VIRTUAL ASSESSMENT OF AUTOMATION IN FIELD OPERATION

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Motivation

Safety is an important topic in the field of automated vehicles (AVs). Generally, the methods to test AVs can be divided into three categories: reality-based, scenario-based and simulation-based. In reality-based methods, AVs are tested under real driving conditions and thus the test results are valuable for the improvement of AVs. However, the test effort and cost for statistical safety validation of AVs are unbearable. In simulation-based method, the test process is accelerated. Nevertheless, valid simulation models are prerequisites. The scenario-based method aims at reducing the test effort by dropping any irrelevant scenario. Thus, identifying relevant scenarios becomes the key point. Under this circumstance, the virtual assessment of automation in field operation (VAAFO) [1] is proposed.

Basic idea

While the physical vehicle is driven in a manual or already released automated mode, virtual AVs (vAV) run in the background. The vAVs receive input from the real sensors, but have no access to the actuators. Thus, the risk-free nature of simulation-based testing and the validity of field operational testing are combined.

In VAAFO, two key parameters are defined. [2]

They are described as:

- Lifetime T_L; a vAV is reset to the state of the physical vehicle after a period of time to avoid too large state deviations between them. This time interval between initialization and reset is defined as the lifetime of a vAV.
- Birth cycle T_B; After a period of time a new vAV is born in order to not neglect a critical situation at the reset moment. This time interval between the initialization of two vAVs is defined as the birth cycle. In addition, a trigger system, based on a criticality metric, is needed. Once the trigger is activated during the driving, the scenarios are deemed relevant and are saved.

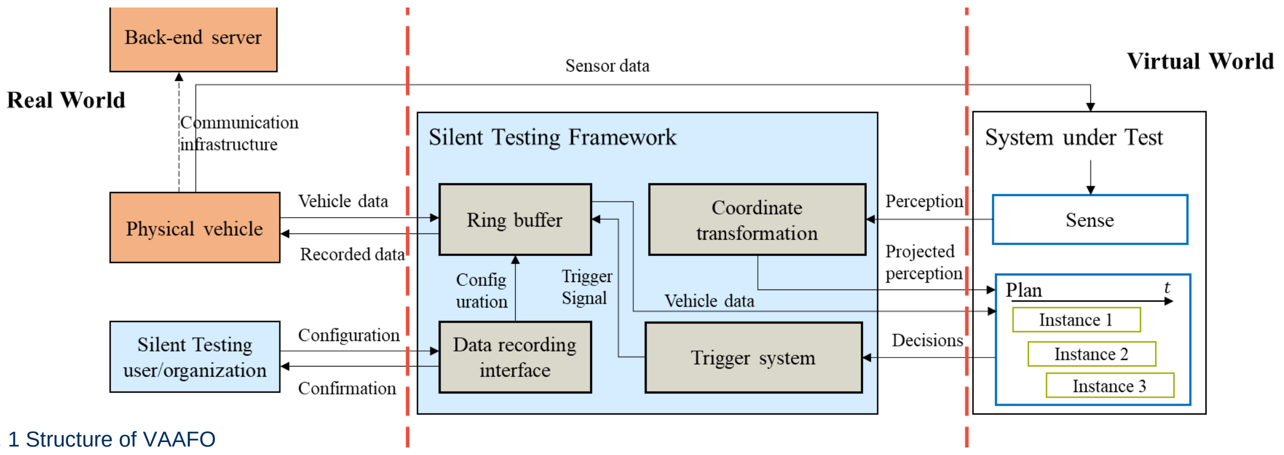

Fig. 1 Structure of VAAFO

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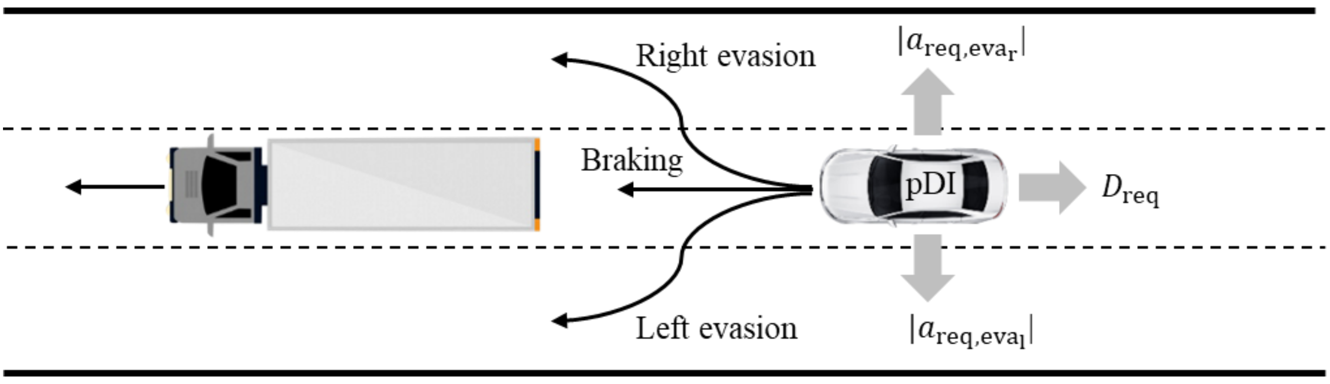

