PROJECT of the PEGASUS FAMILY

VERIFICATION VALIDATION METHODS

Final Event 21 / 22 November 2023

Criticality Metrics and the Identification of criticality phenomena

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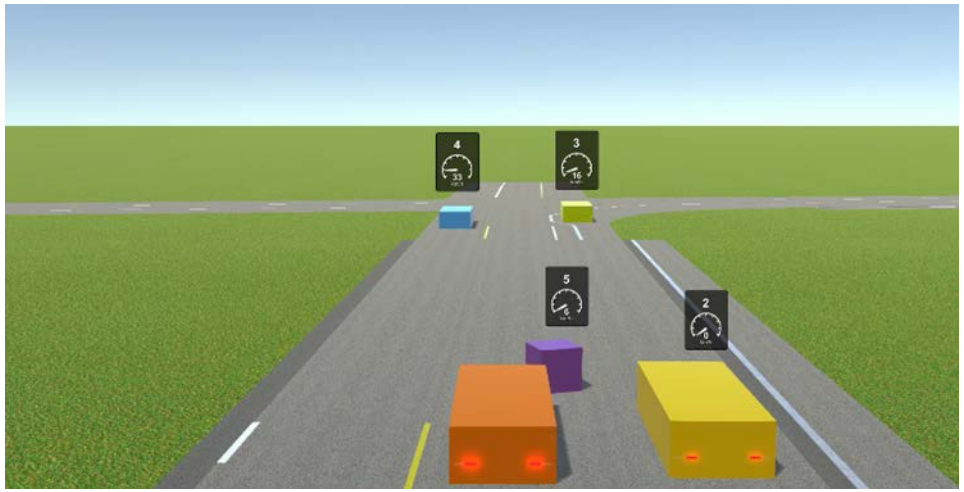
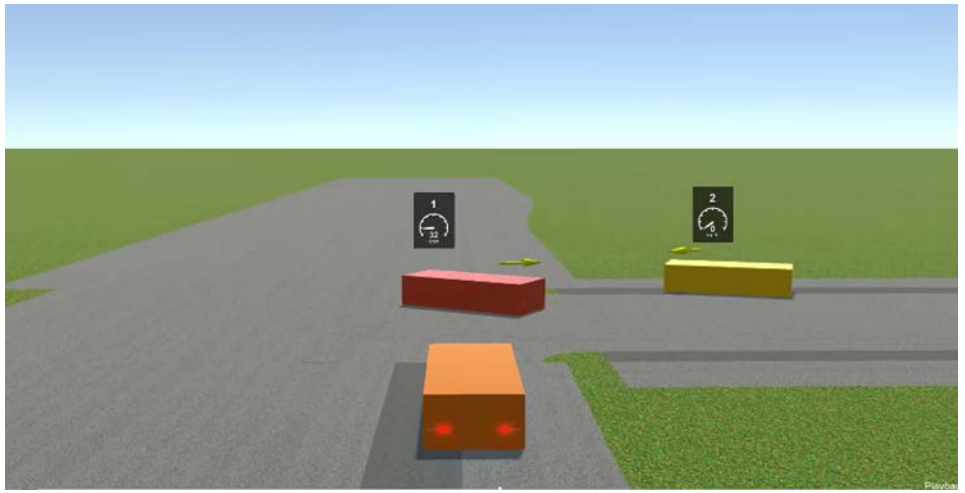
on the basis of a decision by the German Bundestag

