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Driving Safety through ADAS: An Indian Perspective

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ABSTRACT

Analysis of the National Motor Vehicle Crash Causation Survey, conducted by the National Highway Traffic Safety Administration (NHTSA), shows that driver error is a factor in 94% of crashes. Although it is important to remember multiple factors contribute to all crashes, the largest portion of driver error issues involve the driver failing to recognize hazards, including distraction. Around 3,700 people die in traffic every day around the world, and 100,000 are injured. The automotive industry is striving to make driving safer. ADAS in India is comparatively in a nascent stage. However, it is gradually gaining pace. The government's upcoming safety regulations and consumer awareness will give further impetus to this movement.

So, Advanced driver-assistance systems (ADAS) is equipping cars and drivers with advance information and technology to make them become aware of the environment and handle potential situations in better way semi-autonomously. High-quality training and test data is essential in the development and validation of ADAS systems which lay the foundation for autonomous driving technology.

In addition to this, ADAS systems need to be very safe and robust, with the ability to perform in a variety of driving scenarios, and be very secure, being immune from any external cyber-attacks. In order to make ADAS systems safer, the AV will be required to drive more than a billion miles on real roads, taking tens and sometimes hundreds of years to drive those miles, considering even the most aggressive testing assumptions. Every small update to the AV will require another billion miles of testing to be approved for real world use. Moreover, the more advanced the technology becomes, the more miles will need to de driven. Real word testing plays a very crucial role in ADAS and AV development and testing. Nevertheless, relying only on real world testing will significantly slow down the development and testing of such technologies. This is where simulation comes into play.

With the primary objective of road safety improvement, ADAS functionalities will definitely play a big role for automotive industry. In order to tackle Indian specific road infrastructure conditions, and thus improving the safety, a complete tool-chain for developing, deploying and validating ADAS functionalities need to be developed. The presented work shares insights of each and every aspect of this tool-chain with experimental results and real world correlations.

KEYWORDS: Advance Driver Assistance System (ADAS); Driving Safety; Autonomous driving; Safety.

Introduction

India has 3rd largest road network in the world. There is around 300 million vehicles running on these roads. So 2000+ billion vehicle kilometres travelled annually. But with this, number of road accidents is also large. Around 1.5 lakh people lose their life annually in these road accidents. The reasons for these accidents are mainly, driver negligence, bad road infrastructure, driving fatigue, rash driving, bad weather, blind spots, overloading etc. In order to overcome these causes and make Indian roads safer to drive, we need to work on all of these individual causes one-by-one.

So with these challenges, targets for safer mobility are set by the government. One of the most highlighted targets is vision zero. Also, target of 50% reduction in road accident deaths by 2024. To achieve all these targets, the ‘4E’ approach can be implemented. These 4Es corresponds to – Engineering, Economics, Environment and Education. For this ADAS is one of the promising solutions in coming future.

As per SAE, following are the level of automation,

With reference to the SAE level, roadmap to achieve complete autonomy for Indian specific conditions can be,

To achieve this we need to follow step-by-step approach. First we need to understand and analysis typical Indian specific conditions and implementation of ADAS functions to overcome the challenges.

ABBREVIATIONS: ADAS – Advanced Driver Assistance Systems; ARAI – The Automotive Research Association of India; ASAM – Association for Standardization of Automation and Measuring Systems; AV – Autonomous Vehicle; YOLO – You Only Look Once; LiDAR – Light Detection and Ranging; DL – Deep Learning; FCW – Front Collision Warning; GNSS – Global Navigation Satellite System; HIL – Hardware-in-the-Loop.

