ASAM OpenMATERIAL® 3D 1.0.0

Release Presentation

ASAM Working Group

Apr, 03, 2025

ASAM Association for Standardization of Automation and Measuring Systems

Agenda

1	Introduction
2	Motivation for New Release
3	Features
4	QC Framework Rules
5	Backward-Compatibility
6	Relation to Other Standards
7	Deliverables
8	Outlook

Introduction

As the automotive industry moves closer to full autonomy, the demand for realistic simulations of the real world, or "digital twins," is more critical than ever. Accurate sensor simulations require a physically precise representation of the environment, including material properties. To meet this challenge, we have developed ASAM OpenMATERIAL 3D.

ASAM OpenMATERIAL 3D is a newly developed ASAM open-source standard that aims at enhancing the realism of sensor simulations. The standard focuses on two key objectives:

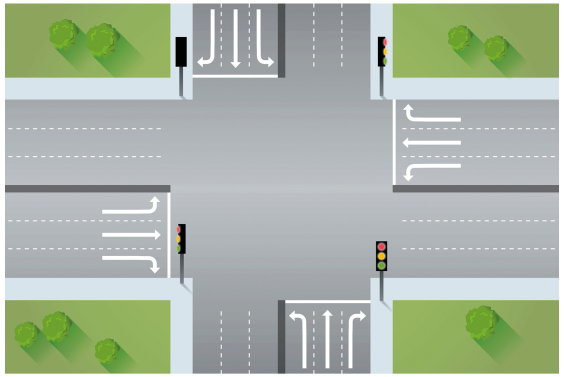
- Defining **physical material properties:** Material properties are stored in dedicated material files that can be linked to 3D geometries. This allows simulations to more accurately reflect real-world behavior for different sensor technologies.
- Standardizing **3D model hierarchy and structure** without creating new formats: ASAM OpenMATERIAL 3D establishes consistent frameworks for elements like coordinate systems and movable parts, making it easier to use existing 3D assets across different simulations.

By integrating standardized material properties and 3D structures, the standard improves the exchangeability and accuracy of perception sensor simulations. This will help generate realistic outputs for lidar, radar, and camera systems, critical for testing and the development of advanced perception algorithms.

Motivation

ASAM OpenX Universe

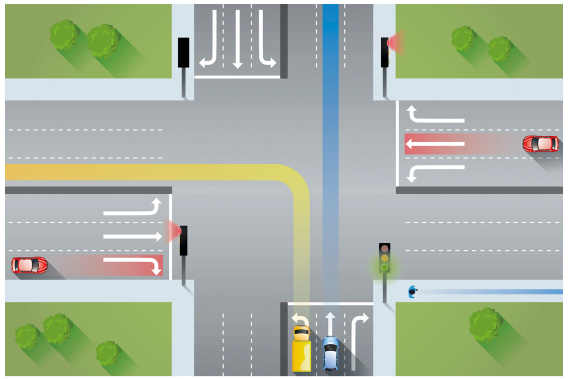
ASAM OpenDRIVE®



Static road network description

Where are we driving?

ASAM OpenSCENARIO®



Dynamic scenario description

What are dynamic elements doing?

ASAM OSI®

Interface for simulation

How to transfer information between models?

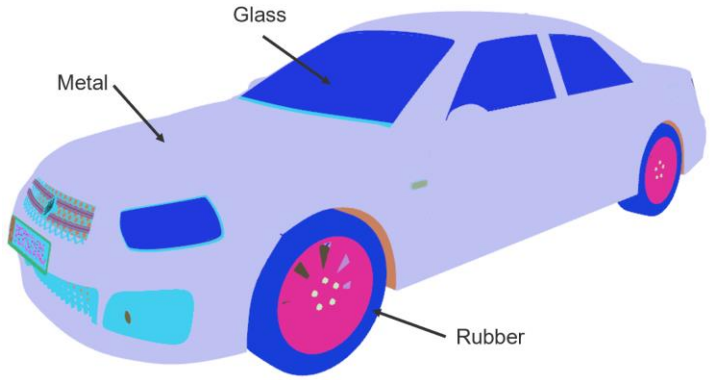
?

What does the environment look like (to perception sensors)?

