https://doi.org/10.3311/PPci.16768

Periodica Polytechnica Civil Engineering, 64(4), pp. 1269–1274, 2020

Creating an OpenDRIVE Model of the Campus of the Budapest University of Technology and Economics for Automotive Simulations

Árpád Barsi[1*], Vivien Potó[1], János Máté Lógó[1], Nikol Krausz[1]

[1] Department of Photogrammetry and Geoinformatics, Faculty of Civil Engineering, Budapest University of Technology and Economics, H-1111 Budapest, Műegyetem rkp. 3, Hungary
[*] Corresponding author, e-mail: barsi.arpad@epito.bme.hu

Received: 30 June 2020, Accepted: 10 August 2020, Published online: 23 September 2020

Abstract

The development of automotive technologies requires quite a significant amount of time and money. To accelerate this procedure, the technology of now is strongly based on computer simulations, where the whole vehicle or its parts can be analyzed in a virtual environment. The behavior of cars, especially equipped with new sensors or assistants, requires long testing, where the automotive simulators can play a cardinal role. The precise vehicular tests request accurate environmental models. These new kinds of models are still standardized; one of the pioneer de facto standards is OpenDRIVE. This standard was initially defined to be able to express all elements with all potential parameters required in high precision simulations. The actual research focused on creating a compliant virtual model based on mobile mapping measurements. A Leica Pegasus Two mobile mapping system was applied to capture field data about the selected pilot area, which is the campus of Budapest University of Technology and Economics (BME). The obtained Lidar point cloud was georeferenced; the merged point cloud is tailored to the driven trajectory, and then it has been evaluated manually. The acquired land use map is converted – similarly manually – into basic road geometry elements: straight lane and bended lane segments. These objects are finally compiled into an XML format, which is compliant with the OpenDRIVE standard. The achieved virtual model has been tested in Driving Scenario Designer of Mathworks Matlab; however, it is promptly ready for use in other widely applied automotive simulators.

Keywords

OpenDRIVE, automotive simulations, mobile mapping, road model, autonomous driving

1 Introduction

One of the most attractive research topics in the automotive world is highly automated driving [1–4]. It has a goal that people have a trip with a vehicle without the need to drive them. The experts agree that this research also requires the maps as an unmissable information source. It gets widely known that the automatization in vehicle control has standardized categories, called levels [5]. Level 0 (No automation) means that the human driver controls each driving task, even if some warning system helps him. Level 1 introduces the Driver Assistance systems; there is a driving mode-specific execution by a vehicle system (e.g., steering OR acceleration/deceleration), but the overall control is at the human driver. Level 2 is called Partial automation because one or more assistant systems control the steering AND acceleration/deceleration, but the environment is monitored by humans, and all remaining dynamic tasks are also performed by him. Level 3 starts the Conditional automation, where the automated driving system delivers all aspects of the driving functions, but the human driver has to respond to any intervention request. Level 4 is the High automation that can respond to all requests, also if the appropriate human intervention fails. Full automation – Level 5 – is the highest level, where the machine control covers all roadway and environmental conditions, and there is no need and mode to human actions [6, 7].

The evolution of the above-described automation levels has a demand for services, called assistants and advanced assistants. These are integrated into the vehicles to improve travel comfort, safety, and efficiency. The increased use of computer technologies resulted the rapid development nowadays. Simulation is maybe the best workhorse of this procedure [7, 8].

Cite this article as: Barsi, Á., Potó, V., Lógó, J. M., Krausz, N. "Creating an OpenDRIVE Model of the Campus of the Budapest University of Technology and Economics for Automotive Simulations", Periodica Polytechnica Civil Engineering, 64(4), pp. 1269–1274, 2020. https://doi.org/10.3311/PPci.16768

Simulation is a technique, which uses sophisticated scientific modeling of a technical system having the same features, behavior, and functionality as the original (natural) system [10, 11]. The simulated model can be used repeatedly with multiple parameters set; therefore, different scenarios can be studied, failures can be detected, various optimizations can be executed – and many further advantages can be enjoyed [12].

The automotive developments started at the Budapest University of Technology and Economics (BME) cover the ecosystem, where this traffic is flown. Several years ago, the Department of Photogrammetry and Geoinformatics had been involved in this development, as the importance of the maps was recognized. This paper has a focus on the geoinformatical efforts in supporting the simulation by highly accurate environmental data in a proper format, which is readable in several automotive simulators.

