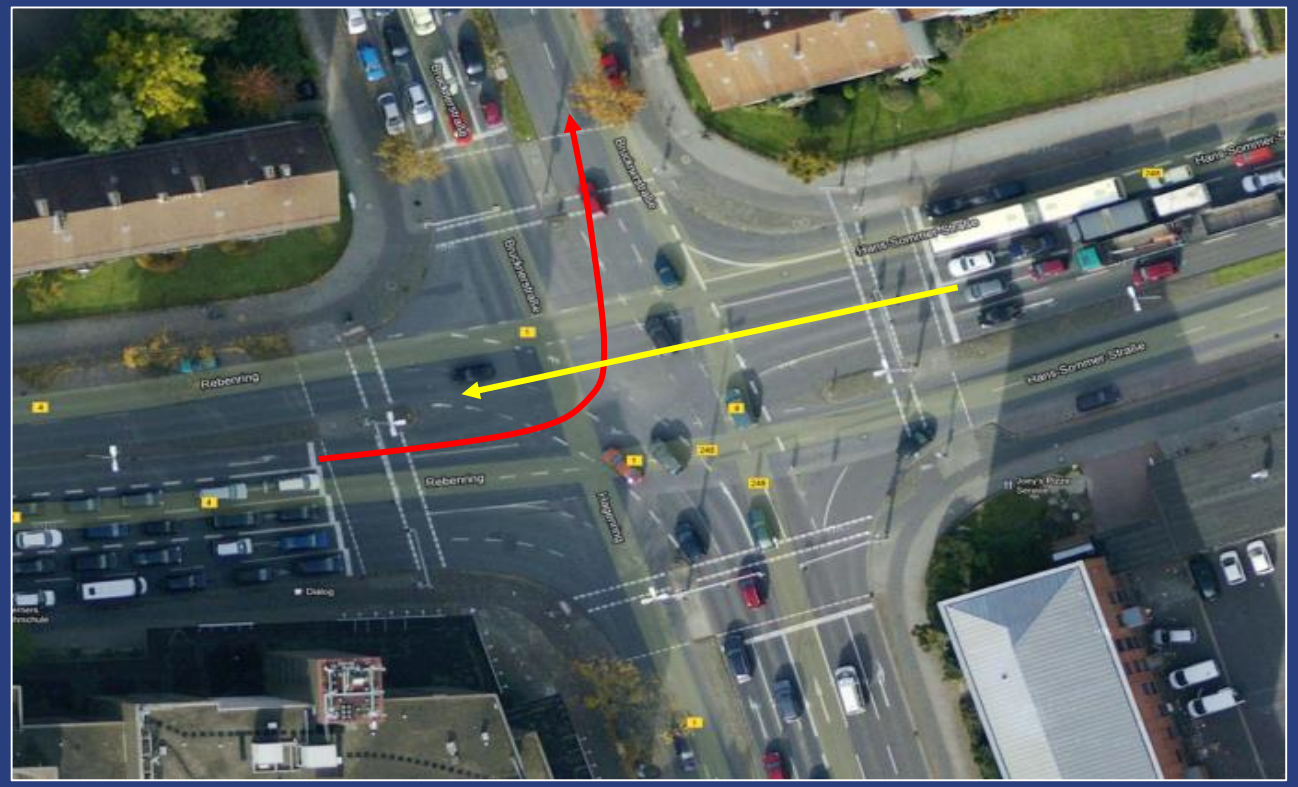
Trajectory data of AIM Research Intersection

Automated vehicle (AV)

- 39 left turn situations of AV turning left from May 14 to June 6, 2019 recorded
- 12 situations had to be discarded due to trajectory corruptions and interactions with right turning vehicles
- 27 situations remained

Manually driven vehicles (MV)