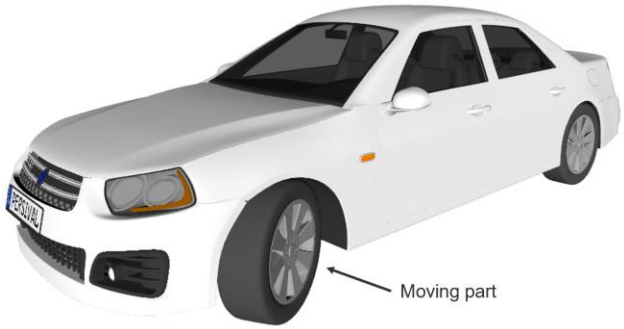
Motivation

Exchangeable 3D assets with materials

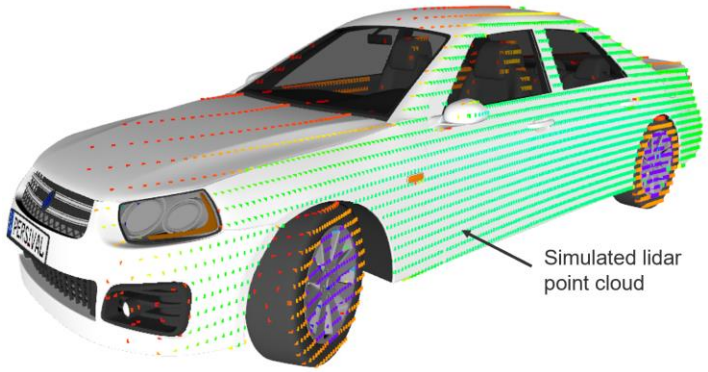
- 3D assets



- Define physical material properties
- Assign materials to 3D geometry



- Define hierarchy and structure
- Coordinate systems of moving parts



- Enable perception sensor simulation

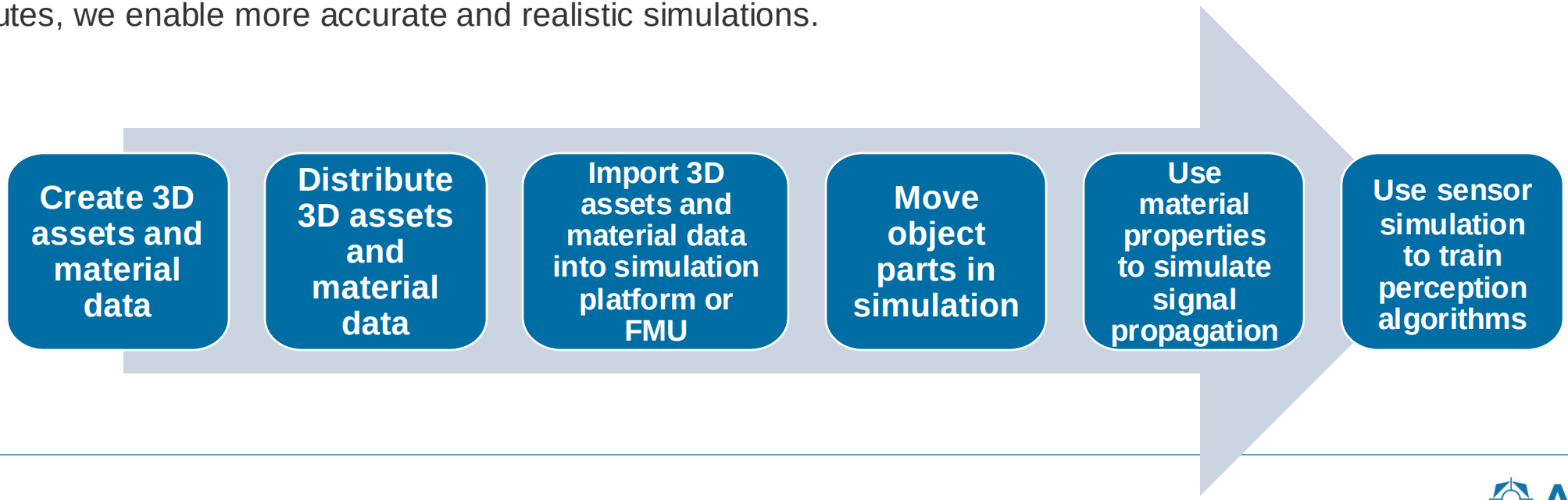
Motivation

Use-cases

Accurate sensor simulation relies on high-quality 3D assets with well-defined material properties. However, the lack of standardization in 3D model structures and material descriptions creates inconsistencies across simulation platforms.

As sensor simulation becomes increasingly vital in the development and validation of autonomous systems, a major challenge remains: ensuring standardized, high-quality 3D assets and material definitions that can be seamlessly integrated across various simulation environments.

Our standard addresses this need by defining structured 3D models and physical material properties for perception sensor simulation. By standardizing how 3D assets are created, shared, and applied, including defining material attributes, we enable more accurate and realistic simulations.



Features

Overview

ASAM OpenMATERIAL 3D has two distinct parts, that may be used independently from another.