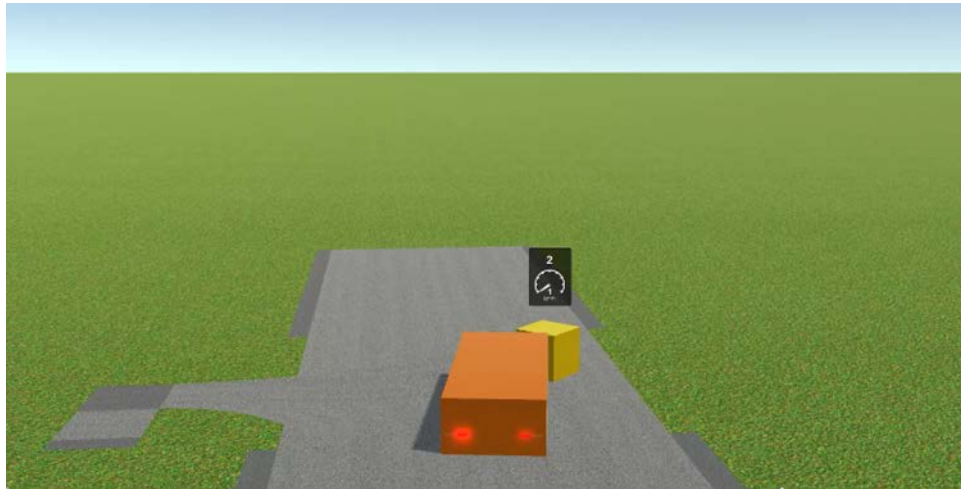
Crossing Pedestrian, Real world scenario – similar to FUC2.3

https://youtu.be/bnPvNGC8qWI?si=kxWa1nd2w6XJ0pke&t=30

Various critical scenarios from a crash and near-crash database

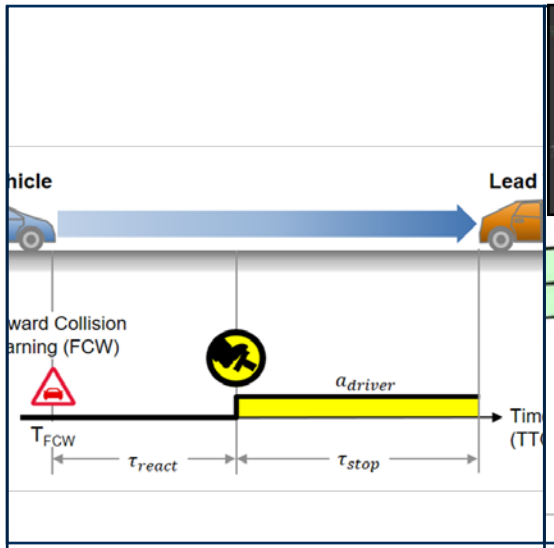






Observation Name	Crash	Belly criticality
Near crash w. pedestrian	0	High
Near crash w. car	0	Low
Crash w. pedestrian	1	Medium

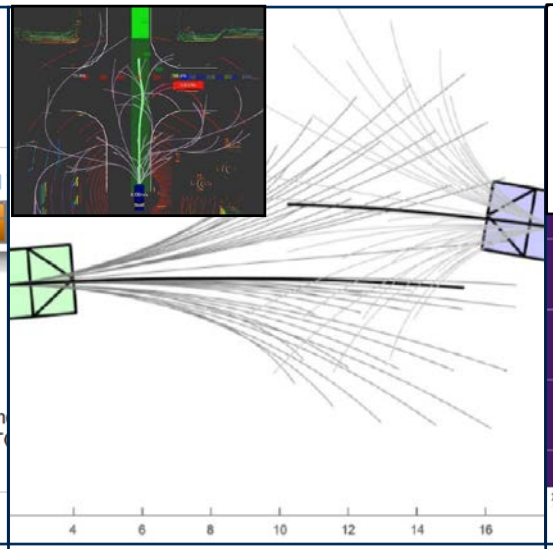
Classes of criticality measures



Simplified measures

- Measures based on simplified geometric and physical relations between objects – solving equation of motions
- are a quick and rough estimation to get a feeling for criticality
- But in most cases, the metrics are just limited to a limited space of functional scenarios

- Used Example:
  - Time to Collision (TTC)

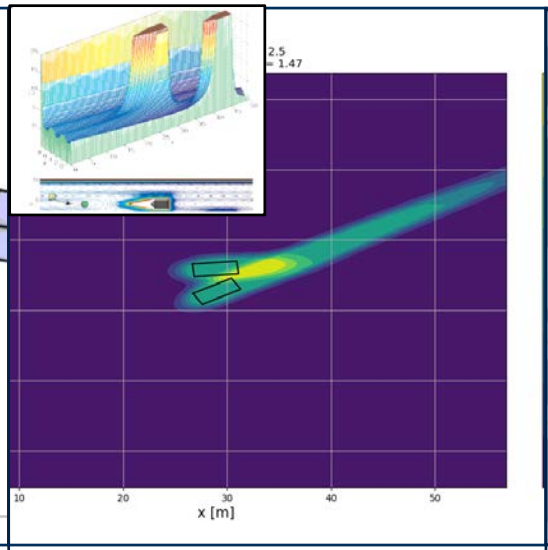


Trajectory-based

- Prediction of near-future trajectories
- Estimation of collision probability

- Good estimation of possible scenario pathway and derived collision probability by solving multiple / infinite pairs of equations of motion