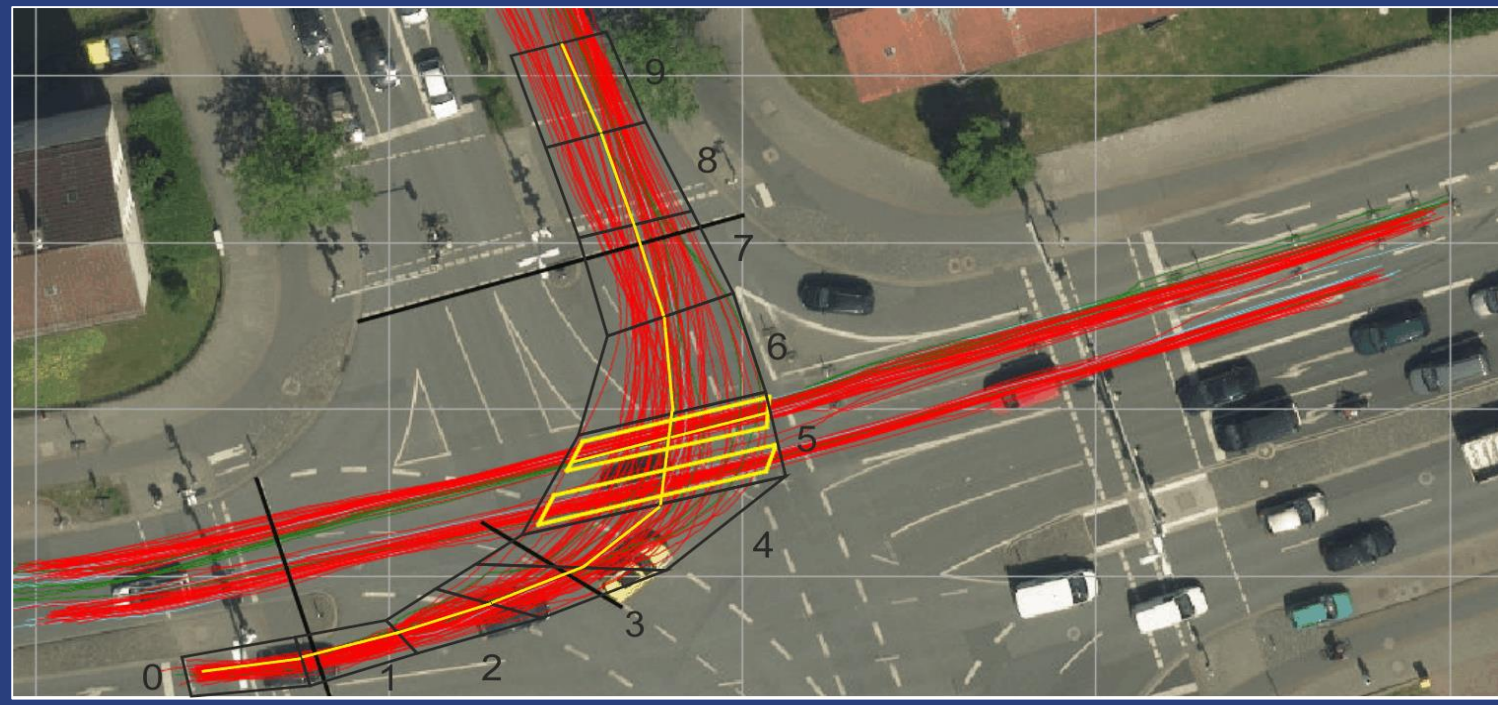
- 72 baseline situations (same conditions, i.e. ± 10 min)
- 2 situations discarded (no interaction with oncoming vehicles)
- 70 situations remained



