# Pro-SiVIC and Roads, a software suite for sensors simulation and virtual prototyping of adas

**Nicolas Hiblot [1], Dominic Gruyer [2], Jean-Sébastien Barreiro [1], Bertrand Monnier [1]**
[1] CIVITEC
25 allée des Marronniers F-78000 Versailles – France
[2] LIVIC (INRETS/LCPC)
14 route de la minière F-78000 Versailles – France
nicolas.hiblot@civitec.net, gruyer@inrets.fr, jsb@civitec.com, bertrand.monnier@civitec.net

***Abstract –*** *The LIVIC – a research department from INRETS and LCPC – focuses on the development and the evaluation of driving assistance systems. Several years ago, for the needs of its research activity, LIVIC launched the development of a software architecture SiVIC™, which made possible simulation of multi-frequency sensors responses embedded on static or dynamic devices, equipments and vehicles commonly used in ADAS. Raw data from perception systems are then replaced by accurate synthesised data whenever the scenarios for creating these data are too complex, too dangerous to realize or simply because data did not exist. CIVITEC has been created in October 2008 as a spin-out of INRETS and LCPC to focus on industrialisation, development and distribution of Pro-SiVIC – commercial and professional version of SiVIC™ – to the research community and industry. To further streamline the virtual prototyping process, several enhancements have been added including road networks modelling. The ROADS software is owned and developed by LIVIC and based on OpenDRIVE® specifications, an open file format for the logical description of road networks. LIVIC and CIVITEC are currently extending their collaboration in order to add ROADS into the CIVITEC software portfolio.*

***Résumé -*** *L'un des thèmes de recherche du LIVIC - laboratoire de recherche commun à l'INRETS et au LCPC - est le développement et l'évaluation des systèmes d'aide à la conduite. Il y a plusieurs années, pour les besoins de son activité de recherche, le LIVIC a lancé le développement du logiciel SiVIC™, qui rend possible la simulation de réponses de capteurs multifréquences intégrés à des appareils statiques ou dynamiques, équipements et véhicules couramment utilisés dans les ADAS. Les données brutes provenant des systèmes de perception sont ensuite remplacées par des données simulées avec précision quand les scénarios sont trop complexes, trop dangereux à réaliser ou tout* *simplement parce que les données n'existent pas. CIVITEC a été créé en octobre 2008 en tant que jeune-pousse de l'INRETS et du LCPC dans le but d'industrialiser, de développer et de distribuer Pro-SiVIC – version commerciale et professionnelle de SiVIC™ – à la communauté de la recherche et l'industrie. Afin de rationaliser davantage le processus de prototypage virtuel, plusieurs améliorations ont été ajoutées, y compris la gestion des réseaux routiers. Le logiciel ROADS appartient et est développé par le LIVIC. Il est basé sur les spécifications du format OpenDRIVE®, un format de fichier libre permettant la description logique des réseaux routiers. Le LIVIC et CIVITEC sont en train d'élargir leur collaboration en vue d'ajouter ce logiciel dans la gamme de logiciels CIVITEC.*

# Introduction

This paper aims at giving an insight on key challenges related to the development of driver assistance systems and how virtual prototyping with physical simulation of sensors, vehicles, and environments can help in this task. A specific highlight will be made on the emergence of an Open Source offering which addresses graphic and rendering techniques and authoring tools that help to reduce the time for the preparation of road networks and environments.

A quick glance shows that the current offering is essentially divided in two worlds. On one hand, the Driving Simulators that focus primarily on realistic models of vehicles to help the driver to feel the vehicle's behaviour in addition to understanding driver’s behaviour in particular situations. The majority of the driving simulators like Racer, Autosim, SIM2, Archisim, Vires, SCANeR ... shows some complexity related to their setup, lack of advanced graphic capabilities and are somehow monolithic which make them not suitable for supporting sensors modelling needed for the development, evaluation and validation of Advanced Driving Assistance Systems (ADAS).