The paper is structured as follows. Section 2 presents the applied field data capture, which was performed by mobile mapping technology. The obtained data has been transformed into a road model, which is compatible with the OpenDRIVE standard. The main aspects of the standard are written in Section 3, while the methodology is described in Section 4. After deriving the model, it has been fed into different simulators to check its usability; Section 5 brings the results of these tests. The paper is concluded in Section 6, and a reference list closes the text.

2 Field data capture

The map support in a vehicular simulation is equivalent to a data collection of a reality-true survey. The best quality survey is nowadays available by the application of mobile mapping technology. A mobile mapping system is capable of capturing point cloud, and imagery data set simultaneously, where the sensor assembly is accurately oriented by a sophisticated (Global Navigation Satellite System) GNSS and Inertial Measurement Unit (IMU) integrated system.

The survey was carried out in a nearly 18.000 m^2 size part of the BME campus where paved roads enable to use of this technology. A Leica Pegasus Two system [13] was driven along with the whole campus-intern road network. The Leica mapping system is composed of a Z + F Lidar unit with a maximal range of 120 m, a viewing angle of 360°. Further components are the cameras – the seven camera units have an image resolution of 2046 × 2049 pixels at 24 bits. The lens has a focal length of 8.0 mm, except for the single zenith camera, which was with 2.7 mm. The frame rate was set to 8 fps. The positioning was done by a Novatel GNSS/IMU system.

The field data acquisition was performed on 18 January 2019; the weather was partly cloudy. The total length of the driven tracks was 4571 m, whereas 951 color images were captured. The laser scanning point clouds were split into 25 segments; the overall size was 13.7 GB (Fig. 1).

The trajectory computation was increased by involving the permanent station very close to the surveyed area. The achieved average absolute accuracy of the three obtained trajectories was 4.9 cm with 3.9, 1.8, and 1.3 cm in X, Y, and Z directions, respectively [14].

3 Road modelling with OpenDRIVE standard

The vehicle production world is one of the most strictly controlled technical ecosystems. The high quality of the vehicles is guaranteed by the consequent use of international standards. Obviously the simulations also use standards. The data formats, the derived measures, the methodologies – all are precisely described and expected by different standards. Consequently, the map data are similarly standardized within this world.

The OpenStandard family is a collection of environment-related data support in vehicular simulations. The flagship of the family is OpenDRIVE, developed to represent the road geometry and its environment. OpenCRG [15] contains an abbreviation for Curved Regular Grid, which is the macroscopic description for road surface in the form of a matrix-like notation [10, 12, 16, 17]. The application of OpenSCENARIO [18] can introduce traffic flow.

Fig. 1 The sample area surveyed by Leica Pegasus Two mobile mapping system. The black line is a logged trajectory

The standard (abbreviated sometimes as ODR) was initially developed by a consortium with Daimler, BMW, Fraunhofer Institute, German Aerospace Center (DLR), the Netherlands Organization for Applied Scientific Research (TNO), Swedish National Road and Transport Research Institute (VTI) – to mention just the most essential stakeholders. The German company VIRES GmbH has the leadership in the standardization job; this small firm has long experiences in automotive simulations. The goal of the standardization efforts was to establish a vendor-independent, possibly internationally known format with clear legal status and usage. Experiencing these features, after some market analyses and software demonstrations, we decided to apply this standard to our mapping investigations.

An OpenDRIVE model is built-up from three basic elements of a road network: the individual roads, junctions, and controllers. It is also to mention that roads can be linked to other roads or junctions. The model is written by XML (Extensible Markup Language). The data format expresses a hierarchical structure, where the standardized beads can be extended by user-defined ones. All values are with SI units; the floating-point numbers (e.g., coordinates, measures) are written with double precision. The format is designed for international use with a focus on the driving simulators. The standard is publicly available; the download and use don't require any licensing.

The roads are first described by a reference line; mainly, it is the centerline. Upon the centerline, the elevation information (longitudinal and lateral profiles, superelevations, etc.), the lanes (widths, road markings, materials, etc.) and other environmental information (road objects, like tunnels, bridges, traffic signs and signals) can be declared. The connectivity (i.e., topology) is handled on road and on lane levels [19]. Fig. 2 shows the element hierarchy.

