VaGAD Executive Summary

Title of Activity: VaGAD - NAVISP Element 2, AO/1-8927/17/NL/MM

Date: 07/02/2022

REFERENCE: VaGAD Executive Summary 07-02-2022

Location: Remote meeting

Project Meeting Participants:

Félix Torán and Paulo Mendes

Attendees:

[NAMES]	[Signature]
Félix Torán	Felix Toran Digitally signed by Felix Toran Date: 2022.02.18 10:24:15 +01'00'
Paulo Mendes	 Digitally signed by Paulo Mendes Date: 2022.02.18 10:17:34 +01'00'

Distribution list:

[NAMES]	[ORGANISATION]	E-mail
Félix Torán	ESA	Felix.Toran@esa.int
Martin Grzebellus	NAVCERT	martin.grzebellus@navcert.de
Franz Kurz	DLR-EOC	Franz.Kurz@dlr.de

Executive Summary

The goal of the VaGAD project was to develop a new method for calibration, validation, and conformity assessment as part of a certification service for GNSS receivers in the automotive industry addressing the SAE-L3 ($L3$) and SAE-L3 ($L4$) levels of automation under real world conditions.

Determining the absolute position of a vehicle with the highest accuracy, as required for autonomous driving (AD), is new and poses a serious challenge to the automotive industry. Nowadays, this mainly concerns vehicles with automated driving functions specifically designed to reach the levels $L3$, $L4$ and $L5$ as defined by the Society of Automotive Engineers.

Originally, the determination of a vehicle's own position in the automotive industry served convenience applications such as route finding and the provision of points of interest (POI). However, safety-relevant applications as for AD now require a far higher accuracy of position determination.

For AD absolute positioning capability with at least lane accuracy and with high integrity in all driving environments is required. One important reference regarding GNSS road specifications in this domain is EUSPA's "Report on Road User Needs and Requirements" according to which the horizontal positioning accuracy should be better than 20 centimetres.

The standard test method to access that the accuracy of the vehicle position and accuracy, as determined by a GNSS-based device onboard of the vehicle, is done by comparing its measurements to the data of a similar but slightly more high-grade device than the one to be tested and under identical conditions and in the same environments This approach tends to ignore the fact that by using the same working principles the reference as well as the test devices are affected by the same underlying error problems.

The proof of evidence regarding the vehicle's required absolute or relative position accuracy derived by mobile GNSS devices including the possibility of using GNSS correction services is quite fundamental in particular to assure the capability of a Safety-of-Life (SoL) systems, such as in AD.

Automotive OEM's and Tier's organisations are aware of these dependencies and are looking for reliable guidance on how to calibrate or validate the GNSS receivers in their automotive systems. Tier organisations require, also, an independent method for validation during development and production, whereas the OEMs are looking at the same time, for an independent method of verification for their GNSS specific Key Performance Indicators (KPIs) in the delivered GNSS products and services.

Methodologies for the determination of a reference trajectory to support the characterisation, development and validation of GNSS-based solutions are need. Two viable approaches for establishing a reference trajectory (position, velocity, orientation, and time) are relative positioning with robotic total stations and absolute positioning using airborne imagery in combination with ground control points (GCP) derived from the SAR satellite or from stationary GNSS devices.

The proposed VaGAD calibration and validation service provides absolute positioning by using simultaneously acquired aerial imagery from a flying platform in combination with ground control points (GCP) derived from the SAR satellite TerraSAR-X based on Radargrammetric measurements or acquired by stationary GNSS devices. This service is based on the idea to compare measurements from a GNSS receiver with those obtained by a validated and GNSS independent reference system (RS) providing higher accuracies and coverage also in GNSS-denied areas, by using aerial imagery.

The VaGAD method allows for the first-time the calibration and the validation of GNSS receivers for the automotive industry under real world conditions through the use of aerial images and GCPs and, unlike previous calibration and validation test procedures, is independent of GNSS-related sources of error.

With this method, the absolute positioning of moving objects using airborne imagery is enabled by forward intersection of image objects. For the forward intersection, the precisely defined position and orientation of the aerial camera together with the position of the vehicle in the image define an image ray, which is intersected with a digital surface model (DSM). By applying the collinearity equations for all image rays in image sequences with a high frame rate, the reference position, velocity, orientation, and time of the mobile GNSS receiver antenna on the vehicle`s roof can be determined.