- Used Example:
  - Evasion Threat Metrics (ETM)
  - Collision Prediction Criticality (COP)

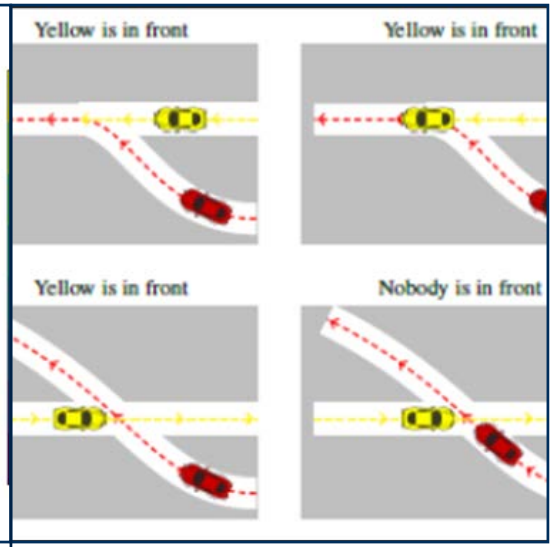


Potential-based

- Object motion induces spatial potential
- Superposition of potentials creates criticality

- Due to spread in the plane able to solve criticality for various functional scenarios. Even for near misses.

- Used Example
  - MerLin

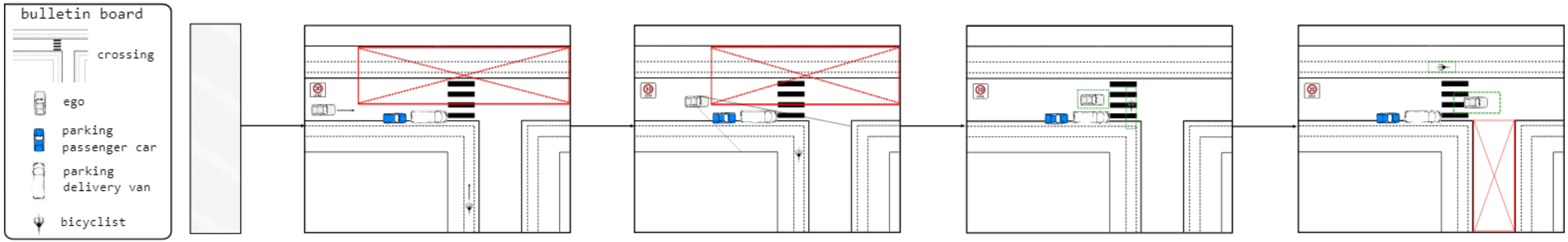


Rule-based

- Distinction of scenarios according to rules or maneuvers
- Appropriate measures for given scenarios
- The rule-based metrics need to have a prior classification of the scenario, which should be evaluated, to choose the right rule.

- Example:
  - MobilEye,
  - but not used, as those measures are per definition not valid for unknown scenarios

Scenario Description



- **Base Parameter Set:**
- Following the approach of a kinematic based motion in multiple maneuvre steps for each traffic participant and following the boundary condition, that ego and pedastrian should met on the street in an uninfluenced scenario, we get the three base parameter:

- $v_{0,ego}$: $[2\ -30]km/h$
- $v_{0,ped}$: $[1-10]km/h$
- Δs: $[-1.01\ -1.01]m$

