Disclaimer

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1. Foreword

ASAM e.V. (Association for Standardization of Automation and Measuring Systems) is a non-profit organization that promotes standardization of tool chains in automotive development and testing. Our members are international car manufacturers, suppliers, tool vendors, engineering service providers, and research institutes. ASAM standards are developed by experts from our member companies and are thus based on real use cases. They enable the easy exchange of data or tools within a tool chain. ASAM is the legal owner of these standards and responsible for their distribution and marketing.

ASAM standards define file formats, data models, protocols, and interfaces for tools that are used for the development, test, and validation of electronic control units (ECUs) and of the entire vehicle. The standards enable easy exchange of data and tools within a tool chain. They are applied worldwide.

2. Introduction

2.1. Overview

This guide is the specification and user guide for ASAM OpenXOntology, an ASAM standard that defines central concepts, properties, and relations between the concepts of the ASAM OpenX standards, including OpenDRIVE, OpenSCENARIO, OpenODD, OSI, and OpenLABEL.

2.1.1. Motivation

All OpenX standards come from the same domain: road traffic. However, they are not founded on a common domain model. Thus, central concepts are redundantly defined and described in each of the standards. Definitions sometimes contradict each other. Overlapping definitions currently exist, for example, for lane references in OpenSCENARIO and OpenDRIVE. This causes the following issues:

- Linking data created with different OpenX standards is difficult.
- It is not easily possible to guarantee compatibility within data sets complying to the same standard, but coming from different suppliers. Examples are scenario labels for driving simulations.

Furthermore, the concepts used in scenarios, their parameters, and their relations are not standardized. This makes it considerably more difficult to:

- Extract scenarios from logged data in a standardized way.
- Manually create unambiguous scenarios.
- Automatically generate synthetic scenarios in a traceable manner.
- Use common labels for objects and scenes.
- Retrieve scenarios based on common queries.

These difficulties apply to both humans and machines responsible for defining, labeling, and retrieving scenarios. They also apply to both existing and future standards related to road traffic.

An ASAM ontology that describes, among others, the concepts of traffic infrastructure, interactions of traffic participants, and environmental conditions can fill this gap by providing a standardized vocabulary, and a domain model for the OpenX standards. This might also facilitate the use of artificial intelligence for OpenX applications.

More on the advantages of an ontology can be found in the chapter on the benefits of an ontology.

2.1.2. What is ASAM OpenXOntology

The OpenX standards describe traffic participants, road networks, driving maneuvers, and test scenarios for driving and traffic simulation, labeling sensor data, and other use cases. The standards share concepts from the domain of road traffic, such as road, lanes, and traffic participants. ASAM OpenXOntology provides an ontology-based architecture for these concepts and thus a common definition of the domain model for the OpenX standards.

ASAM OpenXOntology covers the following concepts from the domain of road traffic:

- Road infrastructure, meaning roads, lanes, junctions, etc.
- Traffic infrastructure, meaning traffic signs, signals, etc.
- Temporal changes in the road and traffic infrastructures, meaning road constructions, diversions, etc.
- Dynamic traffic participants, such as cars, pedestrians, and cyclists.
- Environment, meaning weather, time of day, etc.

- Communication conditions, such as vehicle-to-vehicle communication or GPS localization.

2.1.3. Deliverables of ASAM OpenXOntology

This release contains the following:

- Core ontology, which contains a set of basic concepts and relationships.
- Domain ontology, which describes concepts relevant to road traffic.
- The connected ontology of core and domain parts.

In order to cover specific use cases on application level with the help of ASAM OpenXOntology, developers extend the domain ontology with their application-specific concepts. Application-specific concepts are not part of ASAM OpenXOntology. However, this document describes a method that allows users to incorporate a new concept into ASAM OpenXOntology using the domain ontology, see How to incorporate a new concept into ASAM OpenXOntology.

Furthermore, this document provides concrete examples of using ASAM OpenXOntology for specific application scenarios, see Data journey with ASAM OpenXOntology and related OpenX standards. This serves as a reference as well as a demonstrator of the functionality of ASAM OpenXOntology.

This version of ASAM OpenXOntology contains the following deliverables:

- OWL files for the core and domain ontologies that are part of ASAM OpenXOntology.
- The ASAM OpenXOntology user guide.
- The model reference.

Due to missing object properties and SWRL rules in the domain ontology, reasoning and inference are currently not possible. That means that the domain ontology of this version is mainly a taxonomy, but there are practical examples in the data journey to demonstrate inference and reasoning. ASAM pursues the goal of further developing ASAM OpenXOntology based on user feedback.

2.2. Normative and non-normative statements

This documentation uses a standard information structure. The following rules apply regarding normativity of sections:

- Statements expressed as requirements, permissions, or prohibitions according to the use of modal verbs, as defined in Modal verbs, are normative.
- Architecture diagrams from the OpenXOntology OWL model are normative.
- Code samples and use case descriptions are non-normative.

2.3. Conventions

2.3.1. Units

All numeric values within this standard are using SI units, unless explicitly stated otherwise. Table 1 presents details of the used units.

Unit of	Unit	Symbol
Length	Meter	m
Duration, (relative) time	Second	s

Unit of	Unit	Symbol
Speed	Meters per second	m/s
Acceleration	Meters per second squared	m/s^2
Mass	Kilogram	kg
Angle	Radians	rad
Light intensity	Lux	lx

Table 1. Units

Geographic positions are stated in the unit defined by the spatial coordinate system, for example, in accordance with WGS 84 – EPSG 4326 [1].

2.3.2. Modal verbs

To ensure compliance with the ASAM OpenXOntology standard, users need to be able to distinguish between mandatory requirements, recommendations, permissions, as well as possibilities and capabilities.

The following rules for using modal verbs apply:

Provision	Verbal form
Requirements Requirements shall be followed strictly in order to conform to the standard. Deviations are not allowed.	shall shall not
Recommendations Recommendations indicate that one possibility out of the several available is particularly suitable, without mentioning or excluding the other possibilities.	should should not
Permissions Permissions indicate a course of action permissible within the limits of ASAM OpenXOntology deliverables.	may need not
Possibilities and capabilities Verbal forms used to state possibilities or capabilities, whether technical, material, physical, etc.	can cannot
Obligations and necessities Verbal forms used to describe legal, organizational, or technical obligations and necessities that are not regulated or enforced by the ASAM OpenXOntology standard.	must must not

Table 2. Rules for using modal verbs

2.3.3. Typographic conventions

This documentation uses the following typographical conventions:

Mark-up	Definition
`Code elements`	This format is used for code elements, such as technical names of classes.
`<owl:NamedIndividual rdf:about="http://www.asam.net/ontologies/ABoxMWP#lane1">`	This format is used for excerpts of code that serve as an implementation example.
Terms	This format is used to introduce glossary terms, new terms and to emphasize terms.

Table 3. Typographical conventions

2.4. Contributing to ASAM OpenXOntology

ASAM OpenXOntology is maintained by ASAM e.V. For detailed information about the project, working group, and ways to participate in the standard's development, refer to the ASAM website.

3. Terms, definitions, and abbreviated terms

3.1. Terms and definitions

ABox

Type of statements in a knowledge graph. An ABox is formed by individuals and their relationships established by object properties. The individuals and object properties from a directed graph, in which the individuals are the nodes and the specific relationships are the edges. The *A* can stand for "assertion".

ADS

Automated driving system.

Application ontology

Type of ontology in the context of ASAM OpenX. Application ontologies contain concepts that a particular ASAM OpenX standard is allowed to modify without consulting any other standard working group. Application concepts are only used in that specific standard.

Assertion

A triple where the subject and object are both individuals. In this case, the triple expresses a fact about those particular individuals.

Axiom

A triple where the subject and object are both classes. In this case, the triple expresses a constraint on the definition of both classes.

Class

Ontology class that represents a set of actual things in the domain that have common characteristics. These things are not just physical things that people can touch. In addition to physical objects, they include any things that exist in time and space, for example, events and activities.

Core ontology

Type of ontology in the context of ASAM OpenX. The core ontology defines basic concepts, such as physical objects, states, and events. The core ontology of ASAM OpenXOntology corresponds to a top-level ontology or upper ontology. The core ontology of ASAM OpenXOntology is based on HQDM.

Domain ontology

Type of ontology in the context of ASAM OpenX. The domain ontology defines central concepts of the road traffic domain, for example, lane, road, and vehicle. It contains only concepts that are shared by multiple ASAM OpenX standards using the ASAM OpenXOntology and that are not controlled by a single standard.

Ego vehicle

The vehicle that is the focus of a scenario, meaning the vehicle under test.

HQDM

High-Quality Data Model framework

Individual

Member (or object) of an ontology class.

Inference

Process of deducing new knowledge from existing knowledge and axioms. In an OWL database, inference is used for deducing further knowledge based on the existing OWL data and a formal set of inference rules.

ODD (Operational Design Domain)

Source: SAE J3016 (2021) [2]

Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics.

Ontology

Formal and machine-readable representation of knowledge in a specific domain. ASAM OpenXOntology refers to the traffic domain. Ontologies contain standardized definitions of concepts and describe how the defined concepts relate to and differ from each other. In this way, ontologies enable both humans and machines to have a shared understanding of the meaning of the concepts. Logically formalized ontologies use predicate logic to describe these relations and thus facilitate logical reasoning in order to infer additional knowledge about the data that is exchanged. In the context of this specification, the term ontology refers to logically formalized ontologies, particularly ontologies that are based on a description logic.

Property

Expresses the type of relationship between members of ontology classes.

Reasoning

Inference of logical consequences from a set of asserted facts or axioms.

Reasoner

An application that is able to perform reasoning.

Relationship/Relation

A typed, directed connection between two classes or two individuals of an ontology that expresses that these classes or individuals have a semantic link. The combination of subject-relationship-object is called triple.

SWRL

Semantic Web Rule Language, a proposed language for the Semantic Web that combines OWL with a subset of the Rule Markup Language (RuleML).

TBox

Type of statements in a knowledge graph. A TBox is formed by classes that are related by object properties. The classes and properties form a directed graph, in which the classes are the nodes and the specific relationships are the edges. The *T* can stand for "terminological".

Temporal part: During its lifetime, a whole-life physical object, such as a car, takes part in different activities. For each participation in an activity, ASAM OpenXOntology uses a member of the class `State` to model a temporal part that represents the thing during the activity or event.

Triple

Describes the concrete relationships between two classes or individuals. It is the combination of a subject, an object, and a relationship between them that expresses a statement in the form subject-predicate-object.

Generic example: *Car-driveOn-Road*.

Triples may be formed with classes or individuals.

- If the subject and object of a triple are both classes, the triple expresses a constraint on the definition of both classes. Such a constraint is called an axiom.
- If the subject and object are both individuals, the triple expresses a fact about those particular individuals. Such an expression is called an assertion.

4. Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes some of the requirements set out in this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

- ASAM OpenDRIVE, version 1.7.0 [3]
- ASAM OpenSCENARIO, version 1.1.1 [4]
- ASAM OpenSCENARIO, version 2.0.0 [5]
- ASAM OpenLABEL, version 1.0.0 [6]
- ASAM OpenODD Concept Paper, version 1.0.0 [7]
- ASAM Open Simulation Interface (OSI), version 3.3 [8]
- SAE J3016 (2021) [2]
- BSI PAS 1883 [9]
- ISO TC33 SC33 WG9 [10]
- ISO 704: Terminology work — Principles and methods [11]
- ISO 3450x series (in development)
  - ISO 34501: terms and definitions [12]
  - ISO 34502: engineering framework [13]
  - ISO 34503: ODD taxonomy [14]
  - ISO 34504: Scenario categorization [15]
- ISO TC22 SC32 WG8 [16]
  - SAFAD2 [17]
  - SOTIF [18]

5. Relation to ASAM OpenX

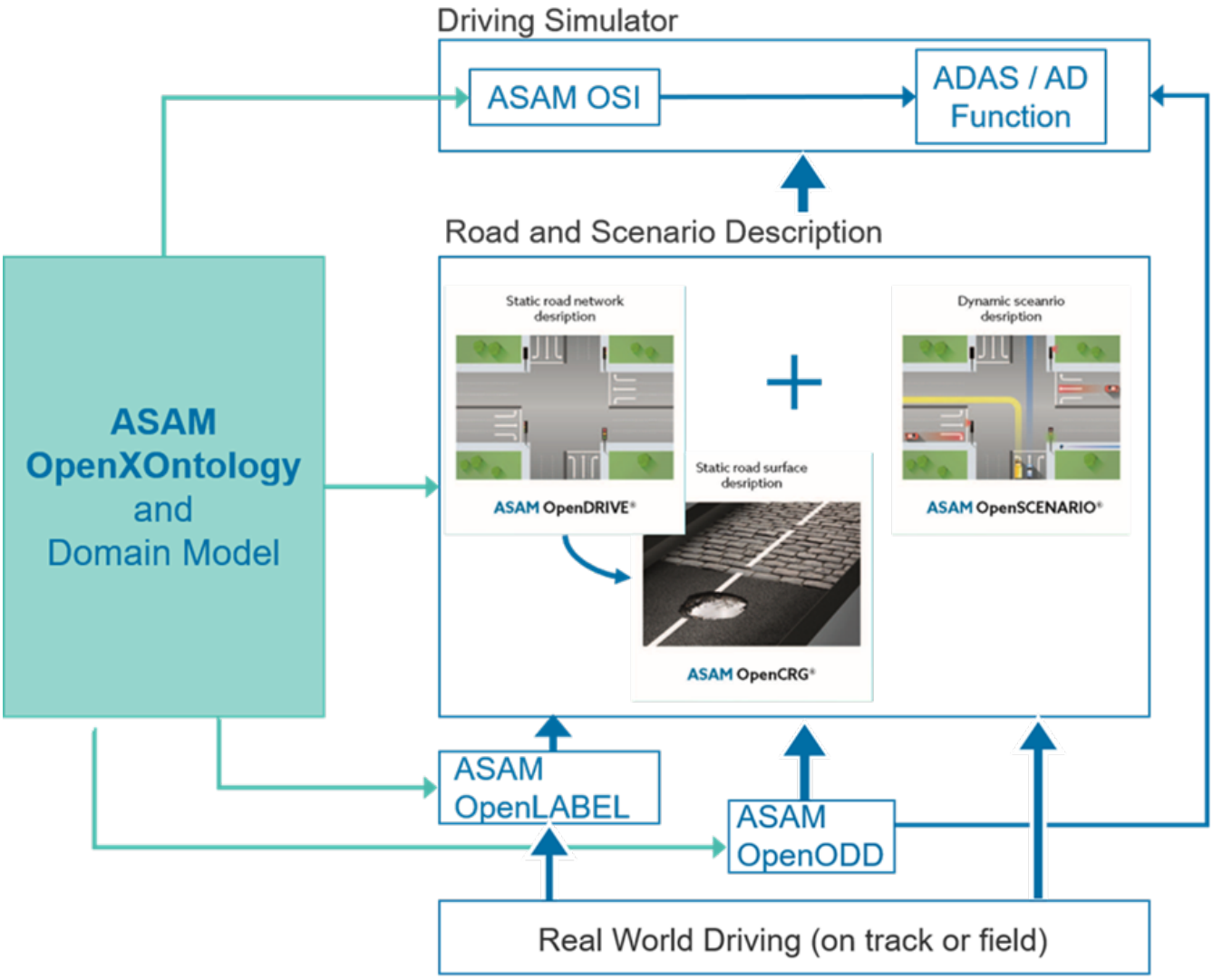


Figure 1. ASAM OpenXOntology and its relation to other ASAM standards

Figure 1 shows the interdependencies between ASAM OpenXOntology and the OpenX standards.

The following sections describe the relation between ASAM OpenXOntology and each of the contributing ASAM OpenX standards using this patterns:

- What does [ASAM OpenX standard] define?
- How can [ASAM OpenX standard] use ASAM OpenXOntology?
- How would ASAM OpenXOntology affect [ASAM OpenX standard]?

5.1. ASAM OpenDRIVE

5.1.1. What does ASAM OpenDRIVE define?

ASAM OpenDRIVE specifies an exchange format for static road networks that can be used by driving simulation applications. ASAM OpenDRIVE focuses on static road infrastructure elements, such as roads, lanes, junctions, and signals. The standard does not cover dynamic content.

5.1.2. How can ASAM OpenDRIVE use ASAM OpenXOntology?

ASAM OpenDRIVE can use ASAM OpenXOntology definitions for static road infrastructure elements that are shared with other OpenX standards. Examples are lanes and roads. Also, ASAM OpenDRIVE can use connective and spatial relationships between the elements that are defined in ASAM OpenXOntology.

5.1.3. How would ASAM OpenXOntology affect ASAM OpenDRIVE?

Harmonization with different ASAM projects is ongoing.

5.2. ASAM OpenLABEL

5.2.1. What does ASAM OpenLABEL define?

ASAM OpenLABEL standardizes the annotation format and the labeling methods for multi-sensor data streams and scenario files. Using a standardized format helps cut costs and save resources used in creating, converting, and transferring annotated and tagged data. ASAM OpenLABEL is represented in a JSON format and can therefore be easily parsed by tools and applications.

5.2.2. How can ASAM OpenLABEL use ASAM OpenXOntology?

The labels in ASAM OpenLABEL define:

- Entities within the road traffic domain.
- Types of geometrical constructs that are adequate to capture those entities in multi-sensor data streams, for example, Lidar 3D bounding boxes, 2D image boxes, and polygons.

ASAM OpenXOntology represents knowledge about the road traffic domain and can thus provide a richer description of the labels. Ontology-based label descriptions are grounded in logic, enabling use of reasoning applications. Finally, ASAM OpenXOntology can support the harmonization of the ASAM OpenLABEL standard with other OpenX standards that exchange information with it.

5.2.3. How would ASAM OpenXOntology affect ASAM OpenLABEL?

The ASAM OpenLABEL project is closely connected to ASAM OpenXOntology because ASAM OpenXOntology can provide the object descriptions for the labels. On the other hand, the ASAM OpenLABEL project delivers requirements to the ontology project with respect to the relevant entities that need to be labeled and their relationships.

The development phases of ASAM OpenLABEL and ASAM OpenXOntology took place in parallel which provided opportunities for alignment. The ASAM OpenLABEL scenario tagging model shares the same structure as the ASAM OpenXOntology domain ontology. At a high level, they both utilize an ODD-based umbrella structure (referenced to BSI PAS 1883) for the environmental conditions and the road topology and infrastructures. For the traffic participant and activity aspect, a one-to-one mapping can be established between the ASAM OpenLABEL scenario tagging model and the ASAM OpenXOntology domain ontology. One of the future alignments between the two standards will focus on how to deal with multiple inheritance for the ASAM OpenLABEL scenario tagging use case, since currently the tagging semantic only consider single inheritance. Furthermore, minor alignments on the class names and definitions between the two standards are also needed in the near future. The goal would be to have a harmonized domain ontology which will be hosted only in ASAM OpenXOntology, and ASAM OpenLABEL scenario tagging will only host application level ontology instead of its own separate domain model.

5.3. ASAM OpenSCENARIO

5.3.1. What does ASAM OpenSCENARIO define?

ASAM OpenSCENARIO 1.1.1 defines a data model and a derived file format for the description of scenarios used in driving and traffic simulators, as well as in automotive virtual development, testing, and validation.

5.3.2. How can OpenSCENARIO use ASAM OpenXOntology?

ASAM OpenSCENARIO 1.1.1 retrieves definitions for spatial and temporal relationships between both dynamic and static traffic participants from ASAM OpenXOntology.

OpenSCENARIO 2.0.0 was developed in parallel with ASAM OpenXOntology. Initial interaction and alignment between the projects took place, but future revisions require further harmonization.

5.3.3. How would ASAM OpenXOntology affect ASAM OpenSCENARIO?

Harmonization with different ASAM projects is ongoing.

5.4. ASAM Open Simulation Interface (OSI)

5.4.1. What does ASAM OSI define?

ASAM OSI is a specification for interfaces between models and components of a distributed simulation. OSI is strongly focused on the environmental perception of automated driving functions.

ASAM OSI contains an object-based environment description that uses the message format of the Protocol Buffer library. Google developed and maintains the Protocol Buffer library. ASAM OSI defines top-level messages that are used to exchange data between separate models. Top-level messages define the `GroundTruth` interface, the `SensorData` interface, and – since ASAM OSI version 3.0.0 – the interfaces `SensorView`, `SensorViewConfiguration`, and `FeatureData`.

5.4.2. How can ASAM OSI use ASAM OpenXOntology?

ASAM OSI can use concepts and relationships of ASAM OpenXOntology to generate ground truth messages as input to sensor and sensor fusion models.

5.4.3. How would ASAM OpenXOntology affect ASAM OSI?

OSI currently defines a fixed message structure, entity classifications, and maneuver actions in order to guarantee connectivity and compatibility with existing sensor models. This requires careful consideration of specifications with regard to the protocol definitions. ASAM OpenXOntology will help to close the gap between scenario engine, environment simulator, and the sensor model using input and output messages from OSI.

5.5. ASAM OpenODD

5.5.1. What does ASAM OpenODD define?

An operational design domain (ODD) refers to the operating environment in which vehicles are designed to operate safely. A more formal definition of an operational design domain as defined by SAE J3016 (2018) [2] states the following:

"Operating conditions under which a given driving automation system or feature thereof is specifically

designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics".

The operational design domain impacts the design of the vehicle, its capabilities as well as its respective validation, particularly with respect to safety. The operational design domain shall be valid throughout the whole vehicle lifetime.

ASAM OpenODD aims at defining a format that represents an abstract operational design domain for a vehicle that is both machine-readable and human-readable. It will enable stakeholders to share, compare, and reuse data. The ASAM OpenODD format will be designed to be machine-processable throughout the vehicle development and lifecycle. Furthermore, it shall be measurable and verifiable. This requires well-defined syntax and semantics.

5.5.2. How can ASAM OpenODD use ASAM OpenXOntology?

Currently, the ASAM OpenODD project is at the concept development stage.

The base set of concepts is referenced to the existing operational design domain standards. For example, BSI PAS 1883 serves as a basis for instantiating individual operational design domain specifications. In the coming phases of the ASAM OpenXOntology harmonization, such standards will be aligned with the concepts at the domain ontology level. ASAM OpenODD will then be able to use concepts and relationships from the ASAM OpenXOntology to build specific operational design domains.

Furthermore, in ASAM OpenODD, one of the key language concpets focuses on the extensibility of the underlying ontology. While the syntax for such extension of ontology has been developed in the ASAM OpenODD project, ASAM OpenXOntology provides the necessary mechanism from an ontological and operational perspectives.

5.5.3. How would ASAM OpenXOntology affect ASAM OpenODD?

Harmonization with different ASAM projects is ongoing. ASAM OpenXOntology will also set out the available relationships to be used when constructing the ASAM ODD specification. This could include the following:

- Specify conditional operational design domain statements: For example, a motorway is only suitable when there is no rain. For an example, see phase 5 of the example data journey.
- Error checking for wrong relations: For example, rain intensity is sunny.
- Wrong keywords used without pre-specifying: For example, rain intensity is *my special rain*.

In addition, as mentioend in the earlier section, ASAM OpenXOntology will enable methods to extend the underlying terminology of ASAM OpenODD, for example, adding a new subclass to rain intensity.

6. Introduction to ontologies

6.1. What is an ontology

The class and property names in this chapter are examples and used for illustration purposes. They do not necessarily represent the naming of classes and properties in ASAM OpenXOntology.

Ontologies are used to represent knowledge in a way that computers can understand. Like a terminology, as defined in ISO 704 [11], an ontology contains standardized definitions of concepts that are used in a particular domain of knowledge, such as road traffic. These standardized definitions are used when data is exchanged by human parties and computer programs working independently. In this way, ontologies and terminologies enable both humans and machines to have a shared understanding of the meaning of the concepts.

Unlike terminologies and taxonomies, ontologies also describe how the defined concepts relate to and differ from each other.

Logically formalized ontologies use predicate logic to describe these relations. In this way, ontologies enable humans and machines to use logical reasoning in order to infer additional knowledge about the data that is exchanged. In the context of this specification, the term *ontology* refers to logically formalized ontologies, particularly ontologies that are based on a description logic.

Classes, properties, and triples

An ontology defines concepts as *classes*. A class represents a set of actual things in the domain that have common characteristics. These things are not just physical things that people can touch. They include any things that exist in time and space, such as:

- Activities and maneuvers, such as walking and overtaking another vehicle.
- Events and decisions, such as the instance that a collision occurs and the decision of a driver to turn left.
- Places, such as junctions, lanes, and connections between road segments.
- Physical objects, such as humans and motor vehicles.

The members of classes are called *individuals*. Individuals may be members of a single class or several different classes.

In addition to the classes, ontologies define *properties*, which express the types of relationships between members of classes. The concrete relationship or predicate between two particular members is a member of a property set, in the same way that individuals are members of classes.

Figure 2. A directed relationship from subject to object

Relationships are directed, meaning they point from a subject to an object. The combination of a subject individual, an object individual, and a relationship between them results in a *triple* that expresses an assertion in the form subject-predicate-object, as shown in Figure 2.

Example:

- A member of the property `hasPart` (predicate) connects a member of the class `RoadVehicles` (subject) to a member of the class `Wheels` (object).
- This relationship can be described by the natural language assertion "This road vehicle has parts that are wheels."

Triples are the method used in ontologies for encoding information. Each triple consists of three parts:

- Predicate: a typed, directed binary relation describing some specific relationship between two things in the domain.
- Subject: the thing in the domain that **has** the relationship. Example: The thing that "has" a `hasPart` relationship.
- Object: the thing in the domain that **is had by** the relationship. Example: The thing that "is had by" a `hasPart` relationship.

Triples may be formed with classes or individuals. If the subject and object of a triple are both classes, the triple expresses a constraint on the definition of both classes. Such a constraint is called an *axiom*. If the subject and object are both individuals, the triple expresses a fact about those particular individuals. Such an expression is called an *assertion*. In general, it is not possible to create a triple to relate a class and an individual.

Inference and logical constructs

Like classes, properties are first-class constructs, meaning that a particular relationship exists independently of the actual things that it relates. Because of the "open-world assumption" in ontologies, this means that a computer can infer the class membership of the two things that are related by a particular relationship.

Example: The `hasPart` property is defined such that the subject is a member of the class `PhysicalObject`. If an individual "X" has a `hasPart` relationship with another individual "Y", the computer program can infer that "X" must be a member of the class `PhysicalObject`.

If such an inference leads to a contradiction, an ontology reasoner can identify this as a semantic error. For example, if another inference has the result that "X" must be a member of the class `Activity`, and the classes `PhysicalObject` and `Activity` are defined as disjoint, then a semantic error is concluded. However, the reasoner cannot decide automatically which of the class memberships is actually correct.

The characteristics of an ontology class are expressed using properties together with a set of logical constructs, such as cardinality and value restrictions, that are provided by the ontology modeling language. ASAM OpenXOntology uses OWL as modeling language. These logical constructs restrict the way that properties may be used with members of the defined class.

For example, the ontology may define that a member of the class `Bicycles`, which is a subclass of the class `RoadVehicles`, shall be related by the property `hasPart` to exactly two members of the class `Wheels`.

Related topics

- Ontology language used for OpenXOntology

TBox and ABox

The classes and properties of an ontology form a directed graph, with the classes as nodes and the properties as edges. The graph made up of classes and properties is called a *TBox*, where the T can stand for "terminological". Semantic applications can transverse the graph and additionally evaluate the logical characteristics defined for the classes and properties in the ontology. In this way, the applications can

identify conflicts and logical incoherencies. For example, if `RoadVehicles` was defined to have as parts exactly four `Wheels`, an ontology reasoner will identify that defining `Bicycles` as a subclass of `RoadVehicles` that have as parts exactly two `Wheels` is a contradiction.

Another graph is formed when particular individuals are connected with directed relationships to other individuals. The individuals are members of classes and the relationships are members of properties. In this graph, the individuals are the nodes and the specific relationships are the edges. These graphs are called *ABoxes*, where the A can stand for "assertion". By applying logical reasoning to an ABox, semantic applications can usually infer the existence of additional relationships and even other individual things from the asserted information.

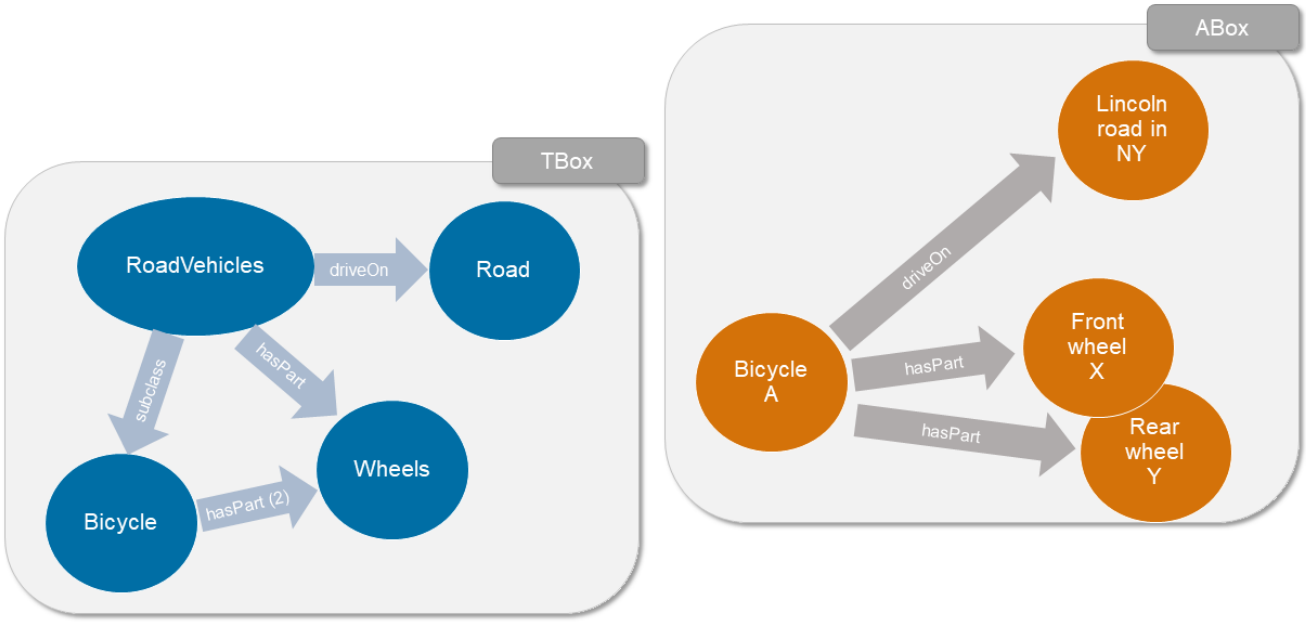


Figure 3. TBox and a possible ABox

To summarize: Triples in the TBox connect classes, whereas triples in the ABox connect individuals, as shown in Figure 3.

Deriving facts from the web of knowledge

An ontology can be viewed as specifying the conceptualization of a particular knowledge domain as a logically formalized graph or web of knowledge.

This web of knowledge enables computer programs to reason about assertions that are made according to an ontology, for example, to derive new facts about things that are not explicitly expressed in the assertions. In addition, an ontology reasoner can be used to check a particular expression for logical incoherencies, which may indicate a misunderstanding or simply a semantic error.

Rule-based languages for ontologies

Many characteristics that one might want to declare between things are too complex to be readily expressed using logical constructors only. For example, it would be difficult to create a purely logical expression of the definition of "Overtaking" as an "Activity" in which the subject vehicle starts in the same lane behind the object vehicle and ends up in the same lane in front. The combination of logical reasoning and rule-based reasoning enables a computer program to make complex inferences from a particular expression, thereby realizing a high level of computer understanding. For this reason, an ontology modeling language, such as OWL, is often used together with a rule-based language, such as SWRL (Semantic Web Rule Language).

Related topics

- SWRL rules

6.2. What are the benefits of an ontology?

The ASAM OpenXOntology project started to address a need identified for common definitions to be used by the ASAM OpenX standards. There are several reasons why an ontology is beneficial to reach this goal.

Common definition of concepts

In a domain such as road traffic, concept definitions are often unclear or they require some special knowledge to interpret. The result is that different people working in the same domain but having different areas of expertise may not understand each other's definitions of a concept. Typical problems are:

- Polysemy, where one term is used to refer to several different concepts
- Homonymy, where several terms are used to refer to the same concept

In the development of technical standards, it is particularly important to address these issues.

A formal theory, which is grounded in some form of logic, makes it possible to create concept definitions in a formalized way. Ontologies provide a base theory for making definitions of concepts used in a particular knowledge domain. This guarantees that all participants, including humans and machines, using the concept definitions will have the same understanding of the concepts. The logical constructs that an ontology facilitates can be used to constrain relationships between concepts. Examples for constraints are:

- The logical construct `some-values-from` can be used to define that `ElectricVehicles` must have at least one value from `ElectricEngines` for the `hasPart` relationship.
- The logical construct `cardinality = 2` may be used to define that `Bicycles` must have exactly two values from `Wheels` for the `hasPart` relationship.

Extensibility

For the formal definition of ontologies, semantic web standards and formats are available, for example, Resource Description Framework Schema (RDFS) and Web Ontology Language (OWL). By adhering to the mechanisms of these standards, different participants of a domain may extend the ontology, for example by introducing a new concept definition, and be assured that other participants will interpret the extension correctly. In the context of ASAM, users of the ASAM OpenSCENARIO 1.1.1 standard who write an expression for `Overtaking` in a particular road traffic scenario can be sure that ASAM OpenDRIVE or ASAM OpenLABEL users understand the intended meaning of the expression.

Both RDFS and OWL are based on XML. For this reason, an ontology can be easily split into multiple files hosted by different web servers.

Rules and reasoning

An ontology that is based on some form of logic or that utilizes some kind of theory for expressing rules (Horn clauses) enables a computer program that implements an ontology reasoner to infer relationships between ontology classes and individuals that are not explicitly stated. Inference can be used to assess the coverage or to extract common patterns shared by different concepts, and even to find semantic errors in the ontology.

Reasoning is especially useful when applied automatically. Applications that are able to read and understand the underlying theory of the ontology can reason about knowledge expressed in some assertion (ABox), make inferences, and assert new knowledge. Furthermore, machine learning can be used to train applications to find new knowledge in an ontology from induction.

Related topics

- An example of reasoning and inference in phase 2 of the data journey.

Determining semantic proximity and similarities

Ontologies make it possible to assess the semantic proximity of different concepts in a domain that are defined by different participants. Finding these proximities enables richer classification of concepts. For example, a participant can identify that a particular concept is in fact a subclass of another concept even if that is not explicitly stated. A richer classification makes the ontology more useful.

Furthermore, ontologies can be used to evaluate the semantic similarity of different assertions (ABoxes comprised of multiple individuals and relationships) made in the domain. In this way, ontologies enable humans and machines to understand that two assertions mean the same thing even if they do not say the same thing. For example, an ontology reasoner could discover similarities between different assertions about road traffic situations or scenarios by finding similarities particularly in the relationships between types of things that are otherwise hidden.

The following are some typical use cases that utilize calculation of semantic similarity:

- Semantic searching and matching to find records in a database that semantically are most similar. Example: Find scenario descriptions in a scenario repository that are similar to the scenario that is currently edited.
- Find clusters by semantic similarity. Example: Identify groups of scenarios that have similar chains of events and relationships between traffic participants.
- Classify large numbers of scenarios according to patterns of relationships between concepts that define different operational design domains.

7. Architecture of ASAM OpenXOntology

7.1. Architectural overview

ASAM OpenXOntology aims to structure and formalize knowledge about the existence of things in the domain of road traffic. This is done as independently as possible of the intended applications in ASAM standard development so that the ontology can be reused for different types of applications.

The architecture of ASAM OpenXOntology intends to ensure flexibility of use, both for ontology developers and ontology users. The following aspects were considered:

- Knowledge comes from different sources.
- Ontologies grow rapidly and can become too large to be easily visualized and managed.
- Different ontologies need to be merged to get new knowledge.

The complexity of creating and using domain-specific ontologies can be reduced by dividing knowledge into multiple areas. The following technical approaches are used for that:

- Modularization: Divide the ontology into individual modules for independent subject areas.
- Configuration management: Provide mechanisms for ontology users to generate a merged ontology from source modules that contains sufficient information for the application.

ASAM OpenXOntology uses modularization and is divided into the following modules:

- Core ontology (deliverable of this release) which is based on the HQDM framework
- Domain ontology (delivered as taxonomy in this release)
- Application ontologies (not yet implemented)
- Application integration ontology for end use (not yet implemented)

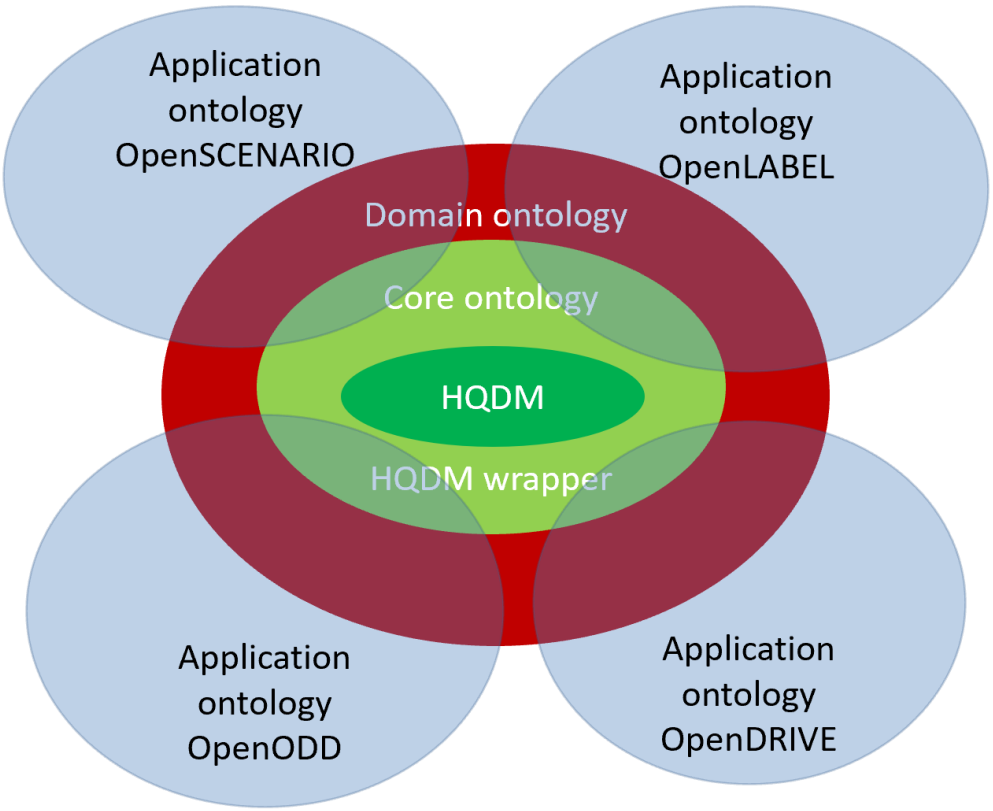


Figure 4. Example visualization of core, domain, and application ontologies

Figure 4 shows how core, domain, and application ontologies interact with each other. The application ontologies will use concepts from both domain ontology and core ontology, as indicated by the overlap of circles.

The application integration ontology will be a dedicated ontology file for the ontology user. This ontology will be the result of merging the core and domain ontologies and one or several application ontologies according to the user requirements. An application integration ontology enables users to use all concepts and properties from the merged ontologies.

Other modules that will be considered in future versions include:

- Parameters and constraints
- Semantic rules

Parameters, constraints, semantic rules, and the application ontology layer are still in development.

Related topics

- Deliverables of OpenXOntology
- HQDM as the basis for the core ontology

7.1.1. Core ontology

The core ontology describes the top-level ontology, a framework of classes and properties that are used as a foundation for the domain-specific content in the domain ontology. These concepts include:

- Physical objects, including both dynamically changing and static unchanging objects. Domain concepts inheriting from these core concepts include vehicles, roads, and traffic signs.
- States of physical objects that correspond to temporal parts of the objects' lifetime. These states have single valued state parameters, such as speed.
- Activities, including actions and behaviors that involve the physical objects in active and passive roles.
- Events that mark the changes in states of physical objects, critical points in time, and triggers or decisions for the start or end of activities.

The object properties defined in the core ontology provide meta models for describing basic compositional, spatial, and temporal relationships between individuals in the domain.

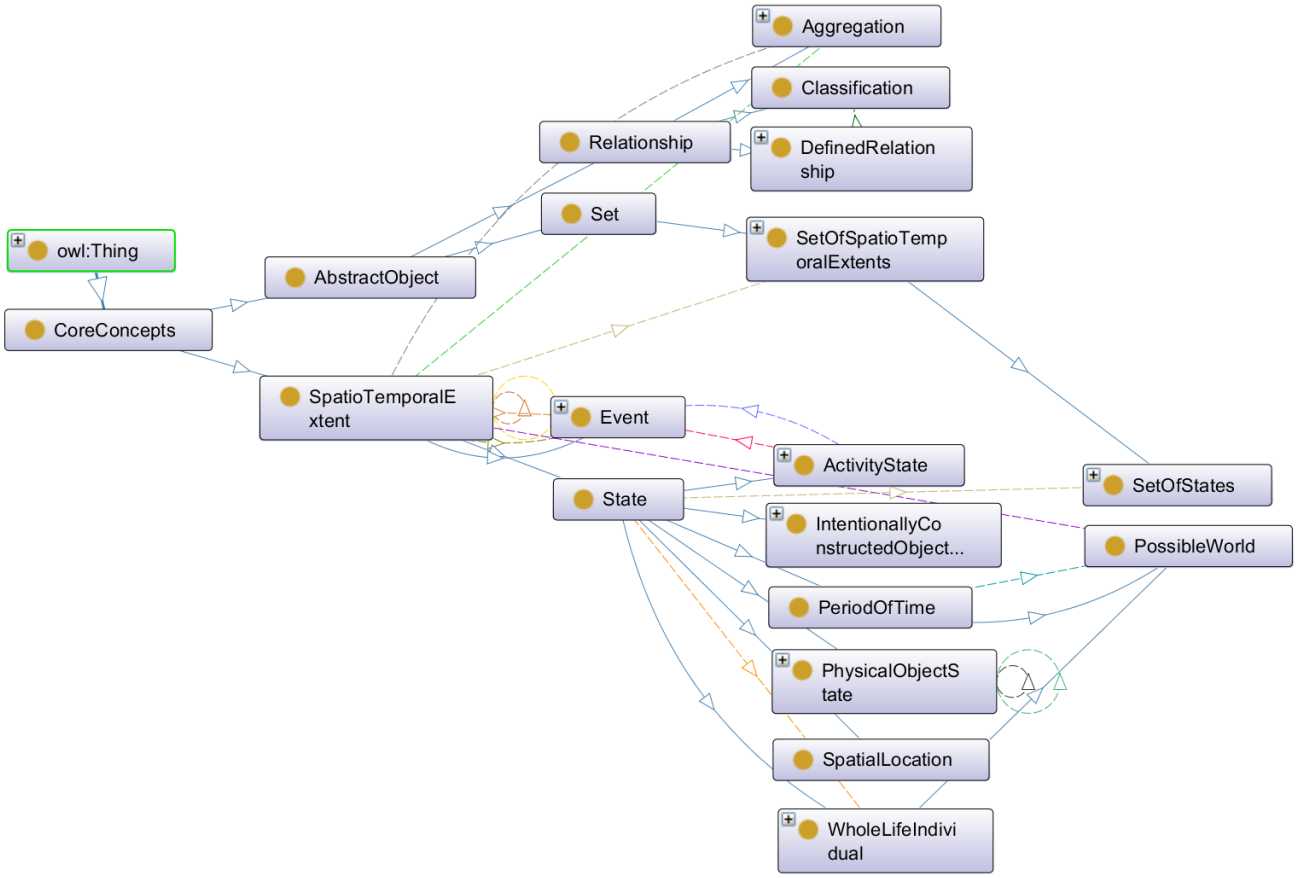


Figure 5. Simplified representation of the core ontology

Figure 5 shows the core ontology.

Related topics

- Overview of the core classes
- The core properties HQDM as the basis for the core ontology

7.1.2. Domain ontology

The domain ontology of ASAM OpenXOntology defines central concepts of the road traffic domain, for example, lane, road, and vehicle. These central concepts are summarized in the domain ontology to provide a consistent and expressive underlying language for the ASAM OpenX standards. The domain ontology currently only includes concepts that are not controlled by any single OpenX standard.

The domain ontology includes the following main concepts:

- Road topology and traffic infrastructure. Examples: road, junction, lane marking, toll plaza, construction signs, and traffic signs
- Traffic participants and their behavior. Examples: activities, such as starting, stopping and overtaking; vehicle and pedestrian.
- Ambient conditions. Examples: rain, fog, lighting condition, road surface condition, V2V communication condition.

The domain ontology does not yet feature object properties that can be used to establish relationships between individuals. These will be added in future releases. In the current release, the domain ontology can mainly be used as a taxonomy.

Related topics

- Overview of the domain classes

7.1.3. Application ontology

ASAM plans to develop one application ontology for every ASAM OpenX standard, for example, OpenDRIVE and OpenLABEL. The application ontology will contain concepts that the particular standard is allowed to modify without consulting any of the other standards. These are normally concepts that are only used in that specific standard.

Application ontologies will import all concepts and properties from the core and domain ontologies, while using only the ones that fit for them.

7.2. Ontology language and rule language

ASAM OpenXOntology uses OWL as ontology language and SWRL as rule language.

The process that led to the decisions to use OWL and SWRL is documented in the appendix.

Web Ontology Language (OWL)

OWL [19] is a semantic markup language for publishing and sharing ontologies on the Web. OWL builds on RDF and RDFS and is part of the W3C recommendations related to the Semantic Web.

OWL goes beyond the basic semantics that can be expressed with RDF Schema. The data described by an ontology in the OWL family is interpreted as a set of individuals and a set of property assertions that relate these individuals to each other. An ontology consists of a set of axioms which place constraints on sets of individuals, meaning classes, and the types of relationships permitted between them. These axioms provide semantics by allowing computers to infer additional information based on the data explicitly provided.

Semantic web rule language (SWRL)

SWRL [20] combines OWL with a subset of the Rule Markup Language (RuleML). It is a proposed rule language for the Semantic Web. SWRL adds rules at the cost of undecidability and lack of complete implementation. A SWRL rule consists of an antecedent (body) and a consequent (head).

7.3. SWRL rules

ASAM OpenXOntology uses the Semantic Web Rule Language (SWRL) to express rules for inference and reasoning.

7.3.1. Function of the SWRL rules

A SWRL rule enables a reasoner to derive a new fact from facts that have been expressed explicitly in the ontology. Furthermore, a SWRL rule acts as a constraint if a derived fact contradicts pre-existing facts. For example, if a SWRL rule states that the subject of a driving activity is a vehicle, and an ABox asserts that the subject of a driving activity is a pedestrian, the reasoner decides that the subject of the driving activity is both a pedestrian and a vehicle. If the ontology states that pedestrians are not vehicles, this results in a contradiction and the reasoner indicates a semantic error.

SWRL rules combine a set of preconditions with usually just one consequence condition. In ASAM OpenXOntology, there shall be at least one and a maximum of ten preconditions. There shall be only one

resultant consequence condition.

In the examples below, preconditions are enclosed in curved brackets and consequence conditions are enclosed in square brackets.

7.3.2. How to write rules

The following rules apply to writing SWRL rules for ASAM OpenXOntology:

1. The SWRL rules shall comply to this format:

```
if conditionA1 and conditionA2 ... and conditionAn, then conditionC.
```

   conditionAx is a single precondition. conditionC is a single consequence condition.

2. An OR relation between two conditions shall be expressed with two separate rules.

   Example 1. OR relationship

   A SWRL rule that states that if vehicleX is the subject of either an overtake activity or a following activity with the object of the activity being vehicleY, then vehicleX is behind vehicleY could be expressed as follows:

```
if (activityZ is an overtake activity) or (activityZ is a following activity)
and (vehicleX is the subject of activityZ) and (vehicleY is the object of
activityZ), then [vehicleX is behind vehicleY]
```

   To comply with the ASAM OpenXOntology specification, this SWRL rule shall be split in two as follows:

```
if (activityZ is an overtake activity) and (vehicleX is the subject of
activityZ) and (vehicleY is the object of activityZ), then [vehicleX is behind
vehicleY].

if (activityZ is a following activity) and (vehicleX is the subject of
activityZ) and (vehicleY is the object of activityZ), then [vehicleX is behind
vehicleY].
```

3. Each condition shall express a relationship between two ontology entities. An ontology entity may be any concept or individual in the ontology. In most cases in the OpenX domain, at least one of the concepts is some physical object, for example, a vehicle, a pedestrian, a road, a stop sign, or some rain.

   The following are all valid examples of conditions:

Condition	Description
vehicleX is a Ambulance; laneY is a Lane	Stating the type of an individual.
vehicleX has location laneY	Relates an actor to a location.

Condition	Description
vehicleX has speed greater than 100 km/h	Relates a physical object to some state parameter.
vehicleX is in front of vehicleY	Relates two actors.
vehicleX is subject of an overtaking activity	Relates an actor to some activity it does.
vehicleX is not a truck	Expresses a negation.
roadA is not icy	Expresses a negation of characteristic.

Table 4. Valid conditions and descriptions

4. Anything that cannot be expressed using these rules shall be written in natural language and stored in the annotations of ASAM OpenXOntology. The description in natural language should be clear and concise. Each condition should be described separately.

   Examples:

   - If a lane is connected to a center lane, then it must be to the right of any other lane that is part of the same road segment and has the same direction.
   - If Y is the subject of activity A and X is a temporal part of Y, then X is also the subject of activity A.
   - If Y is the object of activity A and X is a part of Y, then X is also the object of activity A.
   - If two vehicles are driving straight at the same time and vehicle A is in front of vehicle B, then vehicle B's driving activity is also a following activity.
   - If X is the subject of an activity whose object is lane L, then X is located on L.

7.3.3. SWRL rules in ASAM OpenXOntology

Name	Rule
behind transitivity	autogen1:behind(?x, ?y) ^ autogen1:behind(?y, ?z) → autogen1:behind(?x, ?z)
front of transitivity	autogen1:inFrontOf(?x, ?y) ^ autogen1:inFrontOf(?y, ?z) → autogen1:inFrontOf(?x, ?z)
greater than or equal to	autogen1:PhysicalQuantity(?q1) ^ autogen1:PhysicalQuantity(?q2) ^ autogen1:hasValue(?q1, ?q1val) ^ autogen1:hasValue(?q2, ?q2val) ^ swrlb:greaterThanOrEqual(?q1val, ?q2val) → autogen1:quantityGreaterThanOrEqualTo(?q2, ?q1)
left of transitivity	autogen1:leftOf(?x, ?y) ^ autogen1:leftOf(?y, ?z) → autogen1:leftOf(?x, ?z)
new behind	autogen1:PhysicalObjectState(?p1) ^ autogen1:PhysicalObjectState(?p2) ^ autogen1:DirectionQuantity(?p1h) ^ autogen1:hasHeading(?p1, ?p1h) ^ autogen1:SpatialRelation(?r) ^ autogen1:hasSpatialSubject(?r, ?p1) ^ autogen1:hasSpatialObject(?r, ?p2) ^ autogen1:DirectionQuantity(?rdir1) ^ autogen1:DirectionQuantity(?rdir2) ^ autogen1:hasRelationDirection(?r, ?rdir1) ^ autogen1:hasValue(?p1h, ?p1hvalue) ^ autogen1:hasValue(?rdir1, ?rdir1value) ^ swrlb:subtract(?dirDiff, ?rdir1value, ?p1hvalue) ^ swrlb:lessThan(?dirDiff, 195) ^ swrlb:greaterThan(?dirDiff, 165) → autogen1:behind(?p2, ?p1)

Name	Rule
new in front of	autogen1:PhysicalObjectState(?p1) ^ autogen1:PhysicalObjectState(?p2) ^ autogen1:DirectionQuantity(?p1h) ^ autogen1:hasHeading(?p1, ?p1h) ^ autogen1:SpatialRelation(?r) ^ autogen1:hasSpatialSubject(?r, ?p1) ^ autogen1:hasSpatialObject(?r, ?p2) ^ autogen1:DirectionQuantity(?rdir1) ^ autogen1:DirectionQuantity(?rdir2) ^ autogen1:hasRelationDirection(?r, ?rdir1) ^ autogen1:hasValue(?p1h, ?p1hvalue) ^ autogen1:hasValue(?rdir1, ?rdir1value) ^ swrlb:subtract(?dirDiff, ?rdir1value, ?p1hvalue) ^ swrlb:lessThan(?dirDiff, 15) ^ swrlb:greaterThan(?dirDiff, -15) → autogen1:inFrontOf(?p2, ?p1)
new left of	autogen1:PhysicalObjectState(?p1) ^ autogen1:PhysicalObjectState(?p2) ^ autogen1:DirectionQuantity(?p1h) ^ autogen1:hasHeading(?p1, ?p1h) ^ autogen1:SpatialRelation(?r) ^ autogen1:hasSpatialSubject(?r, ?p1) ^ autogen1:hasSpatialObject(?r, ?p2) ^ autogen1:DirectionQuantity(?rdir1) ^ autogen1:DirectionQuantity(?rdir2) ^ autogen1:hasRelationDirection(?r, ?rdir1) ^ autogen1:hasValue(?p1h, ?p1hvalue) ^ autogen1:hasValue(?rdir1, ?rdir1value) ^ swrlb:subtract(?dirDiff, ?rdir1value, ?p1hvalue) ^ swrlb:lessThan(?dirDiff, -75) ^ swrlb:greaterThan(?dirDiff, -105) → autogen1:leftOf(?p2, ?p1)
new right of	autogen1:PhysicalObjectState(?p1) ^ autogen1:PhysicalObjectState(?p2) ^ autogen1:DirectionQuantity(?p1h) ^ autogen1:hasHeading(?p1, ?p1h) ^ autogen1:SpatialRelation(?r) ^ autogen1:hasSpatialSubject(?r, ?p1) ^ autogen1:hasSpatialObject(?r, ?p2) ^ autogen1:DirectionQuantity(?rdir1) ^ autogen1:DirectionQuantity(?rdir2) ^ autogen1:hasRelationDirection(?r, ?rdir1) ^ autogen1:hasValue(?p1h, ?p1hvalue) ^ autogen1:hasValue(?rdir1, ?rdir1value) ^ swrlb:subtract(?dirDiff, ?rdir1value, ?p1hvalue) ^ swrlb:lessThan(?dirDiff, 105) ^ swrlb:greaterThan(?dirDiff, 75) → autogen1:rightOf(?p2, ?p1)
occurs after transitivity	autogen1:occursAfter(?x, ?y) ^ autogen1:occursAfter(?y, ?z) → autogen1:occursAfter(?x, ?z)
occurs before transitivity	autogen1:occursBefore(?x, ?y) ^ autogen1:occursBefore(?y, ?z) → autogen1:occursBefore(?x, ?z)
quantity approximately equal to	autogen1:PhysicalQuantity(?q1) ^ autogen1:PhysicalQuantity(?q2) ^ autogen1:hasValue(?q1, ?q1val) ^ autogen1:hasValue(?q2, ?q2val) ^ swrlb:subtract(?qdiff, ?q2val, ?q1val) ^ swrlb:multiply(?qmax, ?q2val, 0.1) ^ swrlb:multiply(?qmin, ?q2val, -0.1) ^ swrlb:lessThan(?qdiff, ?qmax) ^ swrlb:greaterThan(?qdiff, ?qmin) → autogen1:approximatelyEqualTo(?q2, ?q1)
quantity equal to	autogen1:PhysicalQuantity(?q1) ^ autogen1:PhysicalQuantity(?q2) ^ autogen1:hasValue(?q1, ?q1val) ^ autogen1:hasValue(?q2, ?q2val) ^ swrlb:add(?q2val, ?q1val, 0.0) → autogen1:quantityEqualTo(?q2, ?q1)
quantity greater than	autogen1:PhysicalQuantity(?q1) ^ autogen1:PhysicalQuantity(?q2) ^ autogen1:hasValue(?q1, ?q1val) ^ autogen1:hasValue(?q2, ?q2val) ^ swrlb:greaterThan(?q1val, ?q2val) → autogen1:quantityGreaterThan(?q2, ?q1)
quantity less than	autogen1:PhysicalQuantity(?q1) ^ autogen1:PhysicalQuantity(?q2) ^ autogen1:hasValue(?q1, ?q1val) ^ autogen1:hasValue(?q2, ?q2val) ^ swrlb:lessThan(?q1val, ?q2val) → autogen1:quantityLessThan(?q2, ?q1)
quantity less than or equal to	autogen1:PhysicalQuantity(?q1) ^ autogen1:PhysicalQuantity(?q2) ^ autogen1:hasValue(?q1, ?q1val) ^ autogen1:hasValue(?q2, ?q2val) ^ swrlb:lessThanOrEqual(?q1val, ?q2val) → autogen1:quantityLessThanOrEqualTo(?q2, ?q1)

Name	Rule
quantity not equal to	autogen1:PhysicalQuantity(?q1) ^ autogen1:PhysicalQuantity(?q2) ^ autogen1:hasValue(?q1, ?q1val) ^ autogen1:hasValue(?q2, ?q2val) ^ swrlb:notEqual(?q1val, ?q2val) → autogen1:quantityNotEqualTo(?q2, ?q1)
right of transitivity	autogen1:rightOf(?x, ?y) ^ autogen1:rightOf(?y, ?z) → autogen1:rightOf(?x, ?z)

Table 5. SWRL rules

ASAM OpenXOntology contains SWRL rules on the core level, as shown in Table 5. To get an overview of the existing SWRL rules, you can use an appropriate ontology editor.

This version of ASAM OpenXOntology does not contain SWRL rules on the domain level.

Related topics

- SWRL rules in the core ontology
- Decision to use SWRL as rule language

7.4. Quantities and parameters

This section explains how quantities and parameters are expressed and stored in ASAM OpenXOntology.

How to describe quantities

The current version of ASAM OpenXOntology provides a simple mechanism to describe quantities:

1. The datatype property `hasValue` assigns a float value to a `PhysicalQuantity`.
2. Each subclass of `Quantity` is defined to have a particular unit, usually the corresponding SI unit. For example, `LengthQuantity` is a subclass of `PhysicalQuantity` that represent lengths in the unit meters.

Example:

A particular road (`roadA`) is meant to have a width of 3 meters.

1. A `LengthQuantity`, `widthOfRoadA`, is declared to be the width of roadA. roadA is a member of the class `Road`.
2. A `hasValue` datatype property is declared to assign a float value of 3.0 to `widthOfRoadA`.

`widthOfRoadA` is the set of all things in the universe that have a length of 3 meters. That means, if vehicleX has a length of 3 meters, then `lengthOfVehicleX`, which is a member of `LengthQuantity`, is the same individual as `widthOfRoadA`. `lengthOfVehicleX` and `widthOfRoadA` are two different names for the same thing: the set of all things in the universe that have a length of 3 meters.

How to use quantities

Perform the following steps to use quantities:

1. Define a quantity (for example, `LengthQuantity`, `WidthQuantity`) as subclass of `PhysicalQuantity`, if there is no existing one.
2. Define a unit, for example, meter, as subclass of `Unit`, if there is no existing one.
3. Optional: Define an object property, for example, `hasLength` or `hasWidth`, as subproperty of

`hasProperty`.

