EVS30 Symposium
Stuttgart, Germany, October 9 - 11, 2017

Identification of real world driving scenarios for the functional safety of autonomous vehicles

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Summary

The knowledge of the real world driving environment for current road vehicles is fundamental in order to better identify safety problems encountered by autonomous vehicles in similar complex situations. This paper presents the context and the methodology applied to collect data, extract the real world driving scenarios and statistically identify the variables playing a role in such scenarios. Thus, it will be possible to improve the robustness of the architectures and systems of the future autonomous vehicles being developed at the VEDECOM Institute.

Keywords: *data acquisition, environment, autonomous, safety*

1 Introduction

Autonomous driving is considered to be the “next big thing” in the automotive domain. This technological and societal challenge is particularly relevant when increasing levels of automation to full automated vehicles – levels 4 and 5 – as defined by the National Highway Traffic Administration (NHSTA) [1]. In the case of level 5 automated vehicles, the driver is said to be completely *out-of-the-loop* as the car is capable of sensing its environment and navigating without human inputs. It is not the same for level 4 automated vehicles as self-driving is supported only in limited areas (geofenced) or under well-known circumstances, like traffic jams. Outside of these areas or circumstances, the vehicle must be able to safely abort the trip, *i.e.* park the car, if the driver does not retake control.

Today, most major car manufacturing companies have active research and development projects in this area, and typically exciting demonstrators are exhibited every year over the world. Nonetheless, serious steps in reliability, security and affordability of the key enabling technologies still need to be taken for developing autonomous vehicles able to take safe decisions in countless situations.

In fact, an autonomous control implies a robust and *safe* performance under significant uncertainties in the *environment* for extended periods of time and the ability to compensate for system failures without external intervention. Automotive community agrees on the fact that the robustness and consequently the safety of autonomous vehicles depend on a clear understanding of how the environment is perceived in real *world driving scenarios*.

Thus, a more specific way should be defined to describe the environmental conditions and the objects surrounding the autonomous vehicles.

In this context, the French Institute for Energy Transition (ITE) VEDECOM (*Véhicule Décarbonné, Communiquant et de sa Mobilité*) leads a variety of R&D projects to promote high-performance innovation in developing the mobility of the future, including autonomous connected vehicles [ref]. Among the multiple functions needed to ensure the global safety of future autonomous vehicles, perception is fundamental in the complex interaction with the environment [2].

To help design engineers to improve the autonomous vehicle perception, a project called MOOVE (*MOnitoring Outillé du Véhicule dans son Environnement*) has been initiated in 2015 at VEDECOM which aims to provide a better interpretation of the environment as it would be perceived by autonomous vehicles.
Thus, this paper is addressing the scientific issue of identifying real world driving scenarios for the functional safety of autonomous vehicles.

With regards to the proposed contribution, Section 2 provides some major references to existing works trying to contribute to this same problem. Then Section 3 proposes the MOOVE project main objectives, while Section 4 describes the methodology applied to collect and process real world driving data, with a focus on the first step – data collection. Finally, conclusions and some perspectives are given in Section 5.

2 Collecting driving related data: State-of-the-art

Recently, several initiatives have been taken around the world for collecting driving related data as in [6] or [7]. Some of these have been performed by car manufacturers or automotive suppliers according to their specific needs. Meanwhile, some Public Organizations carried out studies which led to databases that are shared among different users.

One of the first data set worldwide was collected in the "100 Car Naturalistic Driving Study" [7] sponsored by the National Highway Traffic Safety Administration (NHTSA) and the Virginia Department of Transportation (VDOT). It focused mainly on driver's behavior and performance and the statistical distribution of critical events. In Europe, a first massive collection of road driving related data was organized in the context of the euroFOT project [8] in 2008. The database obtained was used to perform coordinated tests on intelligent vehicles in real traffic conditions. In 2012, another initiative for collecting a massive database was taken in the context of the UDrive project, the first large-scale European naturalistic driving study, [9]. Its main objective was to provide a better understanding of road user behavior.

Finally, some projects exist, such as the German project PEGASUS [10], that do not collect data by themselves. Nevertheless, they have based their studies on different existing databases about real road traffic data, proving ground tests and accident related data.

In general, these studies have provided interesting insights about road driver's behavior. However, there is no evidence of initiatives aiming to build a huge real world driving database. Thus, car manufacturers would better identify safety critical situations encountered by autonomous vehicles in similar complex scenarios. The MOOVE project is a step towards this objective.