4 OpenDRIVE model for the campus

The primary goal of the research was to derive a standardized output by evaluating a high precision mobile mapping data set. Since our university colleagues are regularly working on the campus road network, it was a clear goal to create there a virtual test site. To reach that goal, the Lidar point cloud and the corresponding camera imagery was checked whether the achieved data set suits for this support. After diagnosing the suitability, the necessary data transformations were executed.

The georeferenced and colored point clouds were merged, then the pilot site with its surroundings was cut to reduce the size of the file. The work was done in CloudCompare [20], which can excellently manage the raw LAS file format [21]. After the coarse cut-off, the point cloud was further compacted: vertically only the road pavement and a half meter interval were kept above it; all outlying points were deleted. The geometrically reduced point cloud is not yet clear; the non-permanent field objects, like moving vehicles and pedestrians, can still be found in the point cloud. These points are also to be removed to get only the infrastructure elements. After the manual removal of all unwanted points, the heterogeneity of the point cloud can be managed. Because the point density varies from place to place, a resampling step is needed to get a homogeneous point cloud with reduced size. The obtained point cloud now has ~30 million points compared to the original ~415 million points.

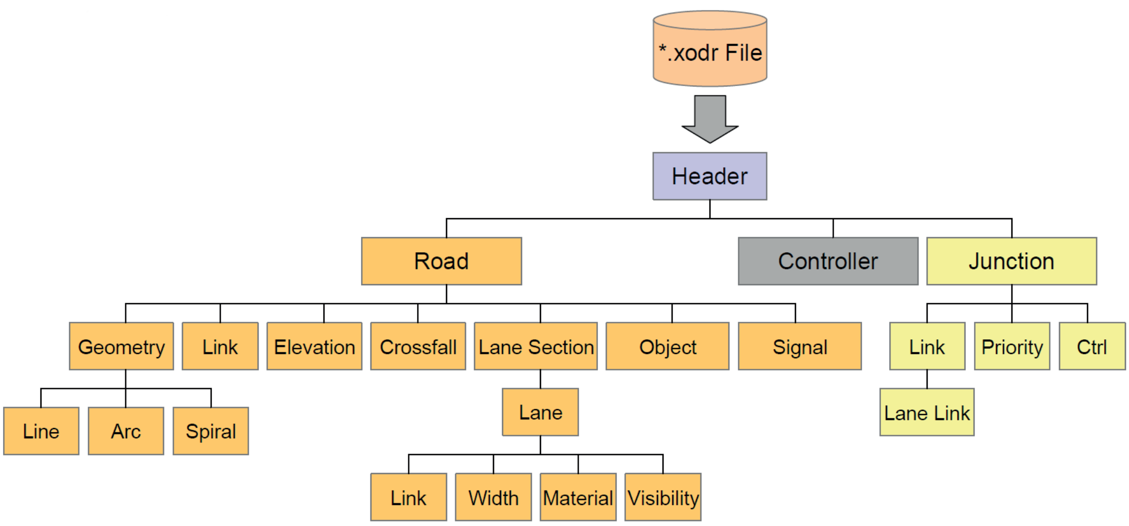

Fig. 2 The beads element hierarchy in the OpenDRIVE standard [OpenDRIVE]

The preprocessed point cloud must be converted into a format, which can be used in the evaluation. Since AutoCAD is part of Autodesk's software ecosystem, it is easy to find a sophisticated software tool to perform the necessary conversion. Autodesk Recap is a reality capturing and 3D point cloud processing component; we have arranged the conversion by this tool. Subsequently, the laser-scanned point cloud can be managed and manually evaluated by using drawing commands of AutoCAD. The goal during the evaluation was set to the delineation of the infrastructure elements, mainly the curbs and lane markings. Additionally, the buildings and the vegetation were also digitized, so we have obtained a layered line map about the test site. Before the actual data evaluation, the staff has built a land-use map (from which an occupancy map and a corresponding grid is derivable) from terrestrial laser scanning (TLS) data [22], so the evaluation procedure was significantly faster, compared to a mapping job in an unknown area. The result is shown in Fig. 3.

