Project Proposal Summary Sheet

Project Number	**P_2023_05**
Project name	ASAM OpenMATERIAL
Domain	Simulation
Impacted standard(s)	ASAM OSI, ASAM OpenSCENARIO, ASAM OpenDRIVE
Project type	Standard development
Start date	01.02.2024
End date	30.01.2025
TSC Submission:	Nov 24, 2023
Proposer(s)	Clemens Linhoff, Persival
ASAM Office Responsible (OR)	Diego Sanchez
Initiating Companies	BMW Kanagawa Institute of Technology V-Drive Technologies BIPROGY Mitsubishi Precision Company Persival
ASAM funds	
Backwards Compatibility	If applicable, indicate to which prior version this release is backward compatible. N/A

For more information on the ASAM project process and the proposal phase in particular, please refer to the ASAM Project Guide.

1 Executive Summary

To achieve a founded safety argumentation for ADAS functionality it is critical to ensure accurate and consistent data across all test environments and techniques being applied.

Previously, simulation was strongly limited by compute capacities, with implementations designed for low memory and compute requirements, often with a visually plausible representation docked on. Physical correctness in the visual representation of those geometries was not fundamental. Simulation was mostly applied during early development, where physically accurate modelling was not always a necessity.

With increasing compute power and more efficient simulation methodologies, virtual testing plays a stronger role throughout all phases of system development. This correlates to a growing need to accurately represent the real world in simulation, a so-called digital twin, particularly as the need for physical sensor simulation grows. However, for this to be feasible, physically correct modelling of material properties is fundamental. To ensure consistent testing across platforms and by different stakeholders, 3D models and corresponding material properties need to be unambiguously exchangeable. The latter must be determined (measured) in a consistent process. It is proposed to develop a standardized format for material properties.

Material properties need to be associated with the 3D models for which they are relevant. Such a model must have a standardized semantic structure, with all information necessary to accurately represent it across different tools and workflows. This project proposes to define a suitable standardized format that represents all information necessary for the use cases defined herein.

The simulation toolchains in the automotive industry today are shifting to modular, distributed architectures. Accurate exchange of information across the various subsystems and models in a framework is critical. It is proposed to extend the definition of Sensor Views in the Open Simulation Interface with the respective material properties defined in this project.

The outputs of this project are an important step towards physically correct simulation. For a fully accurate simulation it is also deemed necessary to accurately represent weather and environmental effects, such as rain, fog or other particulates. These effects are out of scope for this proposal and will be addressed in future initiatives.

2 Overview

2.1 Motivation

Accurate sensor simulation that can replicate physical phenomena is necessary for safety evaluation of AD/ADAS in virtual space.

However, previous simulations were heavily limited by computational power and available memory, and while they appeared visually believable, they were not physically accurate. As a result, previous simulations were primarily used during the early stages of development, where precise physical modeling was not necessarily required.

With increased computing power and streamlined simulation techniques, virtual testing plays a more powerful role at all stages of system development. This correlates with the growing need to accurately represent the real world in simulations, so-called digital twins, especially as the need for physical sensor simulation increases.

One fundamental step to describing the real world virtually is a full physical description of all objects. This includes their material properties, their geometries, and also other environmental effects. To ensure a focused scope, this project will target material property and geometry definition. Additional initiatives will be necessary to address other aspects needed for the definition of a digital twin.
It is extremely important to standardize the representation of data and attributes, such as scenarios, road data, and ASSET data, necessary for AD/ADAS simulation in order to promote the circulation of these data and to obtain consistent results among different systems.
Here, road data is the geometry data of objects such as roads, lanes, and road markers on roads. ASSET data is 3D geometric shape data of road surfaces, surrounding structures, and traffic participants such as vehicles.
Standardization activities have been conducted for scenarios and road data using OpenSCENARIO, OpenDRIVE, OpenCRG, and other standards. It is also necessary to advance standardization for ASSET data and their attribute data.

Therefore, we propose "OpenMATERIAL", an ASSET data format (or formats) that retains various information required for AD/ADAS simulation.