Geometry Features

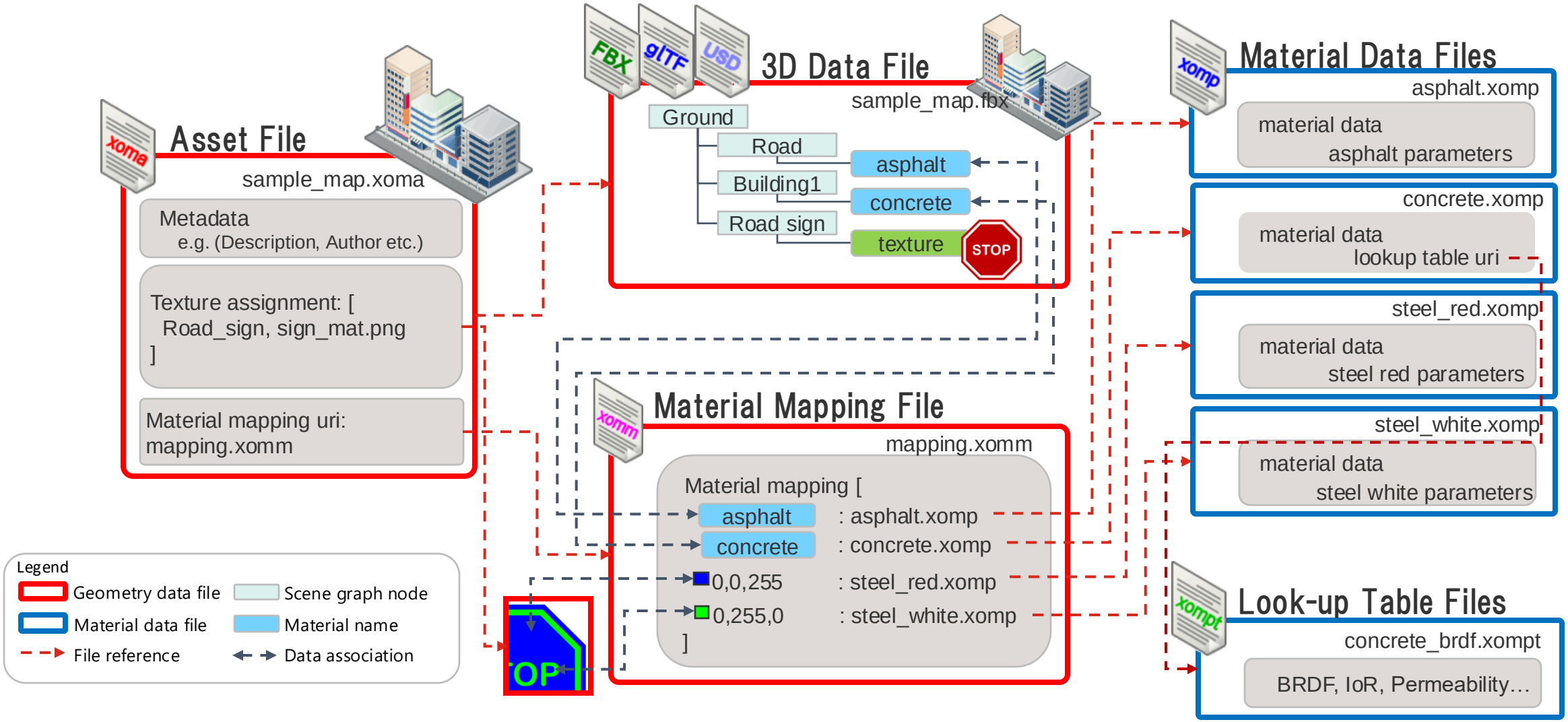
- Node hierarchies in 3D models for vehicles, humans and environment
- Defined coordinate frames for objects and object parts
- Two material mapping mechanisms
  - Map ASAM OpenMATERIAL 3D material property files to material names assigned in the 3D model
  - Map ASAM OpenMATERIAL 3D material property files to RGBA codes in dedicated material assignment textures

Material Features

- Physical material properties
- Wavelength dependent material properties
- BRDF lookup tables enabling to store measured data

Features - Overview

File Structure



Features - Overview

File Formats

A fundamental concept of ASAM OpenMATERIAL 3D model structure is the **separation of 3D geometry, metadata and material information**:

- A **3D Data File** (a 3D model, e.g., in format **USD/FBX/glTF**), is complemented by an **Asset File (file ending .xoma)** with the same name.
- This Asset File comprises meta data (e.g., details and information about the asset), but also a reference to a **Material Mapping File (file ending .xomm).**
- The Material Mapping File maps material names or RGB codes to **Material Property Files (file ending .xomp).**
- Material Property Files comprise material data and references to **Material Property Lookup Tables (file ending .xompt)** containing wavelength dependent properties or measurement data.

Features - Geometry

Vehicle Model Node Structure

- Defined node hierarchy in 3D model
- Naming conventions to identify parts for animation in simulation, e.g.,
  - Doors
  - Lights
  - Wheels
  - Mirrors
- Facilitate different kinds of vehicles for multiple use-cases