4. Assert quantities with values and units.

8. The core ontology

8.1. HQDM as the basis for the core ontology

ASAM OpenXOntology uses a well-proven architecture that supports semantic interoperability of ontologies: the division into top-level ontology (TLO), domain ontology, and application ontology.

The top-level ontology comprises classes for general concepts, such as physical objects, activities, and events, that are common across all domains. Each domain concept of ASAM OpenXOntology, for example, vehicle, scenario, and traffic participants, is based on one or more top-level level concept. The core ontology of ASAM OpenXOntology represents the top-level ontology.

ASAM OpenXOntology uses HQDM, the High-Quality Data Models Framework, as core ontology. HQDM represents a four-dimensional top-level ontology that is based on ISO 15926 [21].

8.1.1. Use of HQDM in ASAM OpenXOntology

The ASAM OpenXOntology core classes and relationships use the HQDM data model [22]. They represent a selection of HQDM elements that are required as a foundation for the concepts of the traffic domain that ASAM OpenXOntology represents. That means that HQDM is not fully included in ASAM OpenXOntology. Rather, selected HQDM concepts are used to model underlying concepts for the traffic domain, such as physical objects, events, activities, and states.

8.1.2. Set-based approach of HQDM

HQDM uses a set-based approach to ontology modeling, which means that classes are defined by their extension over a set of actual individuals. This allows for the use of set-based logical inference, for example, by first-order logic. In HQDM, everything is one of these:

- Something that exists in time and space, like a vehicle. These are called *spatio-temporal extents*.
- A set or tuple that groups things, like the ordered pair of one vehicle that is in front of another. These are called *abstract objects*.

HQDM does not use attributes to describe characteristics. Instead, all characteristics, specifications, and state variables that need to be represented in the ontology are represented using sets or tuples. That means that characteristics are defined as membership to sets. The characteristic “My car is red” means that the individual “My car” is a member of the set of all red things.

The actual sets are not defined in the ABox, but will be defined in the TBox as instances of the abstract object classes that ASAM OpenXOntology provides in the core ontology, for example, `Set`. HQDM uses multiple inheritance, so an individual can be part of more than one set.

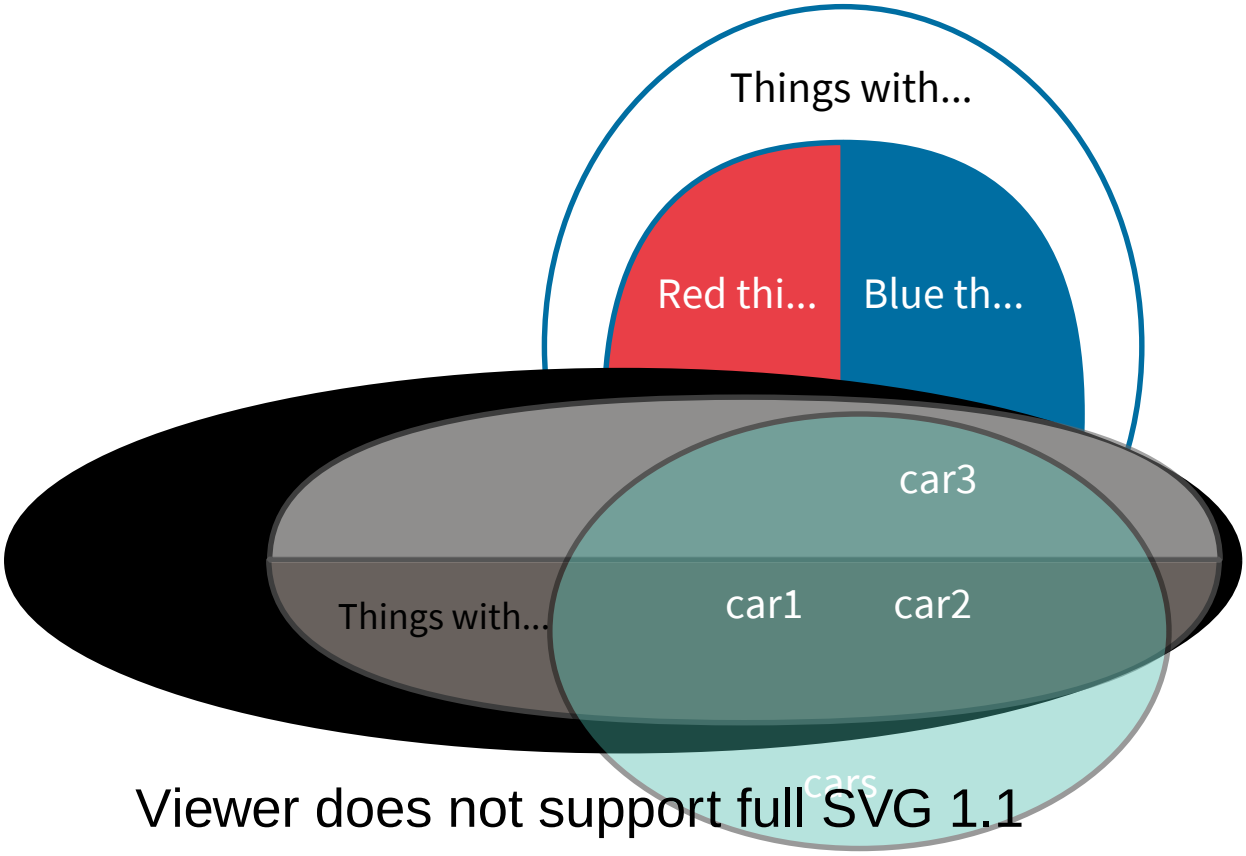


Figure 6. Sample sets for cars

Figure 6 shows the set-based approach of HQDM. It shows sets for cars, things with a specific color, and things with doors. All individuals, that is, car1, car2, and car3, belong to several sets. car1, for example, has 4 doors and is red. Because of these characteristics, it belongs to the sets `Cars`, `Red Things`, and `Things with 4 doors`.

8.2. Overview of the core classes

The ASAM OpenXOntology core classes and relationships use the HQDM data model. They represent a selection of HQDM elements that are required as a foundation for the concepts of the traffic domain that ASAM OpenXOntology represents.

All things modeled in ASAM OpenXOntology are divided into 2 fundamental concepts: spatio-temporal extents and abstract objects.

Spatio-temporal extents

Spatio-temporal extents are things that exist in space and time. They represent the reality, meaning the things that exist in the domain of road traffic. They are represented by the core class `SpatioTemporalExtent`, which includes the following concepts:

- Physical objects: cars, roads, clouds, signs, buildings, people, engines, rain drops, etc.
- Activities: moving, changing state, communicating, and weather phenomena like rain, snow, and wind.
- Events: everything that occurs in an instance, such as the beginning or ending of an activity.
- Periods of time the entire universe over a finite time.
- Possible worlds: mechanism that HQDM uses to handle logical modality.

Abstract objects

Abstract objects are things that do not exist in space and time. They reflect our understanding of the real things. Abstract objects are represented by the core class `AbstractObjects`.

Abstract objects include:

- Sets: A group of things, which can both spatio-temporal extents, sets, and/or tuples. Used to represent types or kind of things, for example, by common characteristics of set members.
- Tuples: An ordered group of things (usually two), which may be spatio-temporal extents, sets, and/or tuples. Used to represent relationships, meaning the way that the first thing is related to the second, and so on. Tuples containing two things are most common and represent binary relationships between the two things, for example, that the first thing is a part of the second thing.

Related topics

- Spatio-temporal extents as 4D representation of things
- Abstract objects

8.2.1. Spatio-temporal extents as 4D representation of things

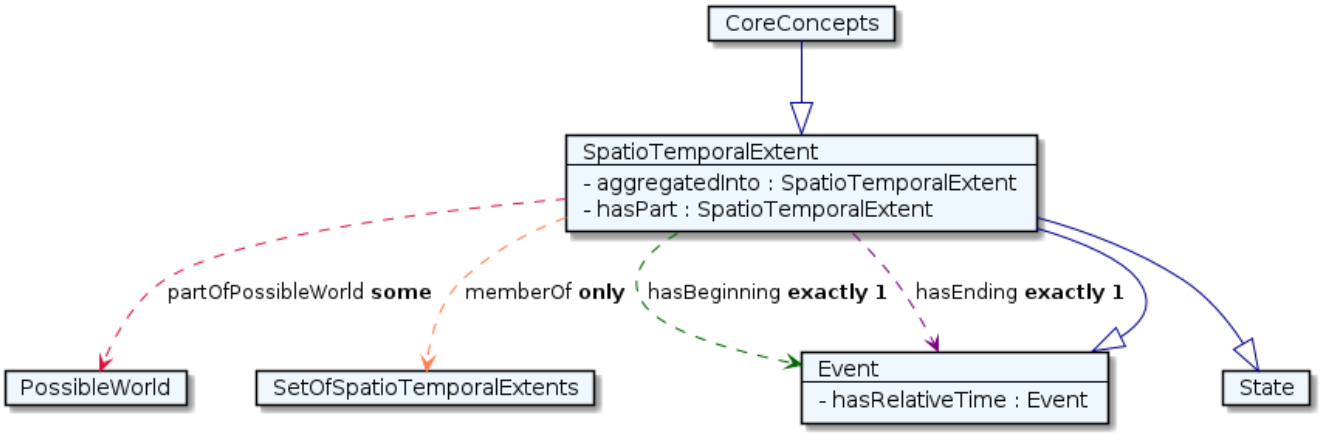
In HQDM, all things that exist in space and time are extended in four dimensions: three spatial and one temporal. ASAM OpenXOntology uses the class `SpatioTemporalExtent` to represent those things. This core class subsumes all other classes of actual things.

All spatio-temporal extents have a start event and an end event. An example is a vehicle whose lifetime starts when its manufacturing is complete and ends when the vehicle is dismantled.

There are two kinds of spatio-temporal extents: states and events.

OWL definition of SpatioTemporalExtent

The following model provides an overview of SpatioTemporalExtent:



Element	Description
Type	Class
Name	SpatioTemporalExtent
IRI	http://ontology.asam.net/ontologies/Core#SpatioTemporalExtent
Subclass of	CoreConcepts
Restriction	partOfPossibleWorld **some** PossibleWorld

Element	Description
Restriction	memberOf **only** SetOfSpatioTemporalExtents
Restriction	hasBeginning **exactly 1** Event
Restriction	hasEnding **exactly 1** Event
Comments	DEF: A thing that exists in time and space, meaning in four dimensions. Each spatio-temporal extent has a start event and an end event.
EXAMPLES: not applicable.	USAGE: This class will generally not be used directly in the OpenX domain.

Related topics

- Events
- States and temporal parts of things
- The state concepts of ASAM OpenXOntology

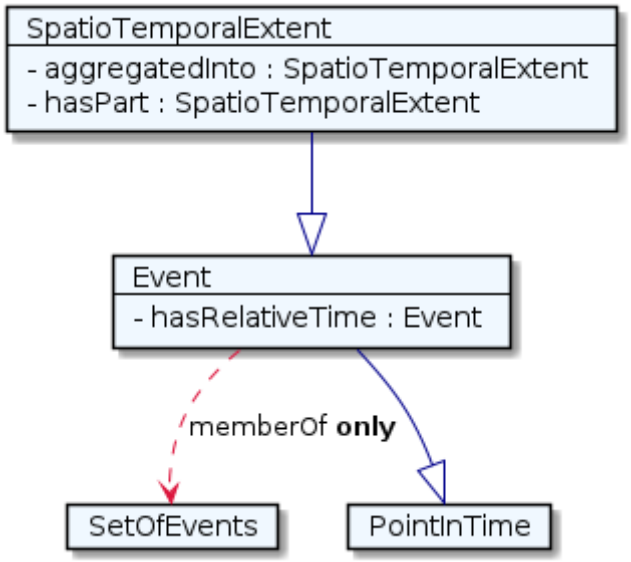
8.2.2. Events

Events are spatio-temporal extents with a time extension of zero, but with an extension in space. Events are represented by the core class `Event`. Events describe something that occurs in an instance, such as the beginning or ending of an activity or the lifetime of a physical object.

An example of an event is the instant when a vehicle stops moving.

OWL definition of Event

The following model provides an overview of Event:



Element	Description
Type	Class
Name	Event
IRI	http://ontology.asam.net/ontologies/Core#Event

Element	Description
Subclass of	SpatioTemporalExtent
Restriction	memberOf **only** SetOfEvents
Disjoint with	State
Comments	DEF: A SpatioTemporalExtent with a time extension of zero, but with an extension in space. Events mark changes in states and are used for something instantaneous.
EXAMPLES:	USAGE: Use this class to specify the state and/or end of activities and temporal parts of physical objects.

The subclass `PointInTime` is defined as an event that is the whole of space. Therefore, a `PointInTime` is the entire universe at an instant in time.

Example 2. Events

A particular time, such as 13:32 July 2, 2021, is a member of the class `PointInTime`.

A `PointInTime` can also be defined relative to another point in time, so the instant that occurs 5 seconds after a collision is also a `PointInTime`. This point in time covers the entire universe at that instant.

8.2.3. States and temporal parts of things

States are spatio-temporal extents with non-zero extension in both space and time. All things that have non-zero extension in space and time are states. This includes physical objects, such as vehicles, and activities, such as overtaking maneuvers.

A state may also represent a *temporal part* of a thing, meaning the thing over a particular time period. During that time period, the thing is characterized by a specific condition that does not change. Once the condition changes, a new temporal part is created. Thus, temporal parts are used to handle the identity of things through change. An example of a temporal part is a vehicle driving at 60 km/h on a specific road for 5 minutes.

Example 3. States and temporal parts of things

The vehicle `V1` is waiting at a red line and therefore not moving until some point in time, at which point it starts moving. The instant in time when the vehicle starts moving may be represented as event `t1`. ASAM OpenXOntology uses states to represent temporal parts of the vehicle `V1` for the event `t1`:

- State `V1notmoving` is the temporal part of `V1` from its beginning to `t1`. The fact that it is not moving is asserted by making it a member of the set of all non-moving things.
- State `V1moving` is the temporal part of `V1` from `t1` to its end. The fact that it is moving is asserted by making it a member of the set of all moving things.

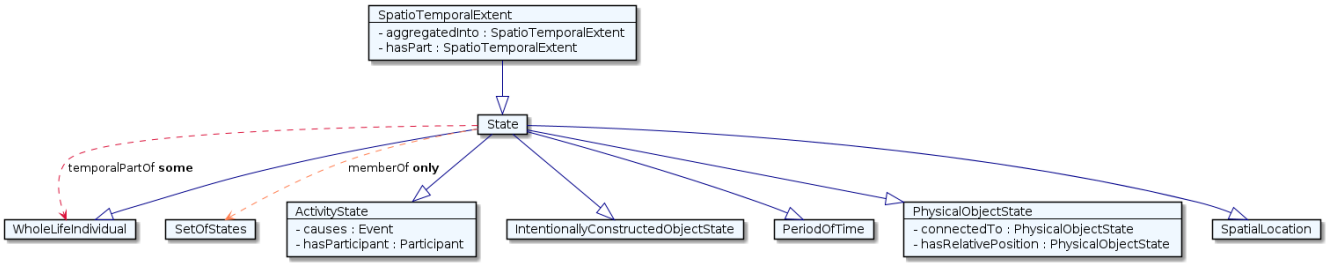
The event `t1` represents the boundary in time between the two temporal parts of `V1`.

8.2.4. The state concepts of ASAM OpenXOntology

All things that have non-zero extension in space and time are states. The core class `State` provides multiple subclasses to model kinds of states, such as periods of time, physical objects, activities, and more.

OWL definition of State

The following model provides an overview of State:



Element	Description
Type	Class
Name	State
IRI	http://ontology.asam.net/ontologies/Core#State
Subclass of	SpatioTemporalExtent
Restriction	temporalPartOf **some** WholeLifeIndividual
Restriction	memberOf **only** SetOfStates
Comments	DEF: A SpatioTemporalExtent with non-zero extension in both space and time. Used to describe, for example, the state of a vehicle, a person, or a manufactured system like a factory. States can apply to the whole life of a thing or represent temporal parts of a thing,
EXAMPLES:	USAGE: Use this class to describe the temporal part of a whole-life individual to which some property applies or to describe the temporal part of a whole-life individual that participates in an activity.

The core ontology of ASAM OpenXOntology contains the following subclasses for `State`:

- `PeriodOfTime`: Analogous to `PointInTime` in `Event`, `PeriodOfTime` is a subclass of `State` that is the whole of space. Therefore, `PeriodOfTime` is the entire universe over a particular period of time. A particular time interval, such as June 21, 2011, is a member of the class `PeriodOfTime`.
- `PossibleWorld`: A `PeriodOfTime` that covers all of time. Therefore, `PossibleWorld` is the entire universe for all of time. This is then the universe we live in. However, possible worlds may also represent different possible universes with pasts or futures that differ from the one we experience.

  This class shall be used to model modality, such as several possible planned futures. Example: a description could contain two possible worlds. The possible world where carA stopped at the pedestrian crossing and where carA did not stop.

- `PhysicalObjectState`: represents all physical objects, including temporal parts of physical objects.

Examples of PhysicalObjectState include just about all tangible things that are modeled in ASAM OpenXOntology, such as vehicles, pedestrians, roads, and trees. The actual classes for these specific things, for example, for vehicles are created in the domain ontology as subclasses of the corresponding core ontology class.

- SpatialLocation: represents all spatio-temporal extents that have continuity of relative position. A SpatialLocation describes a position, an area, or a space that is important in a defined context. A SpatialLocation can be described in various ways, such as by topology, topography, or coordinates. Examples of SpatialLocation are the position of an object, a zoning area, or a country where certain traffic regulations apply.
- ActivityState: Represents activities that consists of their participants and cause some Event. Participants are individuals of PhysicalObjectState that participate in activities. The end event of an activity is caused by that activity, which implies that the activity describes some change between the start event and end event. That means that an activity describes what changes in a state over time. Examples of activities are lane changes, rain falling, and gathering of sensor information.
- IntentionallyConstructedObjectState: HQDM defines intentionally constructed objects as states that exist because of an act of will or agreement. That means that individuals of IntentionallyConstructedObjectState are constructed intentionally by one or more things that have intent, usually humans or robots. Examples of intentionally constructed objects are vehicles, roads, road regulations, and a plan to turn left.

Because many physical objects and even activities are constructed by humans, those things are also members of the class IntentionallyConstructedObjectState.

- SociallyConstructedObjectState: HQDM defines socially constructed objects as intentionally constructed objects that are necessarily constructed by agreement of or acceptance by many people in a social community. Examples of socially constructed objects are contracts, companies, and money.
- IntentionallyConstructedActivityState: An activity that is also an IntentionallyConstructedObjectState and describes planned activities by single persons or intelligent devices.

  Examples are the changing of a signal state by a device in an intelligent transportation system and the plan of a driver to make a right turn at a junction.

- SociallyConstructedActivityState: An activity that is also a SociallyConstructedObjectState. It describes planned activities by a group of persons or intelligent devices.

  Examples are planned activities between multiple people such as meetings and the coordination of multiple traffic signals in an intelligent transportation system.

- WholeLifeIndividual: HQDM differs between the whole life of things and temporal parts. Therefore, a whole-life individual represents the whole life of a particular thing, for example, of a physical object like a car.

Related topics

- Temporal parts of things and the whole life of things
- Physical objects

8.2.5. Temporal parts of things and the whole life of things

HQDM differs between the whole life of things and temporal parts.

Whole-life individual

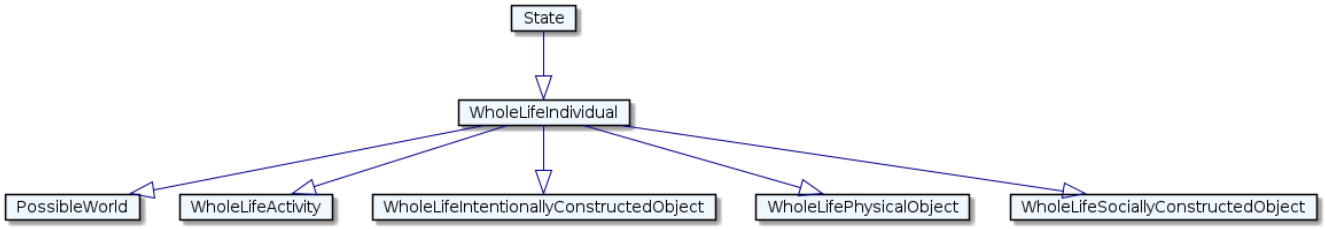
A whole-life individual is a state that is not a temporal part of any other state that is of the same kind. Therefore, a whole-life individual represents the whole life of a particular thing, for example, of a physical object like a car or an activity like a car making a right turn.

To represent *whole-life individuals*, ASAM OpenXOntology uses the HQDM concept `WholeLifeIndividual`.

`PhysicalObjectState`, `ActivityState` and `IntentionallyConstructedObjectState` have corresponding `WholeLifeIndividual` subclasses: `WholeLifePhysicalObject`, `WholeLifeActivity`, `WholeLifeIntentionallyConstructedObject` and `WholeLifeSociallyConstructedObject`.

OWL definition of WholeLifeIndividual

The following model provides an overview of WholeLifeIndividual:



Element	Description
Type	Class
Name	WholeLifeIndividual
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeIndividual
Subclass of	State
Comments	DEF: A State that is not a proper temporalPartOf any other individual of the same kind.
EXAMPLES:	USAGE: Use this class in combination with others to designate that a particular spatio-temporal extent is "its whole life"

`WholeLifeIndividual` may be used in an ABox to indicate the thing that has states participating in various ways in a particular situation. An example is a truck that has a `State` of moving at 100 km/h on the motorway and a `State` of crashed into the side of the road.

Temporal parts (states)

During its lifetime, a whole-life physical object like a car takes part in different activities.

For each participation in an activity, ASAM OpenXOntology uses a member of the class `State` to model a *temporal part* that represents the thing during the activity or event.

Usually, in the traffic domain, a physical object of interest, such as a vehicle making a left turn, is almost always not the complete whole life individual. In most cases, those individuals should be modeled as members of the class `State`, rather than `WholeLifeIndividual`.

In the following, *physical object* is used in the context that anything is a `WholeLifePhysicalObject` and/or a `PhysicalObjectState`. *Activity* is used in the context that anything is a `WholeLifeActivity` and/or an `ActivityState`.

Example 4. Temporal parts

The individual that is the complete lifespan of a traffic sign from the instant it is manufactured to the instant that it is disassembled is a member of `WholeLifeIndividual`.

It is not a temporal part of any other individual representing some temporal part of that traffic sign.

On the other hand, the individual that is the traffic sign for the duration that it is installed on a particular intersection is a temporal part of the whole-life individual that does not include the manufacture of the sign at the factory and the shipping of the sign to the installation site. The second individual is modeled as a state.

8.2.6. Interaction of events, physical objects, and activities

During its lifetime, a whole-life physical object, such as a vehicle, takes part in different activities. For each participation in an activity, ASAM OpenXOntology models a temporal part of the particular whole-life thing that represents the thing during the activity or event.

Example: The whole-life thing can be a specific car. The temporal part is this car making a left turn.

Temporal parts are represented by the class `State`. Temporal parts of whole-life physical objects that participate in activities are also members of the class `Participant`, which is a subclass of `State` > `PhysicalObjectState`.

When describing the dynamics of something like a car using a series of states, each state is related to the thing (usually a `WholeLifeIndividual`) by `temporalPartOf`. This makes it clear that those states are all temporal parts of the thing whose dynamics are being described.

The `participantOf` object property, which is a subproperty of `partOf`, is a relationship pair that indicates that the first thing in the pair is a temporal part of a whole-life object that is participating in the second thing in the pair, which is an activity. The subproperties of `participantOf` - `subjectOf` and `objectOf` - indicate whether the participant is the subject or object of the activity, respectively.

Unlike `temporalPartOf` and its subproperties `beginningOf` and `endingOf`, `participantOf` and its subproperties do not describe a temporal division, meaning the participants of an activity are not temporal parts of that activity.

Example 5. Example of physical objects, events, and activities

An example of the interaction of whole-life objects, temporal parts of physical objects, and activities is an overtaking maneuver on a motorway. This maneuver may be described in an OpenSCENARIO 1.1.1 file as `scenario0`.

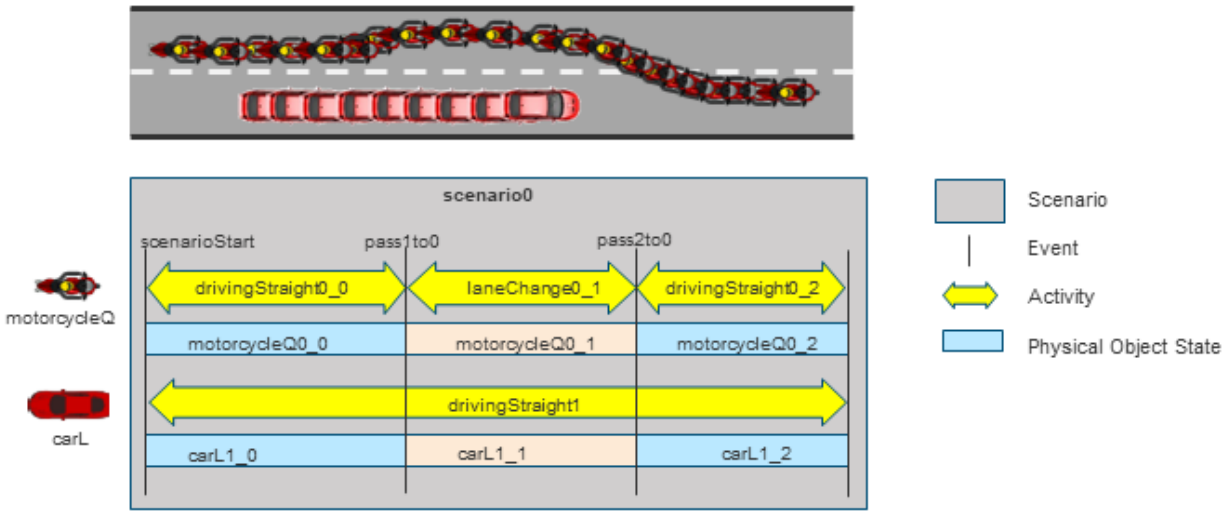


Figure 7. Sample scenario

Figure 7 shows the maneuver.

The maneuver is a member of `WholeLifeActivity`, and several members of `WholeLifePhysicalObjects` participate in the scenario, such as cars, motorcycles, lanes, and more. The temporal parts of those physical objects are represented as members of `Participant`, which is a subclass of `State` > `PhysicalObjectState`. Events determine the start and end of the activities.

The activities specify what changes between the events:

- In the activity `drivingStraight0_0`, the temporal part `motorcycleQ0_0` of `motorcycleQ` passes the temporal part `carL1_0` of `carL`.

  Event `pass1to0` is the end event of the activity.

- In the activity `laneChange0_1`, the temporal part `motorcycleQ0_1` of `motorcycleQ` changes the lane.

  Event `pass2to0` is the end event of the activity.

- In the activity `drivingStraight0_2`, the temporal part `motorcycleQ0_2` of `motorcycleQ` drives in front of `carL` and increases the distance between both vehicles.

8.2.7. Physical objects

The `PhysicalObjectState` class and its subclasses represent physical objects, such as cars, functional objects, such as traffic signs, and installed systems, such as the road infrastructure.

According to HQDM, a `PhysicalObjectState` is a state that “consists of a distribution of matter and/or energy”. A `PhysicalObjectState` is understood to have a bounded distribution; it can be identified as

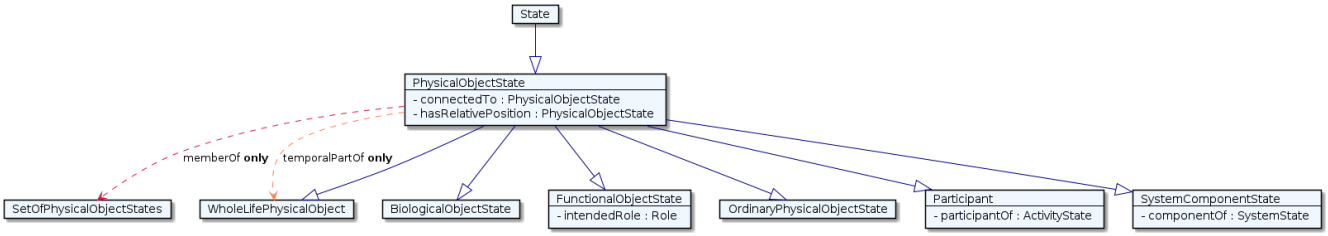
that parcel of matter and/or energy over time. A `PhysicalObjectState` is characterized by what does not change over time.

A `PhysicalObjectState` may be divided into parts:

- Spatial parts (composition) using the `partOf` object property.
- Temporal parts using the `temporalPartOf` object property.

OWL definition of PhysicalObjectState

The following model provides an overview of PhysicalObjectState:



Element	Description
Type	Class
Name	PhysicalObjectState
IRI	http://ontology.asam.net/ontologies/Core#PhysicalObjectState
Subclass of	State
Restriction	memberOf **only** SetOfPhysicalObjectStates
Restriction	temporalPartOf **only** WholeLifePhysicalObject
Comments	DEF: A State that consists of a distribution of matter and/or energy. A PhysicalObjectState is understood to have a bounded distribution, and so it can be identified as that parcel of matter and/or energy over time. A PhysicalObjectState can be thought of as characterizing what does not change over time of a State.
EXAMPLES:	USAGE: Generally use a subclass of this class.

`PhysicalObjectState` contains the following subclasses:

- `Participant`: Participants are physical object states that participate in one or more activities. Examples of participants are the temporal parts of some whole-life individual, such as a pedestrian or a car, that are doing some action, such as walking across the street.

A `Participant` can usually also be classified as an `OrdinaryBiologicalObjectState` or `OrdinaryFunctionalObjectState`.

- `BiologicalObjectState`: Biological objects are physical objects that sustain themselves and reproduce. Examples of biological objects are humans, animals, trees.
- `FunctionalObjectState`: Functional objects are physical objects and intentionally constructed objects that are constructed with a particular function in mind. This function is represented by the intended role of that physical object. The role is assigned with the `intendedRole` object property. In

particular, any artifact that is manufactured for a purpose is a functional object. This includes roads, vehicles, traffic signals, buildings, engines, and ADS controllers.

An example of a thing that is `PhysicalObjectState` but not `FunctionalObjectState` or a `BiologicalObjectState` is a thing that was not created by humans for some purpose, such as a rock, a cloud, or a piece of garbage.

- `OrdinaryPhysicalObjectState`: HQDM defines ordinary physical objects as physical objects that do not survive changing all their parts at once. This is usually true for the physical objects in the ASAM OpenXOntology domain. In general, all physical objects of the core ontology are also ordinary physical objects.

An example of a thing that is `PhysicalObjectState` but not `OrdinaryPhysicalObjectState` is a system component, because a system component, such as a car's engine, does survive changing all of its parts at once, for example, if the engine is replaced completely.

- `WholeLifePhysicalObject`: Physical objects that are not temporal parts of any other physical object. This class may be used to represent a physical object that is its temporal whole. In most cases, however, one of the subclasses should be used.

Related topics

- Interaction of events, physical objects, and activities
- Temporal parts of things and the whole life of things

8.2.8. Systems and system components

ASAM OpenXOntology differentiates between the function of objects, including their membership in a functional system as a system component, and the actual materialized physical object itself. This makes it possible to define components of the traffic infrastructure, such as signs, for example, with a focus on their function. When the actual, tangible object is replaced, because a new sign is installed, the system component stays the same, but the ordinary physical object changes.

The following subclasses of `PhysicalObjectState` are used to model systems and their components:

- `SystemState`: A `OrdinaryPhysicalObjectState` that represents a concrete materialized system.

  `Systems` are ordinary in the sense that they cease to exist when all of their parts are removed.

  They may be combined with `OrdinaryBiologicalObjectState` to represent biological systems, such as humans, trees, and forests.

  Systems are defined as an organized or connected group of physical objects, each of which comprises a component that plays a specific role in how the system functions.

  A `SystemState` may represent the whole life of the system or a temporal part of it.

  It is usually preferable to use the subclass `FunctionalSystemState` for intentionally constructed systems that have specific functions. An example of a `SystemState` that is not a `FunctionalSystemState` is a natural weather system.

Most physical objects of the OpenX domain are systems, including cars, pedestrians, and roads. Exceptions might include things like road barriers and pylons, which are not meaningfully comprised of connected physical objects.

- `FunctionalSystemState`: A `OrdinaryFunctionalObjectState` that is also a `SystemState`.

  This is the preferred class for representing temporal parts of concrete (actual, materialized) systems that cease to exist when all of their parts are removed, such as vehicles, traffic infrastructure, buildings, and traffic lights. They are often combined with `OrdinaryBiologicalObjectState` or `OrdinaryFunctionalObjectState`.

- `WholeLifeSystem`: A `SystemState` that is also a `WholeLifeOrdinaryPhysicalObject`.

  This class may be used to represent a system that is its temporal whole. However, usually it is preferable to use the subclass `WholeLifeFunctionalSystem` for intentionally constructed systems that have specific functions.

  An example of a `WholeLifeSystem` that is not a `WholeLifeFunctionalSystem` is the entire life of a hurricane from when it is formed to when it ceases to exist.

- `WholeLifeFunctionalSystem`: A `FunctionalSystemState` that is also a `WholeLifeSystem`.

  This class is the preferred way to represent a functional system that is its temporal whole, such as a vehicle from when it is manufactured to when it is destroyed.

- `SystemComponentState`: A `PhysicalObjectState` that represents a component of a system. HQDM defines system component as a physical object that is a component of a system and that can be completely replaced without losing its identity.

  A `SystemComponentState` may represent the whole life of the component or a temporal part of it.

  The existence of a `SystemComponentState` depends on the system it is a component of. This is unlike ordinary whole-life physical objects that may be installed as the component during a part of their lifetime. A `SystemComponentState` may be completely replaced without losing its identity, so it is not an `OrdinaryPhysicalObjectState`.

  It is generally preferable to use the subclass `FunctionalSystemComponentState` for physical objects that are components of systems that have specific functions, meaning they are functional systems.

  System components are usually not `OrdinaryPhysicalObjects` because they retain their identity even if all of their parts are replaced simultaneously. An example is a speed limit traffic sign next to a motorway: the actual signal can be replaced but the new signal is still the speed limit signal at this point of the motorway.

- `FunctionalSystemComponentState`: A `FunctionalObjectState` that is also a `SystemComponentState`. Represents a replaceable component of a `FunctionalSystem`.

  The object property `componentOf` is used to relate the object to the `FunctionalSystem`.

  A `FunctionalSystemComponentState` may be the whole life of the component or a temporal part of it.

  This class is the preferred way to represent the components of systems that were created for a specific purpose, for example markings of road or engines of vehicles, that is, as components, not as installed material objects - see `InstalledObject` below.

- `WholeLifeSystemComponent`: A `SystemComponentState` that is also a `WholeLifePhysicalObject`. This class may be used to represent a system component that is its temporal whole, meaning the whole life of a system component, which normally has the same duration as the system it is a component of.

However, usually the subclass `WholeLifeFunctionalSystemComponent` should be used for components of intentionally constructed systems that have specific functions.

An example of a `WholeLifeSystemComponent` that is not a `WholeLifeFunctionalSystemComponent` is the eye of a hurricane.

- `WholeLifeFunctionalSystemComponent`: A `FunctionalSystemComponentState` that is also a `WholeLifeSystemComponent`. This class is the preferred way to represent the whole life of a component of a functional system, such as the component of a junction that is a traffic light, which functions as a signal at a junction, meaning not the individual traffic lights with their serial numbers and dates of production, but the traffic light as a functional component.

  A `WholeLifeSystemComponent` may be temporarily divided into `FunctionalSystemComponentStates` for each of the `InstalledObjects` that acted as the component over the lifetime of the functional system.

- `InstalledObject`: An `OrdinaryPhysicalObjectState` that is installed in a system, meaning that is also a `SystemComponentState`.

  Represents the state of the ordinary physical object that is the temporal part covering the time from when the ordinary physical object is actually installed in the system to when it is removed.

  An example is the temporal part of the traffic sign with the serial number 42 that is installed at a specific location on highway 66.

  The class `InstalledFunctionalSystemComponent`, which is a subclass of `InstalledObject`, should be used in this case, because it indicates that the object is installed in a functional system, and the highway is a functional system.

- `InstalledFunctionalSystemComponent`: A `FunctionalSystemComponentState` that is also a `InstalledObject`. This class is the preferred way to represent the actual, materialized installed components of a functional system, such as the individual traffic lights with their serial numbers and dates of production when they are actually installed and functioning as components of a junction.

Example 6. System and system components

This example illustrates how the classes `FunctionalSystemComponentState` and `OrdinaryPhysicalObjectState` are used to describe the dynamics of a traffic signal that is located at a motorway and is replaced.

The traffic signal exists in the following two aspects:

1. As a component of the traffic infrastructure, meaning it is a functional system component (member of `FunctionalSystemComponentState`).
2. As an ordinary physical object that was manufactured somewhere and has a particular mass, color, etc. (member of `OrdinaryPhysicalObjectState`).

The functional system component is an integral component of the traffic infrastructure system. This means, the component exists in some form as long as the traffic infrastructure exists and has the traffic signal as a component. However, the particular "materialized" ordinary physical object that is acting as the system component may change many times over the systems lifetime. For example, if the installed signal is destroyed, a new signal must be installed. The new signal still works in the same system component, but it becomes a new ordinary physical object with possibly different manufacturer, color, size, etc.

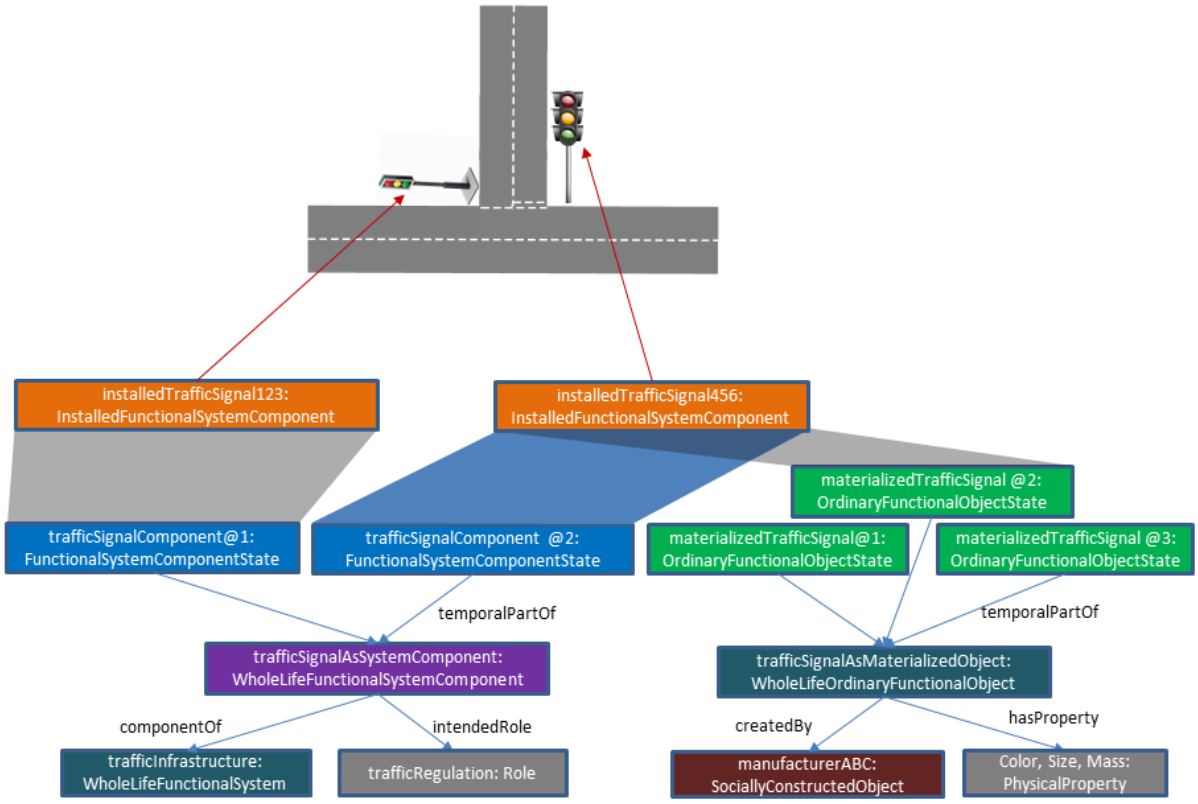


Figure 8. Example of traffic light as functional system component

Figure 8 shows the traffic light as functional system component and physical object.

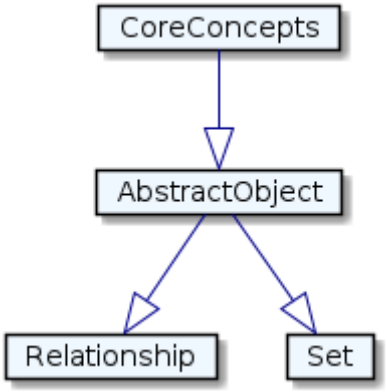
8.2.9. Abstract objects

The second fundamental class of the ASAM OpenXOntology core is `AbstractObject`. Abstract objects are all things that are not spatio-temporal extents, which means all things that do not exist in space and time. Abstract objects are used to express facts about spatio-temporal extents, such as physical properties, physical quantities, roles, and relationships.

`AbstractObject` has two subclasses: `Set` and `Relationship`.

OWL definition of AbstractObject

The following model provides an overview of AbstractObject:



Element	Description
Type	Class
Name	AbstractObject
IRI	http://ontology.asam.net/ontologies/Core#AbstractObject
Subclass of	CoreConcepts
Disjoint with	SpatioTemporalExtent
Comments	DEF: A thing that does not exist in space or time. Abstract objects are used to express characteristics of spatio-temporal extents, such as properties and roles.
EXAMPLES: not applicable.	USAGE: This class will generally not be used directly in the OpenX domain.

8.2.10. Sets

HQDM defines a `Set` as an abstract object that “has members and whose identity is defined by its members”. The members may be relationships or other sets as well as specific spatio-temporal extents.

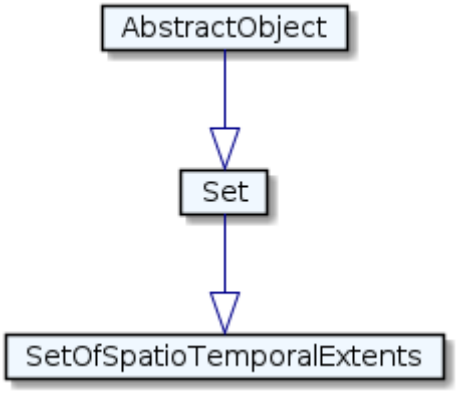
Subclasses of `Set` are generally available for all subclasses of `SpatioTemporalExtent`. However, the ASAM OpenXOntology core currently only includes subclasses of `Set` for `SpatioTemporalExtent` and its main subclasses: `Event`, `State`, `ActivityState`, `PhysicalObjectState`, `Participant` and `WholeLifeIndividual`. That means, `SetOfSpatioTemporalExtents` is a set whose members are all spatio-temporal extents. `SetOfStates` is a set whose members are all states, and so on.

Members of these classes are used to describe specific sets of the corresponding things that are not

already defined as subclasses of that thing in the ontology. For example, use a member of the class `SetOfPhysicalObjects` to describe specific sets or kinds of `PhysicalObjectStates` that are not available already as subclasses of `PhysicalObjectState`.

OWL definition of Set

The following model provides an overview of Set:



Element	Description
Type	Class
Name	Set
IRI	http://ontology.asam.net/ontologies/Core#Set
Subclass of	AbstractObject
Comments	DEF: An AbstractObject that has members and whose identity is defined by those members. The members may be other sets as well as specific spatio-temporal extents.
EXAMPLES: not applicable.	USAGE: This class will generally not be used directly in the OpenX domain.

The subclasses of `Set` include:

- `Role` is a `SetOfParticipants` where all participants in the set share some particular kind of role by participating in the same way in an activity.

  Examples of `Role` are purposes, such as being for transportation or agriculture use, as well as more general roles, such as creator, owner, consumer, controller, asset, and more.

- `PhysicalProperty` is a `SetOfStates` that represents some characteristic that each of the member states possesses. Member states may be activities, events, or physical objects.

  More accurately, a `PhysicalProperty` is a `Set` that groups states by a specific characteristic, but `PhysicalProperty` is understood to be the specific characteristic shared by its members. That means, a member of `PhysicalProperty` is just a characteristic of all states that are members of the `PhysicalProperty` as a `SetOfStates`.

  Examples of `PhysicalProperty` are the color red, a triangle shape, the material surface characteristic of being rough, or the particular duration of an acceleration activity.

- `Geometry` is a `PhysicalProperty` that describes a spatial characteristic of an object in a 1D, 2D, or 3D space.

  While shape only refers to the outer surface, `Geometry` includes other spatial characteristics, for example different kinds of projection, such as cross section and road geometry.

  According to ISO 15926, shape is a property that depends on constant relations of position and proportionate distance among all the points composing its outline or its external surface.

- `PhysicalQuantity` is a `PhysicalProperty` that is a measurable quantity of some kind of physical quantity. This is similar to the model of quantities used by QUDT [23], which defines quantity as “a measure of an observable phenomenon, that, when associated with something, becomes a property of that thing; a particular object, event, or physical system.”

  Examples of `PhysicalQuantity` are the velocity of a particular car, the distance between two cities, and the width of a particular road segment.

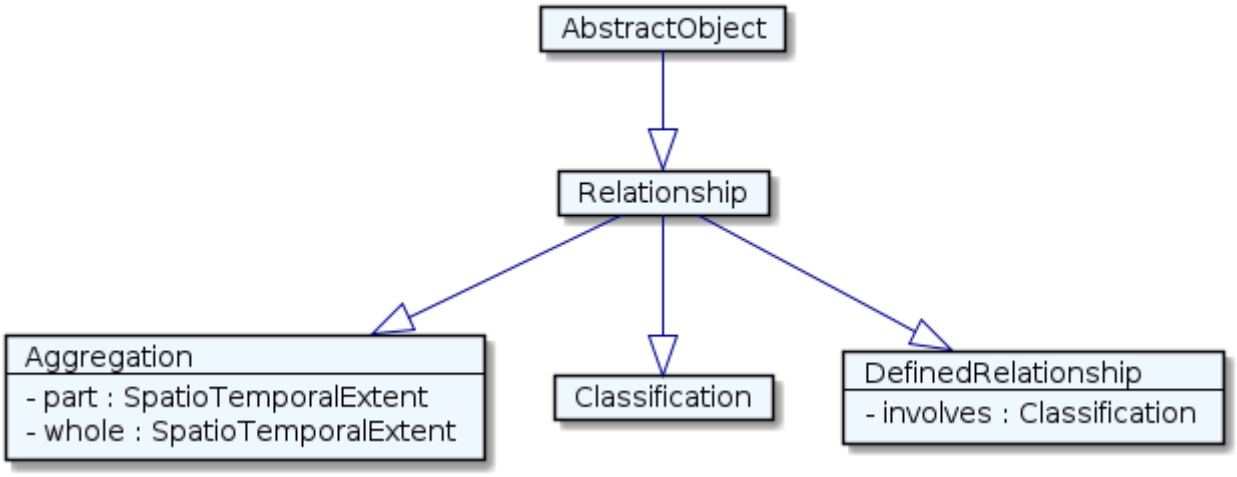
  ASAM OpenXOntology provides subclasses of `PhysicalQuantity` for common quantities, such as `DirectionQuantity`, `LengthQuantity`, `SpeedQuantity`, and `AngleQuantity`.

8.2.11. Relationships

Members of the `Relationship` class are abstract objects that represent the relations between things, that is, what one thing has to do with one or more other things.

OWL definition of Relationship

The following model provides an overview of Relationship:



Element	Description
Type	Class
Name	Relationship
IRI	http://ontology.asam.net/ontologies/Core#Relationship

Element	Description
Subclass of	AbstractObject
Comments	DEF: Relationships form the basis for many object properties.
EXAMPLES: not applicable.	USAGE: This class will generally not be used directly in the OpenX domain.

The following relationship classes are available:

- `Aggregation`: A `Relationship` where the whole is at least the sum of the parts. Basis for object property `aggregatedInto`.
  - `Composition`: An `Aggregation` where the whole is an arrangement of the parts that results in emergent properties. Basis for object properties `partOf` and `hasPart`.
  - `TemporalComposition`: A `Composition` where the part is the entire whole spatially, but part of the whole temporally. Basis for object properties `temporalPartOf` and `hasTemporalPart`.
- `Classification`: A `Relationship` where a thing is a member of a class. Basis for object properties `memberOf` and `hasMember`.
- `DefinedRelationship`: A class provided by HQDM to express relationships of a particular kind. In the OpenX domain, the following kinds of relationships are identified to be important in addition to composition and classification:
  - `TemporalRelation`: A `DefinedRelationship` that describes a temporal relationship between two things, usually between events. Basis for the object properties `occursBefore`, `occursAfter`, and similar.
  - `ConnectionRelation`: A `DefinedRelationship` for relations between things that are connected in any way, physically or otherwise. Basis for the object property `connectedTo`. Use this class to express a connection between two things as a reified relationship, for example, in order to specify characteristics, such as the angle of the connection.
  - `SpatialRelation`: A `DefinedRelationship` between two physical objects that describes their directional relationship, not the distance. Basis for object properties such as `rightOf`, `leftOf`, `inFrontOf`, `behind`, and more. A `SpatialRelation` must have a direction that is a `DirectionQuantity`, a spatial object that is a `PhysicalObjectState`, and a spatial subject that is a `PhysicalObjectState`. A `SpatialRelation` is not a `TemporalRelation` because the classes are disjoint. Use this class to express a general spatial relation between two things as a reified relationship, giving only the direction of the relationship.

8.3. Core properties

There are two types of property in an ontology:

- Object properties specify how things are related to each other. They are the predicate in triples that have the form subject-predicate-object.
- Datatype properties to assign datatypes to classes.

Related topics

- What is an ontology

8.3.1. Object properties in the ASAM OpenXOntology core

Object properties are a fundamental part of an ontology that supports logical inference. Object properties in the ASAM OpenXOntology are all binary tuples, meaning pairs. Therefore, an object property always specifies in an ordered pair how the first element of the pair relates to the second element of the pair.

Examples:

- `hasPart` specifies that the first element has the second element as a part.
- `behind` specifies that the first element is located behind the second element.

Object properties may be assigned logical characteristics, such as transitivity and symmetry to reflect the underlying nature of the relationships that they represent. For example, `partOf` is transitive, while `connectedTo` is symmetric.

In addition, the classes of things that may be the first (domain) and second (range) elements of the binary tuple for a particular object property may be specified. So for the object property `causes`, the domain is `ActivityState` and the range is `Event`. Finally, object properties may be declared to be functional or inverse functional:

- Functional: an individual may only be the first element of one instance of the object property

  An example of a functional object property is `componentOf` because a component can only be the component of one system.

- Inverse functional: an individual may only be the second element of one instance of the object property.

  An example of an object property that is both functional and inverse functional is `hasSpatialSubject`, which connects a `SpatialRelation` to the thing that is the subject of the relation.

HQDM provides a minimal set of object properties mainly for specifying compositional and classification relationships. Compositional relationships are usually between spatio-temporal extents. For example, `temporalPartOf` connects a state to its whole-life individual, and `componentOf` connects a component of a system to the system that it is a component of. However, HQDM does not provide object properties for specifying participation relationships, spatial relationships, temporal ordering relationships, and connective relationships. The ASAM OpenXOntology core provides object properties for these kinds of relationships as well as for other basic relationships that are important in the OpenX domain. The ASAM OpenXOntology core also provides a set of object properties for relating the values of physical quantities.

8.3.2. Datatype properties in the core ontology

OWL uses datatype properties to assign datatypes to classes. The only datatype property defined in ASAM OpenXOntology is `hasValue`, which assigns a float value to each member of the class `PhysicalQuantity`.

Related topics

- Quantities and parameters

8.4. SWRL rules in the core ontology

ASAM OpenXOntology uses SWRL to define logical conditions (Horn clauses) that cannot be specified by only using the DL operators provided by OWL. HQDM does not use SWRL, the SWRL content in the ASAM OpenXOntology core has been added.

The following SWRL rules have been defined in the ASAM OpenXOntology core:

- Transitivity of the object properties for spatial relationships: `inFrontOf`, `behind`, `leftOf`, `rightOf`, etc.
- Transitivity of the object properties for temporal ordering: `occursBefore`, `occursAfter`
- Definitions of the object properties for spatial relationships in terms of `SpatialRelation`
- Definitions of the object properties for physical quantity relationship using the float values given by the `hasValue` datatype property

- Definition of `approximatelyEqualTo` object property to accept values that are within 10% of each other

Related topics

- Decision to use SWRL as rule language

9. The domain ontology

9.1. The harmonization process for the domain ontology

This section explains the harmonization process that the ASAM OpenXOntology domain group followed during the development of the domain ontology. The following questions are answered:

- Which standards did the group consider?
- How did the group extract the domain concepts from these standards?
- How was an umbrella structure for the domain ontology chosen?
- How did the group harmonize the extracted domain concepts and organize them within the umbrella structure?
- How were new domain concepts identified?
- How did the group use multiple inheritance of concepts to accommodate different classification methods?
- How did the group decide on classification methods and the selection of domain classes?

9.1.1. Extraction of concepts for the domain ontology

At the beginning of the harmonization process, the group researched standards in order to decide which of them could serve as a basis for the ASAM OpenXOntology domain ontology. These included released ASAM standards, published non-ASAM standards, and work-in-progress (WIP) ASAM standards and concepts. For the WIP standards and concepts, communication and alignment were established between the ASAM OpenXOntology domain group and the standard/concept development groups.

There are additional standards that the ASAM OpenXOntology domain group has sought to harmonize with ASAM OpenXOntology. However, due to the scope and resources required, the ASAM OpenXOntology domain group did not choose to incorporate them in this version. Any results from such efforts are included as suggestions for future ASAM OpenXOntology versions.

Name	ASAM standard/concept	Still WIP?	In alignment?
ASAM OpenSCENARIO 1.0.0	Yes	No	Yes
ASAM OpenSCENARIO 2.0.0	Yes	Yes	Not yet
ASAM OpenDRIVE 1.6.0	Yes	No	Yes
ASAM OpenODD Concept	Yes	Yes	Yes
ASAM OpenLABEL 1.0.0	Yes	Yes	Yes
ASAM OSI 3.3.0	Yes	No	Not yet
ASAM ODS	Yes	No	Not yet
BSI PAS 1883	No	No	Yes
ISO 34503	No	Yes	Yes

Table 6. Alignment with other standards

Table 6 shows the complete list of standards that were used during the harmonization phase.

General remarks

- ASAM OpenSCENARIO 2.0, ASAM OSI, and ASAM ODS [24] have been taken into consideration, but not yet harmonized with ASAM OpenXOntology.
- The final input to the ASAM OpenXOntology domain group is ASAM OpenSCENARIO 1.0, ASAM OpenDRIVE 1.6, and standards/concepts that take an operational domain design based approach: ASAM OpenODD, ASAM OpenLABEL 1.0, BSI PAS 1883, and ISO 34503.

On the use of BSI PAS 1883

- BSI PAS 1883 introduces a taxonomy for describing the ODD of automated driving systems.
- ISO 34503 is based on BSI PAS 1883 to further develop the taxonomy. Both the scenario-tagging domain model of OpenLABEL 1.0 and the domain model of OpenODD strongly reference BSI PAS 1883. Therefore, among the four ODD-based standards/concepts, there are coherent contributions to the ASAM OpenXOntology that follow the ODD taxonomy of BSI PAS 1883.

On the difference to standards at application level

- ASAM OpenSCENARIO 1.0, ASAM OpenDRIVE 1.6, and ASAM OpenLABEL 1.0 are application-level standards whereas ASAM OpenODD is a domain-level standard. Application- level concepts, such as *bounding box* or *simulation time*, are not domain-related. Therefore, the first task in the harmonization process was to filter and extract the domain concepts from the application-level standards. Because operational domain design related standards are already targeting at the domain level, their concepts have been preserved during this stage.

The process of extracting domain concepts

To extract the domain concepts from ASAM OpenSCENARIO 1.0, ASAM OpenDRIVE 1.6, and ASAM OpenLABEL 1.0, the domain group was divided into several subgroups, each consisting of experts for these standards. Each subgroup extracted domain concepts from the standards that were easy to identify.

Some concepts, however, were difficult to identify during this first stage. For such concepts, three methods were applied to determine their domain relevance.

1. Assume that if a concept appears in more than one application standard, it must be considered until other methods exclude it.
2. A vote within the project group. If the majority classifies a concept as an application-level concept, that concept is removed from the domain ontology.
3. Construct a hypothetical driving context of interest and then select the concepts from the other standards that can be used to describe the driving context.

   Three driving contexts were constructed at the beginning of the project for such purpose. In addition, the group developed the minimum-working-product (MWP) example that uses a series of examples to demonstrate the capability of the ontology.

In this way, the group was able to fill in any missing concepts that were not in the ontology at that time.

In addition to these methods, the project groups had several discussions with the members of the other project group about the mentioned standards and received confirmation from them.

9.1.2. Integration of domain concepts into the umbrella structure

After extracting the domain concepts, the next step was to organize them and fit them into an umbrella structure.

Operational domain design and a behavior-based approach

An operational domain design and a behavior-based approach to describe road-traffic situations in the automated driving system environment have gained popularity in industry and academia. The important role of the operational domain design within the safety assurance of automated driving systems is widely recognized. The objective of the ASAM OpenODD concept project highlights the importance, as does the operational domain design-based and behavior-based approach for the ASAM OpenLABEL scenario-tagging model.

Structure of the extracted domain concepts

The previously extracted domain concepts are not organized in a structure because the application-level standards are not structured according to domain classification.

Structure of the operational domain design-based domain model

The operational domain design-based domain model or taxonomy provides a good domain classification for road topology, traffic infrastructure, and environmental conditions. The only elements that are not reflected completely by the operational domain design-based model are traffic participant and dynamic behavior. For that reason, the group voted to use the operational domain design-based classification as umbrella structure for sorting the extracted domain concepts. A bottom-up approach was developed for the behavioral-domain concepts to define their structure. The umbrella structure contains:

- Road topology and traffic infrastructure
- Traffic participants and dynamic behavior
- Environmental conditions, which include weather-related environmental conditions and connectivity characteristics

This high-level structure is also in line with the proposal made during the concept phase of the project. The only difference is that environmental conditions and connectivity have been merged into one environmental condition branch.

9.1.3. Sorting of the extracted concepts

The extracted concepts were sorted based on these three main categories. However, an ODD-based umbrella structure does not fully reflect dynamic aspects, especially regarding the categorization of behavior and traffic participants.

To address this issue, the group started to gather input from ASAM OpenX members on behavioral concepts, resulting in an extensive list of behavioral concepts.

The domain group then collected suggestions within the group to establish possible structures for organizing these behavioral concepts. More than twenty different proposals for potential organizational structures were received. A voting process was initiated to select the best structures for these behavioral concepts, resulting in a set of final structures.