Considering the fact that the obtained land use map is a delineation of the potential road segments, the next manual evaluation was executed to extract precisely fitting trapezoids representing the lane elements. All these elements can be exactly parameterized in the sense of the OpenDRIVE lane definition. Similarly, the curved road segments were defined as arcs, which are also part of the OpenDRIVE standard lane definition. The so derived elementary evaluation must be transferred into the data format of OpenDRIVE. To achieve this goal, a Matlab script was developed, which takes the lane elements (trapezoids and arcs) as a DXF file and creates the required XML structure. The output of the script is the xodr file, which is directly readable in OpenDRIVE ODR Viewer, where the first check and the content validation was completed (Fig. 4).

5 Use cases of the OpenDRIVE model

The elaborated technology can be evaluated only through the derived products, now via the OpenDRIVE road model. As the aim was to represent the campus in automotive simulators, the best testing was available in these software environments. The most straightforward test was the Matlab simulator (Driving Scenario Designer) because it supports the OpenDRIVE scenario map definition. The imported campus model can be extended by moving vehicles – even equipped with different sensors like cameras or radars. These sensors can be placed on various vehicle parts: in the front panel, rooftop, side panel, etc. Thanks to this opportunity, a test can be executed, where the sensors' visibility or environmental sensing can be modeled. To a higher quality simulation scenario, we have added a car (it is represented by a blue box), defined a trajectory composed from straight and curved road segments, as well as one left turn. A camera was placed on top of the vehicle's roof, directing forward. The simulation

Fig. 3 Land use map after manual evaluation of the cleaned point cloud

Fig. 4 The road network in OpenDRIVE ODR Viewer

use case shows the road network and the car's trajectory as a simulation canvas, further in the bird's eye plot, the road elements scanned actually by the camera (Fig. 5). An exhaustive check of the digital campus road network revealed the inaccuracies in lane border fittings, which was the reason for the manually drawn and independently created lane segments. The future technology development should focus on the elimination of those errors. Other planned use cases can be run in dedicated automotive software packages, like Tass PreScan, IPG CarMaker or Vires Virtual Test Drive) [23–25].

The smooth movement of the simulated vehicle on the digitized road network underlines the need for reality data in these test and development environments.

6 Conclusions

Mobile mapping technology is an excellent tool to capture very accurate data sets with high detail level about the road infrastructure and its neighborhood. The collected Lidar point cloud has been georeferenced, then evaluated manually to get a land-use map. Based on this line sketch, a model can be compiled to be compatible with the OpenDRIVE standard, which is widely used in several automotive simulations. The BME campus project has proven that the mobile laser scanning technology provides an adequate base in supporting vehicular simulation with the needed reality information. The development of the presented technology chain must focus on the automatization: the automatic evaluation of the necessary land use elements should be achieved – supposedly by the help of algorithms with higher complexity, like statistical decision theory or artificial intelligence. The coupled map compilation is a standard-compliant procedure, where the OpenDRIVE format has been created. The obtained model is then directly ready to be used in various simulator software packages. If this automated raw data evaluation and map file compilation methodology can be reached, the mobile mapping technology serves with the essential data source for establishing larger, city- or country-wide virtual models for vehicular simulations.

Acknowledgement

The research reported in this paper was supported by the Higher Education Excellence Program in the frame of the Artificial Intelligence research area of Budapest University of Technology and Economics (BME FIKP-MI/FM).

The project has been supported by the European Union, co-financed by the European Social Fund. EFOP-3.6.3-VEKOP-16-2017-00001.

The authors would like to express their thanks to the students, László Tar and Diána Szigeti, for their contribution in evaluating the mobile mapping data set.

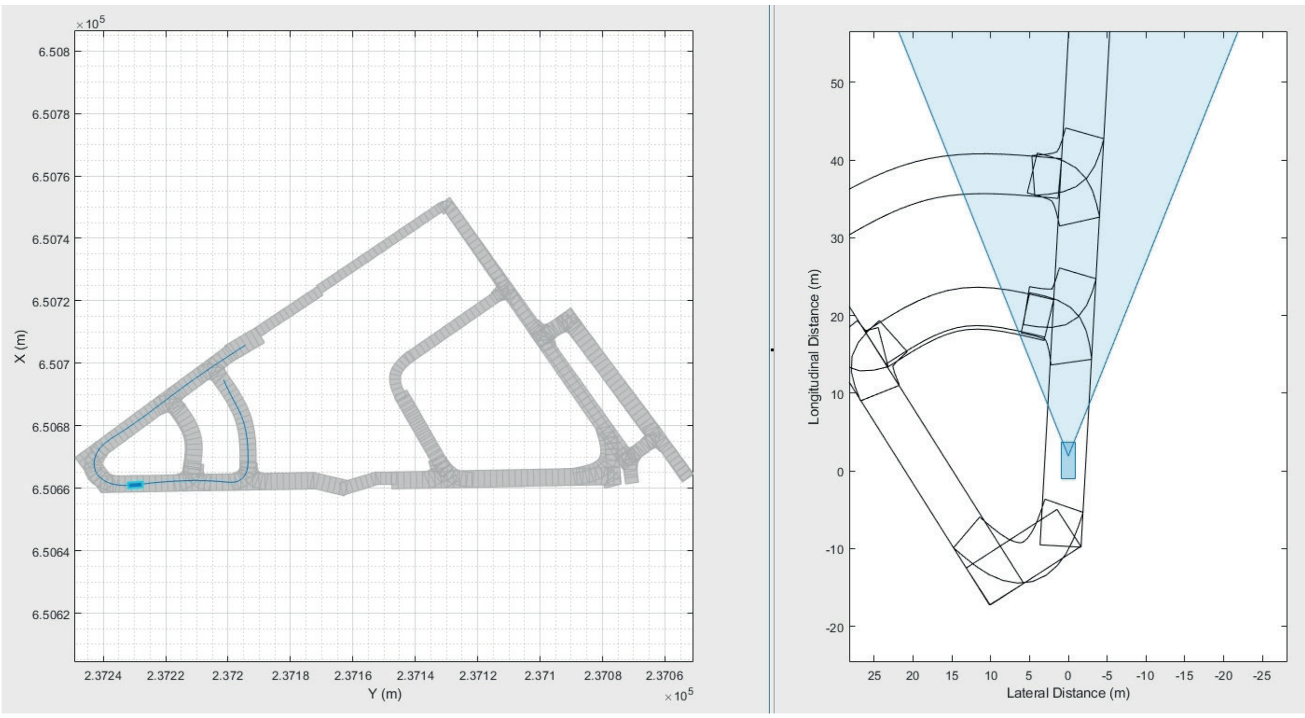

Fig. 5 OpenDRIVE road model of the campus with a test vehicle equipped with a camera. The left picture shows the test trajectory, while the right present the vision sensor visibility field

References

[1] Szalay, Zs., Nyerges, Á., Hamar, Z., Hesz, M. "Technical Specification Methodology for an Automotive Proving Ground Dedicated to Connected and Automated Vehicles", Periodica Polytechnica Transportation Engineering, 45(3), pp. 168–174, 2017. https://doi.org/10.3311/PPtr.10708

[2] SIP "SIP-adus Automated Driving for Universal Service", [online] Available at: http://en.sip-adus.go.jp [Accessed: 06 April 2018]

[3] Németh, H., Háry, A., Szalay, Z., Tihanyi, V., Tóth, B. "Proving Ground Test Scenarios in Mixed Virtual and Real Environment for Highly Automated Driving", In: Mobilität in Zeiten der Veränderung, Springer Gabler, Wiesbaden, Germany, 2019, pp. 199–210. https://doi.org/10.1007/978-3-658-26107-8_15

[4] Szalay, Zs., Tettamanti, T., Esztergár-Kiss, D., Varga, I., Bartolini, C. "Development of a Test Track for Driverless Cars: Vehicle Design, Track Configuration, and Liability Considerations", Periodica Polytechnica Transportation Engineering, 46(1), pp. 29–35, 2018. https://doi.org/10.3311/PPtr.10753

[5] SAE International "J3016_201806 Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles", SAE International, Warrendale, PA, USA, 2018. https://doi.org/10.4271/J3016_201806

[6] SAE International "J3016_201609 Surface vehicle recommended practice", SAE International, Warrendale, PA, USA, 2016.

[7] Kang, Y., Yin, H., Berger, C. "Test Your Self-Driving Algorithm: An Overview of Publicly Available Driving Datasets and Virtual Testing Environments", IEEE Transactions on Intelligent Vehicles, 4(2), pp. 171–185, 2019. https://doi.org/10.1109/TIV.2018.2886678

[8] Ko-HAF, Burg, M. "Simulation as Tool", [computer program] Available at: https://www.ko-haf.de/fileadmin/user_upload/media/abschlusspraesentation/18_Ko-HAF_Simulation-as-Test-Tool.pdf [Accessed: 26 September 2019]

[9] AVL "Advanced Simulation Technologies", [online] Available at: https://www.avl.com/hu/web/guest/simulation [Accessed: 26 September 2019).

