New 3D immersive platform dedicated to prototyping, test, evaluation and acceptability of eco-driving applications

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Abstract: Simulation has been widely used to estimate the benefits of ADAS with embedded sensors or more recent Cooperative Systems based on Inter-Vehicular Communications. This paper presents the proposal of a new architecture built with the both SiVIC and RTMaps platforms in order to prototype, to test and to validate eco-driving applications. In this architecture, the innovation is mainly due to the real-time immersion of a real driver in a 3D virtual environment. In this “Hardware In the Loop” platform, major contributions have been made on dynamic and complex vehicle modelling including several types of engines, interconnection between SiVIC and an Helmet Mounted Display (HMD), integration of HUD (Speed counter and consumption gauges). Moreover, a modelling of a consumption sensor is proposed and implemented in order to carry out some fuel consumption tests on the virtual Satory’s track. All these contributions have been tuned with on-road measurements to improve reality of the scenarios. We will discuss the results of a simple eco-driving scenario implemented to validate our architecture’s capabilities.

Keywords: virtual platform, eco-driving application, 3D immersion, consumption modelling.

1. Introduction

To address the problem of road safety and risk reduction, many studies have been conducted since over 10 years and many laboratories work on developing and evaluating dedicated advanced driving assistance systems (ADAS). These assistance systems are divided into several groups of applications: informative applications and active applications. These applications are done with standalone sensors, embedded systems, and actuators into a vehicle. For active safety applications, the building of local dynamic map and/or extended perception is needed. The data coming from the perception algorithm are used together with the data coming from either the proprioceptive sensors or observers to compute orders to control the vehicle dynamics through the actuators.

Several years ago, the development of a simulation software architecture (SiVIC: Simulator of Vehicle, Infrastructure and sensors), has been launched for supporting these research activities on ADAS prototyping. This software enables the simulation of multi-frequencies sensors embedded in static or dynamic devices, equipments and vehicles commonly used in ADAS. In this context, raw data from perception systems or actuators systems are substituted by realistic synthesized data or devices. This functionality is useful in case of scenarios built with hazardous physical environment, complex situations, and lack of data or failures (sensors and actuators). Moreover, the developed applications could be, at every time, tested and evaluated with an accurate and reliable ground truth. As first, the SiVIC platform was built with the objective to prototype local perception applications. Recently, extensions of this sensor simulation platform have been done in order to allow the virtual prototyping of new hardware in the loop and software in the loop applications.

In parallel, Research interest in Eco-driving is growing due to its potential to reduce fuel consumption and particles emission (Nox, CO2). A wide range of eco-driving strategies have been proposed by traffic psychologists, engineers and traffic simulation researchers. Despite its popularity, there is poor and inconsistent research evidence regarding the effects of different type of eco-driving instructions on fuel consumption. Eco-driving instructions are very context sensitive and have different performance in different situations. Rakotonirainy et al [1] demonstrated that standard instructions do not provide the expected 20% fuel consumption reduction on an automatic car in an urban environment. As far as we know, there is no evidence showing the effectiveness of a particular driving instruction against another. Most of the methods that have been used to assess the benefits of eco-driving instructions lack scientific rigor about the true benefit of a particular instruction.

This paper proposes to use, to adapt and to improve SiVIC platform so as to provide a first generic architecture in order to develop, to study and to test such eco-driving strategies and applications. In order to develop and to prototype these applications, an interconnection of SiVIC is done with the RTMaps platform. In this global architecture, the innovation is mainly due to the real-time immersion of a real driver in a 3D virtual environment. In this hardware in the loop platform, major contributions have been made about vehicle modeling updating, interconnection
between SiVIC and an HMD (Helmet Mounted Display). Moreover, a first modeling of a consumption sensor is proposed and used in order to achieve some tests of fuel consumption on the virtual Satory’s track. All these contributions have been tuned with on-road measurements to improve reality of the scenarios. The selected first representative application is focused on the optimization of the covered distance by a driver with a limited amount of fuel. This scenario is done with a real car and a real driver immersed in a 3D virtual modeling of the real Satory’s track. The results obtained from this simple eco-driving scenario have allowed to validate our architecture’s capabilities.