Source: Google

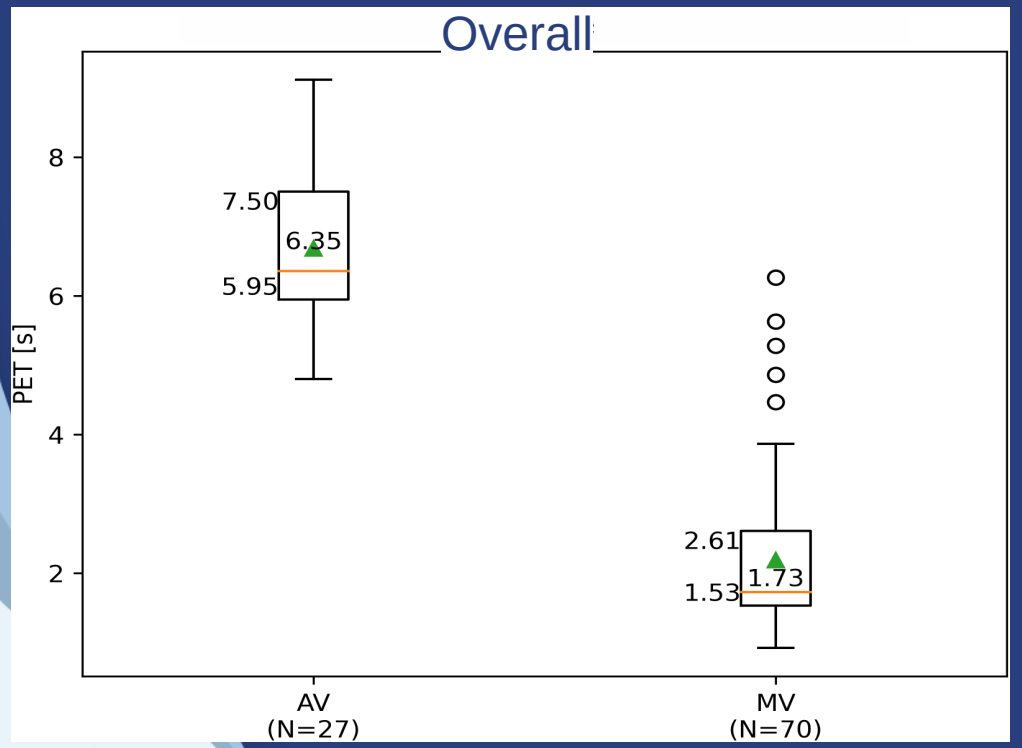
Analysis
Setup and variables

- Equidistant sections
- Kinematics
  - Speed
  - Acceleration
- Interaction
  - Post encroachment time
  - Time/distance to conflict point
  - Accepted/non-accepted time gaps
- Significance tests
  - Confidence $\alpha < 0.05$ and Bonferroni correction
  - Mann-Whitney-U
  - Kruskal-Wallis-H

