

AUTOMATED GENERATION OF VIRTUAL DRIVING SCENARIOS FROM TEST DRIVE DATA

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ABSTRACT

Intelligent vehicle systems such as ADAS, ITS and automated driving systems consist of increasing numbers of sensor technologies as well as increasingly advanced algorithms for sensor fusion, object tracking, object classification, risk estimation, driver status recognition and vehicle control. It is rapidly becoming infeasible to check the performance of each new (sensor) system in the traditional way: By performing test drives, storing data, manually labelling the data for reference, and manually evaluating the results. One of the approaches to address these difficulties is to install a reference sensor system on the test vehicle in addition to the prototype sensor system (device under test). The recorded data from the reference sensor system are processed – partly or fully - automatically to create reference scenarios, based on automatic object labelling and automatic event identification. Based on these reference data, the device under test can be automatically and objectively evaluated. The reference data from the reference sensor system can now be converted into a set of virtual scenarios which can be used within a CAE environment. These simulated “ground-truth reference scenarios” offer a platform for engineers to quickly check the consequences of design changes to the device under test, and allow engineers to subject the device under test to a wide variation of virtual traffic scenarios.

INTRODUCTION

In recent years, automotive active safety systems have become more prevalent. Furthermore, these systems will be used as the foundation for the roll-out of autonomous vehicles. There are a variety of applications that encompass active safety including: Adaptive Cruise Control (ACC), Forward Collision Warning (FCW), Automatic Emergency Braking (AEB), Lane Departure Warning (LDW), Blind Spot Warning (BSW), Lane Keeping Assistance (LKA), Pedestrian Avoidance (PA), Intelligent Headlight Systems (IHS) and Cooperative Driving Systems (CDS). With the rising level of automation onboard vehicles, intelligent vehicle systems have to deal with an increasing amount of complex traffic scenarios. In turn, the intelligent systems themselves are also becoming more complicated. They consist of more and more different sensor technologies as well as increasingly advanced algorithms for sensor fusion, object tracking, classification, risk estimation, driver status recognition and vehicle control. As a result, it is rapidly becoming infeasible to check the performance of each new (sensor) system in the traditional way by driving around, storing data, manually labeling the data for reference, and manually evaluating the results.

ADAS TESTING & REFERENCE SENSING

One of the approaches to address these difficulties is to install an additional reference sensor system (RSS) on the vehicle which is already equipped with the prototype sensor system that is going to be tested (DUT – device under test). The recorded data from the reference sensor system are processed to automatically create reference scenarios, based on automatic labeling of relevant road users and background environment description. Based on these reference data, the device-under-test can be automatically and objectively verified [1,2].

Laser Scanner Advancements

Several advancements in the field of laser scanning [3] allow the sensor technology to be used as a reference sensor system for automatically generating reference scenarios from laser scan data. The current generation of laser scanners can detect objects with a high precision relative to the scanner. If a digital map is available which contains landmarks with centimeter accuracy, then the absolute position of the laser scanner can be determined to within a few centimeters, thus improving the accuracy of all tracked objects. The scanner is effectively used as a differential sensor, analogous to Differential GPS (DGPS), but without the need for a base station or for a clear view of the sky.

Forward-Backward Tracking & Best Situation Classification

A further improvement is the use of offline processing to analyze the scenario. State of the art online tracking algorithms are inherently limited by the requirement to run in real time. If the data is reprocessed offline, it becomes possible to look ahead for all observations of an object and associate them with the first instant that the object is visible, which allows the system to be used as a true reference, since no online sensor can look into the future. This also allows the use of a Best Situation Classifier (BSC). The point in time where an object is most clearly visible can be used to classify the object, and this classification can be extended to the lifetime of the object. Additional benefits are improved robustness to occlusions, reduced uncertainty of the ego vehicle position between landmarks, and increased accuracy of object trajectories.

As an example, consider the scenario in Figure 1a. A sign and an oncoming vehicle are just visible by the laser scanner. Figure 1b and 1c show the results of two tracking approaches. In the online approach (Figure 1b), the approaching vehicle is initially detected, but it is not yet classified and the outline is not clear. As the vehicle gets closer, the outline can be clearly seen and it is classified as a car. In the offline approach (Figure 1c), this information is associated with the object in the first instant that it is visible, allowing a more accurate reconstruction of the scenario.

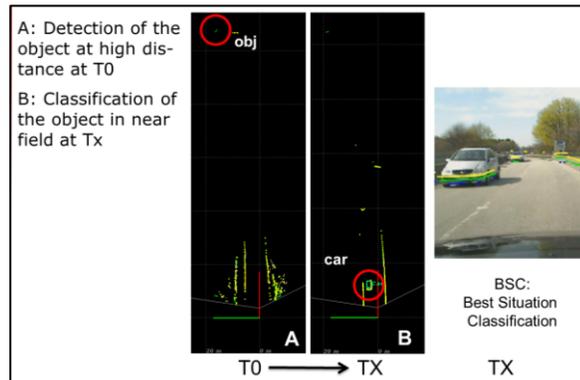
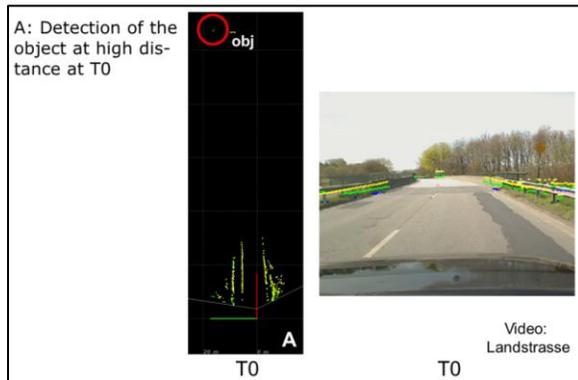


Figure 1a: Online object tracking at time T_0 .

Figure 1b: Online object tracking at time T_X .

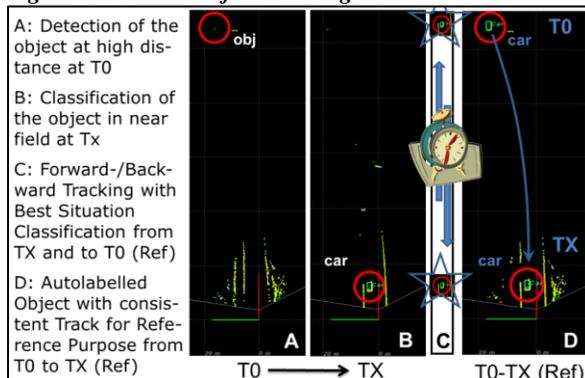


Figure 1c: Forward-Backward Tracking principle.

This process, which provides object information in full detail already at the time of the first detection of the object at high distance, is called Forward-Backward Tracking (FBT). This ensures that the laser scanners, used as a reference sensor system, provide detailed object information very early and with high precision at any time, as shown in the following example (Figure 2).



Figure 2: Application example of post-processing using Best Situation Classification (BSC) and Forward Backward Tracking (FBT).

VIRTUAL DRIVING SCENARIOS FROM REAL WORLD TEST DRIVES

While test driving is still the main method for ADAS system, the resulting data rarely contain events that would be truly tax the active safety system evaluation; even with a million miles driven. Crashes are rare and difficult to capture. Even near crashes are rare. Hence, we end up with much of the collected data being simple false alarm data (i.e. driving with no difficult decision to make). Many of the drawbacks of hardware testing of ADA systems [4] are not present for a virtual test environment. Virtual testing with simulation software provides an efficient and safe environment to design and evaluate ADA systems. Moreover, simulated scenarios are completely quantifiable, controllable and reproducible.