2.2 Use-cases

Here are some typical use cases for ASSET data preparation for AD/ADAS simulation:

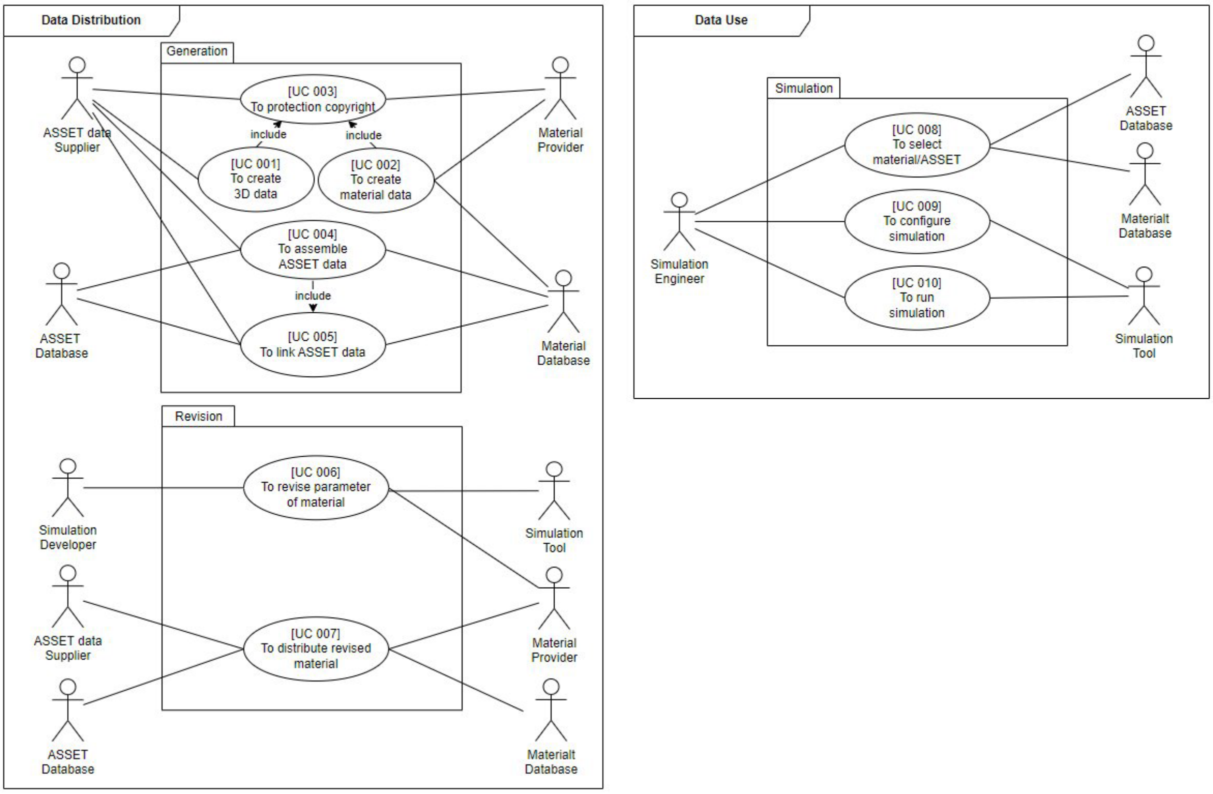

Fig1: Use Case diagram

ID	Description	Type [Business or Technical]
001	To create 3D data	Business Use-Case
002	To create material data	Business Use-Case
003	To protection copyright	Business Use-Case
004	To assemble ASSET data	Business Use-Case
005	To link ASSET data	Business Use-Case
006	To revise parameter of material	Technical Use-Case
007	To distribute revised material	Business Use-Case
008	To select material/ASSET data	Business Use-Case
009	To configure simulation	Technical Use-Case
010	To run simulation	Technical Use-Case

ID	001	Type	Business Use-Case
Title	To create 3D data		
description	Create new 3D data. Create 3D data by 3D shape modeling and 3D measurement.		
Actors	ASSET data supplier.		
Notes			
Mapping	-		

ID	002	Type	Business Use-Case
Title	To create material data		
description	Create new data such as material properties. The created attribute data is stored in the material database as needed.		
Actors	Material provider.		
Notes			
Mapping	-		

ID	003	Type	Business Use-Case
Title	To protection copyright		
description	Protect the copyright of the created 3D data and attribute data.		
Actors	Component supplier, Material provider.		
Notes			
Mapping	-		

ID	004	Type	Business Use-Case
Title	To assemble ASSET data		
description	Link 3D data and attribute data to build part data. The created part data is stored in the parts database as needed.		
Actors	ASSET data supplier		
Notes			
Mapping	-		

ID	005	Type	Business Use-Case
Title	To link ASSET data		
description	Refer to existing 3D data and material data. In order to construct part data, refer (link) to existing 3D data and material data.		
Actors	ASSET data supplier		
Notes			
Mapping	-		