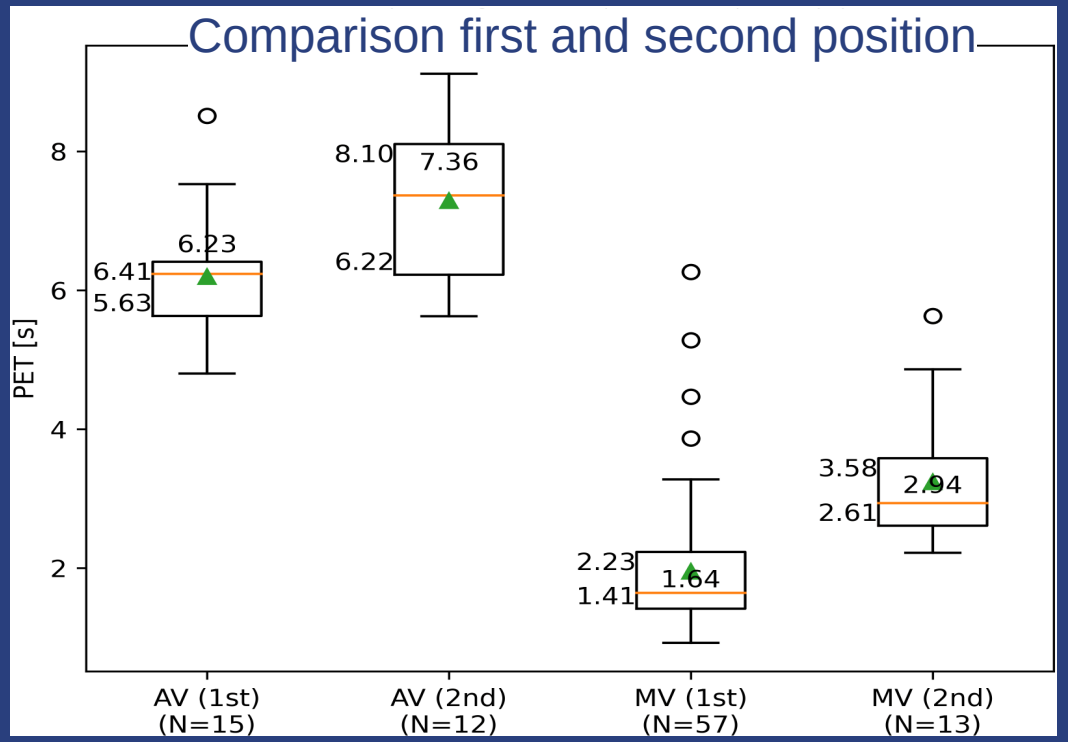


Results
Interaction (PET)

- Significant differences between AV and MV (Mann-Whitney-U)
- Very conservative (safe) left turning manoeuvre of the AV, i.e. very large gaps and very safe PET values, which could be decreased by far to maintain the same safety level
- PET is 1.1-1.3 seconds larger for vehicles at second position