In the remainder of this paper, the sensor and vehicle simulation platform will be presented in section 2: successively SiVIC, RTMaps and finally the interconnection between these two platforms to obtain our desired eco-driving prototyping environment. Section 3 will be devoted to the presentation of the new car consumption sensor implemented in SiVIC. Section 4 presents the immersive and distributed architecture. In this section, the interconnection between SiVIC and the HMD will be tackle. The last section will present the eco-driving application, estimation and control algorithms, as well as path planning applications. Finally, we will conclude and present some perspectives in section 6.

2. SiVIC Platform for sensors, vehicle and environment simulation

2.1 The SiVIC Platform

For more than one decade, it clearly appears that local perception was necessary but not sufficient. Its extension is become essential to minimise risks and maximise driving safety. To achieve such improvement in driver assistance, it is essential to deploy new technical means, not only on vehicles but also on infrastructure. Unfortunately, this kind of deployment is often long, difficult and expensive.

That’s why it appears inevitable, in the first step of driving assistance conception, to use simulation platforms. They allow to model unsafe driving situations and embedded technical means in vehicles (sensors, telecommunications, and displays). The aim of this kind of platform is mainly to provide needed virtual means required to prototype and evaluate new driving assistance applications (local perception, distant perception, vehicle control, inter-vehicle communication, and vehicle-infrastructure communication).

SiVIC platform [3][4] was designed to enhance the process of developing and evaluating ADAS. This platform enables the simulation of multi-frequencies sensors embedded in static or dynamic devices, equipments and vehicles commonly used in ADAS scenarios. The SiVIC platform is a very efficient tool to develop, prototype and evaluate high level ADAS, including distributed applications. SiVIC can be easily interconnected with several external platforms such as RTMaps™ (see next sections of this part) or Matlab (from Mathwork). This interconnection interface is efficient and useful to perform a great number of developments in both SIL and HIL approaches. Once the application is evaluated in virtual condition and validated in simulation, it can be integrated and tested into real embedded hardware architecture (on vehicle) further towards the end of the development cycle.

Figure 1: SiVIC platform: modelling and simulation of embedded sensors.

SiVIC uses a realistic graphical environment, supported by physically accurate behaviors for vehicles and sensors (see figure 1). It can generate a flow of time-stamped and synchronized data that can be recorded and/or interacted with prototyping and/or data processing platforms such as RTMaps or Matlab (see figure 2).

Figure 2: SiVIC, a virtual platform for ADAS prototyping, test and validation.

Furthermore, SiVIC can generate multiple scenarios with events-driven mechanisms, so that the robustness and reliability of control and perception algorithms can be extensively tested on many parameters. This functionality is useful for scenarios...
featuring hazardous environments, complex situations, or missing or erroneous data (from sensors or actuators). Moreover, data analysis can always be performed with accurate ground truth references. Proprioceptive and exteroceptive sensors are modeled in SiVIC, so that, from the point of view of an algorithm, there is no difference between a fully SIL sensor and an on-vehicle sensor. Currently, available sensors in SiVIC are:

- System's variables (called observers) that provide output reference data on an object's position and behavior
- Cameras (configurable either as software or hardware cameras)
- Fisheye and omnidirectional cameras
- Inertial Navigation Systems (3 axes accelerometer + 3 axes gyro meter)
- Odometer
- Telemetric laser scanner (multi-layered, capable of using either ray-tracing or Z-Buffer methods)
- Radiofrequency transponders.
- Realistic Global Positioning System
- Telecommunication mean for transportation
- RADAR with several propagation channels and antennas modeling.

In order to improve and to complete the sensors simulation engine, some plug-ins (filters) have been developed. Two types of filters are provided. The first one is dedicated to the improvement of the environment quality rendering. The second one is focused on the camera modeling.

About the first set of filters, the most important are dedicated to the simulation of the weather conditions (see figure 3). Among these climate filters, the fog and the rain filters (waterfall and raindrops) are the most useful. This weather filters are presented in [5].

2.2 Complex vehicle modeling

In order to provide realistic data for the embedded virtual sensors, it was imperative to reproduce the movement of the vehicle chassis on the three axes (roll, pitch and yaw). These movements must also take into account the effects of the shock absorbers (pumping). The vehicle model is based on works of S. Glaser [6] (see also e.g. [7]). The vehicle body has 6 degrees of freedom (3 in translation and 3 in rotation). Each wheel also has 3 degrees of freedom (vertical movement, wheel rotation and steering). The links between the wheel and the vehicle body includes shock absorbers. The tire road forces are described using non linear coupled forces [8], [9]. The used architecture allows to install in a simple way, a great number of onboard sensors. We will use the notations of the chassis dynamics illustrated in figure 4.
realistic models of actuators. The current actuators implemented in SiVIC are the motor or braking torques applied on each wheel and the steering wheel angle. It is then possible to simulate front wheel drive, rear wheel drive and four wheels drive. Moreover, in order to manage a basic traffic situation, several modes are available. The first one is the control of a vehicle by a human driver. The second mode is done for basic traffic modeling: the vehicle follows a given trajectory without vehicle dynamic consideration. The third mode also is a trajectory following mode, but following a desired trajectory is achieved by use of lateral and longitudinal controllers. In this third mode, the vehicle dynamic is taken into account. The last mode is dedicated to the control of vehicles by input coming from external applications (RTMaps, Matlab, ...). This last mode is the one used in the eco-driving platform proposed in this paper. A summary of these vehicle controls modes with the involved peripherals are shown in the figure 6.

2.3 Distributed solution for complex prototyping

Tree mechanisms have been also implemented in order to share information between SiVIC’s instances, or SiVIC and third party applications in mono or multiple computers solutions. The first mechanism is an optimized shared memory initially developed to carry out the interconnection of SiVIC and RTMaps.

A summary of these vehicle controls modes with the involved peripherals are shown in the figure 6.

Figure 6: The different control modes of a virtual vehicle in the SiVIC platform.

This first data exchange mechanism is dedicated to the management of data flows coming from sensors and orders for actuators. A second complementary solution (DDS: Distributed Data Storage) was proposed. It relies on a data distributed architecture in which SiVIC instances share state vector objects [10]. This mechanism manages the publication and subscription of raw data frames (byte arrays) of resources (object position and current state, events, sensor data, ground truth, weather conditions ...). A DDS data is identified by IP address or DNS alias of computer which publishes it and by a generic name for these data. The general architecture is presented in the following scheme (see figure 7). The red arrow indicates the publication of data on DDS, and the blue arrow represents the consumption of shared data.

Figure 7: Distributed architecture: DDS bus

A third mechanism (SensORB: Sensors Object Request Broker) has been developed in order to manage the raw data flow between several applications or computers without publication and subscription mechanism. This third approach can be seen as a virtual CAN bus.

A current work in progress has for main task to standardize and to merge these 3 data exchange modes in an only one generic communication bus. In the eco-driving platform, these 3 mechanisms are used for specific functions (Share memory for sensor data management, DDS for event management, SensORB for DualScreen management). All these information exchange mechanism are shown in the figure 8. In order to synchronize external application, a additional module allows to provide a time base coming from SiVIC’s time base.

2.3 Event management

In order to manage and to handle possible events coming from the result of algorithms, an event mechanism and event variables are also implemented. These events can be used both from SiVIC or from an external application like RTMaps, Matlab or third party applications. In this paper, two specific events will be used: the ddsless and the ddsgreater events. These two variables are used to reset the SiVIC scenario configuration and the initial configuration of the virtual reality HMD between two trials (see figure 8).
2.4 SiVIC-RTMaps Interconnect platforms

RTMaps™ is marketed by Intempora, based upon work undertaken at Mines ParisTech a decade ago [11]. Its primary goal is to record and to process a large number of simultaneous data flows coming from sensors (Cameras, laser scanner, RADAR, INS, GPS …). Moreover, algorithms, for image processing or data fusion for instance, can be prototyped in this framework. Recorded data can be easily replayed, which is especially useful to precisely tune algorithms with multiple re-runs of a same on-tracks measurement.

The SiVIC/RTMaps interconnection brings RTMaps the capability to replace real-life data by simulated data. Moreover this solution provides a solid framework for advanced prototyping and validation of the ADAS and PADAS applications. Indeed, this software couple provides an efficient and reliable solution for developing SIL applications including virtual vehicle prototypes with their own proprioceptive and exteroceptive sensors. This ADAS design architecture is very efficient because algorithms developed in RTMaps can then be directly transferred as micro-software on real hardware devices. Therefore the simulation model can be considered very close to the realistic models (real vehicles, real sensors).

2.5 Generation of data for 3D display

Currently, the SiVIC platform is mainly useful for sensor modeling and ADAS prototyping. In this specific application of the proposal of an eco-driving platform, 2 main technical tasks are necessary. The first one is to develop a car consumption sensor and the second one is to build a dedicated module for 3D immersion. The first task is presented in the next section. For the second task, we use an HMD to reproduce the human perception functionality. Effectively, when a human looks at an object in front of him, he naturally sees the volume because his eyes (spaced 64 mm on average) receive two almost similar points of view of the object. Then, the brain combines these two images into only one. The same point, located on the left image, moves slightly on the right image. This distance, called parallax, produces the sensation of stereoscopic depth. This phenomenon is reproduced by generating two images of the scene with a corresponding offset in order to reproduce the parallax (see figure 9). The two images are sent simultaneously in an only one image to the HMD which displays them on screens located in front of each eye.

Depending on the orientation of the driver’s head provided by an INS sensor integrated in the HMD, the simulator computes the position and the orientation of the view for each eye. In fact in order to enslave the both environment view to the centre of the camera base (like on the human head), a positionable object is used. The orientation and translation coming from the HMD control this positionable object. In this stereoscopic modeling, the frequency and the parallax can be adjusted in order to optimize the visual comfort and the rendering for the real driver.

A counters and gauges overlay mechanism was added to take into account the display of infinite indicators like the tank level, a speedometer, the curvilinear distance covered by the vehicle and fuel consumption.

3. Modeling of consumption sensor

The main challenge with a fuel consumption model dedicated to eco-driving simulations is that it has to be efficient (low time consumption and accurate enough). But it also has to be tunable enough to represent a wide set of vehicles. The basic hypothesis of this model is that the engine efficiency ratio is a polynomial function of the vehicle speed.

The theoretical consumed energy, $E_{\text{theo}}$, in a time step $dt$ can be evaluated by the following formulae:

$$
\text{d}E_{\text{theo}} = \left( \frac{1}{2} \rho \text{air} \cdot SC_x \cdot v_{\alpha}^2 + C_{rr} \cdot m \cdot g + m \cdot p \cdot g + m \cdot a_{\alpha} \right) v_{\alpha} \text{d}t
$$
where \( \rho_{\text{air}} \approx 1.2 \text{kg.m}^{-3} \) is the density of the air, \( S(\text{m}^2) \) is the end face, \( C_s \) is the longitudinal drag coefficient, \( C_r = 0.015 \) is the coefficient of rolling resistance, \( m \) (kg) is the vehicle mass, \( g = 9.81 \text{m.s}^{-2} \) is the standard gravity, \( p \) (%) is the road grade, \( a_{\alpha}(\text{m.s}^{-2}) \) is the vehicle acceleration and \( dt(s) \) the time step.

Then, an efficiency ratio has been applied to take into account the energy lost in the combustion process and transmission. This ratio has been built on real experiments from [12] where the fuel consumption has been measured at different speeds.

\[
\eta = \frac{E_{\text{theo}}}{E_{\text{meas}}} = 10^5 \times \frac{\frac{1}{2} \rho_{\text{air}} S C_s v_a^2 + C_r m g + m p g}{f(v_a) e_{\text{carb}} p_{\text{carb}}}
\]

where \( E_{\text{theo}} \) is the theoretical energy consumed if the vehicle was the one tested by Wang et al., and \( E_{\text{meas}} \) the measured energy consumed by the test vehicle

\[
f(v_a) = 0.00026 v_a^4 - 0.018 v_a^3 + 0.48 v_a^2 - 5.5 v_a + 25
\]

is a function identified on the works of Wang et al. giving the fuel consumption in liters per hundred kilometers versus the vehicle speed, \( e_{\text{carb}} = 42.5 \times 10^6 \text{J.kg}^{-1} \) is the energy density of fuel and \( p_{\text{carb}} = 0.84 \text{kg.L}^{-1} \) is the fuel density. The computed efficiency ratio can be seen on figure 10.

![Figure 10: The computed efficiency ratio](image)

**4. Immersive and distributed architecture**

4.1 Overall architecture

The developed architecture can be applied to any kind of distributed scenario. Scenarios are built in SIVIC by using script files which specify the location of objects and many other parameters. The actual eco-driving application needs to be developed and implemented in RTMaps.