(T) : Transform / Node-Specific Coordinate Frame

- Grp_Root
  - Grp_Exterior
    - Grp_Exterior_Dynamic
      - Grp_Convertible_Top
      - Grp_Door_Bottom_<door_bottom_idx> (T)
      - Grp_Door_Front_<door_front_idx> (T)
      - Grp_Door_Left_<door_left_idx> (T)
        - Grp_Mirror_Blindspot_Mounting_<blindspot_mirror_mounting_idx> (T)
          - Grp_Mirror_Blindspot_Joint_<blindspot_mirror_joint_idx> (T)
            - Grp_Mirror_Blindspot_View_<blindspot_mirror_view_idx> (T)
        - Grp_Mirror_Side_Mounting_Left_<side_mirror_mounting_left_idx> (T)
          - Grp_Mirror_Side_Joint_Left_<side_mirror_joint_left_idx> (T)
            - Grp_Mirror_Side_View_Left_<side_mirror_view_left_idx> (T)
      - Grp_Door_Rear_<door_rear_idx> (T)
      - Grp_Door_Right_<door_right_idx> (T)
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      - Grp_Door_Top_<door_top_idx> (T)
      - Grp_Hitch_Front (T)
        - Grp_Hitch_Front_Contact_Point (T)
      - Grp_Hitch_Rear (T)
        - Grp_Hitch_Rear_Contact_Point (T)
      - Grp_License_Plate_<license_plate_idx> (T)
      - Grp_Light_Brake_Center_<brake_center_idx> (T)
      - Grp_Light_Brake_Left_<brake_left_idx> (T)
      - Grp_Light_Brake_Right_<brake_right_idx> (T)
      - Grp_Light_Corner_Left_<corner_left_idx> (T)
      - Grp_Light_Corner_Right_<corner_right_idx> (T)
      - Grp_Light_Day_Left_<day_left_idx> (T)
      - Grp_Light_Day_Right_<day_right_idx> (T)
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          - Grp_Mirror_Side_View_Right_<side_mirror_view_right_idx> (T)
      - Grp_Rear_Axle_Center (T)
      - Grp_Wheel_<axle_idx>_<wheel_idx> (T)
        - Grp_Wheel_Steering_<axle_idx>_<wheel_idx> (T)
        - Grp_Wheel_Steering_Rotating_<axle_idx>_<wheel_idx> (T)
    - Grp_Exterior_Static
  - Grp_Interior
    - Grp_Interior_Dynamic
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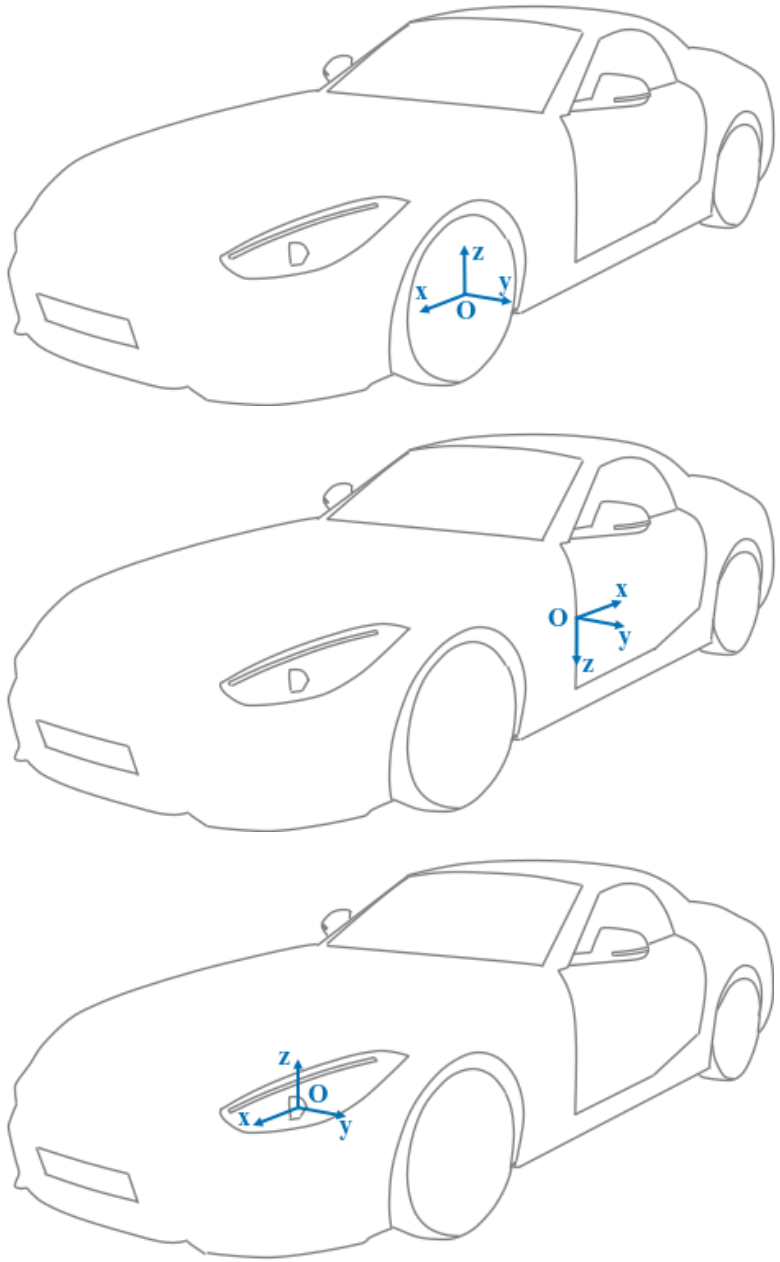
        - Grp_Mirror_Rearview_Joint_<rearview_mirror_joint_idx> (T)
          - Grp_Mirror_Rearview_View_<rearview_mirror_view_idx> (T)
      - Grp_Seat_<seat_row>_<seat_idx> (T)
      - Grp_Steering_Wheel (T)
    - Grp_Interior_Static
  - Grp_Vehicle_Part (T)

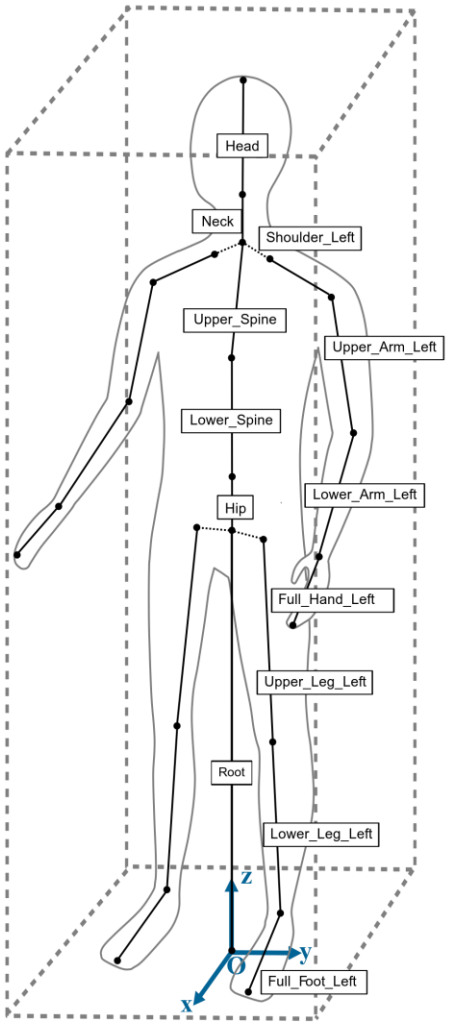


Features - Geometry

Human Model Node Structure

- Defined node hierarchy and armature bone structure
- Naming conventions for bones to enable consistent movement of humans in simulation

- Grp_Root
  - Armature_<Name>
    - Root
      - Hip (T)
        - Lower_Spine (T)
          - Upper_Spine (T)
            - Neck (T)
              - Head (T)
                - Eye_Left (T)
                - Eye_Right (T)
            - Shoulder_Left (T)
              - Upper_Arm_Left (T)
                - Lower_Arm_Left (T)
                  - Hand_Left (T)
                    - Full_Fingers_Left (T)
                    - Full_Thumb_Left (T)
            - Shoulder_Right (T)
              - Upper_Arm_Right (T)
                - Lower_Arm_Right (T)
                  - Hand_Right (T)
                    - Full_Fingers_Right (T)
                    - Full_Thumb_Right (T)
          - Upper_Leg_Left (T)
            - Lower_Leg_Left (T)
              - Foot_Left (T)
                - Full_Toes_Left (T)
          - Upper_Leg_Right (T)
            - Lower_Leg_Right (T)
              - Foot_Right (T)
                - Full_Toes_Right (T)
      - Accessories_<Name>
      - Body_<Name>
      - Clothing_<Name>
      - Hair_<Name>



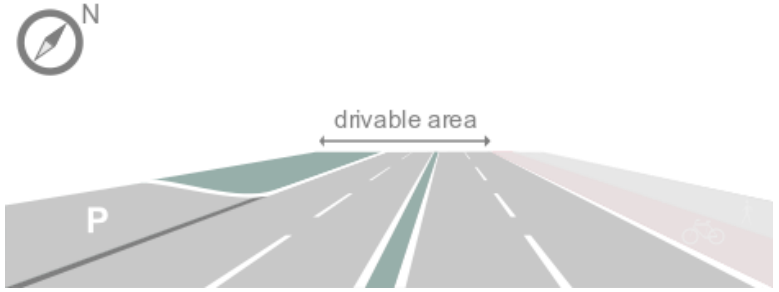
(T) : Transform / Node-Specific Coordinate Frame

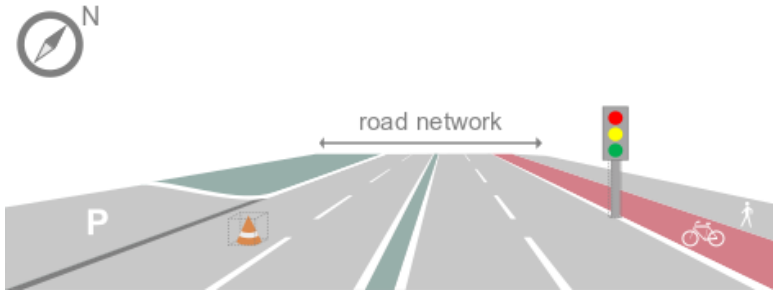
Features - Geometry

Environment Model Node Structure

- Defined node hierarchy in 3D model
- Naming conventions to identify parts for animation or labeling, e.g.,
  - Buildings
  - Vegetation
  - Roads
  - Signs

- Grp_Root
  - Grp_Terrain
  - Grp_Environment_Objects
    - Grp_Buildings
    - Grp_Vegetation
  - Grp_Road_Network
    - Grp_Drivable_Area
    - Grp_Sidewalks
    - Grp_Road_Marks
    - Grp_Road_Objects
    - Grp_Signals
      - Grp_Sign_<signal_idx> (T)
      - Grp_Traffic_Light_<signal_idx> (T)





(T) : Transform / Node-Specific Coordinate Frame

Features - Geometry

Material Mapping and Assignment

Two ways to assign ASAM OpenMATERIAL 3D material properties to a 3D model

1. Assign a material name contained in a 3D model to a Material Property File (.xomp)
2. Assign a value in a dedicated ASAM OpenMATERIAL 3D assignment texture to a Material Property File (.xomp)

Mapping

- Material mapping is stored in separate Material Mapping File (.xomm)
- Material textures are referenced within the Asset File (file ending .xoma)

Excerpt from asset file (xoma)

```
"materialTextureAssignment": [
    ["example_material_name", "example_texture.png"]
  ]
```

Excerpt from mapping file (xomm)

```
"materialMapping": [
    ["material_red", "materials/material_a.xomp", "metal with red paint"],
    ["rgba:10;50;255;127", "materials/material_a.xomp", "metal with red paint"],
    ["material_green", "materials/material_b.xomp", "metal with green paint"],
    ["material_blue", "materials/material_c.xomp", "metal with blue paint"]
  ]
```