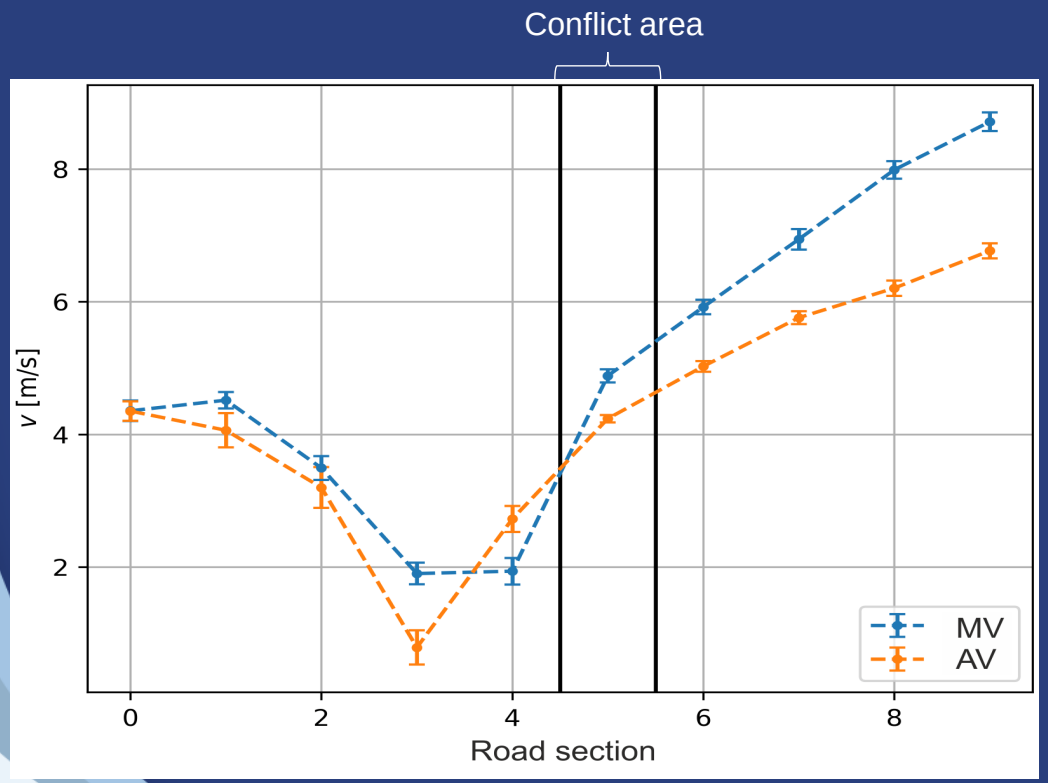
$\alpha = 0.05$, $p < .001$, $r = .756$



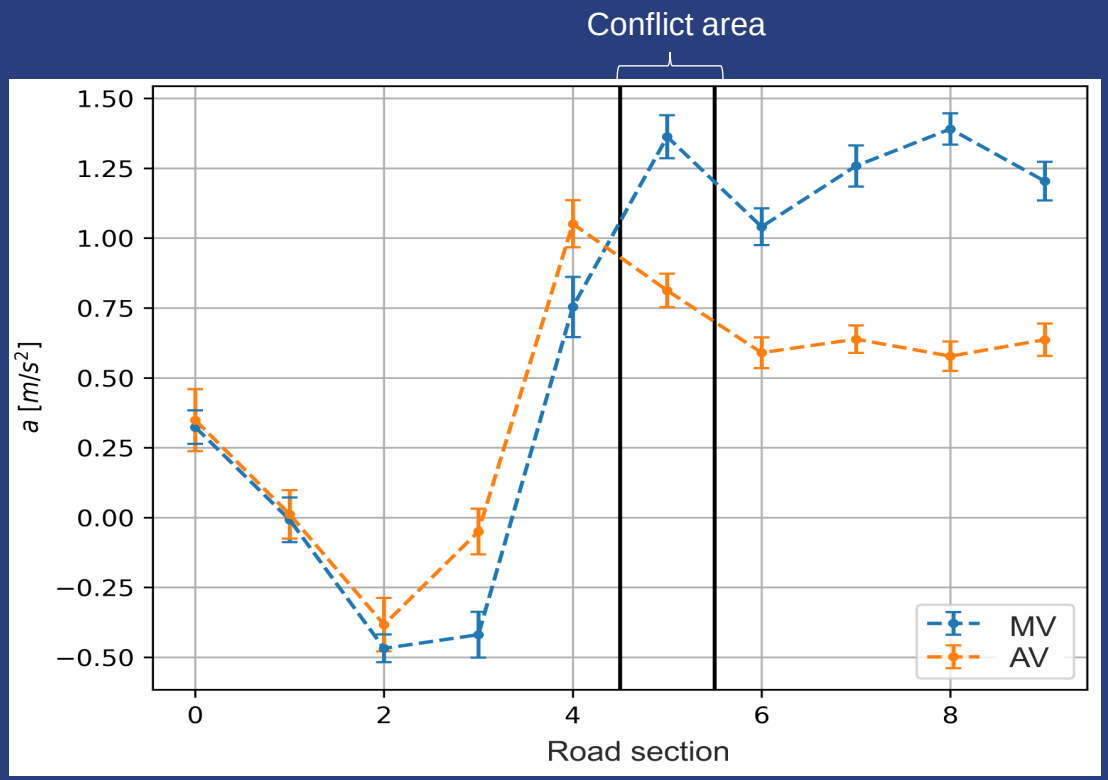
$\alpha = 0.0125$, $p < .001$, $r_{1st} = .681$, $r_{2nd} = 0.838$

Results
Kinematic behaviour

- No significant difference in kinematic behaviour between AV and MV (Kruskal-Wallis-H)