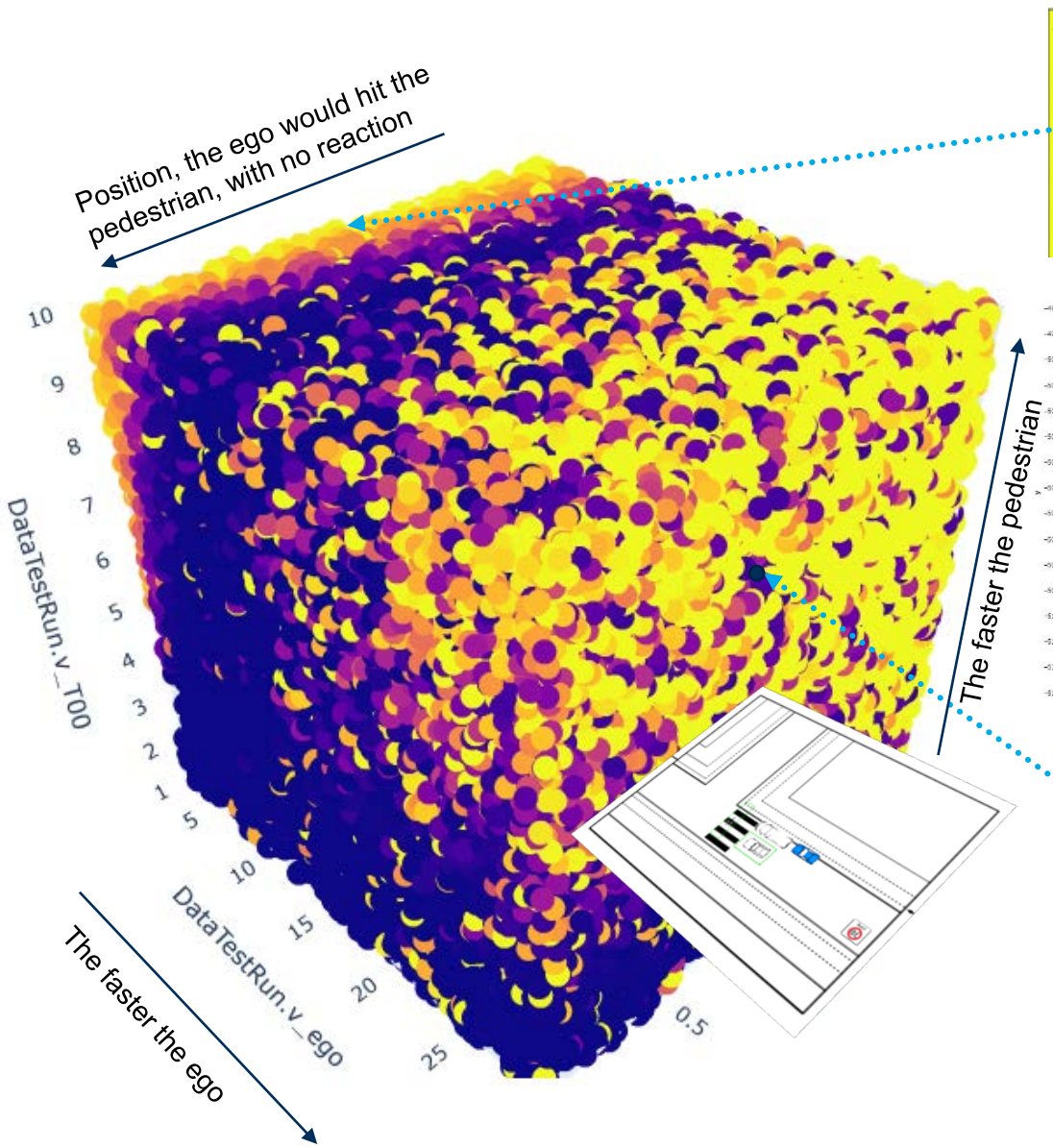
- Dependend parameter:

- $s_{0,ego} = v_{ego} * \frac{s_{0,ped}+\Delta s}{v_{ped}}$

- **Phenomena Parameter Set:**
- Reviewing the list of criticality phenomena, three phenomena were identified as valuable and possible for implementation in simulation:

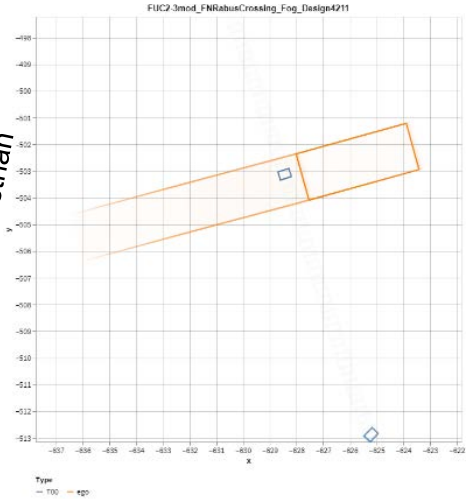
- $dist_{object}$: $[0-11]m$ distance of an occluding vehicle to crosswalk
- μ: $[0-1]$ road friction coefficient
- vis_{fog}: $[40\ -170]m$ visibility due to fog

General discussion on 100,000 sampled simulations



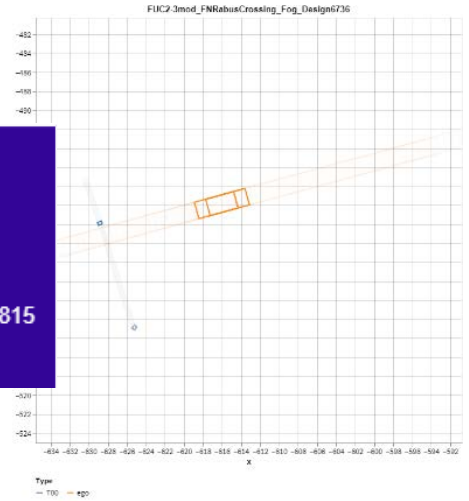
4211

DeltaS=−0.755139
DataTestRun.v_ego=2.79562
DataTestRun.v_T00=9.89358
ID=4211
DataRoadRabusV01.Mu_RoadAll=0.857025
DistStatO=3.766235
DataTestRun.VisRFog=97.84805



6736

DeltaS=0.234091
DataTestRun.v_ego=29.27186
DataTestRun.v_T00=5.510575
ID=6736
DataRoadRabusV01.Mu_RoadAll=0.859815
DistStatO=10.704925
DataTestRun.VisRFog=151.31055

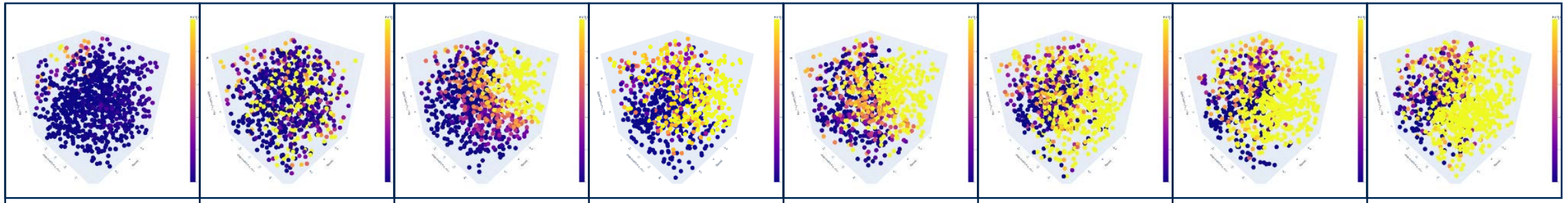


- ➔ The faster the ego, the more critical <- less reaction time
- ➔ The faster the pedestrian, the more ciritcal <- less reaction time
- ➔ Recognicable difference in ‚criticality volume‘ on the near side to the far side

- ➔ One anomaly for small ego velocities and increasing pedastrian velocities
  - ➔ Squaring the circle for potential based measure
- ➔ Another observable effect is the noise in criticality, between high critical points
  - ➔ Hint for unvisualized dimensions