Features - Material

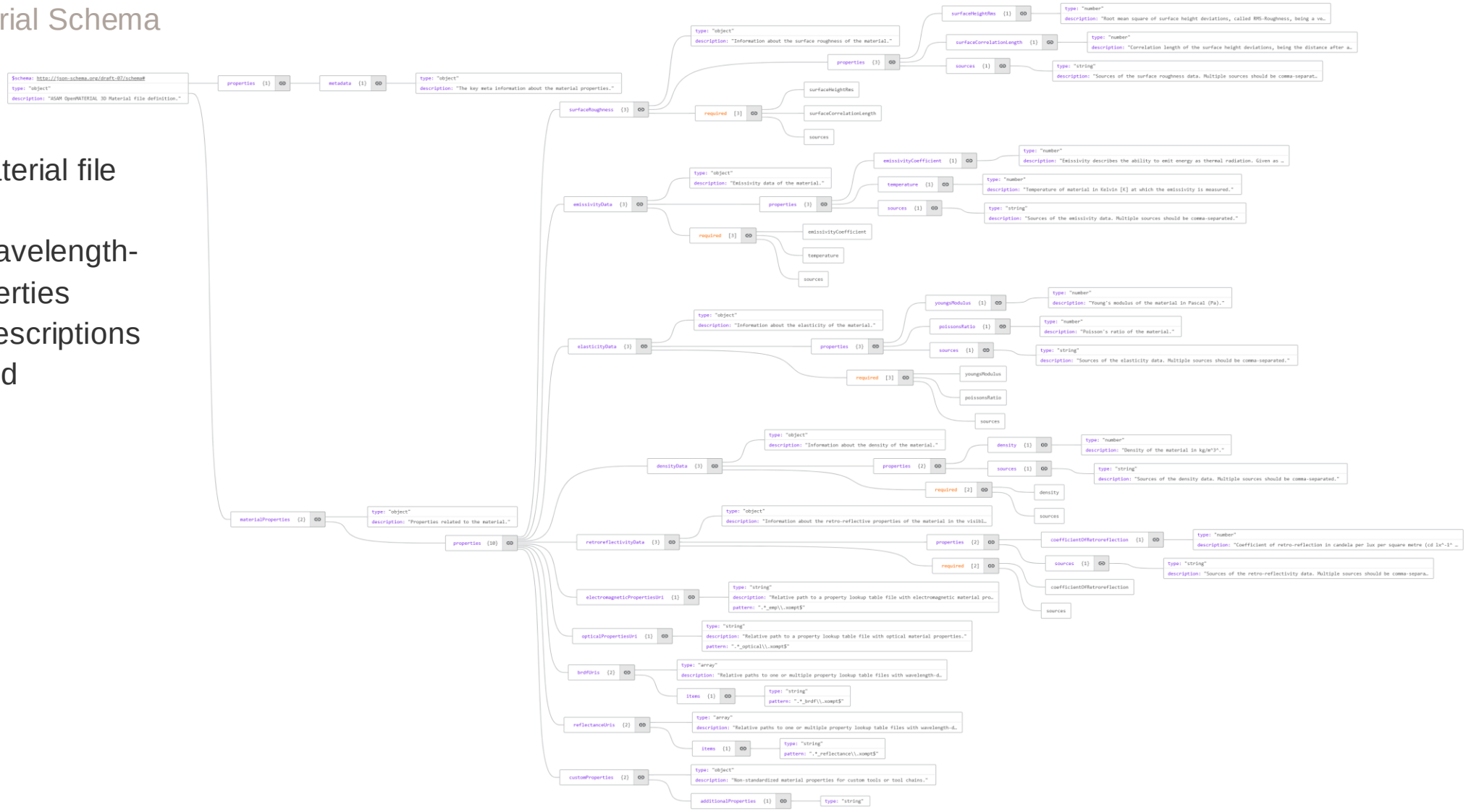
File Structure

- Invariant material properties are stored in **Material Property Files (.xomp)** in JSON format.
- Physical properties focus on **surface properties** to support modeling of perception sensors but also contain some **volumetric properties** of materials, e.g., elasticity (Youngs Modulus, Poisson ratio) and density.
- Material properties that depend on variables (e.g., wavelength, temperature, angle) are stored in separate **Material Property Look-Up Tables (.xompt)**:
  - Electromagnetic properties
  - Optical properties
  - BRDFs (bidirectional reflectance distribution function)
  - Reflectance tables
- Material Look-Up Tables are referenced in Material Property Files in JSON format.
- Both file types also contain metadata section with information about copyright, author, origin, etc.

