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77 GHz Real-time Automotive Radar Scene Simulator for Autonomous Driving

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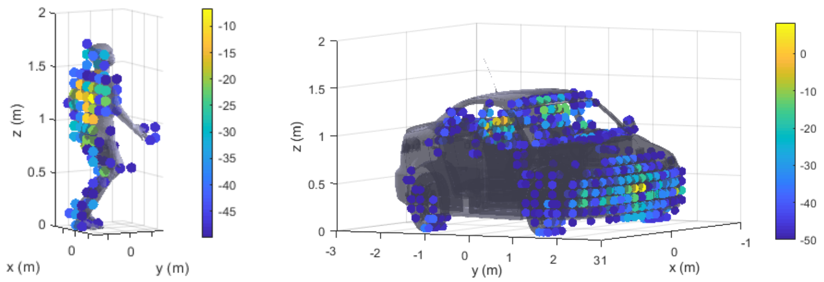
Autonomous transportation and the associated technologies will be one of the driving forces of economy in the next decades. It also provides the potential to reduce millions of accidents and save hundreds of thousands of lives globally each year. Many sensors including optical, infrared, acoustic, and radar are envisioned to achieve situational awareness and collision avoidance. Before such technology is adopted, millions of miles of road testing and performance evaluation of such system under different climate, weather, and country conditions must be completed. Compared to road testing, high-fidelity simulations are far less expensive and far more comprehensive if such simulation environment can be realized. Millimeter wave (MMW) radar is one of the most commonly used sensors in autonomous vehicles, however, because of the complexity of electromagnetic scattering phenomenon, the radar signals are more difficult to simulate and comprehend by engineers than those for other sensors like camera or Lidar. Meanwhile, for sensor fusion purpose, it is desired that the radar simulation could be carried out simultaneously with other sensors in a computationally efficient manner.

One of the major challenges in automotive radar simulation is to correctly and efficiently simulate the process of electromagnetic scattering from traffic environments. Since traffic targets' dimensions are usually electrically very large (more than hundreds of wavelengths) at 77 GHz, the full-wave numerical methods are not applicable and the asymptotic methods like geometric optics (GO) and physical optics (PO) methods are still too slow compared to real time. To accelerate the simulation while keeping fidelity, a novel approach is developed to model traffic targets with both deterministic and statistical information when radar is in the near field of targets. In this approach, targets are represented by a large number of strong and weak scatterers. The positions of scatterers are deterministic, i.e. approximately on the surface of targets, but the radar cross section (RCS) of each scatterer is a random variable due to the random nature of the complex targets encounters in traffic. Gamma distribution is found to be appropriate for this statistical analysis because first it has infinite divisibility property and second it has shown good accuracy to fit the RCS of various complex targets [1]. The statistical information of each scatterer is summarized from Monte Carlo simulation by PO method. Some examples of the scatterers with randomly generated RCS for a pedestrian and a sedan is depicted in Figure 1.



(a) (b)

Figure 1. The randomly generated RCS for many scatterers on the surface of (a) a pedestrian illuminated from the back and (b) a sedan illuminated from the front

The proposed approach can enable high fidelity real-time radar scene simulation. By using parallel computing technology with GPU, one frame of a typical MIMO radar signal that contains about 1.3 million data (512 frequencies×256 chirps×10 channels) can be simulated in 100 ms for 100 strong scatterers on an ordinary PC. This approach has the potential application in autonomous driving simulation and helps to improve the safety of driving in the future.

References

[1] D. A. Shnidman, "Expanded Swerling target models," in *IEEE Trans. Aerosp. Electron. Syst*, vol. 39, no. 3, pp. 1059-1069, July 2003.