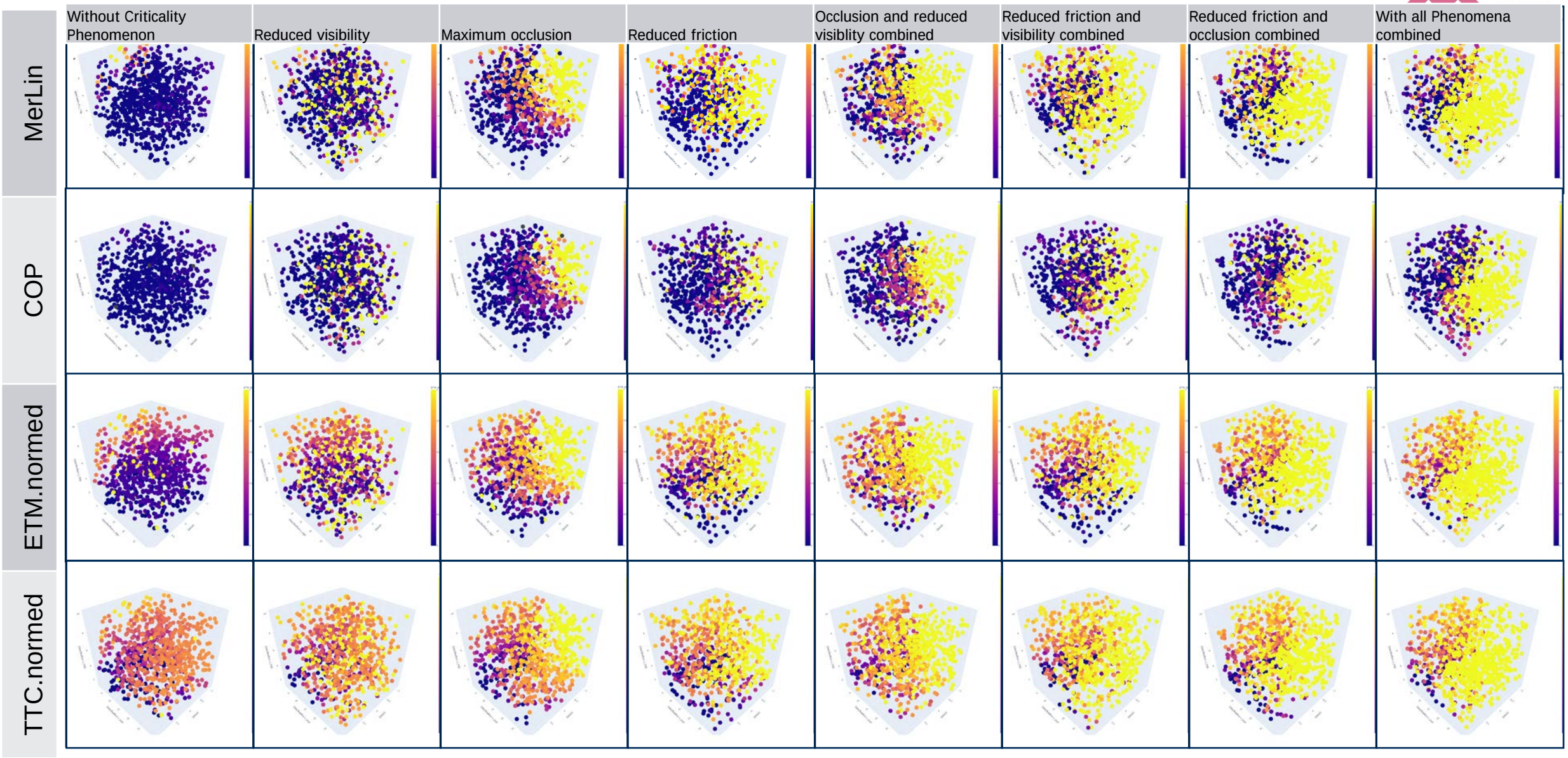
Overview of Phenomena in aggregated Criticality

Phenomena	μ	$dist_{object}$	vis_{fog}
Without Criticality Phenomenon	Max. 80%+	Max. 80%+	Max. 80%+
Reduced visibility	Max. 80%+	Max. 80%+	Min. 20%-
Maximum occlusion	Max. 80%+	Min. 20%-	Max. 80%+
Reduced friction	Min. 20%-	Max. 80%+	Max. 80%+
Occlusion and reduced visibility combined	Max. 80%+	Min. 20%-	Min. 20%-
Reduced friction and visibility combined	Min. 20%-	Max. 20%	Min. 20%-
Reduced friction and occlusion combined	Min. 20%-	Min. 20%-	Max. 80%+
With all Phenomena combined	Min. 20%-	Min. 20%-	Min. 20%-