Deriving 3D positions of objects from a 2D image requires additional information. That is why the method requires an GNSS independent height information at the position of the GNSS antenna on the vehicle roof, with which the horizontal position of the GNSS antenna (X and Y) can be derived. The absolute height of the vehicle GNSS antenna is the central parameter, which is simply the sum of the absolute road surface height at this position and the height of the GNSS receiver relative to the ground. The aerial images are georeferenced by a bundle adjustment using GCPs, aboard GNSS/inertial measurements, and automatically highly dense matched tie points. The method is agnostic relative to the type of GCPs that are provided. GCPs are measured as standard with stationary GNSS device at centimetre accuracy. The reference points used are usually the foot points of poles of lamps or street signs, which can often be clearly identified in both the GCPs from radar satellite data and the aerial images. After georeferencing the images, the vehicle reference trajectory is derived. This is then used to assess the system under test (SUT) trajectory, as derived from GNSS sensor(s), by computing the different KPIs metrics.

In July 2021, the VaGAD method was put into practice as part of a test campaign. For the aerial image sequences acquisition, two nadir looking cameras of the DLR 4k camera system mounted on a helicopter with different focal lengths of 35 mm and 50 mm were used. The predefined test tracks included various real environment scenarios in the Munich area and the city. As SUTs an automotive-grade and a high-grade GNSS receiver were used. Aerial imagery and GNSS data were acquired during the two test campaigns. The main difference between the two test campaigns was the use of GNSS data corrections (DGPS), i.e., with and without RTK correction on the high-grade GNSS receiver.

In this way, it was investigated how the quality of the GNSS sensors is influenced by the environment and what added value the VaGAD method can provide. The VaGAD method proved to be resilient and robust to situations where the GNSS position accuracy degrades, even when RTK is used, as local effects do not impact the VaGAD method.

The following figures show clear deviations of the expected GNSS sensors behaviour in an urban environment. The positions of the vehicle derived by the VaGAD method are marked with yellow circles, the positions of the high-grade GNSS sensor using RTK corrections with red circles, and the positions of the automotive-grade GNSS sensor with blue circles.

Figure 1 - Examples of performance deviations of both the automotive and high grade GNSS sensors. As seen, even for the positions of the high-grade sensor with RTK corrections (red), deviations of varying degrees occur in urban environments compared to the automotive receiver (blue) and the positions derived from aerial imagery (yellow)

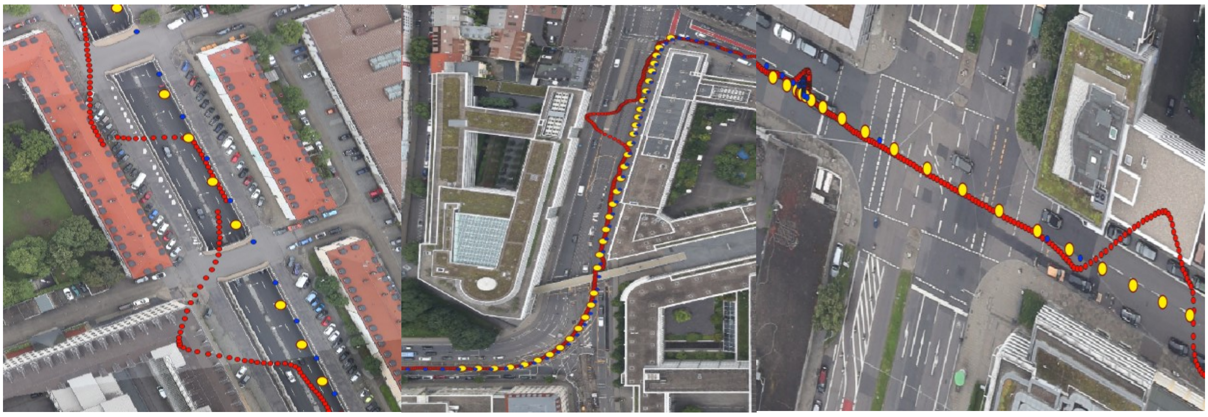

Figure 2 - Examples of performance deviations of both automotive and high grade GNSS receivers. As seen even for the positions of the high-grade receiver without RTK corrections (red), deviations of varying degrees occur in urban environments compared to the automotive receiver (blue) and the positions derived from aerial imagery (yellow).

As shown above, the VaGAD method proved to be resilient and robust to situations when the GNSS position accuracy degrades, even if RTK-GNSS corrections are used, as local effects affecting the GNSS signals have no impact on the VaGAD method. As the VaGAD method provides more accurate positions of ~ 10 cm than the SUT and performs very well for all use cases, it can also be used for calibration, validation, and conformity assessment.

The results of this project show that this method can be used successfully for the process of certifying automotive type grade GNSS receivers aiming to reach $L3$ and $L4$ levels of automation.