Fig. 2 Considered potential actions for the trigger mechanism

Trigger & Criticality Metric

For the trigger mechanism the criticality index metric was derived:

$$C_{\mathrm{a}} = \min(D_{\mathrm{req}}, |a_{\mathrm{req,eva_l}}|, |a_{\mathrm{req,eva_r}}|)$$

with:

$$D_{\mathrm{req}} = D_{\mathrm{obj}} + \frac{v_{\mathrm{rel},x}^2}{2d_x}$$

$$a_{\mathrm{req,eva}} = \frac{2(y_{\mathrm{eva}} - v_{\mathrm{y}} t_{\mathrm{tc},x})}{t_{\mathrm{tc},x}^2}$$

In a critical situation with an obstacle, like shown in Fig. 2, it evaluates the minimum required lateral acceleration or deceleration, in order to evade the critical situation.

Examplary evaluation

As can be seen in Fig. 3 the system under test used by the vAVIs is less safe than the physical driving instance (pDI). Further the C_{a} values for the vAVIs exceed the maximum possible values due to limited traction on the road. Therefore the data indicates that the same scenario in an field operational test or on a proving ground would not have been evaded but resulted in an accident.

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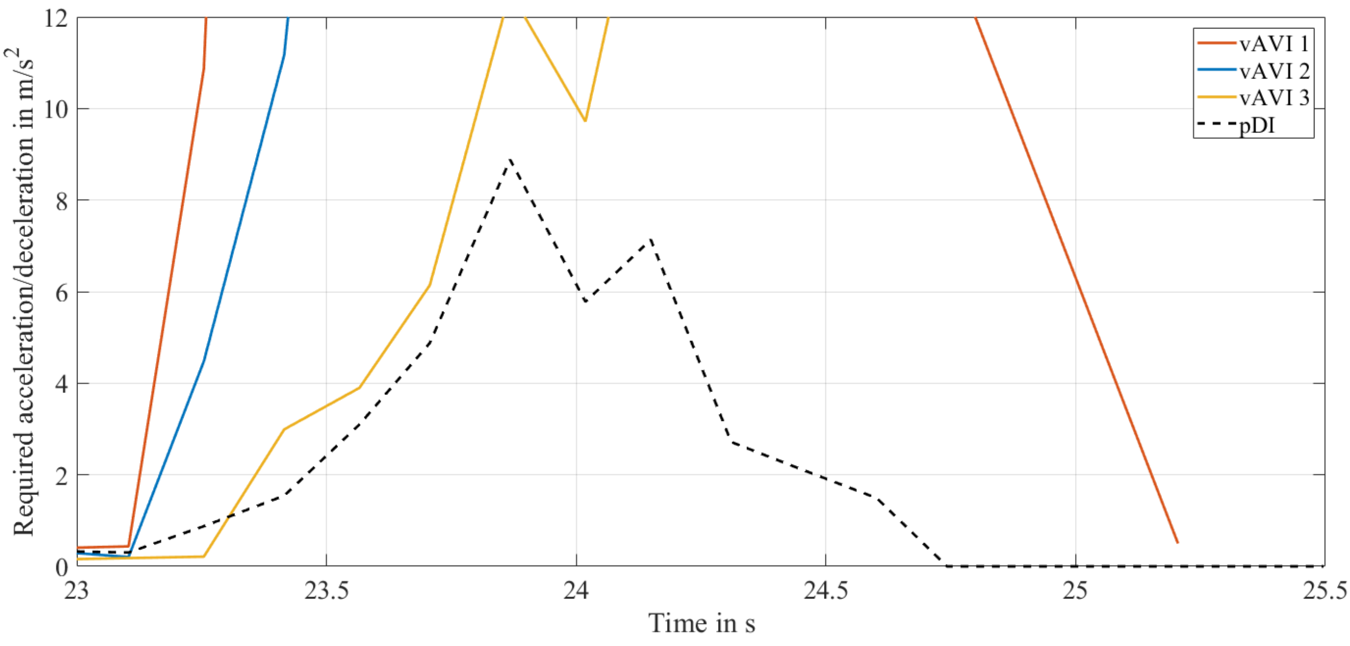