[10] Potó, V., Somogyi, Á., Lovas, T., Barsi, Á., Tihanyi, V., Szalay, Zs. "Creating HD map for autonomous vehicles - a pilot study", In: 34th International Colloquium on Advanced Manufacturing and Repairing Technologies in Vehicle Industry, Visegrád, Magyarország, 2017, pp. 127–130.

[11] Barsi, A., Poto, V., Somogyi, A., Lovas, T., Tihanyi, V., Szalay, Zs. "Supporting autonomous vehicles by creating HD maps", Production Engineering Archives, 16, pp. 43–46, 2017. https://doi.org/10.30657/pea.2017.16.09

[12] Krausz, N., Lovas, T., Barsi, Á. "Radio Frequency Identification in Supporting Traffic Safety", Periodica Polytechnica Civil Engineering, 61(4), pp. 727–731, 2017. https://doi.org/10.3311/PPci.10114

[13] Leica Geosystems "Leica Pegasus:Two Mobile Sensor Platform", [online] Available at: https://leica-geosystems.com/hu-hu/products/mobile-sensor-platforms/capture-platforms/leica-pegasus_two [Aaccessed: 21 July 2020]

[14] Barsi, A., Csepinszky, A., Krausz, N., Neuberger, H., Poto, V., Tihanyi, V. "Environmental data delivery for automotive simulations by laser scanning", The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-2/W16, pp. 41–45, 2019. https://doi.org/10.5194/isprs-archives-XLII-2-W16-41-2019

[15] Open CRG "OpenCRG webpage", [online] Available at: http://www.opencrg.org/ [Accessed: 06 April 2018]

[16] Potó, V., Csepinszky, A., Barsi, Á. "Representing road related laserscanned data in curved regular grid: A support to autonomous vehicles", The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-2, pp. 917–921, 2018. https://doi.org/10.5194/isprs-archives-XLII-2-917-2018

[17] Barsi, A., Poto, V., Tihanyi, V. "Creating OpenCRG Road Surface Model from Terrestrial Laser Scanning Data for Autonomous Vehicles", In: Jármai, K., Bolló, B. (eds.) Vehicle and Automotive Engineering 2, Proceedings of the 2nd VAE2018, Springer, Cham, Switzerland, 2018, pp. 361–369. https://doi.org/10.1007/978-3-319-75677-6_30

[18] VIRES "OpenSCENARIO webpage", [online] Available at: http://www.openscenario.org/ [Accessed: 06 April 2018]

[19] VIRES "OpenDRIVE webpage", [online] Available at: http://www.opendrive.org/ [Accessed: 06 April 2018]

[20] EDF R&D "CloudCompare", [computer program] Available at: https://www.danielgm.net/cc/ [Accessed: 06 April 2018]

[21] American Society for Photogrammetry and Remote Sensing "LAS (LASer) File Format, (1.4)", [computer program] Available at: https://www.loc.gov/preservation/digital/formats/fdd/fdd000418.shtml

[22] Tar, L., Csepinszky, A., Krausz, N., Neuberger, H. "Helymeghatározási jelölők kinyerése mobil térképezéssel nyert adatokból" (Extract location markers from data obtained by mobile mapping), In: Molnár, V. A. (ed.) Az elmélet és a gyakorlat találkozása a térinformatikában X.: Theory meets practice in GIS, Debrecen University Press, Debrecen, Hungary, 2019, pp. 317–324. [online] Available at: https://www.researchgate.net/publication/335976749_Helymeghatarozasi_jelolok_kinyerese_mobil_terkepezessel_nyert_adatokbol

[23] HEXAGON "VTD - VIRES Virtual Test Drive", [online] Available at: https://vires.mscsoftware.com/?s=VTD+-+VIRES+Virtual+Test+Drive [Accessed: 26 September 2019]

[24] Tass International "PreScan, (2019.2)", [computer program] Available at: https://tass.plm.automation.siemens.com/prescan [Accessed: 26 September 2019]

[25] IPG Automotive "CarMaker: Virtual testing of automobiles and light-duty vehicles", [computer program] Available at: https://ipg-automotive.com/products-services/simulation-software/carmaker/ [Accessed: 26 September 2019]