Virtual Radar Sensor with Characteristic Properties

Rain, glare or dirt – factors any driver is familiar with as interfering with the perception of the environment affect sensors as well. Advanced driver assistance systems (ADAS) have to cope with them and initiate vital actions in spite of faulty sensor data. To reproducibly validate this in virtual test driving, researchers from the Institute for Automotive Engineering of TU Graz together with Magna Steyr Engineering developed a radar sensor model that realistically simulates the sensor properties and can be used as early as in the concept stage. The model was comprehensively examined and tested using CarMaker.

Sensors are the sense organs of intelligent advanced driver assistance systems. They identify potential sources of danger and ensure that the assistance systems trigger the correct vehicle responses to avoid accidents. In the field of environment recognition technology, radar sensors, in addition to laser, ultrasonic and video sensors, have become particularly prevalent. Their special strengths lie in very good measurement and separation capabilities of relative speeds. A radar system for instance is able to precisely measure distances, easily separate several targets from each other and track their movements. Radar sensors therefore provide the ideal basis for adaptive cruise control (ACC) and predictive emergency braking systems (AEB).

Naturally, even the best sensor is afflicted with disturbance variables and measurement inaccuracies. They result from other objects obstructing the sensor beams, latencies between the time of the measurement and the provision of the signal as well as short-term random object losses. Consequently, developing reliable systems which correctly detect and evaluate the driving situation and initiate the necessary actions in spite of the unreliable sensor input data poses a major challenge to ADAS development.

Taking Sensor Faults into Account at an Early Stage

Various test methods are suitable for ADAS validation, depending on the development stage. They range from the exclusive use of office simulation, hardware-in-the-loop tests to on-road testing. As commonly known, the latter is very time-consuming and resource-intensive, and suitable only for limited use – particularly in the field of ADAS due to the high complexity of the test scenarios involved. OEMs and suppliers therefore shift large parts of ADAS validation into early stages of the development in which faults in the system can be corrected with greater ease and, above all, at lower costs. To do so, they utilize powerful simulation tools such as CarMaker which make it possible to integrate control systems into a virtual test vehicle and to investigate them under reproducible conditions in virtual test driving.

CarMaker simulates freely configurable traffic situations in the environment of a virtual ego vehicle. All test scenarios can be efficiently modeled in maneuvers and run in automated mode by the Test Manager in CarMaker. The software also includes a sensor model that detects objects in the environment of the ego vehicle. The sensor properties such as aperture angle and range, plus its position on the vehicle, can be freely configured on this model to simulate a wide range of sensor types. However, this is a generic, ideal sensor model that operates based on position data from the traffic simulation in CarMaker. As the model, by default, makes no measurement errors and does not know any latency periods either, it issues the information about a detected objected at the same time the object appears.

However, depending on the use case, it may be advantageous to model the sensor properties in more detail at an early stage of development. Thus, for instance, it would be possible as early as in the concept stage of an autonomous emergency braking assist (AEB) system to feed the latency periods for the acquisition of suddenly appearing traffic objects into the requirements for the braking system.

Overview

Users

- Institute for Automotive Engineering, Graz University of Technology (Austria)
- Magna Steyr Engineering

Countries

Germany, Austria

Product

CM

CarMaker

Challenge

Development of a radar sensor model that models the characteristic properties of real-world sensors while minimizing the required computing time.

Solution

A phenomenological sensor model efficiently calculates physical sensor effects based on mathematical correlations. The model has been validated and optimized in virtual test driving.

Time-Efficient Modeling of Real-World Sensor Effects

Available physical sensor models are unsuitable for such concept studies. They typically lead to long computing times and usually involve a complex parameterization effort. For this reason, a research team from the Institute for Automotive Engineering of Graz University of Technology together with Magna Steyr Engineering has developed a phenomenological sensor model which realistically simulates the properties of radar sensors and requires considerably less computing time compared with physical models.

Like the sensor in CarMaker, the model operates with geometrical information from the simulation environment. It analyzes whether the simulated traffic objects are located within the acquisition range of the sensor and if they are obstructed by other objects. The list of objects generated this way is subsequently loaded with radar-specific measurement noise. In this process, the properties of real-world sensor components are modeled by means of simple

mathematical correlations in a way that makes efficient use of computing time. Environmental influences such as weather and the properties of the detected objects are taken into account here as well. Additionally, the virtual sensor randomly loses previously detected objects for a short period of time. Like in real-world sensors, the noisy signals are processed with a Kalman filter and subsequently made available to the assistance system.

Sensor Model Validation Using Real-World and Virtual Test Driving

To validate and optimize this model, measurements were made in test driving with a real-world radar sensor and compared with the simulation results of the sensor model. Two vehicles were used: an ego vehicle with a built-in radar sensor and a target vehicle. To precisely measure the motion data, both vehicles were equipped with a DGPS-based measurement system (positioning accuracy +/- 2 cm). The radar sensor – a production sensor with an open interface – as output for the validation delivered a list of the detected objects, i.e. the position, speed and acceleration of the objects, their dimensions and the probabilities that the objects exist.

The real-world on-road tests were subsequently transferred exactly into the simulation with CarMaker. For this purpose, the virtual ego vehicle and the virtual target vehicle were moved exactly with the data acquired by the reference measurement system. Subsequently, it was possible to directly compare the output of the radar sensor with the results of the sensor model.