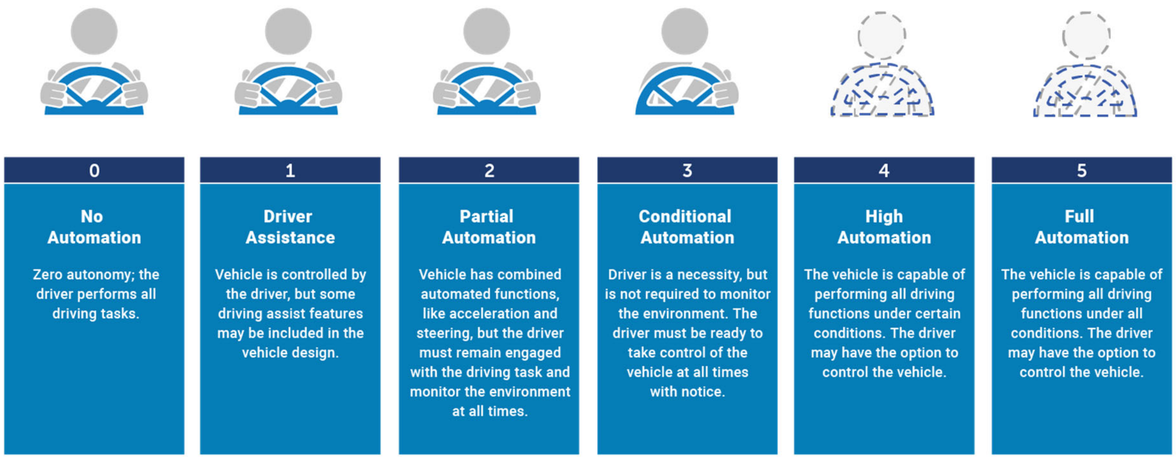

Fig. 1. SAE levels of automation (https://www.nhtsa.gov/).

Fig. 2. Roadmap for complete Autonomy.

On ADAS regulations front, US, Japan and European regulatory agencies have done a lot of work structuring the adaptation of ADAS technologies in the vehicles. From 2000 through 2014, the automotive industry introduced several ADAS features[1]. At lower levels of automation (e.g., SAE Levels 1 and 2), manufacturers and developers are not constrained by current Federal Motor Vehicle Safety Standards (FMVSS) when it comes to developing new ADAS technology. At higher levels of automation (e.g., SAE Levels 4 and 5), the vehicle begins to depart from conventional designs, meaning manufacturers may run into compliance issues with current FMVSS. On similar lines, for very challenging Indian specific conditions regulatory bodies of India are also brainstorming and structuring regulations for ADAS functions.

In addition to this, legislators and regulators also play an important role in bringing technologies like ADAS to main stream. As per[1], relying only on real world testing will significantly slows down the development. So ultimately, simulation will be the key for making ADAS vehicles safer and improve the development speed. Also, regulators are well positioned to speed the rate of ADAS adaptation. This states that in order to make the mobility safer with ADAS, every component of the ecosystem needs to contribute in one way or another.

To begin, we will start understanding the technology, analyze some of the focused features and talk about the cases studied with the presented work. The typical architecture of self-driving cars organized as the perception system and decision-making system[2]. These systems are typically divided into multiple subsystems are presented in figure 1.

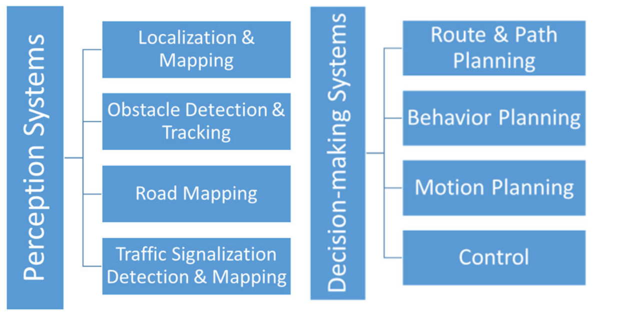

Fig.3. Self-Driving Car Systems.

In order to develop various ADAS functionalities, both 'perception systems' and 'decision making systems' need to be considered thoroughly. It is also well known that ADAS and AV technologies need to be tested very extensively. Traditionally, typical automotive components have been significantly simpler and their operating conditions have been well defined and recreated in controlled settings. So, here simulation also plays a vital role.

One of the basic aspects of making any vehicle smart with the use of ADAS systems, is data captured from various sensors mounted on the vehicle. As the test runs increase, for various environmental conditions, various road conditions, various traffic conditions, etc. the amount of data increases. There has to be a streamlined process to capture, sanitize, analyse and secure the data.

The use of simulation is also inevitable for development of ADAS functionalities, as because real world data collection can never be complete. Traffic conditions, road infrastructure, weather conditions etc. do always change. So, in order to make the vehicle smart for all of these practically infinite conditions, simulation is a must thing.

Then the third part of this complete tool-chain can be considered as verification and validation. Also, correlation of experimental and simulation data is also inevitable to maximize the performance of any ADAS function.

So, the purpose of this study is to capture all the aspects of this complete ADAS functions development tool-chain. This tool-chain is no doubt a complex task to establish. But, we have tried to work on some of the aspects for ADAS functionality development and to bring these together to make the process smooth with experimental as well as simulation results.

ARAI Initiative

Under the Intelligent Vehicle Technology Program, The Automotive Research Association of India (ARAI) is spearheading the development, testing, verification and validation of ADAS and AV technologies for Indian use cases. ARAI has converted a passenger electric vehicle into a drive-by-wire vehicle and instrumented it with necessary sensors like camera, LiDAR, RADAR, GNSS and ultrasonic sensors.

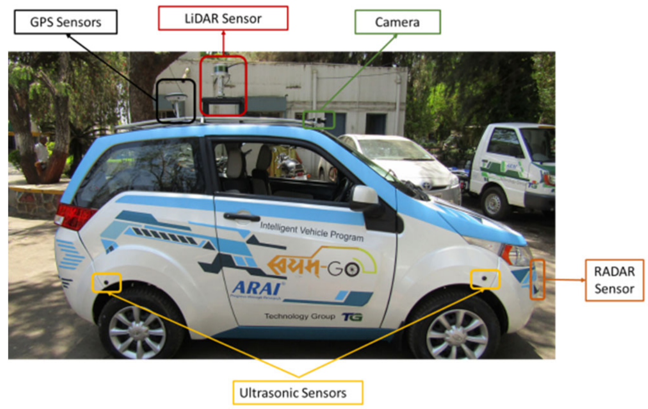

Fig. 4. Installation of sensors on test vehicle of Intelligent Vehicle Technology Program.

Using this platform, ARAI has successfully demonstrated SAE L2 autonomy features on a closed test track, under controlled conditions. ARAI is also working on establishing entire ADAS and AV V&V tool- chain.

Methodology

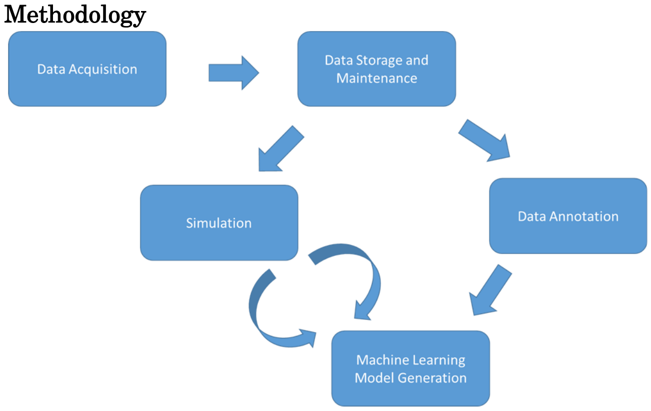

Fig. 5. Methodology for ADAS tool-chain development.

Each of the step in the methodology/flow of work is explained in detail in the following sections.

1. ***Data acquisition***

As discussed in previous section, first and important task is data acquisition. There are lot of efforts done in US and Europe to generate all-inclusive database. There are some open source databases available as well. But as Indian conditions vary drastically, there is a need to collect data for Indian conditions.

Factors which need to be considered for Indian context can be –

- Road networks like city, highway, ruler, Ghat sections etc.
- Environmental conditions like fog, snow, smog, day time, night time, twilight, rains etc.
- Various linguistic traffic signs and direction boards
- Traffic patterns and traffic discipline in various regions

In order to acquire data, we have mounted various sensors like camera, lidar, radar, GPS, IMU etc. on our ego vehicle. To capture data from all these sensors synchronously, a robust hardware and software system is required to be deployed into the vehicle. With the use of all these sensors per hour run gathers around 4 to 5 GB of data. To store and sanitize the data is also a challenge.