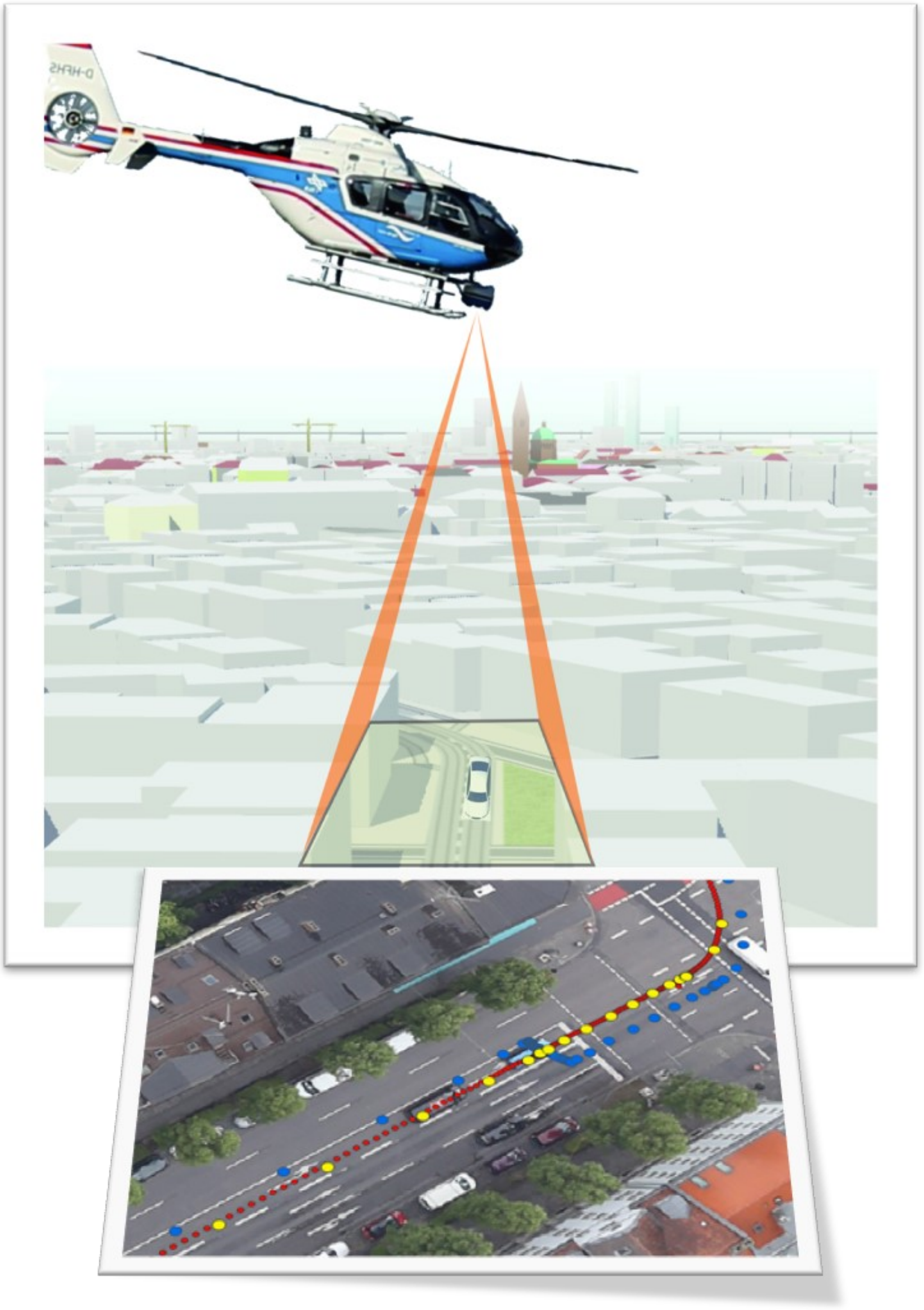

Figure 3 – Conceptual application of the VaGAD method and real-world results obtained during a test campaign.

This new method can be used by OEM and Tier 1 companies during the development and test activities facilitating the calibration, validation, and performance assessment of their position and navigation systems. In addition, as an independent method providing high accurate position data it can be used as a certification tool to which GNSS receiver manufactures can apply for to certify their products. Henceforth, the new method can be used for calibration, validation, and support the developed conformity scheme required for certification activities which will be commercially exploited by NavCert. As certifier, NavCert will offer a voluntary certification service, for GNSS receivers, by issuing a certificate and provide the TÜV SÜD certification mark as proof of evidence of the achieved performance.