Fig. 3 Example data of a critical situtation on the prooving ground

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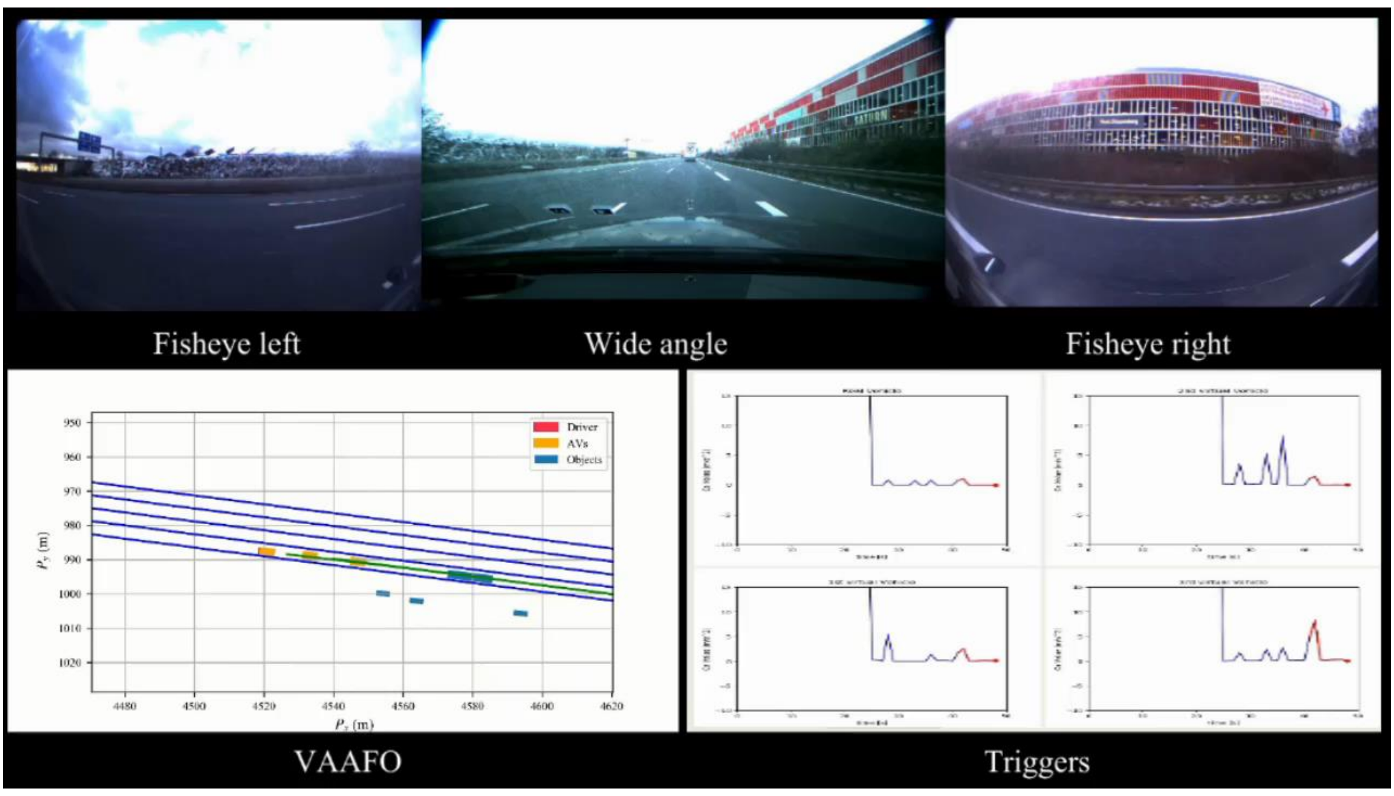
Evaluation in simulations

A co-simulation platform using CarMaker and ROS was established to evaluate the approach. Different concrete scenarios were simulated in CarMaker, while automated driving functions ran in ROS. Random traffic flow was also be simulated to determine if the approach could assess the safety of automated vehicles (AVs) in near-real traffic situations.

Evaluation in reality (Highway)

The approach was implemented in a real test vehicle and first applied in motorway scenarios. In this case, a human driver drives the test vehicle on the motorway A5 (Germany), while three virtual AVs (vAVs) perform their planning processes in the background during the scenario. Different object classes with various driving speed are available on the motorway. Based on the trigger system, the safety of each vAV was evaluated.



VAAFO being applied on the Highway

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Evaluation in reality (Intersection)

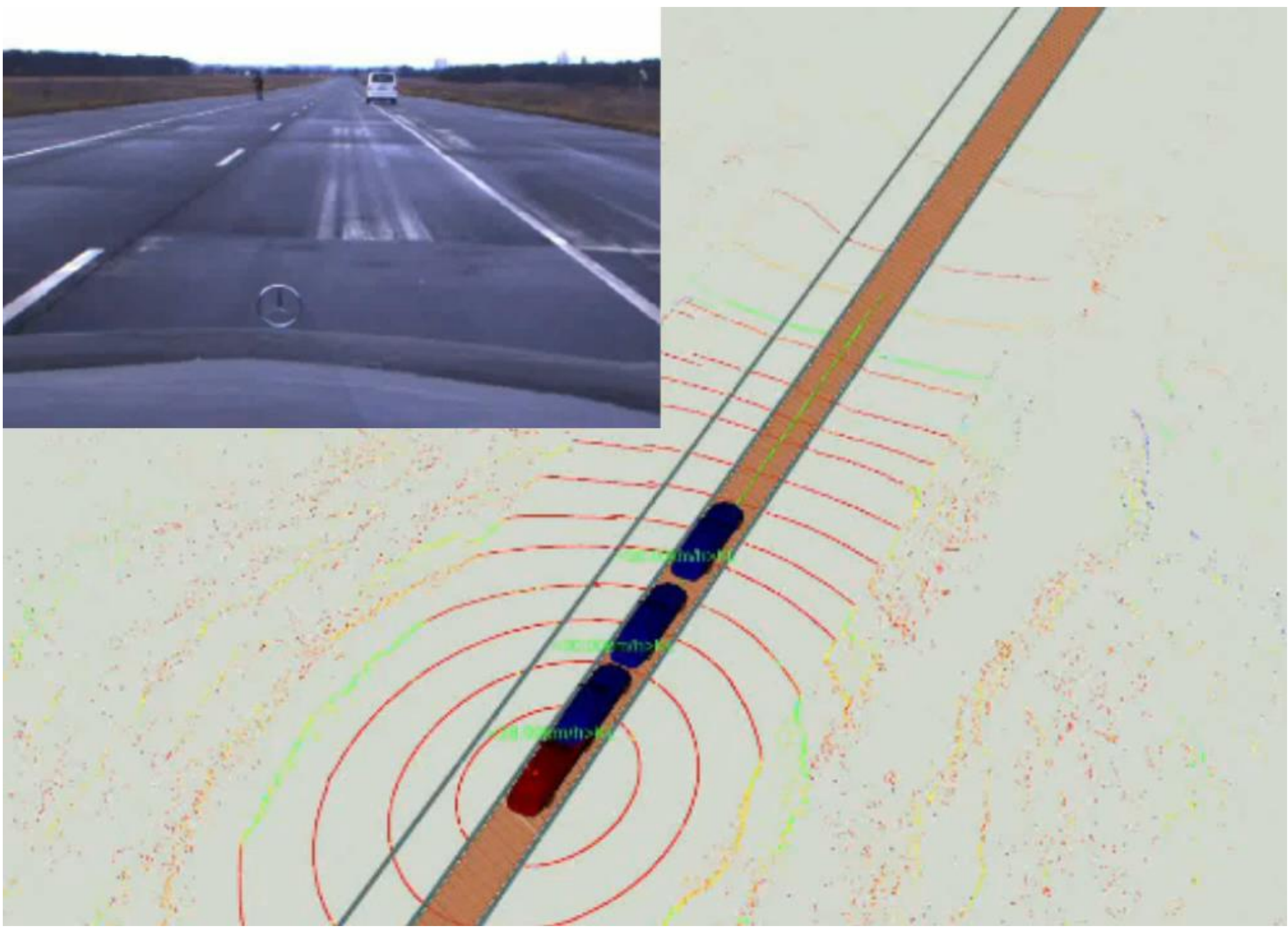
Since urban scenarios are more challenging for AVs, the approach is also tested in intersection scenarios on a proving ground. In this case, a pedestrian dummy is covered by a parked van. When the physical vehicle approaches the parked van, the dummy appears suddenly in front. By defining different parameters in the scenarios, critical and uncritical scenarios can emerge. By driving in those scenarios, it is determined whether the approach can successfully assess the safety of AVs and identify only critical scenarios.

Conclusion

Evaluations in both motorway and urban scenarios prove that the approach is capable of assessing the safety of AVs during the driving and also identifying critical scenarios

Sources

[1] Wachenfeld, W.; Winner, H. (2015): Virtual Assessment of Automation in Field Operation – A New Runtime Validation Method.
[2] Wang, C.; Storms, K.; Winner, H. (2021):
Online Safety Assessment of Automated Vehicles Using Silent Testing.



An intersection Scenario with an unsave vAVI