A synchronous data acquisition is very critical task and requires considerable amount of efforts to build on our own. Commercially available systems are costly and most of them are not available in India. OEMs may have their own synchronous data acquisition systems but those are proprietary ones. For the scope of the work mentioned in this paper, we have developed our own synchronous data acquisition system to capture data from camera, lidar and GPS sensor, based on Robot Operating System (ROS). Instead of working with hardware extensively, we have used software codes and algorithms to capture data from these sensors synchronously. A single instrument PC with the capability to attach all the mentioned sensors is used. The complete system is well mounted on the vehicle. Data acquisition is mainly done on the roads of Pune city and surrounding areas. We have acquired data of different traffic conditions, different roads (thus different road signs), and with different time of day. Around 1000 km of data is acquired for the scope of this study.

2. ***Data storage and maintenance***

Advanced Driver Assistance System / Autonomous Driving (ADAS/AD) development relies on massive amounts of real-world training data, consisting of sensor data gathered over the course of millions of miles of test driving, which is used across tens to hundreds of thousands of concurrent simulations. With current state of vehicle and sensors mounted, raw data generation is approximately of order of 1GB/min. So in order to cope up with this data intensive activity a data storage and maintenance facility is a must.

Storage needs can be unpredictable in the automotive market – especially ADAS – making storage forecasting and investments difficult. So, in order to begin the infrastructure development, an end-to-end solution as a data centre is to be established, as shown in the following figure.

This step will handle all raw data, sanitize it, store it and can be used for further analysis/processing. We can directly link ADAS development systems like, ML models, HIL, SIL systems, Simulation setups etc. with this architecture.

3. ***Data annotation***

In order to feed any data to machine learning model, to train the model, the data needs to be annotated with required classes. As we are considering only image data for the scope of this study, we have used open source annotation tool to annotate around 50000 key-frames of front camera.

Annotating camera frames is a complete manual work and requires precision. We have used CVAT tool to annotate images with above mentioned classes. Figure 7 shows sample annotations from CVAT.