However, the creation of many virtual driving scenarios can be a time-consuming and laborious activity; in particular, when real testing scenarios and conditions must be manually converted into virtual scenarios for further testing. It is thus extremely valuable to be able to automatically obtain virtual scenarios from real world test drives.

The reference data from the reference sensor system as presented in previous section are well-suited to serve as basis for automatic creation of virtual scenarios. They can be converted into a set of simulated scenarios which can be used within a CAE environment. These simulated “ground-truth reference scenarios” offer a platform for engineers to quickly check the consequences of design changes to the device under test, or even to try out completely new system concepts.

RESULTS

The concept of creation of virtual driving scenarios from real-world test drives was evaluated using an Ibeo laser scanner setup with two lasers scanners (see Figure 3).

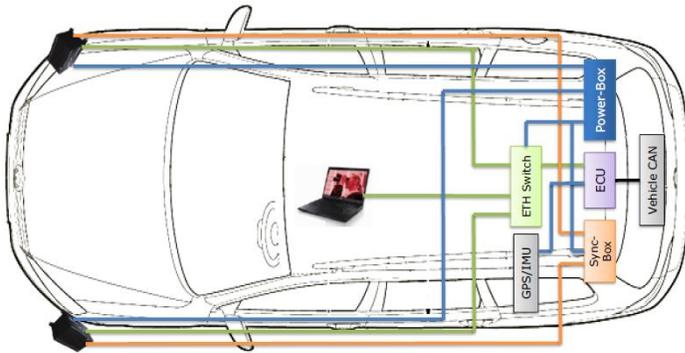


Figure 3: Ibeo Sensor System mounted on a test vehicle. Red circles indicate two Lux scanners from a 2- Sensor fusion system mounted on the front bumper of the car.

The recorded data is automatically labelled with a post-processing tool. These labels are then provided for the processing and evaluation of a device under test, and the conversion to virtual driving scenarios in the simulation software PreScan [5]. Figure 4a and 4b show a sample result in which a passenger car and pedestrians are detected, classified, and converted to a virtual environment. The applied laser system is able to classify passenger cars, trucks, motorcycles, bicyclists and pedestrians.

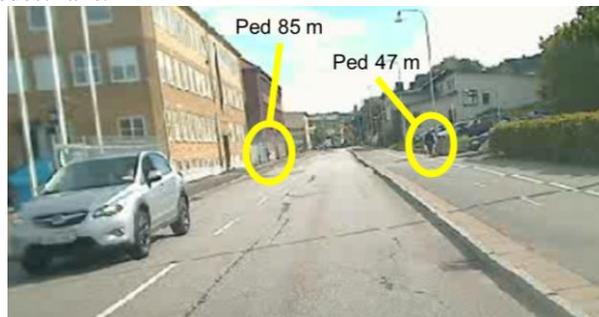


Figure 4a: Reference scenario from real world test drive.

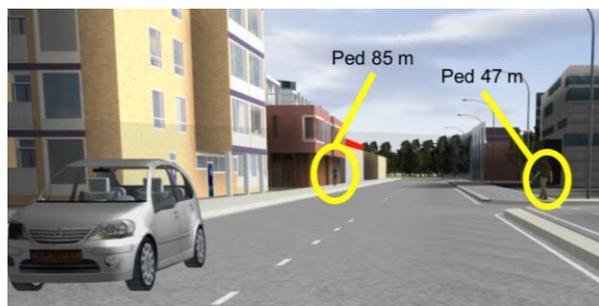


Figure 4b: Virtual driving scenarios derived from real world test data.

CONCLUSIONS

This paper presented the use of advanced perception systems for obtaining reference data for the automated generation of simulated driving scenarios. We described our advances in the fields of laser scanning processing for reference generation, and illustrated the use of reference data for constructing simulated virtual scenarios that can be loaded, manipulated and used within a commercial simulator.

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