International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

PO181

CHARACTERIZATION OF REFLECTIVITY AND GEOMETRY FOR SOFT CAR TARGETS

Mikael Lindgren et al.

DOI 10.25039/x46.2019.PO181

from

CIE x046:2019

Proceedings
of the
29th CIE SESSION
Washington D.C., USA, June 14 – 22, 2019

(DOI 10.25039/x46.2019)

CIE Central Bureau
Babenbergerstrasse 9
A-1010 Vienna
Austria
Tel.: +43 1 714 3187
e-mail: ciecb@cie.co.at
www.cie.co.at

CHARACTERIZATION OF REFLECTIVITY AND GEOMETRY FOR SOFT CAR TARGETS

Lindgren, M., Spetz, J., and Nord, S.
RISE Research Institutes of Sweden AB, Borås, SWEDEN

Mikael.Lindgren@ri.se

DOI 10.25039/x46.2019.PO181

Abstract

This paper reports on results from a study of characteristics for 3D soft surrogate vehicle targets. Such targets are used extensively for testing and verification of optical sensor systems for Advanced Driver Assistance Systems and Automated Driving. However, the influence of wear-and-tear on the vehicle target is not well known. Consequently, no clear requirement exists on how many collisions a soft target can be exposed to before it no longer performs well.

Important characteristics for optical sensor systems are surface reflectance in the relevant wavelength range and geometry of the soft target. We report on measurements of spectral reflectivity and geometry performed before, during and after an accelerated ageing campaign involving 100 rear-end collisions at 50 km/h. The reflectivity was found to change very little while the geometry was strongly affected.

Keywords: ADAS, AD, 3D soft vehicle target, spectral reflectivity, laser scanning, geometry

1 Background

Advanced Driver Assistance Systems (ADAS) and Automated Driving (AD) vehicles rely heavily on optical sensors. Extensive testing of optical sensors is required and typically performed at test tracks like AstaZero in Sweden. Soft surrogate vehicle targets are used for safety reasons, but the optical characteristics of surrogate targets may differ considerably from that of real vehicles. During tests the quality of the soft surrogate targets deteriorates due to repeated impacts and reassembly of the targets, and there is a need for methods to secure the quality of the soft surrogate targets over time.

The objective of the study was to enable 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 surrogate targets.
- Provide input to the development of more realistic surrogate vehicle targets for safe testing of automotive optical sensor systems.
- Supporting international standardization with standard methods enabling future verification and calibration of optical and geometrical characteristics of active safety soft surrogate targets.

2 Methods

2.1 Situation analysis

Optical requirements for a 3D Vehicle Target (VT) are described in the draft standard ISO/WD 19206-3 [ISO 2016]. The draft standard includes the following optical sensor principles:

- CCD and CMOS camera sensors and stereo camera sensors
- Photonic Mixer Devices (PMD)
- Light Detection and Ranging (LIDAR)

Camera sensors cover the visible and near-infrared wavelength range while PMD and LIDAR are more reliant on IR reflectivity of the target surface. Other requirements are more generic and are mostly expressed in terms of visible vehicle features that the VT should resemble.

The 3D Vehicle Target Specification [4activeSystems 2017] from 4a (one VT manufacturer) states that “the VT shall represent reflections of a real car, the windows (windscreen, side windows, rear window) shall look like transparent. They shall be illustrated by using a shining, polymer self-adhesive digital print film. For a more realistic representation, also the interior of a real car (seat, steering wheel, rear view mirror, driver) shall be indicated.”

The conclusion is that both standards and specifications currently are open for interpretations and there is a lack of scientific approach in determining what parameters are important for a VT to resemble a real target from an optical sensor perspective. As the VTs are being used on test tracks, its properties may change with time due to collisions. This means that the standard should include tolerances that can be used for discarding a worn-out VT and perhaps also to secure tolerances during production of VTs.

In contrast to the 3D car VT, more work has been done in studying VT for vulnerable road users. In [LEMMENT 2013] the IR reflectivity is specified in more detail with the IR reflectivity around 850 nm measured at both 45° and 90° at specified locations on the dummy.