ID	006	Type	Technical Use-Case
Title	To revise parameter of material		
description	Add parameters such as material properties. Parameters added by adding functions such as sensor models and simulators.		
Actors	Simulation developer, Material provider		
Notes			
Mapping	-		

ID	007	Type	Business Use-Case
Title	To distribute revised material		
description	Distribute material data with added parameters.		
Actors	ASSET data supplier, Material provider		
Notes			
Mapping	-		

ID	008	Type	Business Use-Case
Title	To select material/ASSET data		
description	Select the part data and material data required for the simulation.		
Actors	Simulation Engineer		

Notes	
Mapping	-

ID	009	Type	Technical Use-Case
Title	To configure simulation		
description	Perform various settings necessary for simulation.		
Actors	Simulation Engineer		
Notes			
Mapping	-		

ID	010	Type	Technical Use-Case
Title	To run simulation		
description	Run the simulation.		
Actors	Simulation Engineer		
Notes			
Mapping	-		

2.3 Requirements, user stories, features or issues

The requirements for this data structure are as follows:

ID	**Description**	**Related Use Cases (IDs)**
1	Material property data must enable sensor simulation, such as cameras, lidars, millimeter-wave radars, and ultrasonic sensors.	002、004、005、006、008
2	Data structures, including material properties, must be easily extensible to allow for future properties to be added.	002、004、005、006
3	A data structure that can share existing data such as 3D shape data and measured material property data is desirable.	001、002、004、005
4	The created ASSET data must be a data structure that holds the data description so that it can be searched.	005、007
5	3D shape data, measured material property data, etc. must have a data structure that can be copyrighted if necessary.	003

2.4 Relations to other standards, or organizations

- Standards

- ASAM OpenSCENARIO – it may be necessary to reference 3D models with corresponding material properties from a scenario description. Often edge cases may occur as materials change, for example different clothing textures or patterns may lead to issues. Alignment with OpenSCENARIO will take place to determine needed additions to the standard
- ASAM OpenDRIVE/OpenCRG – 3D models with corresponding material description (e.g. road surfaces and road markings) will require additions to these standards
- ASAM OSI – An extension to this standard will be developed to add compatibility with referenced 3D models and corresponding material properties. Referencing of 3D models may be based on the existing “model_reference” field in the OSI::GroundTruth message. Other extensions and alignment may be required for further topics.

- Organizations
  - ISO

    As the automotive industry shift their attention into simulation, ISO also starts the standardization of simulation. At the online vote that has held in June 2023, it has formally decided to set up an ISO 11010-2 committee on sensor models for AD/ADAS chaired by Dr. Rainer Aue of Continental. At the time of voting, a comment that "when applying the physical sensor model, describing method of the object reflectance such as OpenMATERIAL of ASAM will be required." is added from Japan.

2.5 Other projects and corporation involved

- Project
  - VIVALDI

    Together with the VIVALDI project in Germany, VIVID has launched a joint project to realize international autonomous driving and safety assessments, and is exchanging various information including material data.
  -
- Corporation
  - Japan OEM Manufacturers

    Three Japanese OEM manufacturers are experimenting with sophisticated sensor simulations using material measurement data.

3 Technical content

This chapter provides an overview of the proposed OpenMATERIAL data structure.

3.1 Data contents

To achieve the goal of obtaining consistent test results among all stages of AD/ADAS simulation (rendering, sensor simulation, autonomous driving, and result validation) and across different systems, OpenMATERIAL aims to standard data structure for ASSET. Therefore, it is necessary to include not only 3D data and accompanying material characteristic information but also information relevant to AD/ADAS simulation related to the ASSET in the structure.

As examples of data types to include in this structure, the following are listed.

- 3D Shape data
  3D geometric information such as polygons and basic animation information such as bones.
- Material parameters
  Material properties data associated with 3D shapes.
- Parts behavior information
  Behavior information of parts in ASSET.
- Part semantic information
  Semantic information of ASSET components.
- Data description information
  Data feature information.

"Part semantic information" refers to the metadata of the elements within the file. This metadata includes various attributes of the components, such as the part type, coordinates, orientation, and color. This enables the system to read the semantic information of the components from the ASSET file and understand the meaning corresponding to each element.

After the creation of ASSET data, information about the content of the data can be obtained from meta data, , e.g. license and copyright information.

