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Physically based radar simulation parameter of road surfaces in OpenMATERIAL

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Abstract

To enable autonomous driving simulations are getting more and more important. A common method is ray tracing depending on geometrical optics. However, this method is not always sufficient, but has to be enhanced. It can be essential to consider material parameter, which have to be provided anyhow. OpenMATERIAL is a project collecting reliable physically based material parameter data for automotive simulations, which is published open source. Ideally the database will contain data of all important materials in future. Furthermore, the datasets have to distinguish for all in automotive applications implemented sensor types. To pursue this idea we here suggest material parameters that are important for radar applications and integrate them in OpenMATERIAL. Moreover, we provide material parameter files containing information regarding radar wave behaviour for five different road surface types in this format.

1 Introduction

Autonomous driving is discussed as one of the key technologies of the latest century. Besides challenges in development of autonomous vehilcles, legal aspects cause problems for a release. Even though laws are currently adapted to enable autonomous driving, there are still missing questions to resolve until approval is possible. Germany for example changed the road traffic act, but only clarifies some basic points [1]. To simplify an approval process, motor vehicle manufacturer hence strive for safety proofs. Since experts agree that real world tests are too expensive to cover an overall proof, attempts to substitute real world driving by simulations are made [2]. Many simulations use only geometrically correct shapings of the represented environment. Therefore, the accuracy of the resulting representation is often not high enough. One way to improve the physical correctness, material properties can be added to the objects in the scenario and implemented in the simulations. Obviously, such information facilitates the actual development as well.
As different operators perform simulations in automotive context, it is useful to standardise file formats and interfaces to make results easily exchangable and replicable. Already existing standards that are commonly used are for example ASAM OpenDRIVE providing a road network description or ASAM OpenSCENARIO defining a file format to describe a driving scene. But a commonly accepted standard to implement and exchange physically correct material data is still missing.

2 OpenMATERIAL

An attempt to create such a standard is the project OpenMATERIAL. It proposes extensions to the glTF 2.0 specification, which was defined by the Khronos group in order to make transmission and loading of 3D scences and models more efficient. This format is already commonly used for gaming purpuses and therefore highly developed, what makes an appliciation less elaborate. This means that the defined standard is not only applicable for sensor simulation, but obviously can be used to improve rendering results in terms of light or shadows for other applications. The main effort consists of defining all data parameters that are necessary for a profound description and gaining the corresponding physically based data. While the database can be used for any purpuse with the need of material information, it is designed to collect all material data that is important in an automotive development as well as for testing and validation. It is set up as a open source project to gather and share information effectively and enable to get audits of the whole scientific and developing community. All data that is implemented in the dataset must be based on an investigation and a documention of the measurement environment as well as the source of the evaluation has to be referenced. Limits of the data for example in frequency ranges or incidence angles, where it can be applied, are defined, too. It was primarily established for optical sensor systems.
The OpenMATERIAL definition and various data files are published in a github repository created by Ludwig Friedmann (github: LudwigFriedmann), which can be found in [3]. The repository not only contains the gltf files including the physical material parameters, but examples for its usage as well. To be more accurate it primarily delivers an object directory with several glTF 3D objects, to which the material properties can be assigned. Furthermore, a simple raycaster/ pathtracer is provided to demonstate how object and material can be used in a simulation. Likewise ideas how the standard can be used in combination with other standards and model types are presented. The project is documented in great detail, so further information can be found in the repository.

3 Parameter

As mentioned above, OpenMATERIAL has the goal to determine all important material parameters for all sensor types that are implemented in automotive applications. Also, various environmental conditions having an influence on the sensors should be considered. In time it hereby should be possible to classify influence factors according to their importance. This would enable an effective extension for future sensor types. The dataset is already used for camera and lidar sensor simulations. To make the before existing database usable for radar sensor simulations as well the before defined parameter set had to be extended. Therefore, permittivity and permeablity are defined parameters in the material files now. The dataset does not claim to be complete, but to contain only values determined by scientific work. Interpolations or additional assumptions can be done by the users of the data in their application. Therefore, the temperature during measurements is also noted as well as the incidence angle θ of the wave, for which the measurements were realised. The incidence angle is defined as the angle between the surface normal $\vec{n}$ and the incidence wave like shown in Figure 1.

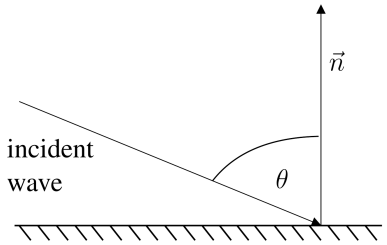

Figure 1. Definition of the incidence angle of a wave on a surface θ.

As a distiction between specular and diffuse reflection of the wave on the hit surface is important for radar simulations, the roughness is included in the dataset. Using the Rayleigh criterion defined in [4], the minimum incidence angle to have specular reflection can be calculated. Besides the roughness, it depends on the wavelength or respectively on the frequency.

4 Final material files

Modern automotive radar sensors commonly use the 77 GHz band, so the integrated data was recorded for this band. The values, which are additionally implemented in the database, have been determined with an open space measurement setup that is described in [5]. The measurements itself as well as some extra measurements with qualitative behaviour observations have already been published as well and can be found in [6]. Here permittivity and roughness were determined. For completeness the conducted measurement results of all investigated road surfaces have been published in this source. However, with the remark that the results for the open-pored surfaces have to be checked due to difficulties to apply the setup because of an underestimated roughness. This is the reason, why only asphalt concrete, split mastix asphalt with a maximum grain size of 8mm and respectively 11mm, concrete installed as factory made plate and concrete installed using broom finish technique are included in the dataset. All these road surfaces are commonly used for highways. To have a complete set of the main surface types, the open-pored surfaces meaning very silent roads have to be added. The data is remarked with the environment temperature during the measurements (280-283K), the measurement frequencies (77-81GHz) and the incidence angle of the wave (78°). The corresponding publications are recorded as well.
These files are available from the end of January 2022 in the subfolder "materials" of the github repository in [3].

5 Conclusion

We extended the open source dataset OpenMATERIAL collecting physically based material data for automotive applications. For this purpose, we defined and implemented parameter, which are important for radar simulations. Furthermore, we created data files for 5 different road surface types containing before determined values of permittivity and roughness in the automotive 77 GHz band. These files are available on github by the end of January 2022. In future the database shall be enhanced with further scientifically analysed material data for automotive applications.

References

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