There is certainly room for more work to improve existing requirements and measurement methods.

2.2 Sensors

For this work we have focused on the following sensors:

Camera sensors – the main importance of a VT is that it resembles a true car as much as possible. To represent a reasonable range of camera sensor variants the focus for this study has been in the visual spectrum.

LIDAR sensors – the most used wavelength ranges for these are around 900 nm and around 1550 nm. For practical purposes we have limited this study to wavelengths up to 1000 nm.

2.3 Measuring instruments

In this study we have used the following instruments for characterization of the VT surface and geometry:

Spectroradiometer – provides spectrally resolved radiance/luminance from a surface defined by optics. Typically, it provides a spot measurement with no direct spatial information. The instrument used in this study was a lab instrument and could not be used for field measurements.

VIS/NIR spectrometer – provides direct measurement of reflectivity in the wavelength range 300 – 1000 nm. This device was equipped with a fiber-optic probe which facilitated field measurements.

Light source – a broadband light source based on a filament lamp was chosen to enable subsequent calculation of reflectivity for different target illuminations.

Laser scanner – provides a point cloud based on measurement of the geometry of the VT. The device also has a built-in high-dynamic-range camera which was used to assign colour to each point in the point cloud.

2.4 Vehicle targets

In the study we used several different soft surrogate vehicle targets:

The Euro NCAP 2018 AEB car-to-car test protocol uses a new global vehicle target (GVT) shown below in Figure 1. It replicates a typical passenger vehicle (Ford Fiesta 2011, white) in terms of visual, radar and LIDAR aspects [Euro NCAP 2017].

Figure 1 – Euro NCAP 2018 Global Vehicle Target (GVT)

DRI Advanced Test Systems is a subsidiary of Dynamic Research Inc. and have developed the Soft Car 360, of which the hatchback version is also the GVT used in Euro NCAP 2018. There are different versions of the target [Anthony Best Dynamics 2019] and the latest version offers:

- Realistic radar signature with radar reflective material in bumpers, doors and bonnet
- Reflective printed vehicle lights and number plates
- Radar absorbing material underskirts
- Foam wheels with corner reflectors
- Attachable side mirrors

The version used is depicted below in Figure 2. Note that the side mirrors, wheels and window appearance have been updated.

Figure 2 – DRI Advanced test systems, Soft car 360

The chassis of the target is made from multiple foam pieces covered in vinyl which are attached together by Velcro. The chassis is then covered by a sheet with a car print to mimic a real vehicle. Figure 3 shows the chassis before the vinyl sheet is attached.

Figure 3 – The chassis for Soft car 360, which is subsequently covered by several printed sheets

4activeSystems is a company located in Traboch, Austria. They develop and produce both test equipment and target dummies for ADAS testing. Their free-standing car target, 4activeC2, is a 3D target with radar and visual properties like that of a real car, see Figure 4. It weighs 55 kg and may be crashed in to from all directions at speeds up to 65 km/h. It is built in a modular system with zippers and fasteners, allowing rebuilding after collision with a test vehicle. The target has reflective panels in the front and rear and it has reflective license plates. 4A also produce other targets (bicyclist, pedestrian and motorcycle) and target carriers for their targets [4activeSystems 2019].

Figure 4 – The 4activeC2 3D car target

3 Results

Measurements were performed both in laboratory conditions and in the field. They consisted of measurement of reflectivity and of VT geometry, before and after the stationary VT was exposed to 100 collisions at 50 km/h speed, see Figure 5.

The purpose of the accelerated ageing tests and measurement was to get reference data to be compared with measurements done on “mint condition” soft vehicle targets to investigate differences in geometrical shape and reflectance after heavy use. This could provide valuable input on the measurement methods to be able to identify and define calibration criteria that could be used to decide if the target should be repaired or replaced.

The ageing tests and measurements took place at the City Area test track at AstaZero proving ground during w10 and w12 2018. The ageing tests were conducted as a series of collisions at 50 km/h speed hitting the stationary soft vehicle target from the rear. One Mercedes and one Volvo car were used, whose built-in safety systems had been disabled in order to actually collide with the VT.