For example, a behavior, such as *making a turn*, can be categorized in the following ways:

- By the type of state changing, in this case a moving activity.
- By its relation to other participants, in this case a single-participant activity.
- By the type of participant, in this case a vehicle activity.

With traditional modeling approaches, incorporating multiple categorization approaches can be challenging. However, OWL allows assigning multiple parent classes to the same concept. In this case, all completed structures are modeled as different inheritance branches for the same set of concepts. Ontology users can decide during the usage time which method they prefer.

9.2. Overview of the domain classes

ASAM OpenXOntology has the goal to provide a foundation of common definitions, attributes, and relationships for ASAM OpenX standards, such as ASAM OpenDRIVE, ASAM OpenSCENARIO, ASAM OpenLABEL, ASAM OpenODD, and others. All these standards deal with different aspects of a common domain: road traffic.

9.2.1. ASAM OpenXOntology as OpenX domain model

The domain ontology of ASAM OpenXOntology represents the common domain model for the OpenX standards. To ensure an efficient use of the ASAM OpenXOntology domain model in the OpenX standards, the following aspects are important:

- Domain concepts shall be separated from application concepts. Application concepts shall be defined in application ontologies.

  Application ontologies contain concepts that the particular standard is allowed to modify without consulting any of the other standards. These are normally concepts that are only used in that specific standard.

- Identical concepts that are defined in more than one ASAM OpenX standard shall be extracted and added to the domain ontology.
- Similar concepts that are defined in more than one ASAM OpenX standard shall be harmonized and added to the domain ontology.
- New concepts shall be added continuously as part of the ASAM OpenX development.

The OpenX standards that have contributed to ASAM OpenXOntology cover the following areas:

- Road topology and traffic infrastructure
- Traffic participants and their behavior
- Ambient conditions

Related topics

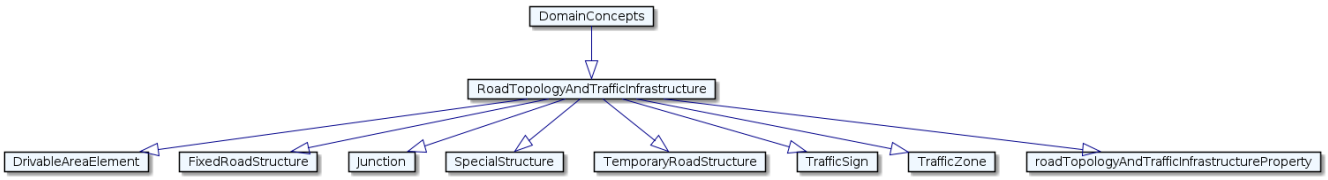
- Which ASAM OpenX standards contribute to the ontology
- Architectural overview
- Harmonizing domain ontology

9.2.2. Concepts for road topology and traffic infrastructure

The `RoadTopologyAndTrafficInfrastructure` class represents the top-most parent class for road topology and traffic infrastructure concepts.

OWL definition of RoadTopologyAndTrafficInfrastructure

The following model provides an overview of RoadTopologyAndTrafficInfrastructure:



Element	Description
Type	Class
Name	RoadTopologyAndTrafficInfrastructure
IRI	http://ontology.asam.net/ontologies/Domain#RoadTopologyAndTrafficInfrastructure
Subclass of	DomainConcepts
Comments	DEF: A set of features for describing the logical road network, traffic infrastructure elements, and related conditions.

The `RoadTopologyAndTrafficInfrastructure` class contains the following main concepts:

- `DrivableAreaElement` provides subclasses for areas in the traffic infrastructure that vehicles are supposed and permitted to drive in.

  Examples: road, lane, road marking.

- `FixedRoadStructure` contains subclasses for built or natural elements of the traffic infrastructure that are located near a drivable area but are not approved for traffic.

  Examples: building, streetlight, traffic island.

- The subclasses in `Junction` represent different intersection types and roundabouts.

  Examples: T-intersection, staggered intersection.

- `SpecialStructure` contains subclasses for elements of the road infrastructure that are located on top of the road network and through or on which traffic participants are permitted to travel.

  Examples: bridge, pedestrian crossing, tunnel.

- `TemporaryRoadStructure` represents elements of the road infrastructure that only temporarily exist on top of the road network.

  Examples: construction site detour, roadblock, traffic cone.

- In `TrafficSign`, different types of traffic signals are categorized according to their state or function.

  Examples: dynamic traffic signal, static signal, warning signal.

- The `TrafficZone` class provides subclasses for geographic areas with special road configurations, driving regulations, or environmental conditions.

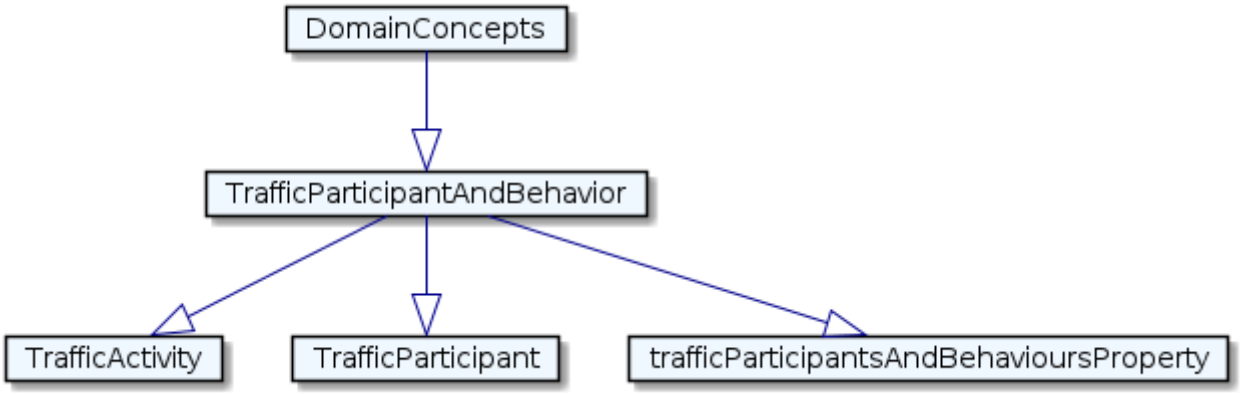
  Examples: geo-fenced zone, school zone, traffic management zone.

9.2.3. Concepts for traffic participants and their behavior

The `TrafficParticipantAndBehavior` class represents the top-most parent class for the concepts for vehicle types, traffic participants, and maneuvers.

OWL definition of TrafficParticipantAndBehavior

The following model provides an overview of TrafficParticipantAndBehavior:



Element	Description
Type	Class
Name	TrafficParticipantAndBehavior
IRI	http://ontology.asam.net/ontologies/Domain#TrafficParticipantAndBehavior
Subclass of	DomainConcepts
Comments	DEF: A set of activities, physical objects, and functional objects that describe traffic participants and their dynamic behavior.

The `TrafficParticipantAndBehavior` class contains the following main concepts:

- The `TrafficActivity` class and its subclasses represent actions performed by traffic participants during a traffic situation, typically to achieve a specific goal, like changing a lane. Activities are categorized as follows:
  - Complexity of the action, ranging from primitive to mission level.
  - The number of participants.
  - The state changes.
  - The traffic participant type.

  Examples: cutting in, overtaking, waving, using hazard light, accelerating.
- The `TrafficFunctionalObject` class defines types of vehicles.

  Examples: truck, van, public bus.
- The `TrafficParticipant` class defines types of traffic participant. The subclasses represent different sets:
  - Groups of traffic participants by type, like humans or animals.
  - Groups by vulnerability of the participant.

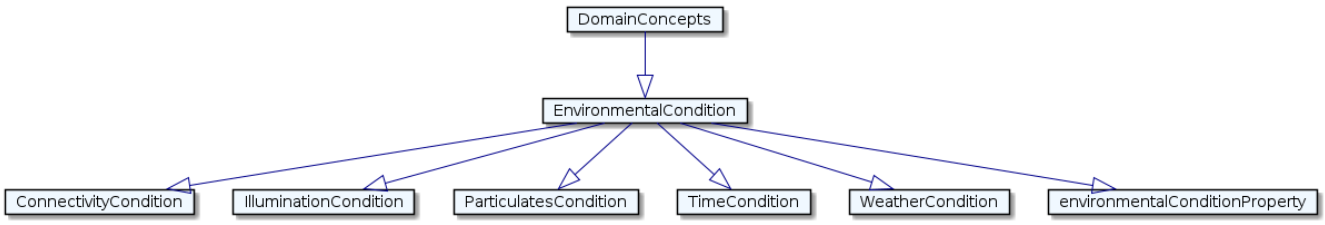
  Examples: pedestrian, driver, animal, agricultural vehicle, emergency vehicle.

9.2.4. Concepts for ambient conditions

The `EnvironmentalCondition` class represents the top-most parent class for the concepts for environmental conditions, such as weather, illumination, and communication.

OWL definition of EnvironmentalCondition

The following model provides an overview of EnvironmentalCondition:



Element	Description
Type	Class
Name	EnvironmentalCondition
IRI	http://ontology.asam.net/ontologies/Domain#EnvironmentalCondition
Subclass of	DomainConcepts
Comments	DEF: A set of environmental parameters that applies to a complete area, such as a town or a district. Conditions can have natural causes, for example rain or snowfall, or can be created artificially, for example by light sources or communication devices using specific methods like vehice-to-vehicle communication.

The `EnvironmentalCondition` class contains the following main concepts:

- The subclasses in `ConnectivityCondition` represent a vehicle's ability to receive and transmit data in order to identify its position or communicate with other traffic participants.

  Examples: GPS, vehicle-to-vehicle communication.

- The subclasses in `IlluminationCondition` describe the effect of light within a specific traffic situation. The scene may be illuminated, for example, by artificial or natural light.

  Examples: daylight, streetlight, vehicle light.

- `ParticulatesCondition` categorizes environmental conditions that are characterized by specific particles which lead to a limited visibility or obscuration of things. Particles may be, for example, water drops or sand.

  Examples: fog, smoke, dust.

- `TimeCondition` gives information about the time at which a specific traffic situation occurs, for example, a specific time of the day or a specific date in the year.
- `WeatherCondition` contains subclasses for specific weather situations.

  Examples: rainfall, snow, wind, cloud coverage of the sky.

10. Using ASAM OpenXOntology

10.1. How to incorporate a new concept

This section explains how new concepts that are developed by an ASAM simulation standard become part of ASAM OpenXOntology. The following questions are answered:

- How to integrate a new concept in ASAM OpenXOntology.
- How to determine whether to integrate the new concept on core, domain, or application level.
- How to determine the correct parent class(es).

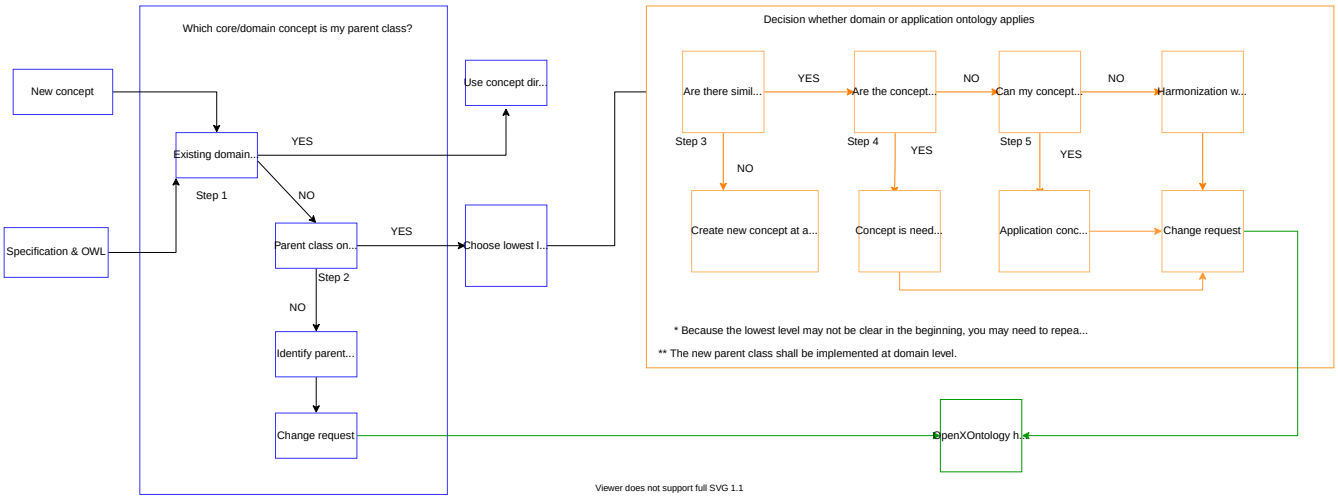


Figure 9. Incorporate a new concept into OpenXOntology

Figure 9 shows the workflow proposed by ASAM OpenXOntology to incorporate a new concept.

Proceed as follows to integrate a concept into ASAM OpenXOntology:

1. Compare your concept with the specification of ASAM OpenXOntology and the corresponding OWL file. Check whether the new concept corresponds to an existing domain concept or not.
   a. If the answer is YES, you shall use the existing domain concept directly.
   b. If the answer is NO, proceed with step 2.
2. Check whether you can find a suitable parent class for your concept in the domain ontology. Example: A suitable parent class for `childPedestrian` (your concept) would be the domain class `TrafficParticipant`.
   a. NO: If you cannot find a suitable parent class on domain level, check the core ontology for a suitable parent class. Submit a change request to the ASAM OpenXOntology group to enable a mapping of the identified parent core class to the new domain concept.
   b. YES: If you find a suitable parent class at domain level, compare your concept with the subclasses of this parent class. Check whether one of the subclasses would be better suited as parent class. Repeat this step until you find a suitable class at the lowest possible level within the class hierarchy of the domain ontology.

      Result: Once you identified the lowest possible domain concept that can serve as parent class, you need to determine whether the new concept belongs to the domain ontology or should be added at application level (see orange box).
3. Research whether any other ASAM simulation standard has a similar concept at application level that is related to the new concept. These concepts may already be linked to the domain concept that you identified in the previous step.

   a. If the answer is NO, your concept belongs to the application level. A new concept at application level shall be created. This concept shall be a subclass of the domain concept selected as suitable parent.
   b. If the answer is YES, proceed with step 4.
4. Research whether your concept and the related application concepts that you identified in the previous step are fully equivalent.
   a. If the answer is YES, the concepts from the different ASAM standards shall be harmonized and incorporated as a new concept at domain level. To start this process, submit a change request to the ASAM OpenXOntology group.
   b. If the answer is NO, proceed with step 5.
5. Decide whether your concept can be used as parent class for the identified application-level concept(s).
   a. If the answer is YES, your concept needs to be at domain level. Submit a corresponding change request to the ASAM OpenXOntology group.
   b. If the answer is NO, your concept needs to be harmonized with the other application-level concepts. Submit a corresponding change request to the ASAM OpenXOntology group.

10.1.1. Examples

Example 1

An ASAM standard drafted the new concept *passenger car* and run the process:

1. Step 1: The project group examines the ASAM OpenXOntology specification and finds the class `Car` in the domain ontology. That means that the concept *passenger car* is mapped to the *car* concept at the domain level. No further steps are needed.

Example 2

An ASAM standard drafted the new concept *Segway* and run the process:

1. Step 1: The project group examines the ASAM OpenXOntology specification, but there is no direct equivalent domain concept for *Segway*. However, there are superordinate concepts, such as *Traffic participant*, *vehicle*, and *VRU*.
2. Step 2: The project group chooses the lowest possible domain concept that can be used as parent class. In this case either *vehicle* or *VRU*.
3. Step 3: The project group researches whether there are other application-level concepts that are similar to *Segway*. They find one concept called *airwheel X3*.
4. Step 4: The project group considers *Segway* as a superordinate concept that is needed at domain level. They submit a change request to the ASAM OpenXOntology group for harmonization.

10.2. Sample data journey in ASAM OpenX

10.2.1. Data journey with ASAM OpenXOntology and related OpenX standards

An underlying formal representation of the taxonomy for OpenX standards has many advantages, as described in the chapter on the motivation to create an ontology for ASAM. ASAM OpenXOntology can also further enrich existing use cases that leverage ASAM OpenX standards. This section demonstrates various examples of such enriched workflows compiled into a Minimum Working Product (MWP).

These are highly simplified examples that use a small subset of ASAM OpenXOntology. Currently, the full ASAM OpenXOntology does not support inference or reasoning.

The content of the data journey is non-normative.

A data journey was defined to show how ASAM OpenXOntology helps to connect all areas of the scenario-based testing workflow. The data journey comprises five phases, starting with labeling sensor data and ending with checking a simulated scenario against an operational domain design.

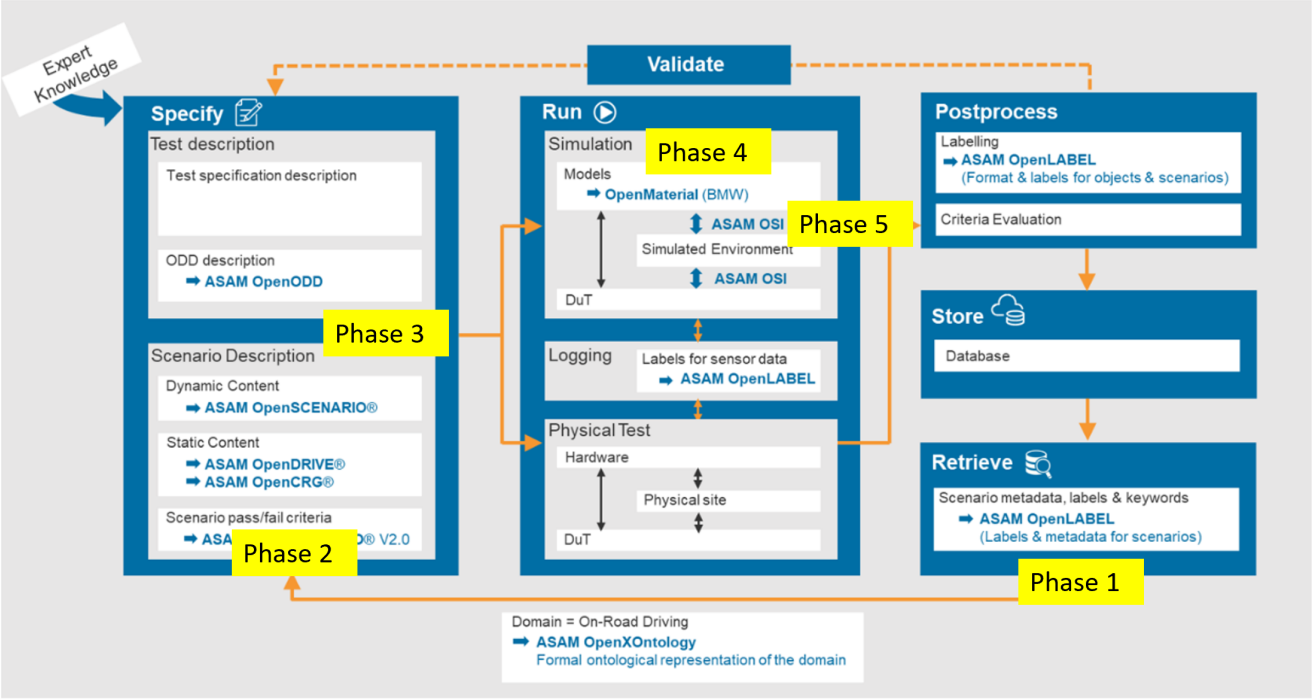


Figure 10. Phases of the data journey in the OpenX standard framework

Figure 10 shows the position of the MWP phases in the standardized workflow based on the OpenX standards.

The data journey comprises the following phases:

1. Label sensor data with OpenLABEL annotations, see phase 1 of the data journey: Label sensor data.
2. Check the data with a semantic application and infer knowledge, see phase 2 of the data journey: Check data and infer knowledge.
3. Generate scenario details and export OpenSCENARIO 1.1.1 and OpenDRIVE files, see phase 3 of the data journey: Detail the scenario.
4. Simulate the scenario, see phase 4 of the data journey: Simulate the scenario.
5. Check the OSI stream against an ODD, see phase 5 of the data journey: Check against ODD.

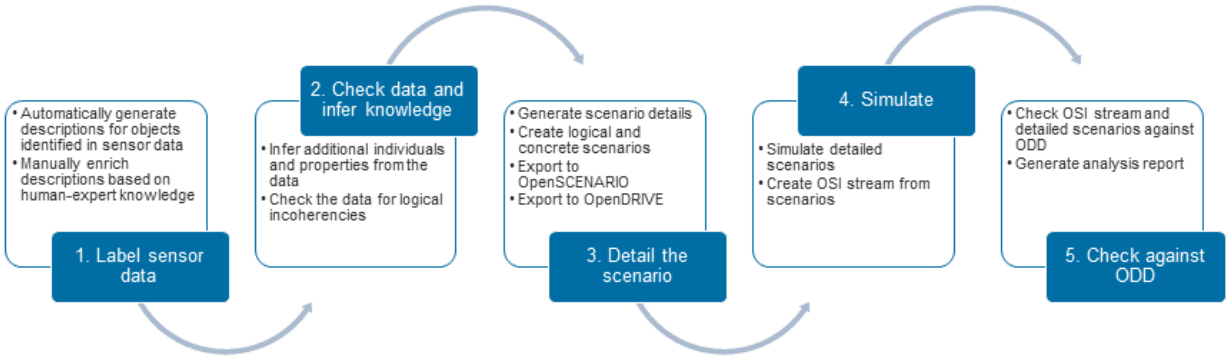


Figure 11. Data journey through the OpenX standards

Figure 11 shows a detailed overview of the journey.

TBox used for the data journey

ASAM OpenXOntology provides the TBox for generating ontology-based scenario descriptions and other data.

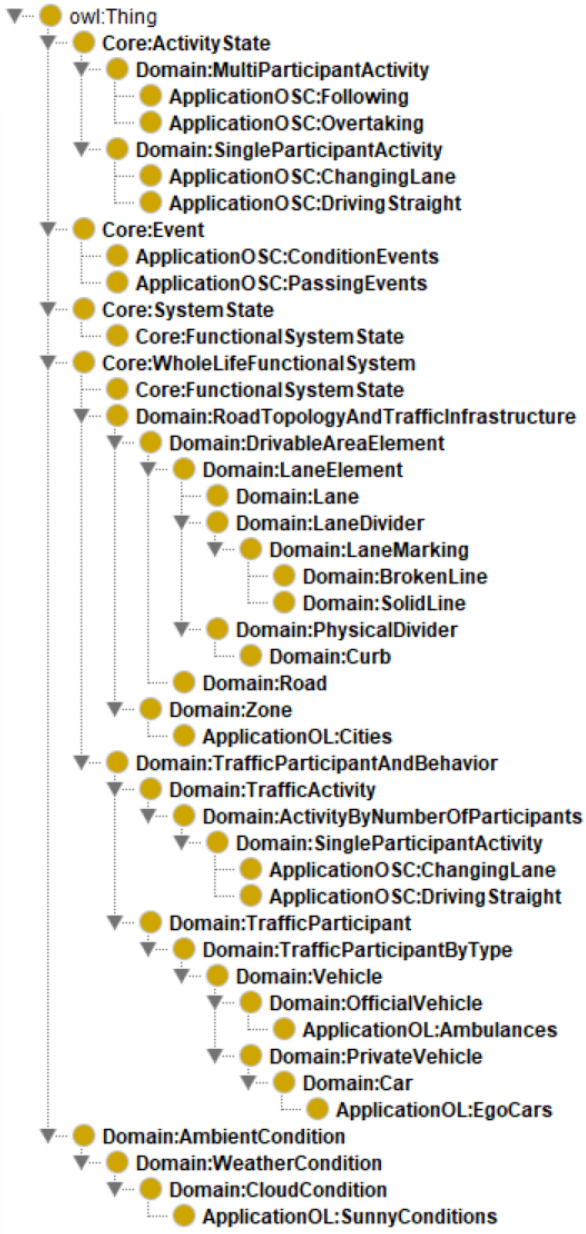


Figure 12. TBox for the data journey

Figure 12 shows the ontology classes in the data journey.

The TBox contains a subset of the classes from the core, domain, and application levels of OpenXOntology, as described in Architectural overview.

10.2.2. Phase 1 of the data journey: Label sensor data

In phase 1, sensor data is processed to generate OpenLABEL annotations for the physical objects detected in the sensor data, such as vehicles, lanes, and lane dividers. Annotations are first generated by a tool and second by a human annotator.

The input sensor data can be of different types, such as video footage or images.

The data journey uses the following traffic situation as an example:

- The situation occurs on a two-lanes road in the city on a sunny day.
- An ego vehicle (yellow) drives parallel to an ambulance and a red car. The ambulance and the red car

drive on the second lane.

- Both the ambulance and the red car pass the ego vehicle.
- The ego vehicle changes to the right lane and drives behind ambulance and red car.

The following figures show the start and end scenes of the traffic situation.

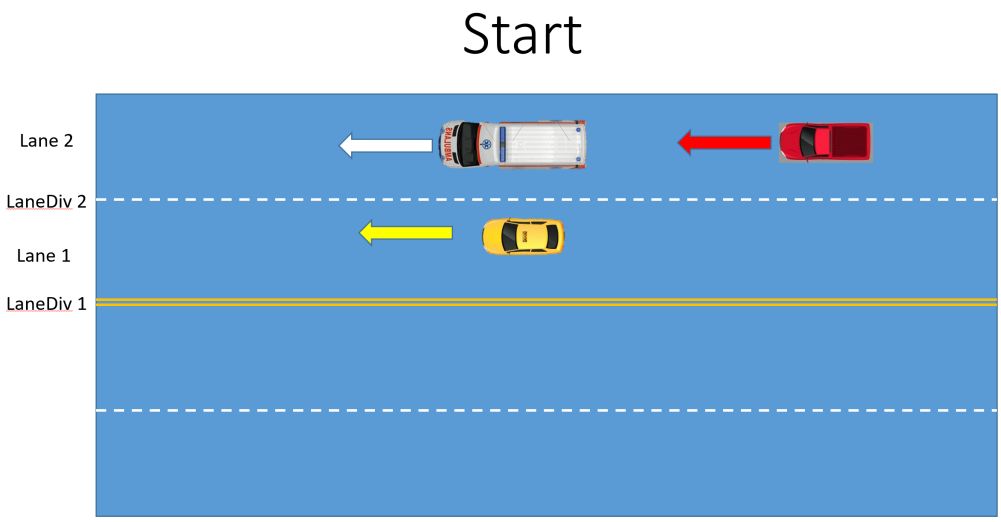


Figure 13. Start scene of the traffic situation

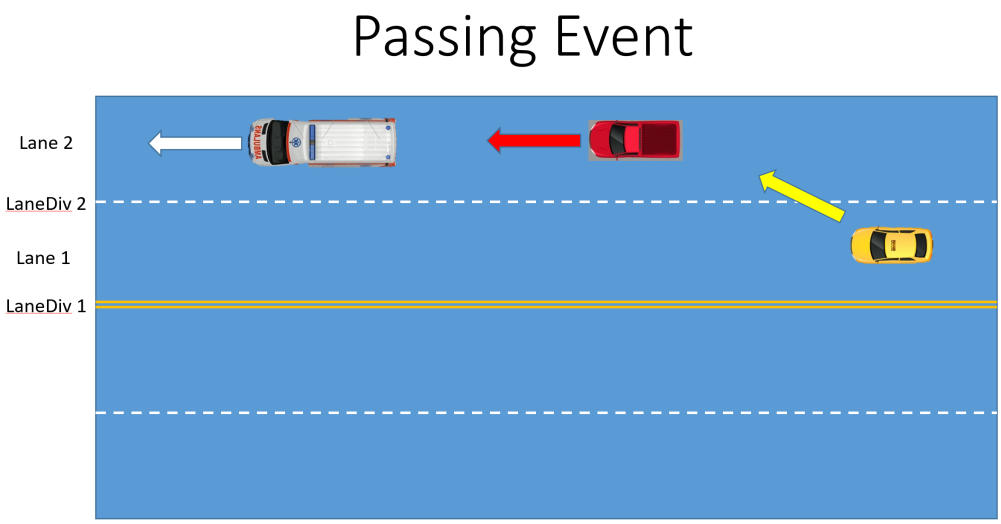


Figure 14. Traffic situation during the passing event

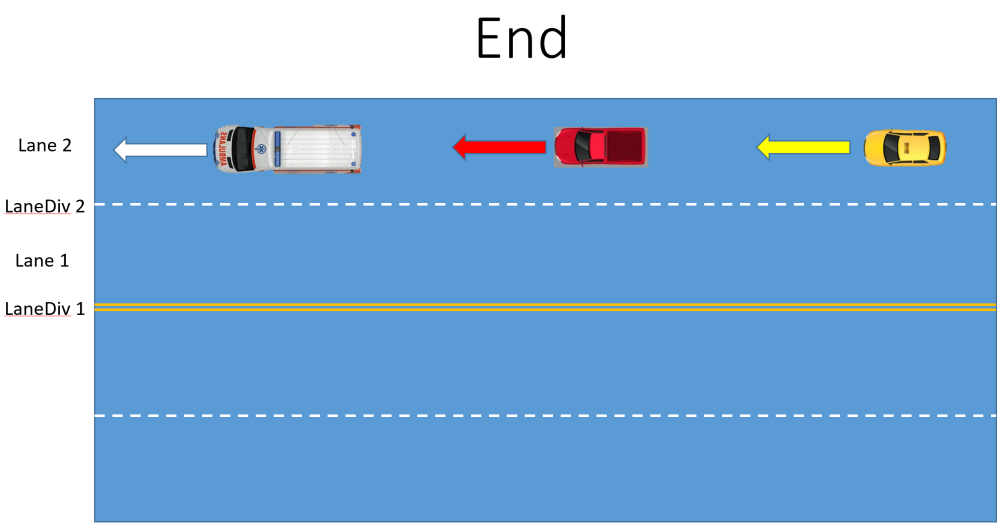


Figure 15. End scene of the traffic situation

Steps in phase 1

1. A label annotation software processes the sensor data and identifies the traffic participants, the involved road infrastructure, and the environmental conditions.
2. The label annotation software creates object labels using OpenLABEL syntax. OpenXOntology provides descriptions for the terms in the OpenLABEL syntax.
3. The label annotation software stores the labels in JSON files.
4. The OpenLABEL-formatted JSON files are converted to OWL triples, which are grounded in OpenXOntology. This step usually requires the addition of individuals and relationships because the label annotation software cannot detect all of the information required to describe the full situation. Currently, this must be done manually. To assist the human annotator, an ABox editing tool, such as EKOSS, can be used.

   In particular, for `WholeLifeFunctionalSystem` such as `Vehicle` that change their states over the time duration of interest, temporal parts of those `WholeLifeFunctionalSystem` shall be created as members of the class `FunctionalSystemState`. For example, `egoCar0` begins in one lane and later moves to the other lane. To represent this, the annotator creates three `FunctionalSystemState`:

   - `egoCar0_0` is the temporal part of the `egoCar0` that is in `lane1`
   - `egoCar0_1` is the temporal part of the `egoCar0` that is changing lanes
   - `egoCar0_0` is the temporal part of the `egoCar0` that is in `lane2`.

   The annotator specifies the beginning and ending for each of the `FunctionalSystemState` as one of the `Event` marking important points of time, such as the start or end of one of the `ActivityState`.

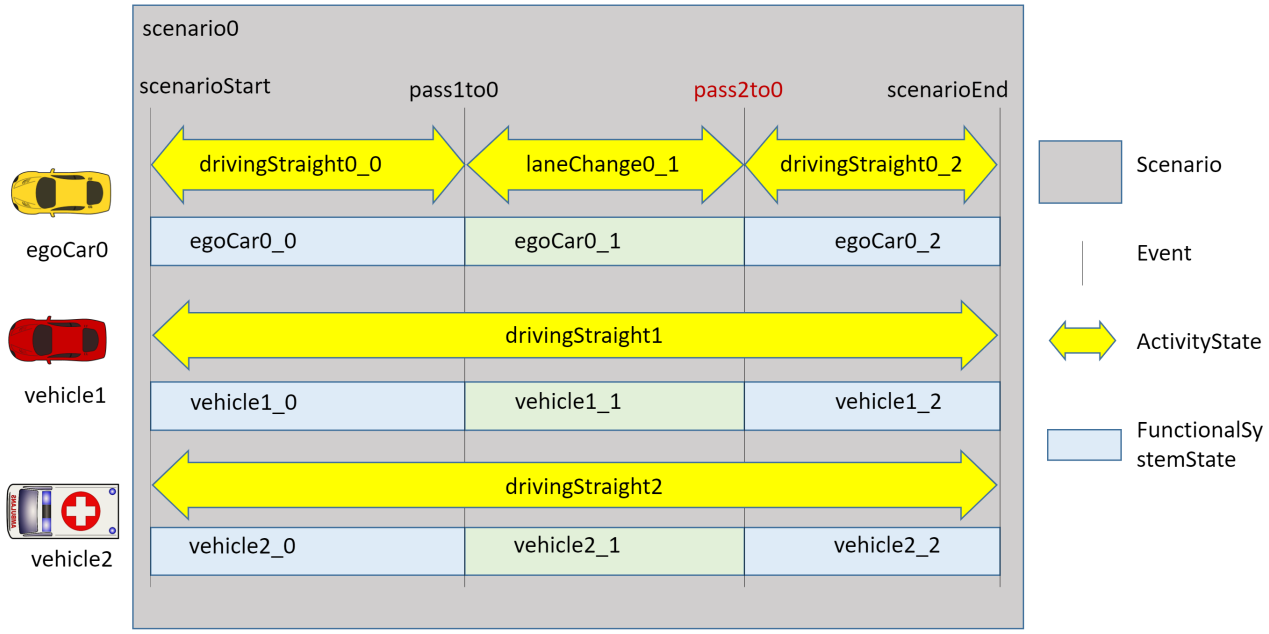


Figure 16. Interactions of scenario components

Figure 16 shows the interactions of the `Event`, `ActivityState`, and `FunctionalSystemState`.

5. The label annotator stores the enriched descriptions as an OWL file. This OWL file represents a complete ABox expressing the road traffic situation.

In this phase, only basic consistency checks are conducted on the annotation information that is generated.

Output example

Data in JSON files used to create OWL triples. The example shows the statements about the lanes that are part of a road.

```
    "objects": {
      "9": {
        "name": "Lane1",
        "type": "Lane",
        "object_data": "{...}",
        "object_data_pointers": "{...}"
        }
      }
      "10": {
        "name": "Lane2",
        "type": "Lane",
        "object_data": "{...}",
        "object_data_pointers": "{...}"
      }
      "11": {
        "name": "Road1",
        "type": "Road",
        "object_data": "{...}",
        "object_data_pointers": "{...}"
      }

    "relations": {
      "0": {
        "name": "",
        "type": "partOf",
        "rdf_subjects": [
          {
            "uid": "9",
            "type": "object"
          }
        ]
        "rdf_objects": [
          {
            "uid": "11",
            "type": "object"
          }
        ]
      }
    }
```

Extract from the enriched OWL file, road definition with lanes

```
<owl:NamedIndividual rdf:about="ABoxMWP#road1">
    <rdf:type rdf:resource="Domain#Road"/>
    <core:hasPart rdf:resource="ABoxMWP#lane1"/>
    <core:hasPart rdf:resource="ABoxMWP#lane2"/>
    <domain:hasNumberOfLanes rdf:datatype="integer">2</domain:hasNumberOfLanes>
</owl:NamedIndividual>
```

Extract from the enriched OWL file, definition of `lane1` *and connections to lane dividers*

```
<owl:NamedIndividual rdf:about="ABoxMWP#lane1">
    <rdf:type rdf:resource="Domain#Lane"/>
    <rdf:type>
        <owl:Restriction>
            <owl:onProperty rdf:resource="Core#connectedTo"/>
            <owl:maxQualifiedCardinality
                    rdf:datatype="nonNegativeInteger">2</owl:maxQualifiedCardinality>
            <owl:onClass rdf:resource="Domain#LaneDivider"/>
        </owl:Restriction>
    </rdf:type>
    <domain:connectedTo rdf:resource="ABoxMWP#laneDiv1"/>
    <domain:connectedTo rdf:resource="ABoxMWP#laneDiv2"/>
    <domain:objectOf rdf:resource="ABoxMWP#drivingStraight0_0"/>
</owl:NamedIndividual>
```

Role of OpenXOntology

OpenXOntology provides the TBox, meaning the terminological component for labeling the input data in the automatic processing step and enriching the labeling in the manual annotation step. For example, OpenXOntology provides the base classes and definitions for the physical objects to be labeled, such as Lane.

As for other ASAM standards, OpenLABEL is used in this phase.

10.2.3. Phase 2 of the data journey: Check data and infer knowledge

In phase 2, a semantic application parses and checks the triples created in phase 1 in order to infer new knowledge and identify semantic conflicts.

The input for phase 2 is the ABox generated in phase 1 and stored as OWL file. This ABox represents a functional scenario and contains the assertions on the identified traffic objects and road traffic situation.

Steps in phase 2

1. A reasoner parses the data in the existing ABox and infers additional individuals and relationships from the ABox, based on OpenXOntology. The new data is added to the OWL file, resulting in an enriched OWL file.
   - In the example scenario, the RDF triples generated in phase 1 contain the information that lane 1 and lane 2 are both connected to lane divider 2, but only lane 1 is connected to lane divider 1. Knowing that lane divider 1 is the center lane divider and the traffic drives on the right side of the road, the

reasoner can infer that lane 2 must be located to the right of lane 1.

- For this inference, SWRL rules need to be used. Specifically, the following rule is used to identify the positioning of neighboring lanes belonging to the same road: `domain:Road(?w) ^ domain:Lane(?x) ^ domain:Lane(?y) ^ core:hasPart(?w, ?x) ^ core:hasPart(?w, ?y) ^ differentFrom(?x, ?y) ^ domain:LaneDivider(?z0) ^ domain:SolidLine(?z1) ^ domain:connectedTo(?x, ?z0) ^ domain:connectedTo(?y, ?z0) ^ domain:connectedTo(?x, ?z1) → domain:RightOf(?x, ?y)`
- For the sample scenario, the HermiT reasoner is used.

2. A reasoner checks the OWL file for semantic conflicts. The ontology gives logical and rule-based constraints on the concepts it defines. These constraints can be used to detect semantic conflicts in a description of a situation or scenario. If the reasoner identifies a conflict, it outputs an explanation of why the conflict has occurred, for example, which rules and logical characteristics were found to be in conflict. A human user can use that information to decide how to solve the conflicts.
   - In the example scenario, the OWL file generated in phase 1 contains incorrect information about the passing event. The ABox contains the assertion that `vehicle2_2` passes `egoCar0_2`, which is in conflict with the assertion that `egoCar0_2` is behind `vehicle2_2`:

```
<owl:NamedIndividual rdf:about="AboxMWP#pass2to0">
    <rdf:type rdf:resource="ApplicationOSC#PassingEvents"/>
    <domain:hasObject rdf:resource="AboxMWP#egoCar0_2"/>
    <domain:hasSubject rdf:resource="AboxMWP#vehicle2_2"/>
</owl:NamedIndividual>
```

   - A logical reasoner such as HermiT can provide information about what assertions may be contributing to this semantic conflict as shown in Figure 17.

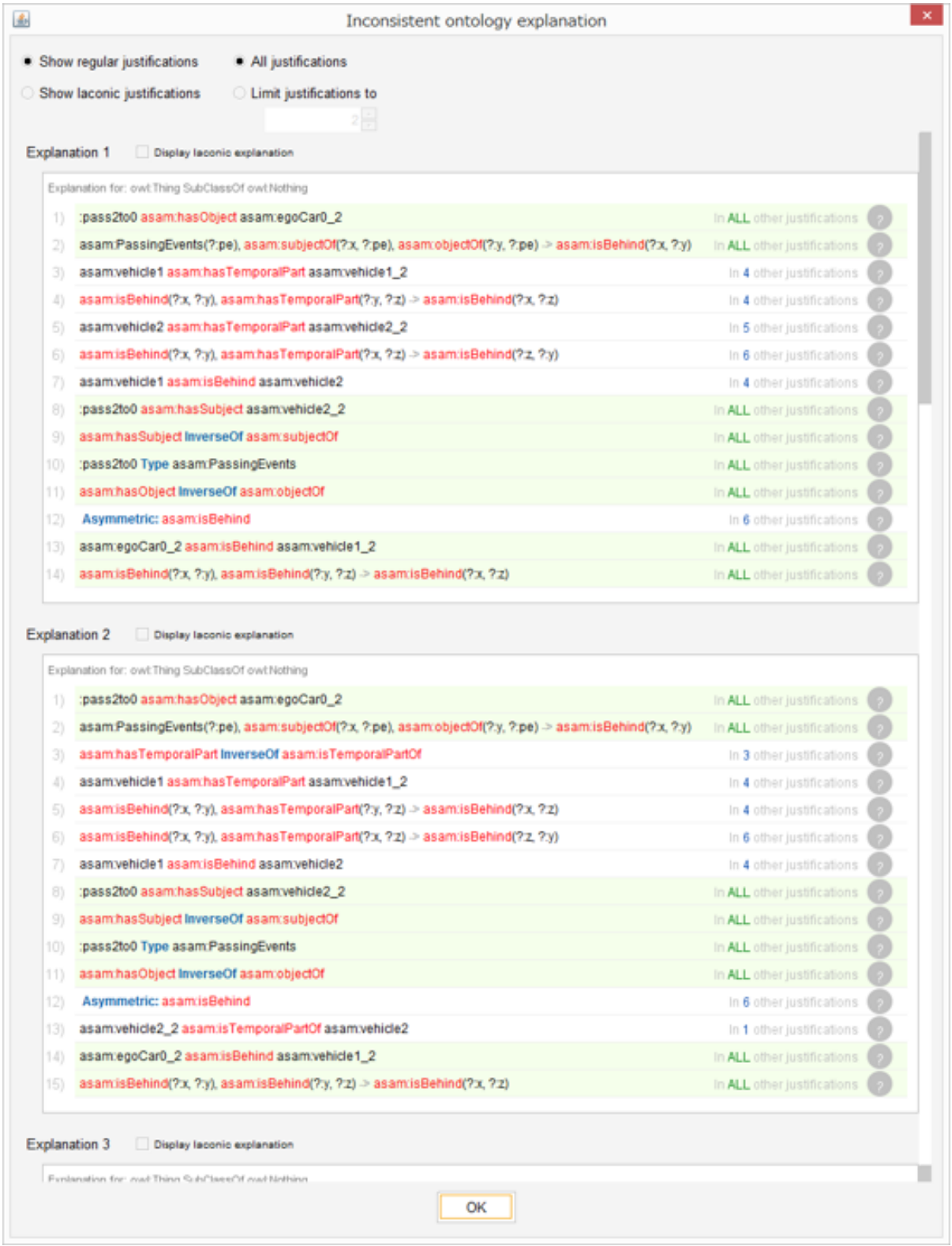


Figure 17. Example of information provided by a logical reasoner about a semantic conflict

- In this data journey, the human user could resolve this semantic conflict by switching the `hasObject` and `hasSubject` individuals or removing the assertion about the passing event completely.

3. Once the human user has resolved the semantic conflicts, the reasoner application stores the results in an OWL file.

The output data of this phase is a functional scenario that is described in OWL.

Output examples

The reasoner adds a triple to the definition of lane 1 in the ABox for the position of lane 1 to the right of lane 2.

The logical reasoner also adds other inferences, such as the membership of lane 1 to the upper level classes `RoadTopologyAndTrafficInfrastructure` and `FunctionalSystemState` and the fact that because road 1 has part lane 1, lane 1 is part of road 1.

```
<owl:NamedIndividual rdf:about="AboxMWP#lane1">
    <rdf:type rdf:resource="Domain#Lane"/>
    <rdf:type rdf:resource="Domain#RoadTopologyAndTrafficInfrastructure"/>
    <rdf:type rdf:resource="Domain#FunctionalSystemState"/>
    <rdf:type>
        <owl:Restriction>
            <owl:onProperty rdf:resource="Domain#connectedTo"/>
            <owl:maxQualifiedCardinality
                    rdf:datatype="nonNegativeInteger">2</owl:maxQualifiedCardinality>
            <owl:onClass rdf:resource="Domain#LaneDivider"/>
        </owl:Restriction>
    </rdf:type>
    <domain:connectedTo rdf:resource="AboxMWP#laneDiv1"/>
    <domain:connectedTo rdf:resource="AboxMWP#laneDiv2"/>
    <core:isPartOf rdf:resource="AboxMWP#road1"/>
    <domain:isRightOf rdf:resource="AboxMWP#lane2"/>
    <domain:objectOf rdf:resource="AboxMWP#drivingStraight0_0"/>
</owl:NamedIndividual>
```

Role of OpenXOntology

The TBox and the SWRL rules of OpenXOntology are used to check the ABox for conflicts and infer new individuals and relationships. The resulting OWL file is more comprehensive and semantically correct.

10.2.4. Phase 3 of the data journey: Detail the scenario

Phase 3 details the functional scenario to a logical scenario and then to a concrete scenario. To detail a functional scenario to a logical scenario, parameters and parameter ranges have to be defined in a first step. In a second step, constraints between these parameters have to be identified to guarantee meaningful scenarios. Afterwards, this logical scenario can be used as a basis to set parameter values and generate the ASAM OpenDRIVE and ASAM OpenSCENARIO 1.1.1 files for the corresponding concrete scenario.

The input data of phase 3 is the functional scenario generated in phase 2 and stored as OWL file.

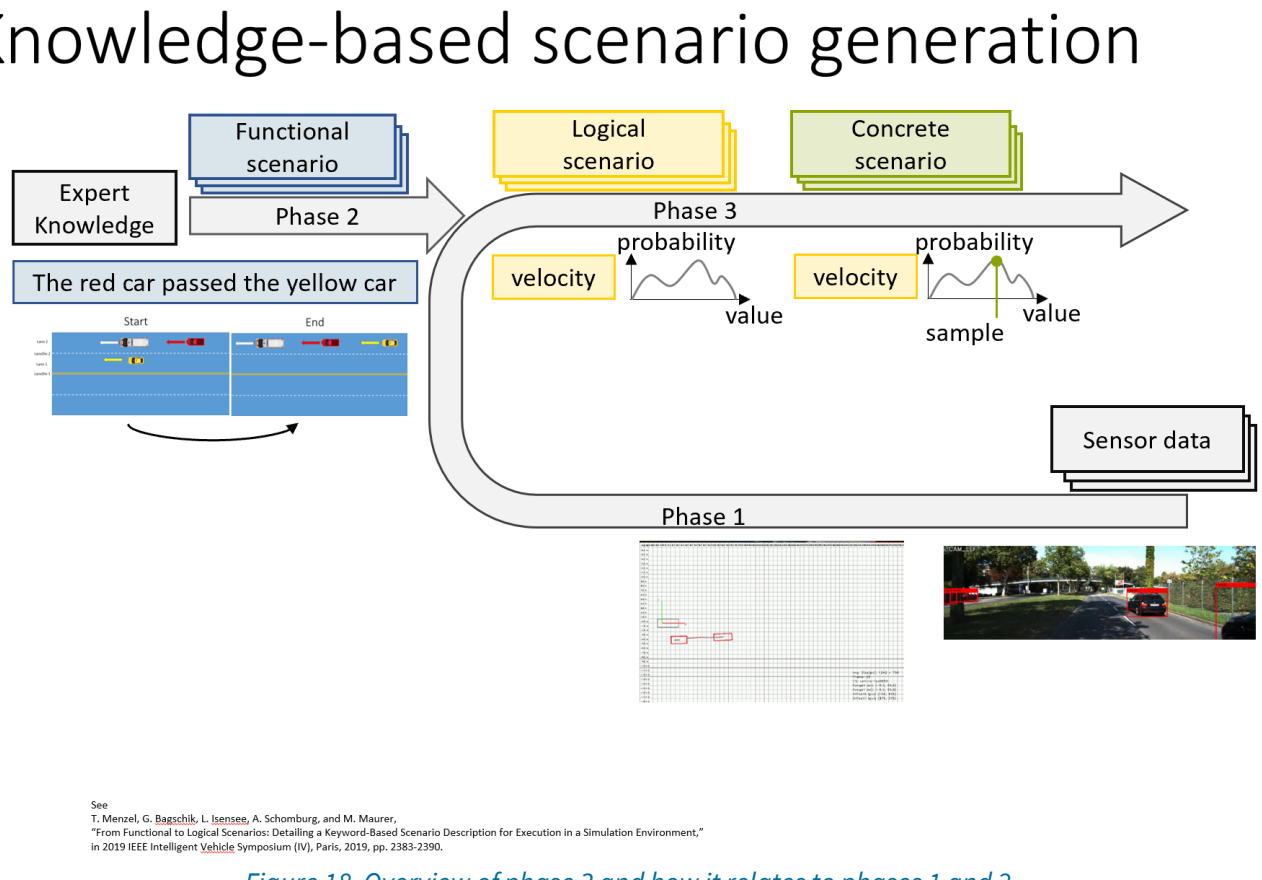


Figure 18. Overview of phase 3 and how it relates to phases 1 and 2

Figure 18 provides an overview of phases 1, 2, 3 and how they interact with each other.

Steps in phase 3

1. Define parameters and parameter ranges

In this step, a suitable computer program, for example, a python module working with ASAM OpenXOntology, identifies the parameter space for the scenario elements described in the functional scenario and adds the parameters to the OWL file (ABox).

The generation of the data formats for simulation, for example ASAM OpenDRIVE or ASAM OpenSCENARIO 1.1.1, requires that the parameters and their relations are defined in the ABox. ASAM OpenXOntology can be used to specify parameters for each class.

For example, in the MWP scenario, there are three traffic participants of the class `Vehicle`: `egoCar0`, `vehicle1`, and `vehicle2`. To generate ASAM OpenSCENARIO 1.1.1 data, the velocity of each vehicle must be known.

The definitions of the core ontology require that a physical object, such as a vehicle, shall be divided into temporal parts called *states* if the object has more than one value for a particular state parameter, for example velocity, over the time period of interest. Each state shall have a single parameter value. Following this modelling approach, ASAM OpenXOntology requires that every individual that is a member of the class `WholeLifeFunctionalSystem`, including `FunctionalSystemState`, shall have a maximum of one value for a particular state parameter, such as velocity.

For example, the `egoCar0` is divided into three states:

- `egoCar0_0` for the temporal part that is driving initially.
- `egoCar0_1` for the temporal part that slows down before changing lanes.
- `egoCar0_2` for the temporal part that resumes the previous cruising speed.

```
<owl:Class rdf:about="Core#WholeLifeFunctionalSystem">
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="Parameters#hasParameter"/>
      <owl:maxQualifiedCardinality rdf:datatype="nonNegativeInteger">1
        </owl:maxQualifiedCardinality>
      <owl:onClass rdf:resource="Parameters#Velocity"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```

In addition, domain and application ontologies may contain further restrictions on the classes defined there. For example, the following definition restricts the maximum velocity that is allowable for an ambulance to 40 m/s.

The first axiom states that ambulances shall have at least one `AmbulanceVelocity`. Because `Ambulances` is a subclass of `WholeLifeFunctionalSystem`, it is defined that ambulances shall have a maximum of 1 `Velocity`, and because `AmbulanceVelocity` is a subclass of `Velocity`, it is defined that ambulances shall only have `AmbulanceVelocity` as their velocity.

```
<owl:Class rdf:about="ApplicationOL#Ambulances">
    <rdfs:subClassOf rdf:resource="Domain#Vehicle"/>
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource="Parameters#hasParameter"/>
            <owl:someValuesFrom rdf:resource="ApplicationOL#AmbulanceVelocity"/>
        </owl:Restriction>
    </rdfs:subClassOf>
</owl:Class>
```

The following axiom states that every individual that is an `AmbulanceVelocity` shall be less than the individual called `AmbulanceVelocityMax`:

```
<owl:Class rdf:about="ApplicationOL#AmbulanceVelocity">
    <rdfs:subClassOf rdf:resource="Parameters#Velocity"/>
    <rdfs:subClassOf>
      <owl:Restriction>
        <owl:onProperty rdf:resource="#lessThan" />
        <owl:hasValue rdf:resource="#AmbulanceVelocityMax" />
      </owl:Restriction>
    </rdfs:subClassOf>
</owl:Class>
```

Finally, the following axiom states that `AmbulanceVelocityMax` is a member of `AmbulanceVelocity` that has a maximum parameter value of 40.0. For this example, it is assumed that all parameters are given in SI units, but units may be added to the TBox as required.

```
<owl:NamedIndividual rdf:about="AboxMWP#AmbulanceVelocityMax">
    <rdf:type rdf:resource="Parameters#Velocity"/>
    <parameters:hasParameterValueMax
rdf:datatype="float">40.0</asam:hasParameterValueMax>
</owl:NamedIndividual>
```

Based on this information in the TBox, the application automatically extends the ABox by adding a new individual for each parameter to be specified, together with the required relations to other individuals in the functional scenario level ABox. The following code sample shows the individual that is added to describe the velocity of the `egoCar0_0`.

```
<owl:NamedIndividual rdf:about="AboxMWP#egoCar0_0">
    <rdf:type rdf:resource="Core#FunctionalSystemState"/>
    <core:hasBeginning rdf:resource="AboxMWP#scenarioStart"/>
    <core:hasEnding rdf:resource="AboxMWP#pass1to0"/>
    <parameters:hasParameter rdf:resource="AboxMWP#egoCar0_0velocity"/>
    <core:isTemporalPartOf rdf:resource="AboxMWP#egoCar0"/>
</owl:NamedIndividual>
```

2. Identify parameter constraints

In this step, the application identifies additional constraints on each parameter based on ASAM OpenXOntology. The application adds the parameter constraints to the OWL file. The OWL file containing both parameters and parameter constraints represents a basic description of a logical scenario.

To ensure that the scenario remains valid when parameters and parameter values are specified in detail, parameter constraints need to be considered. These constraints shall be specified in the TBox and may be described by SWRL rules.

In the MWP scenario, each vehicle has a velocity parameter. However, the values for the velocities are sometimes constrained by other scenario elements, such as `PassingEvents`. In the example scenario, `vehicle1` and `vehicle2` pass `egoCar0`. Consequently, the velocity of `vehicle1` and `vehicle2` must be higher than the velocity of `egoCar0`. The following SWRL rule guarantees that the subject vehicle of a passing event must have a velocity that is greater than the object of the passing event.

SWRL rule:

```
ApplicationOSC:PassingEvents(?pe) ^ parameters:hasSubject(?pe, ?sub) ^
parameters:hasParameter(?sub, ?subVel) ^ parameters:Velocity(?subVel) ^
domain:hasObject(?pe, ?obj) ^ parameters:hasParameter(?obj, ?objVel) ^
parameters:Velocity(?objVel) -> parameters:greaterThan(?subVel, ?objVel)
```

The outcome of applying this rule to the ABox in the example is as follows:

```
<owl:NamedIndividual rdf:about="AboxMWP#egoCar0_1velocity">
    <rdf:type rdf:resource="Parameters#Velocity"/>
    <parameters:lessThan rdf:resource="AboxMWP#vehicle1_1velocity"/>
</owl:NamedIndividual>
```

3. Scenario concretization and export

In this step, a human scenario editor uses an appropriate application, for example, a python module, to define a discrete value for each parameter in the logical scenario. The tool supports the human editor by monitoring whether all parameter constraints are met.

After setting all parameter values, a suitable computer program, for example, a python module, converts the concrete scenario into a data format that can be used for simulation: ASAM OpenDRIVE and ASAM OpenSCENARIO 1.1.1. The resulting files represent standardized scenario descriptions (ASAM OpenSCENARIO 1.1.1) and road network definitions (ASAM OpenDRIVE).

Output example

In phase 3, the files that can be used for simulation (ASAM OpenDRIVE and ASAM OpenSCENARIO 1.1.1) are generated.

In this snippet, the initial velocity of vehicle_1 is set.