Features - Material

File Content - Material Schema

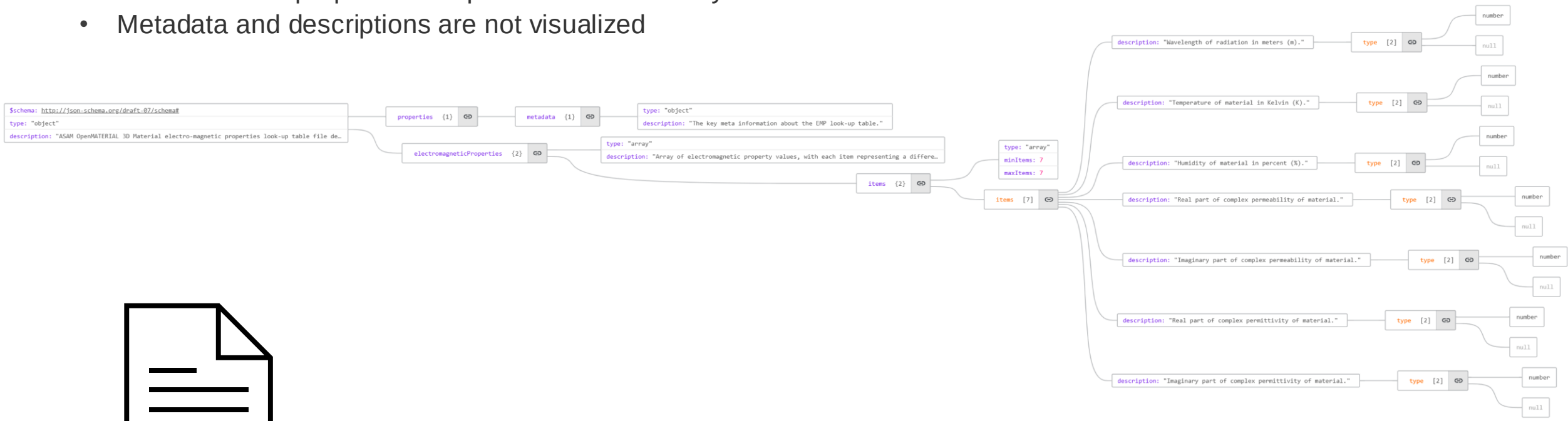
- Overview of material file content
- Physical, non-wavelength-dependent properties
- Metadata and descriptions are not visualized



Features - Material

File Content - Electromagnetic Properties Schema

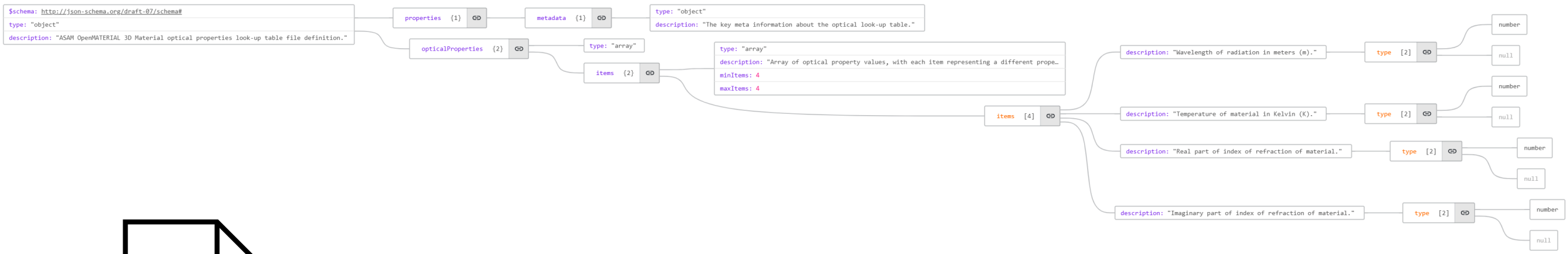
- All properties are defined with respect to wavelength
- Environmental properties temperature and humidity can be included
- Metadata and descriptions are not visualized

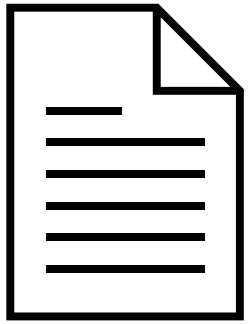


Features - Material

File Content - Optical Properties Schema

- All properties are defined with respect to wavelength
- Environmental properties temperature and humidity can be include
- Metadata and descriptions are not visualized

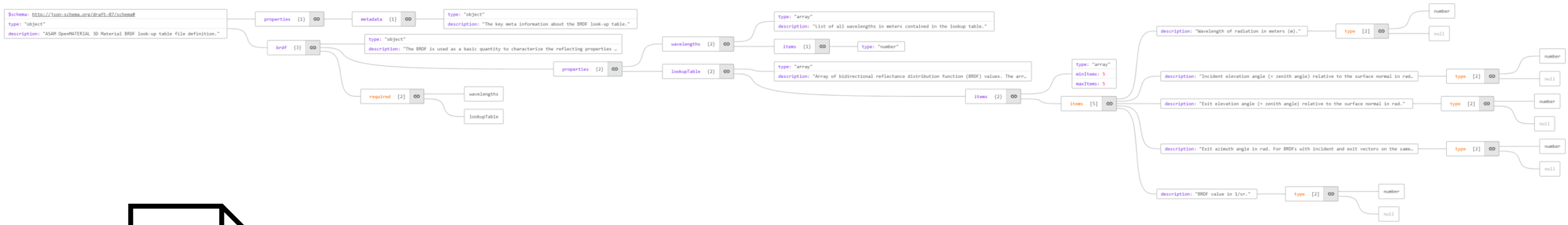


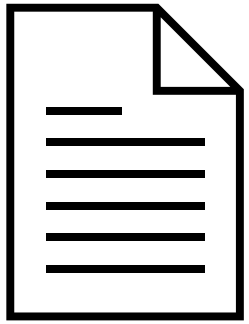


Features - Material

File Content - BRDF Schema

- All properties are defined with respect to wavelength
- Metadata and descriptions are not visualized

