AnteMotion's solution for automatic creation of simulation environments for ADAS and AV

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Abstract - *In the automotive industry, simulation plays a key role for testing and validation of assistive and autonomous driving technologies and, in this context, AnteMotion positions itself to address one of the main criticalities: the need for scalable and efficient simulation tools. This is done by introducing innovative approaches for the automatic creation of simulation environments, exploiting high-definition real-world maps to create high-fidelity environments that are deeply rooted in real-world data, improving the relevance and reliability of simulation results. One of the key aspects of AnteMotion's toolchain is the fact that it operates fully automatically, converting HD maps into OpenDRIVE files effortlessly. From these OpenDRIVE files, high-quality 3D environments are procedurally generated, enriching the scene with several objects. In addition, these virtual environments are optimized for real-time simulations, supporting a wide range of development and validation activities for ADAS and AV systems.*

Keywords: *driving simulations, real-time performance, procedural generation, OpenDRIVE maps, realistic environments.*

Introduction

In the rapidly evolving landscape of Advanced Driver Assistance Systems (ADAS) and Autonomous Vehicles (AV), simulation has become an indispensable requirement (Alghodhaifi and Lakshmanan, 2021; Hanke, et al., 2015; Maag, et al., 2011; Mahadevan, et al., 2019; Molenaar, et al., 2015; Rosique, et al., 2019). The development and validation of these sophisticated technologies necessitate environments that replicate real-world with high fidelity. This requirement not only encompasses the modelling of complex road networks but also demands the generation of detailed 3D simulation environments that are perfectly aligned with these networks (Merenda, et al., 2019). Moreover, simulations need to match the requirement of photo-realistic rendering for the training & validation of perceptions stack neural networks (Mania and Beetz, 2019).
Current industry challenges highlight a growing demand of simulation environments from Automotive OEMs and their engineering providers. These stakeholders are intensively working on the software stack for ADAS and AV technologies and require simulation environments that not only support basic functionality tests but also cater to the development of perception stacks.
For the latter, the environments must possess high rendering quality to simulate realistic visual inputs for the vehicle's camera sensors (see Fig. 1). Creating these content-rich, high-precision simulation environments manually is not only time-consuming but can be prohibitively expensive. Furthermore, it can be difficult to acquire specialized workers capable of crafting such environments, due to the competitive videogame market.
Such non-automatized methods lack scalability and fail to meet the fast-paced development and validation needs of ADAS and AV systems. Therefore, there is a distinct gap in the market for tools that can

Figure 1: Examples of AnteMotion's high-quality real-time driving environments, automatically generated with Maze and Procedural Worlds pipeline.

automate the creation of accurate road network models and detailed 3D simulation environments.
Antemotion is a growing company that operates in this field, which is populated by a few competitors. Some of the competitors develop software with partial automatization capabilities but that lacks the high-fidelity graphics needed for visual sensing experiments. Other competitors are able to provide visually detailed environments, although those are built predominantly with manual effort.
AnteMotion covers this gap, addressing the critical need for scalable and efficient simulation tools for environment generation, by introducing automatized solutions that have the potential to transform the landscape of ADAS and AV development.
Our toolchain leverages real-world High-Definition (HD) maps - identical to those used in current ADAS/AV navigation and localization systems - to create precise simulation data. This innovative approach ensures that the simulated environments are comparable with real-world data, enhancing the relevance and reliability of the simulation results.

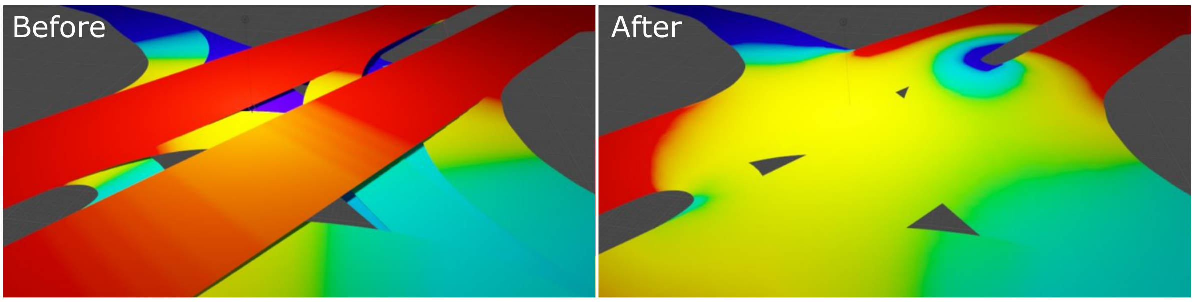
Production solution

AnteMotion's pipeline operates in a fully automated manner, converting HD maps into OpenDRIVE files effortlessly. OpenDRIVE, a standard format for describing road networks, serves as the foundational layer upon which complex simulations are built. Indeed, from OpenDRIVE files, the pipeline procedurally generates high-quality 3D environments tailored for simulation purposes. These procedurally generated worlds are optimized both for physical-based rendering and to achieve maximum performance in real-time simulations. This is crucial for running sophisticated simulation scenarios that can support a wide range of development and validation activities for ADAS and AV systems (i.e., DIL, HIL, and SIL simulations).
AnteMotion's pipeline for automatic generation of realistic simulation environments for ADAS and AV experiments is mainly based on two in-house developed applications, named Maze and Procedural Worlds.
The pipeline has been implemented using open standards, in order to favor the customization of the operative flow, avoid vendor lock-in, and allow the usage of both software as standalone products.

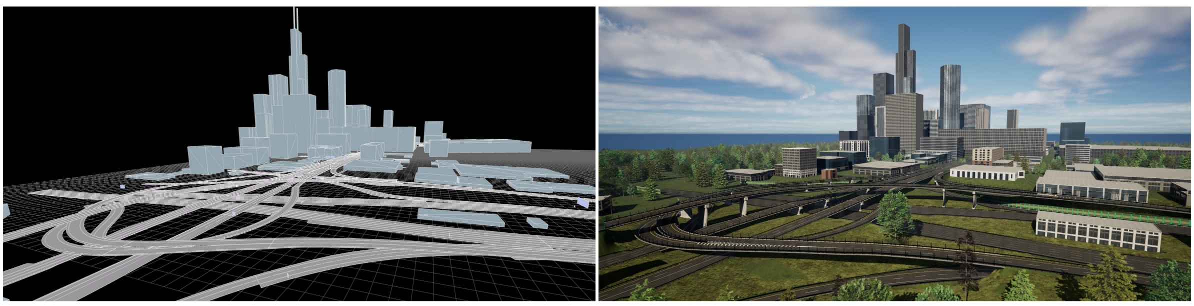
Maze

Maze is a software that encodes different Geographic Information System (GIS) sources into various output formats representing road networks. Within the AnteMotion pipeline, Maze is used for the conversion and data fusion of GIS sources and HD maps to generate OpenDRIVE databases for simulation scenarios and environments generation. Some of the unique features of Maze in generating OpenDRIVE include:

- software as a service (SaaS, optionally with HERE HD Live Maps credentials included in the service);
- the reference line geometry is guaranteed to have both continuous heading and continuous curvature;
- automatic real GIS sources to create the most comprehensive OpenDRIVE possible;
- support for various roadside elements such as traffic signals, traffic lights, barriers, buildings, and poles;
- procedural generation of road-marks and road-markings like directional arrows, stop lines, and yield lines;
- procedural generation of traffic light intersections, with detail at both the road level and lane level;



(a)



(b)

Figure 2: Top: advanced smoothing of a junction surface in Maze. Bottom: environment creation and enrichment with Procedural Worlds.

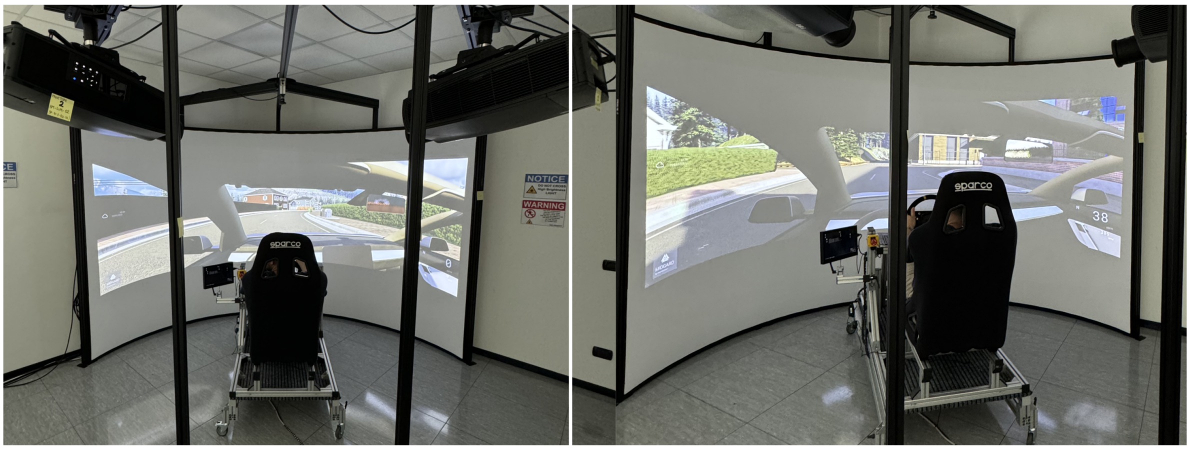


Figure 3: Typical use case of an environment created with AnteMotion's pipeline: DIL simulation (at the AnteMotion Simulation Room, Rovereto, Italy).

- automatic smoothing of junction surfaces, exploiting the road <*shape*> OpenDRIVE definitions (see Fig. 2a).

Procedural Worlds

Procedural Worlds, the downstream software in the AnteMotion's pipeline, exploits the OpenDRIVE, optionally created with Maze, by procedurally generating a 3D simulation environment, formalized with the Universal Scene Descriptor (USD) file format or in Unreal Engine (UE) 5.3 level, enriched with multiple features, and optimized for real-time rendering. Its main capabilities are:

- from the input OpenDRIVE file:
  - the full 3D road surface is created;
  - 3D assets and props such as road signs, objects, and road-markings are created or placed according to input information;
  - Complex road intersections are smoothed;
- the automatized enrichment of the scene adding features that are not present in the OpenDRIVE input (see Fig. 2b). This includes:
  - creating terrain from digital terrain models.
  - solving junctions issues such as non-continuous boundaries;
  - adding buildings, vegetation, and missing road props (guardrails, wind/sound barriers, bumpers, extra road markings, and gantries);
  - detecting bridges and creating a proper mesh of their structure.

Methodology

In order to create a simulation environment, the user selects the region of interest in the Maze web-interface. Then, after setting a few hyper-parameters such as the *smart road markings generation* or the *procedural generation of traffic lights*, Maze generates the OpenDRIVE of the selected area according to desired settings.
The OpenDRIVE is imported in Procedural Worlds, which generates an enriched and fully-operational simulation environment guided through a simple set of parameters. As a final step, the user is given the possibility to manually modify the environment according to their needs.
The output of the pipeline (a USD file or a UE 5.3 level) is complete and simulation-ready. As an example, generated environments can be applied in training and validation of virtual autonomuos drivers applications, or in performance characterization for ADAS systems, by means of HIL, DIL or SIL simulations.
An usage example of a generated environment, imported in the Midgard rendering solution (another in-house developed software) is presented in Fig. 3 which shows a driver-in-the-loop simulation.

Results

The performance of AnteMotion's pipeline is evaluated in terms of the following metrics:

- Maze:
  - generation time (min/km);
  - percentage of HD maps roads that are discarded;
  - percentage of HD maps roads that are re-traced (re-constructed or fixed);
- Procedural Worlds:
  - generation time (min/km);
  - number of procedurally created objects per kilometer (#/km).

Average values for the proposed metrics are reported Tab. 1 and Tab. 2 for Maze and Procedural Worlds respectively.

Table 1: Maze performance

Metric	Value	Unit
generation time	< 0.3	minutes/km
% of discarded roads	≈ 0.5	%
% of re-traced roads	≈ 1.6	%

Table 2: Procedural Worlds performance

Metric	Value	Unit
generation time	≈ 0.4	minutes/km
# of procedural objects	≈ 12	#/km

The dataset used to estimate the average Maze metrics is composed of 100 generation tasks of real use-cases (urban, sub-urban, highway). As an important

Figure 4: Simulation environment of the A8 highway in Germany, generated by AnteMotion.

note, theoretically there is no limit on the maximum map area that can be generated with Maze. Up to now, the largest map created is the *Pegasus Projekt loop* in Germany (approximately 700 drivable kilometers of highway over an area of almost 600 km^2).
The metrics of Procedural Worlds are evaluated from a dataset of five OpenDRIVEs, representing urban areas of large cities, characterised by an high density of motorways and nearby roads. The number of generated objects includes barriers, buildings, road marking and bridges.
As can be seen by the numbers reported in the Tab. 1 and Tab. 2, Maze and Procedural Worlds performance is excellent, allowing the user to generate a typical use case environment in a matter of minutes.

Conclusions

AnteMotion is at the forefront of innovation in simulation technology for ADAS and AV development (see Fig. 4). By automating the creation of high-fidelity simulation content from real-world data, our toolchain significantly reduces the time and cost associated with traditional manual methods. This enables faster, more efficient development cycles and helps meet the rapidly growing demands of the industry. Our commitment to compatibility with open standards and high-performance ensures that our solutions are not only cutting-edge but also practical, providing value to costumers and engineers focused on the development of the next-generation automotive technologies.
The development roadmap for AnteMotion pipeline focuses on further reducing the time spent on manual refinement of the generated environment, with the ultimate goal of full automation. Moreover, the possibility for costumers to manually modify any aspect of the created environment will remain, to ensure maximum flexibility.

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