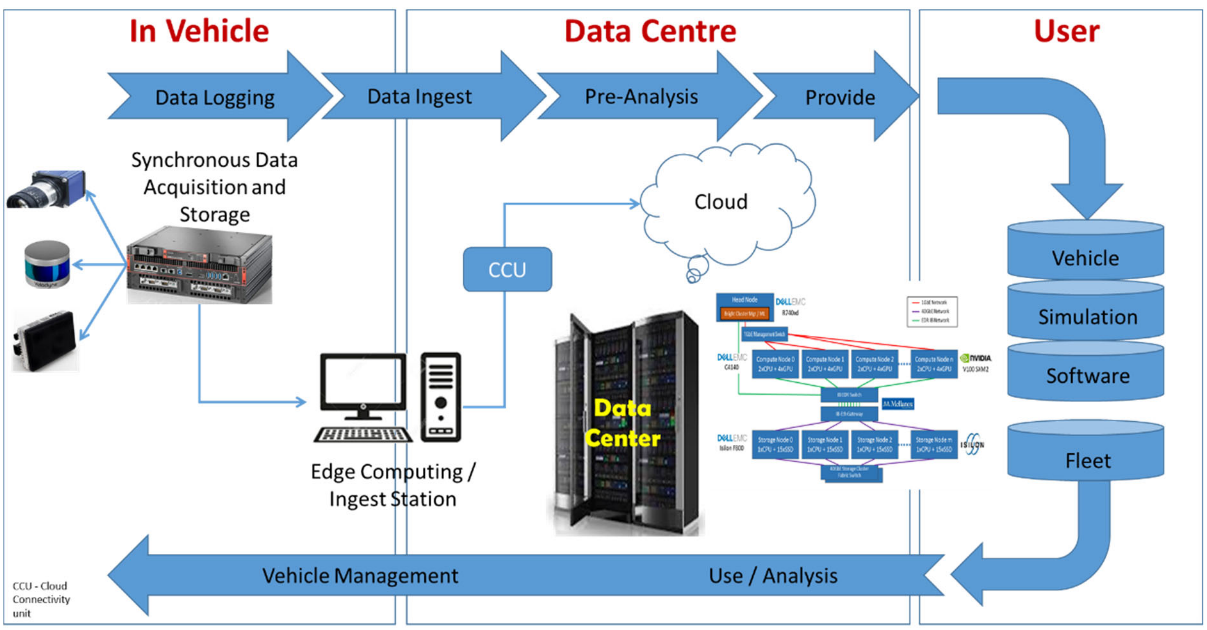

Fig. 6. Typical Data Centre Architecture.

Fig. 7. Sample Annotations from CVAT.

The annotations then saved as a YOLO format .txt file. All these annotation files along with respective images are then used to train the YOLO models in further steps.

Camera records data with 30fps. But all the captured data is not needed for annotation purpose. So, in order to annotate only key-frames, camera frames with the equal interval of 2 seconds are considered as key-frames, and thus used for annotations.

4. ***Machine learning model generation for object detection***

There are various machine learning models for various perception functions, to develop ADAS functions. Out of different perception functions, to demonstrate the development tool-chain, we have demonstrated object detection function in the current work presented.

For object detection with camera sensor there are various open source models available. Out of these models YOLOv3 model is selected due to its speed and accuracy trade-off for real time object detection.

Object detection detects the semantic objects in digital images and videos like car, fruits, etc. Self-driving cars is one of the most prominent application area for object detection. In this, the task is to detect multiple objects from an image or real time video footage. For locating the objects in the image, object localization is used (bounding boxes) and it is needed to locate more than one object in real-time systems. The object detection technique can be categorized into two methods, first is the algorithms based on Classifications like CNN, RNN[3]. In classifications, we select the interested regions from the image and classify them using Convolutional Neural Network. This method is very slow because we have to run a prediction model for every selected region. Regression forms the second category for object detection algorithm. YOLO method comes under this category. The need of selecting area of interest from the image is eliminated in this method. YOLO predicts the classes and bounding boxes of the whole image during a single run of the algorithm as well as detects multiple objects using a single neural network. The efficiency and quality of object detection algorithm is based on its accuracy to give bounding boxes to all the objects of different sizes and in parallel have faster processing and computational capabilities like YOLO algorithm. Earlier techniques (R-CNN and its variations) involved multiple steps due to their pipeline structure of architecture which resulted in slow speed along with the increased complexity in optimization as it has to train separately every individual object.

In order to test the detection capability of the YOLOv3-DL algorithm, we collected vehicles' driving videos for experiments in a variety of different scenarios and different weathers. The test results show that it takes an average of 32 ms to count the vehicles per frame image, and the monitoring of traffic flows using the YOLOv3-DL algorithm. The obtained experimental results demonstrate that the detection capability and prediction probability of YOLOv3 is significantly higher than YOLOv3-tiny, as visualized in Figures (8). Most of the classes in frames were accurately detected with acceptable prediction probability by YOLOv3. YOLOv3 trained on 50k images gives true predictions of all the objects and is capable of detecting even small-size objects figure (9). However, YOLOv3-tiny gives false predictions for small objects like traffic sign and signal as shown in figure (10) and YOLOv3 trained on 20k images fails to detect small objects like traffic sign or signal or detects it with less accuracy.

Detection results

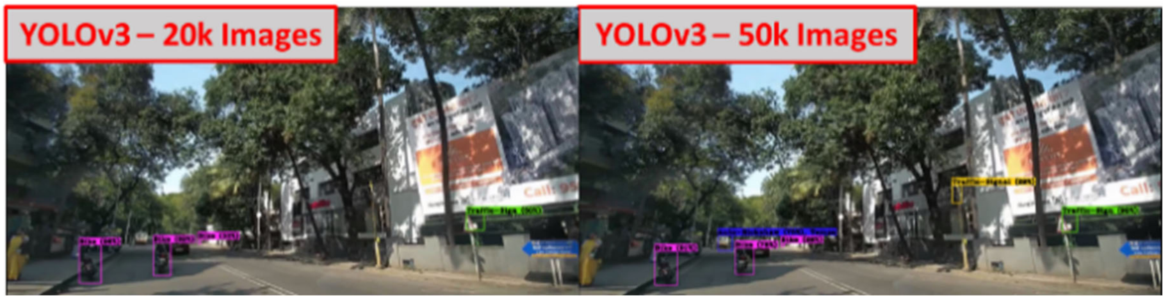

Fig. 8. Prediction with increase in no. of training images.

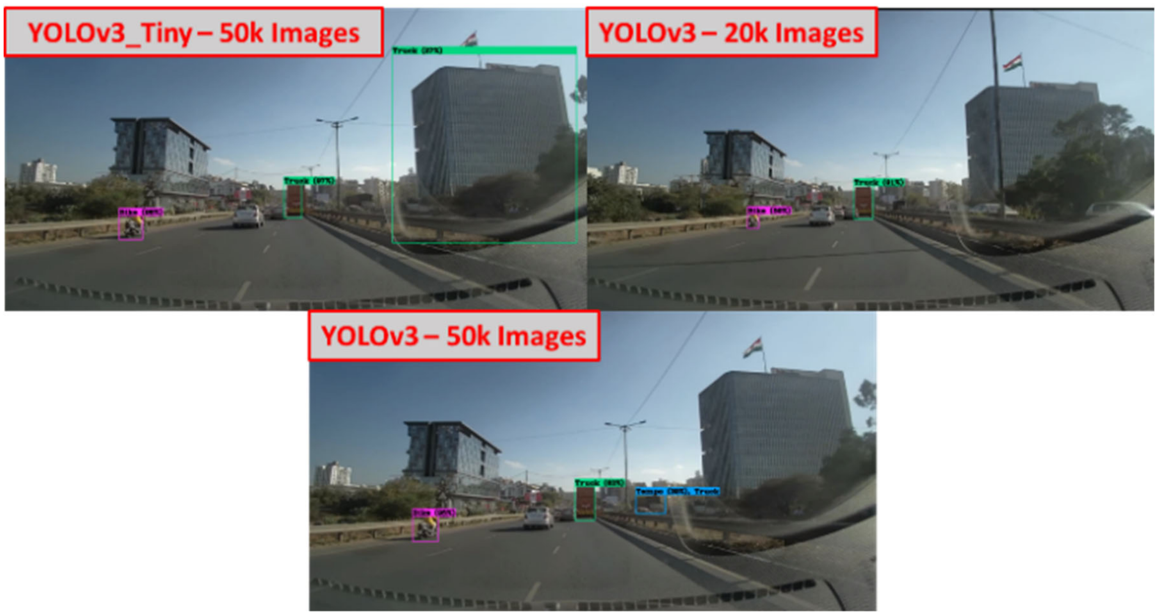

Fig. 9. Detection of different classes with different models and different number of training images.

Fig. 10. False Positive by YOLOv3_tiny.

5. ***Simulation***

In order to go with the integrated approach, it is necessary to validate the algorithm developed, before implementing it on the vehicle. Relying only on real world testing will significantly slows down the development. So ultimately, simulation will be the key for making ADAS vehicles safer and improve the development speed. Simulation can be used for virtual validation and later the same can be implemented on the vehicle directly. Typical simulation environment can be shown as in figure 11.

The World and the Vehicle

The digital world incorporates static environment features like roads (network and surface data), road markings, road signs, buildings etc. and dynamic environment features like subject vehicle (with physical and control systems), weather, time of the day, other vehicles, pedestrians, bicyclists etc.