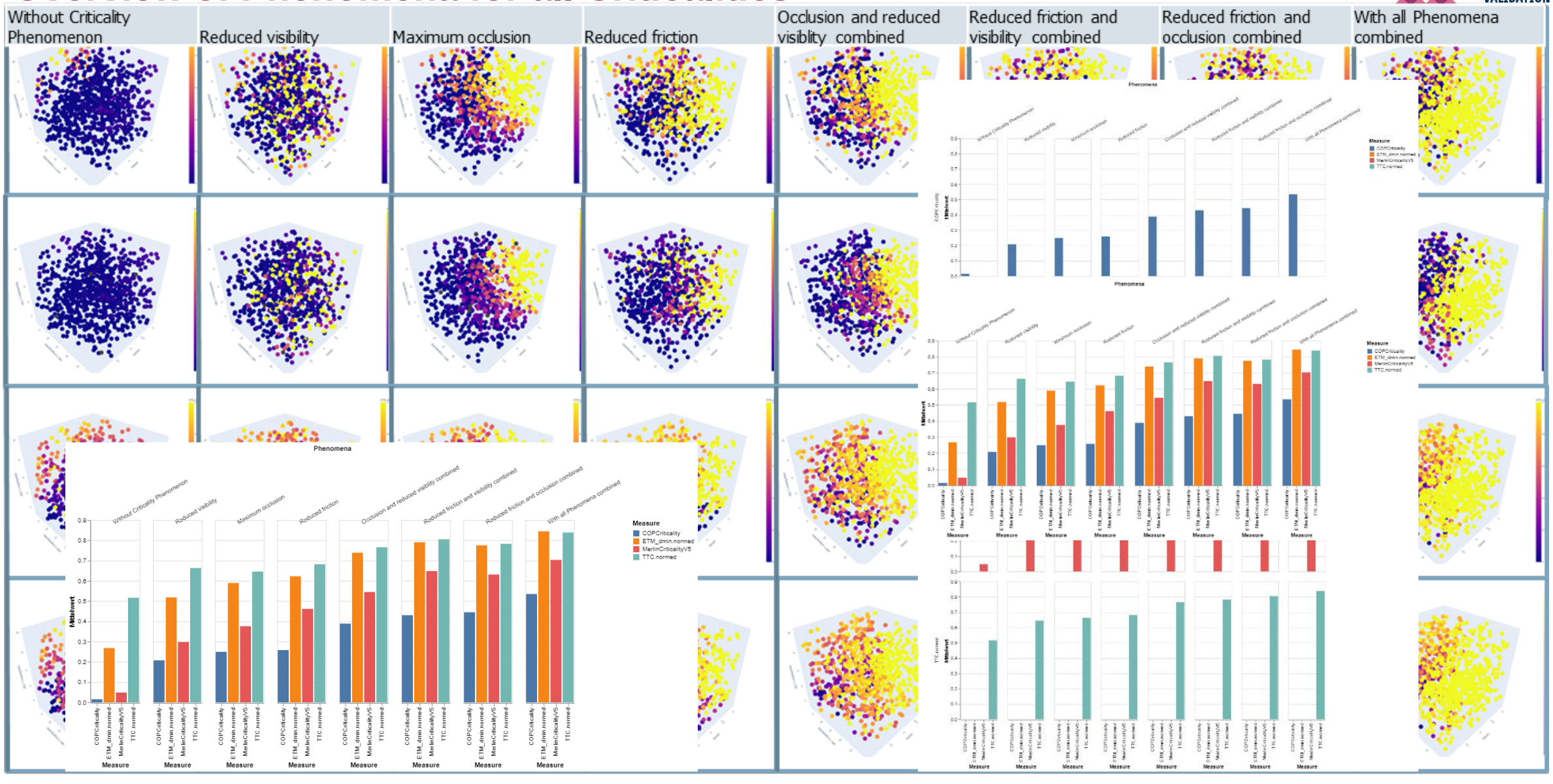


Without Criticality Phenomenon	Just with reduce visibility	Just with maximum occlusion	Just with reduced friction	Occlusion and reduced visiblity combined	Reduced friction and visibility combined	Reduced friction and occlusion combined	With all Phenomena combined