```
<Private entityRef="vehicle_1">
    <PrivateAction>
        <LongitudinalAction>
            <SpeedAction>
                <SpeedActionDynamics dynamicsDimension="time" dynamicsShape="step"
value="0.0"/>
                <SpeedActionTarget>
                    <AbsoluteTargetSpeed value="16.6666666667"/>
                </SpeedActionTarget>
            </SpeedAction>
        </LongitudinalAction>
    </PrivateAction>
</Private>
```

Role of ASAM OpenXOntology

ASAM OpenXOntology is used as a basis to specify the parameters for detailing the functional scenario. The explicit specification of parameters and constraints ensures consistent assumptions throughout the development process.

As other ASAM standards, ASAM OpenDRIVE and ASAM OpenSCENARIO 1.1.1 are used.

10.2.5. Phase 4 of the data journey: Simulate the scenario

In phase 4, the ASAM OpenDRIVE and ASAM OpenSCENARIO 1.1.1 data generated in phase 3 are executed within an environment simulator. ASAM OSI ground truth is generated from the simulator.

A environment simulator creates the ground truth, which contains the object list. This object list is

compatible with ISO 23150 and is communicated to the sensor view via an ASAM OSI protobuf message. Currently, the protobuf message is converted to an ASAM OSI trace file.

Output example

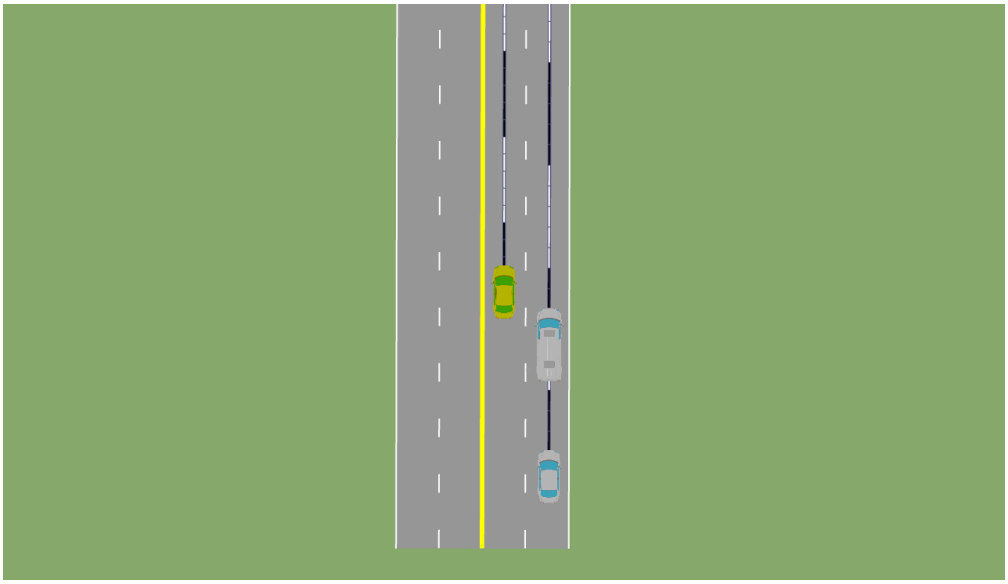


Figure 19. Animated traffic simulator results

Role of ASAM OpenXOntology

- ASAM OpenXOntology is used to tag the object list within the ASAM OSI ground-truth trace file. It can further be used to tag the actions of each traffic participants that are present within the ground truth.
- ASAM OpenXOntology provides the TBox for such tagging mechanism with common logical definitions and structure. An example of a logical definition is the following:

  The ontology classifies *lane divider* from the object list as static, non-changing object. Hence, ASAM OSI could choose to not update the lane divider frequently.

- ASAM OpenXOntology will be a common basis for ASAM OpenLABEL and ASAM OpenSCENARIO 1.1.1. The subsequent phase 5, that is ASAMODD checking, also requires that the parameter spaces associated with ASAM OpenSCENARIO 1.1.1, ASAM OpenLABEL, ASAM OSI, and ASAMODD are harmonized. For example, if ASAM OSI has a smaller parameter space than ASAM OpenSCENARIO 1.1.1 for operational domain design related parameters, this simulation environment has an incomplete coverage.
- Optionally, if ASAM OSI can write ground-truth trace files in ASAM OpenLABEL format then it can be useful to compare scene-by-scene simulation execution results with ground-truth data from real-word driving.

10.2.6. Phase 5 of the data journey: Check against ASAMODD

Phase 5 checks the concrete scenario generated in phase 3 for validity against an operational design domain, verifying that the scenario conditions are covered by the operational design domain.

The inputs for this phase are the ASAM OSI stream data from phase 4 together with the ASAM OpenDRIVE and ASAM OpenSCENARIO 1.1.1 files generated in phase 3.

Steps in phase 5

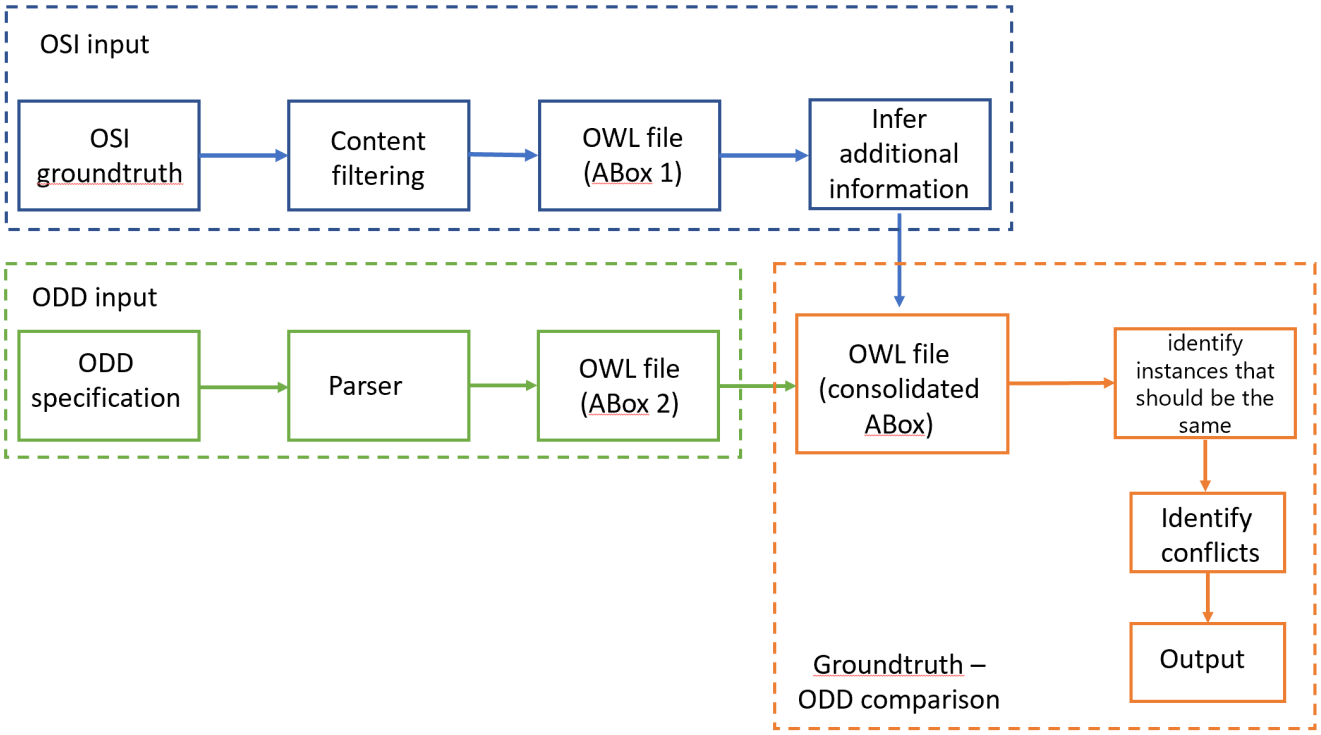


Figure 20. Overview of phase 5

Figure 20 shows the steps in phase 5.

1. Receiving ASAM OSI ground-truth and converting into OWL format

- The ground-truth data is received from phase 4. It contains the road information, including lanes, traffic participants, and environment conditions with the associated elements.
- A python module filters the ground-truth data and outputs another ground-truth file that only contains domain elements.
- Another python module converts the filtered ground-truth into OWL format using the ASAM OpenXOntology TBox: this corresponds to ABox1 in Figure 20.
- The role of ASAM OpenXOntology is to provide the TBox to generate the ABox which contains only the domain elements used in the operational design domain.

2. Parsing and converting ASAMODD specification into OWL format

- Example of the ASAMODD specification:

```
... UNSUITABLE InducedRoadSurfaceCondition WHEN Icy ...
```

- A human expert or a python module parses the values in the ASAMODD specification.
- A python module converts the parsing output into an OWL representation using the ASAM OpenXOntology TBox. This corresponds to ABox2 in in Figure 20.
- The role of ASAM OpenXOntology is to provide the TBox to generate the ABox.

3. Performing inference on ABox1 and adding additional information

- A semantic reasoner performs inference on the OWL file generated from the filtered ground-truth data (ABox 1 in the figure) in order to add missing information.
- In this demonstration box, the goal of the reasoner is to infer `InducedRoadSurfaceCondition` based on `Precipitation` and `Temperature`. That is why the following three SWRL rules can be constrcuted:

- Rule 1: Infer that when temperature is below zero and when precipitation is above zero, the induced road surface condition will be icy road

```
InducedRoadSurfaceConditions(?x) ^ RainfallCondition(?r) ^
precipitationIntensity(?p) ^ has_property(?r, ?p) ^ has_real_value(?p, ?pvalue) ^
temperature(?t)^ has_real_value(?t, ?tvalue) ^ swrlb:lessThan(?tvalue, 0.0) ^
swrlb:greaterThan(?pvalue, 0.0)  -> IcyRoadCondition(?x)
```

- Rule 2: Infer that when temperature is above zero and when precipitation is above zero, the induced road surface condition will be wet road

```
InducedRoadSurfaceConditions(?x) ^ RainfallCondition(?r) ^
precipitationIntensity(?p) ^ has_property(?r, ?p) ^ has_real_value(?p, ?pvalue) ^
temperature(?t)^ has_real_value(?t, ?tvalue) ^ swrlb:greaterThan(?tvalue, 0.0) ^
swrlb:greaterThan(?pvalue, 0.0)  -> WetRoadCondition(?x)
```

- Rule 3: Infer that when precipitation is equal to zero, the induced road surface condition will be dry road

```
InducedRoadSurfaceConditions(?x) ^ RainfallCondition(?r) ^
precipitationIntensity(?p) ^ has_property(?r, ?p) ^ has_real_value(?p, ?pvalue) ^
swrlb:equal(?pvalue, 0.0)  -> DryRoadCondition(?x)
```

- Example of rule-based inference on ground-truth data:

  Input from ASAM OSI ground-truth:

```
{... "Temperature": "265",
      "EnvironmentalConditions": {
                                  {"Precipitation": Light", ... }
                                                          } } ...
```

- Based on the specification that the temperature is "265" (in 'Kelvin' unit which corresponding to -8.15 degree C) and that the precipitation is "Light", the semantic tool could infer based on the SWRL rules that the `InducedRoadSurfaceCondition` is `IcyRoadCondition`. This `IcyRoadCondition` condition is an additional ground-truth.
- The role of ASAM OpenXOntology is to enable a semantic reasoner to infer additional information about the ground-truth data.

4. Checking whether the ASAM OSI ground-truth data is covered by the operational design domain

- A python module checks the operational design domain every time a new ASAM OSI ground-truth is received during runtime to determine whether the vehicle is within or outside the operational design domain.
- There are two ways to achieve this comparison. In the first, a python module executes the content of ABox2 as a SPARQL query against ABox1. In the second, a python module consolidates ABox1 and ABox2 into one single file. For each individual in ABox1 that must match a particular individual in ABox2, the python module adds a `sameAs` relation. Then the python module uses a semantic reasoner to check for

semantic conflicts causes by making the pairs of individuals from each ABox the same. If a semantic conflict occurs between a pair of individuals, then for the ASAMODD attribute represented by the individuals, the current ASAM OSI ground-truth is outside ASAMODD.

- The role of ASAM OpenXOntology is to enable a semantic reasoner to infer additional information required to determine whether the ASAM OSI ground-truth is covered by the ASAMODD.

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[32] *R2RML: RDB to RDF Mapping Language* - *https://www.w3.org/TR/r2rml/*. W3C consortium, 2012.

Appendix A: ASAM OpenXOntology: Model Reference

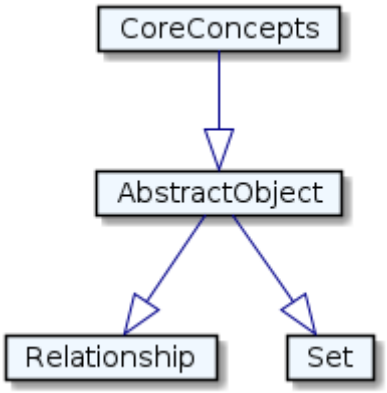
Ontology Version Information

ASAM OpenXOntology Version 1.0.0

A.1. Core

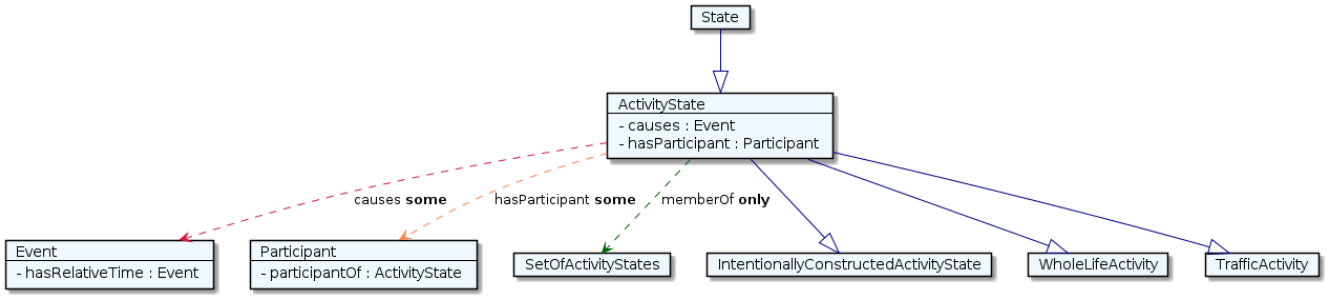
A.1.1. Classes

AbstractObject



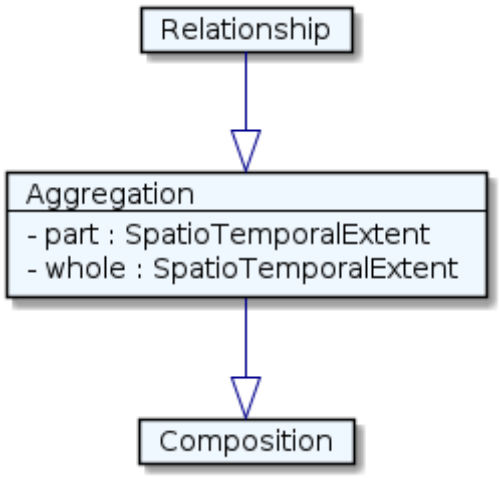
Element	Description
Type	Class
Name	AbstractObject
IRI	http://ontology.asam.net/ontologies/Core#AbstractObject
Subclass of	CoreConcepts
Disjoint with	SpatioTemporalExtent
Comments	DEF: A thing that does not exist in space or time. Abstract objects are used to express characteristics of spatio-temporal extents, such as properties and roles.
EXAMPLES: not applicable.	USAGE: This class will generally not be used directly in the OpenX domain.

ActivityState



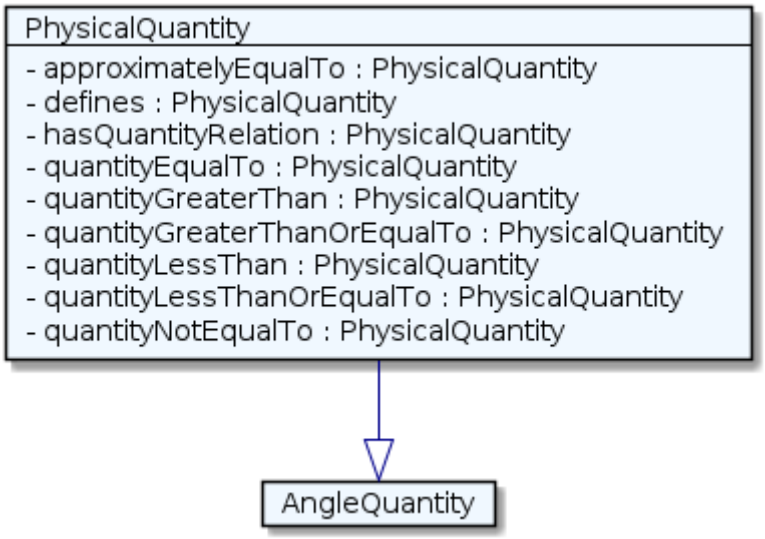
Element	Description
Type	Class
Name	ActivityState
IRI	http://ontology.asam.net/ontologies/Core#ActivityState
Subclass of	State
Restriction	causes **some** Event
Restriction	hasParticipant **some** Participant
Restriction	memberOf **only** SetOfActivityStates
Comments	DEF: A State that represents the whole life of an activity or a temporal part of an activity. Activities consist of their participants, which are members of PhysicalObjectState, and cause some event. The end event of an activity state is caused by that activity, which implies that the activity describes some change between the start event and end event.
EXAMPLES: the movements of a cloud or an animal crossing a road.	USAGE: Use this class for (temporal parts of) activities that are not the direct result of some intent, for example, a person's intent.

Aggregation



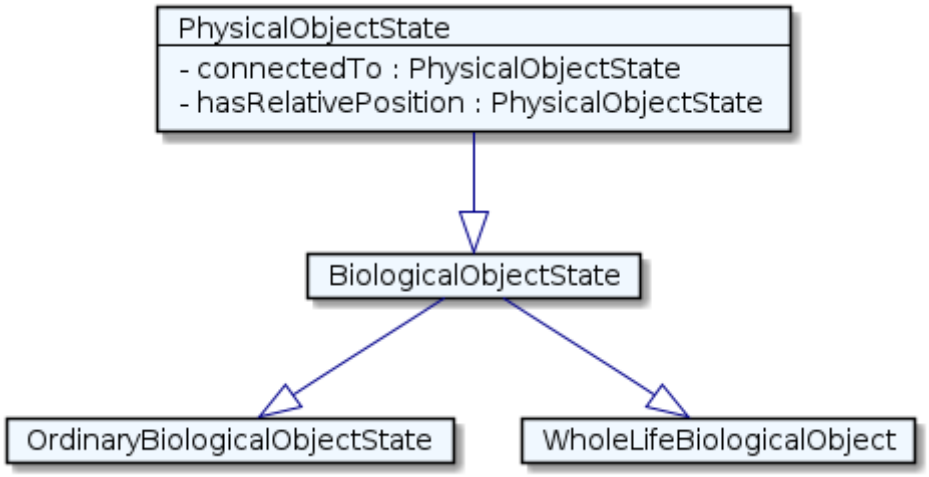
Element	Description
Type	Class
Name	Aggregation
IRI	http://ontology.asam.net/ontologies/Core#Aggregation
Subclass of	Relationship
Comments	DEF: A Relationship where the whole is at least the sum of the parts. Basis for object property aggregatedInto.
EXAMPLES: not applicable.	USAGE: This class will generally not be used directly in the OpenX domain.

AngleQuantity



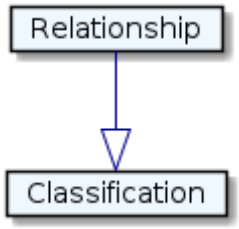
Element	Description
Type	Class
Name	AngleQuantity
IRI	http://ontology.asam.net/ontologies/Core#AngleQuantity
Subclass of	PhysicalQuantity
Comments	DEF: A PhysicalQuantity that is an angle value in degrees, between 0 and 360.
EXAMPLES:	USAGE: Use this class instead of DirectionQuantity when specifying angles that are not actual directions respective to some coordinate system.

BiologicalObjectState



Element	Description
Type	Class
Name	BiologicalObjectState
IRI	http://ontology.asam.net/ontologies/Core#BiologicalObjectState
Subclass of	PhysicalObjectState
Comments	DEF: A PhysicalObjectState that sustains itself and reproduces. A BiologicalObjectState may represent the whole life of the object or a temporal part of it.
EXAMPLES: a BiologicalObjectState that is not an OrdinaryBiologicalObjectState would be one that survives the replacement of all of its parts, so an example might be my dog (which might be a completely different dog over time).	USAGE: generally use OrdinaryBiologicalObjectState instead of this class

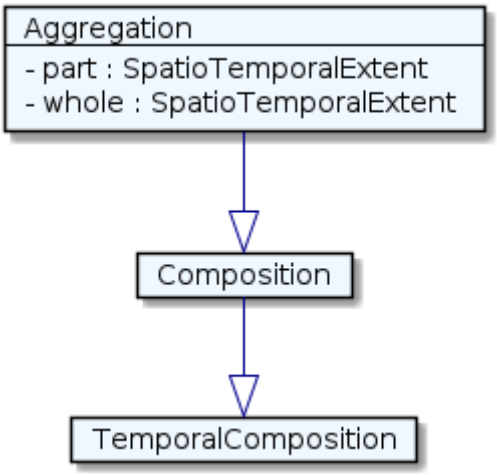
Classification



Element	Description
Type	Class
Name	Classification
IRI	http://ontology.asam.net/ontologies/Core#Classification
Subclass of	Relationship

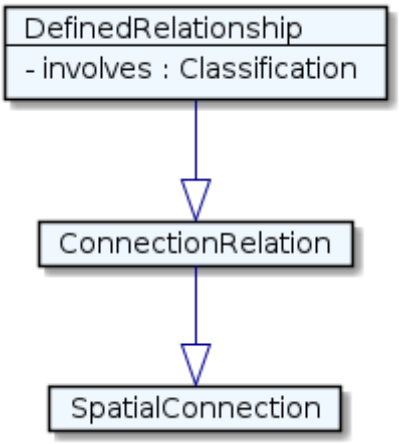
Element	Description
Comments	DEF: A Relationship where a thing is a member of a class. Basis for object properties memberOf and hasMember.
EXAMPLES: not applicable.	USAGE: This class will generally not be used directly in the OpenX domain.

Composition



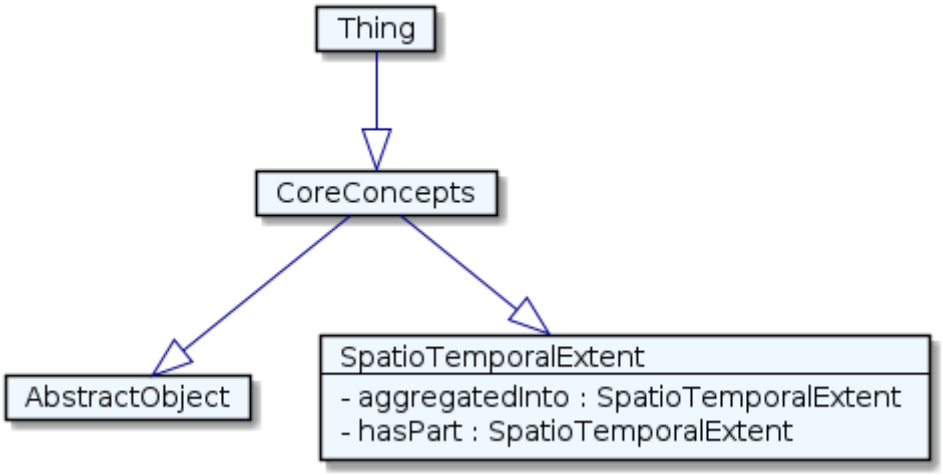
Element	Description
Type	Class
Name	Composition
IRI	http://ontology.asam.net/ontologies/Core#Composition
Subclass of	Aggregation
Comments	DEF: An Aggregation where the whole is an arrangement of the parts that results in emergent properties. Basis for object properties partOf and hasPart.
EXAMPLES: not applicable.	USAGE: This class will generally not be used directly in the OpenX domain.

ConnectionRelation



Element	Description
Type	Class
Name	ConnectionRelation
IRI	http://ontology.asam.net/ontologies/Core#ConnectionRelation
Subclass of	DefinedRelationship
Comments	DEF: A DefinedRelationship for relations between things that are connected in any way, physically or otherwise. Basis for the object property connectedTo.
EXAMPLES:	USAGE: Use this class to express a connection between two things as a reified relationship, e.g. in order to specify characteristics such as the angle of the connection.

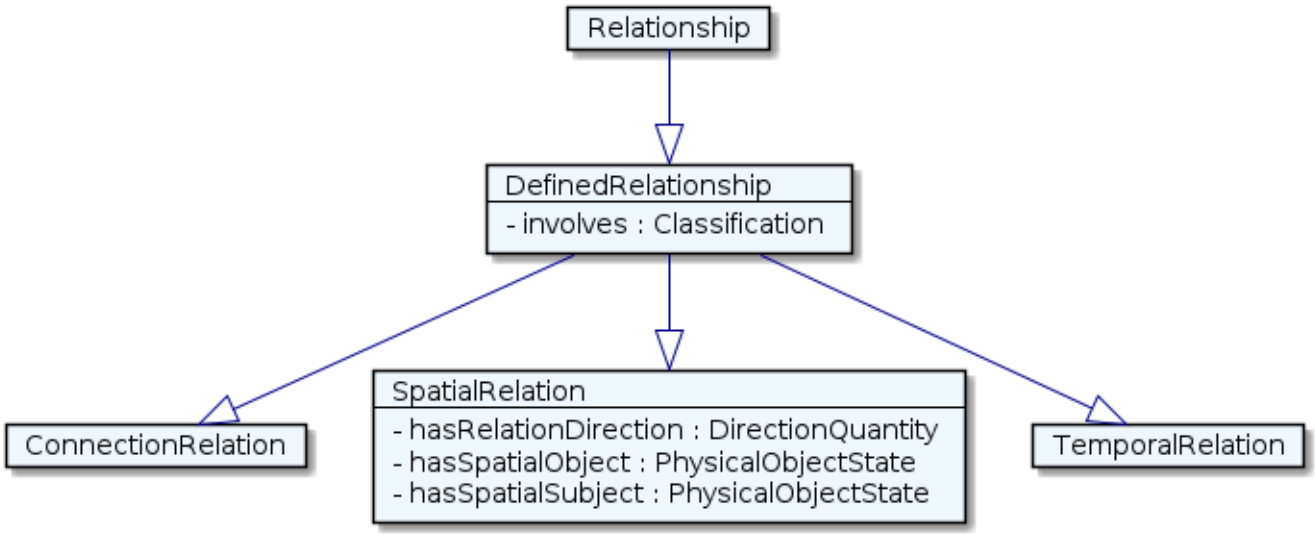
CoreConcepts



Element	Description
Type	Class
Name	CoreConcepts

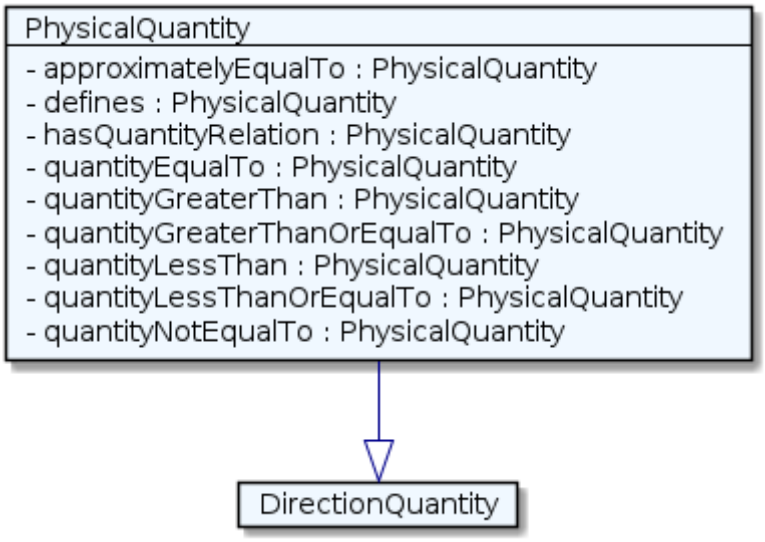
Element	Description
IRI	http://ontology.asam.net/ontologies/Core#CoreConcepts
Subclass of	Thing
Comments	DEF: Top-level container that separates core concepts in the OpenXOntology. The CoreConcepts define basic concepts, such as physical objects, states, and events. The core ontology of ASAM OpenXOntology corresponds to a top-level ontology or upper ontology. The core ontology of ASAM OpenXOntology is based on HQDM.

DefinedRelationship



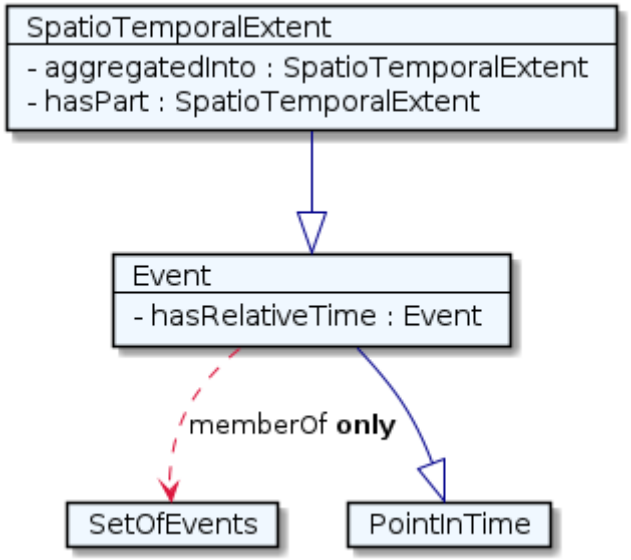
Element	Description
Type	Class
Name	DefinedRelationship
IRI	http://ontology.asam.net/ontologies/Core#DefinedRelationship
Subclass of	Relationship
Comments	DEF: A Relationship of a certain kind. This may be temporal, spatial, compositional, or other other relationships.
EXAMPLES: not applicable.	USAGE: This class will generally not be used directly in the OpenX domain.

DirectionQuantity



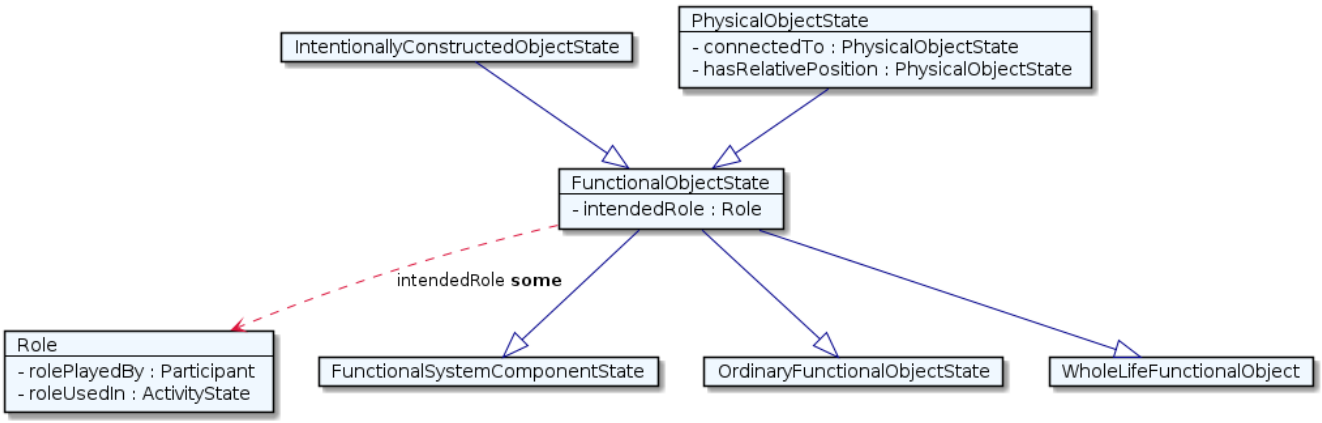
Element	Description
Type	Class
Name	DirectionQuantity
IRI	http://ontology.asam.net/ontologies/Core#DirectionQuantity
Subclass of	PhysicalQuantity
Comments	DEF: A PhysicalQuantity that defines a direction in degrees, between 0 and 360. May be used to quantify the direction of a vector described by a SpatialRelation, a SeparationDistance, or similar.
EXAMPLES:	USAGE: Use this class instead of AngleQuantity when specifying actual directions respective to some coordinate system.

Event



Element	Description
Type	Class
Name	Event
IRI	http://ontology.asam.net/ontologies/Core#Event
Subclass of	SpatioTemporalExtent
Restriction	memberOf **only** SetOfEvents
Disjoint with	State
Comments	DEF: A SpatioTemporalExtent with a time extension of zero, but with an extension in space. Events mark changes in states and are used for something instantaneous.
EXAMPLES:	USAGE: Use this class to specify the state and/or end of activities and temporal parts of physical objects.

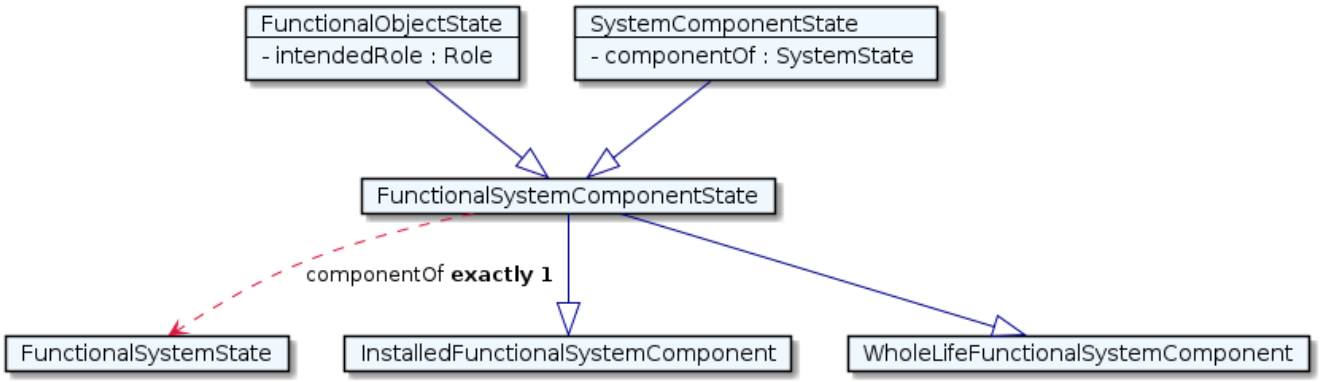
FunctionalObjectState



Element	Description
Type	Class
Name	FunctionalObjectState
IRI	http://ontology.asam.net/ontologies/Core#FunctionalObjectState
Subclass of	IntentionallyConstructedObjectState
Subclass of	PhysicalObjectState
Restriction	intendedRole **some** Role
Comments	DEF: An IntentionallyConstructedObjectState and PhysicalObjectState that has an intendedRole. A FunctionalObjectState may represent the whole life of the object or a temporal part of it.

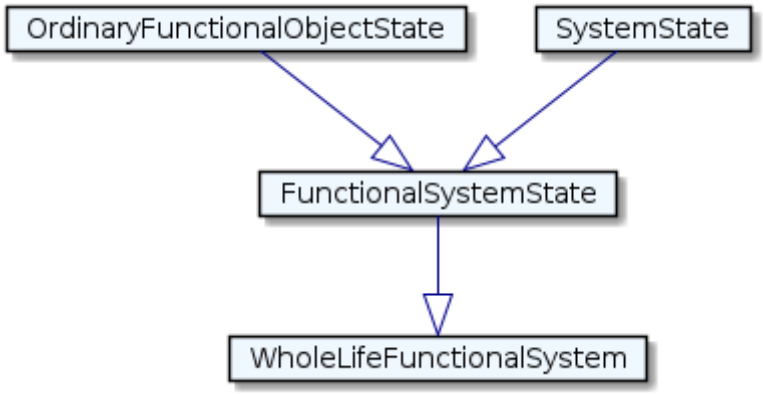
Element	Description
EXAMPLES: a FunctionalObjectState that is not an OrdinaryFunctionalObjectState would be one that survives the replacement of all of its parts, so an example might be my car (which might be a completely different car over time).	USAGE: generally use OrdinaryFunctionalObjectState instead of this class

FunctionalSystemComponentState



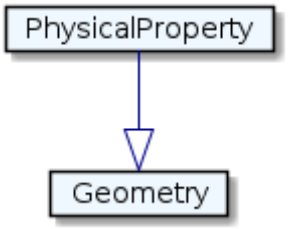
Element	Description
Type	Class
Name	FunctionalSystemComponentState
IRI	http://ontology.asam.net/ontologies/Core#FunctionalSystemComponentState
Subclass of	FunctionalObjectState
Subclass of	SystemComponentState
Restriction	componentOf **exactly 1** FunctionalSystemState
Comments	DEF: An IntentionallyConstructedObjectState that represents a replaceable component of a FunctionalSystem. The object property componentOf is used to relate the object to the FunctionalSystem. A FunctionalSystemComponentState may be the whole life of the component or a temporal part of it.
EXAMPLES: markings of road or engines of vehicles	USAGE: Use this class to represent the components of things that were created for a specific purpose, for example markings of road or engines of vehicles.

FunctionalSystemState



Element	Description
Type	Class
Name	FunctionalSystemState
IRI	http://ontology.asam.net/ontologies/Core#FunctionalSystemState
Subclass of	OrdinaryFunctionalObjectState
Subclass of	SystemState
Comments	DEF: An OrdinaryFunctionalObjectState that is also a SystemState.
EXAMPLES: Vehicles, traffic infrastructure, buildings, traffic lights.	USAGE: Use this class for describing (temporal parts) of concrete (actual, materialized) systems that cease to exist when all of their parts are removed. Often combined with OrdinaryBiologicalObjectState or OrdinaryFunctionalObjectState

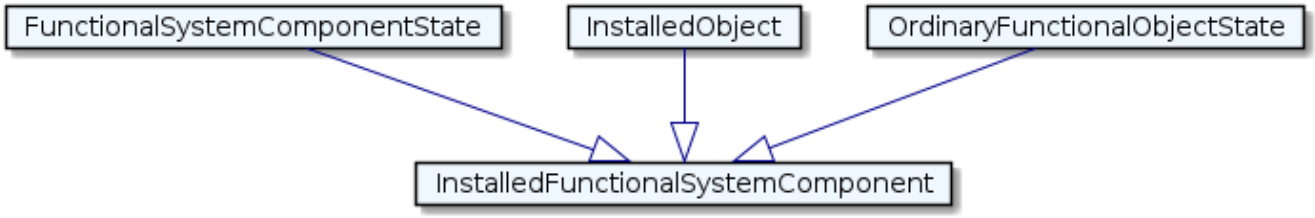
Geometry



Element	Description
Type	Class
Name	Geometry
IRI	http://ontology.asam.net/ontologies/Core#Geometry
Subclass of	PhysicalProperty

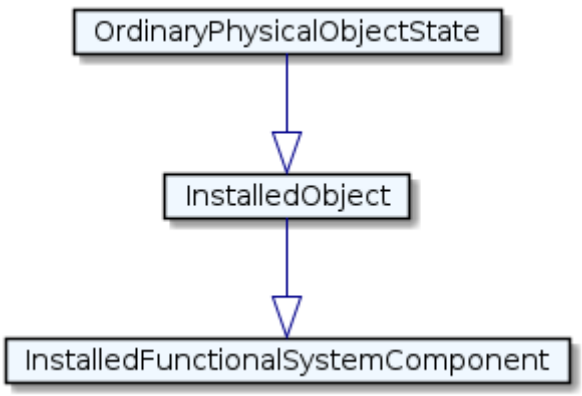
Element	Description
Comments	DEF: A PhysicalProperty that describes a spatial characteristic of an Object in a 1D, 2D or 3D space. Unlike "shape", which only refers to the outer surface, "geometry" can include other characteristics, e.g. different kind of projections like cross section, road geometry.
EXAMPLES:	USAGE:

InstalledFunctionalSystemComponent



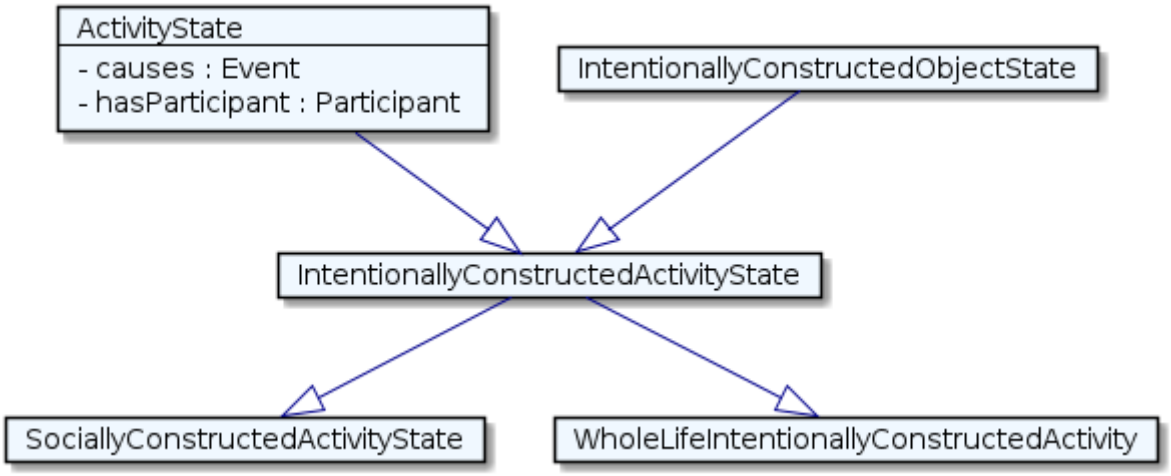
Element	Description
Type	Class
Name	InstalledFunctionalSystemComponent
IRI	http://ontology.asam.net/ontologies/Core#InstalledFunctionalSystemComponent
Subclass of	FunctionalSystemComponentState
Subclass of	InstalledObject
Subclass of	OrdinaryFunctionalObjectState
Comments	DEF: An InstalledObject that is also a OrdinaryFunctionalObjectState and a FunctionalSystemComponentState.
EXAMPLES: the particular tire that was installed on car42's right front wheel between time1 and time2	USAGE: Use this class for describing the actual, materialized installed components of a system.

InstalledObject



Element	Description
Type	Class
Name	InstalledObject
IRI	http://ontology.asam.net/ontologies/Core#InstalledObject
Subclass of	OrdinaryPhysicalObjectState
Comments	DEF: An OrdinaryPhysicalObjectState that is installed in a system, meaning that is also a SystemComponentState. The state of the ordinary physical object is the temporal part that covers the time from when the ordinary physical object is installed in the system to when it is removed.
EXAMPLES: The time that the traffic sign with the serial number 42 is installed at a specific location on highway 66. (note that this would actually be an InstalledFunctionalSystemComponent because the highway is a FunctionalSystem).	USAGE: Use this class to describe the temporal part of a physical object when it is the actual component of a system.

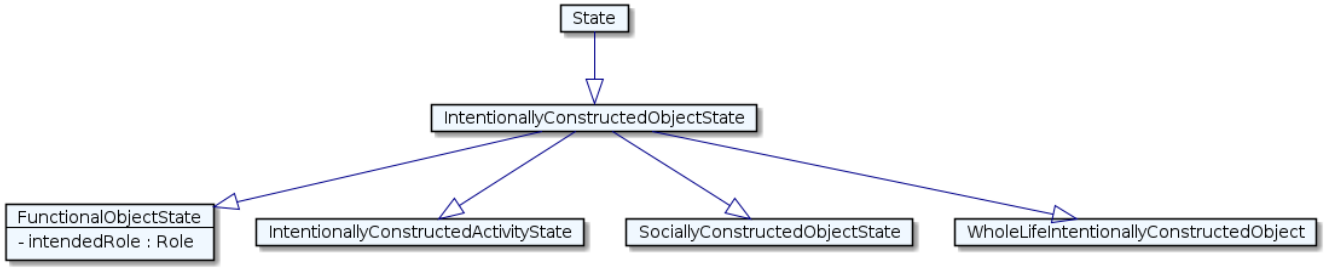
IntentionallyConstructedActivityState



Element	Description
Type	Class
Name	IntentionallyConstructedActivityState
IRI	http://ontology.asam.net/ontologies/Core#IntentionallyConstructedActivityState
Subclass of	ActivityState
Subclass of	IntentionallyConstructedObjectState
Comments	DEF: An ActivityState that is also an IntentionallyConstructedObjectState.

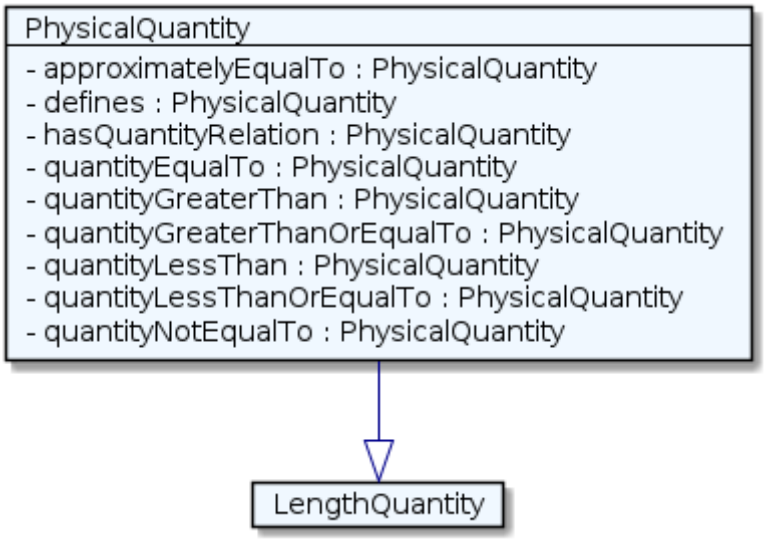
Element	Description
EXAMPLES: the changing of a signal state by a device in an intelligent transportation system	USAGE: Use this class to describe planned activities by single persons or intelligent devices, such as the changing of a signal state by a device in an intelligent transportation system.

IntentionallyConstructedObjectState



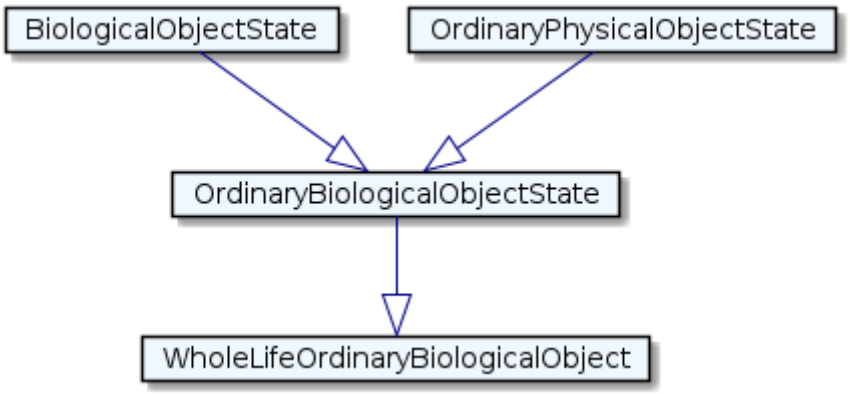
Element	Description
Type	Class
Name	IntentionallyConstructedObjectState
IRI	http://ontology.asam.net/ontologies/Core#IntentionallyConstructedObjectState
Subclass of	State
Comments	DEF: A State that exists because of an act of will or agreement. That means that IntentionallyConstructedObjects are constructed intentionally by one or more things that have intent, usually humans or robots.
EXAMPLES: an idea, a design, or a component specification	USAGE: Generally use FunctionalObjectState or one of its subclasses rather than this class. However, a thing that was created by humans for some purpose but does not exist materially, such as an idea, a design, or a component specification, would be a IntentionallyConstructedObjectState but not a FunctionalObjectState.

LengthQuantity



Element	Description
Type	Class
Name	LengthQuantity
IRI	http://ontology.asam.net/ontologies/Core#LengthQuantity
Subclass of	PhysicalQuantity
Comments	DEF: A PhysicalQuantity that is a length value in meters.
EXAMPLES:	USAGE:

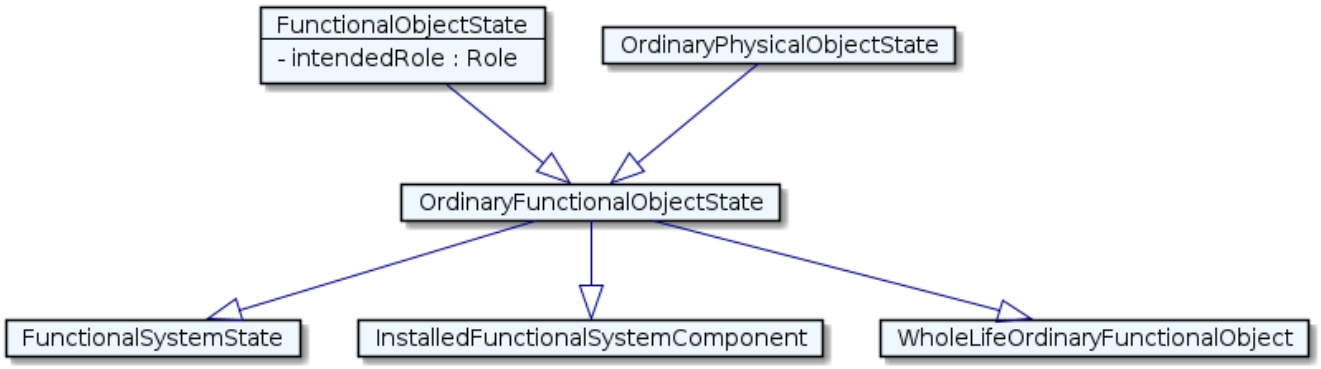
OrdinaryBiologicalObjectState



Element	Description
Type	Class
Name	OrdinaryBiologicalObjectState
IRI	http://ontology.asam.net/ontologies/Core#OrdinaryBiologicalObjectState
Subclass of	BiologicalObjectState

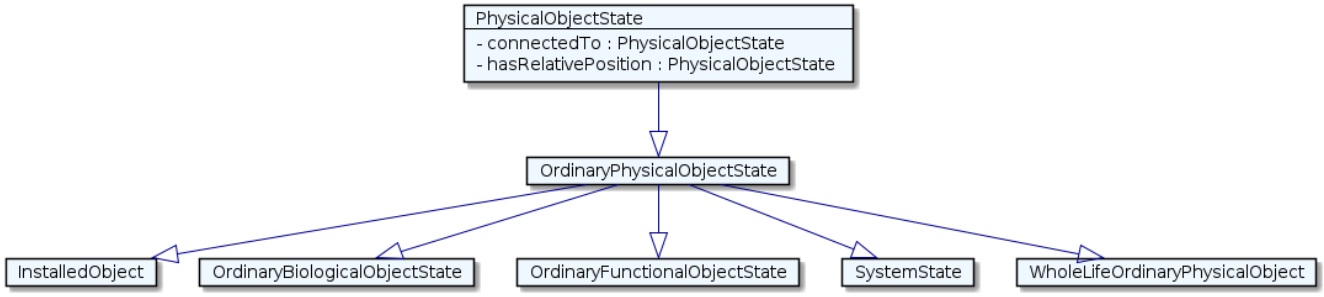
Element	Description
Subclass of	OrdinaryPhysicalObjectState
Comments	DEF: A BiologicalObjectState that describes biological objects that do not survive changing all their parts at once. An OrdinaryBiologicalObjectState may represent the whole life of the object or a temporal part of it.
EXAMPLES: humans, animals, and trees	USAGE: Use this class for describing temporal parts of living things that cease to exist when all of their parts are removed.

OrdinaryFunctionalObjectState



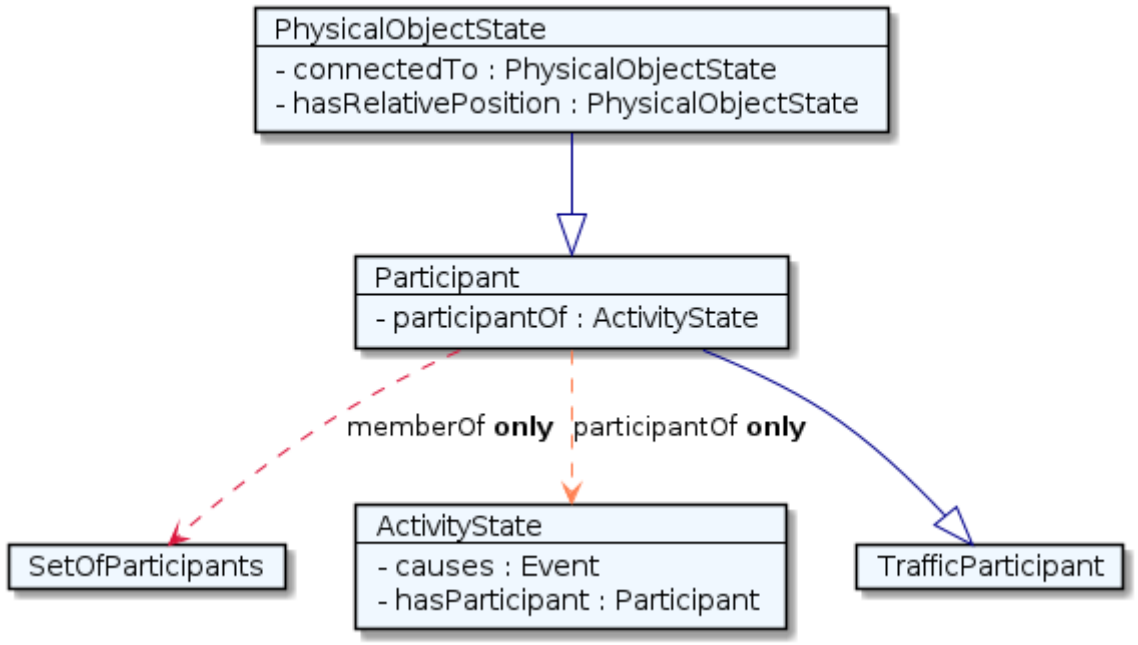
Element	Description
Type	Class
Name	OrdinaryFunctionalObjectState
IRI	http://ontology.asam.net/ontologies/Core#OrdinaryFunctionalObjectState
Subclass of	FunctionalObjectState
Subclass of	OrdinaryPhysicalObjectState
Comments	DEF: A FunctionalObjectState that describes functional objects that do not survive changing all their parts at once. An OrdinaryFunctionalObjectState may represent the whole life of the object or a temporal part of it.
EXAMPLES: A steel bar with no components and is not a component of any other thing but was created for a specific purpose could be an OrdinaryFunctionalObjectState.	USAGE: Use this class for temporal parts of manufactured things that were constructed for some purpose and that cease to exist when all of their parts are removed. However, if the thing is a system and/or a system component, it is preferable to use the corresponding subclass.

OrdinaryPhysicalObjectState



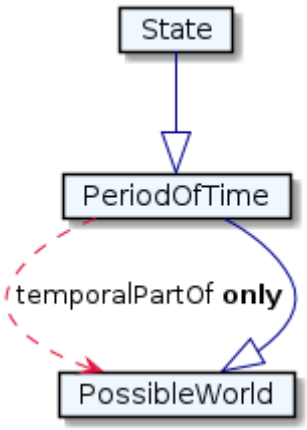
Element	Description
Type	Class
Name	OrdinaryPhysicalObjectState
IRI	http://ontology.asam.net/ontologies/Core#OrdinaryPhysicalObjectState
Subclass of	PhysicalObjectState
Comments	DEF: A PhysicalObjectState that describes physical objects that do not survive changing all their parts at once. An OrdinaryPhysicalObjectState may represent the whole life of the object or a temporal part of it.
EXAMPLES: cloud, raindrop, rock, sunlight	USAGE: Use this class for temporal parts of physical objects that cease to exist when all of their parts are removed and that are neither biological objects (OrdinaryBiologicalObjectState) nor manufactured things constructed for some purpose (OrdinaryFunctionalObjectState).

Participant



Element	Description
Type	Class
Name	Participant
IRI	http://ontology.asam.net/ontologies/Core#Participant
Subclass of	PhysicalObjectState
Restriction	memberOf **only** SetOfParticipants
Restriction	participantOf **only** ActivityState
Comments	DEF: A PhysicalObjectState that represents a participant of an ActivityState. The ActivityState consists of these Participants, where each Participant is a member of the Role in which it is participating.
EXAMPLES: The state (temporal part) of a vehicle that is making a left turn.	USAGE: Use this class for describing the temporal part of physical objects that are participating in activities. Usually combined with OrdinaryBiologicalObjectState or OrdinaryFunctionalObjectState

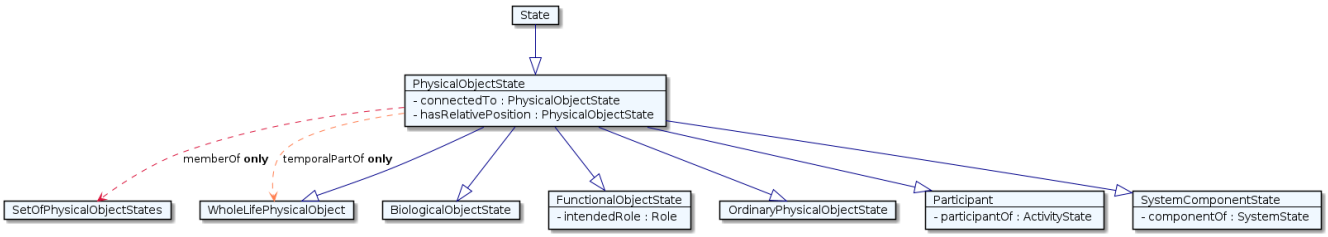
PeriodOfTime



Element	Description
Type	Class
Name	PeriodOfTime
IRI	http://ontology.asam.net/ontologies/Core#PeriodOfTime
Subclass of	State
Restriction	temporalPartOf **only** PossibleWorld
Comments	DEF: A State that is a temporal part of some PossibleWorld. That means the period of time is a temporal duration of some possible world, which could be the actual world.

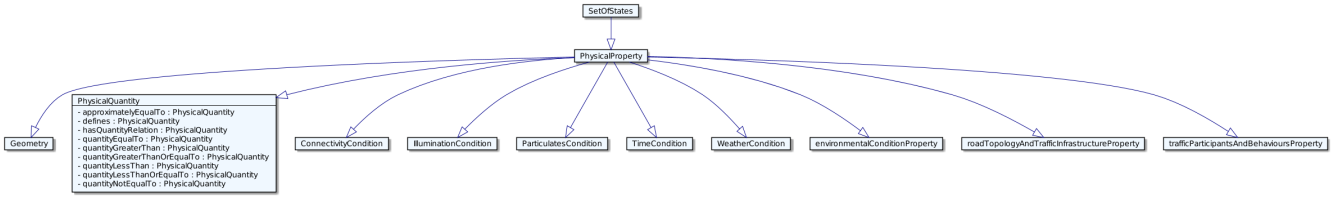
Element	Description
EXAMPLES:	USAGE:

PhysicalObjectState



Element	Description
Type	Class
Name	PhysicalObjectState
IRI	http://ontology.asam.net/ontologies/Core#PhysicalObjectState
Subclass of	State
Restriction	memberOf **only** SetOfPhysicalObjectStates
Restriction	temporalPartOf **only** WholeLifePhysicalObject
Comments	DEF: A State that consists of a distribution of matter and/or energy. A PhysicalObjectState is understood to have a bounded distribution, and so it can be identified as that parcel of matter and/or energy over time. A PhysicalObjectState can be thought of as characterizing what does not change over time of a State.
EXAMPLES:	USAGE: Generally use a subclass of this class.

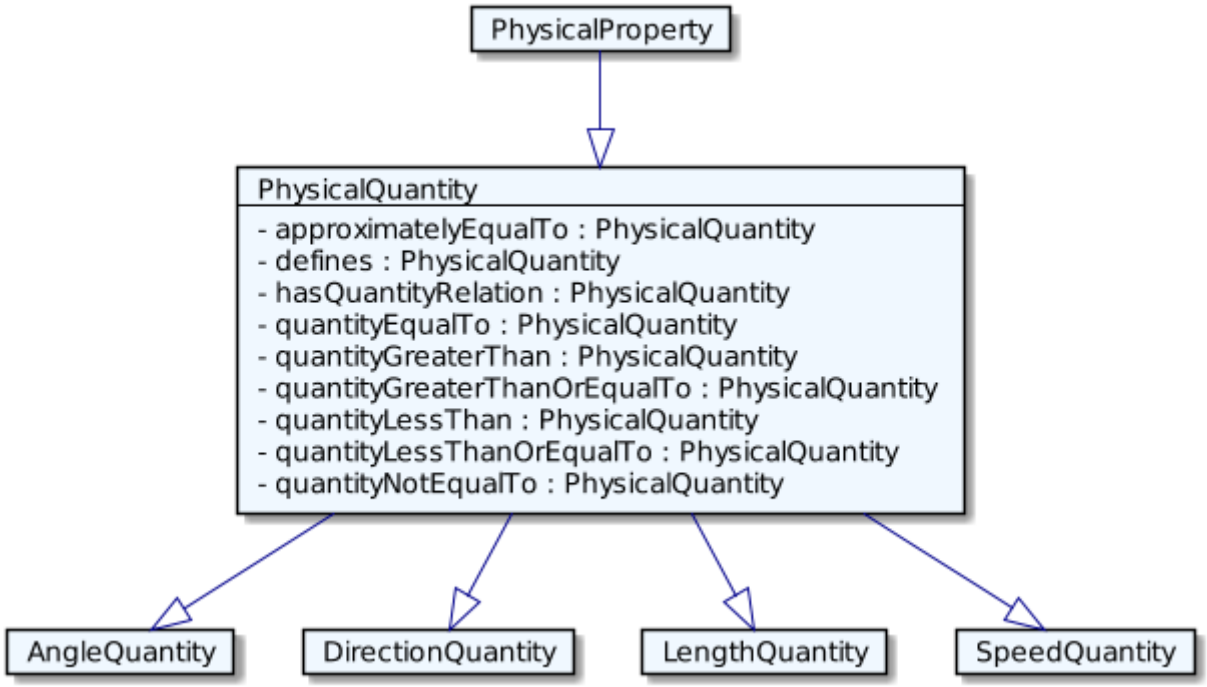
PhysicalProperty



Element	Description
Type	Class
Name	PhysicalProperty
IRI	http://ontology.asam.net/ontologies/Core#PhysicalProperty
Subclass of	SetOfStates

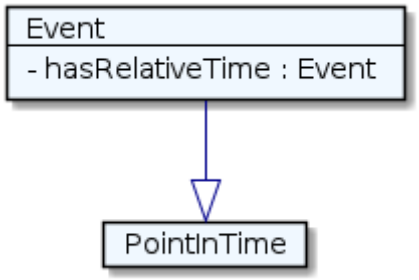
Element	Description
Comments	DEF: A SetOfStates is some characteristic that is the same for each state that possesses it (is a memberOf it). More accurately, a PhysicalProperty is a Set that groups states by a specific characteristic, but PhysicalProperty is understood to be the specific characteristic shared by its members.
EXAMPLES: The color red is a PhysicalProperty.	USAGE: Use this class for physical properties of both physical objects, for example mass and length, and activities, for example speed and duration.

PhysicalQuantity



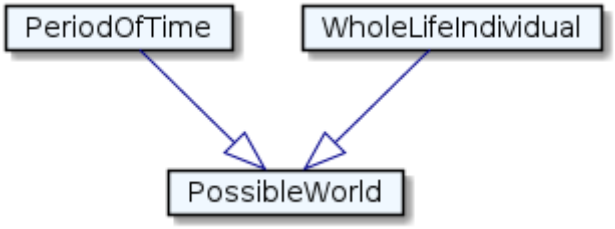
Element	Description
Type	Class
Name	PhysicalQuantity
IRI	http://ontology.asam.net/ontologies/Core#PhysicalQuantity
Subclass of	PhysicalProperty
Comments	DEF: A PhysicalProperty that represents a measurable quantity of a characteristic.
EXAMPLES: length, speed, and angle.	USAGE:

PointInTime



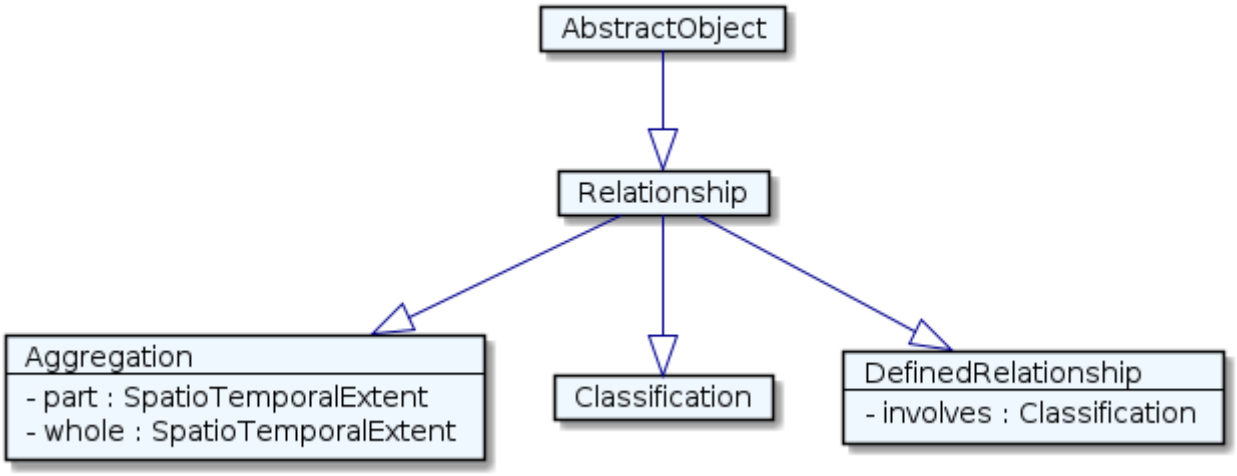
Element	Description
Type	Class
Name	PointInTime
IRI	http://ontology.asam.net/ontologies/Core#PointInTime
Subclass of	Event
Comments	DEF: An Event that is the whole of space at an instant from some viewpoint.
EXAMPLES:	USAGE:

PossibleWorld



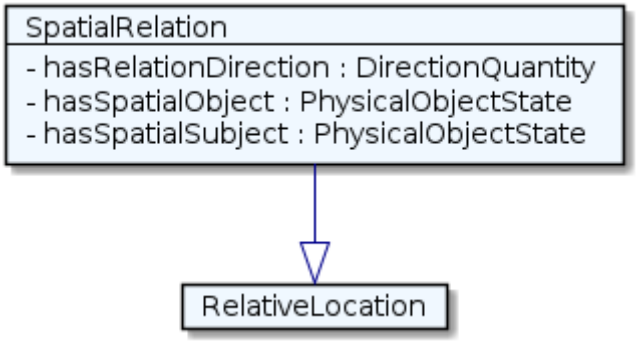
Element	Description
Type	Class
Name	PossibleWorld
IRI	http://ontology.asam.net/ontologies/Core#PossibleWorld
Subclass of	PeriodOfTime
Subclass of	WholeLifeIndividual
Comments	DEF: A WholeLifeIndividual that is a complete spatio-temporal history of some possible world. The actual world is one of the possible worlds.
EXAMPLES: a description could contain two PossibleWorlds, the possible world where carA stopped at the pedestrian crossing and where carA did not stop.	USAGE: Use this class to model modality (modal realism rather than modal logic), such as several possible planned futures or alternative pasts.

Relationship



Element	Description
Type	Class
Name	Relationship
IRI	http://ontology.asam.net/ontologies/Core#Relationship
Subclass of	AbstractObject
Comments	DEF: Relationships form the basis for many object properties.
EXAMPLES: not applicable.	USAGE: This class will generally not be used directly in the OpenX domain.

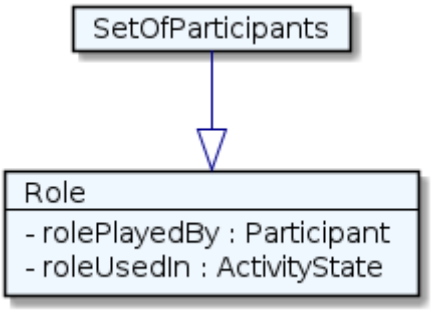
RelativeLocation



Element	Description
Type	Class
Name	RelativeLocation
IRI	http://ontology.asam.net/ontologies/Core#RelativeLocation
Subclass of	SpatialRelation

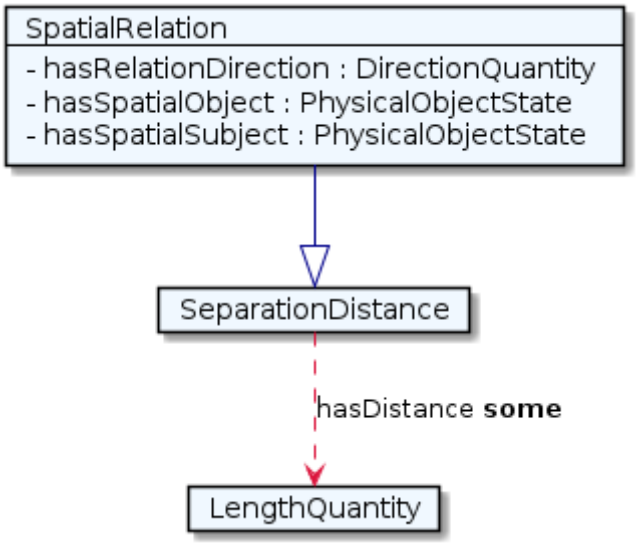
Element	Description
Comments	DEF: A SpatialRelation that describes that the subject is located on the object. Basis for the object property locatedOn.
EXAMPLES:	USAGE: Use this class to express the location of one thing with respect to another as a reified relationship, e.g. in order to specify characteristics such as the precise position of location.

Role



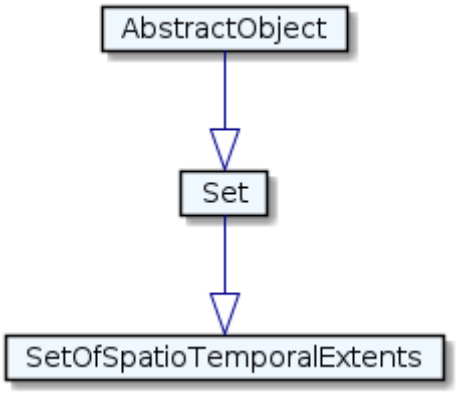
Element	Description
Type	Class
Name	Role
IRI	http://ontology.asam.net/ontologies/Core#Role
Subclass of	SetOfParticipants
Comments	DEF: A SetOfParticipants where each member participates in the same way in an ActivityState. In HQDM, a role is a kind of participant. So subclasses of Participant are members of the class Role, including TrafficParticipant, Owner, Employer, and Asset.
EXAMPLES: subclasses of Participant, including TrafficParticipant, Owner, Employer, and Asset	USAGE:

SeparationDistance



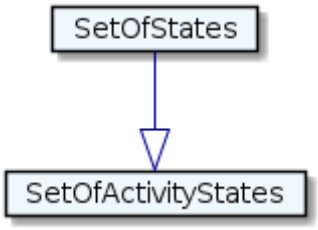
Element	Description
Type	Class
Name	SeparationDistance
IRI	http://ontology.asam.net/ontologies/Core#SeparationDistance
Subclass of	SpatialRelation
Restriction	hasDistance **some** LengthQuantity
Comments	DEF: A SpatialRelation that also describes a distance between two connected objects. Gives a complete description of a vector and an exact relative position.
EXAMPLES:	USAGE: Use this class to express the separation distance between two things as a reified relationship, e.g. in order to specify characteristics such as the distance and direction of the separation.

Set



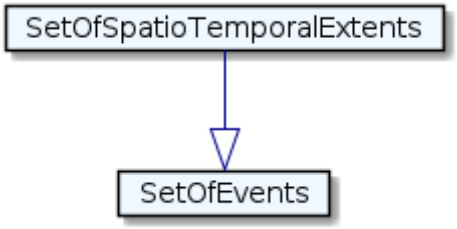
Element	Description
Type	Class
Name	Set
IRI	http://ontology.asam.net/ontologies/Core#Set
Subclass of	AbstractObject
Comments	DEF: An AbstractObject that has members and whose identity is defined by those members. The members may be other sets as well as specific spatio-temporal extents.
EXAMPLES: not applicable.	USAGE: This class will generally not be used directly in the OpenX domain.

SetOfActivityStates



Element	Description
Type	Class
Name	SetOfActivityStates
IRI	http://ontology.asam.net/ontologies/Core#SetOfActivityStates
Subclass of	SetOfStates
Comments	DEF: A SetOfStates that groups activities.
EXAMPLES:	USAGE: Use this class to describe specific sets or kinds of ActivityStates that are not available already as subclasses of ActivityState.

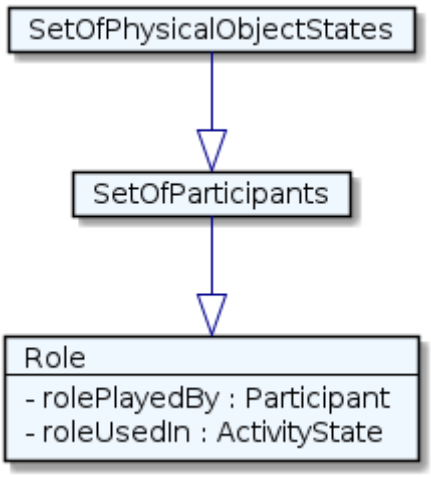
SetOfEvents



Element	Description
Type	Class
Name	SetOfEvents

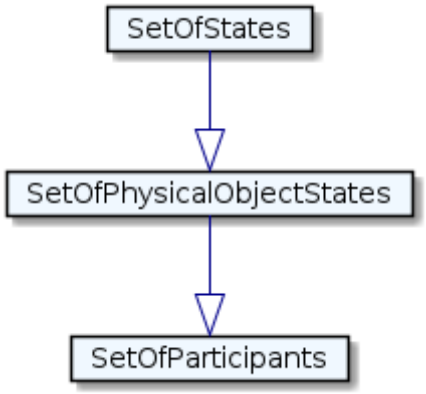
Element	Description
IRI	http://ontology.asam.net/ontologies/Core#SetOfEvents
Subclass of	SetOfSpatioTemporalExtents
Comments	DEF: A SetOfSpatioTemporalExtents that groups kinds of events.
EXAMPLES: triggered and absolute events, start and end events, etc.	USAGE: Use this class to describe specific sets or kinds of Events that are not available already as subclasses of Event.

SetOfParticipants



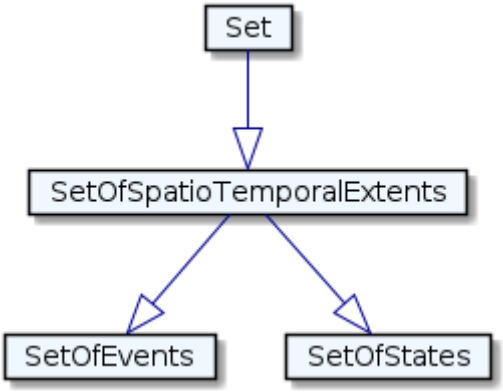
Element	Description
Type	Class
Name	SetOfParticipants
IRI	http://ontology.asam.net/ontologies/Core#SetOfParticipants
Subclass of	SetOfPhysicalObjectStates
Comments	DEF: A SetOfPhysicalObjectStates that groups participants of activities.
EXAMPLES:	USAGE: Generally use Role rather than this class.

SetOfPhysicalObjectStates



Element	Description
Type	Class
Name	SetOfPhysicalObjectStates
IRI	http://ontology.asam.net/ontologies/Core#SetOfPhysicalObjectStates
Subclass of	SetOfStates
Comments	DEF: A SetOfStates that groups physical object states.
EXAMPLES:	USAGE: Use this class to describe specific sets or kinds of PhysicalObjectStates that are not available already as subclasses of PhysicalObjectState.

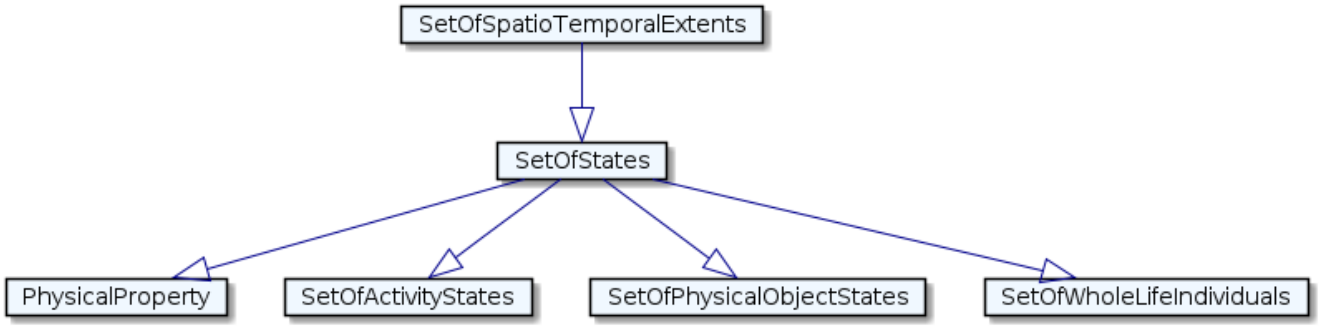
SetOfSpatioTemporalExtents



Element	Description
Type	Class
Name	SetOfSpatioTemporalExtents
IRI	http://ontology.asam.net/ontologies/Core#SetOfSpatioTemporalExtents
Subclass of	Set
Comments	DEF: A Set whose members are spatio-temporal extents.

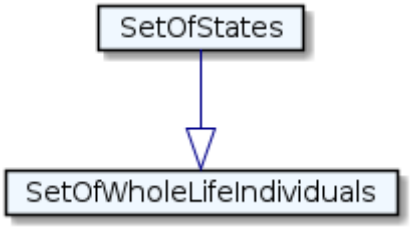
Element	Description
EXAMPLES:	USAGE: Use this class to describe specific sets or kinds of SpatioTemporalExtents that are not available already as subclasses of SpatioTemporalExtent.

SetOfStates



Element	Description
Type	Class
Name	SetOfStates
IRI	http://ontology.asam.net/ontologies/Core#SetOfStates
Subclass of	SetOfSpatioTemporalExtents
Comments	DEF: A SetOfSpatioTemporalExtents that groups states.
EXAMPLES:	USAGE: Use this class to describe specific sets or kinds of States that are not available already as subclasses of State.

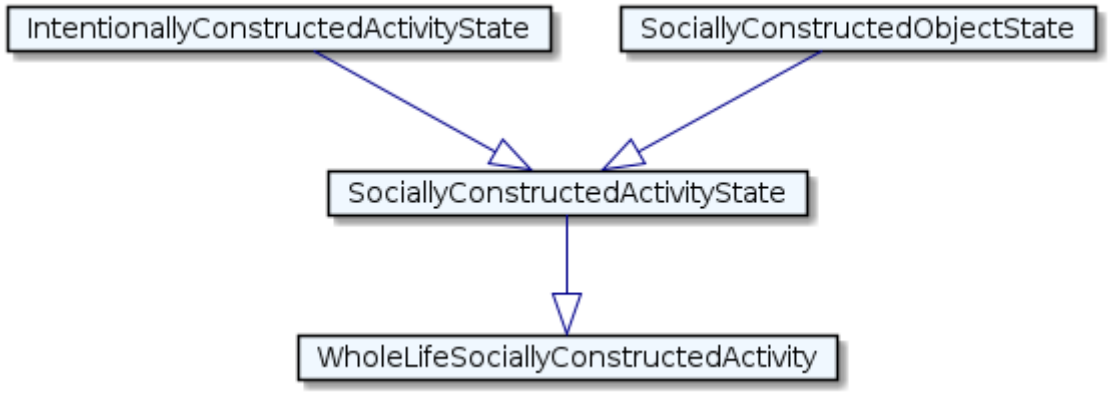
SetOfWholeLifeIndividuals



Element	Description
Type	Class
Name	SetOfWholeLifeIndividuals
IRI	http://ontology.asam.net/ontologies/Core#SetOfWholeLifeIndividuals
Subclass of	SetOfStates

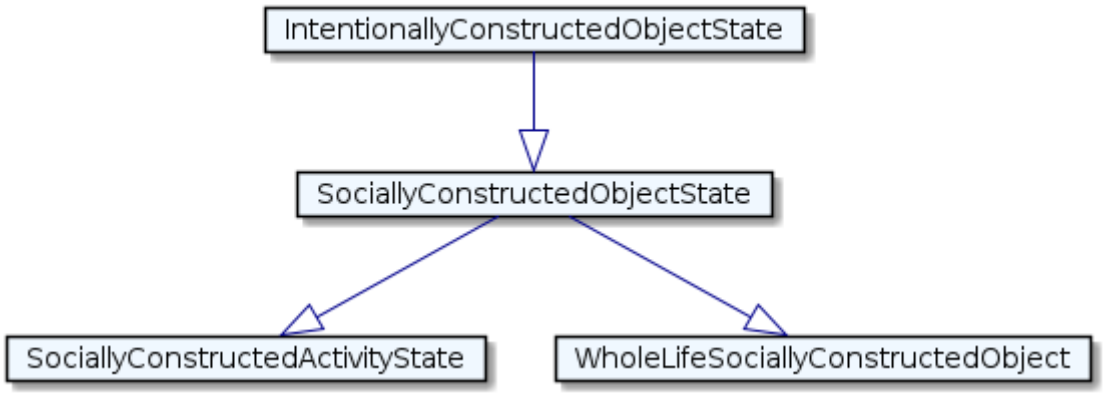
Element	Description
Comments	DEF: A SetOfStates that groups whole-life individuals.
EXAMPLES:	USAGE: Use this class to describe specific sets or kinds of WholeLifeIndividuals that are not available already as subclasses of WholeLifeIndividual.

SociallyConstructedActivityState



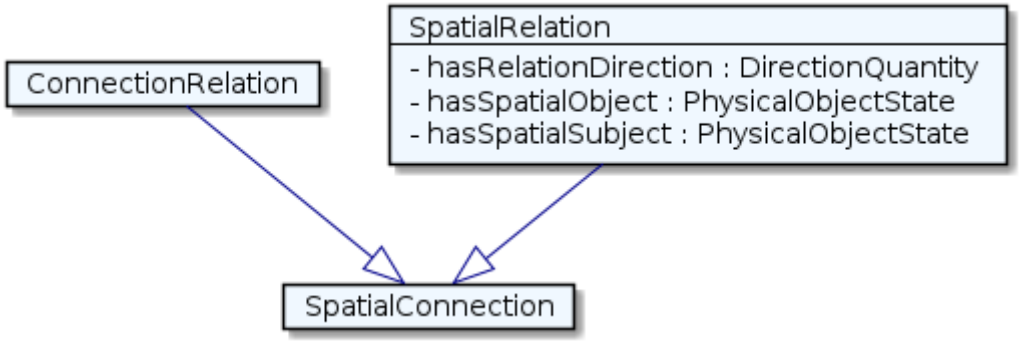
Element	Description
Type	Class
Name	SociallyConstructedActivityState
IRI	http://ontology.asam.net/ontologies/Core#SociallyConstructedActivityState
Subclass of	IntentionallyConstructedActivityState
Subclass of	SociallyConstructedObjectState
Comments	DEF: An ActivityState that is also a SociallyConstructedObjectState.
EXAMPLES: planned activities between multiple people such as meetings; the coordination of multiple traffic signals in an intelligent transportation system.	USAGE: Use this class to describe planned activities by a group of persons or intelligent devices.

SociallyConstructedObjectState



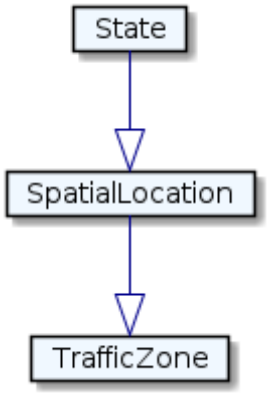
Element	Description
Type	Class
Name	SociallyConstructedObjectState
IRI	http://ontology.asam.net/ontologies/Core#SociallyConstructedObjectState
Subclass of	IntentionallyConstructedObjectState
Comments	DEF: An IntentionallyConstructedObjectState that is necessarily constructed by agreement of or acceptance by many people.
EXAMPLES: contracts, companies, and money	USAGE:

SpatialConnection



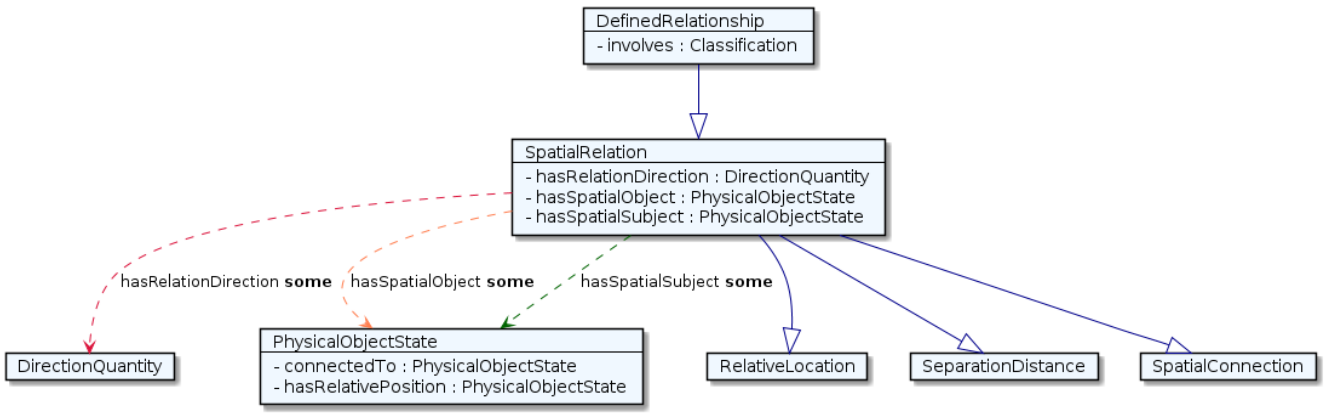
Element	Description
Type	Class
Name	SpatialConnection
IRI	http://ontology.asam.net/ontologies/Core#SpatialConnection
Subclass of	ConnectionRelation
Subclass of	SpatialRelation
Comments	DEF: A ConnectionRelation for relations between things that touch. Spatial connections create bridges for the transfer of energy or other things between the objects. Basis for the object property connectedTo.
EXAMPLES:	USAGE: Use this class to express a spatial connection between two things as a reified relationship, e.g. in order to specify characteristics such as the surface area of the connecting surface.

SpatialLocation



Element	Description
Type	Class
Name	SpatialLocation
IRI	http://ontology.asam.net/ontologies/Core#SpatialLocation
Subclass of	State
Comments	DEF: A State that describes the relative continuity of a position, an area or a space that is important in a defined context. The type of description of a SpatialLocation can be topological, topographical, coordinates, or any other type.
EXAMPLES: the position of an object, a country where certain regulations apply.	USAGE:

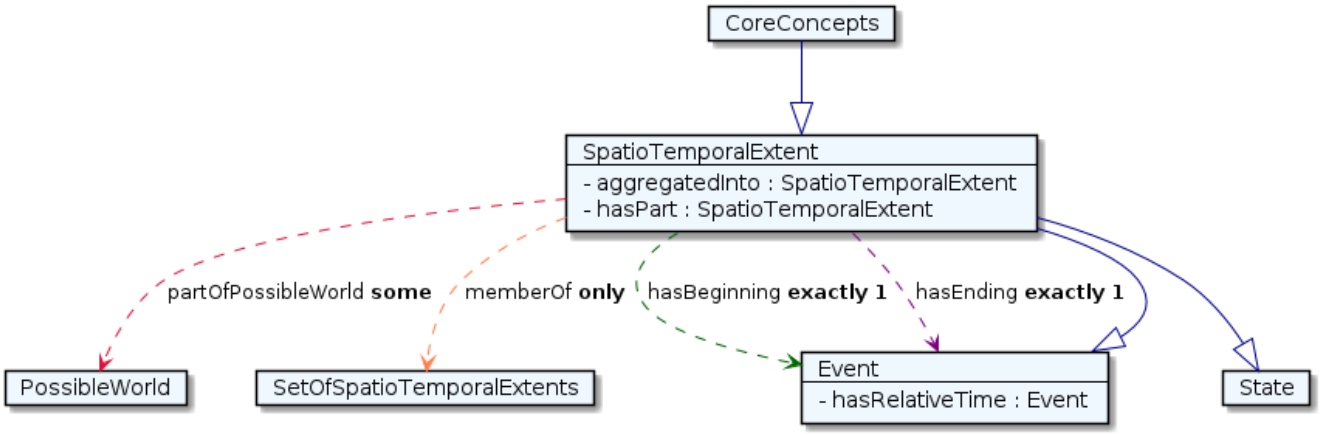
SpatialRelation



Element	Description
Type	Class
Name	SpatialRelation
IRI	http://ontology.asam.net/ontologies/Core#SpatialRelation
Subclass of	DefinedRelationship

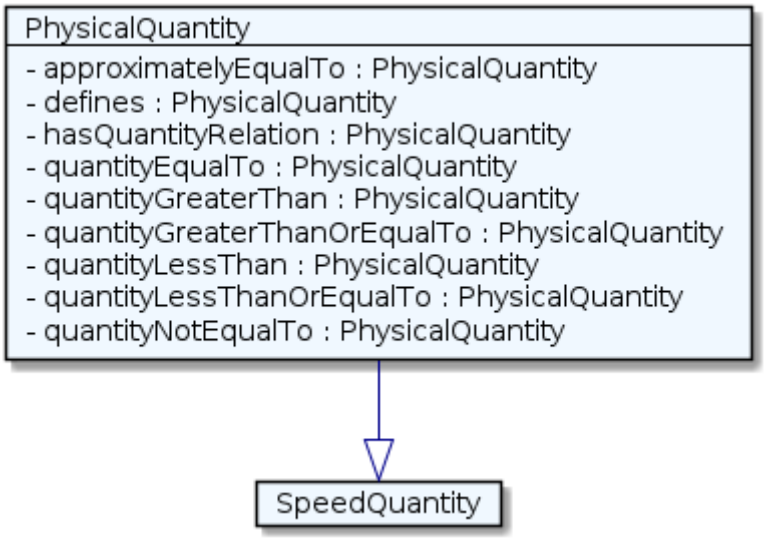
Element	Description
Restriction	hasRelationDirection **some** DirectionQuantity
Restriction	hasSpatialObject **some** PhysicalObjectState
Restriction	hasSpatialSubject **some** PhysicalObjectState
Disjoint with	TemporalRelation
Comments	DEF: A DefinedRelationship between two physical objects that describes their directional relationship, not the distance. Basis for object properties such as rightOf, leftOf, inFrontOf, behind, etc.
EXAMPLES:	USAGE: Use this class to express a general spatial relation between two things as a reified relationship, giving only the direction of the relationship.

SpatioTemporalExtent



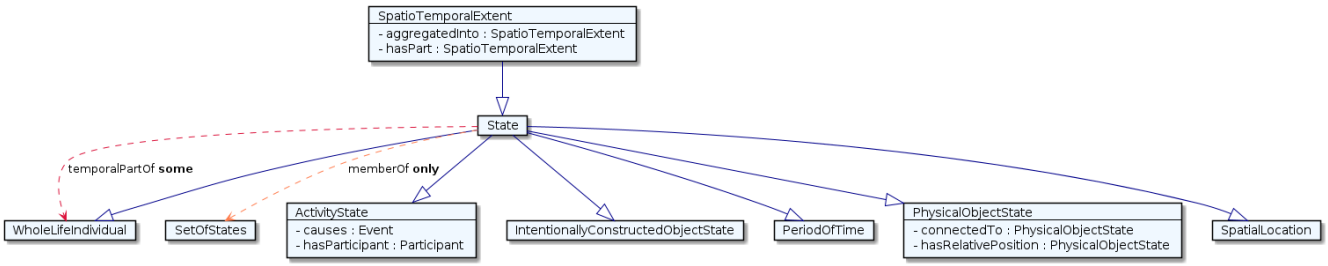
Element	Description
Type	Class
Name	SpatioTemporalExtent
IRI	http://ontology.asam.net/ontologies/Core#SpatioTemporalExtent
Subclass of	CoreConcepts
Restriction	partOfPossibleWorld **some** PossibleWorld
Restriction	memberOf **only** SetOfSpatioTemporalExtents
Restriction	hasBeginning **exactly 1** Event
Restriction	hasEnding **exactly 1** Event
Comments	DEF: A thing that exists in time and space, meaning in four dimensions. Each spatio-temporal extent has a start event and an end event.
EXAMPLES: not applicable.	USAGE: This class will generally not be used directly in the OpenX domain.

SpeedQuantity



Element	Description
Type	Class
Name	SpeedQuantity
IRI	http://ontology.asam.net/ontologies/Core#SpeedQuantity
Subclass of	PhysicalQuantity
Comments	DEF: A PhysicalQuantity that is a speed value in meters per second.
EXAMPLES:	USAGE:

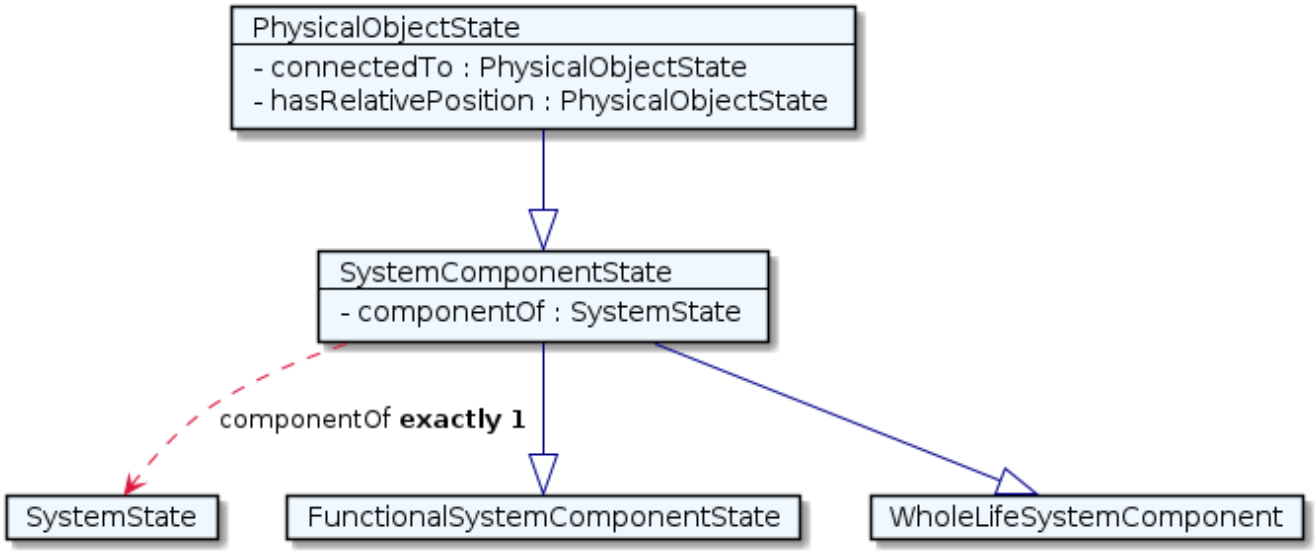
State



Element	Description
Type	Class
Name	State
IRI	http://ontology.asam.net/ontologies/Core#State
Subclass of	SpatioTemporalExtent
Restriction	temporalPartOf **some** WholeLifeIndividual
Restriction	memberOf **only** SetOfStates

Element	Description
Comments	DEF: A SpatioTemporalExtent with non-zero extension in both space and time. Used to describe, for example, the state of a vehicle, a person, or a manufactured system like a factory. States can apply to the whole life of a thing or represent temporal parts of a thing,
EXAMPLES:	USAGE: Use this class to describe the temporal part of a whole-life individual to which some property applies or to describe the temporal part of a whole-life individual that participates in an activity.

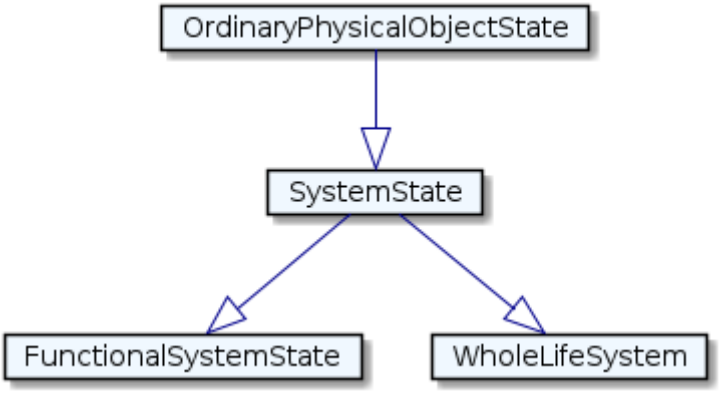
SystemComponentState



Element	Description
Type	Class
Name	SystemComponentState
IRI	http://ontology.asam.net/ontologies/Core#SystemComponentState
Subclass of	PhysicalObjectState
Restriction	componentOf **exactly 1** SystemState
Comments	DEF: A PhysicalObjectState that represents a component of a system. The state may represent the whole life of the component or a temporal part of it. The state can be completely replaced without losing its identity. A SystemComponentState can only exist when the System exists. On the other hand, the OrdinaryPhysicalObject that is installed as the component may exist before or after the System.

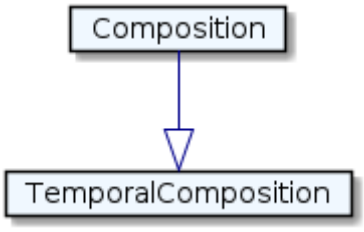
Element	Description