3 Identification of real world driving scenarios in the MOOVE project

The MOOVE project aims to collect a large amount of driving related data by using non-automated vehicles. Sensing technologies on MOOVE vehicles have been specifically identifying to study the environment, but they eventually can be very close to those used on future autonomous vehicles. Moreover, the equipment is highly integrated in the MOOVE vehicles. In that way, they look like standard vehicles and we avoid other road users from having any anomalous reaction.

The MOOVE project has the following main objectives:

- Identify critical situations for autonomous road vehicles
- Quantify of the dimensioning parameters relating to the surrounding environment and dynamics, e.g. distance and speed between neighborhood vehicles, etc. These parameters enable the extraction of safety critical situations
- Carry out statistics about the occurrence and consequences of critical situations so as to combine each one with an Automotive Safety Integrity Level (ASIL) [3]. Therefore performance criteria can be identified to improve perception and supervision systems of autonomous vehicle;
- Set up a database to be used in simulators for road driving situations in order to assess the behavior of autonomous vehicle systems

First data recordings are representative of all possible traffic driving conditions on highways and peripheral roads. Specifications for the MOOVE vehicles were defined considering the data required for the environment perception.

4 The MOOVE project methodology

The MOOVE methodology relies on the following steps:

- The *first step* is ***data acquisition***. Data collected on each of the MOOVE vehicles are synchronized, stocked on a SSD mass storage and then imported on the datacenter to perform analyses. Finally, results can be used from all partners sharing the MOOVE project (Fig.1).

All MOOVE vehicles are equipped with:

1. Smart sensors based on 3 main technologies (Radar, Lidar, Camera)
2. Real world based cameras
3. Onboard annotation tool
4. Real time drive recording tools (data logger).

- The *second step* is ***data processing***. Data are analyzed and the results provide answers relating to:
  - The dynamic and static objects surrounding the MOOVE vehicle
  - The road infrastructure
  - The environmental conditions (including weather).

A 500 TB infrastructure has been set up for storing collected data and results obtained from calculations. Moreover, multiple backup systems work to ensure databases protection redundancy. A database server and scientific computers complete the whole HW system.

In this paper, we focus on the first part, *i.e.* data acquisition.

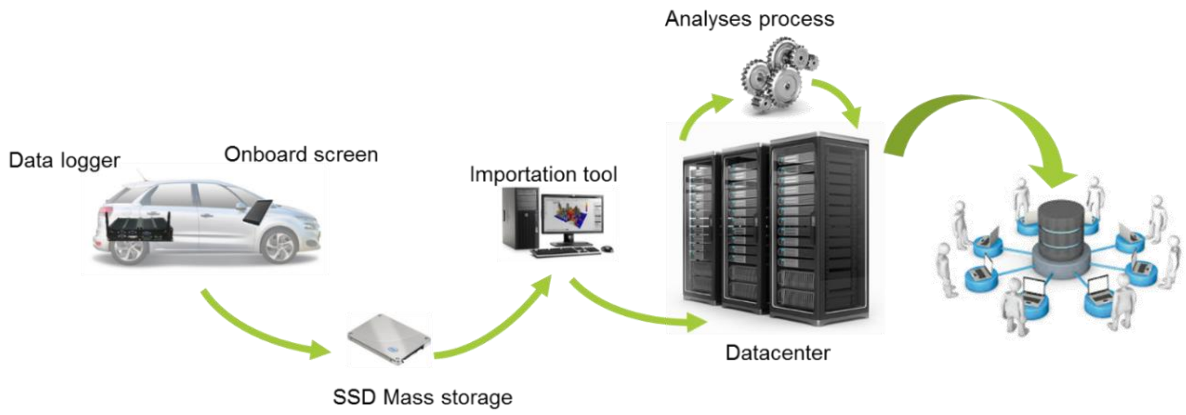

Figure1: Data collection synopsis in MOOVE

4.1 Smart sensors

The MOOVE vehicles have been equipped using standard experimental sensing technologies (some of which currently available in today ADAS [4]). The following devices have been properly integrated on the vehicles:

- Short Range Radars 360°
- Front Long range Radar
- Front and rear LIDARs
- Front smart Camera
- Global Navigation Satellite System (GNSS) receivers
- Inertial measurement unit (IMU).

In general, smart sensing devices are used to detect and analyze the surrounding static and dynamic objects to reproduce a unique environmental model (Fig.2).

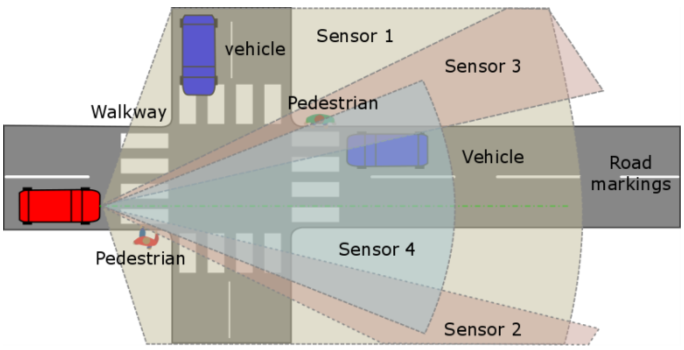

Figure 2: Surrounding sensing mindset

In the MOOVE project, vehicles are equipped using a specific sensing configuration in which sensor devices have been optimally installed so as to limit as far as possible blind spots. A long range radar, a Lidar and a smart camera were set up so as to achieve an optimal frontal detection. At the rear, detection is obtained with the only use of a Lidar. Although vehicle sides are not totally covered, the short range radars belt ensures detection for cyclists passing very close to the doors.

It is important to remind here that the purpose of the MOOVE project is not to test and qualify sensing technologies, but to collect information about the surrounding environment. Thus, the choice of different technologies has to be seen as a form of redundancy to guaranty the needed continuity to the environment perception. In that way, the impact of disturbances specific to each technology does not affect data collection.

4.2 Real world based cameras

In addition to the smart sensors, 5 real world cameras are set up on the vehicles to record the surroundings. Thus, it is possible to know how exactly collected data correspond to objects in real world. In that way, we can eventually fix erroneous interpretations resulting from sensors failing or limited operation. Secondly, we can propose algorithms allowing for seeking in cameras recordings the use cases potentially leading to a critical scenario. Finally, these cameras can provide additional information to that gained from sensing technologies. Nevertheless, a deeper analysis is needed to integrate this information to the records.

Real world reality cameras are highly integrated in MOOVE vehicles as well and arranged to reduce blind spots. Both front and rear cameras are in high definition and have low distortion. To which are added cameras with fish eye lens. In addition, three cameras have been provided to observe the driver in the case of future treatments.

4.3 Onboard annotation tool

An onboard screen allows the driver to add (in real time) tags or vocal information as well as he can mark recordings containing relevant driving situations. Thus, it is possible to easily identified the marked situations and withdraw interesting features about the surrounding environmental conditions. It also allows the driver to make diagnostics about the current state of all equipment and subsequently start, continue or stop to recording.

4.4 Data Logger

Data collected from smart sensors and real world cameras are directly synchronized by using an embedded data logger linked to 8 CAN networks, 3 independent Ethernet networks and miscellaneous inputs.

Several kinds of watchdog have been implemented to ensure a high quality transferring of the recorded data from the data logger. The first one is performed in real-time and enables the driver to start the recording. For each input, the number of frames per second is compared to the rate expected values. Thanks to the records reporting sent to the datacenter, a deeper check is performed by looking at the frame identifier and frame rates. Finally, a last check is performed by quantifying for each parameter significant values, for example the maximum and the minimum.

5 Results

Today, the data logging is in progress with almost 400,000 km already recorded at the end of June and a target set to 500,000 kilometers (of which a non-negligible part covering very low-speed driving conditions like in traffic jam) by the end of 2017. An initial focus on multiple use-cases on the French roads is defined. About 2TB of data is collected every day since six months. Meanwhile, ongoing research is dedicated to the development of analysis oriented tools enabling higher processing and annotation of all databases.

Several interesting sequences have already been recorded like accidents, hazardous driving situations, and so on. Data collected are periodically analyzed to ensure that the expected relevant use cases are identified and the MOOVE vehicles itinerary may be modified according to results.

As a final goal, the MOOVE database is expected to be representative of all road driving situations observable in real world scenarios. In the second step of the proposed methodology, it will be possible to certainly identify:

- Safety related driving scenarios and statistical features about the surrounding environmental conditions [5];
- Dimensioning parameters making robust the autonomous vehicle architecture.

6 Conclusions and perspectives

Today, a full autonomous driving is still far to be achieved and several technological and societal issues have to be addressed by the scientific community. To better identify safety problems encountered by autonomous vehicles in complex situations, a deeper understanding of how environment is perceived is fundamental. The MOOVE project is an important step towards this objective.

Today, a huge database of real driving situations is available. Meanwhile, several data scientists work to perform deep statistical analyses. According to these analyses, it will be possible to define the perception dimensioning parameters for critical driving scenarios. The robustness of autonomous functions could be validated by the dimensioning of these parameters.

In the next future, current sensing technologies could be replaced by a new generation of sensors ensuring a more efficient detection in well-identified complicated use cases.

Whenever the drivers, the vehicles or the environment change, it will be mandatory to record such data to ensure the safety of future autonomous vehicles.

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