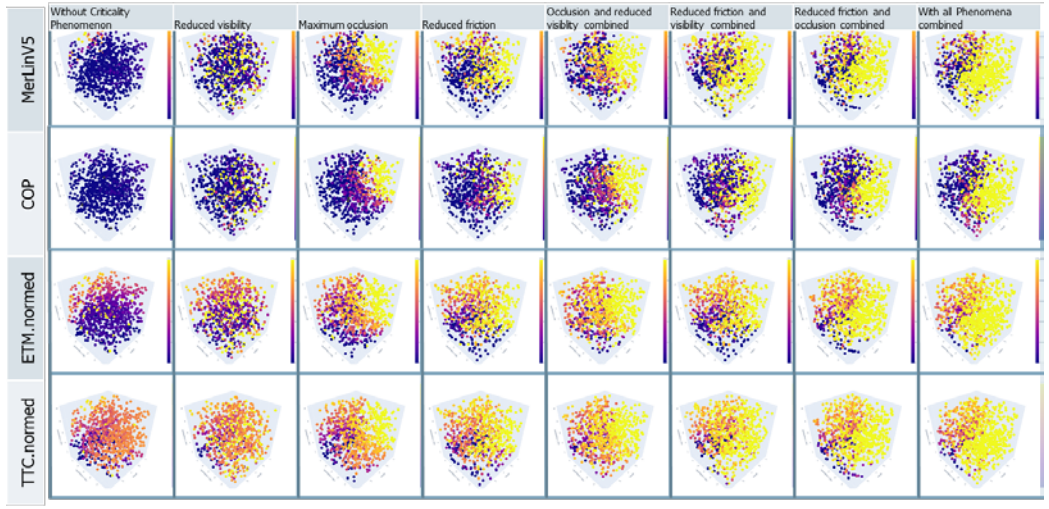
Overview of Phenomena for all Criticalities

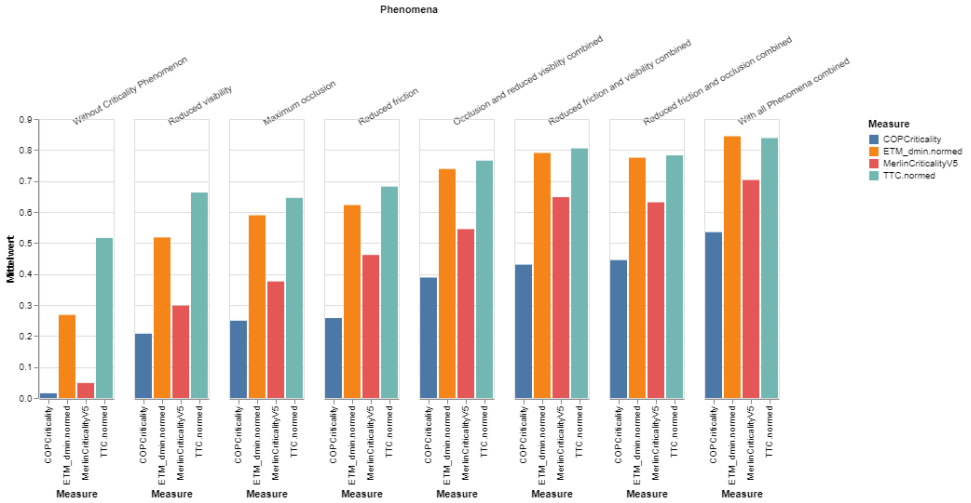


Overview of Phenomena for all Criticalities



Discussion





- All analyzed criticality phenomena have an effect to the criticality density -> all hypthesis regarding criticality phenomena are true!
- All used measures are able to show the effect of each criticality phenomenon
- The crash regions are marked as those with every measure -> a crash is identified as 1 (one)

- Due to different slopes of each measure between 0 and 1 and to the reason, that a criticality of 0 (zero) is defined different in each measure, the differentiation of a criticality density with one, two or more effects is not alway clear.
- The most clear differenciation can be made, using COP measure.
- ETM shows a good differentiation, using average criticality as performance indicator, too.
- In optical analysis, the differentiation between the phenomena and the combined phenomena can be made using MerLin tool

VERIFICATION
VALIDATION
METHODS

Thank you!

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VDA LEITINITIATIVE

A project developed by the VDA Leitinitiative
autonomous and connected driving

Supported by:

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for Economic Affairs
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on the basis of a decision
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