EXAMPLES: vehicles and pedestrians are components of the traffic system (actually FunctionalSystemComponentStates - not WholeLifeIndividuals because the whole life of a vehicle or pedestrian would include temporal parts that are not components of the same traffic system)	USAGE: Use this class only for physical objects that are components of systems that do not have specific functions (are not FunctionalSystems)

SystemState



Element	Description
Type	Class
Name	SystemState
IRI	http://ontology.asam.net/ontologies/Core#SystemState
Subclass of	OrdinaryPhysicalObjectState
Comments	DEF: An OrdinaryPhysicalObjectState that represents a concrete materialized system. Systems are defined as an organized or connected group of physical objects. A SystemState may represent the whole life of the system or a temporal part of it.
EXAMPLES: A natural weather system.	USAGE: Use this class only for systems that do not have specific functions

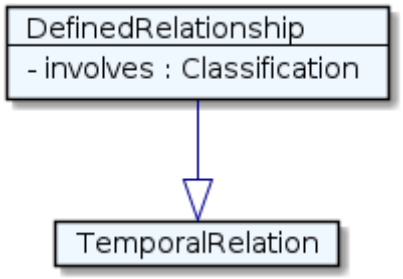
TemporalComposition



Element	Description
Type	Class

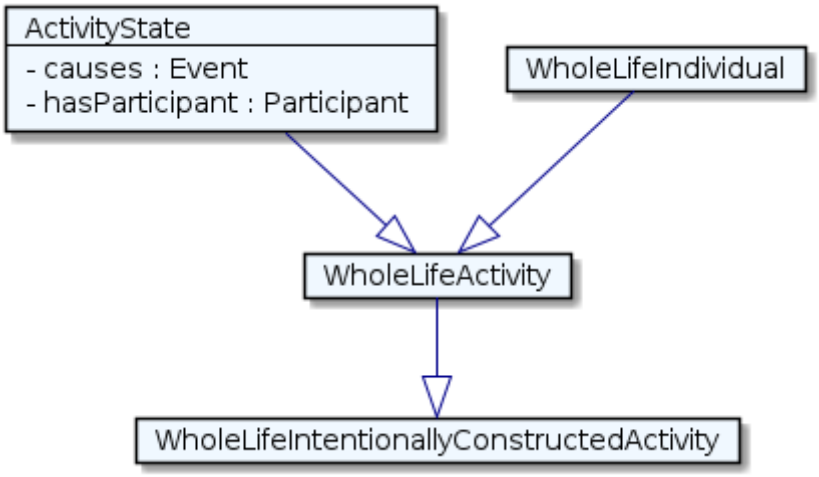
Element	Description
Name	TemporalComposition
IRI	http://ontology.asam.net/ontologies/Core#TemporalComposition
Subclass of	Composition
Comments	DEF: A Composition where the part is the entire whole spatially, but part of the whole temporally.
EXAMPLES: not applicable.	USAGE: This class will generally not be used directly in the OpenX domain.

TemporalRelation



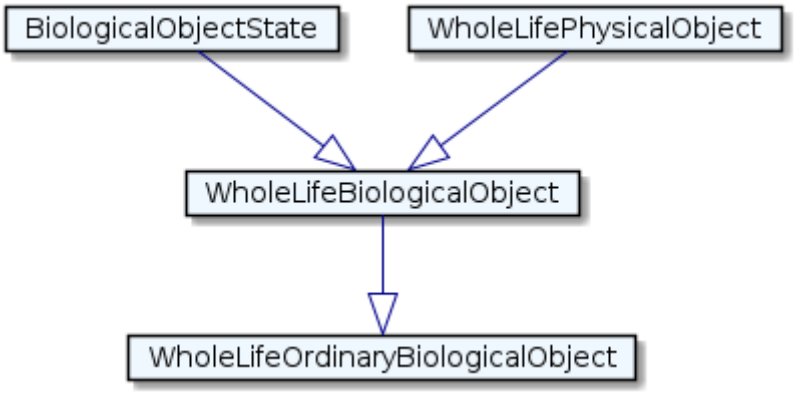
Element	Description
Type	Class
Name	TemporalRelation
IRI	http://ontology.asam.net/ontologies/Core#TemporalRelation
Subclass of	DefinedRelationship
Comments	DEF: A DefinedRelationship that describes a temporal relationship between two things, usually between events. Basis for the object properties occursBefore, occursAfter, and similar.
EXAMPLES: not applicable.	USAGE: This class will generally not be used directly in the OpenX domain.

WholeLifeActivity



Element	Description
Type	Class
Name	WholeLifeActivity
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeActivity
Subclass of	ActivityState
Subclass of	WholeLifeIndividual
Comments	DEF: An ActivityState that represents the whole life of the activity.
EXAMPLES: the entire activity of overtaking another vehicle.	USAGE: Use this class for an activity that is its temporal whole.

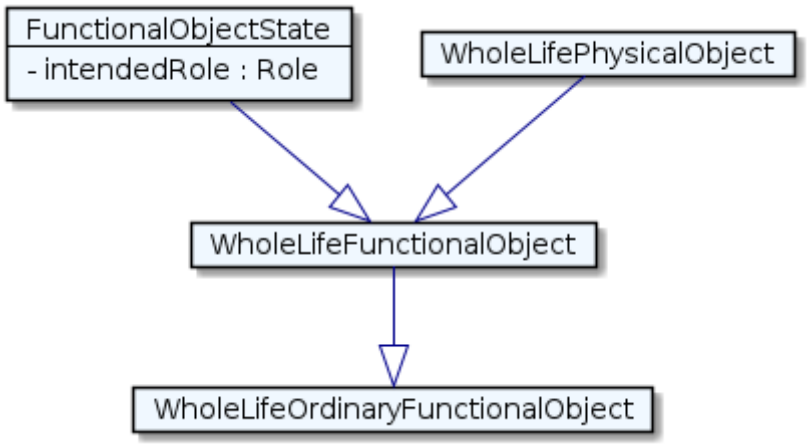
WholeLifeBiologicalObject



Element	Description
Type	Class
Name	WholeLifeBiologicalObject
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeBiologicalObject
Subclass of	BiologicalObjectState

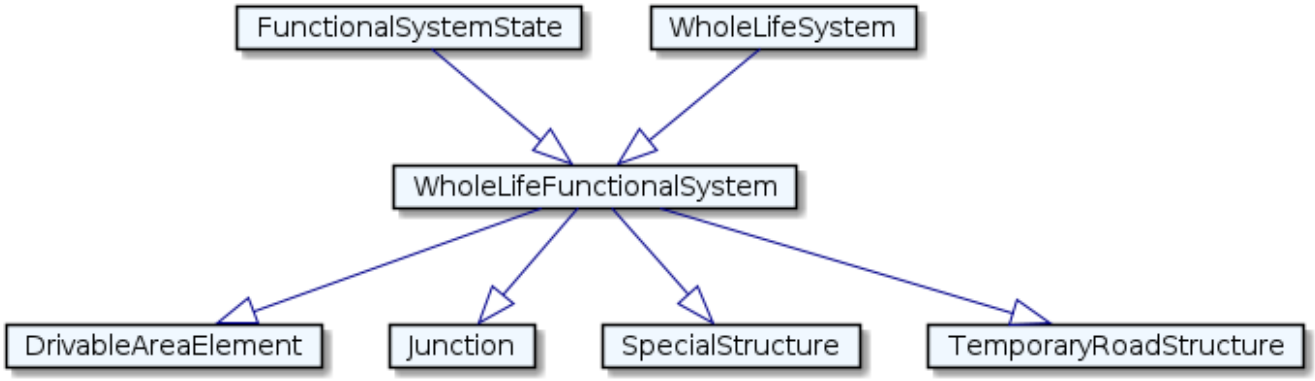
Element	Description
Subclass of	WholeLifePhysicalObject
Comments	DEF: A BiologicalObjectState that represents the whole life of the biological object.
EXAMPLES: a person from their birth to their death.	USAGE: Use this class for a biological object that is its temporal whole. Note that usually it is preferable to use the subclass WholeLifeOrdinaryBiologicalObject.

WholeLifeFunctionalObject



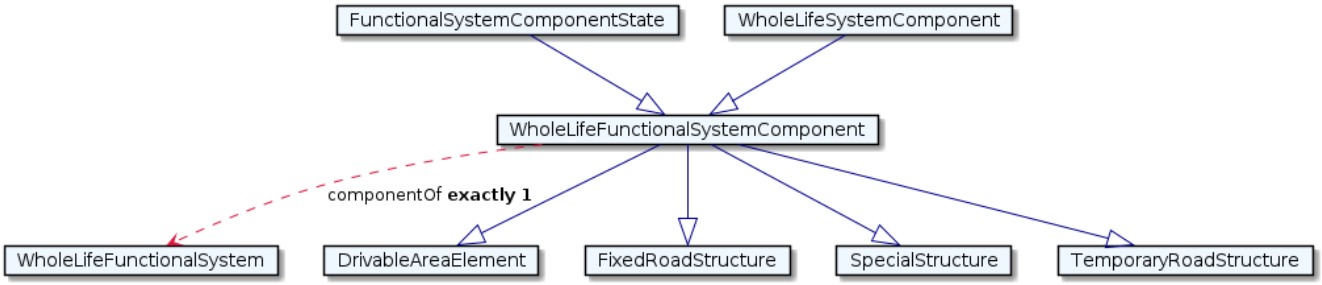
Element	Description
Type	Class
Name	WholeLifeFunctionalObject
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeFunctionalObject
Subclass of	FunctionalObjectState
Subclass of	WholeLifePhysicalObject
Comments	DEF: A FunctionalObjectState that represents the whole life of the functional object.
EXAMPLES:	USAGE: Use this class for a functional object that is its temporal whole. Note that usually it is preferable to use the subclass WholeLifeOrdinaryFunctionalObject.

WholeLifeFunctionalSystem



Element	Description
Type	Class
Name	WholeLifeFunctionalSystem
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeFunctionalSystem
Subclass of	FunctionalSystemState
Subclass of	WholeLifeSystem
Comments	DEF: A FunctionalSystemState that represents the whole life of the functional system.
EXAMPLES: A vehicle from when it is manufactured to when it is destroyed.	USAGE: Use this class for describing individual concrete (actual, materialized) systems that cease to exist when all of their parts are removed. Often combined with WholeLifeOrdinaryBiologicalObject or WholeLifeOrdinaryFunctionalObject

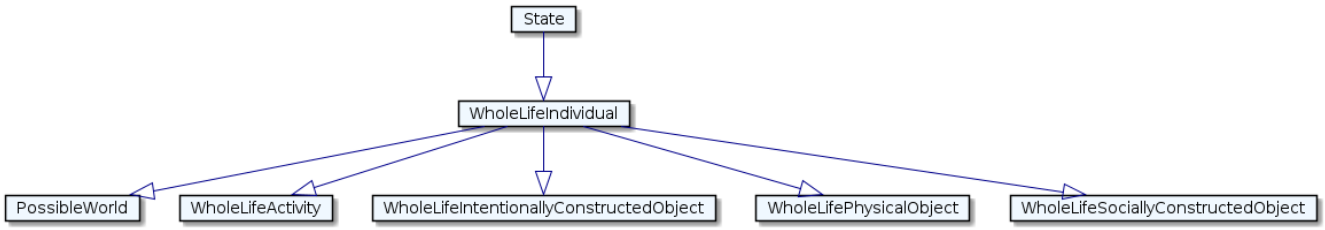
WholeLifeFunctionalSystemComponent



Element	Description
Type	Class
Name	WholeLifeFunctionalSystemComponent
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeFunctionalSystemComponent
Subclass of	FunctionalSystemComponentState
Subclass of	WholeLifeSystemComponent

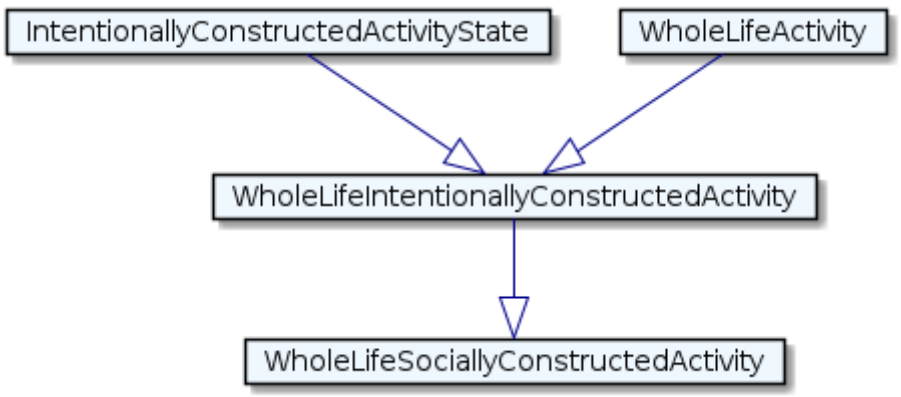
Element	Description
Restriction	componentOf **exactly 1** WholeLifeFunctionalSystem
Comments	DEF: A FunctionalSystemComponentState that represents the whole life of the functional system component.
EXAMPLES: The component of a junction that is the a traffic light, which functions as a signal at a junction (not the individual traffic lights with their serial numbers and dates of production, but the traffic light as a functional component).	USAGE: Use this class to specify the whole life of a component of a functional system, which could be temporally divided into FunctionalSystemComponentStates for each of the InstalledObjects that acted as the component over the lifetime of the functional system.

WholeLifeIndividual



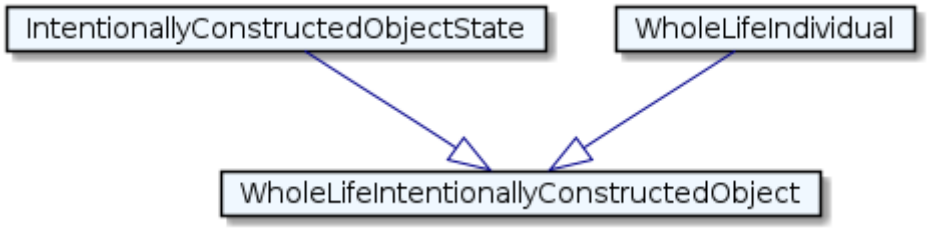
Element	Description
Type	Class
Name	WholeLifeIndividual
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeIndividual
Subclass of	State
Comments	DEF: A State that is not a proper temporalPartOf any other individual of the same kind.
EXAMPLES:	USAGE: Use this class in combination with others to designate that a particular spatio-temporal extent is "its whole life"

WholeLifeIntentionallyConstructedActivity



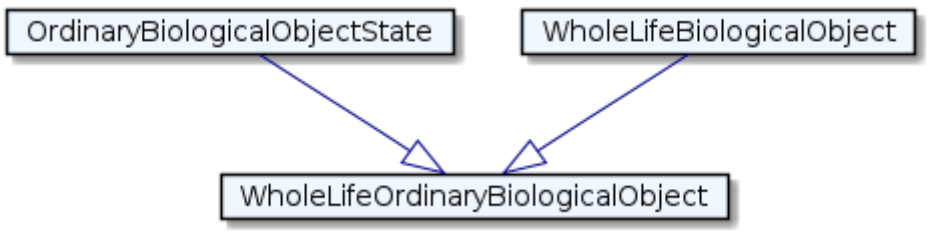
Element	Description
Type	Class
Name	WholeLifeIntentionallyConstructedActivity
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeIntentionallyConstructedActivity
Subclass of	IntentionallyConstructedActivityState
Subclass of	WholeLifeActivity
Comments	DEF: A WholeLifeIntentionallyConstructedObject that is also a WholeLifeActivity.
EXAMPLES:	USAGE:

WholeLifeIntentionallyConstructedObject



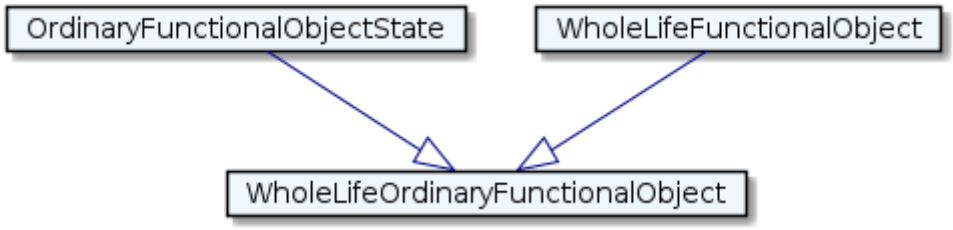
Element	Description
Type	Class
Name	WholeLifeIntentionallyConstructedObject
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeIntentionallyConstructedObject
Subclass of	IntentionallyConstructedObjectState
Subclass of	WholeLifeIndividual
Comments	DEF: An IntentionallyConstructedObjectState that represents the whole life of the intentionally constructed object.
EXAMPLES:	USAGE: Use this class for an intentionally constructed object that is its temporal whole. Note that usually it is preferable to use one of the subclasses.

WholeLifeOrdinaryBiologicalObject



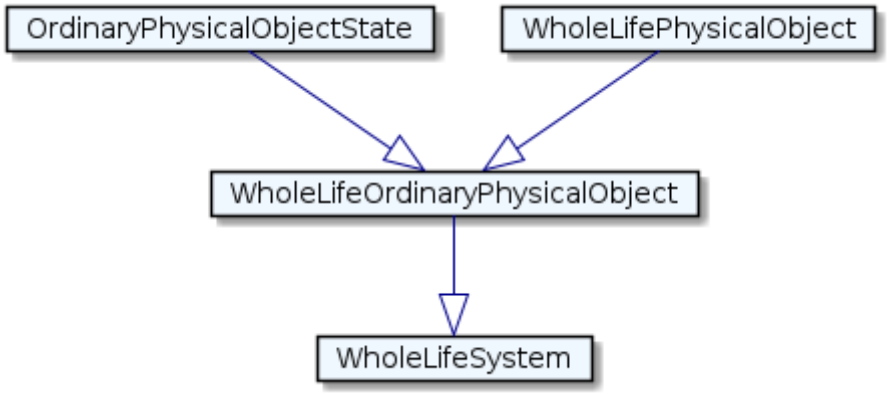
Element	Description
Type	Class
Name	WholeLifeOrdinaryBiologicalObject
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeOrdinaryBiologicalObject
Subclass of	OrdinaryBiologicalObjectState
Subclass of	WholeLifeBiologicalObject
Comments	DEF: An OrdinaryBiologicalObjectState that represents the whole life of the ordinary biological object.
EXAMPLES: a particular person from the instant that person was born to the instant that the person dies	USAGE: Use this class for describing individual living things that cease to exist when all of their parts are removed.

WholeLifeOrdinaryFunctionalObject



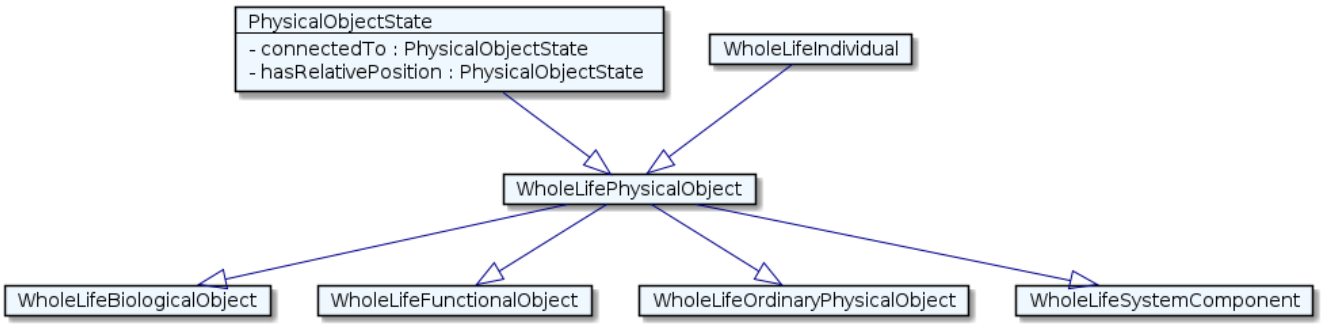
Element	Description
Type	Class
Name	WholeLifeOrdinaryFunctionalObject
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeOrdinaryFunctionalObject
Subclass of	OrdinaryFunctionalObjectState
Subclass of	WholeLifeFunctionalObject
Comments	DEF: An OrdinaryFunctionalObjectState that represents the whole life of the ordinary functional object.
EXAMPLES: a particular car (or traffic sign, road intersection, etc.) from the instant it is manufactured to the instant it is disassembled or otherwise ceases to be a car	USAGE: Use this class for describing individual manufactured things that were constructed for some purpose and that cease to exist when all of their parts are removed

WholeLifeOrdinaryPhysicalObject



Element	Description
Type	Class
Name	WholeLifeOrdinaryPhysicalObject
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeOrdinaryPhysicalObject
Subclass of	OrdinaryPhysicalObjectState
Subclass of	WholeLifePhysicalObject
Comments	DEF: A OrdinaryPhysicalObjectState that represents the whole life of the ordinary physical object.
EXAMPLES:	USAGE: Use this class for an ordinary physical object that is its temporal whole.

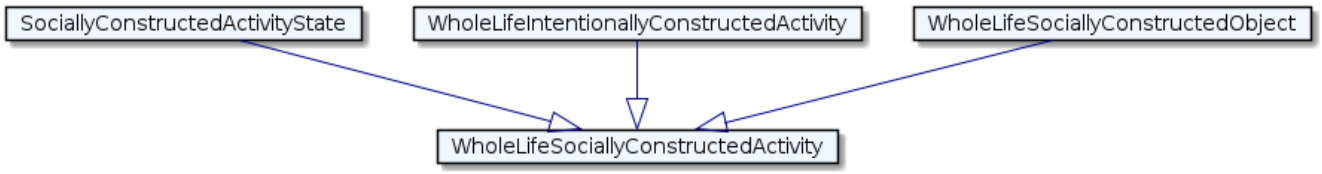
WholeLifePhysicalObject



Element	Description
Type	Class
Name	WholeLifePhysicalObject
IRI	http://ontology.asam.net/ontologies/Core#WholeLifePhysicalObject
Subclass of	PhysicalObjectState
Subclass of	WholeLifeIndividual
Comments	DEF: A PhysicalObjectState that represents the whole life of the physical object.

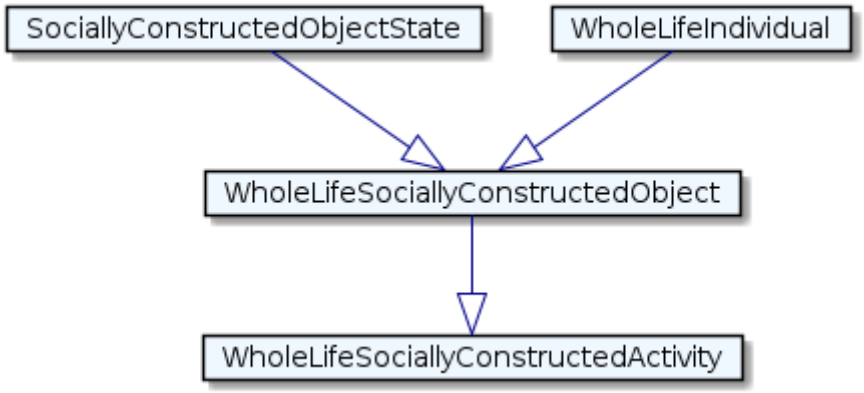
Element	Description
EXAMPLES:	USAGE: Use this class for a physical object that is its temporal whole. Note that it is generally preferable to use one of the subclasses.

WholeLifeSociallyConstructedActivity



Element	Description
Type	Class
Name	WholeLifeSociallyConstructedActivity
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeSociallyConstructedActivity
Subclass of	SociallyConstructedActivityState
Subclass of	WholeLifeIntentionallyConstructedActivity
Subclass of	WholeLifeSociallyConstructedObject
Comments	DEF: A WholeLifeSociallyConstructedObject that is also a WholeLifeActivity.
EXAMPLES:	USAGE: Use this class for an socially constructed activity that is its temporal whole.

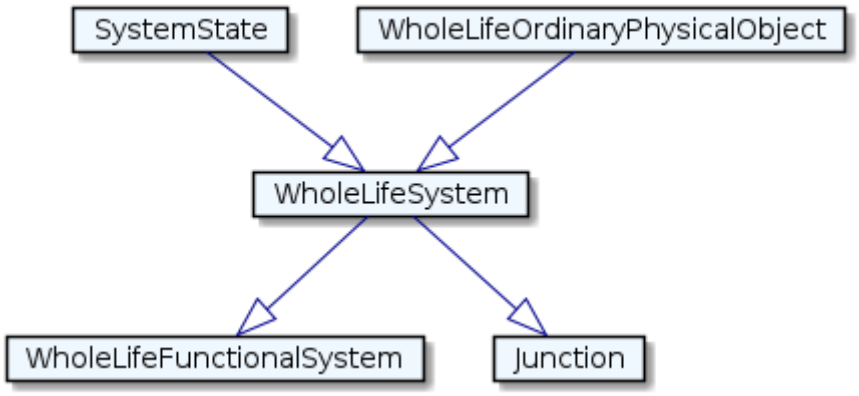
WholeLifeSociallyConstructedObject



Element	Description
Type	Class
Name	WholeLifeSociallyConstructedObject
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeSociallyConstructedObject

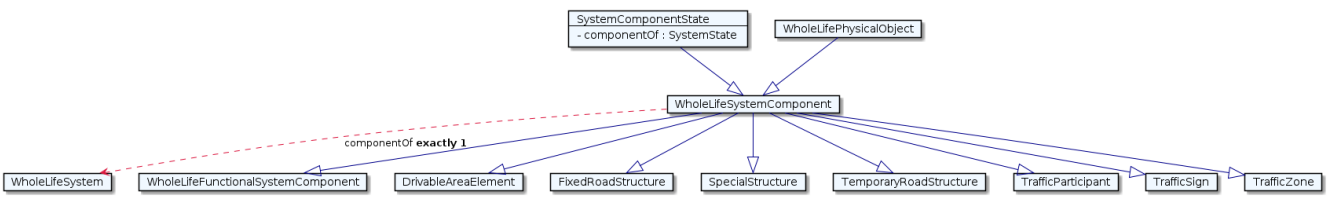
Element	Description
Subclass of	SociallyConstructedObjectState
Subclass of	WholeLifeIndividual
Comments	DEF: A SociallyConstructedObjectState that represents the whole life of the socially constructed object.
EXAMPLES:	USAGE: Use this class for an socially constructed object that is its temporal whole.

WholeLifeSystem



Element	Description
Type	Class
Name	WholeLifeSystem
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeSystem
Subclass of	SystemState
Subclass of	WholeLifeOrdinaryPhysicalObject
Comments	DEF: An OrdinaryPhysicalObject that is an organized or connected group of PhysicalObjects that are SystemComponents and each have a role in how the overall system functions.
EXAMPLES: The entire life of a hurricane from when it was formed to when it ceases to exist.	USAGE: Use this class for a system that is its temporal whole. Note that usually it is preferable to use the subclass WholeLifeFunctionalSystem for systems that are intentionally constructed for some purpose.

WholeLifeSystemComponent



Element	Description
Type	Class
Name	WholeLifeSystemComponent
IRI	http://ontology.asam.net/ontologies/Core#WholeLifeSystemComponent
Subclass of	SystemComponentState
Subclass of	WholeLifePhysicalObject
Restriction	componentOf **exactly 1** WholeLifeSystem
Comments	DEF: A SystemComponentState that represents the whole life of the system component.
EXAMPLES: the eye of a hurricane.	USAGE: Use this class to specify the whole life of a component of a system that is not functional.

A.1.2. Properties

aggregatedInto

Element	Description
Type	ObjectProperty
Name	aggregatedInto
IRI	http://ontology.asam.net/ontologies/Core#aggregatedInto
Has domain	SpatioTemporalExtent
Has range	SpatioTemporalExtent
Characteristic	Asymmetric
Comments	DEF: A relationship type where a SpatioTemporalExtent may be aggregated into one or more others. This object property has the same meaning as the class Aggregation, but a different representation.

appliesTo

Element	Description
Type	ObjectProperty
Name	appliesTo
IRI	http://ontology.asam.net/ontologies/Core#appliesTo
Comments	DEF: This relation is used to describe that a specification or regularity applies to a particular object. For example, this relation can be used to describe which lanes a speed limit sign applies to.

approximatelyEqualTo

Element	Description
Type	ObjectProperty
Name	approximatelyEqualTo
IRI	http://ontology.asam.net/ontologies/Core#approximatelyEqualTo
Subproperty of	hasQuantityRelation
Has domain	PhysicalQuantity
Has range	PhysicalQuantity
Characteristic	Symmetric
Comments	DEF: A hasQuantityRelation relationship type, where the value for the second quantity is within the range of the first quantity. The deviation between the values is no greater than +/- 10% of the first value.

beginningOf

Element	Description
Type	ObjectProperty
Name	beginningOf
IRI	http://ontology.asam.net/ontologies/Core#beginningOf
Subproperty of	temporalPartOf
Has domain	Event
Inverse	hasBeginning
Comments	DEF: A temporalPartOf relationship type where a SpatioTemporalExtent has exactly one event that is its beginning.

behind

Element	Description
Type	ObjectProperty
Name	behind
IRI	http://ontology.asam.net/ontologies/Core#behind
Subproperty of	hasRelativePosition
Inverse	inFrontOf
Characteristic	Asymmetric

Element	Description
Comments	DEF: A hasRelativePosition relationship type where the first PhysicalObject is behind the second PhysicalObject.

behindConnectedTo

Element	Description
Type	ObjectProperty
Name	behindConnectedTo
IRI	http://ontology.asam.net/ontologies/Core#behindConnectedTo
Subproperty of	longitudinalConnectedTo
Comments	DEF: A longitudinalConnectedTo relationship type where two PhysicalObjects are connected and the first PhysicalObject is behind the second PhysicalObject.

behindLeftOf

Element	Description
Type	ObjectProperty
Name	behindLeftOf
IRI	http://ontology.asam.net/ontologies/Core#behindLeftOf
Subproperty of	hasRelativePosition
Inverse	frontRightOf
Characteristic	Asymmetric
Comments	DEF: A hasRelativePosition relationship type where the first PhysicalObject is behind and to the left of the second PhysicalObject.

behindRightOf

Element	Description
Type	ObjectProperty
Name	behindRightOf
IRI	http://ontology.asam.net/ontologies/Core#behindRightOf
Subproperty of	hasRelativePosition
Inverse	frontLeftOf
Characteristic	Asymmetric

Element	Description
Comments	DEF: A hasRelativePosition relationship type where the first PhysicalObject is behind and to the right of the second PhysicalObject.

causes

Element	Description
Type	ObjectProperty
Name	causes
IRI	http://ontology.asam.net/ontologies/Core#causes
Has domain	ActivityState
Has range	ActivityState
Comments	DEF: A relationship type where each activity is the cause of one or more events.

componentOf

Element	Description
Type	ObjectProperty
Name	componentOf
IRI	http://ontology.asam.net/ontologies/Core#componentOf
Subproperty of	partOf
Has domain	SystemComponentState
Has range	SystemComponentState
Inverse	hasComponent
Characteristic	Functional
Comments	DEF: A partOf relationship type where each SystemComponent is partOf exactly one System.

connectedTo

Element	Description
Type	ObjectProperty
Name	connectedTo
IRI	http://ontology.asam.net/ontologies/Core#connectedTo
Has domain	PhysicalObjectState
Has range	PhysicalObjectState

Element	Description
Characteristic	Symmetric
Comments	DEF: A relationship type where two physical object have a spatial connection and touch each other. Spatial connections create bridges for the transfer of energy or other things between the objects. This object property has the same meaning as the class SpatialConnection, but a different representation.

defines

Element	Description
Type	ObjectProperty
Name	defines
IRI	http://ontology.asam.net/ontologies/Core#defines
Has domain	PhysicalQuantity
Has range	PhysicalQuantity
Characteristic	Transitive
Comments	DEF: A relationship type that relates two numeric parameters. It expresses that one parameter value is determined by the other parameter value.

endingOf

Element	Description
Type	ObjectProperty
Name	endingOf
IRI	http://ontology.asam.net/ontologies/Core#endingOf
Subproperty of	temporalPartOf
Has domain	Event
Inverse	hasEnding
Comments	DEF: A temporalPartOf relationship type where a SpatioTemporalExtent has exactly one event that is its ending.

frontConnectedTo

Element	Description
Type	ObjectProperty
Name	frontConnectedTo

Element	Description
IRI	http://ontology.asam.net/ontologies/Core#frontConnectedTo
Subproperty of	longitudinalConnectedTo
Comments	DEF: A longitudinalConnectedTo relationship type where two PhysicalObjects are connected and the first PhysicalObject is in front of the second PhysicalObject.

frontLeftOf

Element	Description
Type	ObjectProperty
Name	frontLeftOf
IRI	http://ontology.asam.net/ontologies/Core#frontLeftOf
Subproperty of	hasRelativePosition
Characteristic	Asymmetric
Comments	DEF: A hasRelativePosition relationship type where the first PhysicalObject is in front and to the left of the second PhysicalObject.

frontRightOf

Element	Description
Type	ObjectProperty
Name	frontRightOf
IRI	http://ontology.asam.net/ontologies/Core#frontRightOf
Subproperty of	hasRelativePosition
Characteristic	Asymmetric
Comments	DEF: A hasRelativePosition relationship type where the first PhysicalObject is in front and to the right of the second PhysicalObject.

hasAngle

Element	Description
Type	ObjectProperty
Name	hasAngle
IRI	http://ontology.asam.net/ontologies/Core#hasAngle

Element	Description
Subproperty of	hasQuantity
Comments	DEF: A hasQuantity relationship type that specifies an angle quantity of something.

hasBeginning

Element	Description
Type	ObjectProperty
Name	hasBeginning
IRI	http://ontology.asam.net/ontologies/Core#hasBeginning
Subproperty of	hasTemporalPart
Comments	DEF: Inverse relationship of beginningOf

hasColor

Element	Description
Type	ObjectProperty
Name	hasColor
IRI	http://ontology.asam.net/ontologies/Core#hasColor
Subproperty of	hasProperty
Comments	DEF: A hasPropertyrelationship type that specifies the color of something.

hasComponent

Element	Description
Type	ObjectProperty
Name	hasComponent
IRI	http://ontology.asam.net/ontologies/Core#hasComponent
Subproperty of	hasPart
Comments	DEF: Inverse relationship of componentOf

hasDirection

Element	Description
Type	ObjectProperty
Name	hasDirection

Element	Description
IRI	http://ontology.asam.net/ontologies/Core#hasDirection
Subproperty of	hasQuantity
Comments	DEF: A hasQuantity relationship type that specifies a direction quantity of something.

hasDistance

Element	Description
Type	ObjectProperty
Name	hasDistance
IRI	http://ontology.asam.net/ontologies/Core#hasDistance
Subproperty of	hasLength
Comments	DEF: A hasQuantity relationship type that specifies a distance quantity of something.

hasEnding

Element	Description
Type	ObjectProperty
Name	hasEnding
IRI	http://ontology.asam.net/ontologies/Core#hasEnding
Subproperty of	hasTemporalPart
Comments	DEF: Inverse relationship of endingOf

hasGeometry

Element	Description
Type	ObjectProperty
Name	hasGeometry
IRI	http://ontology.asam.net/ontologies/Core#hasGeometry
Subproperty of	hasProperty
Comments	DEF: A hasProperty relationship type that specifies the geometry of something, usually a physical object.

hasHeading

Element	Description
Type	ObjectProperty
Name	hasHeading
IRI	http://ontology.asam.net/ontologies/Core#hasHeading
Subproperty of	hasDirection
Has domain	PhysicalObjectState
Comments	DEF: A hasQuantity relationship type that specifies a direction that a moving object is heading in. This property is required for defining leftOf, rightOf, etc.

hasLength

Element	Description
Type	ObjectProperty
Name	hasLength
IRI	http://ontology.asam.net/ontologies/Core#hasLength
Subproperty of	hasQuantity
Comments	DEF: A hasQuantity relationship type that specifies the length quantity of something.

hasMember

Element	Description
Type	ObjectProperty
Name	hasMember
IRI	http://ontology.asam.net/ontologies/Core#hasMember
Has domain	Set
Inverse	memberOf
Characteristic	Asymmetric
Comments	DEF: A relationship type stating that a Set has a particular thing as a member. A set can have anything of the respective type as a member.

hasObject

Element	Description
Type	ObjectProperty

Element	Description
Name	hasObject
IRI	http://ontology.asam.net/ontologies/Core#hasObject
Subproperty of	hasParticipant
Inverse	objectOf
Comments	DEF: A hasParticipant relationship type that relates some activity to a physical object as object of the activity. The object is a non-actor participant. Inverse relationship of objectOf.

hasPart

Element	Description
Type	ObjectProperty
Name	hasPart
IRI	http://ontology.asam.net/ontologies/Core#hasPart
Has domain	SpatioTemporalExtent
Has range	SpatioTemporalExtent
Inverse	partOf
Characteristic	Asymmetric
Comments	DEF: A relationship type where a SpatioTemporalExtent may consist of one or more others. Inverse relationship of partOf.

hasParticipant

Element	Description
Type	ObjectProperty
Name	hasParticipant
IRI	http://ontology.asam.net/ontologies/Core#hasParticipant
Subproperty of	hasPart
Has domain	ActivityState
Has range	ActivityState
Inverse	participantOf
Comments	DEF: A hasPart relationship type where an ActivityState hasPart one or more Participants.

hasProperty

Element	Description
Type	ObjectProperty
Name	hasProperty
IRI	http://ontology.asam.net/ontologies/Core#hasProperty
Comments	DEF: Relationship type for specifying properties of particular things

hasQuantity

Element	Description
Type	ObjectProperty
Name	hasQuantity
IRI	http://ontology.asam.net/ontologies/Core#hasQuantity
Subproperty of	hasProperty
Comments	DEF: A relationship type for specifying quantities of particular things

hasQuantityRelation

Element	Description
Type	ObjectProperty
Name	hasQuantityRelation
IRI	http://ontology.asam.net/ontologies/Core#hasQuantityRelation
Has domain	PhysicalQuantity
Has range	PhysicalQuantity
Comments	DEF: A relationship type for basic arithmetic relationships between quantities

hasRelationDirection

Element	Description
Type	ObjectProperty
Name	hasRelationDirection
IRI	http://ontology.asam.net/ontologies/Core#hasRelationDirection
Subproperty of	hasDirection
Subproperty of	relationProperty

Element	Description
Has domain	SpatialRelation
Has range	SpatialRelation
Comments	DEF: A hasQuantity relationship type that specifies the direction of a spatial relation.

hasRelativePosition

Element	Description
Type	ObjectProperty
Name	hasRelativePosition
IRI	http://ontology.asam.net/ontologies/Core#hasRelativePosition
Has domain	PhysicalObjectState
Has range	PhysicalObjectState
Comments	DEF: Object properties derived from SpatialRelation

hasRelativeTime

Element	Description
Type	ObjectProperty
Name	hasRelativeTime
IRI	http://ontology.asam.net/ontologies/Core#hasRelativeTime
Has domain	Event
Has range	Event
Comments	DEF: Object properties derived from TemporalRelation

hasSpatialObject

Element	Description
Type	ObjectProperty
Name	hasSpatialObject
IRI	http://ontology.asam.net/ontologies/Core#hasSpatialObject
Subproperty of	relationProperty
Has domain	SpatialRelation
Has range	SpatialRelation
Characteristic	Functional

Element	Description
Characteristic	Inverse Functional
Comments	DEF: A relationProperty designating the object, destination, or "recepient" in a SpatialRelation.

hasSpatialSubject

Element	Description
Type	ObjectProperty
Name	hasSpatialSubject
IRI	http://ontology.asam.net/ontologies/Core#hasSpatialSubject
Subproperty of	relationProperty
Has domain	SpatialRelation
Has range	SpatialRelation
Characteristic	Functional
Characteristic	Inverse Functional
Comments	DEF: A relationProperty designating the subject, origin, or "owner" in a SpatialRelation.

hasSpeed

Element	Description
Type	ObjectProperty
Name	hasSpeed
IRI	http://ontology.asam.net/ontologies/Core#hasSpeed
Subproperty of	hasQuantity
Comments	DEF: A hasQuantity relationship type that specifies speed.

hasSubject

Element	Description
Type	ObjectProperty
Name	hasSubject
IRI	http://ontology.asam.net/ontologies/Core#hasSubject
Subproperty of	hasParticipant
Inverse	subjectOf

Element	Description
Comments	DEF: A hasParticipant relationship type that relates some activity to a physical object as subject of the activity. The subject is an actor participant. Inverse relationship of subjectOf.

hasTemporalPart

Element	Description
Type	ObjectProperty
Name	hasTemporalPart
IRI	http://ontology.asam.net/ontologies/Core#hasTemporalPart
Subproperty of	hasPart
Inverse	temporalPartOf
Comments	DEF: A hasPart relationship type where one spatio-temporal extent has another spatio-temporal extent as a temporal part. This implies that the temporal extent of the part is within the temporal extent of the whole. Inverse relationship of temporalPartOf.

inFrontOf

Element	Description
Type	ObjectProperty
Name	inFrontOf
IRI	http://ontology.asam.net/ontologies/Core#inFrontOf
Subproperty of	hasRelativePosition
Characteristic	Asymmetric
Comments	DEF: A hasRelativePosition relationship type where the first PhysicalObject is in front of the second PhysicalObject.

intendedRole

Element	Description
Type	ObjectProperty
Name	intendedRole
IRI	http://ontology.asam.net/ontologies/Core#intendedRole
Has domain	FunctionalObjectState

Element	Description
Has range	FunctionalObjectState
Comments	DEF: A relationship type where a FunctionalObject has one or more intended role(s).

involves

Element	Description
Type	ObjectProperty
Name	involves
IRI	http://ontology.asam.net/ontologies/Core#involves
Subproperty of	relationProperty
Has domain	DefinedRelationship
Has range	DefinedRelationship
Characteristic	Functional
Characteristic	Inverse Functional
Comments	DEF: A relationProperty that states that the classification of some thing in a role is involved in a relationship.

latitudinalConnectedTo

Element	Description
Type	ObjectProperty
Name	latitudinalConnectedTo
IRI	http://ontology.asam.net/ontologies/Core#latitudinalConnectedTo
Subproperty of	connectedTo
Comments	DEF: A connectedTo relationship type where the connection is in the latitudinal (East-West) direction with reference to the reference coordinate system.

leftConnectedTo

Element	Description
Type	ObjectProperty
Name	leftConnectedTo
IRI	http://ontology.asam.net/ontologies/Core#leftConnectedTo
Subproperty of	latitudinalConnectedTo

Element	Description
Comments	DEF: A latitudinalConnectedTo relationship type where two PhysicalObjects are connected and the first PhysicalObject is to the left of the second PhysicalObject.

leftOf

Element	Description
Type	ObjectProperty
Name	leftOf
IRI	http://ontology.asam.net/ontologies/Core#leftOf
Subproperty of	hasRelativePosition
Inverse	rightOf
Characteristic	Asymmetric
Comments	DEF: A hasRelativePosition relationship type where the first PhysicalObject is to the left of the second PhysicalObject.

locatedOn

Element	Description
Type	ObjectProperty
Name	locatedOn
IRI	http://ontology.asam.net/ontologies/Core#locatedOn
Has domain	PhysicalObjectState
Characteristic	Asymmetric
Comments	DEF: Object property version of RelativeLocation. Note that when using "locatedOn", it is not possible to describe the actual position of the located object on the location object (you need a RelativeLocation for that).

longitudinalConnectedTo

Element	Description
Type	ObjectProperty
Name	longitudinalConnectedTo
IRI	http://ontology.asam.net/ontologies/Core#longitudinalConnectedTo
Subproperty of	connectedTo

Element	Description
Comments	DEF: A connectedTo relationship type where the connection is in the longitudinal (North-South) direction with reference to the reference coordinate system.

memberOf

Element	Description
Type	ObjectProperty
Name	memberOf
IRI	http://ontology.asam.net/ontologies/Core#memberOf
Characteristic	Asymmetric
Comments	DEF: A relationship type stating that a thing is a member of some Set. A set can have anything of the respective type as a member, even other Sets.

objectOf

Element	Description
Type	ObjectProperty
Name	objectOf
IRI	http://ontology.asam.net/ontologies/Core#objectOf
Subproperty of	participantOf
Comments	DEF: A participantOf relationship type that relates some physical object as object to some activity. The object is a non-actor participant.

occursAfter

Element	Description
Type	ObjectProperty
Name	occursAfter
IRI	http://ontology.asam.net/ontologies/Core#occursAfter
Subproperty of	occursAtDifferentTime
Inverse	occursBefore
Comments	DEF: A hasRelativeTime relationship type specifying that the first event (marking the beginning or ending of some activity of physical object) occurs after the second event.

occursAtDifferentTime

Element	Description
Type	ObjectProperty
Name	occursAtDifferentTime
IRI	http://ontology.asam.net/ontologies/Core#occursAtDifferentTime
Subproperty of	hasRelativeTime
Characteristic	Asymmetric
Comments	DEF: A hasRelativeTime relationship type specifying that the first event (marking the beginning or ending of some activity of physical object) occurs at a different time from the second event.

occursAtSameTime

Element	Description
Type	ObjectProperty
Name	occursAtSameTime
IRI	http://ontology.asam.net/ontologies/Core#occursAtSameTime
Subproperty of	hasRelativeTime
Characteristic	Symmetric
Comments	DEF: A hasRelativeTime relationship type specifying that the first event (marking the beginning or ending of some activity of physical object) occurs at the same this as the second event. Note that when two events occur at the same time, the events are both parts of the same PointInTime

occursBefore

Element	Description
Type	ObjectProperty
Name	occursBefore
IRI	http://ontology.asam.net/ontologies/Core#occursBefore
Subproperty of	occursAtDifferentTime
Comments	DEF: A hasRelativeTime relationship type specifying that the first event (marking the beginning or ending of some activity of physical object) occurs before the second event

part

Element	Description
Type	ObjectProperty
Name	part
IRI	http://ontology.asam.net/ontologies/Core#part
Subproperty of	relationProperty
Has domain	Aggregation
Has range	Aggregation
Characteristic	Functional
Characteristic	Inverse Functional
Comments	DEF: A relationProperty that states that each Aggregation has exactly one spatioTemporalExtent that is the part in the Aggregation.

partOf

Element	Description
Type	ObjectProperty
Name	partOf
IRI	http://ontology.asam.net/ontologies/Core#partOf
Subproperty of	aggregatedInto
Comments	DEF: An aggregatedInto relationship type where a SpatioTemporalExtent may be part of another and the whole has emergent properties and is more than just the sum of its parts. This object property has the same meaning as the class Composition, but a different representation.

partOfPossibleWorld

Element	Description
Type	ObjectProperty
Name	partOfPossibleWorld
IRI	http://ontology.asam.net/ontologies/Core#partOfPossibleWorld
Subproperty of	partOf
Comments	DEF: A partOf relationship type where a SpatioTemporalExtent may be partOf one or more PossibleWorld.

participantOf

Element	Description
Type	ObjectProperty
Name	participantOf
IRI	http://ontology.asam.net/ontologies/Core#participantOf
Subproperty of	partOf
Has domain	Participant
Has range	Participant
Comments	DEF: A relationship stating the participation of a physical object in an activity.

quantityEqualTo

Element	Description
Type	ObjectProperty
Name	quantityEqualTo
IRI	http://ontology.asam.net/ontologies/Core#quantityEqualTo
Subproperty of	hasQuantityRelation
Has domain	PhysicalQuantity
Has range	PhysicalQuantity
Characteristic	Symmetric
Comments	DEF: A hasQuantityRelation relationship type, where the value for the second quantity is equal to the value of the first quantity.

quantityGreaterThan

Element	Description
Type	ObjectProperty
Name	quantityGreaterThan
IRI	http://ontology.asam.net/ontologies/Core#quantityGreaterThan
Subproperty of	hasQuantityRelation
Has domain	PhysicalQuantity
Has range	PhysicalQuantity
Inverse	quantityLessThanOrEqualTo
Characteristic	Transitive

Element	Description
Comments	DEF: A hasQuantityRelation relationship type, where the value for the second quantity is strictly greater than the value of the first quantity.

quantityGreaterThanOrEqualTo

Element	Description
Type	ObjectProperty
Name	quantityGreaterThanOrEqualTo
IRI	http://ontology.asam.net/ontologies/Core#quantityGreaterThanOrEqualTo
Subproperty of	hasQuantityRelation
Has domain	PhysicalQuantity
Has range	PhysicalQuantity
Inverse	quantityLessThan
Characteristic	Transitive
Comments	DEF: A hasQuantityRelation relationship type, where the value for the second quantity is greater than or equal to the value of the first quantity.