Figure 5 – Accelerated ageing tests were performed on AstaZero proving grounds, Borås, Sweden

3.1 Reflectivity

The spectral reflectance was measured in ~50 points (Figure 6), distributed in the white areas of the VT surface. Pieces of tape were added to identify reference points to measure at, see Figure 7.

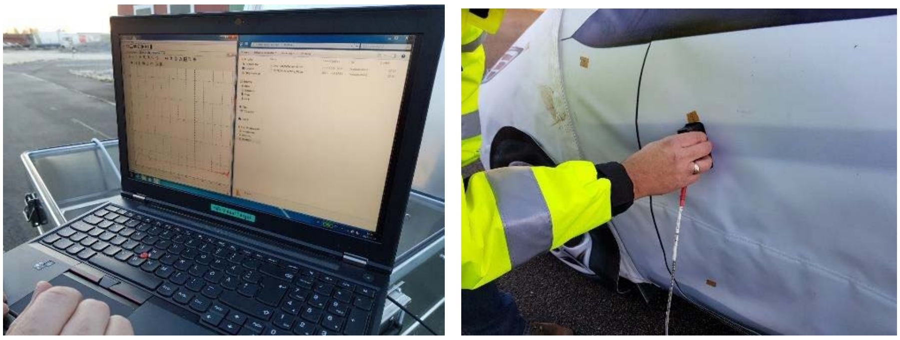


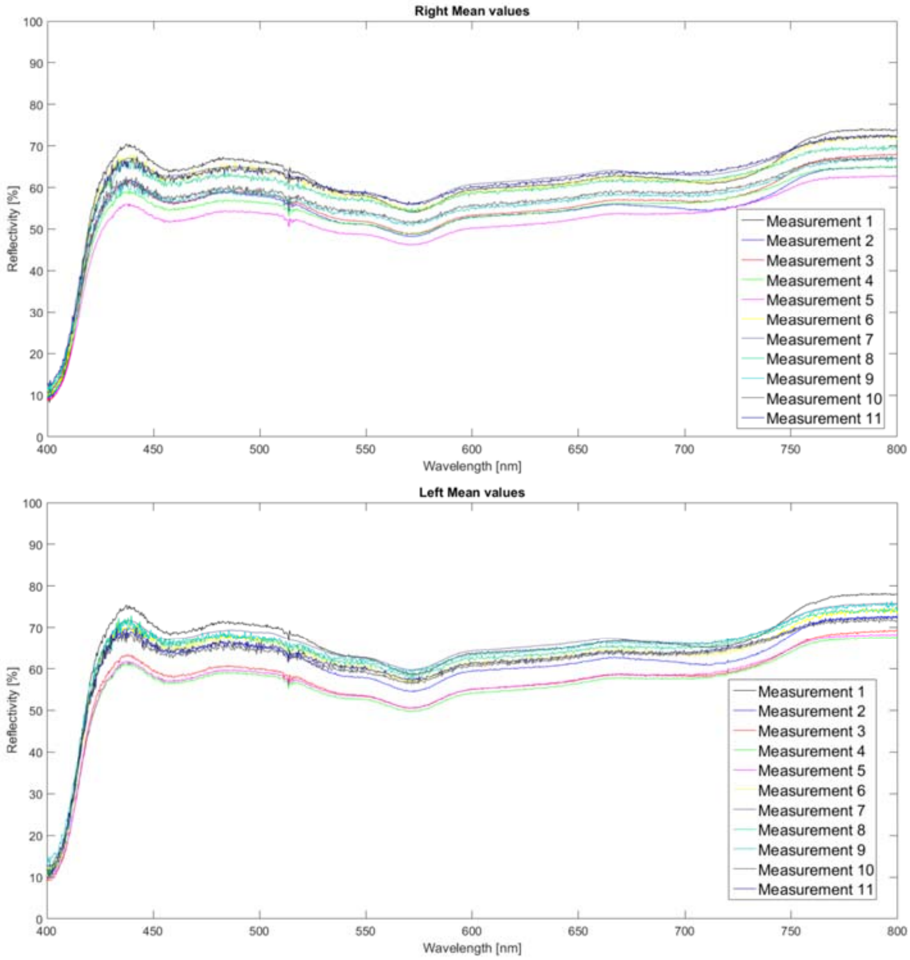
Figure 6 – Measurement of spectral reflectance by the use of spectrometer and fiberoptic probe

Figure 7 – Measurement of spectral reflectance was made in ~100 points on the VT

The visual appearance of the VT changed significantly during the collision campaign, most notable is the wear caused by the printed sheet sliding on the asphalt after having been thrown off the VT. This wear results in a checkered pattern appearing, most likely due to the interior structure of the sheet, see Figure 8.

Figure 8 – The visual appearance of the VT before and after 100 collisions

The resulting graphs of spectral reflectance are shown in Figure 9, divided between the four sides of the VT (front/left/rear/right). The graphs in general show rather small differences. 11 measurements were made, at approximately 10-collision intervals. Looking in detail at the results, there is in fact no clear trend. Instead, the observable differences are attributed to soiling of the sheet due to inclement weather.



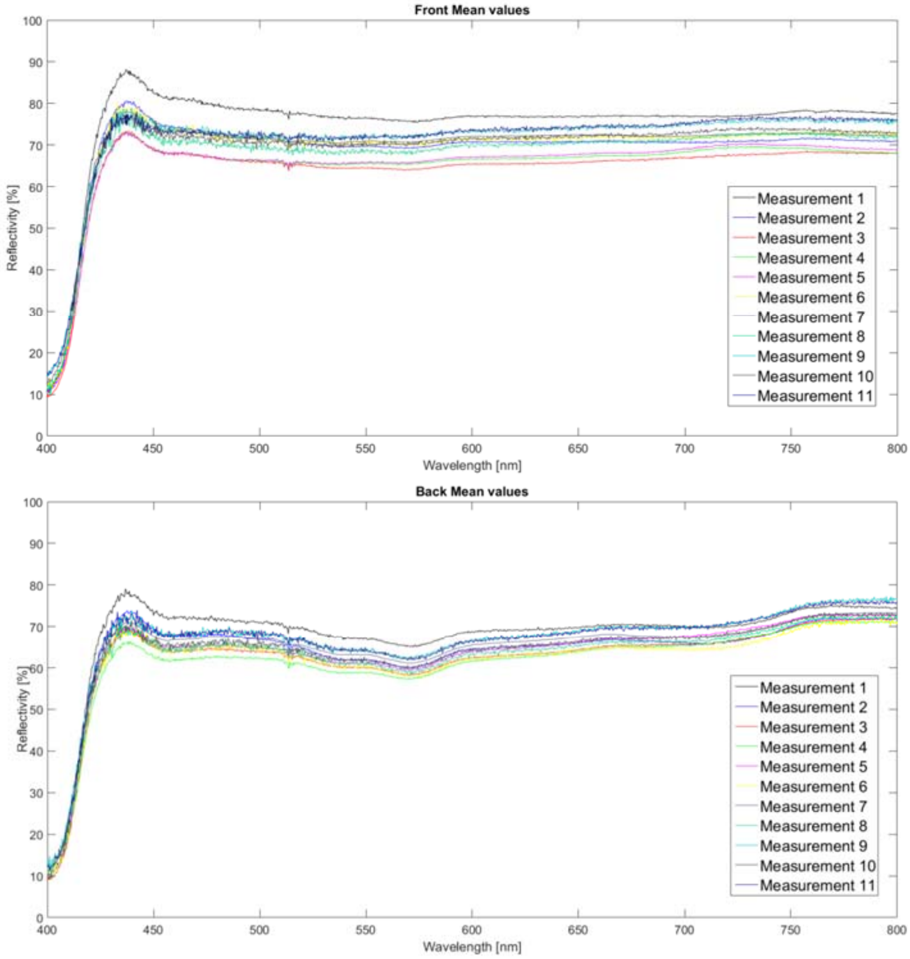


Figure 9 – Spectral reflectance as measured during the accelerated ageing test

The results for reflectance in the 890 – 920 nm region show very similar results, with reflectance in the range 70 – 75 %, across the entire campaign duration.

3.2 Geometry

A terrestrial laser scanner (ZF 5010X) was used to capture the geometry of the car, see Figure 10. The point cloud was also coloured in RGB using the scanner's internal HDR camera.

In addition, a handheld scanner (Dotproduct DPI-8X) was tested to investigate its use in outdoor scanning of the VT in a proving ground environment.

The density of the point cloud on the surface of the VT was approximately 2 mm. Geometry scans were done before any collisions, 3 times during the campaign, and finally, at the end, i.e. after 100 collisions. Along with the 3 laser scans during the campaign, the handheld scanner was also used.

Figure 10 – Laser scanner measurement of VT geometry

During the project three different models of VT's have been studied. The older version of DRI (one new and one used), DRI360 and 4a. They are all based upon the characteristics of a Ford Fiesta model year 2011. So, for comparison, a real car was also part of the study.

The geometrical part of the project comprises different aspects:

- Differences between the VT and a real car
- Variations of the same VT due to assembly
- Variations of the same VT due to ageing

The point cloud images are shown in Figure 11 – Figure 15.

Figure 11 – Point cloud image of the real Ford Fiesta, model year 2011

Figure 12 – Point cloud image of the old DRI VT – unused

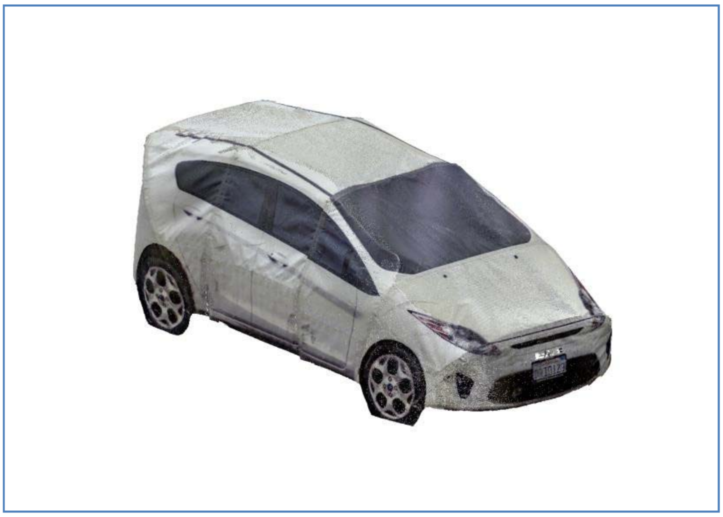


Figure 13 – Point cloud image of the old DRI VT – after 100 collisions

Figure 14 – Point cloud image of the new DRI VT – unused

Figure 15 – Point cloud image of the new 4a VT – unused

The studied VTs are similar but not identical in shape or dimensions. The draft standard ISO 19206-3 provides no defined requirements regarding the static dimensions of the car body. There are, however, requirements regarding dynamic aspects down to 10 mm.

For comparison, the data from the full scan of the real Ford Fiesta has been used as reference. The scan data from the VTs has then been aligned using best fit. This alignment approach is rough but helps visualizing the differences.

Clipping planes in the two main directions are presented in Figure 16 and Figure 17. The impact of these differences in a real sensor-test situation has not been further studied.