There are three ways of generating a digital/virtual world. They are - Manual, Semi-automatic and Outsourcing. In Manual method of generating a digital world, satellite imagery and LiDAR scanning is used to build HD maps. These HD maps contain data on all elements of the digital twin in multiple layers of data. The digital world created using such method offer high grade of accuracy with its real world contemporary. The second method involves using various software tools like CarMaker Scenario Editor, MathWorksRoadRunner, etc. for creating the virtual world. Such tools provide simple and quick methods of creating digital world. However, the accuracy of the digital replica is not as high as that of HD Maps. The third method suggests outsourcing the creation of digital world to service providers. These services provide a highly accurate digital world. ASAM's Open DRIVE standard is used to describe road networks, whereas ASAM's OpenCRG standard is used to describe the road surface. Both standards allow easy exchange of virtual environments between different simulation tools and are becoming increasingly popular.

In order to replicate some real world scenarios or create custom scenarios, various traffic objects with individual trajectories can easily be introduced inside the digital world. ASAM's OpenSCENARIO standard aims to standardize the definition of the dynamic environment of the world.

The vehicle represents the ego vehicle, which comprises of multiple sensors, vehicle control systems and vehicle physical systems. The ego vehicles to be tested for multiple level of autonomy can have different configurations of sensors depending on the application. In simulations, the sensors can be selected based on the functional requirement of the simulation. Sensor model fidelity can range from an ideal sensor up to a physics based sensor. The vehicle control systems communicate with the sensors and control multiple vehicle physical systems like brakes, steering, etc. to control the vehicle.

(a) ***Road creation***

One of the methods for creating road network required for the simulations was by importing files of required road sections from Google Earth. Google Earth provides the option of exporting Keyhole-markup (.kml) files which include information on the location co-ordinates of the selected road section. These files were imported in IPG CarMaker Scenario Editor. Post the import of the road sections, other road elements like road markings, traffic lights and signs, vegetation, trees, and building were added to complete the virtual environment.

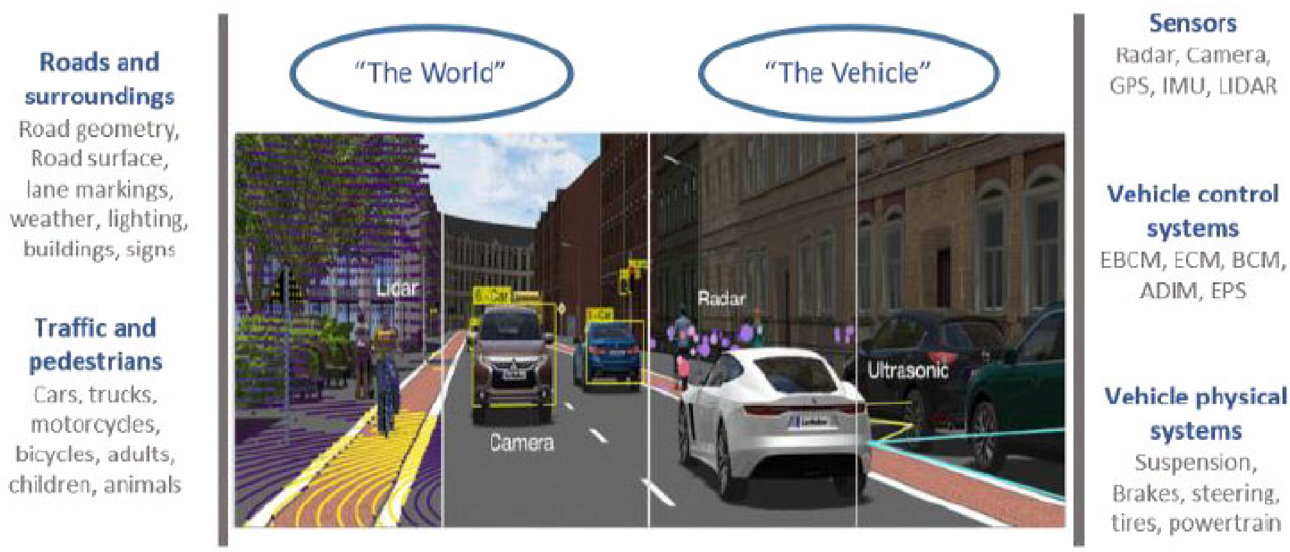

Fig. 11. Description of World and Vehicle in a typical simulation.

Fig. 12. Virtual 3D environment created in IPG CarMaker.