quantityLessThan

Element	Description
Type	ObjectProperty
Name	quantityLessThan
IRI	http://ontology.asam.net/ontologies/Core#quantityLessThan
Subproperty of	hasQuantityRelation
Has domain	PhysicalQuantity
Has range	PhysicalQuantity
Characteristic	Transitive
Comments	DEF: A hasQuantityRelation relationship type, where the value for the second quantity is strictly less than the value of the first quantity.

quantityLessThanOrEqualTo

Element	Description
Type	ObjectProperty
Name	quantityLessThanOrEqualTo

Element	Description
IRI	http://ontology.asam.net/ontologies/Core#quantityLessThanOrEqualTo
Subproperty of	hasQuantityRelation
Has domain	PhysicalQuantity
Has range	PhysicalQuantity
Characteristic	Transitive
Comments	DEF: A hasQuantityRelation relationship type, where the value for the second quantity is less than or equal to the value of the first quantity.

quantityNotEqualTo

Element	Description
Type	ObjectProperty
Name	quantityNotEqualTo
IRI	http://ontology.asam.net/ontologies/Core#quantityNotEqualTo
Subproperty of	hasQuantityRelation
Has domain	PhysicalQuantity
Has range	PhysicalQuantity
Characteristic	Symmetric
Comments	DEF: A hasQuantityRelation relationship type, where the value for the second quantity is not equal to the value of the first quantity.

relationProperty

Element	Description
Type	ObjectProperty
Name	relationProperty
IRI	http://ontology.asam.net/ontologies/Core#relationProperty
Has domain	Relationship
Comments	DEF: Relationship types that are generally used only to define other properties, for example, using SWRL.

rightConnectedTo

Element	Description
Type	ObjectProperty
Name	rightConnectedTo
IRI	http://ontology.asam.net/ontologies/Core#rightConnectedTo
Subproperty of	latitudinalConnectedTo
Comments	DEF: A latitudinalConnectedTo relationship type where two PhysicalObjects are connected and the first PhysicalObject is to the right of the second PhysicalObject.

rightOf

Element	Description
Type	ObjectProperty
Name	rightOf
IRI	http://ontology.asam.net/ontologies/Core#rightOf
Subproperty of	hasRelativePosition
Characteristic	Asymmetric
Comments	DEF: A hasRelativePosition relationship type where the first PhysicalObject is to the right of the second PhysicalObject.

rolePlayedBy

Element	Description
Type	ObjectProperty
Name	rolePlayedBy
IRI	http://ontology.asam.net/ontologies/Core#rolePlayedBy
Subproperty of	relationProperty
Has domain	Role
Has range	Role
Comments	DEF: A relationProperty that states that a Role is the role of some Participant.

roleUsedIn

Element	Description
Type	ObjectProperty
Name	roleUsedIn

Element	Description
IRI	http://ontology.asam.net/ontologies/Core#roleUsedIn
Subproperty of	relationProperty
Has domain	Role
Has range	Role
Comments	DEF: A relationProperty that states that a Role is used in an Activity.

subjectOf

Element	Description
Type	ObjectProperty
Name	subjectOf
IRI	http://ontology.asam.net/ontologies/Core#subjectOf
Subproperty of	participantOf
Comments	DEF: A participantOf relationship type that relates some physical object as subject to some activity. The subject is an actor participant.

temporalPartOf

Element	Description
Type	ObjectProperty
Name	temporalPartOf
IRI	http://ontology.asam.net/ontologies/Core#temporalPartOf
Subproperty of	partOf
Comments	DEF: A partOf relationship type where a SpatioTemporalExtent may be a temporal part of one or more other SpatioTemporalExtent. This object property has the same meaning as the class TemporalComposition, but a different representation.

whole

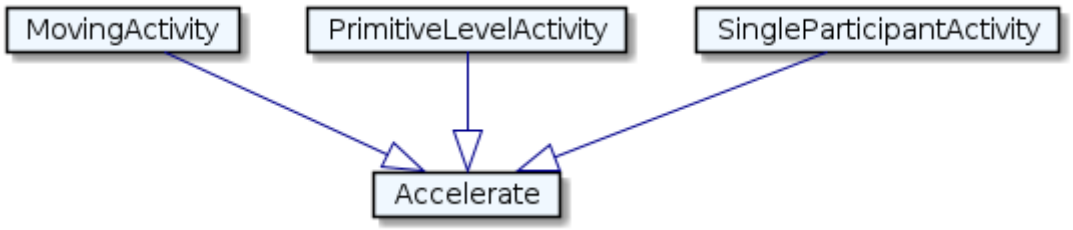
Element	Description
Type	ObjectProperty
Name	whole
IRI	http://ontology.asam.net/ontologies/Core#whole

Element	Description
Subproperty of	relationProperty
Has domain	Aggregation
Has range	Aggregation
Characteristic	Functional
Characteristic	Inverse Functional
Comments	DEF: A relationProperty that states that each Aggregation has exactly one spatioTemporalExtent that is the whole in the Aggregation.

A.2. Domain

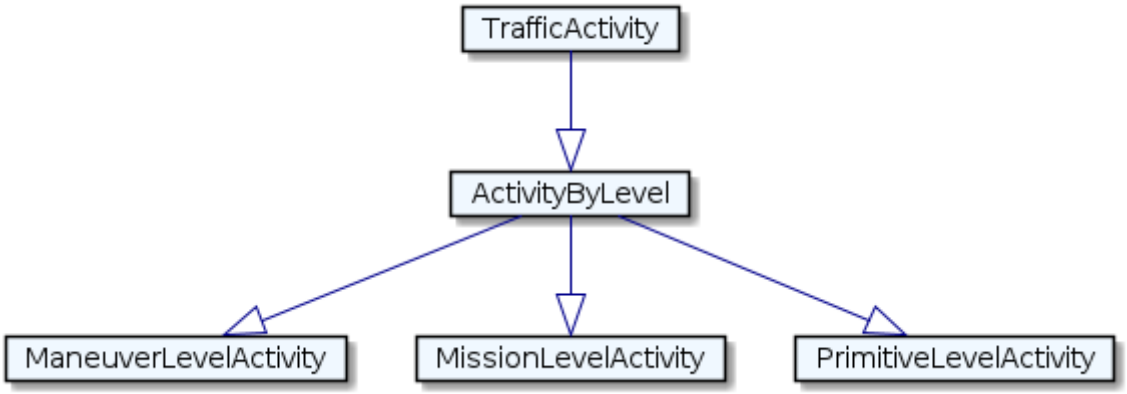
A.2.1. Classes

Accelerate



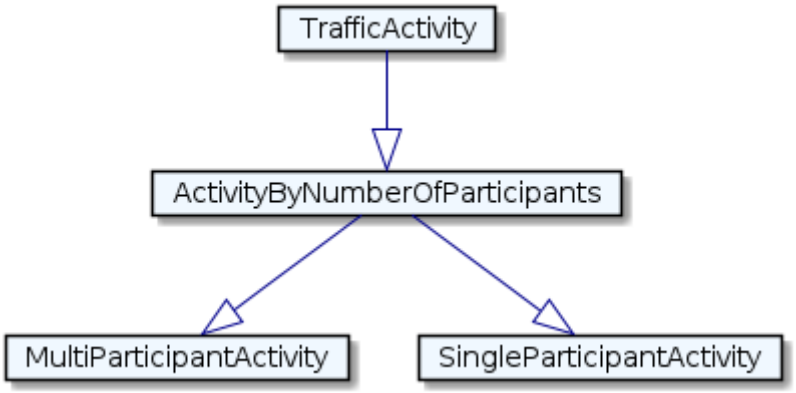
Element	Description
Type	Class
Name	Accelerate
IRI	http://ontology.asam.net/ontologies/Domain#Accelerate
Subclass of	MovingActivity
Subclass of	PrimitiveLevelActivity
Subclass of	SingleParticipantActivity
Comments	DEF: A MovingActivity with one traffic participant during which the speed of the traffic participant increases continuously.

ActivityByLevel



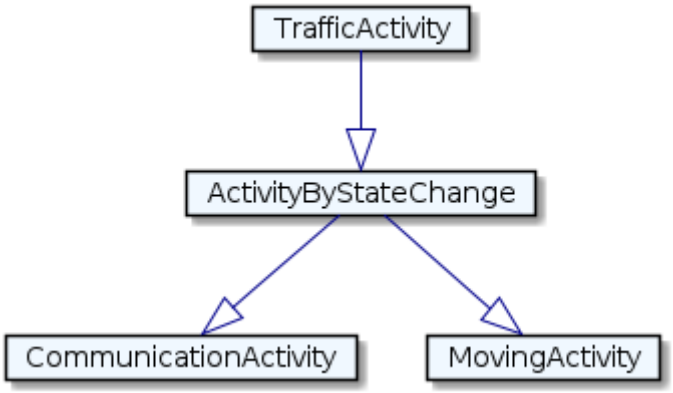
Element	Description
Type	Class
Name	ActivityByLevel
IRI	http://ontology.asam.net/ontologies/Domain#ActivityByLevel
Subclass of	TrafficActivity
Comments	DEF: A set of activities categorized according to the complexity of the action ranging from primitive to mission level.

ActivityByNumberOfParticipants



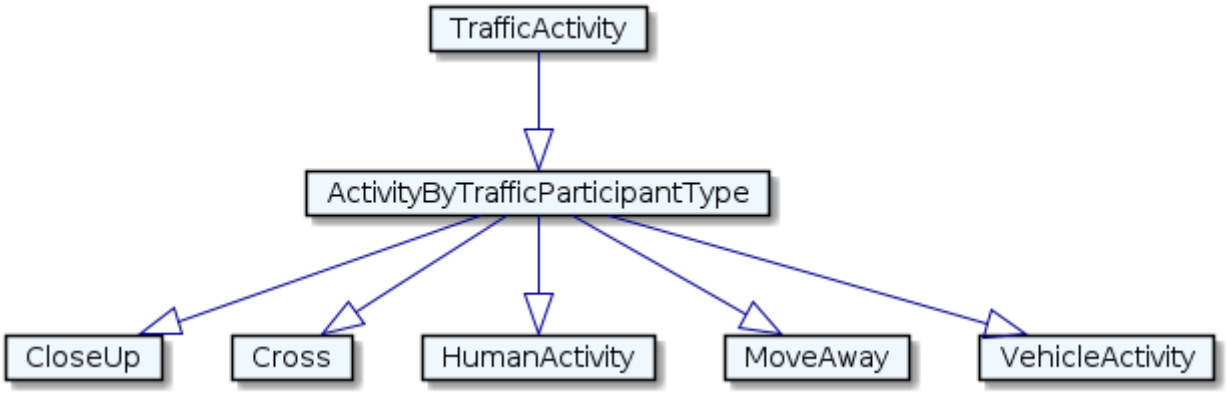
Element	Description
Type	Class
Name	ActivityByNumberOfParticipants
IRI	http://ontology.asam.net/ontologies/Domain#ActivityByNumberOfParticipants
Subclass of	TrafficActivity
Comments	DEF: A set of activities categorized according to the number of traffic participants involved.

ActivityByStateChange



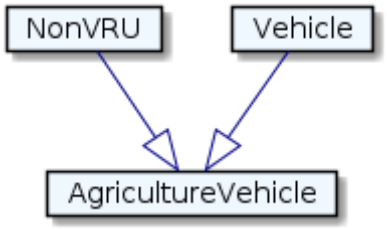
Element	Description
Type	Class
Name	ActivityByStateChange
IRI	http://ontology.asam.net/ontologies/Domain#ActivityByStateChange
Subclass of	TrafficActivity
Comments	DEF: A set of activities characterized by the participants moving or communicating.

ActivityByTrafficParticipantType



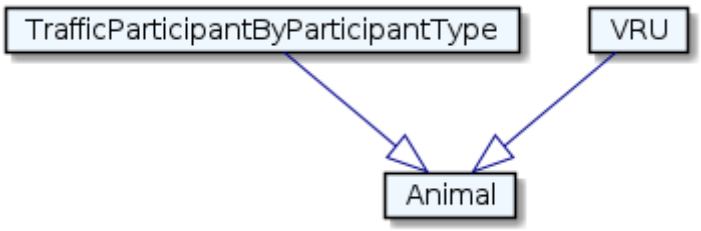
Element	Description
Type	Class
Name	ActivityByTrafficParticipantType
IRI	http://ontology.asam.net/ontologies/Domain#ActivityByTrafficParticipantType
Subclass of	TrafficActivity
Comments	DEF: A set of activities categorized according to the type of traffic participants.

AgricultureVehicle



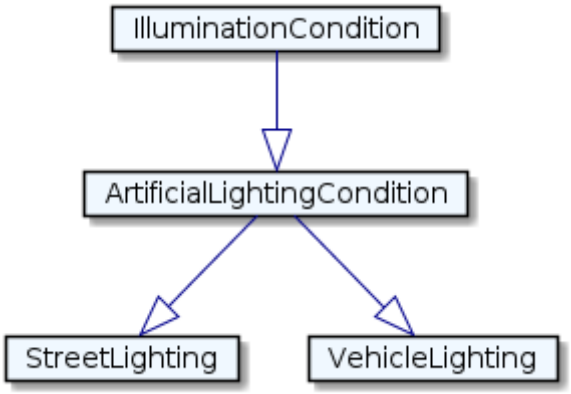
Element	Description
Type	Class
Name	AgricultureVehicle
IRI	http://ontology.asam.net/ontologies/Domain#AgricultureVehicle
Subclass of	NonVRU
Subclass of	Vehicle
Comments	DEF: A vehicle that is specifically constructed for and used in farming.

Animal



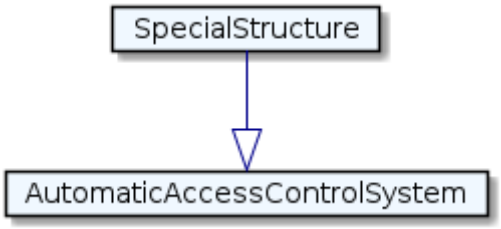
Element	Description
Type	Class
Name	Animal
IRI	http://ontology.asam.net/ontologies/Domain#Animal
Subclass of	TrafficParticipantByParticipantType
Subclass of	VRU
Comments	DEF: A TrafficParticipant that is a non-human biological object.

ArtificialLightingCondition



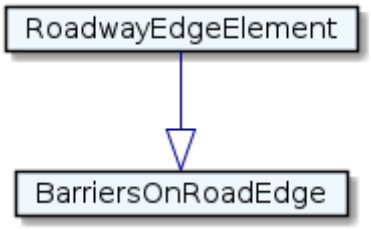
Element	Description
Type	Class
Name	ArtificialLightingCondition
IRI	http://ontology.asam.net/ontologies/Domain#ArtificialLightingCondition
Subclass of	IlluminationCondition
Comments	DEF: An IlluminationCondition characterized by non-natural light from manufactured light sources, such as candles and electric lamps.

AutomaticAccessControlSystem



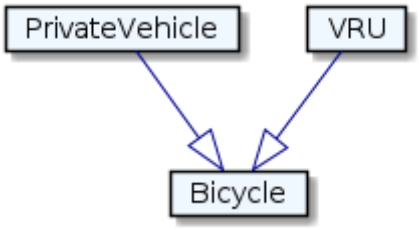
Element	Description
Type	Class
Name	AutomaticAccessControlSystem
IRI	http://ontology.asam.net/ontologies/Domain#AutomaticAccessControlSystem
Subclass of	SpecialStructure
Comments	DEF: A SpecialStructure that provides detection and audit to limit who can go where. They can be combined with assured physical barriers to provide delay into a secure site or can be used with demarcation barriers, meaning half-height gates, to provide only detection

BarriersOnRoadEdge



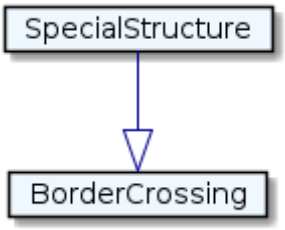
Element	Description
Type	Class
Name	BarriersOnRoadEdge
IRI	http://ontology.asam.net/ontologies/Domain#BarriersOnRoadEdge
Subclass of	RoadwayEdgeElement
Comments	DEF: A RoadwayEdgeElement that forms a barrier along the edge of the road.

Bicycle



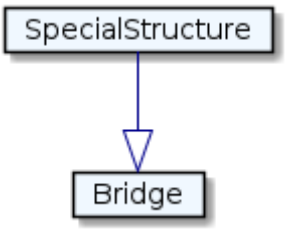
Element	Description
Type	Class
Name	Bicycle
IRI	http://ontology.asam.net/ontologies/Domain#Bicycle
Subclass of	PrivateVehicle
Subclass of	VRU
Comments	DEF: A human-powered or motor-powered, pedal-driven, single-track Vehicle that has two wheels attached to a frame, one behind the other.

BorderCrossing



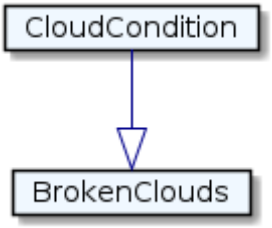
Element	Description
Type	Class
Name	BorderCrossing
IRI	http://ontology.asam.net/ontologies/Domain#BorderCrossing
Subclass of	SpecialStructure
Comments	DEF: A SpecialStructure that is located at the border between states and that supports monitoring and regulating the movement of people, animals, and goods across the border.

Bridge



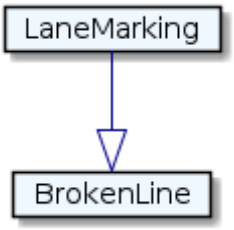
Element	Description
Type	Class
Name	Bridge
IRI	http://ontology.asam.net/ontologies/Domain#Bridge
Subclass of	SpecialStructure
Comments	DEF: A SpecialStructure built to span a physical obstacle, such as a river, a valley or a road, withouth blocking the way underneath. A bridge provides passage over the obstacle.

BrokenClouds



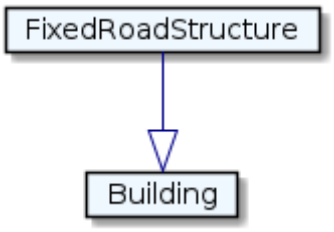
Element	Description
Type	Class
Name	BrokenClouds
IRI	http://ontology.asam.net/ontologies/Domain#BrokenClouds
Subclass of	CloudCondition
Comments	DEF: BrokenClouds is a CloudCondition, is it described by the cloudinessLevel property using oktas unit, BrokenClouds is when the cloudinessLevel is 5-7 oktas.

BrokenLine



Element	Description
Type	Class
Name	BrokenLine
IRI	http://ontology.asam.net/ontologies/Domain#BrokenLine
Subclass of	LaneMarking
Comments	DEF: BrokenLine is a LaneMarking that is used to mark the middle of a two lane highway to separate traffic on both directions. Drivers are supposed to keep left but can cross the broken line for overtaking if situations permit

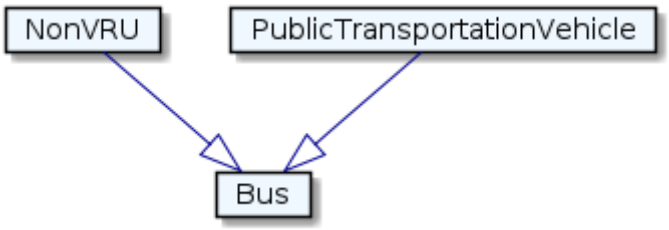
Building



Element	Description
Type	Class
Name	Building

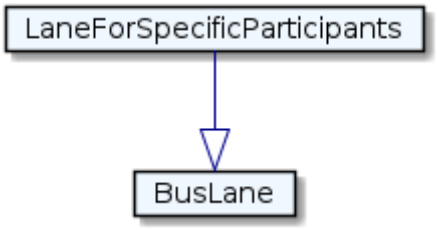
Element	Description
IRI	http://ontology.asam.net/ontologies/Domain#Building
Subclass of	FixedRoadStructure
Comments	DEF: A FixedRoadStructure that is a built physical structure with a roof and walls standing more or less permanently in one place.

Bus



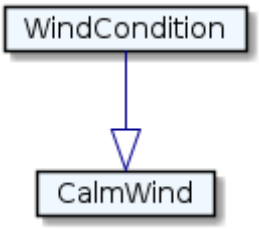
Element	Description
Type	Class
Name	Bus
IRI	http://ontology.asam.net/ontologies/Domain#Bus
Subclass of	NonVRU
Subclass of	PublicTransportationVehicle
Comments	DEF: A vehicle that is designed to carry many passengers and that usually travels along a fixed route according to a schedule.

BusLane



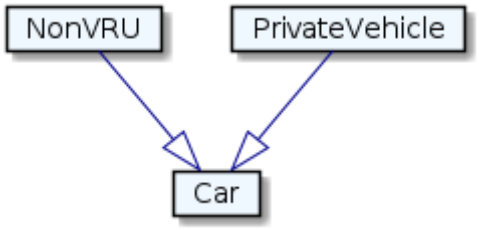
Element	Description
Type	Class
Name	BusLane
IRI	http://ontology.asam.net/ontologies/Domain#BusLane
Subclass of	LaneForSpecificParticipants
Comments	DEF: BusLane is a LaneForSpecificParticipants that is a lane where only buses are allowed to drive

CalmWind



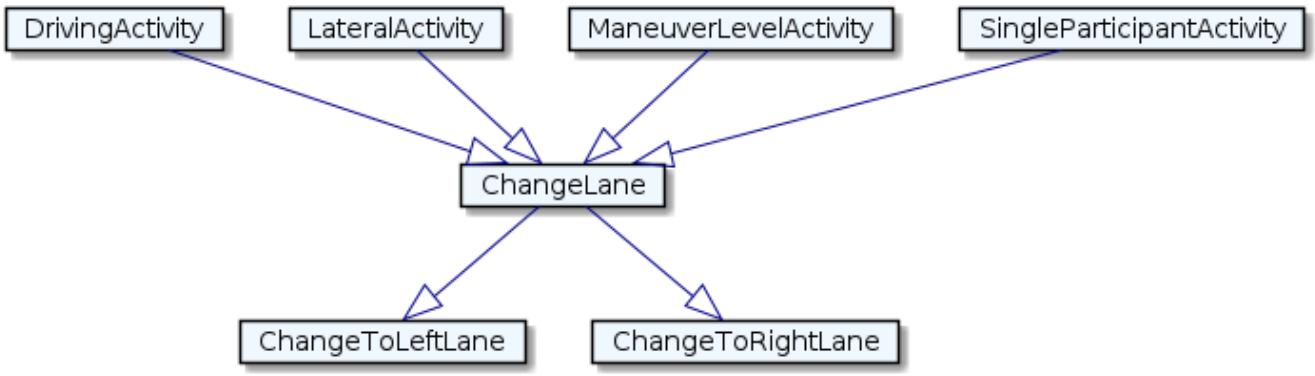
Element	Description
Type	Class
Name	CalmWind
IRI	http://ontology.asam.net/ontologies/Domain#CalmWind
Subclass of	WindCondition
Comments	DEF: CalmWind is a WindCondition, is it described by the WindSpeed property using m/s, CalmWind is when the WindSpeed is 0 - 0.2 m/s.

Car



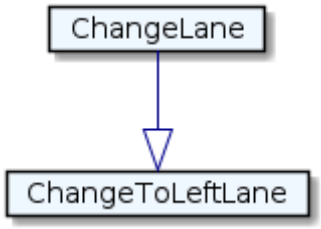
Element	Description
Type	Class
Name	Car
IRI	http://ontology.asam.net/ontologies/Domain#Car
Subclass of	NonVRU
Subclass of	PrivateVehicle
Comments	DEF: A Vehicle that is an automobile. It is a motor-powered vehicle used for transporting a small number of people.

ChangeLane



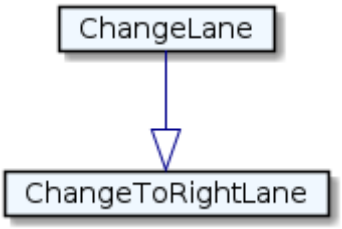
Element	Description
Type	Class
Name	ChangeLane
IRI	http://ontology.asam.net/ontologies/Domain#ChangeLane
Subclass of	DrivingActivity
Subclass of	LateralActivity
Subclass of	ManeuverLevelActivity
Subclass of	SingleParticipantActivity
Comments	DEF: An activity in which the subject vehicle starts from one lane at the beginning of the activity and drives in a different lane at the end of the activity.

ChangeToLeftLane



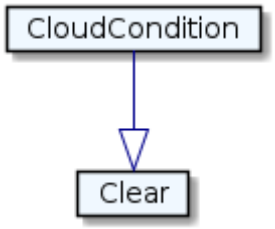
Element	Description
Type	Class
Name	ChangeToLeftLane
IRI	http://ontology.asam.net/ontologies/Domain#ChangeToLeftLane
Subclass of	ChangeLane
Comments	DEF: A ChangeLane activity where the vehicle drives in one lane at the beginning of the activity and drives in the lane left to the original lane at the end of the activity.

ChangeToRightLane



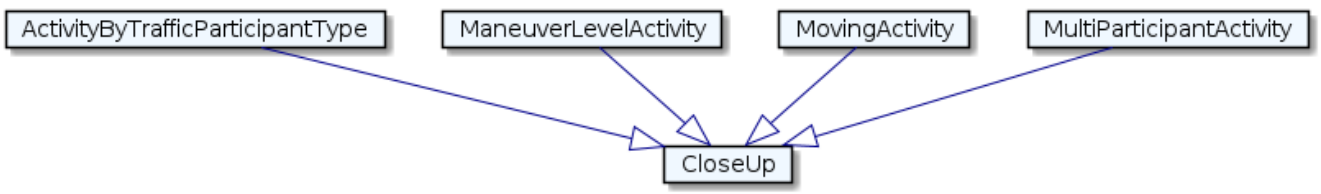
Element	Description
Type	Class
Name	ChangeToRightLane
IRI	http://ontology.asam.net/ontologies/Domain#ChangeToRightLane
Subclass of	ChangeLane
Comments	DEF: A ChangeLane activity where the vehicle drives in one lane at the beginning of the activity and drives in the lane right to the original lane at the end of the activity.

Clear



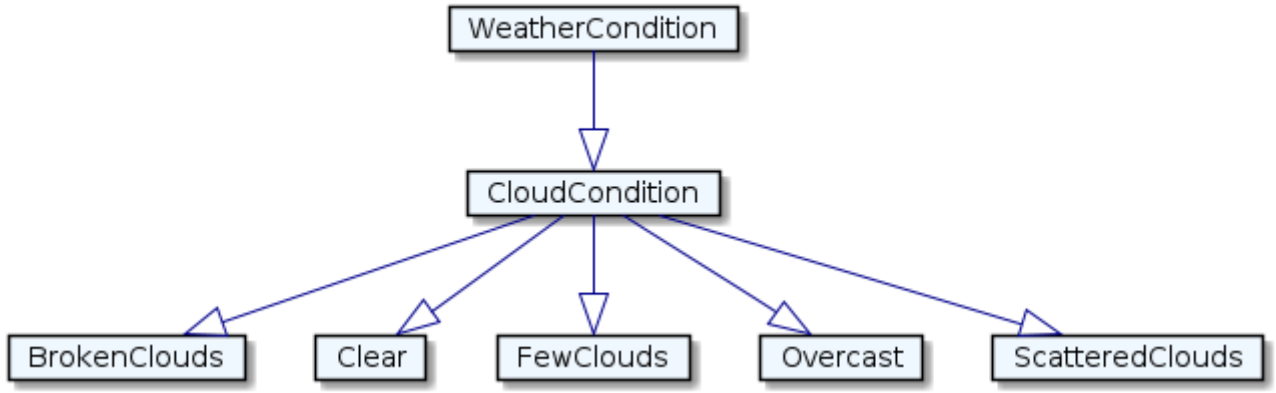
Element	Description
Type	Class
Name	Clear
IRI	http://ontology.asam.net/ontologies/Domain#Clear
Subclass of	CloudCondition
Comments	DEF: Clear is a CloudCondition, is it described by the cloudinessLevel property using oktas unit, Clear is when the cloudinessLevel is 0-1 oktas.

CloseUp



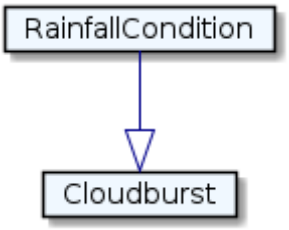
Element	Description
Type	Class
Name	CloseUp
IRI	http://ontology.asam.net/ontologies/Domain#CloseUp
Subclass of	ActivityByTrafficParticipantType
Subclass of	ManeuverLevelActivity
Subclass of	MovingActivity
Subclass of	MultiParticipantActivity
Comments	DEF: A MovingActivity during which the subject traffic participant moves closer to the object traffic participant.

CloudCondition



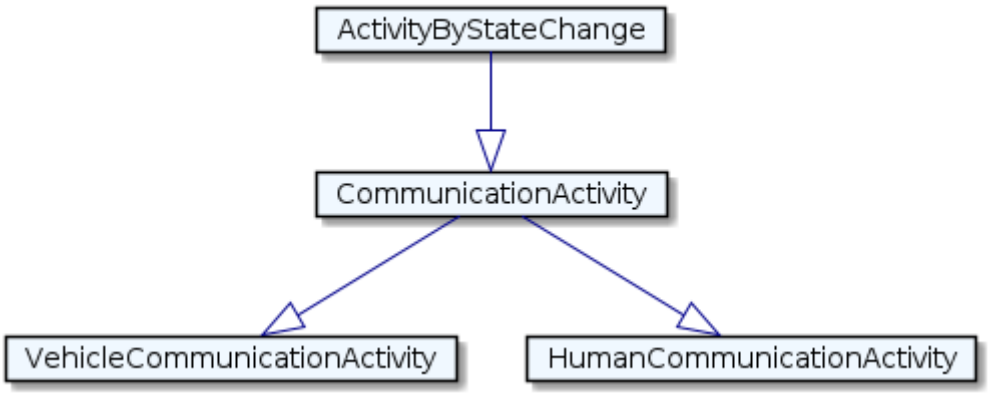
Element	Description
Type	Class
Name	CloudCondition
IRI	http://ontology.asam.net/ontologies/Domain#CloudCondition
Subclass of	WeatherCondition
Comments	DEF: A WeatherCondition in which a specific amount of the sky is covered by clouds, which affects the illumination of things. This condition can occur during day and night. The amount of sky covered in clouds may be described with the cloudinessLevel property.

Cloudburst



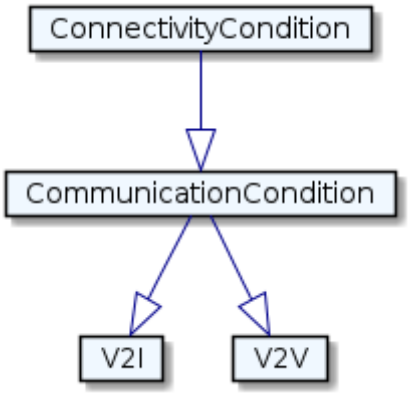
Element	Description
Type	Class
Name	Cloudburst
IRI	http://ontology.asam.net/ontologies/Domain#Cloudburst
Subclass of	RainfallCondition
Comments	DEF: Cloudburst is a RainfallCondition, is it described by the precipitationIntensity property using mm/hr, Cloudburst is when the precipitationIntensity is > 100mm/hr.

CommunicationActivity



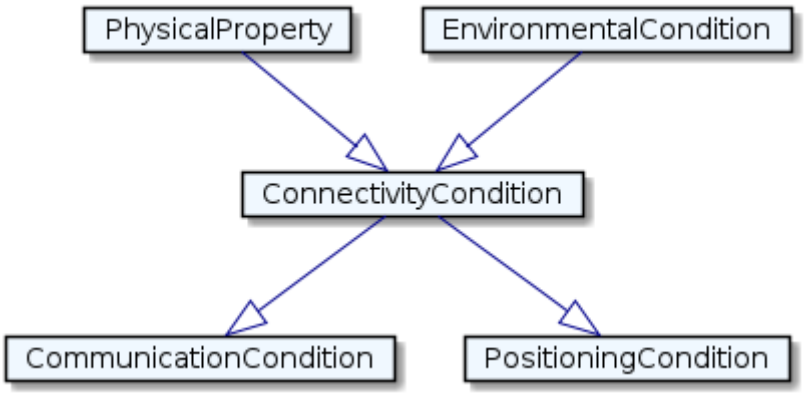
Element	Description
Type	Class
Name	CommunicationActivity
IRI	http://ontology.asam.net/ontologies/Domain#CommunicationActivity
Subclass of	ActivityByStateChange
Comments	DEF: A set of activites that are characterized by the subject traffic participant giving visual or acoustic signals in order to relay its intentions to other traffic participants.

CommunicationCondition



Element	Description
Type	Class
Name	CommunicationCondition
IRI	http://ontology.asam.net/ontologies/Domain#CommunicationCondition
Subclass of	ConnectivityCondition
Comments	DEF: A ConnectivityCondition that defines the type of communication method used for the communication between vehicle and other elements of the traffic domain, such as infrastructure (V2I) or other vehicles (V2V).

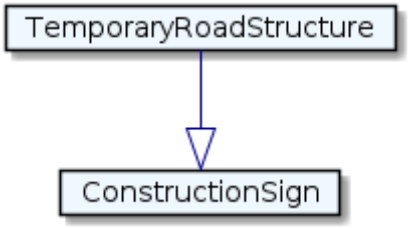
ConnectivityCondition



Element	Description
Type	Class
Name	ConnectivityCondition
IRI	http://ontology.asam.net/ontologies/Domain#ConnectivityCondition
Subclass of	PhysicalProperty
Subclass of	EnvironmentalCondition

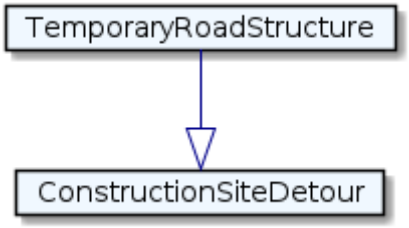
Element	Description
Comments	DEF: An EnvironmentalCondition that indicates a vehicle's ability to receive data from or transmit data to external systems. The purpose of the data transfer can be positioning of the vehicle or communication with other elements of the traffic domain.

ConstructionSign



Element	Description
Type	Class
Name	ConstructionSign
IRI	http://ontology.asam.net/ontologies/Domain#ConstructionSign
Subclass of	TemporaryRoadStructure
Comments	DEF: A TemporaryRoadStructure that is a traffic sign indicating construction or landscaping work in a specific area.

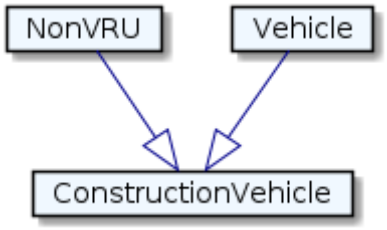
ConstructionSiteDetour



Element	Description
Type	Class
Name	ConstructionSiteDetour
IRI	http://ontology.asam.net/ontologies/Domain#ConstructionSiteDetour
Subclass of	TemporaryRoadStructure

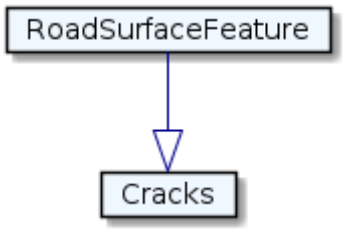
Element	Description
Comments	DEF: A TemporaryRoadStructure that provides a detour or temporary route around an area that needs to be avoided, for example, due to construction work.

ConstructionVehicle



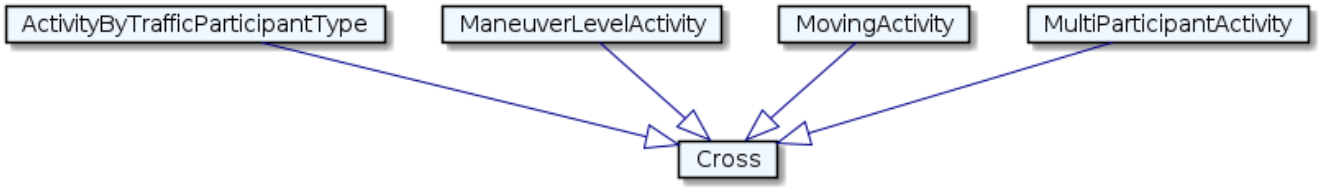
Element	Description
Type	Class
Name	ConstructionVehicle
IRI	http://ontology.asam.net/ontologies/Domain#ConstructionVehicle
Subclass of	NonVRU
Subclass of	Vehicle
Comments	DEF: A vehicle that is specifically built for and used in construction work.

Cracks



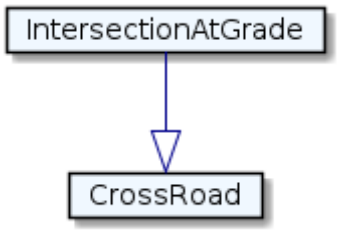
Element	Description
Type	Class
Name	Cracks
IRI	http://ontology.asam.net/ontologies/Domain#Cracks
Subclass of	RoadSurfaceFeature
Comments	DEF:Cracks is a RoadSurfaceFeature that are fractures or discontinuation of the road surface.

Cross



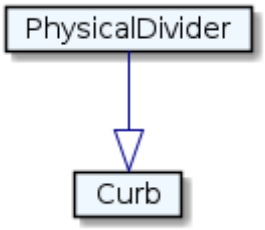
Element	Description
Type	Class
Name	Cross
IRI	http://ontology.asam.net/ontologies/Domain#Cross
Subclass of	ActivityByTrafficParticipantType
Subclass of	ManeuverLevelActivity
Subclass of	MovingActivity
Subclass of	MultiParticipantActivity
Comments	DEF: A MovingActivity during which the path of the subject traffic participant crosses the path of the object traffic participant.

CrossRoad



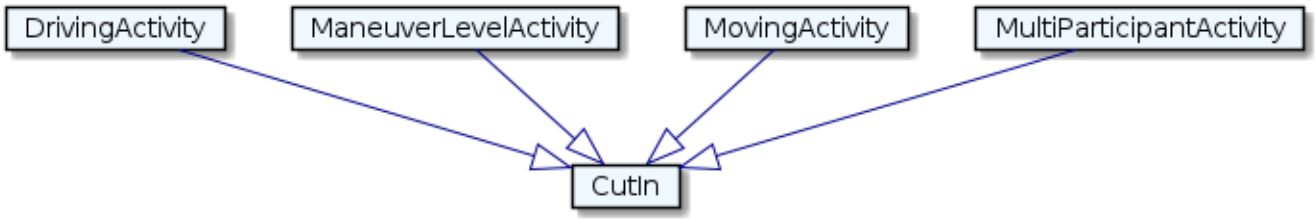
Element	Description
Type	Class
Name	CrossRoad
IRI	http://ontology.asam.net/ontologies/Domain#CrossRoad
Subclass of	IntersectionAtGrade
Comments	DEF: An Intersection where exactly four roads meet.

Curb



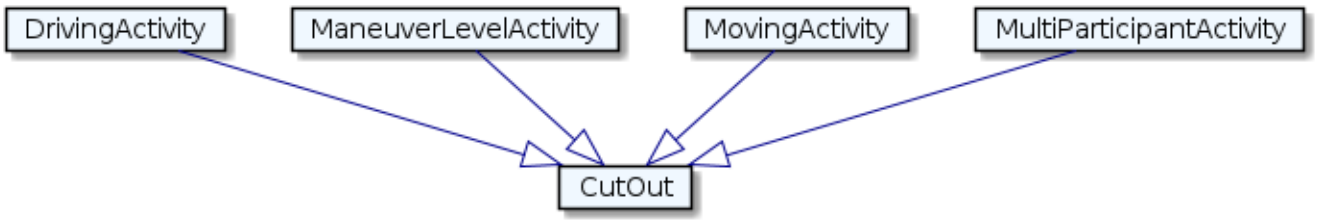
Element	Description
Type	Class
Name	Curb
IRI	http://ontology.asam.net/ontologies/Domain#Curb
Subclass of	PhysicalDivider
Comments	DEF: Curb is a PhysicalDivider that is the edge where a raised sidewalk or road median/central reservation meets a street or other roadway.

CutIn



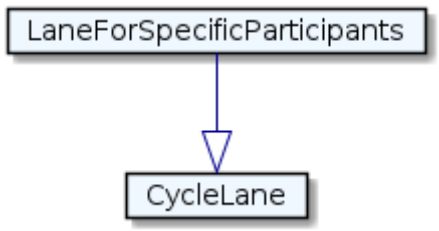
Element	Description
Type	Class
Name	CutIn
IRI	http://ontology.asam.net/ontologies/Domain#CutIn
Subclass of	DrivingActivity
Subclass of	ManeuverLevelActivity
Subclass of	MovingActivity
Subclass of	MultiParticipantActivity
Comments	DEF: A MovingActivity in which the subject traffic participant ends up directly in front of the object traffic participant. A cutting-in activity can affect the behavior of the object.

CutOut



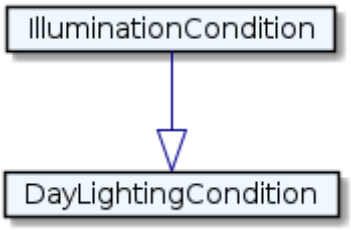
Element	Description
Type	Class
Name	CutOut
IRI	http://ontology.asam.net/ontologies/Domain#CutOut
Subclass of	DrivingActivity
Subclass of	ManeuverLevelActivity
Subclass of	MovingActivity
Subclass of	MultiParticipantActivity
Comments	DEF: A MovingActivity where the subject and the object traffic participants start in the same lane. During the activity, the object traffic participant suddenly leaves the lane.

CycleLane



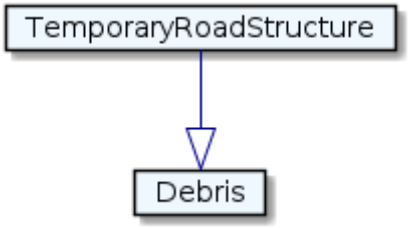
Element	Description
Type	Class
Name	CycleLane
IRI	http://ontology.asam.net/ontologies/Domain#CycleLane
Subclass of	LaneForSpecificParticipants
Comments	DEF: CycleLane is a LaneForSpecificParticipants that is paved and intended for bicycle use only. Contains only regions or ground specifically designated for cyclists where pedestrians and cars should not enter.

DayLightingCondition



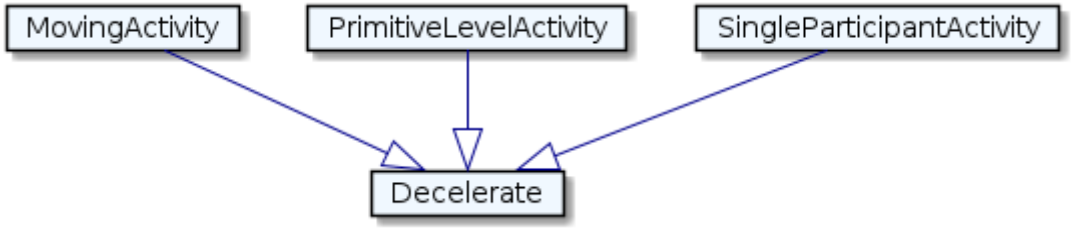
Element	Description
Type	Class
Name	DayLightingCondition
IRI	http://ontology.asam.net/ontologies/Domain#DayLightingCondition
Subclass of	IlluminationCondition
Comments	DEF: An IlluminationCondition where illuminance is greater than 2000 lux.

Debris



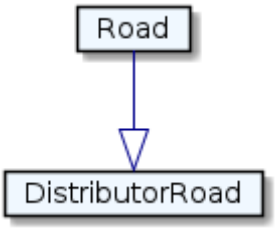
Element	Description
Type	Class
Name	Debris
IRI	http://ontology.asam.net/ontologies/Domain#Debris
Subclass of	TemporaryRoadStructure
Comments	DEF: A TemporaryRoadStructure that consists of scattered pieces of rock, rubbish or other loose material on the road surface; placed not by intention, but by accident or construction work.

Decelerate



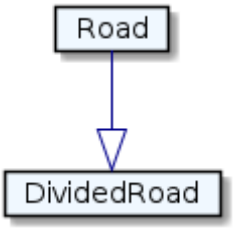
Element	Description
Type	Class
Name	Decelerate
IRI	http://ontology.asam.net/ontologies/Domain#Decelerate
Subclass of	MovingActivity
Subclass of	PrimitiveLevelActivity
Subclass of	SingleParticipantActivity
Comments	DEF: A MovingActivity with one traffic participant during which the speed of the traffic participant decreases continuously.

DistributorRoad



Element	Description
Type	Class
Name	DistributorRoad
IRI	http://ontology.asam.net/ontologies/Domain#DistributorRoad
Subclass of	Road
Comments	DEF: A Road with low to moderate capacity that connects local and minor roads to arterial roads.

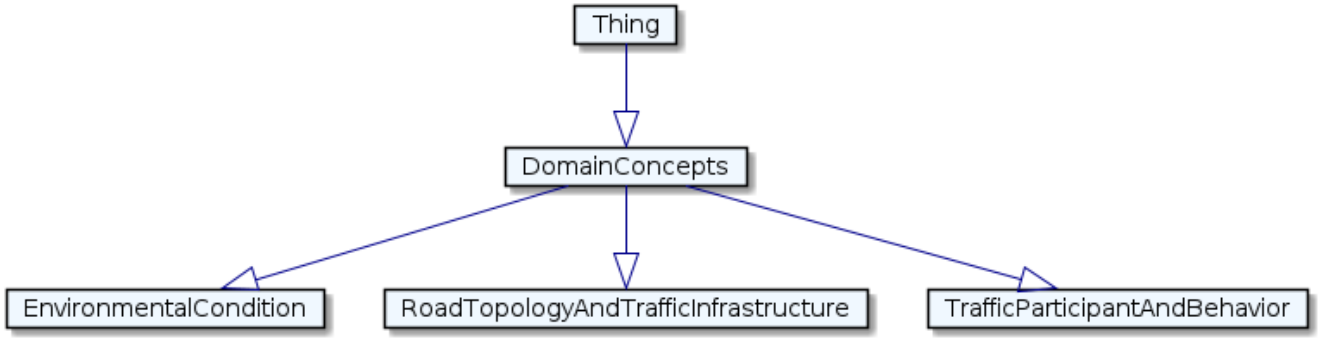
DividedRoad



Element	Description
Type	Class
Name	DividedRoad

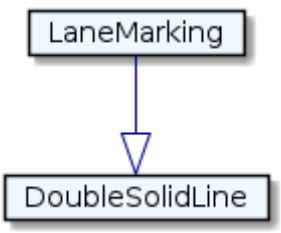
Element	Description
IRI	http://ontology.asam.net/ontologies/Domain#DividedRoad
Subclass of	Road
Comments	DEF: A type of road that has several carriageways for traffic travelling in opposite directions. The carriageways are separated by a central reservation.

DomainConcepts



Element	Description
Type	Class
Name	DomainConcepts
IRI	http://ontology.asam.net/ontologies/Domain#DomainConcepts
Subclass of	Thing
Comments	DEF: Top-level container that separates domain concepts in the OpenXOntology. The DomainConcepts define central concepts of the road traffic domain, for example, lane, road, and vehicle. It contains only concepts that are shared by multiple ASAM OpenX standards using the ASAM OpenXOntology and that are not controlled by a single standard.

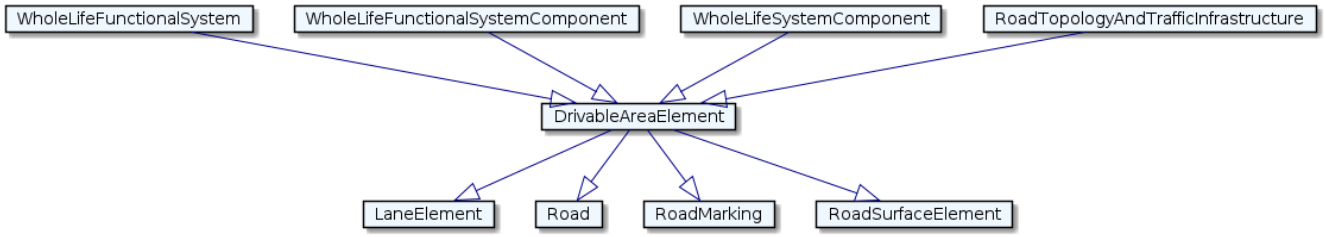
DoubleSolidLine



Element	Description
Type	Class

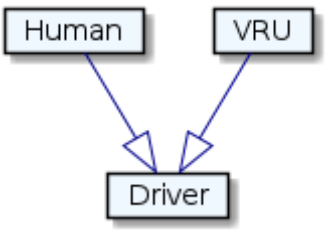
Element	Description
Name	DoubleSolidLine
IRI	http://ontology.asam.net/ontologies/Domain#DoubleSolidLine
Subclass of	LaneMarking
Comments	DEF: DoubleSolidLine is a LaneMarking that separates two lanes.

DrivableAreaElement



Element	Description
Type	Class
Name	DrivableAreaElement
IRI	http://ontology.asam.net/ontologies/Domain#DrivableAreaElement
Subclass of	WholeLifeFunctionalSystem
Subclass of	WholeLifeFunctionalSystemComponent
Subclass of	WholeLifeSystemComponent
Subclass of	RoadTopologyAndTrafficInfrastructure
Comments	DEF: Areas in the traffic infrastructure that vehicles are supposed and permitted to drive in.

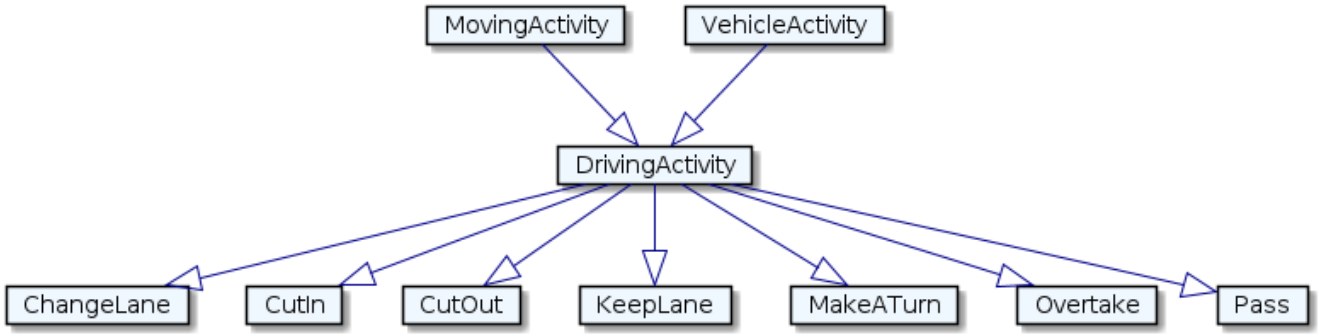
Driver



Element	Description
Type	Class
Name	Driver
IRI	http://ontology.asam.net/ontologies/Domain#Driver

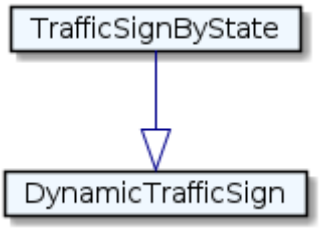
Element	Description
Subclass of	Human
Subclass of	VRU
Comments	DEF: A HumanParticipant who controls a vehicle.

DrivingActivity



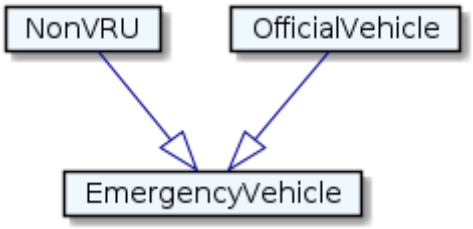
Element	Description
Type	Class
Name	DrivingActivity
IRI	http://ontology.asam.net/ontologies/Domain#DrivingActivity
Subclass of	MovingActivity
Subclass of	VehicleActivity
Comments	DEF: A set of moving activites that are characterized by a continuous movement of the traffic participants during the complete activity.

DynamicTrafficSign



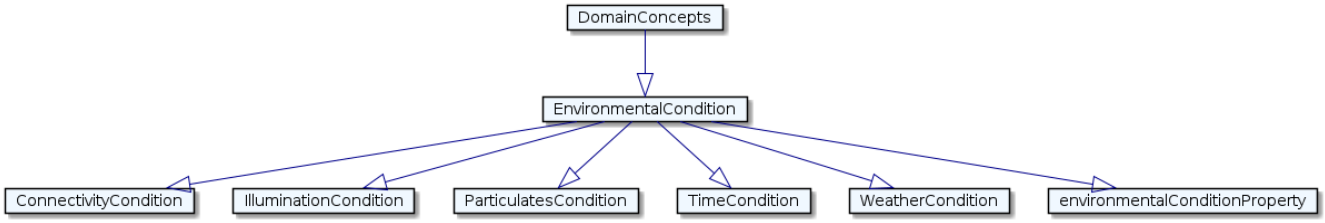
Element	Description
Type	Class
Name	DynamicTrafficSign
IRI	http://ontology.asam.net/ontologies/Domain#DynamicTrafficSign
Subclass of	TrafficSignByState
Comments	DEF: A traffic sign whose content can be changed.

EmergencyVehicle



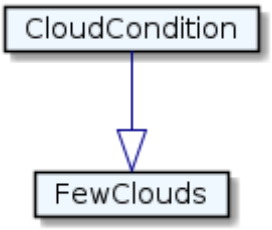
Element	Description
Type	Class
Name	EmergencyVehicle
IRI	http://ontology.asam.net/ontologies/Domain#EmergencyVehicle
Subclass of	NonVRU
Subclass of	OfficialVehicle
Comments	DEF: A vehicle that is used by an emergency service to respond to incidents.

EnvironmentalCondition



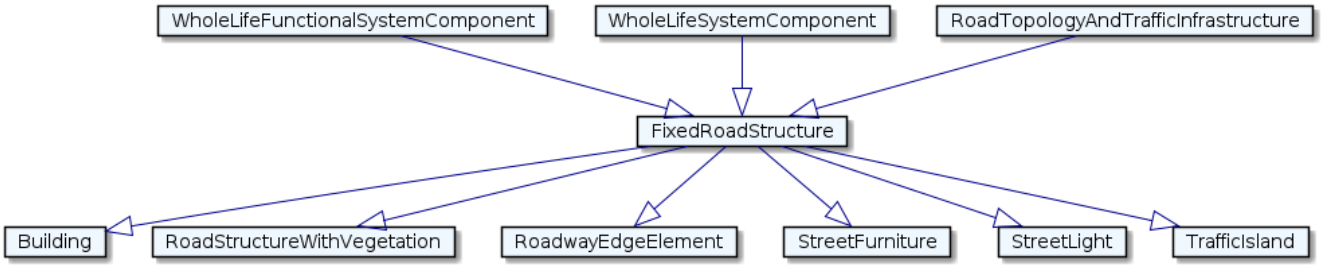
Element	Description
Type	Class
Name	EnvironmentalCondition
IRI	http://ontology.asam.net/ontologies/Domain#EnvironmentalCondition
Subclass of	DomainConcepts
Comments	DEF: A set of environmental parameters that applies to a complete area, such as a town or a district. Conditions can have natural causes, for example rain or snowfall, or can be created artificially, for example by light sources or communication devices using specific methods like vehice-to-vehicle communication.

FewClouds



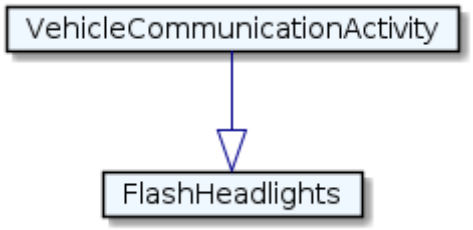
Element	Description
Type	Class
Name	FewClouds
IRI	http://ontology.asam.net/ontologies/Domain#FewClouds
Subclass of	CloudCondition
Comments	DEF: FewClouds is a CloudCondition, is it described by the cloudinessLevel property using oktas unit, FewClouds is when the cloudinessLevel is 1-2 oktas.

FixedRoadStructure



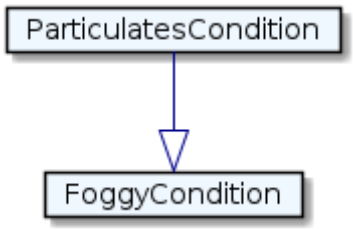
Element	Description
Type	Class
Name	FixedRoadStructure
IRI	http://ontology.asam.net/ontologies/Domain#FixedRoadStructure
Subclass of	WholeLifeFunctionalSystemComponent
Subclass of	WholeLifeSystemComponent
Subclass of	RoadTopologyAndTrafficInfrastructure
Comments	DEF: An element of the traffic infrastructure with a physical form that is either built or natural and is located near to or on a drivable area. Vehicles are not allowed to drive on a FixedRoadStructure.

FlashHeadlights



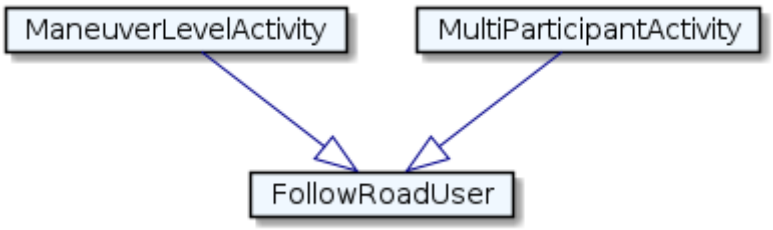
Element	Description
Type	Class
Name	FlashHeadlights
IRI	http://ontology.asam.net/ontologies/Domain#FlashHeadlights
Subclass of	VehicleCommunicationActivity
Comments	DEF: A VehicleCommunicatingActivity in which the subject vehicle communicates a potential warning to the object vehicle by either briefly switching on the headlights or switching between low beams and high beams.

FoggyCondition



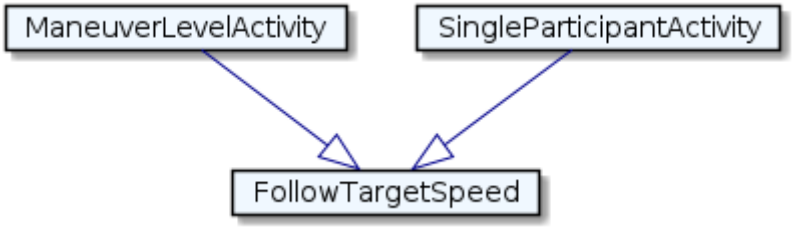
Element	Description
Type	Class
Name	FoggyCondition
IRI	http://ontology.asam.net/ontologies/Domain#FoggyCondition
Subclass of	ParticulatesCondition
Comments	DEF: A ParticulateCondition where the particles are a mixture of non-precipitating water droplets or ice crystals.

FollowRoadUser



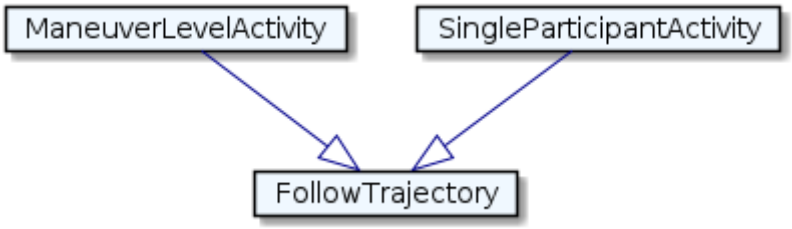
Element	Description
Type	Class
Name	FollowRoadUser
IRI	http://ontology.asam.net/ontologies/Domain#FollowRoadUser
Subclass of	ManeuverLevelActivity
Subclass of	MultiParticipantActivity
Comments	DEF: An activity in which the subject traffic participant drives behind the object traffic participant at the same speed.

FollowTargetSpeed



Element	Description
Type	Class
Name	FollowTargetSpeed
IRI	http://ontology.asam.net/ontologies/Domain#FollowTargetSpeed
Subclass of	ManeuverLevelActivity
Subclass of	SingleParticipantActivity
Comments	DEF: An activity in which the subject traffic participant drives at a fixed, configured speed.

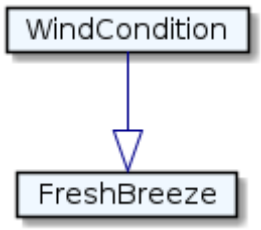
FollowTrajectory



Element	Description
Type	Class
Name	FollowTrajectory

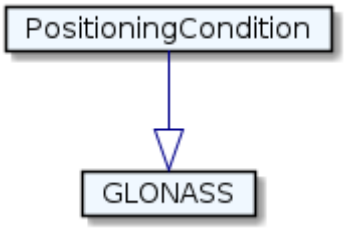
Element	Description
IRI	http://ontology.asam.net/ontologies/Domain#FollowTrajectory
Subclass of	ManeuverLevelActivity
Subclass of	SingleParticipantActivity
Comments	DEF: An activity in which the subject traffic participant follows a defined driving path for a specific period of time.

FreshBreeze



Element	Description
Type	Class
Name	FreshBreeze
IRI	http://ontology.asam.net/ontologies/Domain#FreshBreeze
Subclass of	WindCondition
Comments	DEF: FreshBreeze is a WindCondition, is it described by the WindSpeed property using m/s, FreshBreeze is when the WindSpeed is 8.0-10.7 m/s.

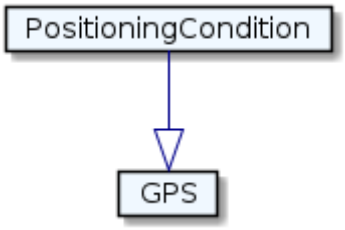
GLONASS



Element	Description
Type	Class
Name	GLONASS
IRI	http://ontology.asam.net/ontologies/Domain#GLONASS
Subclass of	PositioningCondition

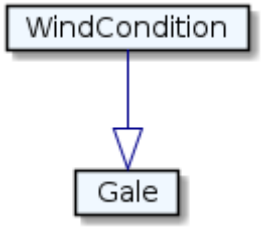
Element	Description
Comments	DEF: A PositioningCondition in which the vehicle's position is determined using the GLONASS global navigation satellite system.

GPS



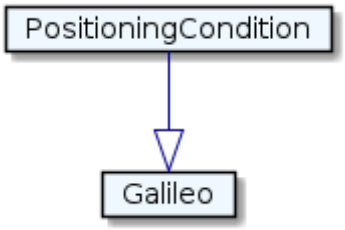
Element	Description
Type	Class
Name	GPS
IRI	http://ontology.asam.net/ontologies/Domain#GPS
Subclass of	PositioningCondition
Comments	DEF: A PositioningCondition in which the vehicle's position is determined using the Global Positioning System (GPS).

Gale



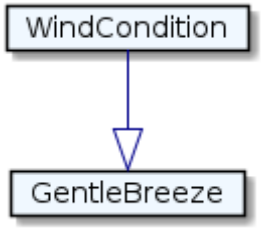
Element	Description
Type	Class
Name	Gale
IRI	http://ontology.asam.net/ontologies/Domain#Gale
Subclass of	WindCondition
Comments	DEF: Gale is a WindCondition, is it described by the WindSpeed property using m/s, Gale is when the WindSpeed is 17.2-20.7 m/s.

Galileo



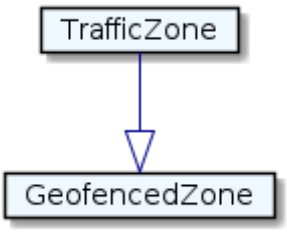
Element	Description
Type	Class
Name	Galileo
IRI	http://ontology.asam.net/ontologies/Domain#Galileo
Subclass of	PositioningCondition
Comments	DEF: A PositioningCondition in which the vehicle's position is determined using the Galileo global navigation satellite system.

GentleBreeze



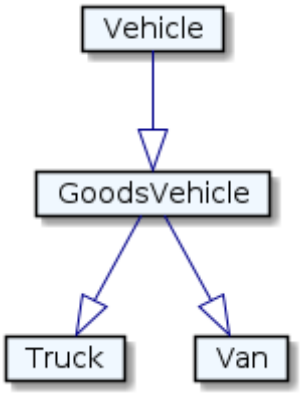
Element	Description
Type	Class
Name	GentleBreeze
IRI	http://ontology.asam.net/ontologies/Domain#GentleBreeze
Subclass of	WindCondition
Comments	DEF: GentleBreeze is a WindCondition, is it described by the WindSpeed property using m/s, GentleBreeze is when the WindSpeed is 3.4-5.4 m/s.

GeofencedZone



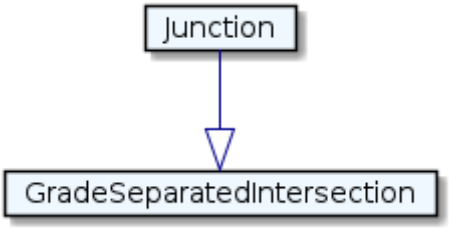
Element	Description
Type	Class
Name	GeofencedZone
IRI	http://ontology.asam.net/ontologies/Domain#GeofencedZone
Subclass of	TrafficZone
Comments	DEF: A geographic Zone with a virtual perimeter. Geofencing uses the GPS signal or other device services to track when a device crosses the virtual perimeter and enters the geo-fenced zone.

GoodsVehicle



Element	Description
Type	Class
Name	GoodsVehicle
IRI	http://ontology.asam.net/ontologies/Domain#GoodsVehicle
Subclass of	Vehicle
Comments	DEF: Goods vehicles are vehicles with their designed purpose of transporting goods

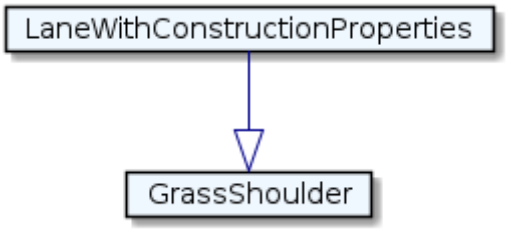
GradeSeparatedIntersection



Element	Description
Type	Class

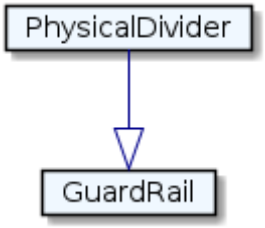
Element	Description
Name	GradeSeparatedIntersection
IRI	http://ontology.asam.net/ontologies/Domain#GradeSeparatedIntersection
Subclass of	Junction
Comments	DEF: A Junction with two or more roads at different heights (grades). This layout ensures that the traffic flow on each axis is not disrupted by the crossing. The grade separation of the roads is achieved by means of overpasses, for example bridges, or underpasses, for example tunnels, or a combination of both.

GrassShoulder



Element	Description
Type	Class
Name	GrassShoulder
IRI	http://ontology.asam.net/ontologies/Domain#GrassShoulder
Subclass of	LaneWithConstructionProperties
Comments	DEF: GrassShoulder is a LanesWithConstructionProperties that is an emergency stopping lane by the verge of a road or motorway. Hence, a shoulder, where the surface of a lane consists out of grass is called grass shoulder

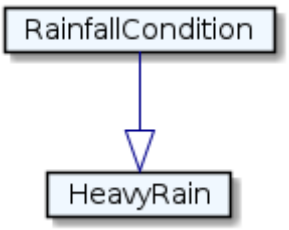
GuardRail



Element	Description
Type	Class

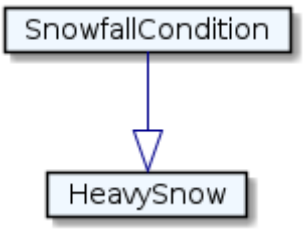
Element	Description
Name	GuardRail
IRI	http://ontology.asam.net/ontologies/Domain#GuardRail
Subclass of	PhysicalDivider
Comments	DEF: GuardRail is a PhysicalDivider that is a strong fence at the side of a road or in the middle of an expressway, intended to reduce the risk of serious accidents; a crash barrier.

HeavyRain



Element	Description
Type	Class
Name	HeavyRain
IRI	http://ontology.asam.net/ontologies/Domain#HeavyRain
Subclass of	RainfallCondition
Comments	DEF: HeavyRain is a RainfallCondition, is it described by the precipitationIntensity property using mm/hr, HeavyRain is when the precipitationIntensity is 7.6 - 50 mm/hr.

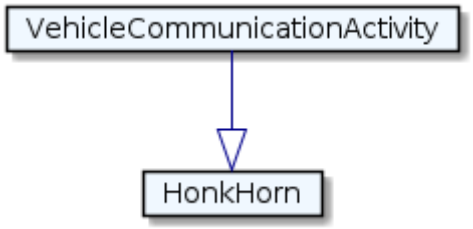
HeavySnow



Element	Description
Type	Class
Name	HeavySnow
IRI	http://ontology.asam.net/ontologies/Domain#HeavySnow

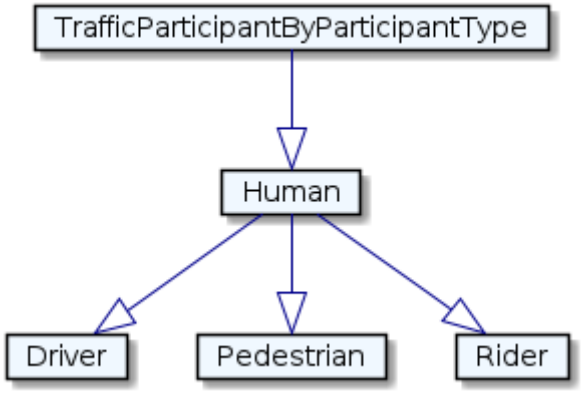
Element	Description
Subclass of	SnowfallCondition
Comments	DEF: HeavySnow is a SnowfallCondition, is it described by the SnowfallIntensity property using visibility, HeavySnow is when the SnowfallIntensity is < 0.5 km.

HonkHorn



Element	Description
Type	Class
Name	HonkHorn
IRI	http://ontology.asam.net/ontologies/Domain#HonkHorn
Subclass of	VehicleCommunicationActivity
Comments	DEF: A VehicleCommunicatingActivity in which the subject vehicle sounds the car horn in order to warn other traffic participants.

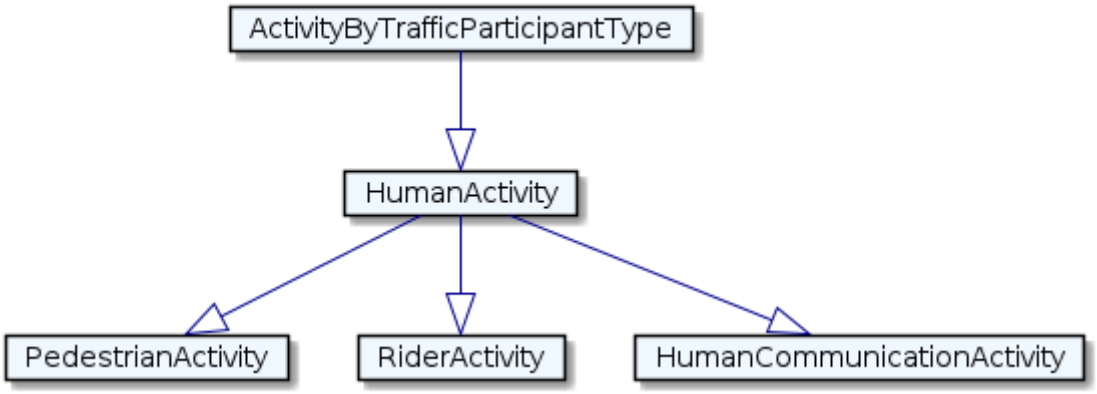
Human



Element	Description
Type	Class
Name	Human
IRI	http://ontology.asam.net/ontologies/Domain#Human
Subclass of	TrafficParticipantByParticipantType

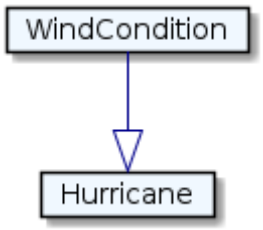
Element	Description
Comments	DEF: A human TrafficParticipant that is driving or moving in traffic, either within/on a vehicle or as pedestrian.

HumanActivity



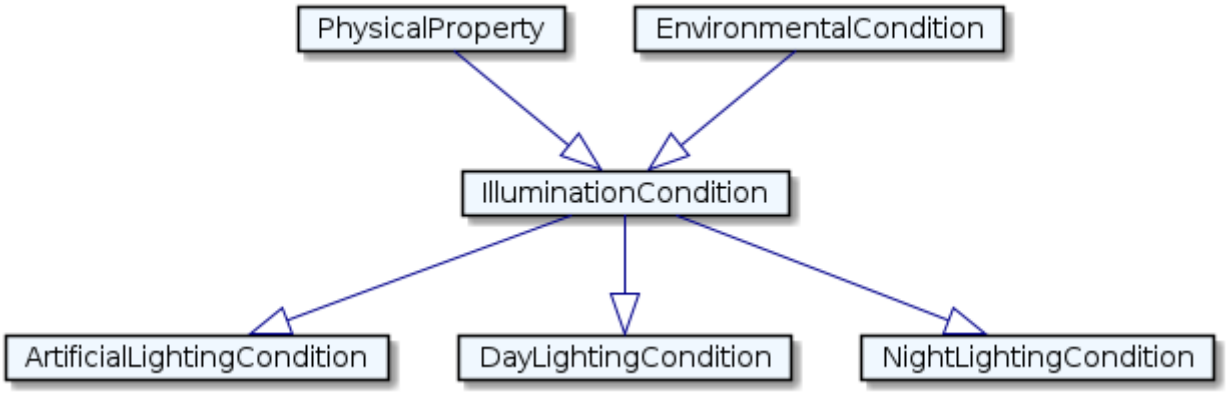
Element	Description
Type	Class
Name	HumanActivity
IRI	http://ontology.asam.net/ontologies/Domain#HumanActivity
Subclass of	ActivityByTrafficParticipantType
