Reliability assessment of environment perceiving sensors in the context of automated driving vehicles

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Background
The environment perception provided by lidar, radar, camera and ultrasonic sensors is enabling automated driving vehicles. The sensors are employed to detect and localize relevant objects surrounding an automated driving vehicle as the basis of its decision making. With increasing level of driving automation, the environment perception becomes increasingly safety relevant. To ensure different levels of functional safe driving automation, one therefore has to assess and demonstrate the reliability of the environment perception. Depending on the level of automation, failure of the full sensor set in a specific application could lead to serious consequences. Before introducing new systems, it has to be demonstrated that the associated risk is acceptably low.

Research aim and challenges
The aim of this research project is to develop statistical methods to assess and demonstrate the reliability of environment perceiving sensors in the context of automated driving vehicles. Several challenges are associated with assessing the reliability of environment perceiving sensors, which have to be accounted for. First of all, a large empirical test effort is required to demonstrate the sensors’ reliability by means of real driving [1]. A reference truth (ground truth) is usually required to identify unacceptable perception deficiencies. Due to the involved human data labelling, the reference truth is hard to set up for large test data sets. Also, the performance of environment perceiving sensors is to some degree sensitive towards environmental conditions such as rainfall, snowfall, fog, the properties of the targets and dirt on the sensors. Due to these influencing factors, the sensors’
Project overview
In a first step, relevant uncertainties associated with the environment perception are described with adequate reliability metrics [2]:

- Existence uncertainty (false positive, false negative object detections)
- State uncertainty (position, size, velocity, acceleration of objects…)
- Classification uncertainty (car, truck, pedestrian, traffic light, street sign…)

Second, to address the challenges discussed before, we proposed a Bayesian method to demonstrate the reliability of the environment perception considering sensor error dependence [1, 3]. As the required empirical test effort for strict reliability targets is large and the required reference truth is hard to set up, we additionally proposed a framework that in principle allows to estimate the sensors’ performance without a reference truth, by exploiting sensor redundancy [3]. This framework allows to parallelize the testing to a large extent as no costly reference truth is required.

Third, to complement the developed testing framework, we exemplarily developed a physically based simulation framework that allows to estimate a sensors detection performance under rainy conditions in function of a variable detection threshold, leading to a sensor’s ROC curve [4]. Further, to learn and quantify the effect of different environmental influences (temperature, rainfall, fog, snowfall…), we proposed hierarchical regression models [2]. The learned relationship between a sensor’s performance and the environmental condition is then the basis for sensor performance predictions and virtual simulations.

Summary and outlook
A suite of statistical methods to assess the reliability of the automotive environment perception has been developed. Future work concentrates on validating and improving the proposed testing framework without a reference truth [3] in a practical application as well as synthesizing the different developed methods.

References