![Figure 11: Data flows and relationships between the environment, sensors and algorithms in the eco-driving simulation architecture](image)

The figure 11 shows the data flow and relationships between the environment, sensors and algorithms software parts. The virtual vehicle is equipped with a ground truth sensor (car observer), a beacon receiver, a car consumption sensor and a tracker module. The dual screen sensor is attached to the tracker in order to control its position and orientation. In this architecture it is easy to add dynamic vehicles, dynamic pedestrians and obstacles in order to disturb the driver behavior.

The figure 12 shows the actual implementation of relationships and functionalities from figure 11 in the SIVIC/RTMaps/Third party environment. Vehicle is controlled from RTMaps, with the combination of the cooperative decision module (constraint which limit the speed when the vehicle is out of the road) and the control block. This application uses information coming from real actuators and decision module to provide adapted torques and steering wheel order to the SIVIC car actuators.

![Figure 12: Eco-driving simulation architecture’s detailed functions in SIVIC-RTMaps™](image)
4.2 Head Mounted Display

The simulated environment rendered by SiVIC and more specifically by the DualScreen sensor is displayed via a Sensics Z-sight HMD with two SXGA (image resolution 1280 x 1024 pixels) color displays (see figure 13 - left).

![Image of Sensics Z-sight head mounted display](image1)

Figure 13: Sensics Z-sight head mounted display and the vehicle prototype (SEMCA F16)

This HMD embeds an integrated tracking system based on an inertial sensor. The HMD control unit computes the helmet orientation, given as a quaternion. The quaternion is then converted into Euler’s angle (yaw, pitch, and roll). The helmet relative position is not provided by the tracking system, the relative position of the driver head in the car is also considered constant in the simulator. Due to the sensor bias, the provided orientation deviates (approximately 2 degrees/minute). In order to limit the head position deviation, the test scenario is limited to 5 minutes. A simple initialization procedure has been integrated in order to cancel the head pose deviation at the beginning of test scenario. The operator resets the head pose angle via a SiVIC DDS event, while the driver is asked to maintain his head straight forward.

4.3 Integration into real vehicle

To improve the immersion feeling, the simulator has been integrated into a real vehicle SECMA F16 (see figure 13 - right). The user is set in the driver position and he controls the simulated vehicle via the real car steering wheel. The steering wheel turn angle is measured via an optical angle sensor (BEI IDEACOD CHM 510-13BT-002) fixed on the upper shaft of the steering column. To facilitate the steering wheel rotation, the vehicle front wheels have been raised.

A supplementary brake and throttle foot pedal unit has been added in the vehicle. The pedals deflection rate and the steering wheel angle are transmitted to the simulator via a CAN interface.

5. Eco-driving application

To educate users about problems of eco-driving, a storyboard has been defined. The scene takes place on the Satory’s test track in Versailles - France. To obtain a high quality 3D immersion for the real drivers in the virtual environment, a realistic 3D reproduction of the real track was produced by LIVIC. The figure 14 shows the similarity of this simulation in comparison with the same perspective on the real track. In this figure, the first line provides virtual renderings and the second line gives the real pictures from the same point of view.

![Image of Sensics Z-sight head mounted display](image2)

Figure 14: Modeling and simulation of the Satory’s track in the SiVIC platform.

In this scenario, the vehicle tank is almost empty (only 0.15 liters of gasoline). The driver is asked to travel the greatest distance with this fuel amount. The ratio between the distance traveled by the driver and the maximum distance obtained in strict accordance with instructions (eco-driving rules: maintain a constant speed, limit acceleration and deceleration) provided its score. The max speed is constrained and limited to 16 m/s. Moreover if the driver tries to drive out of the road, a speed limitation mechanism is applied in order to limit the speed at 2.7 m/s (10 km/h). In this case, the maneuvers made in order to join the road area will increase significantly the fuel consumption and will degrade the final score.

The experimentation is done in 3 stages. The first step is made to discover the simulator as well as the instruments, indicators, and constraints associated with the experiment. In the figure 15, the full hardware and software platform is showed. The users can already try to limit their consumption in order to go further.

The second step consists in providing some advices to the current driver in order to think about his driving and for instance, to adapt its speed in a turn, to adjust its speed in straight road, or to limit the accelerations and the braking.

The third consists in redoing the first experiment but while taking into account the advices. An example of the result which can be obtained by a virtual driver is presented in the figures 16 and 17. In this result, the
driver has used a strong acceleration in order to reach quickly the desired speed.

