

Sensor simulation and future in-cabin capabilities with VTD

By Tushar Bhanage, Dan Marinac, Venkatesulu Reddy
Product Marketing Manager, Director Global Product Marketing, Senior Technical Specialist

Autonomous vehicles work on the same principle as we human beings do. We understand our surroundings with our senses, and our neural system processes it and provides us a logical call to action. A similar concept is also applicable in autonomous vehicles, where sensors provide surrounding information, and the neural system

is the Electronic Control Unit (ECU). Autonomous vehicles perceive their surroundings through sensors, and the information is transferred to the path planning phase, which decides and predicts future action and guides the actuation system accordingly. For the autonomous vehicle to run smoothly on real roads without any issues, the

multiple sensors must understand their surroundings accurately and transfer the data accordingly. Various sensors are used in autonomous vehicles such as camera, RADAR, LiDAR, Ultrasonic, etc., serving numerous purposes and ranges. (Figure 1) The perceived data from these sensors should be appropriately

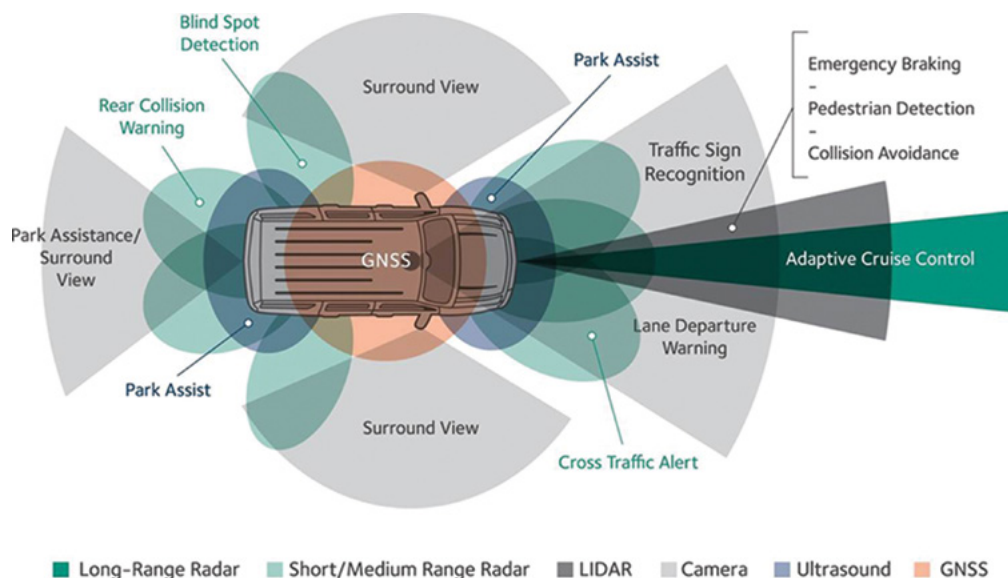


Figure 1: Sensors with different functionalities

fused so that the path planning can be done efficiently, and future steps can be taken.

Sensor fusion is one of the most critical elements in autonomous vehicles. It serves multiple purposes, such as 360-degree object detection, localisation, and mapping. For an autonomous vehicle to be able to self-drive, consistent data must be fed to the system that is most accurate and dependable. Sensor fusion helps to increase data quality and reliability, estimate the unmeasured states, and increase coverage around the vehicle. However, before the sensor fusion systems are even ready and usable in public, they must be rigorously tested. There is a requirement of multiple sensor inputs for testing these systems that physical tests can hinder due to the associated cost of hardware and limitation on performing repeated tests. Multiple sensor inputs from simulation solutions connecting with the sensor fusion system can solve the problem of repeated testing and development time, along with cost reduction.

One of the primary challenges facing customers involves correct interpretation of scenes captured by sensors such as cameras, LIDAR, RADAR and Ultrasonic for Hardware-

in-the-Loop (HiL) and Software-in-the-Loop (SiL) tests and sensor fusion. Raw data captured by real-world cameras is corrected for low light, white balance, tone curves, etc., of the scene. Inside Virtual Test Drive (VTD) the simulated cameras also must adjust the light, white balance, tone curves, etc., of the captured scene to match the raw image's specific HiL testing requirements. The correction and adjustment of raw image is performed with lens simulation and image signal processing (ISP) in the simulated camera. Several issues related to lens and ISP of the simulated cameras need to be addressed. The simulated lens experiences issues of chromatic aberration or optical distortion, and the image signal processing of the simulated camera has problems accurately interpreting colors. For more realistic simulation and sensor fusion, the design of sensors such as RADAR, LiDAR and Ultrasonic is an essential requirement as testing of sensor fusion kits involves input of multiple sensors.

The system under test requires the specific data from simulated camera modules. It might include the images with RGB Bayer pattern varying number of bits per pixel based on the requirement. This requirement can be fulfilled by calibrating the ISP in the

system under test compared to the true camera module. VTD enables the ISP tuning of the simulated camera for HiL testing to improve the color accuracy, contrast, and resolution. One can interpret this image to be effectively identical to the real-world image with simulated camera from VTD (Figure 2). For solving the problem related to the simulated lens, optical distortion simulation model research was conducted. Through this research, VTD now provides the method of obtaining distortion parameters based on real camera characteristics parameters. It also provides the image model of a long focal length lens, enhancing lens design and shading's camera calibration capabilities. Based on the System Under Test (SUT) to validate, VTD provides different camera modules like pinhole, distortion, fisheye, non-fisheye, etc., and even noise generation is possible.

For accurate analysis of sensor fusion kit, multiple sensor inputs are required that also includes simulated RADAR, LiDAR and Ultrasonic sensors. The RADAR & LiDAR models in VTD are equipped with ray tracing capabilities to resemble the real sensors. The ray-tracing capabilities are useful in the simulation when defining the material properties and needing photo-realistic images (Figure 3



Figure 2: Physically Based Rendering with Camera

& 4). Latest millimetre-Wave radar technology from VTD allows the customer to configure and simulate analog to digital converter (ADC) / Fast Fourier Transform (FFT) data in real-time. With a software development kit, customers can design and develop their own physics-based radar models. The generated ADC/FFT can be directly fed into (electronic control unit) ECU for raw signal processing of clustering, object detection, tracking, and classification. VTD single ray and multiple ray sensors offer customers to design and simulate physics-based ultrasonic sensors data in real-time; the generated data can be directly fed into ECU for perception validation.

For testing the algorithms for sensor fusion, VTD generates the multiple sensor inputs in parallel and can now scale for software-in-the-loop. With

all these developments with sensors, VTD enables the distributed sensor simulation with deterministic behavior to feed the synchronised sensor data as much as possible to sensor fusion systems under test based on the specific requirements. It is now possible to configure the simulation setups with 13 cameras, 5 LiDAR, 12 ultrasonic perfect radars, and 6 millimeter-wave perfect radars.

Along with the current applications in sensor fusion, VTD is working on technology for in-cabin monitoring systems. The in-cabin monitoring systems consist of driver monitoring systems and passenger monitoring systems. The driver monitoring system is primarily required to help the driver reduce the errors caused due to distraction, drowsiness, and non-alertness. Various driver assisting

systems includes driver drowsiness detection, driver monitoring system, forward collision warning, intersection assistant, wrong way driving warning, etc. To test all these functionalities on a proving ground or in real-world is an expensive business, and there is a problem of adaption from drivers. These functionalities can be tested with simulators effectively with the provision of the virtual environment.

VTD is working on technology for ADAS functionalities as in-cabin capabilities for driver assistance that will be providing realistic virtual environments. For the drivers to get the real feel of driving in a driving simulator with front and rear view, VTD can provide a 360-degree projection with the possibility to vary the weather conditions, time of day, etc. The real sensors fitted in the cabin of the simulator will be connected to the virtual environment from VTD. These sensors will monitor the driver and information about the surrounding environment in which the car (simulator) will be driving. If the driver is distracted and there is a critical situation in the virtual environment, the driver will be alerted. This is just one example where VTD is focusing now with multiple options in mind for the future.

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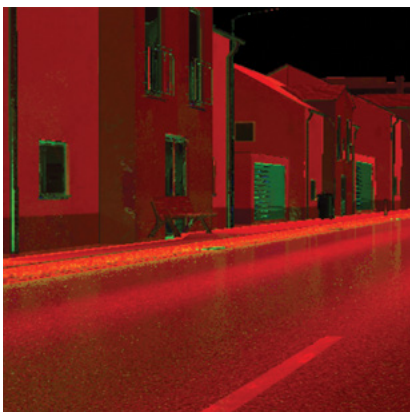


Figure 3: Physically Based Rendering with LiDAR

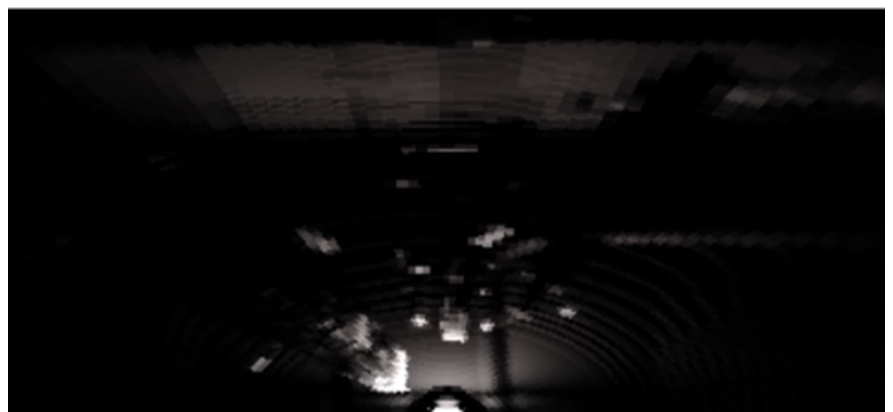


Figure 4: RADAR with Ray Tracing