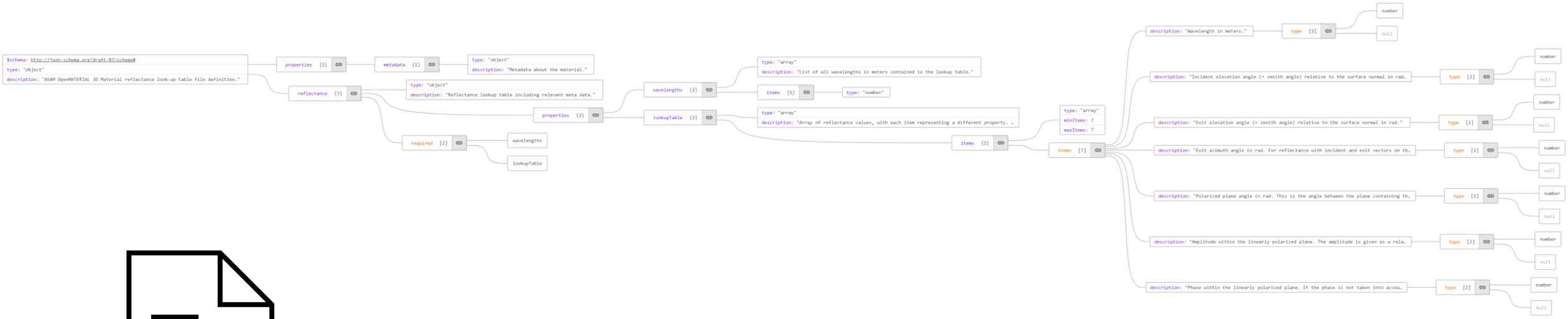


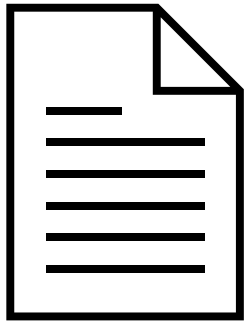


Features - Material

File Content - Reflectance Schema

- All properties are defined with respect to wavelength
- Metadata and descriptions are not visualized





QC Framework Rules

- ASAM OpenMATERIAL 3D Checker Bundle: asam-ev/qc-openmaterial-3d at v1.0.0-rc1
- Rule definitions for ASAM Quality Checker Framework
- Naming schema harmonized with other ASAM standards: <emanating-entity>:<standard>:x.y.z:rule_set.rule_name
- Three standard short strings
  - `xom`: General rules applicable for both parts or not categorizable because they are in-between.
  - `xom-geo`: Rules that only apply to the geometry part of ASAM OpenMATERIAL 3D.
  - `xom-mat`: Rules that only apply to the material part of ASAM OpenMATERIAL 3D.

Examples

- asam.net:xom:1.0.0:general.valid_json_document
  ASAM OpenMATERIAL 3D files with the file extensions .xoma, .xomm, .xomp, or .xompt shall be valid JSON documents.
- asam.net:xom-geo:1.0.0:xoma.vehicle_class_data_defined
  If an asset is of type 'vehicle', the property 'vehicleClassData' must be set in the metadata.
- asam.net:xom-mat:1.0.0:xomp.surface_height_rms_valid_range
  The surface height root mean square in meters (m) shall not be below 0.

Backward compatibility

This is the first release of this standard published by ASAM. Therefore, no information about the backward compatibility of this standard has been added to this section.

Relation to other standards

ASAM OpenDRIVE

- Object class "Environment" allows the definition of a 3D environment that aligns with an ASAM OpenDRIVE map.

ASAM OpenSCENARIO XML

- Asset file (.xoma) of a 3D environment shall be linked in ASAM OpenSCENARIO XML using the SceneGraphFile property
- Asset files (.xoma) of individual objects, such as vehicles, shall be linked using the model3d property.

ASAM Open Simulation Interface

- Asset file (.xoma) of a 3D environment shall be linked in ASAM OSI using the GroundTruth::model_reference
- Asset files (.xoma) of individual objects, like vehicles, shall be linked with the MovingObject::model_reference or the StationaryObject::model_reference

Deliverables

Documents

- ASAM OpenMATERIAL 3D BS 1.0.0 Specification, 2025-04-03 :: ASAM OpenMATERIAL® 3D

Checker Bundle

- ASAM OpenMATERIAL 3D Checker Bundle: asam-ev/qc-openmaterial-3d at v1.0.0-rc1

Supplementary Files

- ***JSON schema*** files for all JSON formats
- ***Example files*** for all defined file formats (contained in the ASAM OpenMATERIAL 3D Github repository) and further examples of
  - a ***vehicle*** (contained in the ASAM OpenMATERIAL 3D Github repository)
  - a ***human*** (contained in the ASAM OpenMATERIAL 3D Github repository)
  - an ***environment*** (contained in the ASAM OpenMATERIAL 3D Github repository)

Outlook

General

- Consider ASAM OpenSCENARIO DSL use-cases
- Further develop ASAM OpenMATERIAL 3D checker bundle for ASAM QC Framework

Geometry

- Define more object classes, e.g., animals, trains, buildings, vegetation etc.
- Define more complex vehicles, e.g., excavators to facilitate off-road domain
- Introduce level of detail to assets
- Enable instancing of assets

Material

- Add more volumetric properties to facilitate off-road simulation
- Layered materials ("composite material file")
- Emissive materials
- Material classification for RGBA channels

Thank you!

GitHub Repository:
ASAM OpenMATERIAL 3D

If you have any questions, contact us here:
info@asam.net