On the other hand, Vehicle Simulation software providers such as CarMaker, CarSim, Tesis Dynaware, German truck simulator... carry their effort on vehicle architecture and on accurate vehicle functional performance analysis but generally with standard graphic rendering of the road itself and its surrounding and perfect sensors modelling (no physical models). All these tools require accurate roads and environments descriptions; OKTAL with RoadXML© or Vires with OpenDrive® are initiatives to describe properly road networks and allow data exchange between the communities of simulation software solutions and their users. Finally, advanced modelling of perception sensors is an emerging but promising market where companies like TNO with PreScan or CarSim are trying to position themselves.

However, in order to achieve a realistic sensor simulation, we know that a physical modelling of the environment, of the sensors and of the situations are necessary in order to obtain a behaviour close to the real world; it further allows to reproduce false alarms, and to study the reliability of perception systems.

 

**ROADS** and **Pro-SiVIC** are software components that help the achievements of virtual prototyping of ADAS, by combining tools to build easily road networks and environments based on OpenDrive® format, and advanced simulation software solutions for the modelling of multi-frequency sensors and vehicle dynamic to feed detection and control/command algorithms early in the development process.

# ROADS – software dedicated to the creation of road networks

Due to the persistent need of an editing tool enabling the creation of roads geometry and topology the LIVIC (a research laboratory for advanced driving assistance systems) decided to develop, two years ago, a new and efficient software dedicated to the creation of road networks: **ROADS**.

A quick glance at the software offering on the market shows that most of the software packages lack of flexibility and suffer of using complexity concerning roads intersection management, roads convergence/separation, road networks sketching...

Moreover, the need of advanced software architecture suitable to easily extend software capabilities is essential. The stability and upgradeability capabilities of such applications are also a guarantee of success. **ROADS** offers these advantages and provides an efficient way to model a road network with the use of specifications accepted by industries and researchers including easy support of Windows and Linux platform.

In fact **ROADS** includes overall specifications from the open file format OpenDRIVE®.

Therefore, **ROADS** helps to dramatically reduce execution time for the creation of simple to complex road networks with an easy-to-use and efficient environment. Figure 1, below, shows the typical incorporation of an OpenDRIVE® file into a simulation application:

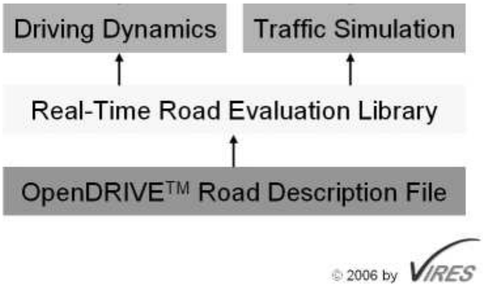


**Figure 1. Typical incorporation of an OpenDRIVE® file into a simulation application**

Additional information can be founded on the OpenDRIVE® project at the following address: www.opendrive.org. OpenDRIVE® is powered by VIRES Simulationstechnologie GmbH, Rosenheim, Germany.

**ROADS** (Figure 4) creates roads geometry and topology by a combination of straights and curves segments, various intersections shapes and lanes separations, convergences and connections capabilities between these elements. The mathematical formulation for enabling the connections is a combination of straight, arc and clothoïd profiles.

Several methods are proposed to build a road network:

- Freehand sketch
- Along a path (defined by a set of points)
- Road connection
- Road extension.

**Figure 2. Road portion shape design with ROADS**

Additional functions help to ease the construction of the road network such as copy, paste, delete and the capability to add a background image.

By combining the methods and the functions available in **ROADS**, it becomes easy and efficient to build a road network and all its complexity (one way, multi-lanes, cross-roads, junctions …).

Some original functions are outlined herewith like the freehand sketch, inspired by the work of McCrae, J. and Singh, K. (1). The main idea is to use, as a first step, the freehand drawing in terms of curvature only and to apply the combination of a rotation with a translation to comply, the most faithful way, with the drawn path.

As well as for the road along a path, the work of Hun Shin, Dong and Singh, Sanjiv (2) was used as a foundation combined with a search algorithm of minimum Golden Section.