(b) *Synthetic scenario generation*

The process of scenario creation starts with the compilation of a scenario database. A scenario database consists of multiple base scenarios along with variations of each. This database can be compiled by taking references from multiple standard sources like ISO standards, NCAPs, UN regulations etc. It is used for exposing ADAS and AV technologies to varying conditions and evaluating system performance before going on track.

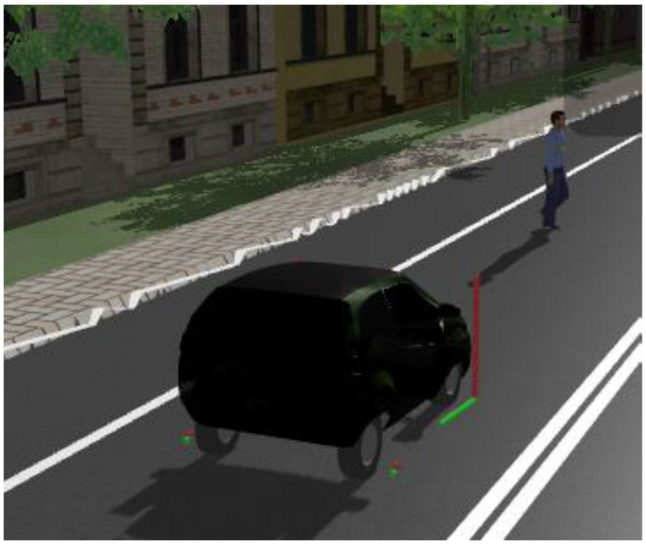

Fig. 13. Virtual realization of a scenario and structure of sample scenario database.

(c) *Vehicle modelling*

Creating an accurate digital twin of the ego vehicle in the simulation environment is very critical for good comprehension of the simulation results. A generic simulation tool offers default parameterization of basic vehicle parameters and sub-systems. Basic parameters include vehicle external dimensions, kerb weight, CG location, etc. The models of vehicle sub-systems utilized in simulation should have high affinity to those in real world. Thus creating accurate vehicle sub-systems is a formidable task. Vehicle and system testing on bench and real world can help in gathering the data required for modelling the vehicle in simulation. As the basic purpose of simulation is testing various control strategies, along with the default options provided by simulation tool, provision of importing custom-models or co-simulation with other tools provides a flexible solution in the simulation workflow.

For the AEBS case study, the ego vehicle used in simulation was a digital twin of ARAI's test vehicle. On-bench testing of vehicle sub-systems was done to collect required data for modelling the vehicle. In the case study, since the main idea was to setup a flexible simulation-based V&V workflow, the default longitudinal controller provided by the simulation tool was used. However, a custom controller to be tested can replace the default controller.

So with the use of these three basic methods to replicate the real world scenario in the simulation world, many of the actual road conditions can be evaluated and simulated to test the ADAS functionality.

Conclusion

ADAS and AV technologies promise to enhance safety and democratize transportation. Therefore, there is a strong need to bring such technologies in the market quickly. However, before they are released into the market there is a necessity to ensure that they are safe, secure and robust. This calls for a greater need for their extensive testing. Also, as the importance of AI and ML in the field of ADAS is increasing, it is in evident to implement and test AI/ML models for constructing any ADAS function. To actually implement the ADAS function in the vehicle, number of sensors are required to get the surrounding as well as vehicle data in real time. This all leads to the development of complete tool-chin for ADAS functionality development. With the work presented in the paper, the complete methodology and approach can be useful to develop a broad level tool-chain to streamline the ADAS function development.

As the study shows real life as well as simulation results for some of the aspects of ADAS functions, it can be very well concluded that, an end-to-end approach is required to implement and test any of the ADAS functionalities.

Future Scope

Having demonstrated the approach followed, the aim is to broaden the scope of this exercise for Indian test conditions. The models developed for non-Indian conditions are hardly effective with very diverse Indian conditions. So there is a need to develop an Indian specific tool-chain models for each and every ADAS functionality. The future tasks include developing these models and testing those in simulation as well as in the real world scenarios.

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