
Simulation of Automotive Radar Point Clouds in Standardized Frameworks

Thomas Eder

Dissertation



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*Essentially, all models are
wrong, but some are useful.*

GEORGE E. P. BOX



Abstract

Driver assistance systems have evolved rapidly in recent years and are an indispensable feature of many of today's vehicle models. The increasing trend of industry and research is certainly towards autonomous driving. The complexity of the system and the complexity of the test cases can no longer be covered by real driving tests in an economically sustainable way. For this reason, researchers and industry experts are trying to replace actual test drives with simulation-based tests designed to be as close to reality as possible. The simulation of the vehicle's environmental sensors, the so-called sensor simulation, is therefore crucial. Automobile manufacturers are increasingly focusing on a standardized architecture with a high level of abstraction. In order to simulate the sensors, such as radar sensors, most realistically on a point cloud level, data-based methods are used in many cases. In general, and specifically in case of radar sensors, there are still challenges to be faced. Therefore, four research questions are addressed:

Is a certain physical model of a frequency modulated continuous wave radar sensor accurate enough to generate synthetic training data for data-based models? This question is answered by means of a thorough and detailed investigation of the underlying method and the associated approximations. Among the results are a detailed error analyses based on an exact formula for the beam expansion derived herein.

Which statistical approaches are suitable for the simulation of entire radar point clouds and how shall their learning capacities be evaluated? Generative neural networks and kernel density estimation methods for point cloud simulation are developed. Based on exemplary metrics, the methods are compared objectively. Finally, a subjective evaluation from the developer's point of view regarding the genericity of the methods is given.

Furthermore, a generic and user-friendly hybrid approach is developed to circumvent the disadvantages of purely statistical techniques. Based on a simple ray-tracing based approach, a radar detection model is developed that takes simplified physical laws into account and may be fitted to a specific sensor without the need of large amounts of data. Finally, numerous opportunities for enhancement are discussed.

The problem of evaluation and validation of radar point cloud models is discussed and a consistency criteria is proposed and discussed. A simple example highlights current challenges and is followed by the presentation of a criterion for consistency of validation methods, which is tested by means of statistical tests presented herein for the first time.



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