 

So far, we have flat roads geometry and topology, **ROADS** allows the edition of OpenDRIVE® data to define i.e. the appropriate road transverse profile along the road path. Others information such as terrains can be also added.

The road network and its environment data are then exported straightforward as objects suitable to be use in software simulation tools such as **Pro-SiVIC**.

**ROADS** uses currently standard 3D modelling format such as Wavefront OBJ files and OpenDRIVE® v1.2 data model so it can be used with many driving simulators (Figure 3).

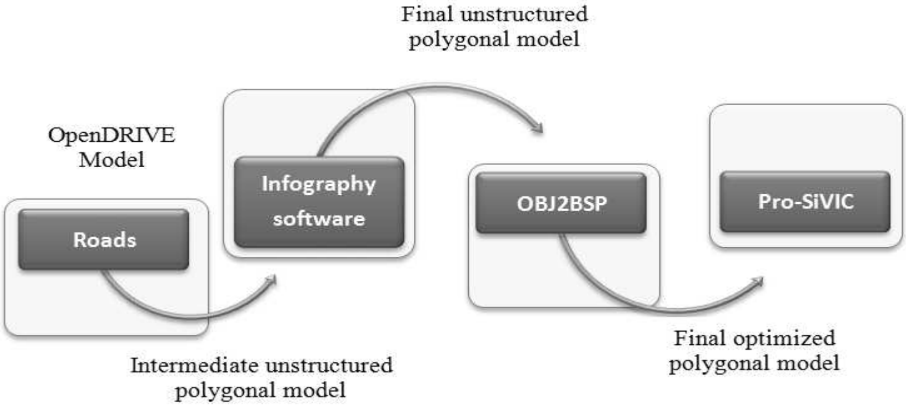


**Figure 3. Integration process of roads environmental data in Pro-SiVIC**

The major benefits of **ROADS** lie in its ease of use and its ability to quickly and intuitively get a road network; it allows drawing arbitrary road networks without the need of predefined tiles, neither library of predefined configuration.

**ROADS** will be further extended with several new enhancements and thanks to the collaboration with the LIVIC valued by CIVITEC throughout its software portfolio. Due to its flexibility and capabilities, **ROADS** will be able to be extended to manage scenarios and to support the setup of traffic modelling functionalities.

# Pro-SiVIC: modelling software dedicated to sensors simulation

Many driver assistance systems are studied to improve the safety of road environments. An ego vehicle perception and the corresponding reaction of the vehicle, as braking or accelerating, are generally taken into account. However, an ego perception is not enough in many cases. Risk has to be as low as possible and driving security must be increased by adding information. The resources needed are however time-consuming and expensive. It therefore becomes essential to have a simulation environment (3), (4) allowing prototyping and evaluating extended, enriched and cooperative driving assistance systems in the early stage of the system design. To build a virtual simulation platform, models of road environments, virtual embedded sensors (proprioceptive, exterioceptive), sensors on the infrastructure and communicating devices, have to be pooled according to the laws of physics (5). A vehicle dynamic modelling (physic-based), combined with actuators (steering wheel angle, torques on each wheel) will allow a realistic vehicle's behaviour.

This is the area where **Pro-SiVIC** acts (4) and meets all these criteria and allows the development and the prototyping of a high level autonomous driving system with cooperative and extended environment perception.

**Pro-SiVIC** is a combination of a dedicated, Open Source, graphic engine and a sensors simulation engine.

# A new 3D Graphic Engine

Position a new 3D graphic engine in a landscape where plenty of Open Source and COTS software exist is indeed challenging. Moreover, virtual reality, games and serious games are a fast growing market where technologies evolved every day.

Nevertheless, for the needs and objectives of the **Pro-SiVIC** simulation software's platform, which target the modelling and simulation of perception sensors, the pre-requisites are at least the following:

- 3D graphic engine, cross platform, programmed in C++
- Dynamic management of user classes as plugins loaded at run-time
- Scripting language with online console, which make easy testing new components
- OpenGL-based graphic rendering for high performance with state-of-the-art video cards
- Ability to run also on low-end machines with a 3D graphics accelerator card
- High-level 3D rendering capabilities
- Support of material data, advanced multi-texturing including HDR, transparency
- Advanced objects shadows
- Ray tracing capabilities for simulation of collision, vehicle/terrain interaction, ...
- Weather conditions: rain, snow, fog

Among others capabilities, the objects animation used an interpolation mechanism, the reflections management used planar reflection and cube maps reflexion.

Given the capabilities and performances of this 3D graphics engine, we think that the field of applications could go beyond the scientific modelling of perception sensors.

Mobile robotic, games and serious games, visual simulations are areas that could benefit of the present 3D graphic engine. In this view, it will be made available as an Open Source project to further extend and accelerate the capabilities. CIVITEC is looking forward to build a core team of industries, research centres, and academics willing to support this initiative.

 

## Tuning the 3D Graphic Engine for Sensors Modelling and Simulation

To find a way to overcome the constraints related to the modelling of varied perception sensors, specific mechanisms of adapted rendering has been added to the above 3D graphic engine. These mechanisms allow the definition of a "multi-rendering" approach, which suit perfectly to the simulation of sensors. Several rendering's plugins provide scalable rendering capabilities depending on the requirements for the simulation. For instance a simulation can be used together with a basic graphical rendering of an optical sensor, or RADAR rendering, or a GPS rendering, or switched to a more realistic optical sensor with HDR (High Dynamic Range) textures, shadows, Filters and Tone Mapper.

Among the two current rendering models, one provides a classical 3D graphical engine rendering and the second one gives a better shadows (direct, ambient, occlude, pre processing) and lights management.

Additional enhancements have been provided such as the level of details for a virtual scene (dynamic customization), a set of post processing filters (glow, blur, auto exposition) and the layers management (level of visibility).

## Dynamic Plugins for Road Scenario

**Pro-SiVIC** uses the above simulation engine for the graphical and physical rendering stages. Nowadays, plugins architectures are a must as they offer the flexibility for evolution and scalability including interaction with 3$^{rd}$ party applications. Several external modules are taking care of the simulation of all the actors of a road situation.

These modules are naturally included as dynamical elements. A communication protocol allows an access to all the parameters of the sensors and vehicles models. The mechanism used for this communications protocol is thus made adjustable and is distributed on all the **Pro-SiVIC** modules.

### Modelling the Sensors

A set of proprioceptive and exterioceptive sensors are modelled inside **Pro-SiVIC**.

The modelling capabilities enable up-front virtual prototyping of sensors immersed in a dynamic environment taking into account their behaviours as measurements instrument which produce realistic raw data. In addition, enhanced sensors models help to the identification of sensors qualification and validation by the simulation. Currently, the following sensors modules are available:

- A camera module which simulates a set of several cameras. This one is configurable either by using the traditional parameters of a camera (size of matrix, focal distance...) or by using the parameters related to the OpenGL field of view (fovy, Znear, Zfar and aspect ratio),
- An Inertial Navigation System module which simulates an inertial navigation sensor (3-axis accelerometers and 3 axis gyrometers),

- An IR LED transmitter module which emulates, at this moment, a very simple behaviour of an IR transmitter in the eye sight field. Then some filters allow converting the image obtained from the rendering stage in order to match a more realistic IR camera result,
- An odometer module which simulates the optical coder type providing the distance covered (curvilinear X-coordinate) by a vehicle,
- A laser range finder which simulates the behaviour of a laser scanner. Two methods were implemented to carry out this particular simulation. One uses the ray tracing method; unfortunately this one requires a lot of machine resources. The second one, simpler and thus faster, uses the matrix of depth (Z-Buffer) to emulate the distances of the impacts for each beam of the laser scanner.
- A beacon which models a transponder type of sensor. Two sets compose this sensor. The data frames to be sent with the range of the communication are first taken into account by the transmitter. Then, the receiver is attached and embedded into a vehicle. Several transmitters with their own setups and several receivers can be defined and used simultaneously,
- A set of observers provides accurate and reliable references of objects. Four types of reference's sensors have been developed: a car observer, a pedestrian observer, an object observer and finally a road observer which provides road reference information at the vehicle location.

As described above the simulation engine provides the rendering functionalities which are used by the camera model. We will describe here more in details the advanced capabilities for vision sensor modelling, which is among others sensors the most widely used. The mechanism of filters addition is a powerful and efficient capability for a realistic modelling of vision sensors' physic. Indeed, several existing filters can be added during the simulation process to tune the picture rendering in order to produce a realistic image as close as possible to the image produced by a real camera.

The current implementation reproduces the optical system up to the illumination received in the sensor plane as described in the Figure 4 below. Further developments are on going to model the sensor chip behaviour itself in order to reproduce a faithful realism notably for the image capture, integration time and A/D conversion...

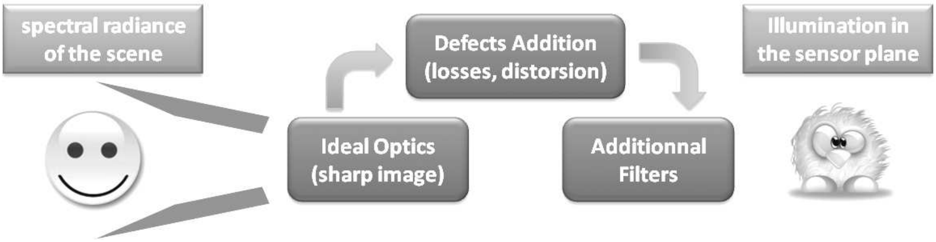


**Figure 4. Vision sensors modelling process**

 

The noise, the optical distortion, the depth of field, the glow, the fog, the rain drops, the rain fall, the auto exposure and the auto focus showed below in Figure 5 are some of the filters already available (6).


**Figure 5. Multi-rendering and filters mechanism:**
**a) Noise, b) Depth of field, c) Color, d) Rain drop, e) Auto exposure, f) Fog**

## Modelling four wheels vehicle

Using simulation to reproduce realistic measurement's instruments such as a vision sensor implies to take into account the dynamic behaviour of the body where this sensor is attached. Thanks again to the **Pro-SiVIC** plugin architecture;

it becomes possible to couple the sensor to a moving object. This object can be any object as long as its behaviour is described by mathematical equations in order to represent its motion and dynamic. In the case of a four wheels vehicle, the motion of its bodywork on the three axes (roll, pitch and head) is reproduced to provide realistic data for the embedded virtual sensors. Some effects, like the shock absorbers (pumping), have to be taken into account by these movements.

The vehicle model is based on works done by S. Glaser (7) and includes shock absorbers, non linear tire road forces (8), (9). A coupling between longitudinal/lateral axes, the impact of the normal force variations and the moment of the car alignment can also be simulated as described in Figure 6.

A lumped mass at the CG is used to model the weight of the vehicle bodywork. Improvements of this model is possible by adding others components such as a steering column, a differential, etc. It can be replaced also by others vehicle dynamic models thru API defining inputs/outputs allowing an interface with i.e. 3rd party software dedicated to car dynamic modelling or C++ coding

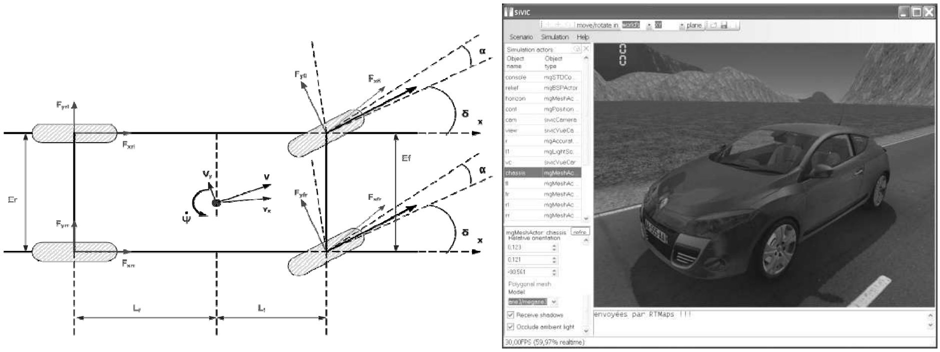

**Figure 6. Vehicle modelling**

Closing the loop is one of the key challenges when developing an ADAS function, therefore the vehicle model needs to be controlled to enable the complete virtual prototyping such as the one for i.e. obstacle avoidance.

Apart from the vehicle vector states output, the vehicle dynamic model is controlled thanks to actuators input to reproduce precisely the manoeuvres. To achieve these manoeuvres an input torque order independent to each of the wheel allows front wheels drive, rear wheels drive and four wheels drive and is suitable for electrical engine as well. The input for the vehicle orientation is achieved therefore by applying a rotation on the steering wheel. The wheel can be also independently controlled if necessary.

Finally, in order to manage a basic traffic situation, several setups are available to control vehicles' trajectories. With haptic inputs (steering wheel, keyboards, joystick), the vehicle can be controlled by a human driver. Others setups allow basic traffic modelling (vehicle following a trajectory); an extension of the previous one enables to have lateral and longitudinal controllers but also to control the vehicles by orders coming from 3rd party applications.

 

# Conclusion & future works

The first research release of **ROADS** has been launched in April 2010 and the LIVIC is continuing its effort of development to further increase capabilities. **ROADS** offers an efficient tools to build road networks of different levels of complexity. The compliance of **ROADS** to the OpenDRIVE® format combined with its intuitive interface is very attractive but additional developments are needed to further increase capabilities. Among others, the additions of road signs, sidewalks, advanced road marking, buildings, terrains, contents management. Moreover, a new plugin will be added in **ROADS** in order to use road network modelling in support of traffic generation. The traffic outcomes could be use in the **Pro-SiVIC** platform in order to reproduce either urban, peri-urban or motorway conditions. CIVITEC will soon take the distribution of **ROADS** and make it a commercial off-the-shelf (COTS) solution.

Through the Open Source diffusion, the 3D graphic engine of **Pro-SiVIC** should benefit of a larger community and usages. Improvements on render quality with bump mapping techniques or hardware optimisation (Graphics Processing Unit) are indeed some areas of improvements.

**Pro-SiVIC** is currently sold by CIVITEC as a COTS and it offers a large set of functionalities making it possible to model and test various advanced sensors. It can reproduce, in the most faithful way, the reality of a situation, the behaviour of a vehicle and the behaviour of the sensors which can be embedded inside a vehicle.

Concerning the realistic rendering of the scene, we currently use a camera based on the view generated by the OpenGL graphic functions with realistic optical effects. For instance, the current vision sensor model takes into account the optics distortions, the integration time, and noise effects. A weather module (rain, snow...) with effects on the light reflection is also integrated and usable.

Actually, **Pro-SiVIC** allows also to test and to evaluate the perception and control algorithms associated with the perception sensors and this functionality is one of the important advantages of this platform. By changing parameters of the environment (weather, light, traffic, road …), of the sensors (focal, resolution, distortion, blur …) it is possible to assess upfront in the design process the robustness of the perception function and the ADAS performances.

**Pro-SiVIC** has been successfully used these years in research projects (ARCOS, LOVe, Safespot and is currently part of the reference platforms for the projects Have-It, Isi-PADAS and E-MOTIVE. The later will help to increase **Pro-SiVIC** capabilities in scenario building and management, traffic computation, sensors and ADAS prototyping, test and evaluation as well as multiplatform's improvement on sensors models, easiness-of-use (GUI), extension in computational capabilities (multiprocessor architectures, GPU).

Keywords: Physic-based Sensors Modelling, ADAS Virtual Prototyping, Perception Sensors Simulation, Vehicle Dynamic Modelling, Road Networks Modelling, Physic-based Immersive Virtual Environment, Real-time 3D Graphic Engine, Environment Rendering & Modelling

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