Figure 15: Test in real condition in the french science festival, Cité des sciences, Paris.

This stage brings on a high but temporary consumption. Once this speed limit is reached and kept, the consumption stays almost constant. After 3400 meters, the fuel tank is empty and the speed goes down due to the resistive forces applied to the vehicle. The vehicle stops definitively after 3500 meters.

In real situation and from the real 300 people who participated to this small very playful experimentation, we can assess that the average distance covered by a driver with 0.15 liter of fuel is 3142 meters. The standard deviation is 385 meters.

Figure 16: Instantaneous and cumulative fuel consumption with a real driver in the French science festival, Paris.

A second application more theoretical is in progress in order to test the capabilities of SiVIC to self control virtual vehicle in order to compute different acceleration profiles (Normal acceleration, strong acceleration, low acceleration) and to derive a simple theoretical consumption model $C_{sim}$ using the Intelligent Driver Model (IDM) [13]. Moreover this new experimentation is really necessary to evaluate the impact of current vehicle characteristics on its consumption. For instance, what would be the impact of the tire grip level, the impact of acceleration and braking capacities on the car consumption? The figure 18 shows a first result which presents the covered distance with 0.15 liter of fuel depending on both the speed and the acceleration of the ego-vehicle. In this specific case, an average speed about 50km/h provides the best performance in term of distance covered. At this speed, the impact of acceleration can be neglected. However at low and high speed, the impact of acceleration is very strong. However, the fuel use model does not take into account the engine speed. It is assumed that the impact of the acceleration is stronger in reality because a strong acceleration is correlated to high RPM where fuel use is higher.

6. Conclusion and future work

In this paper, a new architecture is proposed in order to prototype, to test, to evaluate and to validate eco-driving applications and strategies. This platform is developed from several existing platforms (SiVIC and RTMaps). In order to improve the realistic aspect and the driving feeling, a real vehicle and an HMD are connected to the software architecture.

Initially, the SiVIC platform was built to simulate embedded sensors, vehicle dynamic and realistic environment in order to prototype ADAS. The camera models provided in the SiVIC platform has shown their efficiency in a lot of projects for the prototyping of algorithms based on images processing. To adapt this software to the needs of an eco-driving simulator, two main functionalities have been developed. The first one is dedicated to the modeling of a car consumption sensor. The second development was focused on the generation

Figure 17: Speed profile and fuel tank level during the real experimentation.

Figure 18: Covered distance depending on both the speed and the acceleration of the ego-vehicle.
of a stereoscopic image taking into account the parallax between two human eyes. A complete loop has been done between SIVIC’s stereoscopic sensor and the HMD. The real driver can watch the virtual scene in 3D in every direction in real time. Moreover, the possibility to develop eco-driving application in RTMaps environment allows to test this application not only in a virtual environment but also in real condition, in a real vehicle and on a real test track. Nevertheless, in its current state of development, this SIL or HIL eco-driving platform is operational and offers a large set of functionalities making it possible to model and test various advanced eco-driving applications and strategies. It can reproduce, in the most faithful way, the reality of a situation, the behaviour of a vehicle and the behaviour of the stereoscopic sensor which can be embedded inside the virtual and real vehicle.

In the experiment carried out during 3 days, up to 300 people were able to test their driving capability with a real vehicle but in a virtual immersive environment. With both the real steering wheel and pedals (acceleration, braking), these peoples were able to drive a car in this virtual environment and they obtained an eco-driving note depending of their driving behavior. Comparatively to multi-screen simulator, this platform provides a 3D 360° display providing a full immersion, a light and affordable solution easily transportable, and quick to implement.

In futures works, this platform will be connected to an accurate ego-localization module in order to drive in the real Satory’s track and with the HMD in the SIVIC’s environment. This offers new perspectives in order to test eco-driving strategies with ADAS and with augmented reality (virtual pedestrians, vehicles, obstacles …). A second improvement will consist in finalizing an extended electrical engine and battery modeling in SIVIC in order to test hybrid solutions for consumption optimization.

Finally, new experimentations will be done in order to quantify the impacts of the behavior of other vehicles, of a flow of vehicle partially equipped with eco-driving advisors, and of the specific configuration of a road. These last future developments will allow to prototype cooperative eco-driving application with the use of communication devices and extended dynamic perception maps.

7. References


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