3.2 Data Structure

Among the contents data mentioned above, "material parameters,", are likely to include data obtained by measuring physical phenomena for the purpose of conducting physical simulations. Generally, such measurement data consists of tables of tens of thousands of rows and it is not practical to include all material measurement data in a single ASSET data file from a maintainability and data size perspective. The same applies to 3D shape data, and by adopting a separate file structure, it becomes possible to share data among multiple ASSET data files.
In OpenMATERIAL, it is also possible to separate 3,D shape data and associated material property data into a separate file structure from the ASSET file.

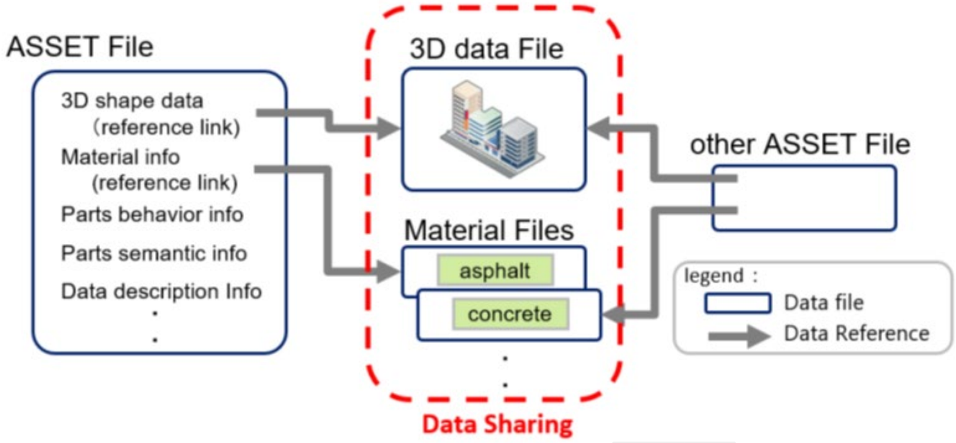

Fig1: Data Structure.

3.3 3D data structure and associating with material data.

As mentioned earlier, in OpenMATERIAL, it is possible to separate ASSET files and 3D shape files. In that case, we do not specify the format of the 3D shape file. The format must be a general scene graph structure where each node that becomes a hierarchical structure has a node name and information such as material name and UV information can be added to those nodes.

Material characteristic data needs to be associated with the target 3D model. If 3D shape data files and material data files are separated from the ASSET data in the manner shown in Figure 1, within the ASSET data file, the 3D shape data and material data will only be in the form of link information to external files. In this case, the association between the 3D shape and material information can only be done by linking the material name set in the 3D shape and the material name declared in the material data.

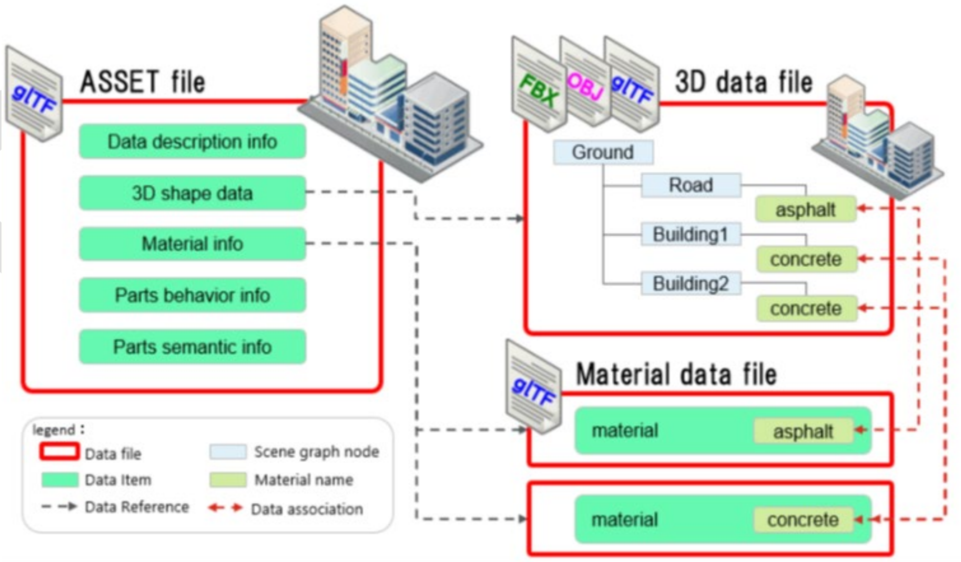

Fig2: 3D data structure and associating with material data

3.4 Target data model.

The virtual space seen from the camera / LiDAR / radar / ultrasonic sensor to be simulated is modeled and further classified as follows.