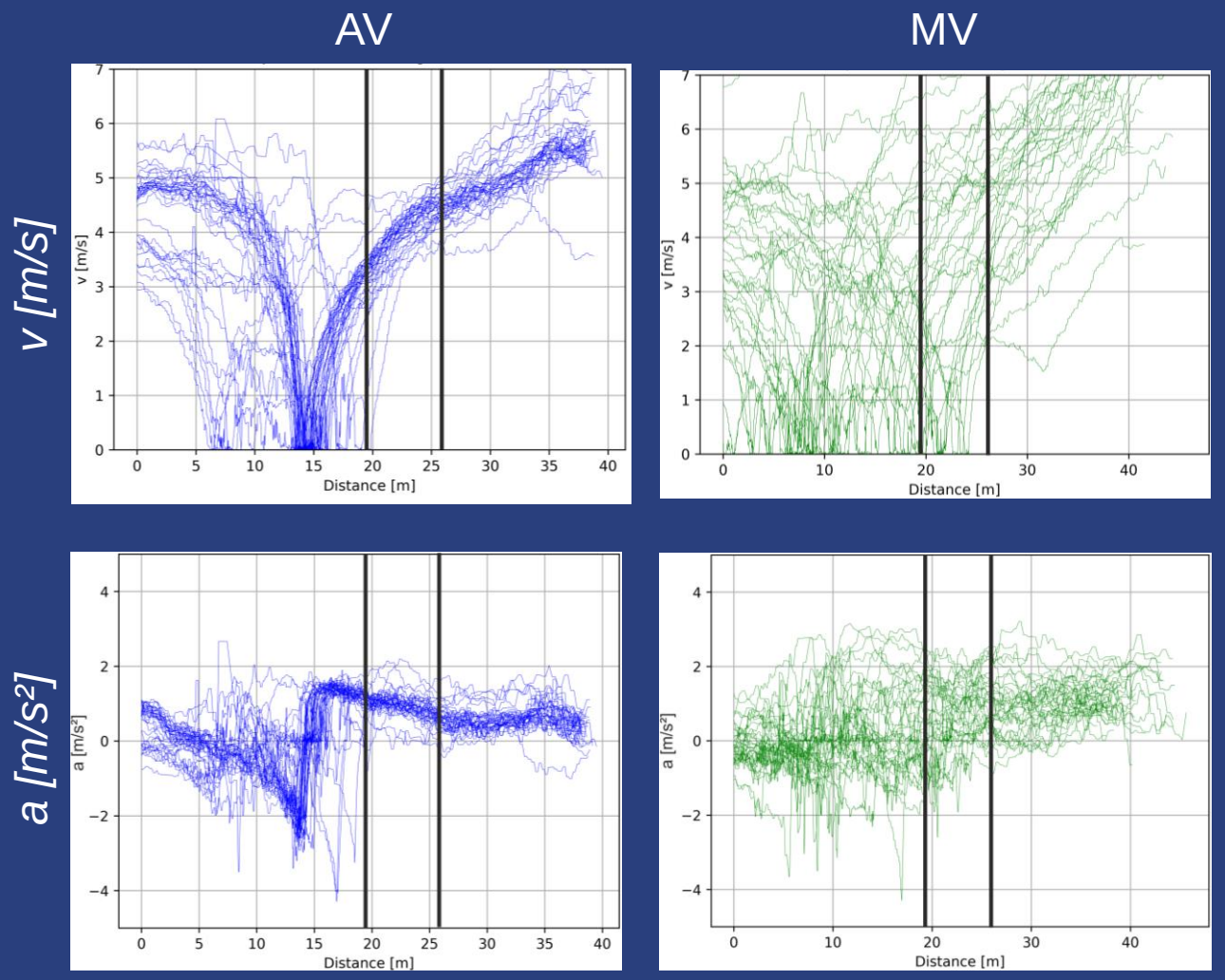
$\alpha = 0.005$, DF = 9, p = .406



$\alpha = 0.005$, DF = 9, p = .364

Interpretation and implications

- Driving behaviour of AV predictable, but similar to MV
- Human driver may anticipate situations better than the AV, maybe due to lack of relevant information or limited senor range and not distinguishing between the adopted lanes of oncoming traffic
- Results should be used to mature ADF



Research question and hypotheses

"What are the differences in conditionally tolerable left turns in oncoming traffic between an automated vehicle (AV) and manually driven vehicles (MV)?"

→ Differences regarding interaction
→ No (significant) differences regarding kinematic behaviour

- H1: speed of AV lower than MV during approaching, passing and leaving intersection
- H2: acceleration/deceleration of AV less intensive than MV
- H4: PET distribution of AV has more uncritical PET (post encroachment time) values than MV

Thank you very much for your attention!

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