Among other things, the scientists investigated whether the sensor model developed simulates the latency periods of real-world sensors with sufficient accuracy. To verify this, they recorded the time at which the filtered data is provided by the real-world sensor and by the sensor model, in other words how much time elapses between the emergence of the object within the sensor's range and the provision of the data. Latency periods in particular are a result of the signal processing of the measurements acquired by the sensor's receiver. Objects must be detected as such, tracked over time and classified (passenger car, truck, stationary object, etc.). In addition, the driving function has to rate specific objects as relevant (for instance the target vehicle in the case of ACC). This "search for the needle in a haystack" requires appropriate processing time.

Ideal vs. Phenomenological Sensor

The value which the phenomenological model adds to the development work is exhibited in the concrete application, for instance in the virtual development of an AEB system. To investigate the influence of the sensor modeling on the simulation results, the researchers from TU Graz integrated an AEB controller into the CarMaker vehicle model. This controller initiates an emergency braking event if the calculated time to collision (TTC) drops below the limit value of 0.9 seconds. Consequently, typical test scenarios from the maneuver catalog for ADAS were simulated in CarMaker, each with the ideal model from CarMaker and with the model developed.

A classic situation on freeways is an example from the maneuver catalog: a slower vehicle cutting in front of a faster ego vehicle (see Figure 2). This scenario was simulated with the following parameters: The ego vehicle travels at a constant speed (v=130 km/h) and constant distance (d =72m) behind T1 in the left lane. T2 and T3 are traveling at a constant speed of 90 km/h in the right lane. When the distance between the ego vehicle and T2 drops below a limit value (here: d=24m), T2, with constant speed, will change into the left lane in front of the ego vehicle. The virtual driver does not respond to this.

It was found that the AEB system in the case of the ideal sensor model manages to decelerate the ego vehicle in time to prevent a collision. As soon as T2 changes into the left lane, the model provides the AEB system with information about the detected object. By comparison, the phenomenological sensor model provides the information about a relevant object to the AEB controller only at a later point in time. Although the AEB controller immediately initiates an emergency braking event reducing the relative speed between the ego vehicle and T2, a collision cannot be completely prevented as the limit value TTC=0.9s has already been undercut by the latency period of the sensor model.

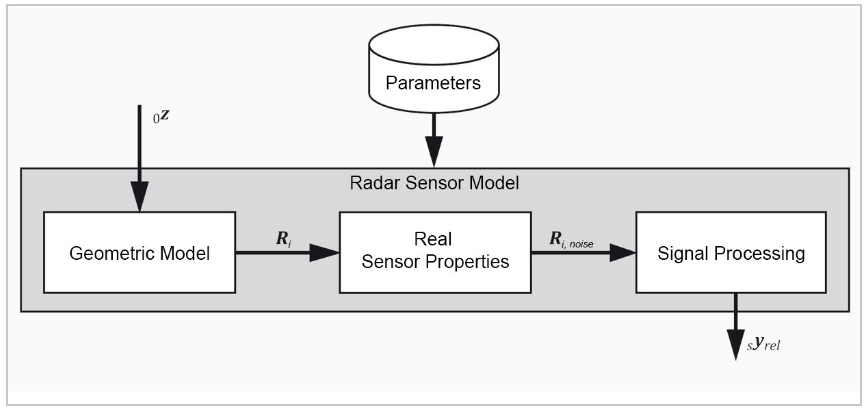

Figure 1: Functional schematic of the phenomenological radar sensor model

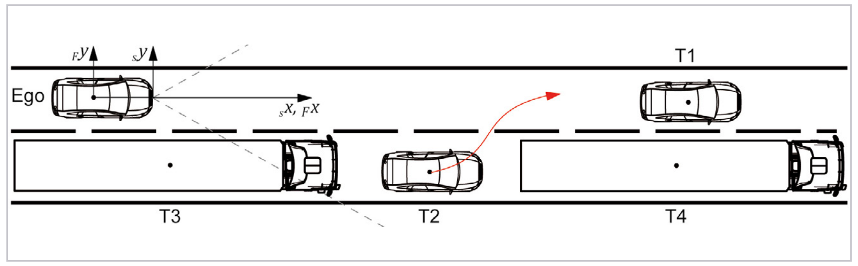

Figure 2: Simulated freeway scenario

Advantages for the Development Process

The simulation results illustrate the relevance of testing ADAS in the context of dealing with realistic, i.e. faulty, sensor signals. The phenomenological sensor model developed by TU Graz and Magna Steyr Engineering can be used as early as in the concept stage for virtual development and validation; at a time when only a small amount of data from measurements is available. It minimizes the required computing time and is easy to parameterize based on data sheets. The utilization of this model in the virtual development with CarMaker can lead to a high level of maturity of a system even in early stages. As a result, costly development loops can be avoided and development times significantly reduced.

Conclusion and Outlook

The work presented shows that CarMaker not only serves as a reliable development platform for model-based testing of ADAS for OEMs and suppliers. For universities and research institutes, CarMaker offers optimum conditions for fundamental and systematic testing of concepts and development methods as well. Particularly the open design of the platform and the possibility to easily and quickly integrate models into the virtual vehicle environment, make CarMaker a preferred tool for scientists.

The vehicle engineers of TU Graz intend to continue the successful development of the radar sensor model and provide the model with real-time capability for hardware-in-the-loop use. In addition, it is planned to extend the phenomeno-logical model in order to realistically simulate other types of sensors such as laser sensors. For the development and validation of the new models, the CarMaker open integration and test platform will be used in the future as well.

Figure 3: Comparison between an ideal and a phenomenological radar sensor model