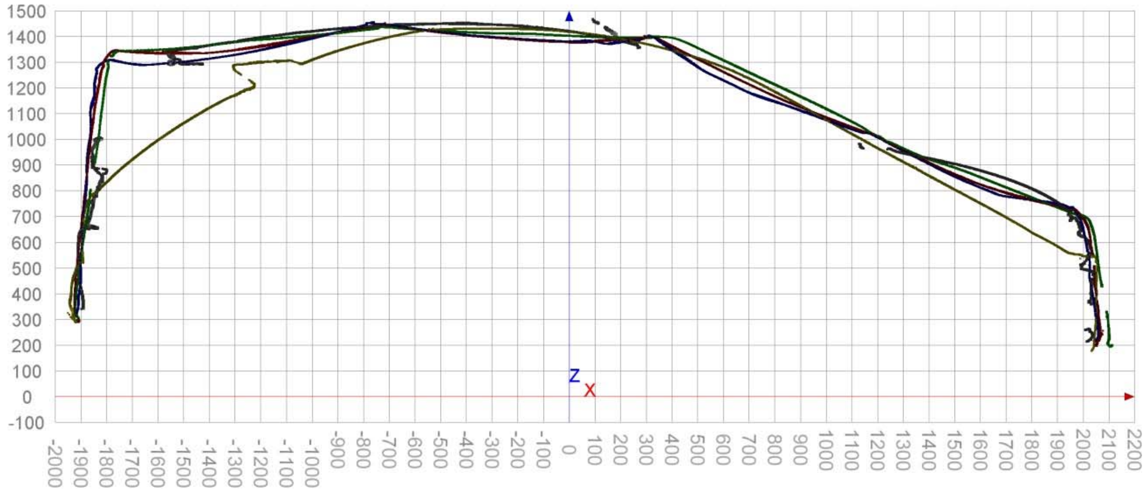


Figure 16 – Longitudinal profile of real car and VT's (scale in mm)

The longitudinal profile shows some noticeable differences. The DRI (both old and new model) have a higher profile at the rear, whilst the 4a target has a lower profile at the rear and front.

The transverse profile shows only minor differences, see Figure 17.

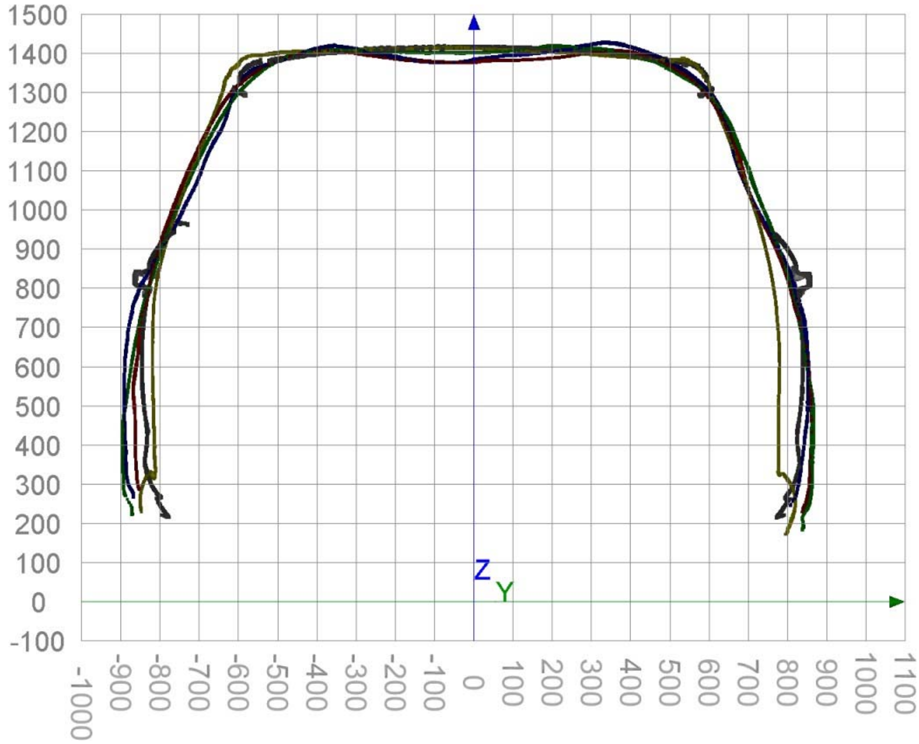


Figure 17 – Transverse profile of real car and VTs (scale in mm)

One purpose of the geometrical part in this project has been to study the variations due to assembly. Consistency in shape and dimension is believed to have a great impact in a real test scenario.

A VT (old DRI) which has been in use at AstaZero was used. It showed clear signs of wear and tear. The VT was assembled – taken apart – assembled and fully scanned 3 times. Figure 18 shows a comparison between the first and third assembly.

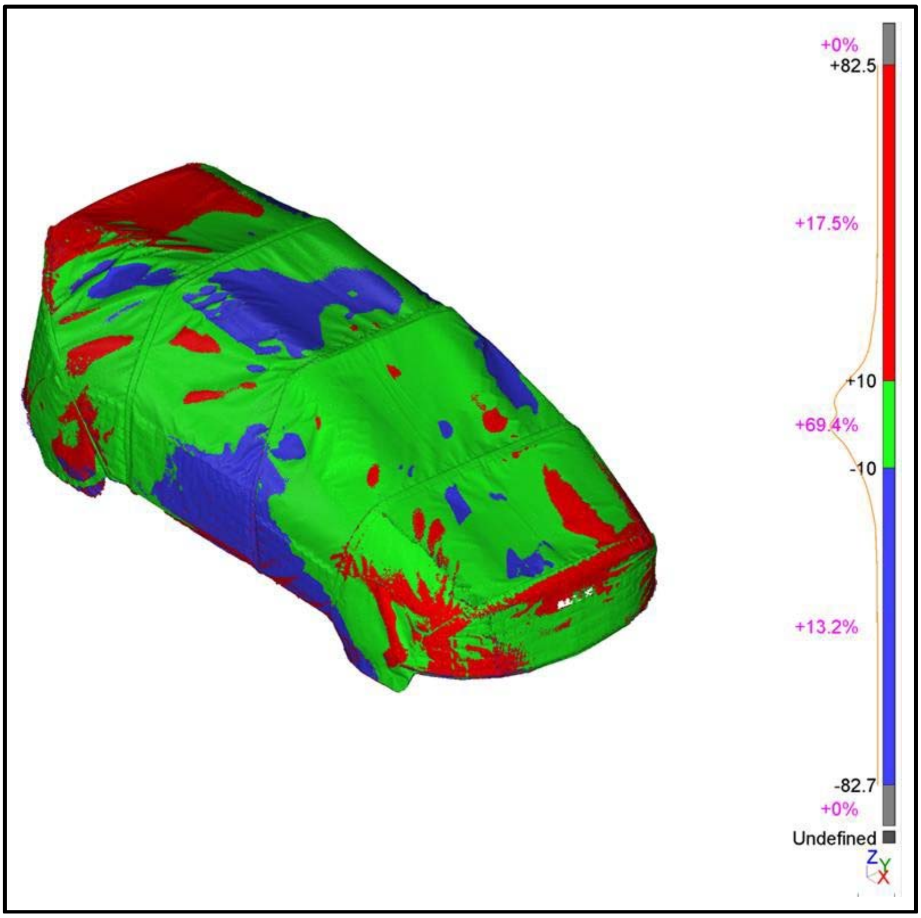


Figure 18 – Comparison between first and third assembly for old used DRI VT (scale in mm)

The variation between assemblies is considerably larger than the 10-mm range (indicated by green colour) which is proposed in the draft standard. A similar study of new VTs shows a better repeatability, as expected when the VT has not been exposed to collisions.

The VT used in accelerated ageing was also measured before, during, and after the ageing campaign. Figure 19 shows the difference between measurements before (new VT) and after 100 collisions.