- Environmental model
  1. ① Target objects: Traffic participants such as cars and people.
  2. ② Surrounding structures: fixed objects that make up the city.
  3. ③ Road surface: road surface

- Environmental conditions
  4. ④ Space: Light source, rain/fog/snow, etc.
  5. ⑤ Interface: The interface between the sensor and space. Raindrops, dirt, etc. on the sensor surface.

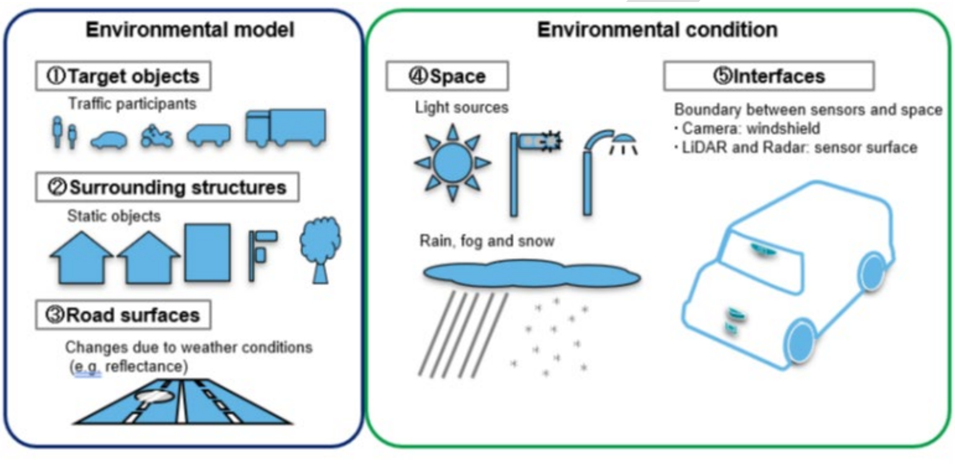

Fig3: Virtual space seen from sensors.

Considerations for "Environmental conditions" will be excluded from the scope of this project at the beginning stage and will be addressed in the future.

3.5 Approximate computing model in space rendering.

In order to conduct safety assessments of autonomous driving systems in a virtual environment, it is essential to have a physically replicable sensor malfunction simulation to accurately simulate the behavior of reflections, diffusions, refractions, and diffractions of each wavelength used by the sensors. This requires the numerical solution of Maxwell's equations (FDTD, FEM, MoM, etc.), but this method requires a significant amount of calculation time and is mostly used for research purposes. As an alternative, the geometrical optics approximation, and physical optics approximation, which represent the propagation of electromagnetic waves by light rays, are widely used.
This proposal suggests a data structure that does not rely on a specific approximation calculation model, but the initially defined model parameters are assumed to be based on the geometrical and physical optics approximations.

3.6 Model parameter

Parameter values for the Environmental model are variables required for the aforementioned approximation calculations. Some parameters may refer to external measurement data tables, and the content of those data tables may differ depending on the sensor, even if the parameters

are the same. Therefore, the parameter definitions are common to all sensors, but the actual parameters are maintained separately for each sensor.
Furthermore, the model parameters need to flexibly respond to the expansion of the target sensor and the approximate calculation method, and a data structure that maintains expandability is required.

Example of Environmental model parameters

- Measured reflectance data (Measurement data table. e.g., angle of incidence and reflection, amplitude/phase, and amplitude by wavelength)
- Complex refractive index by wavelength
- Transparency
- Resistivity
- Relative permittivity
- Relative permeability

4 Project resources

Prior to approving a project proposal, ASAM needs to ensure that the relation between project scope, the corresponding resource requirements and the manpower being committed by participants are comparable. This section allows such an evaluation to be performed.

All information for project resources can be found in the accompanying Excel file.

Filename/URL:

5 Deliverables

At the end of the project, the project group will hand over the following deliverables to ASAM:

Item No.	Description
1	OpenMATERIAL specification • OpenMATERIAL purpose and vision • ASSET specification • Material file format specification
2	Sample data

5.1 Review Process

The process for deliverable review documented in the project guide is applicable to all projects (see here).

The ASAM OR will provide further details on quality criteria and tools used prior to the initiation of a review in a project.

Please indicate whether the project is aiming to perform an ASAM member review or a full public review. This is not required for maintenance projects.

Public Review

6 References

Provide a list of documents and their authors that are referenced in earlier chapters. Use the sequential number in squared brackets for referencing them in earlier chapters.

See guidance on References in the [ASAM Editorial Guide]

Appendix: