OpenDRIVE 2010 and Beyond – Status and Future of the de facto Standard for the Description of Road Networks

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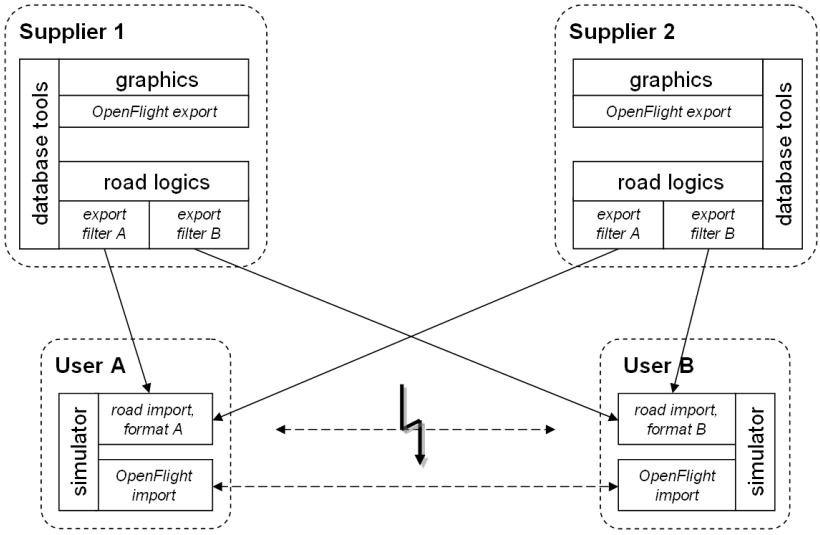
Abstract – *OpenDRIVE was launched in early 2006 and made its first appearance to a broad audience of driving simulation experts at the DSC in September 2006 [1]. Four years later, this paper provides an overview of the project's status and current applications. It will not so much focus on technical details of the data format since these are publicly available via the format specification [2]. Instead, it will take a closer look at the OpenDRIVE project itself, the processes which are implied and the use cases. A detailed user report will show OpenDRIVE's strengths in terms of the exchange of databases. Another open project, based on the ideas of OpenDRIVE and extending its range of applications will be introduced. Finally, an outlook on future developments will be given.*

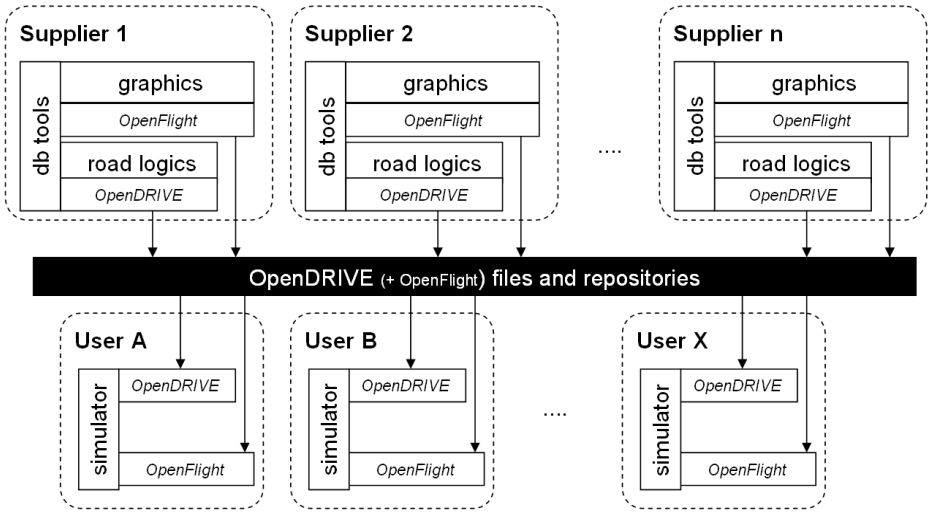
Background

Motivation

The idea of OpenDRIVE emerged during the implementation of Daimler's "DRIVE" format by VIRES into several tools for the creation and real-time evaluation of road network databases. Implementing yet another proprietary solution worked well, but it didn't quite provide the perspective of long-term flexibility, especially when it came to identifying additional repositories of road databases, exchanging data within heterogeneous projects etc. The following figure illustrates this situation at the start of the project.



The exchangeability of data that had already been established for visual databases by means of the *OpenFlight* Format [3] was a good benchmark for what had to be done for the logical description of road networks. This initial aim is shown in the following figure:



As the figure illustrates, only the involvement of a broad range of road network creators and users would provide a solid foundation for a successful initiative.

A Short History of OpenDRIVE

The design of the OpenDRIVE project was laid out as a draft in 2005 and the project itself was made public in 2006 [1]. From the public start, a broad team of simulation professionals was involved in the design of the OpenDRIVE format [2] and the project itself.

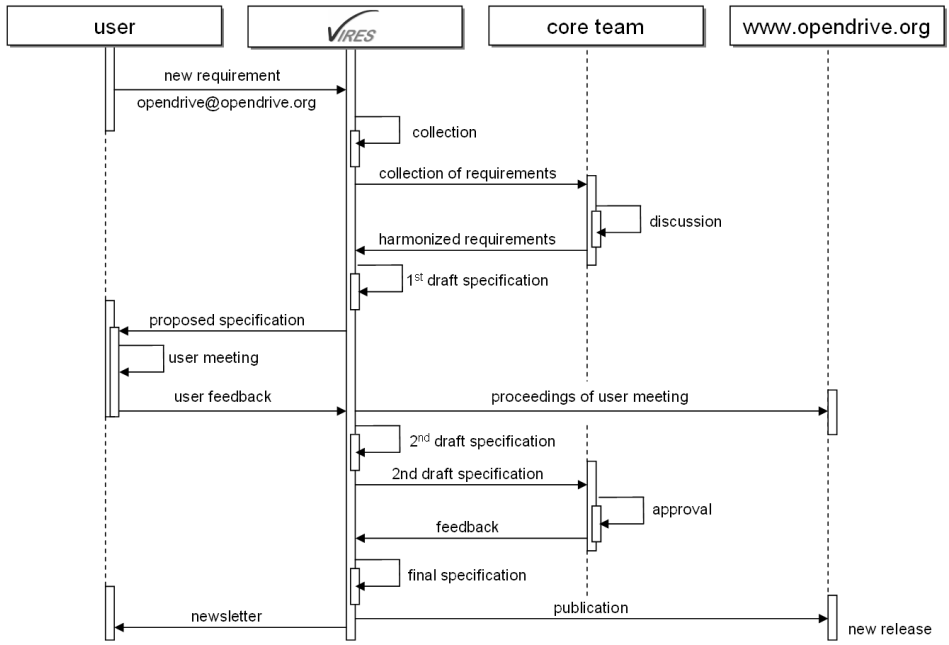
Meanwhile, OpenDRIVE has been in the market for more than four years and can definitely be called a de-facto standard. It is to be considered stable in terms of its design and the procedures of the on-going development process. The format is supported and used by a permanently growing user community world-wide.

Status Report

The OpenDRIVE Process

The OpenDRIVE project is managed by a core team of simulation professionals, all of them playing vital roles at research institutes, simulator manufacturers, software suppliers and simulator operators. The management of the core-team and the entire project itself is performed by VIRES.

The real force behind the project is the user base which provides a vast source of new requirements and constant feedback. The following figure illustrates the iterative process of permanently enhancing OpenDRIVE by means of these user inputs.



Proposals for the extension or modification of the format may be submitted by any (potential) user via "opendrive@opendrive.org". VIRES collects these proposals and forwards them to the core-team members for further discussion. Once enough inputs have been collected which justify a new revision of the format, a draft specification is issued which will then be discussed at an OpenDRIVE user meeting.

With the feedback from the user meeting, the specification will be further adapted and finally approved by the core-team members. The final version of the specification will be published on the OpenDRIVE website and users registered in the newsletter distribution list (via newsletter@opendrive.org) will be notified.

The User Base

The user base of OpenDRIVE can be split into two major groups:

- *Direct users* will typically take care of writing, reading and/or evaluating OpenDRIVE data by means of their own tools. They interface with the OpenDRIVE XML files without any higher level software in-between.
- *Indirect users* are the ones whose simulator software components are also able to interface with OpenDRIVE data. However, the tools for doing so will usually have been written by a supplier who is, again, to be counted as direct user.

Both types of users enjoy the benefits of OpenDRIVE. Whereas formerly there were strong links between road network database customers and their respective suppliers due to the fact that both had to invest into adaptations of tools for proprietary formats, these links are now broken up and both – suppliers and customers – may re-group in an open market.

The total size of the OpenDRIVE user community is unknown since the format specification may be downloaded for free and without prior registration from the OpenDRIVE website. However, a list of users who are willing (and able) to show their support of both the format and the initiative in public is available via the OpenDRIVE website [4]. This list is steadily growing and for every published user there are a couple of others who have at least registered for the OpenDRIVE newsletter.

Applications

Applications and tools complying with the OpenDRIVE standard are currently confirmed in the following areas:

- database generation
- traffic simulation (automotive and tram)
- vehicle dynamics
- driver assistance systems (e.g. navigation)

User reports presented at the OpenDRIVE meeting in January 2010 gave a good overview of recent developments and actual projects involving the OpenDRIVE data format. These are (among others):

- OpenDRIVE as meta-format for the fusion of navigation and elevation data from different data sources (various users)
- OpenDRIVE as input format for road database generation tools
- OpenDRIVE roads as basis for high quality 3d vehicle dynamics and for vehicle dynamics control systems

- OpenDRIVE as part of additional commercial products (e.g. veDYNA, Modelica)

Another positive message of this recent meeting is that OpenDRIVE is making its way into 3rd party applications without any commercial involvement of its "inventors". Previous concerns that using OpenDRIVE would mean getting into some sort of dependency from key companies (i.e. at the beginning: from VIRES) have been proven wrong. What is more, a data format that is being used in a great variety of applications and by a broad range of users – most of them not commercially linked to each other, many even competing – can really claim to be a de-facto standard.

Building on OpenDRIVE's Strength: Exchanging Databases

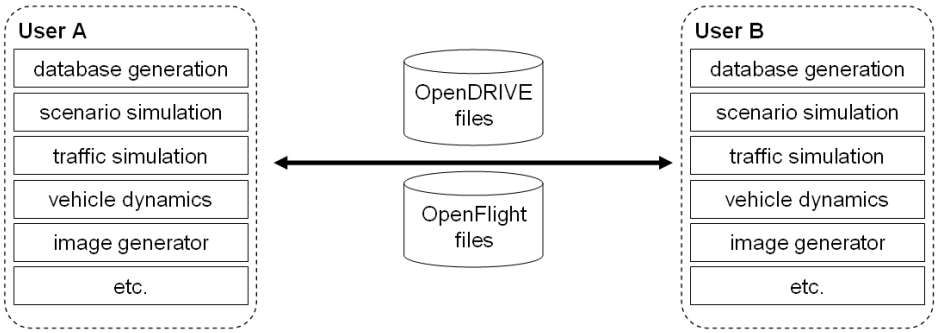
Overview

With the introduction of OpenDRIVE, users have for the first time been able to exchange road networks between simulators which differ considerably in terms of their core components (framework, vehicle dynamics, traffic/scenario simulation, visual etc.).

Typically, these components are developed by the user or are provided by different suppliers. Therefore, requiring all parties to comply with the OpenDRIVE standard at the level of reading / writing the road network data is the key to the successful database exchange.

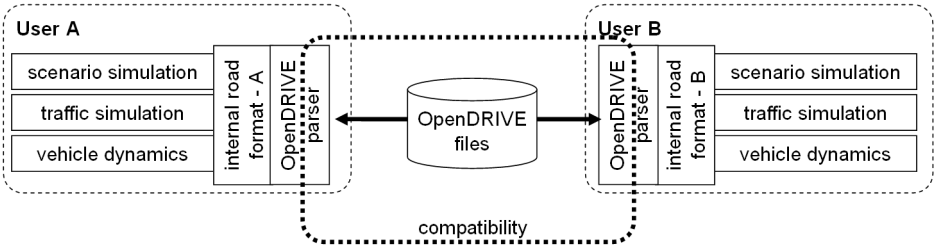
In addition, of course, also the data format of the visual database should be harmonized, but this is considered a minor issue here since quite a number of de-facto standards have been around for these data for a long time already.

The following figure illustrates the very simple interface between otherwise incompatible simulators.



The internal representation of the data within the components may comply with the OpenDRIVE format but is actually independent of OpenDRIVE. The users have to make sure that their file parsers translate the OpenDRIVE data correctly into the established data structures, so that the need for adaptation to

OpenDRIVE remains at a considerably low level (technically and in terms of workforce).



For the design of OpenDRIVE, this implies that the format has to provide all types of data required by the respective components. Therefore, the development process of OpenDRIVE itself has to rely primarily on the user requirements and feedback as noted above.

BMW Group Research and Technology and Daimler – a Real Use-Case

One example which is to be considered as a proof of these concepts is the database exchange between BMW Group Research and Technology, Munich, and Daimler AG, Sindelfingen, both located in Germany. In 2009 these companies exchanged various databases for use in their respective simulators.

BMW Group Research and Technology had already switched to OpenDRIVE in 2006 because of the obvious advantages of this road description format which are: huge feature set, flexibility, community proven approach and last but not least the possibility to exchange databases with other users of OpenDRIVE.

Key Concepts and Software Architecture

Both companies use a so-called tile concept. They compose their actual simulation databases - according to the test requirements - of a set of tiles which are drawn from extensive repositories.

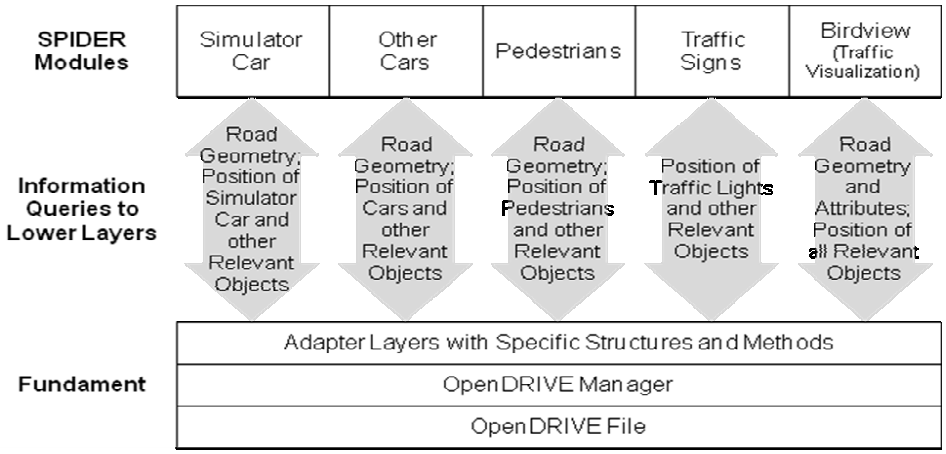
By exchanging tiles, both companies extended their repositories and still stuck to their workflow. Each new tile provided them with new opportunities for creating road networks. In addition, there was no need to disclose any additional information about the actual application of the databases since the composition of the tiles and, therefore, the driving task remains hidden from the other party.

BMW Group Research and Technology decided to switch to the tile concept in 2007. After years of using only complete databases for investigations at the simulators this concept was convincing in terms of flexibility. The databases are built now according to the design of the trials and not vice versa anymore.

The software components interacting with the OpenDRIVE information during run-time (i.e. vehicle dynamics, traffic/scenario etc.) are proprietary solutions developed in-house as well as applications delivered by suppliers. Both companies are using VIRES' OpenDRIVE Manager Real-Time Library for reading

and evaluating OpenDRIVE data. This also means that the subsequent processing of the OpenDRIVE information after reading the OpenDRIVE files may differ considerably.

The driving simulation software of BMW Group Research and Technology is called SPIDER [5]. The following figure shows SPIDER modules that use OpenDRIVE data for different reasons. Due to the fact that these modules can run on different computers each of them reads the OpenDRIVE file independently by means of the OpenDRIVE Manager mentioned above. After reading, most of the OpenDRIVE data are converted to internal data structures.



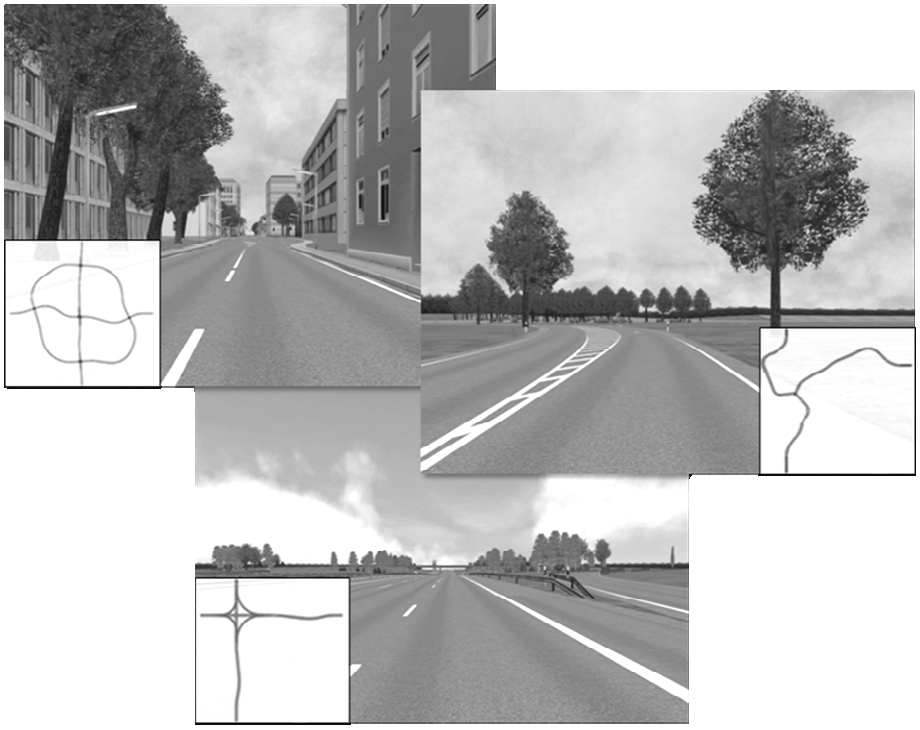
A similar structure of simulation software is used at the Daimler Driving Simulator, however all simulation modules using OpenDRIVE are running on the same simulation server.

The Exchange in Detail

In detail the exchange of the database tiles between both companies proceeded like this:

1) Each company identified tiles that were available for the exchange.
2) These tiles were presented to the exchange partner.
3) Beside road design additional features like bus stops or zebra crossings were taken into account.
4) Each company selected those tiles of the exchange partner which were of most interest and listed them.
5) The out-coming lists were compared and an equivalent amount of tiles was identified on both sides.
6) The actual exchange of these tiles took place.
7) Site-specific modifications were done by each company to receive compatible database tiles without any loss of functionality.

In the figure below a general overview of the exchanged database parts is given. Some snapshots are shown with small insets illustrating the basic road design of the respective tile. Country road, motorway as well as city road tiles were exchanged. Among many others, special constructions like road crossings, highway exit and on-ramp, bus stops, speed bump, park lanes and zebra crossings were part of these tiles.



Limitations and Conclusions

Concluding from the process described here, the database exchange really took place based on the strength of OpenDRIVE as a de facto standard open format.

One additional thing that has to be noted is that both companies use identical software for creating the databases, i.e. the OpenFlight and OpenDRIVE data. However, for the use case “exchange of road networks”, this does not imply any restrictions since the idea behind OpenDRIVE is to exchange the data based on the results of database generation tools.

During the database exchange the parties came to an important conclusion that has to be addressed: The OpenDRIVE format technically provides all necessary information for the road networks but this information may sometimes be provided in different ways.

In the actual case described here, one point was that traffic lights and signals in junctions may be positioned at various locations (e.g. on tracks leading to a junction or on connecting tracks within junctions). Both ways of positioning these

elements are correct in terms of the OpenDRIVE format but may lead to different interpretation within the respective traffic modules.

Furthermore there is a difference in the usage of OpenDRIVE controllers to group traffic lights. In the software of BMW Group Research and Technology any controllers are ignored because traffic lights are controlled separately via their ID.

From the point of view of BMW Group Research and Technology the exchange of database tiles with Daimler Driving Simulators was very beneficial because of the following reasons:

1) Database repositories of both BMW Group Research and Technology and Daimler Driving Simulators were extended by complementary tiles of the other company.
2) Namable costs only emerged from the site-specific adaption of the tiles.
3) The exchange was a technically uncomplicated procedure.

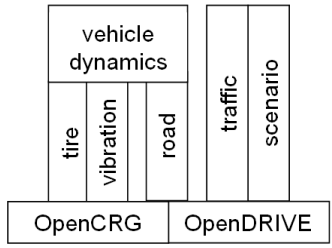
Lessons Learned

There are two key lessons learned from the database exchange performed by BMW Group Research and Technology and Daimler Driving Simulators regarding OpenDRIVE:

1) OpenDRIVE enables users of substantially different simulation software to exchange road networks without major effort.
2) OpenDRIVE requires a “style guide” which complements the current technical format description and supports the design of road networks with maximum compatibility.

Having successfully proven the feasibility of exchanging mere road networks, the next challenge will be finding a way for the exchange of complete scenarios. This, however, implies considerably more complexity than the current task.

From Logics to the Surface: OpenDRIVE and OpenCRG



OpenDRIVE has meanwhile been complemented by another open project, called “OpenCRG” [6]. Where OpenDRIVE concentrates on the macroscopic description of road networks in terms of logics, OpenCRG concentrates on the microscopic description of (selected) road surfaces e.g. for tire and vibration

simulation. The current OpenDRIVE format provides a means to refer to OpenCRG data from within a road network description, so that users may drive on an OpenDRIVE network and use OpenCRG surface descriptions at the same time.

The coherence between OpenDRIVE and OpenCRG data can be guaranteed in two ways: either by providing data along identical reference lines (so-called *genuine* mode, see [2]) or by mapping OpenCRG data along the OpenDRIVE reference line (*attached* mode). The typical use case will be the *attached* mode, for two reasons: first, it would require great effort to match OpenCRG and OpenDRIVE reference lines in *genuine* mode unless they were extracted from the same data source; second, OpenCRG surface data will typically be used for "enhancing" all or parts of OpenDRIVE roads with detailed surface information (e.g. rough road, potholes) not for replacing them.

This leads to a re-use of OpenCRG data sets (or patches) on various sections of a road network and also requires far less physical memory than would otherwise be required for an entire OpenCRG network (example: 10km of an OpenCRG cross-country road with 1cm resolution would require about 4GB of memory, compared with 400kB for a typical OpenDRIVE road of same length but without detailed surface information).

The OpenCRG project is similar in its structure to OpenDRIVE. It provides an open format, is maintained by a team of simulation professionals and involves actual users to a great extent. Beyond the current level of OpenDRIVE, OpenCRG is a full open source project, so that the users are provided with the data format, complemented by the tools necessary to create, modify, manage and evaluate the data.

2010 and Beyond: The Future of OpenDRIVE

User Base

Only a diversified, heterogeneous user base will justify calling OpenDRIVE a de-facto standard. Therefore, efforts are made to further promote the initiative either directly at potential users or via conferences, exhibitions etc. Having established a quite respectable user base since starting from scratch four years ago, the task is now to build on this solid foundation and further “spread the word”.

Removing Barriers

Getting involved with OpenDRIVE currently requires a detailed understanding of the format specification and writing some software for the actual data import and/or export. Commercial tools are available (e.g. by VIRES) but emphasizing the term “open” in OpenDRIVE will be one of the goals of the near future.

This goal shall be achieved by adding more examples to the ones already available via the OpenDRIVE website, complemented by a “style guide” and by providing some pieces of free and – at least partially – open source software.

The Way to a Formal Standardization

Good ideas spread. So, it's no wonder that as recently as 2009 other initiatives came up to seek what OpenDRIVE had already achieved. For OpenDRIVE– if it wants to stick to its initial aim of providing a common base for the exchange of road networks and if it wants to keep the leading role – this means that the dialog with new initiatives is mandatory.

If multiple initiatives exist for the same subject, it might well make sense to think about bringing them together in order to go all the way to a formal standardization on e.g. European level. This would give the users the certainty of a "real" standard and would also help reaching more users who might today still be (over-) cautious when it comes to making a decision for a road network data format.

With these thoughts in mind, the last OpenDRIVE user group meeting decided to take a closer look at another road data format proposed by a single supplier and to investigate possibilities of further co-operation in terms of formal standardization.

Whatever the outcome of the investigation, which is due to take place until mid 2010 (i.e. after committing the final version of this paper) and which will include an in-depth comparison of technical details of both formats, the following statements of the OpenDRIVE initiative will remain valid:

1. **OpenDRIVE is strong**: its user base is large and growing; OpenDRIVE is supported by the key players in driving simulation; it does not depend on a single supplier; it has been implemented independently by various users.
2. **The users come first**: any decision for the future direction of OpenDRIVE and/or a formal standard must be based on a thorough assessment of the impact on current users; only the solution with minimum overall impact will be acceptable.
3. **Building on OpenDRIVE today is not at risk**: if there was a tbd. format in future, the OpenDRIVE initiative would make sure that migrating from OpenDRIVE to this format would be strongly supported by free software packages.
4. **OpenDRIVE will not** accept any standard of less quality and usability than what is available today.

Beside these arguments, a formal standardization is a long-term process and the OpenDRIVE initiative will remain in place and proceed with no less effort than in the past for the foreseeable future. So, for the distant future, expect either a formal standard with strong involvement of OpenDRIVE, or…OpenDRIVE!

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