HiFi Visual Target – Methods for measuring optical and geometrical characteristics of soft car targets for ADAS and AD

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Abstract

Advanced Driver Assistance Systems (ADAS) and Automated Driving (AD) vehicles rely on a variety of sensors and among them optical sensors. Extensive testing of functions using optical sensors is required and typically performed at proving grounds like AstaZero. Soft surrogate targets are used for safety reasons but the optical and geometrical characteristics of soft car targets may differ considerably from that of real vehicles. During tests the quality of the soft car targets deteriorates due to repeated impacts and reassembly of the targets, and there is a need of methods for securing the quality of the soft car targets over time. One of the main goals of the HiFi Visual Target project is to develop and validate accurate and repeatable measurement methods of the optical and geometric characteristics of soft car targets.

1 Background

There are three grand challenges the transportations of tomorrow face: environment, safety and congestion. One key element in meeting these challenges, and also to reach the VisionZero stated by the Swedish government in 1997, is development of active safety systems and AD (Automated Driving) systems assisting or replacing the driver in both normal traffic situations as well as critical situations. These systems have already proven to decrease the number and severity of injuries and insurance cost [1]-[2]. The development of higher levels of AD puts stronger requirements on reliability, and therefore on its sensory input and the interpretation of this input. There exist several sensor types that typically are employed in sensor systems in ADAS and AD, such as visible spectrum and infrared cameras, laser scanners, ultrasonic sensors, and radars. In the HiFi Visual Target project the focus is on the optical sensors. Validation of the optical sensor systems and identification of possible performance issues require extensive testing of the systems, both during optical sensor system development, and during verification of ADAS and AD vehicles. Controllability and safety of testing dictates that most testing is typically performed at closed test tracks

2 Soft car targets

Since it is not possible to test situations that may result in collision with real vehicles, pedestrians etc. as targets, surrogate objects are used, see Fig. 1. These are typically mock-up objects made of soft materials that can be repeatedly hit without damage to themselves or the test vehicle [3]. In order to make testing with surrogate targets to be valid, sensor response of the surrogate target must be consistent with the response of the corresponding real target. While several studies have been conducted where sensor-responses of cars and humans have been measured [4]-[5], most of the work has either been concentrated on radar sensor responses (RCS properties) of cars and humans or the optical characteristics of human targets [6]. There is lacking a more thorough work on the optical and geometrical characteristics of soft car targets. Most of the work has also been focused on the rear-end aspects of car targets, but analysis of rear-end aspects only provides validation for rear-end scenarios. The aspects that might emerge in more complex traffic scenarios, for example, intersection collision avoidance [7], or merging, overtaking and cut-in cases for AD vehicles, where the optical sensor responses on target vehicles may vary rapidly, are not covered, limiting the applicability of the studied surrogate target for testing of these situations.
Moreover, analyses of other types of surrogate targets available on the market, as well as studies of possible improvements of the latter, are lacking. This poses limitations for OEMs, optical sensor developers and test tracks who need reliable surrogate targets for increasing need for reliable and safe optical sensor testing.

Fig. 1. Soft Car Targets (SCT) are used for safe and repeatable evaluation of ADAS and AD.

There is a need to accelerate development and minimize conflicting requirements for test targets that vehicle manufacturers, suppliers, legislators and consumer organizations can use for the safe and repeatable evaluation of vehicles. Euro NCAP (European New Car Assessment Programme), NHTSA (National Highway Traffic Safety Administration) and IIHS (Insurance Institute for Highway Safety) are collaborating on specifications and assessing designs for a harmonized future 3D vehicle test target that will be compatible with a variety of target carriers. Additionally there is a need of methods for validation that test targets fulfills its specifications over time and that any method developed for use on the test track must be fast and easy to use in order to save time and money as equipment and test track are big investments that call for efficient use for high productivity.

3 Project Goals

The objective of the project is to enable more efficient and reliable verification of optical sensor systems, including ADAS and AD systems that rely on the optical sensors, through:

- development and validation of accurate and repeatable measurement methods of the optical and geometrical characteristics of soft car targets,
- providing input to the development of more realistic soft car targets for safe testing of automotive optical sensor systems,
- demonstration of improved verification with the developed measurement methods,
- supporting international standardization (ISO) with standard methods enabling future verification and calibration of optical characteristics of soft car targets.

The ambition in the project is to contribute to these goals through delivering (i) test methods and equipment specifications for securing the optical and geometric properties of soft car targets over time (ii) proposal on improvements of high fidelity soft car targets that significantly enhances current state-of-the-art. Throughout the project, we will:

- investigate what test setup is needed for measurement of optical and geometric characteristics of automotive targets with focus on cars,
- analyze the optical and geometric characteristics of real targets and introduce requirements for the characteristics that soft car targets shall have. We will assess the soft car targets and evaluate their resemblance with real counterparts for optical sensors, and
- propose improvement of soft car targets to match requirements for target characteristics.

4 Initial Measurements and Results

4.1 Measurement Setup

Two SCTs (Soft Car Targets) of the same type were studied, one in near mint condition and one heavily used, see Fig. 2. Two different setups were used to study different properties of the SCTs; one optical setup and one geometry-measuring setup.

Fig. 2. The used SCTs, left is in near mint condition and right has been heavily used.

4.1.1 Optical Measurement Setup

In the optical setup the surface reflectance of the SCTs was measured by means of a spectroradiometer and a typical Autoliv vehicle camera system. The SCTs were placed in an enclosed space with covered windows. The reflectance was measured in ~60 different points all around the SCT. In Fig. 3 each measurement point is marked with a small black pointer.

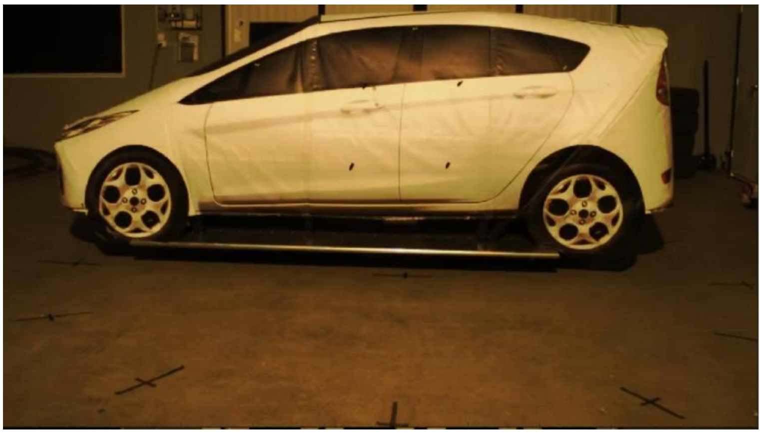

Fig. 3. Example of the image collected by the vehicle camera system. Four black pointers on the SCT side indicate the position of measurement spots for the spectroradiometer. Also visible on the floor are the markings for center position and rotation of the SCT.

An incandescent light source was used to illuminate the SCT for measurement. The light source was placed 10 m from the SCT and at an angle of ~30° relative to the horizontal plane. The SCT was rotated around its vertical axis into 12 different positions (30° interval) for measurement to take place at roughly normal incidence to the selected measurement spot. The spectroradiometer was placed 5 m from the target and used a 1° measurement field-of-view, equivalent to a spot size of ~88 mm on the SCT surface.

4.1.2 Geometry Measurement Setup

The geometry was measured by means of a laser scanner, capable of generating a point cloud with three-dimensional information with an accuracy down to millimeters. Fig. 4 shows the setup with the laser scanner and spectroradiometer.

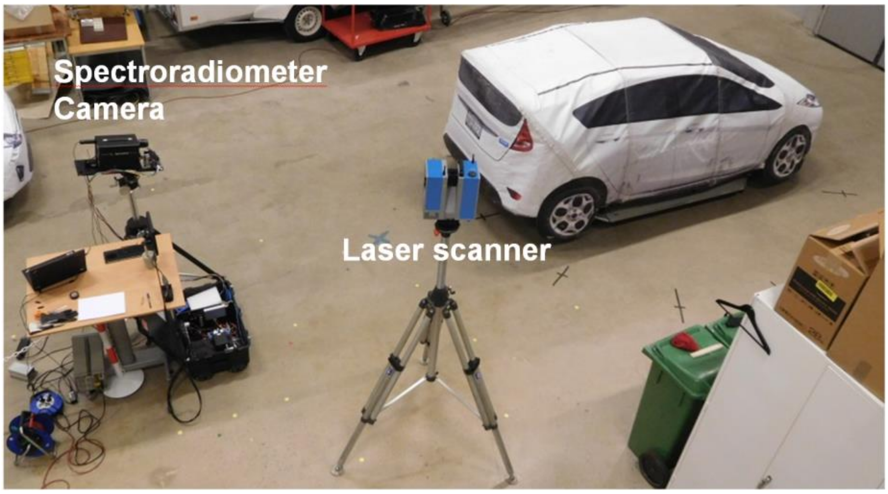

Fig. 4. Measurement setup with the laser scanner and the spectroradiometer. The SCT is in the position used for geometry measurement.

4.2 Preliminary results

At the time of writing the results from measurement are still being evaluated and preliminary results are presented here.

4.2.1 Optical Measurement Results

The reflectance for the measured spots is shown in Fig. 5.

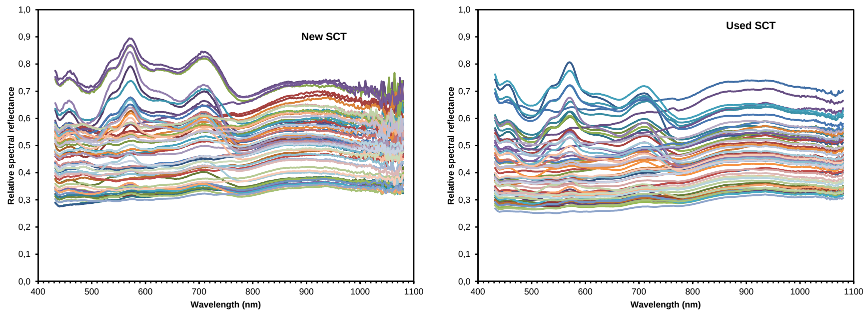

Fig. 5. Raw data for spectral reflectance. Further analysis is required to determine the relevant differences between the new and used SCT.

The data shows a considerable resemblance between the measurements made on two different SCTs, one heavily used and one in near mint condition, indicating that the effect of hitting the SCT does not degrade the material very quickly. Also in the infrared wavelength region, which is used by laser radar (typically 905 nm), there is not a significant change in appearance.

4.2.2 Geometry variation due to assembly

The SCTs consist of a structure that requires careful assembly. Due to their design and the fact that they can be used on different target carriers, variations in geometry are obviously to be expected. In order to understand what impact the assembly will make on the geometry, both SCTs were assembled and disassembled several times. For each step, they were scanned in full using a TLS (Terrestrial Laser Scanner). A full scan consisted of at least 4 setups which were then registered in to a full set of data. Both spatial and RGB data was captured. Snapshot of the colorized point cloud captured can be seen in Fig. 6.

Fig. 6. Registered scan (point cloud) of one of the assembled SCTs.

A mesh was constructed from the initial point cloud of each SCT acting as the reference geometry. The following data-sets were then compared to the initial mesh. The result of these comparisons can be seen in Fig. 7. In this initial test different carriers (as used by the respective owner) were used. Therefore, the comparison covers only the body of the SCT itself. The initial analysis shows, as expected, larger variations for the heavily used SCT.

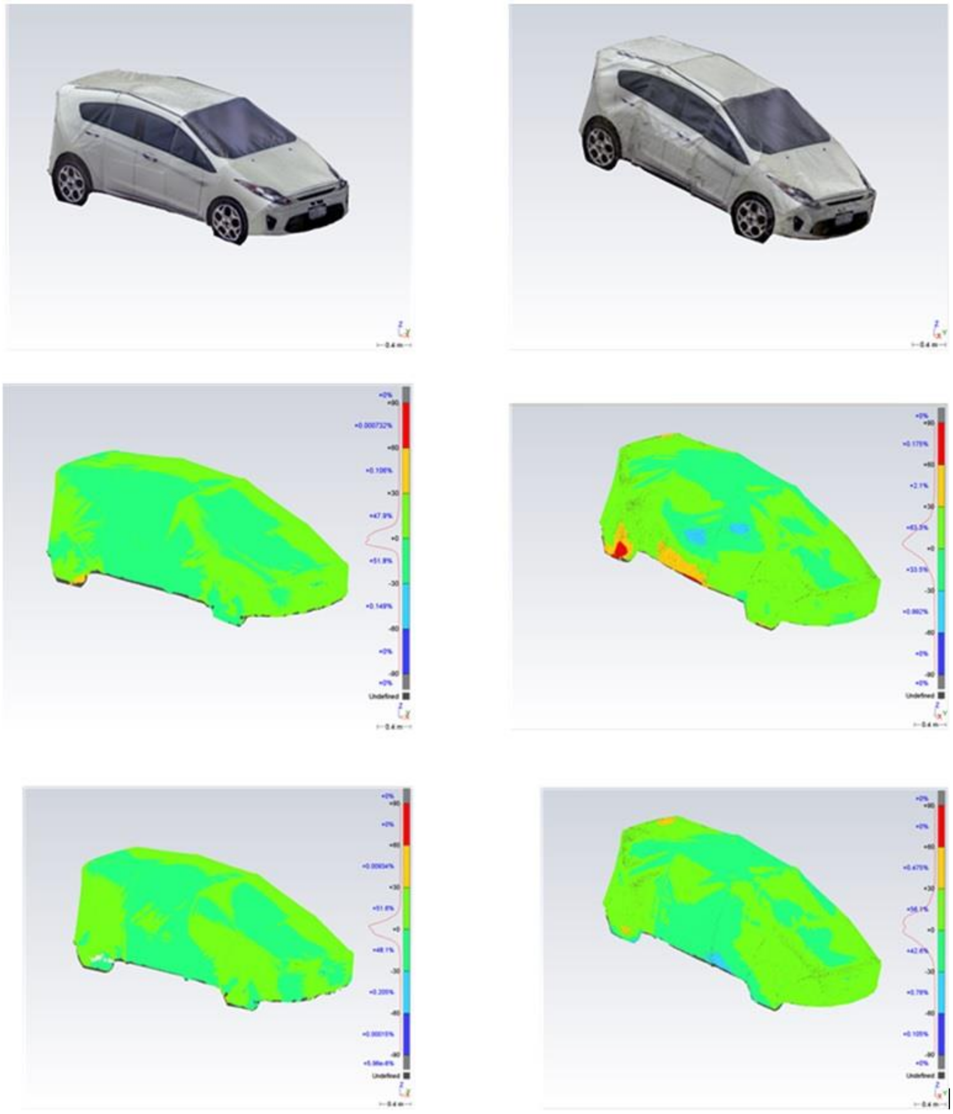

Fig. 7. Left column shows result for the new SCT, right column for the used SCT.

5 Conclusions and Future Work

This paper presented the objectives and initial results of the currently running project HiFi Visual Target. The preliminary results based on the initial measurements show that it should be possible to develop a measurement method that secures the validity of Soft Car Targets used for testing of ADAS and AD vehicles from both a geometrical and optical sensor perspective. The geometry of the target could e.g. be specified in a way that could simplify the verification of the shape in order to secure that it fulfils its specification, even after long time usage and a large number of assembly and disassembly. Future work includes further analysis of measurement data, measurements on real vehicles and wearing out an SCT while applying developed measurement methods at the AstaZero proving ground.

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