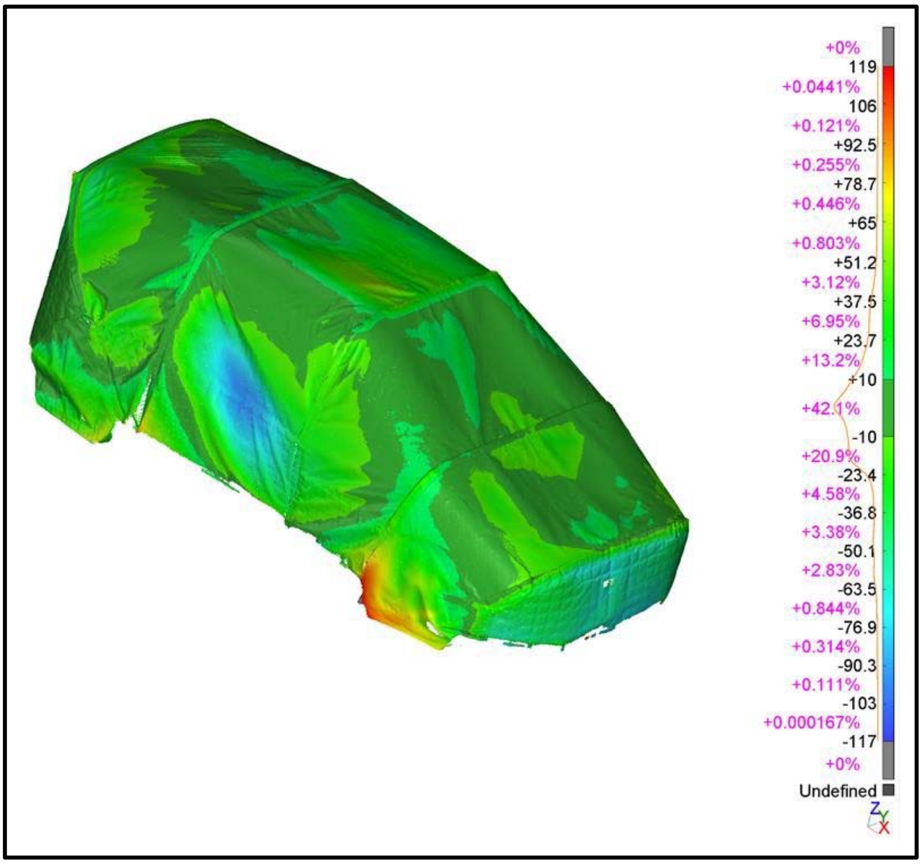


Figure 19 – Comparison between before and after ageing campaign for new DRI VT (scale in mm)

Also in this case is the variation between assemblies considerably larger than the 10-mm range (indicated by dark green colour).

4 Conclusions

The measurement of spectral reflectance shows small differences due to wear and tear, according to the accelerated ageing test. The reflectance is more affected by dirt than by plain wear.

More noticeable, from the standpoint of an optical sensor, is the wear experienced by the printed features, e.g. wheels, headlamps, windows, etc. The details of these were not explicitly studied, but is clearly observable to the naked eye, as in Figure 8. It is expected that this type of wear will also affect the performance of camera-based sensor systems.

The geometry measurements show that variations widely exceed the 10-mm range proposed in the draft standard, both as a result of repeated assembly and from wear during accelerated ageing. The effect of these variations on a camera-based sensor system has not been investigated in this study.

5 Acknowledgments

The work reported was conducted as part of a larger project, together with partners from Volvo Car Corporation and Veoneer, whose contribution is appreciated. The Authors also acknowledge Vinnova, the Swedish government innovation agency, for supporting these activities within the HiFi Visual Target project under grant agreement number 2016-02496.

References

ISO/WD 19206-3. 2016. Active safety targets - Vehicle 3D targets

4activeSystems. 2017. 4A Vehicle Target Specification Version 0.5 (not publicly available)

LEMMENT P. 2013. Evaluation of Pedestrian Targets Used in AEB Testing: A Report from Harmonisation Platform 2 Dealing with Test Equipment. 23rd International Technical Conference on the Enhanced Safety of Vehicles (ESV). No. 13-0124, Seoul, Korea, South, May 27-30, 2013

Euro NCAP. 2017. Test Protocol – AEB Systems. Accessed 2019-04-26. https://cdn.euroncap.com/media/26996/euro-ncap-aeb-c2c-test-protocol-v20.pdf

Anthony Best Dynamics. 2019. Guided Soft Target. Accessed 2019-04-26. https://www.abdynamics.com/resources/files/SP-6013-Mk2-Guided-Soft-Target-GST-Specification-1.pdf

4activeSystems. 2019. 4activeC2 free standing car target. Accessed 2019-04-26. http://www.4activesystems.at/en/products/dummies/4activec2.html