Comments	DEF: A set of activities performed by humans, such as pedestrians.

Hurricane



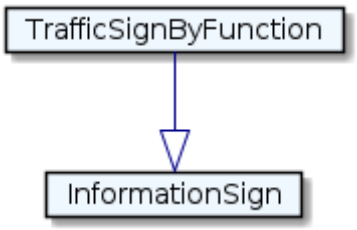
Element	Description
Type	Class
Name	Hurricane
IRI	http://ontology.asam.net/ontologies/Domain#Hurricane
Subclass of	WindCondition
Comments	DEF: Hurricane is a WindCondition, is it described by the WindSpeed property using m/s, Hurricane is when the WindSpeed is >= 32.7 m/s.

IlluminationCondition



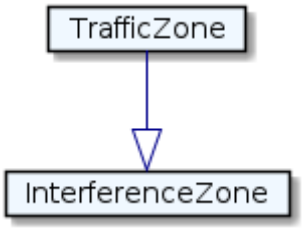
Element	Description
Type	Class
Name	IlluminationCondition
IRI	http://ontology.asam.net/ontologies/Domain#IlluminationCondition
Subclass of	PhysicalProperty
Subclass of	EnvironmentalCondition
Comments	DEF: An EnvironmentalCondition that is defined by the characteristics of light within a specific traffic situation. The objects that emit the light may be manufactured, such as lamps, or natural, like the sun. Illumination can improve the visibility of things or deteriorate it, for example by shadows or glare.

InformationSign



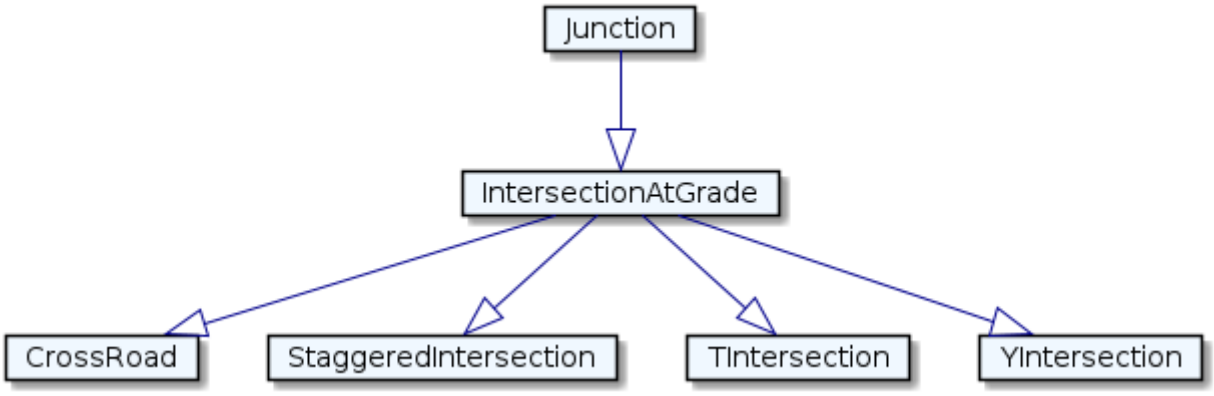
Element	Description
Type	Class
Name	InformationSign
IRI	http://ontology.asam.net/ontologies/Domain#InformationSign
Subclass of	TrafficSignByFunction
Comments	DEF: A traffic sign that provides information to traffic participants regarding the route, traffic flow, or road condition, but does not enforce any traffic rule.

InterferenceZone



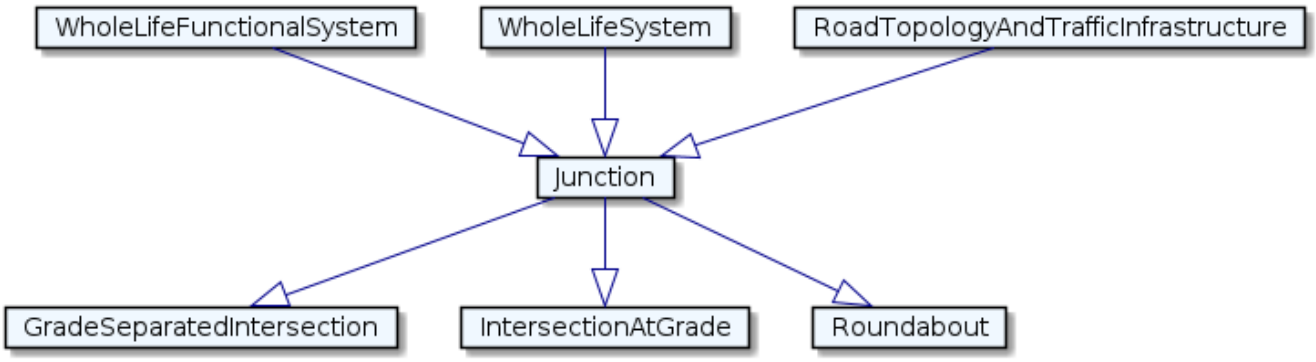
Element	Description
Type	Class
Name	InterferenceZone
IRI	http://ontology.asam.net/ontologies/Domain#InterferenceZone
Subclass of	TrafficZone
Comments	DEF: A zone with limited positioning-signal reception caused by dense foliage on surfaces, tall buildings, tunnels, atmospheric interference, or similar.

IntersectionAtGrade



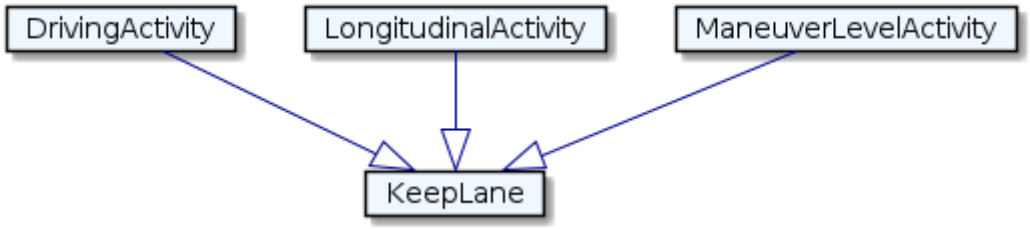
Element	Description
Type	Class
Name	IntersectionAtGrade
IRI	http://ontology.asam.net/ontologies/Domain#IntersectionAtGrade
Subclass of	Junction
Comments	DEF: A Junction where two or more roads meet at the same level.

Junction



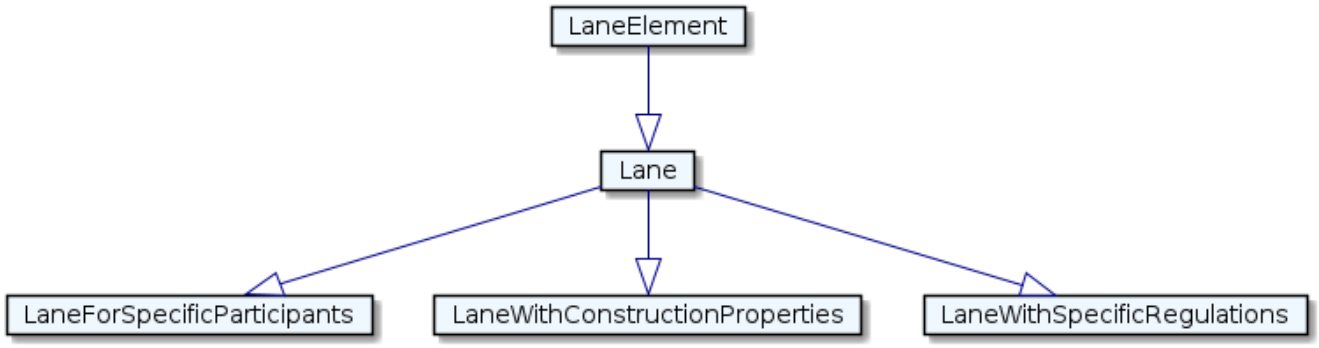
Element	Description
Type	Class
Name	Junction
IRI	http://ontology.asam.net/ontologies/Domain#Junction
Subclass of	WholeLifeFunctionalSystem
Subclass of	WholeLifeSystem
Subclass of	RoadTopologyAndTrafficInfrastructure
Comments	DEF: A RoadTopologyAndTrafficInfrastructure where two or more roads meet.

KeepLane



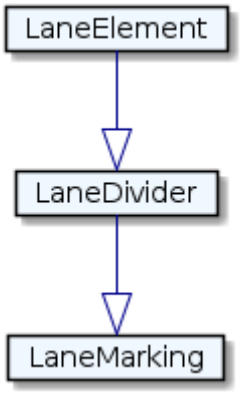
Element	Description
Type	Class
Name	KeepLane
IRI	http://ontology.asam.net/ontologies/Domain#KeepLane
Subclass of	DrivingActivity
Subclass of	LongitudinalActivity
Subclass of	ManeuverLevelActivity
Comments	DEF: A MovingActivity in which the subject traffic participant keeps the same lane for the entire duration of the activity.

Lane



Element	Description
Type	Class
Name	Lane
IRI	http://ontology.asam.net/ontologies/Domain#Lane
Subclass of	LaneElement
Comments	DEF: Lane is a LaneElements that is a division of a road that is marked out by dividers, it is intended for use by traffic participants. The lane class contains the type of lanes that can be used to form part of the road

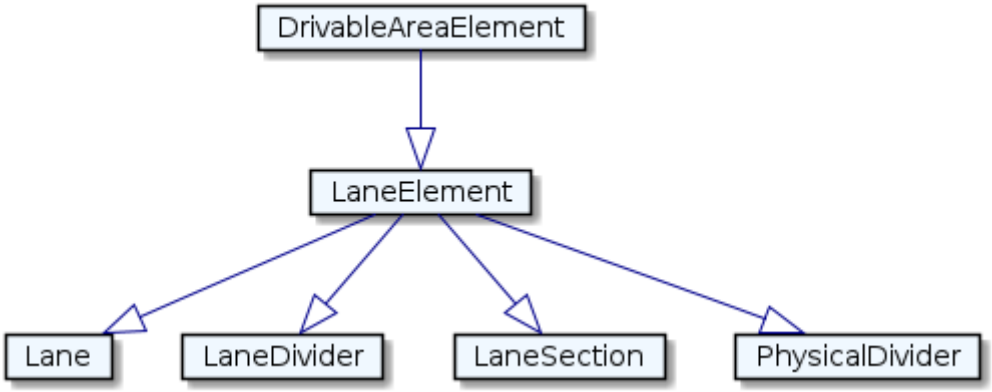
LaneDivider



Element	Description
Type	Class
Name	LaneDivider
IRI	http://ontology.asam.net/ontologies/Domain#LaneDivider
Subclass of	LaneElement

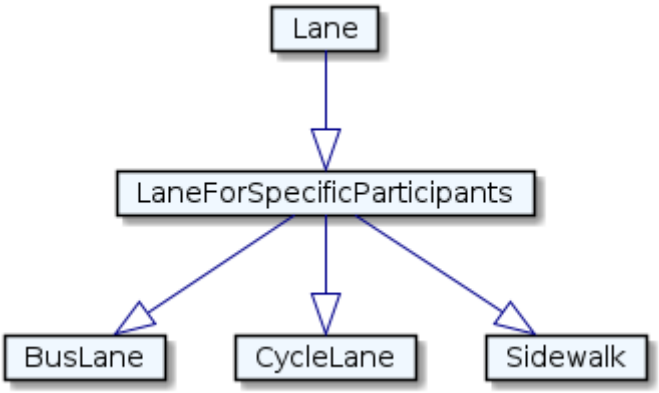
Element	Description
Comments	DEF: LaneDivider is a LaneElement that is the extruded or painted component that separate one lane from the others. Typical lane dividers include lane markings and physical extrusion features such as guardrails or curbs.

LaneElement



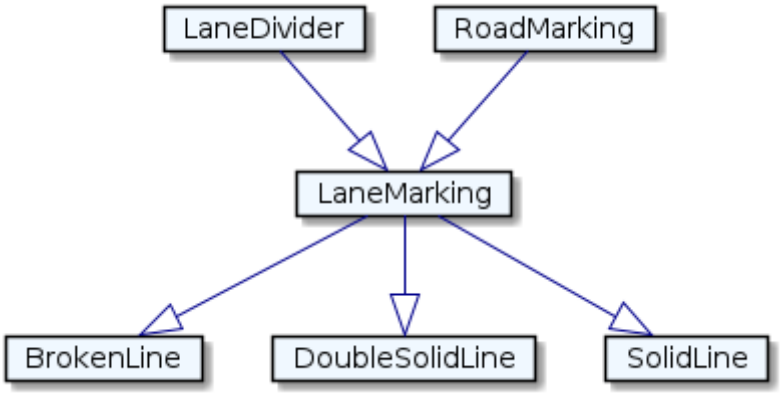
Element	Description
Type	Class
Name	LaneElement
IRI	http://ontology.asam.net/ontologies/Domain#LaneElement
Subclass of	DrivableAreaElement
Comments	DEF: A DriveableArea element that represents a part of a road, usually marked by lines, that is designed to be used by a single line of vehicles. Lanes may have different types, for example, dependent on the allowed vehicle types, and may have different characteristics, such as markings and curbs.

LaneForSpecificParticipants



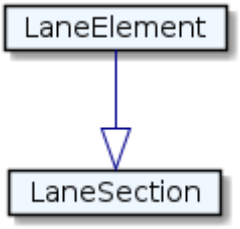
Element	Description
Type	Class
Name	LaneForSpecificParticipants
IRI	http://ontology.asam.net/ontologies/Domain#LaneForSpecificParticipants
Subclass of	Lane
Comments	DEF: LaneForSpecificParticipants is a lane, which can be assoiated and categorized based on specific types of allowed traffic participants.

LaneMarking



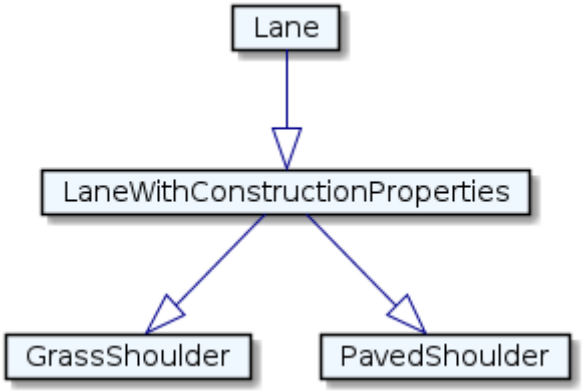
Element	Description
Type	Class
Name	LaneMarking
IRI	http://ontology.asam.net/ontologies/Domain#LaneMarking
Subclass of	LaneDivider
Subclass of	RoadMarking
Comments	DEF: LaneMarking is a type of LaneDivider, that is applied to individual indicating traffic rules such as lane change restriction.

LaneSection



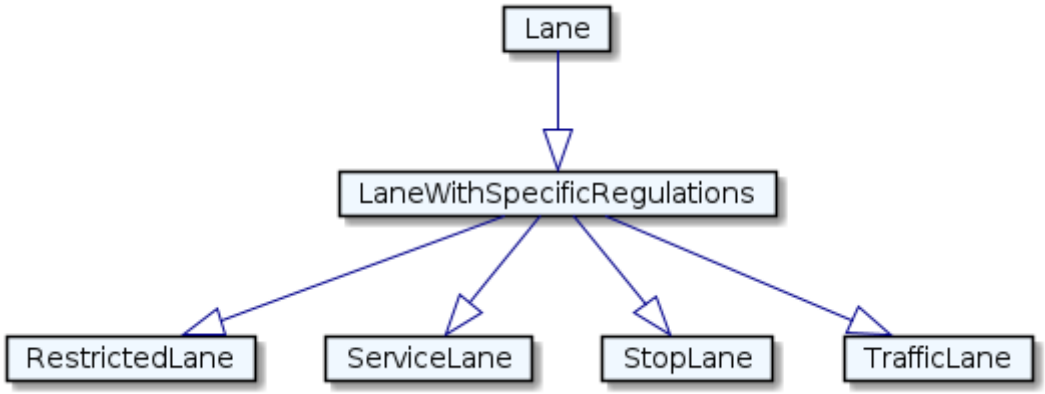
Element	Description
Type	Class
Name	LaneSection
IRI	http://ontology.asam.net/ontologies/Domain#LaneSection
Subclass of	LaneElement
Comments	DEF: LaneSection is a LaneElements. Lanes may be split into multiple lane sections. Each lane section contains a fixed number of lanes. Every time the number of lanes changes, a new lane section is required Lane sections are defined in ascending order along the road reference line.

LaneWithConstructionProperties



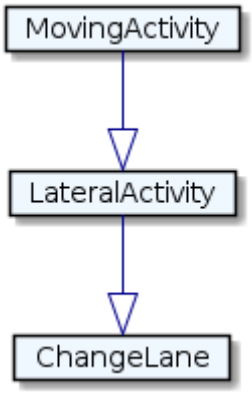
Element	Description
Type	Class
Name	LaneWithConstructionProperties
IRI	http://ontology.asam.net/ontologies/Domain#LaneWithConstructionProperties
Subclass of	Lane
Comments	DEF: LaneWithConstructionProperties is a lane, which can be assoiated and categorized based on surface material.

LaneWithSpecificRegulations



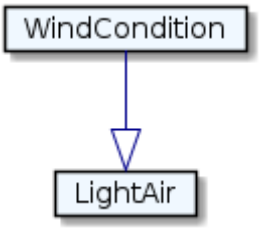
Element	Description
Type	Class
Name	LaneWithSpecificRegulations
IRI	http://ontology.asam.net/ontologies/Domain#LaneWithSpecificRegulations
Subclass of	Lane
Comments	DEF: LaneWithSpecificRegulations is a lane, which can be assoiated and categorized based on allowed traffic function and rules.

LateralActivity



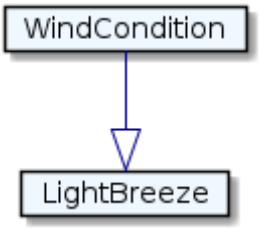
Element	Description
Type	Class
Name	LateralActivity
IRI	http://ontology.asam.net/ontologies/Domain#LateralActivity
Subclass of	MovingActivity
Comments	DEF: A MovingActivity which is characterized by sideways movement.

LightAir



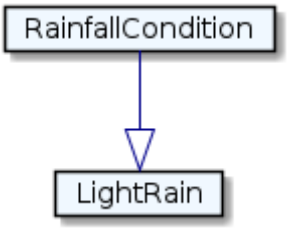
Element	Description
Type	Class
Name	LightAir
IRI	http://ontology.asam.net/ontologies/Domain#LightAir
Subclass of	WindCondition
Comments	DEF: LightAir is a WindCondition, is it described by the WindSpeed property using m/s, LightAir is when the WindSpeed is 0.3-1.5 m/s.

LightBreeze



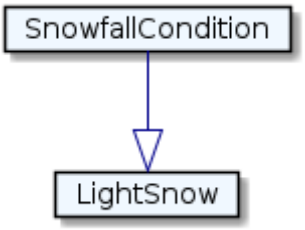
Element	Description
Type	Class
Name	LightBreeze
IRI	http://ontology.asam.net/ontologies/Domain#LightBreeze
Subclass of	WindCondition
Comments	DEF: LightBreeze is a WindCondition, is it described by the WindSpeed property using m/s, LightBreeze is when the WindSpeed is 1.6-3.3 m/s.

LightRain



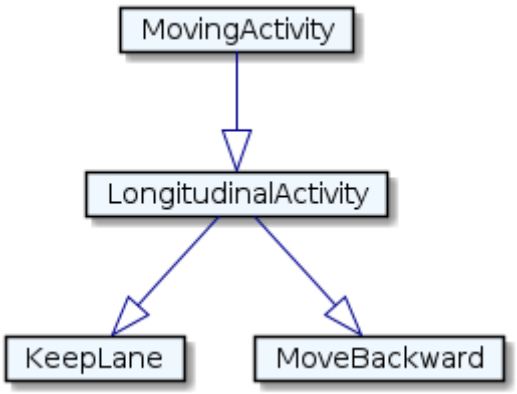
Element	Description
Type	Class
Name	LightRain
IRI	http://ontology.asam.net/ontologies/Domain#LightRain
Subclass of	RainfallCondition
Comments	DEF: LightRain is a RainfallCondition, is it described by the precipitationIntensity property using mm/hr, LightRain is when the precipitationIntensity is < 2.5 mm/hr.

LightSnow



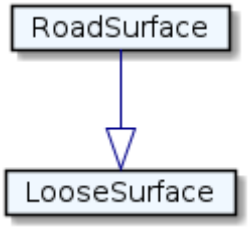
Element	Description
Type	Class
Name	LightSnow
IRI	http://ontology.asam.net/ontologies/Domain#LightSnow
Subclass of	SnowfallCondition
Comments	DEF: LightSnow is a SnowfallCondition, is it described by the SnowfallIntensity property using visibility, LightSnowis is when the SnowfallIntensity is > 1.0 km.

LongitudinalActivity



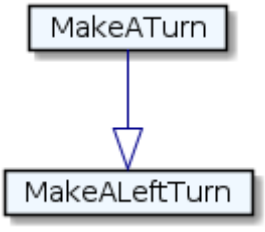
Element	Description
Type	Class
Name	LongitudinalActivity
IRI	http://ontology.asam.net/ontologies/Domain#LongitudinalActivity
Subclass of	MovingActivity
Comments	DEF: A MovingActivity which is characterized by lengthwise movement.

LooseSurface



Element	Description
Type	Class
Name	LooseSurface
IRI	http://ontology.asam.net/ontologies/Domain#LooseSurface
Subclass of	RoadSurface
Comments	DEF:LooseSurface is a RoadSurface that contains loose chippings such as loose gravel or stone fragments on a road surface

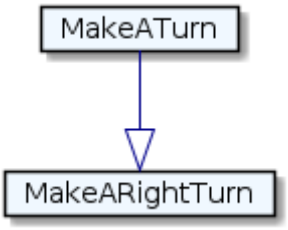
MakeALeftTurn



Element	Description
Type	Class
Name	MakeALeftTurn
IRI	http://ontology.asam.net/ontologies/Domain#MakeALeftTurn
Subclass of	MakeATurn

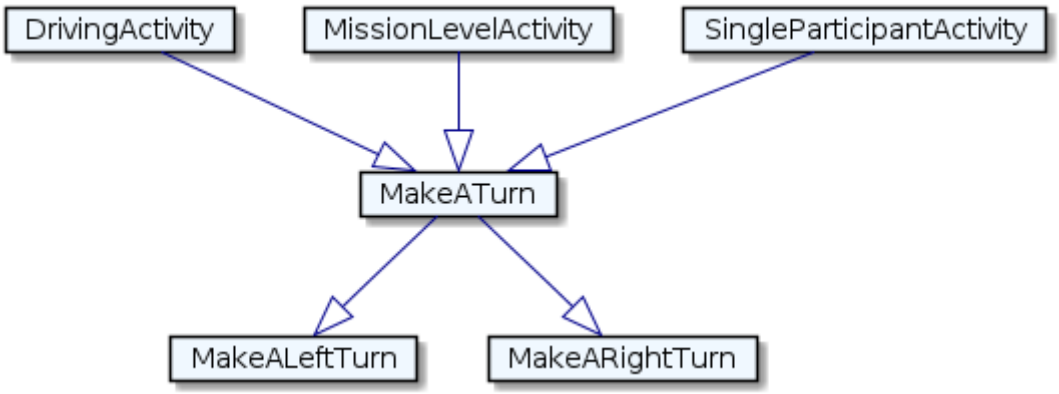
Element	Description
Comments	DEF: A MakeATurn activity during which the subject traffic participant navigates through an intersection and exits the intersection on a road that is located to the left of the orginal road.

MakeARightTurn



Element	Description
Type	Class
Name	MakeARightTurn
IRI	http://ontology.asam.net/ontologies/Domain#MakeARightTurn
Subclass of	MakeATurn
Comments	DEF: A MakeATurn activity during which the subject traffic participant navigates through an intersection and exits the intersection on a road that is located to the right of the orginal road.

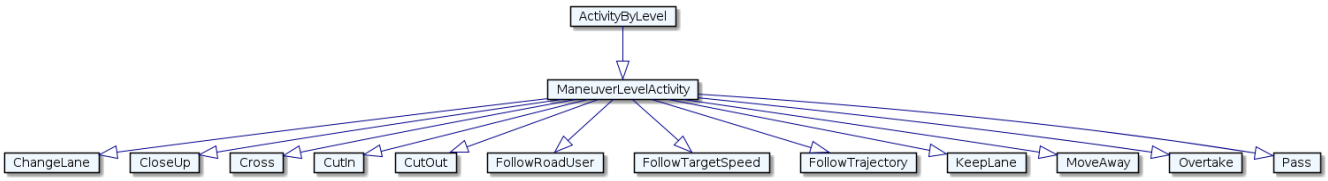
MakeATurn



Element	Description
Type	Class
Name	MakeATurn
IRI	http://ontology.asam.net/ontologies/Domain#MakeATurn
Subclass of	DrivingActivity

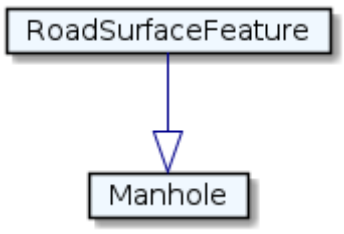
Element	Description
Subclass of	MissionLevelActivity
Subclass of	SingleParticipantActivity
Comments	DEF: A MovingActivity at mission level during which the subject traffic participant changes its direction in reference to a traffic infrastructure element, such as an intersection or a road, and has a different direction at the end of the activity.

ManeuverLevelActivity



Element	Description
Type	Class
Name	ManeuverLevelActivity
IRI	http://ontology.asam.net/ontologies/Domain#ManeuverLevelActivity
Subclass of	ActivityByLevel
Comments	DEF: A set of activities with actions on maneuver level. This level contains abstract descriptions for the movements of a vehicle. It abstracts the physically continuous vehicle motion into a discrete logical state. This state is only partially observable from the outside. Every driving maneuver is linked to an intention.

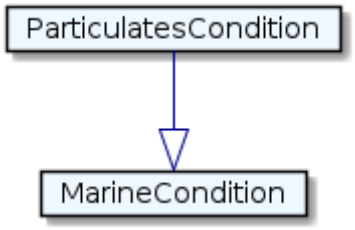
Manhole



Element	Description
Type	Class
Name	Manhole
IRI	http://ontology.asam.net/ontologies/Domain#Manhole
Subclass of	RoadSurfaceFeature

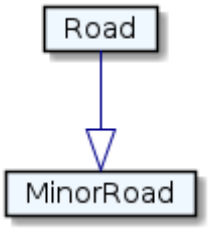
Element	Description
Comments	DEF:Manhole is a RoadSurfaceFeature that is an opening in road to access canal system. Has to be big enough to fit a person and includes squared ones.

MarineCondition



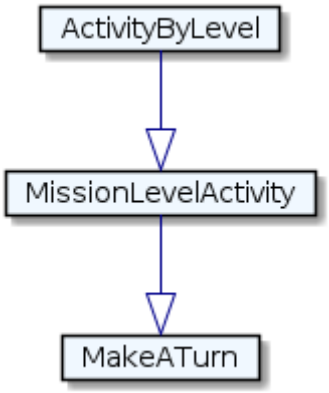
Element	Description
Type	Class
Name	MarineCondition
IRI	http://ontology.asam.net/ontologies/Domain#MarineCondition
Subclass of	ParticulatesCondition
Comments	DEF: An AmbientCondition in an area near the sea where spray from the sea gets mixed into the atmosphere.

MinorRoad



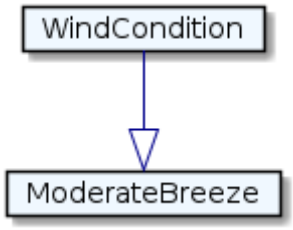
Element	Description
Type	Class
Name	MinorRoad
IRI	http://ontology.asam.net/ontologies/Domain#MinorRoad
Subclass of	Road
Comments	DEF: MinorRoad is a Road that provides access to residential areas and other local developments.

MissionLevelActivity



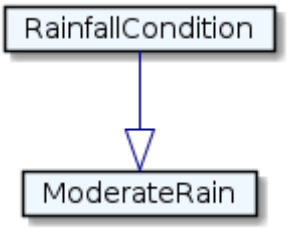
Element	Description
Type	Class
Name	MissionLevelActivity
IRI	http://ontology.asam.net/ontologies/Domain#MissionLevelActivity
Subclass of	ActivityByLevel
Comments	DEF: MissionLevelActivity is a ActivityByLevel, which structures the vehicle behavior at the level of mission or route planning and serves to achieve a higher-level goal. "Mission elements are abstract task descriptions with no knowledge about how they will be executed by the system."

ModerateBreeze



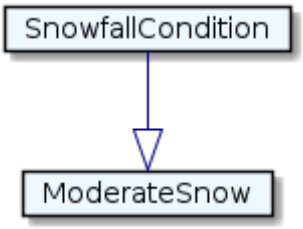
Element	Description
Type	Class
Name	ModerateBreeze
IRI	http://ontology.asam.net/ontologies/Domain#ModerateBreeze
Subclass of	WindCondition
Comments	DEF: ModerateBreeze is a WindCondition, is it described by the WindSpeed property using m/s, ModerateBreeze is when the WindSpeed is 5.5-7.9 m/s.

ModerateRain



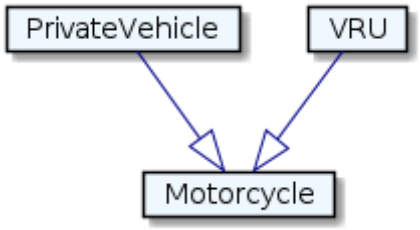
Element	Description
Type	Class
Name	ModerateRain
IRI	http://ontology.asam.net/ontologies/Domain#ModerateRain
Subclass of	RainfallCondition
Comments	DEF: ModerateRain is a RainfallCondition, is it described by the precipitationIntensity property using mm/hr, ModerateRain is when the precipitationIntensity is <2.5 - 7.6 mm/hr.

ModerateSnow



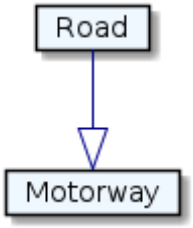
Element	Description
Type	Class
Name	ModerateSnow
IRI	http://ontology.asam.net/ontologies/Domain#ModerateSnow
Subclass of	SnowfallCondition
Comments	DEF: ModerateSnow is a SnowfallCondition, is it described by the SnowfallIntensity property using visibility, ModerateSnow is when the SnowfallIntensity is 0.5 - 1.0 km.

Motorcycle



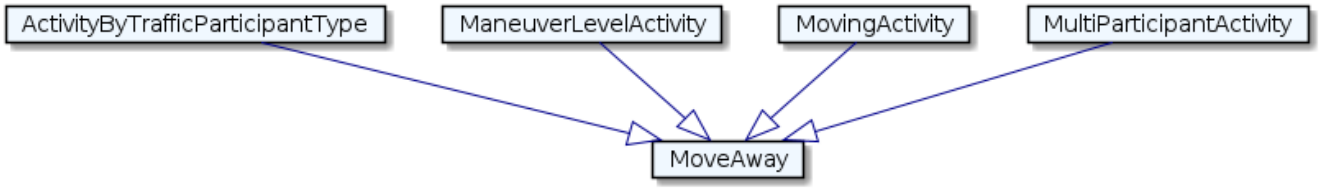
Element	Description
Type	Class
Name	Motorcycle
IRI	http://ontology.asam.net/ontologies/Domain#Motorcycle
Subclass of	PrivateVehicle
Subclass of	VRU
Comments	DEF: A motor-powered Vehicle, also called motorbike or bike, that has two or three wheels and is used for transporting people.

Motorway



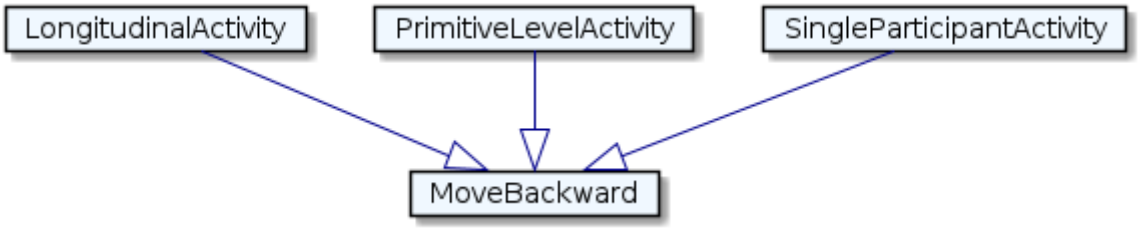
Element	Description
Type	Class
Name	Motorway
IRI	http://ontology.asam.net/ontologies/Domain#Motorway
Subclass of	Road
Comments	DEF: A Road that is designed for high speed and high traffic volume and has controlled entries and exits. Non-motorized vehicles and pedestrians are prohibited on motorways.

MoveAway



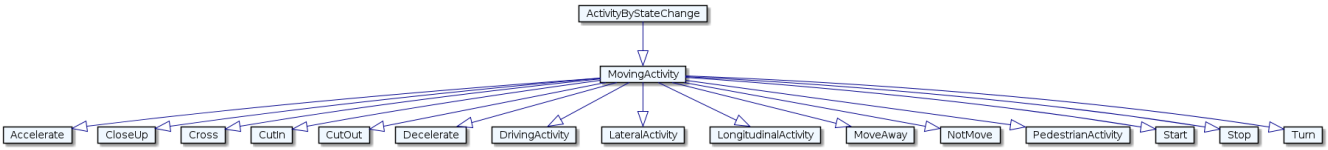
Element	Description
Type	Class
Name	MoveAway
IRI	http://ontology.asam.net/ontologies/Domain#MoveAway
Subclass of	ActivityByTrafficParticipantType
Subclass of	ManeuverLevelActivity
Subclass of	MovingActivity
Subclass of	MultiParticipantActivity
Comments	DEF: A MovingActivity with moving traffic participants in which the subject traffic participant moves away from the object traffic participant.

MoveBackward



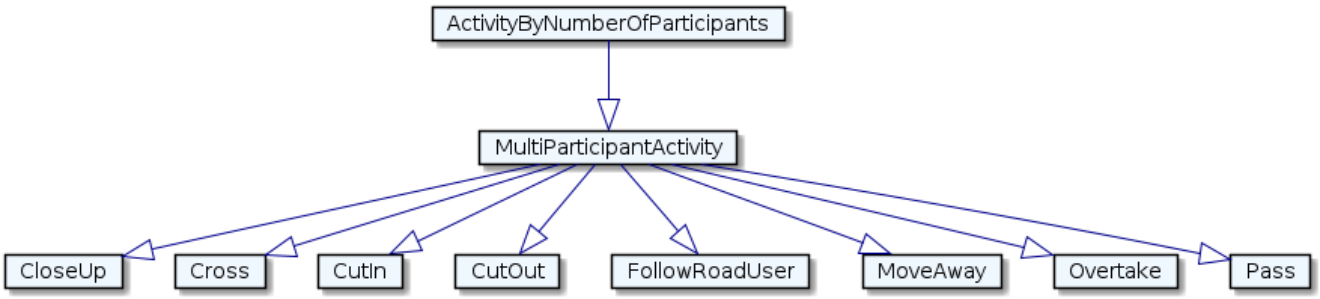
Element	Description
Type	Class
Name	MoveBackward
IRI	http://ontology.asam.net/ontologies/Domain#MoveBackward
Subclass of	LongitudinalActivity
Subclass of	PrimitiveLevelActivity
Subclass of	SingleParticipantActivity
Comments	DEF: An Activity with one traffic participant in which the traffic participant moves into the direction that is opposite to the original one without changing its orientation.

MovingActivity



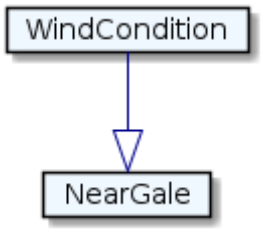
Element	Description
Type	Class
Name	MovingActivity
IRI	http://ontology.asam.net/ontologies/Domain#MovingActivity
Subclass of	ActivityByStateChange
Comments	DEF: A set of activities which result in a changed location of the subject traffic participant.

MultiParticipantActivity



Element	Description
Type	Class
Name	MultiParticipantActivity
IRI	http://ontology.asam.net/ontologies/Domain#MultiParticipantActivity
Subclass of	ActivityByNumberOfParticipants
Comments	DEF: A set of activities which involve more than one traffic participant.

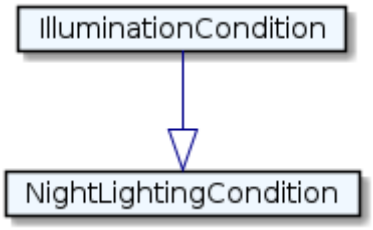
NearGale



Element	Description
Type	Class
Name	NearGale
IRI	http://ontology.asam.net/ontologies/Domain#NearGale
Subclass of	WindCondition

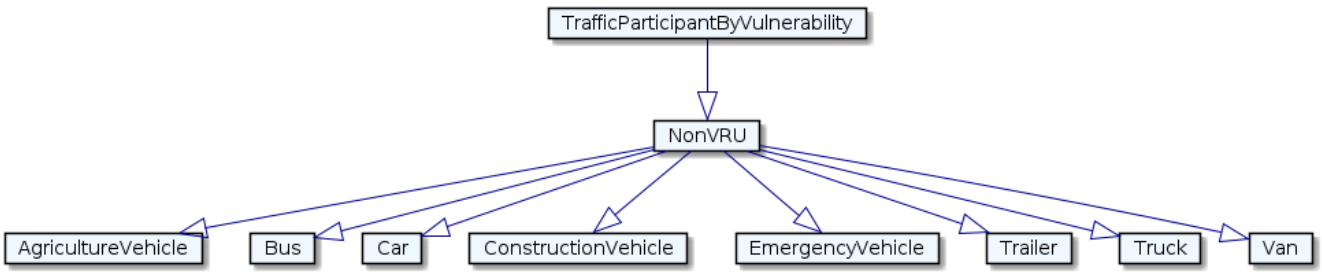
Element	Description
Comments	DEF: NearGale is a WindCondition, is it described by the WindSpeed property using m/s, NearGale is when the WindSpeed is 17.2-20.7 m/s.

NightLightingCondition



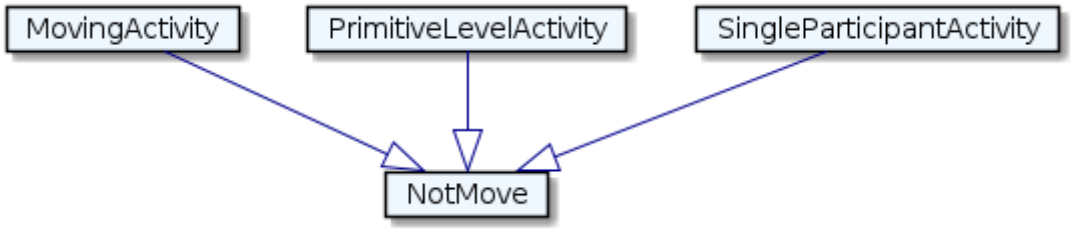
Element	Description
Type	Class
Name	NightLightingCondition
IRI	http://ontology.asam.net/ontologies/Domain#NightLightingCondition
Subclass of	IlluminationCondition
Comments	DEF: An IlluminationCondition where illuminance is below 1 lux.

NonVRU



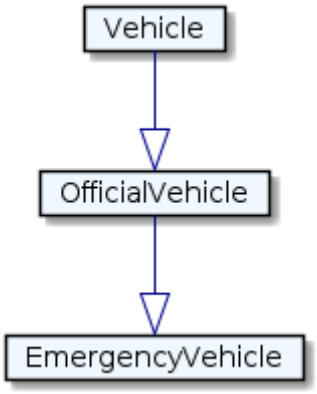
Element	Description
Type	Class
Name	NonVRU
IRI	http://ontology.asam.net/ontologies/Domain#NonVRU
Subclass of	TrafficParticipantByVulnerability
Comments	DEF: A set of non-vulnerable road users.

NotMove



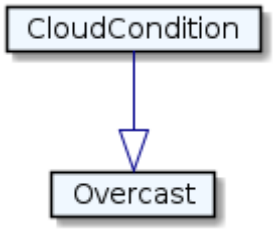
Element	Description
Type	Class
Name	NotMove
IRI	http://ontology.asam.net/ontologies/Domain#NotMove
Subclass of	MovingActivity
Subclass of	PrimitiveLevelActivity
Subclass of	SingleParticipantActivity
Comments	DEF: An Activity during which the traffic participant has a speed of zero.

OfficialVehicle



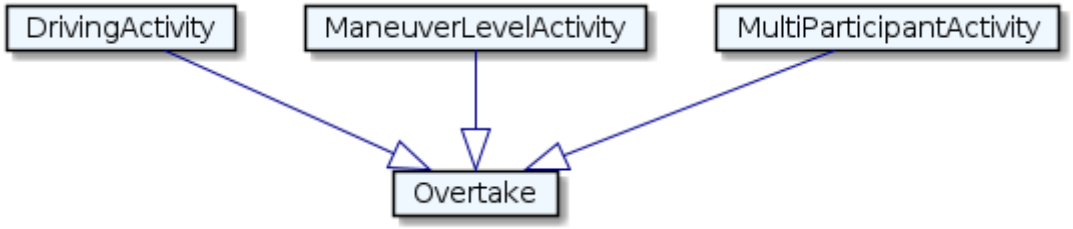
Element	Description
Type	Class
Name	OfficialVehicle
IRI	http://ontology.asam.net/ontologies/Domain#OfficialVehicle
Subclass of	Vehicle
Comments	DEF: Official vehicles are vehicles with special access and operational authorities, such as ambulance, police vehicle

Overcast



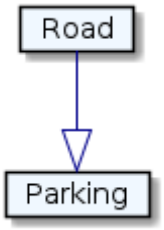
Element	Description
Type	Class
Name	Overcast
IRI	http://ontology.asam.net/ontologies/Domain#Overcast
Subclass of	CloudCondition
Comments	DEF: Overcast is a CloudCondition, is it described by the cloudinessLevel property using oktas unit, Overcast is when the cloudinessLevel is 8 oktas.

Overtake



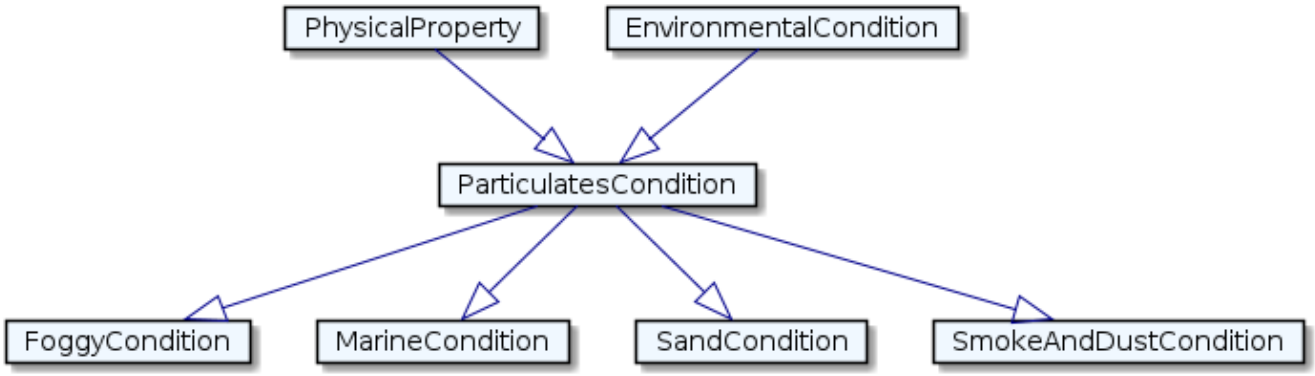
Element	Description
Type	Class
Name	Overtake
IRI	http://ontology.asam.net/ontologies/Domain#Overtake
Subclass of	DrivingActivity
Subclass of	ManeuverLevelActivity
Subclass of	MultiParticipantActivity
Comments	DEF: An activity in which the subject traffic participant starts behind the object traffic participant and ends up in front of the object traffic participant. The subject changes lanes two time during the activity.

Parking



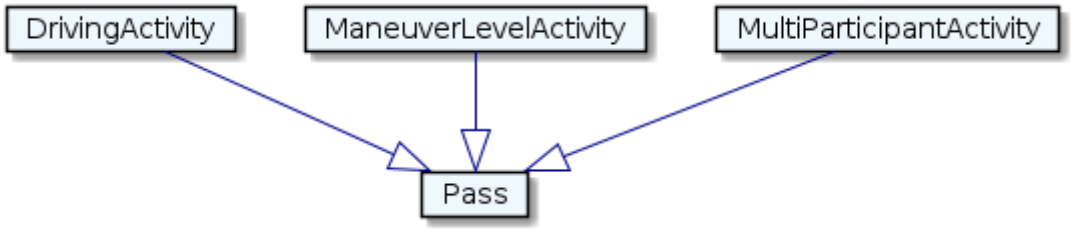
Element	Description
Type	Class
Name	Parking
IRI	http://ontology.asam.net/ontologies/Domain#Parking
Subclass of	Road
Comments	DEF: A Road where vehicles are allowed to park.

ParticulatesCondition



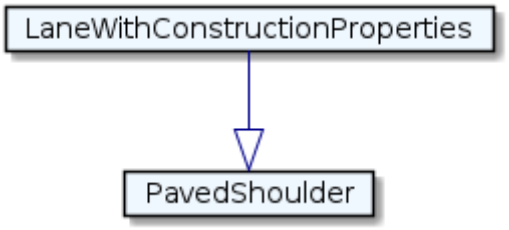
Element	Description
Type	Class
Name	ParticulatesCondition
IRI	http://ontology.asam.net/ontologies/Domain#ParticulatesCondition
Subclass of	PhysicalProperty
Subclass of	EnvironmentalCondition
Comments	DEF: An EnvironmentalCondition where particles in the atmosphere lead to a limited visibility or obscuration of things. Particulates can be of different materials, for example water or sand.

Pass



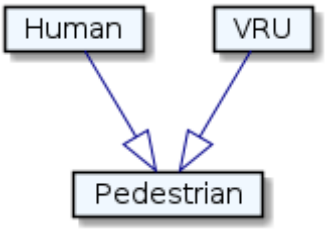
Element	Description
Type	Class
Name	Pass
IRI	http://ontology.asam.net/ontologies/Domain#Pass
Subclass of	DrivingActivity
Subclass of	ManeuverLevelActivity
Subclass of	MultiParticipantActivity
Comments	DEF: An activity in which the subject traffic participant is located in a lane adjacent to the lane in which the object traffic participant drives. The subject starts behind the object and is position ahead of the object at the end of the activity. The subject does not change lanes.

PavedShoulder



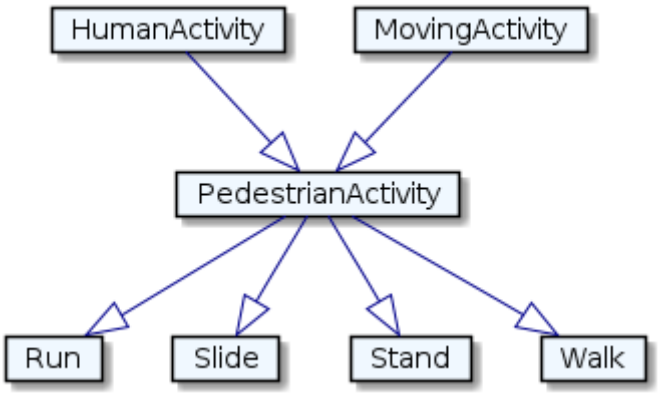
Element	Description
Type	Class
Name	PavedShoulder
IRI	http://ontology.asam.net/ontologies/Domain#PavedShoulder
Subclass of	LaneWithConstructionProperties
Comments	DEF: PavedShoulder is a LanesWithConstructionProperties that is an emergency stopping lane by the verge of a road or motorway. Hence, a shoulder, where the surface of a lane is paved is called paved shoulder

Pedestrian



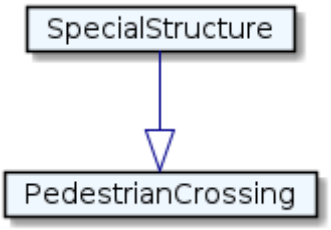
Element	Description
Type	Class
Name	Pedestrian
IRI	http://ontology.asam.net/ontologies/Domain#Pedestrian
Subclass of	Human
Subclass of	VRU
Comments	DEF: A HumanParticipant who moves in traffic on foot.

PedestrianActivity



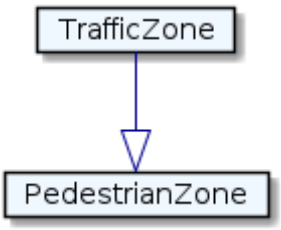
Element	Description
Type	Class
Name	PedestrianActivity
IRI	http://ontology.asam.net/ontologies/Domain#PedestrianActivity
Subclass of	HumanActivity
Subclass of	MovingActivity
Comments	DEF: A set of activities performed by pedestrians.

PedestrianCrossing



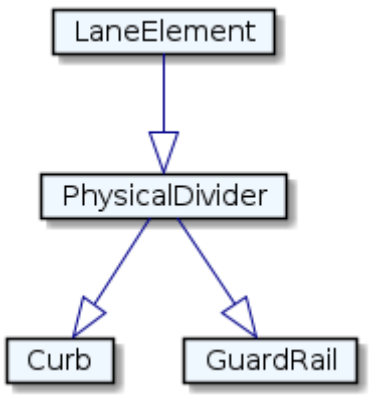
Element	Description
Type	Class
Name	PedestrianCrossing
IRI	http://ontology.asam.net/ontologies/Domain#PedestrianCrossing
Subclass of	SpecialStructure
Comments	DEF: A SpecialStructure that creates a place or area where pedestrians are able to cross a road or lane.

PedestrianZone



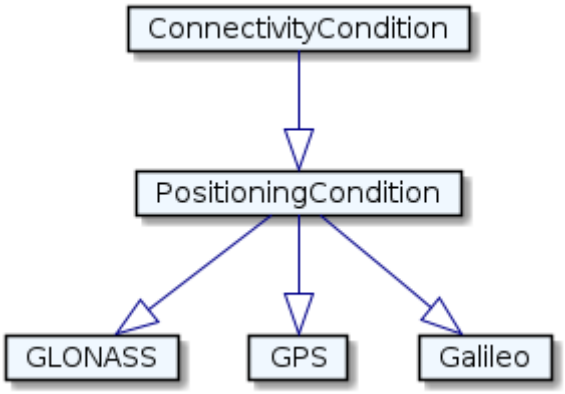
Element	Description
Type	Class
Name	PedestrianZone
IRI	http://ontology.asam.net/ontologies/Domain#PedestrianZone
Subclass of	TrafficZone
Comments	DEF: A Zone where only pedestrians are allowed.

PhysicalDivider



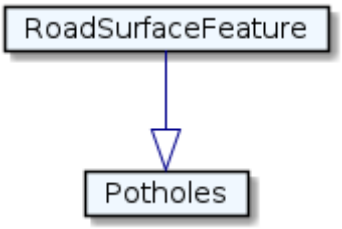
Element	Description
Type	Class
Name	PhysicalDivider
IRI	http://ontology.asam.net/ontologies/Domain#PhysicalDivider
Subclass of	LaneElement
Comments	DEF: PhysicalDivider is a LaneDivider that is a description of a way which has a physical or legal divider that divides opposing direction lanes and prevents crossing the way in a particular direction. In right side driving countries left turns and u-turns are not allowed, in left side driving countries right turns and u-turns are not allowed.

PositioningCondition



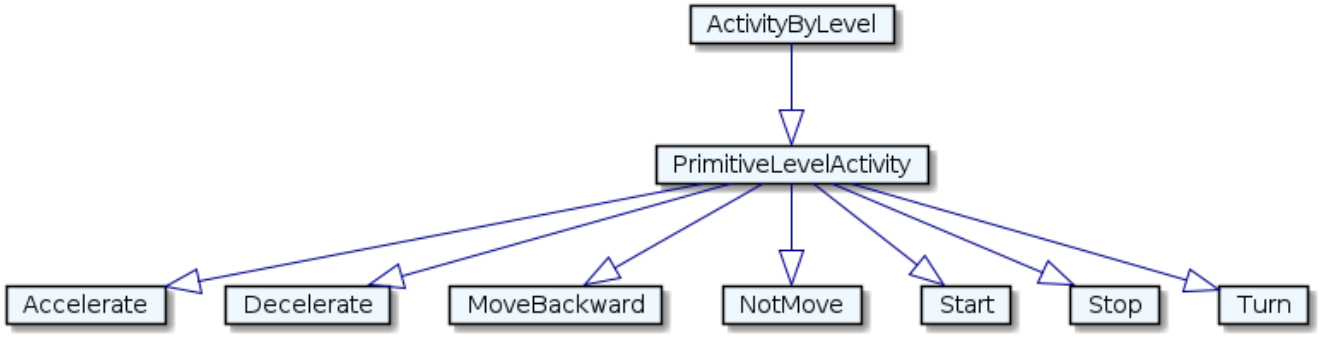
Element	Description
Type	Class
Name	PositioningCondition
IRI	http://ontology.asam.net/ontologies/Domain#PositioningCondition
Subclass of	ConnectivityCondition
Comments	DEF: A ConnectivityCondition that specifies the system or mechanism used by a vehicle to determine its position. Examples: GPS and GLONASS.

Potholes



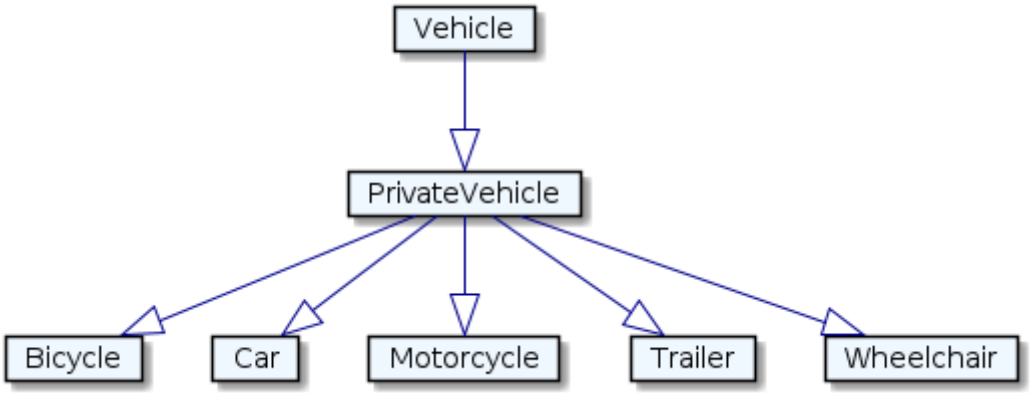
Element	Description
Type	Class
Name	Potholes
IRI	http://ontology.asam.net/ontologies/Domain#Potholes
Subclass of	RoadSurfaceFeature
Comments	DEF:Potholes is a RoadSurfaceFeature that is a depression in a road surface, usually asphalt pavement, where traffic has removed broken pieces of the pavement. It is usually the result of water in the underlying soil structure and traffic passing over the affected area

PrimitiveLevelActivity



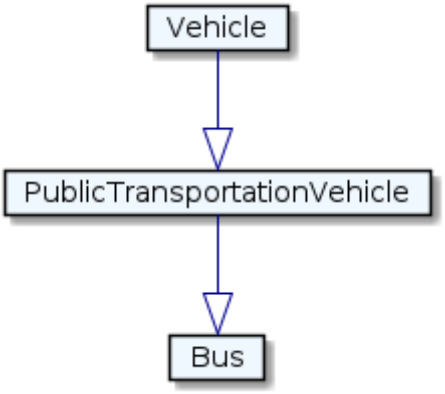
Element	Description
Type	Class
Name	PrimitiveLevelActivity
IRI	http://ontology.asam.net/ontologies/Domain#PrimitiveLevelActivity
Subclass of	ActivityByLevel
Comments	DEF: A set of activities that describe the course of state variables through which a maneuver is to be implemented. While a maneuver is often defined relative to the traffic infrastructure, a motion primitive is defined in the vehicle coordinate system. A motion primitive can be a yaw rate, an acceleration or a deceleration.

PrivateVehicle



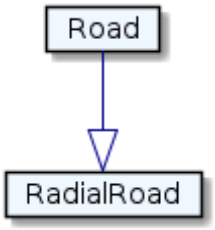
Element	Description
Type	Class
Name	PrivateVehicle
IRI	http://ontology.asam.net/ontologies/Domain#PrivateVehicle
Subclass of	Vehicle
Comments	DEF: Private vehicles are vehicles owned and used by private individuals.

PublicTransportationVehicle



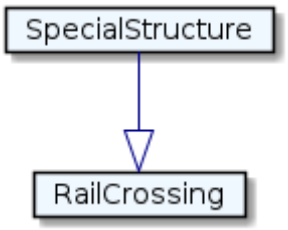
Element	Description
Type	Class
Name	PublicTransportationVehicle
IRI	http://ontology.asam.net/ontologies/Domain#PublicTransportationVehicle
Subclass of	Vehicle
Comments	DEF: Public transporation vehicles are vehicles operated to transport individuals from the public.

RadialRoad



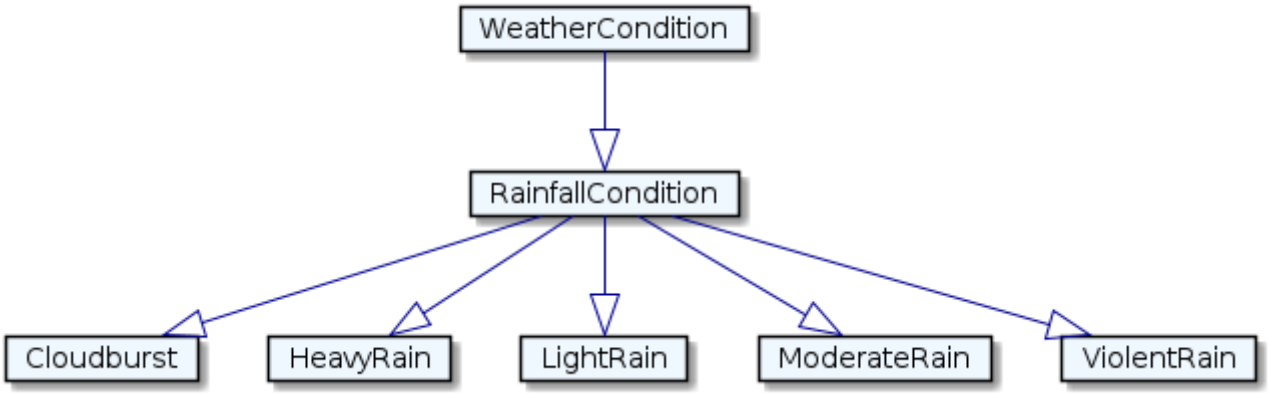
Element	Description
Type	Class
Name	RadialRoad
IRI	http://ontology.asam.net/ontologies/Domain#RadialRoad
Subclass of	Road
Comments	DEF: A Road for high-density traffic that connects motorways to distributor roads or city centers.

RailCrossing



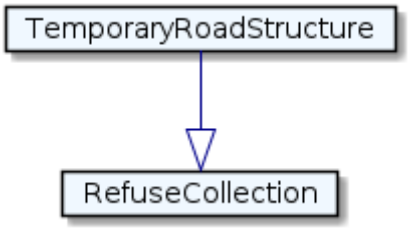
Element	Description
Type	Class
Name	RailCrossing
IRI	http://ontology.asam.net/ontologies/Domain#RailCrossing
Subclass of	SpecialStructure
Comments	DEF: A SpecialStructure that is an intersection between a road and a railway track.

RainfallCondition



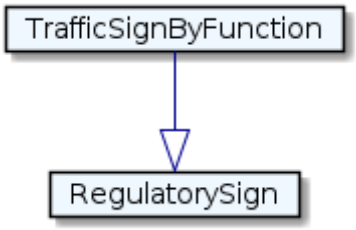
Element	Description
Type	Class
Name	RainfallCondition
IRI	http://ontology.asam.net/ontologies/Domain#RainfallCondition
Subclass of	WeatherCondition
Comments	DEF: A WeatherCondition where it is raining. The intensity of the rainfall may be described using the precipitationIntensity property.

RefuseCollection



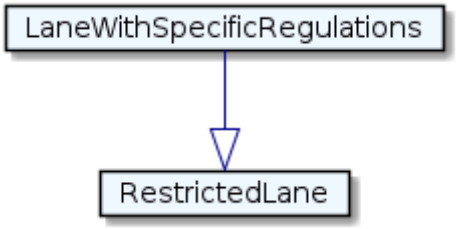
Element	Description
Type	Class
Name	RefuseCollection
IRI	http://ontology.asam.net/ontologies/Domain#RefuseCollection
Subclass of	TemporaryRoadStructure
Comments	DEF: A TemporaryRoadStructure that contains rubbish or waste that has not been disposed yet.

RegulatorySign



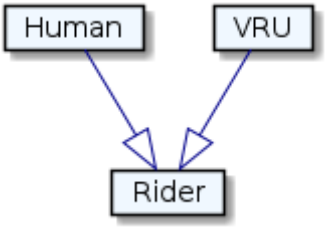
Element	Description
Type	Class
Name	RegulatorySign
IRI	http://ontology.asam.net/ontologies/Domain#RegulatorySign
Subclass of	TrafficSignByFunction
Comments	DEF: A traffic sign that indicates rules, restrictions, and prohibitions for all or specific traffic participants.

RestrictedLane



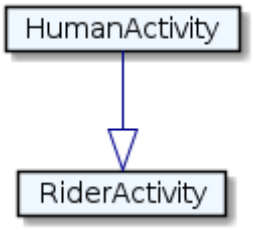
Element	Description
Type	Class
Name	RestrictedLane
IRI	http://ontology.asam.net/ontologies/Domain#RestrictedLane
Subclass of	LaneWithSpecificRegulations
Comments	DEF: RestrictedLane is a LaneWithSpecificRegulations that can have restrictions towards time, traffic participant type etc. For example, when two lanes split there is an area, where driving is forbidden.

Rider



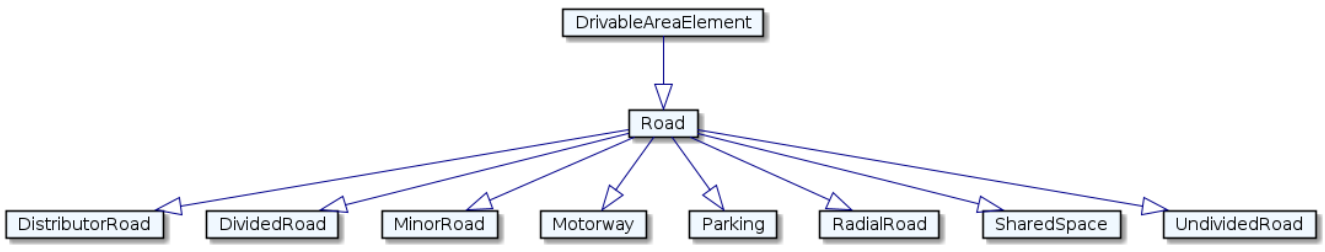
Element	Description
Type	Class
Name	Rider
IRI	http://ontology.asam.net/ontologies/Domain#Rider
Subclass of	Human
Subclass of	VRU
Comments	DEF: A type of VRU which consists of a human rider and the transporting vehicle the rider is controlling, examples of such vehicles can be animal, bicycle, motorcycle, etc.

RiderActivity



Element	Description
Type	Class
Name	RiderActivity
IRI	http://ontology.asam.net/ontologies/Domain#RiderActivity
Subclass of	HumanActivity
Comments	DEF: A BiologicalObjectActivity where the participant is a bicyclist or motorcyclist.

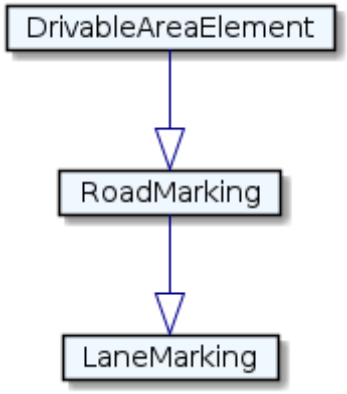
Road



Element	Description
Type	Class
Name	Road

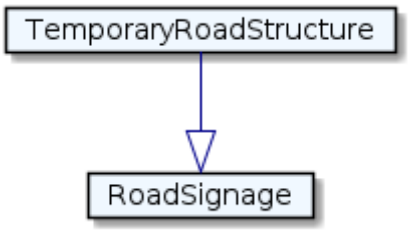
Element	Description
IRI	http://ontology.asam.net/ontologies/Domain#Road
Subclass of	DrivableAreaElement
Comments	DEF: A DriveableArea that is a long stretch with a smooth or paved surface leading from one place to another. Made to be used by traffic participants.

RoadMarking



Element	Description
Type	Class
Name	RoadMarking
IRI	http://ontology.asam.net/ontologies/Domain#RoadMarking
Subclass of	DrivableAreaElement
Comments	DEF: A DriveableArea on a road surface that may consist of lines or other symbols and that conveys regulatory information about traffic rules.

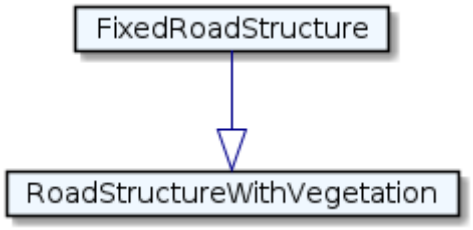
RoadSignage



Element	Description
Type	Class
Name	RoadSignage
IRI	http://ontology.asam.net/ontologies/Domain#RoadSignage

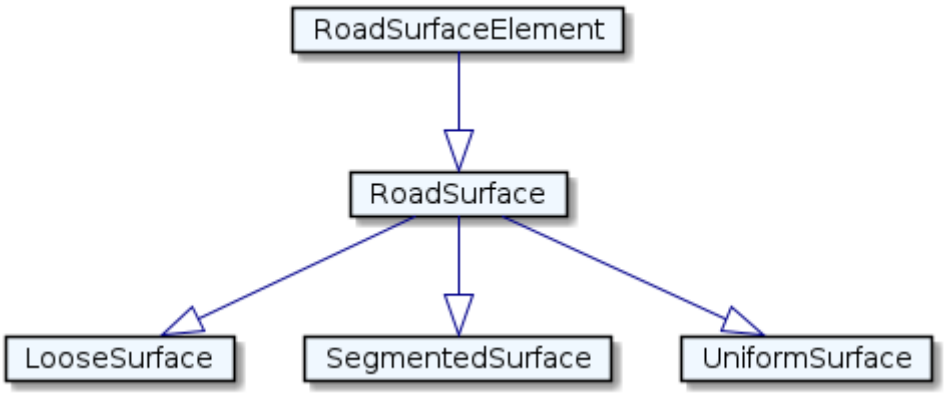
Element	Description
Subclass of	TemporaryRoadStructure
Comments	DEF: A TemporaryRoadStructure that are signs or symbols on the road and that provide information about temporary changes to traffic routes, about road closures, construction works, detours, etc.

RoadStructureWithVegetation



Element	Description
Type	Class
Name	RoadStructureWithVegetation
IRI	http://ontology.asam.net/ontologies/Domain#RoadStructureWithVegetation
Subclass of	FixedRoadStructure
Comments	DEF: A FixedRoadStructure that consist of a several plants and the ground they cover.

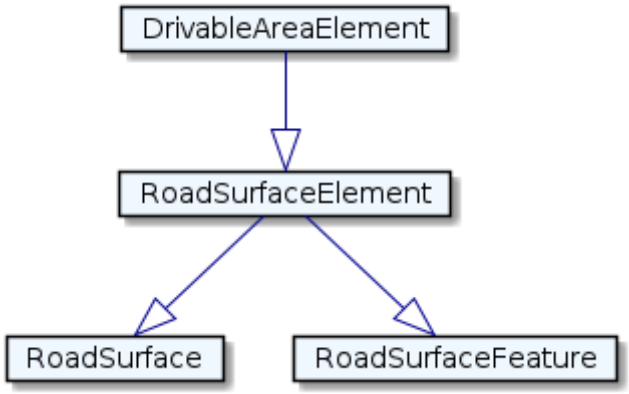
RoadSurface



Element	Description
Type	Class
Name	RoadSurface
IRI	http://ontology.asam.net/ontologies/Domain#RoadSurface
Subclass of	RoadSurfaceElement

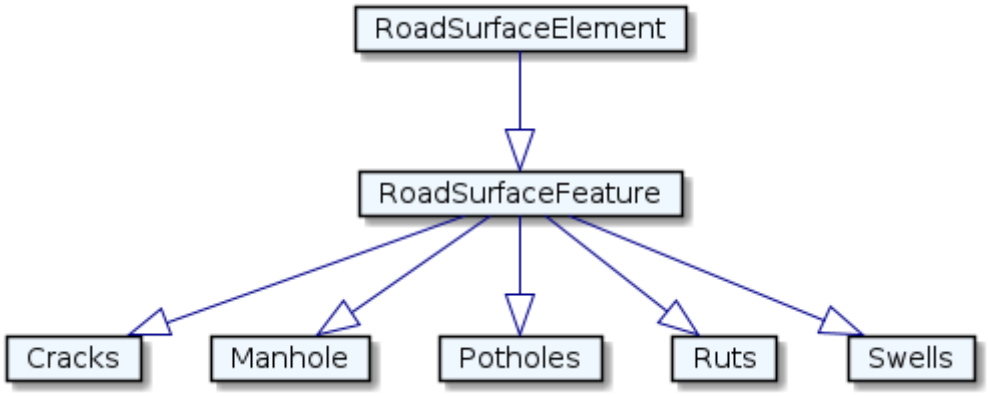
Element	Description
Comments	DEF:RoadSurface is a RoadSurfaceElement, which classify the road surface into different types based on characteristics of the surface material, for example segmented, uniform and loose.

RoadSurfaceElement



Element	Description
Type	Class
Name	RoadSurfaceElement
IRI	http://ontology.asam.net/ontologies/Domain#RoadSurfaceElement
Subclass of	DrivableAreaElement
Comments	DEF: A DrivableArea on a road or sidewalk that is characterized by a specific surface, material, or coating.

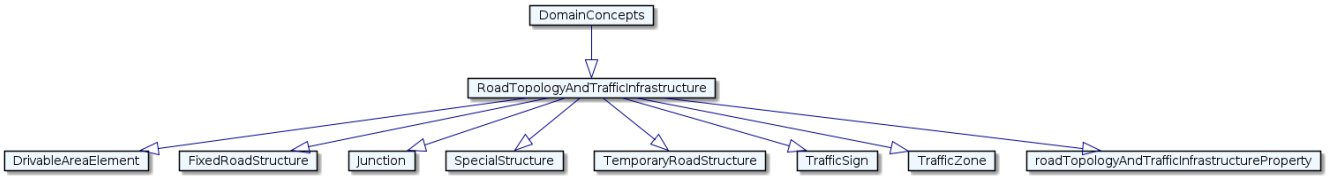
RoadSurfaceFeature



Element	Description
Type	Class
Name	RoadSurfaceFeature

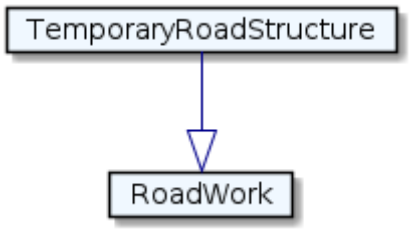
Element	Description
IRI	http://ontology.asam.net/ontologies/Domain#RoadSurfaceFeature
Subclass of	RoadSurfaceElement
Comments	DEF: RoadSurfaceFeature is a RoadSurfaceElements. Drivable area surface features shall include damage caused by traffic and weather. Any road damage (and the resulting different surface features) shall be classified into cracks, potholes, ruts or swells.

RoadTopologyAndTrafficInfrastructure



Element	Description
Type	Class
Name	RoadTopologyAndTrafficInfrastructure
IRI	http://ontology.asam.net/ontologies/Domain#RoadTopologyAndTrafficInfrastructure
Subclass of	DomainConcepts
Comments	DEF: A set of features for describing the logical road network, traffic infrastructure elements, and related conditions.

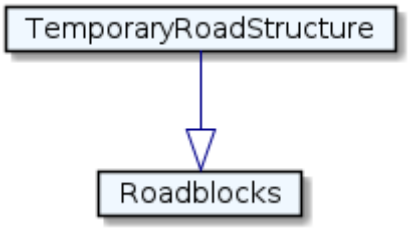
RoadWork



Element	Description
Type	Class
Name	RoadWork
IRI	http://ontology.asam.net/ontologies/Domain#RoadWork
Subclass of	TemporaryRoadStructure

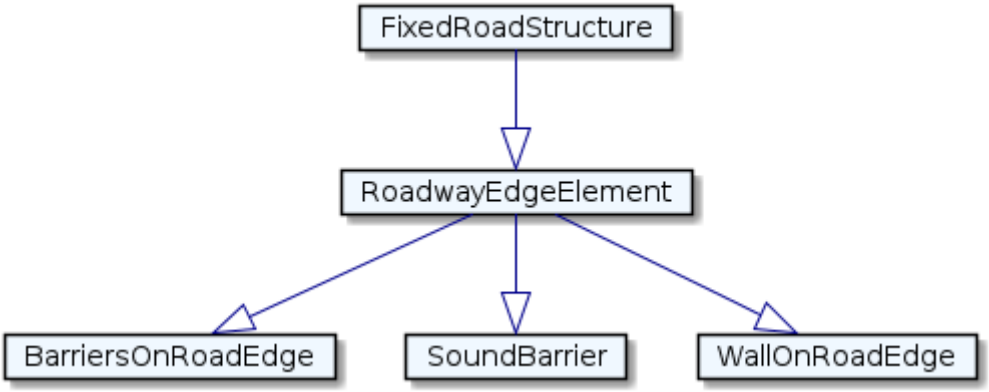
Element	Description
Comments	DEF: A TemporaryRoadStructure that is the part of a road under construction. As a result, the road layout may change.

Roadblocks



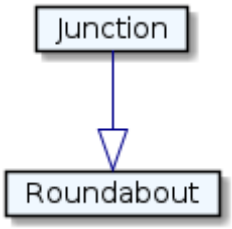
Element	Description
Type	Class
Name	Roadblocks
IRI	http://ontology.asam.net/ontologies/Domain#Roadblocks
Subclass of	TemporaryRoadStructure
Comments	DEF: A TemporaryRoadStructure that is set up to block or control traffic along a road.

RoadwayEdgeElement



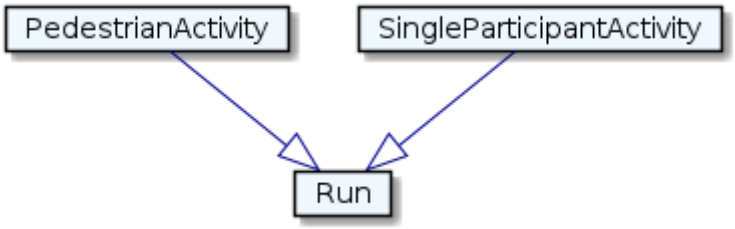
Element	Description
Type	Class
Name	RoadwayEdgeElement
IRI	http://ontology.asam.net/ontologies/Domain#RoadwayEdgeElement
Subclass of	FixedRoadStructure
Comments	DEF: A FixedRoadStructure that forms the side boundary of a road.

Roundabout



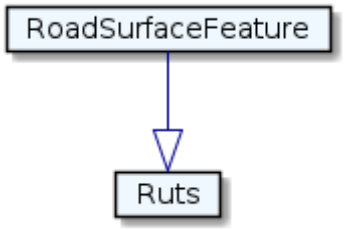
Element	Description
Type	Class
Name	Roundabout
IRI	http://ontology.asam.net/ontologies/Domain#Roundabout
Subclass of	Junction
Comments	DEF: An Intersection where traffic moves into one direction in a circular shape around a central island to reach one of the roads leading into or out of the traffic circle. Roundabouts may have traffic signals.

Run



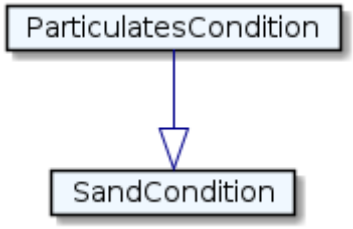
Element	Description
Type	Class
Name	Run
IRI	http://ontology.asam.net/ontologies/Domain#Run
Subclass of	PedestrianActivity
Subclass of	SingleParticipantActivity
Comments	DEF: A PedestrianActivity where the biological object moves in such a way that at a specific point in time no foot touches the ground.

Ruts



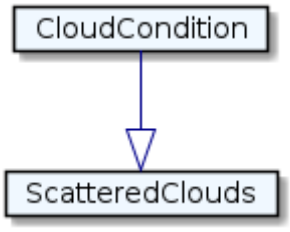
Element	Description
Type	Class
Name	Ruts
IRI	http://ontology.asam.net/ontologies/Domain#Ruts
Subclass of	RoadSurfaceFeature

SandCondition



Element	Description
Type	Class
Name	SandCondition
IRI	http://ontology.asam.net/ontologies/Domain#SandCondition
Subclass of	ParticulatesCondition
Comments	DEF: A ParticulateCondition where the particles consist of sand or dust.

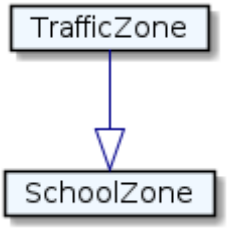
ScatteredClouds



Element	Description
Type	Class
Name	ScatteredClouds

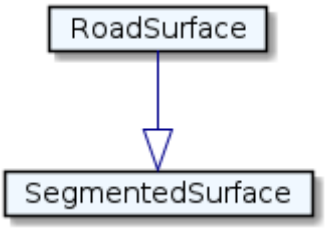
Element	Description
IRI	http://ontology.asam.net/ontologies/Domain#ScatteredClouds
Subclass of	CloudCondition
Comments	DEF: ScatteredClouds is a CloudCondition, is it described by the cloudinessLevel property using oktas unit, ScatteredClouds is when the cloudinessLevel is 3-4 oktas.

SchoolZone



Element	Description
Type	Class
Name	SchoolZone
IRI	http://ontology.asam.net/ontologies/Domain#SchoolZone
Subclass of	TrafficZone
Comments	DEF: A Zone that is a road section near a school or near a crosswalk used by students. It is likely that younger pedestrians are present in this area.

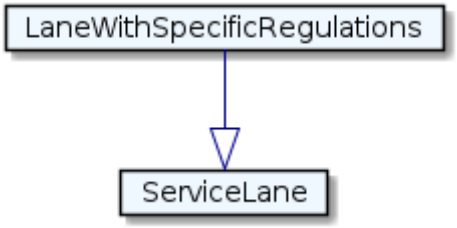
SegmentedSurface



Element	Description
Type	Class
Name	SegmentedSurface
IRI	http://ontology.asam.net/ontologies/Domain#SegmentedSurface
Subclass of	RoadSurface

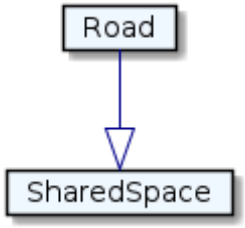
Element	Description
Comments	DEF:SegmentedSurface is a RoadSurface that consists of individual segments of certain type of surface material. An example of a segmented road surface could contain segments of concrete panels to form the surface.

ServiceLane



Element	Description
Type	Class
Name	ServiceLane
IRI	http://ontology.asam.net/ontologies/Domain#ServiceLane
Subclass of	LaneWithSpecificRegulations
Comments	DEF: ServiceLane is a LaneWithSpecificRegulations that which offer enough space for a car to drive and stop in emergency cases - typically on highways. Usually on the right side of drivable lanes, but can also be on the left side.

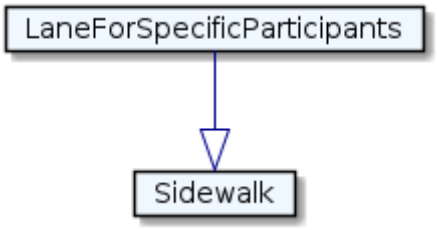
SharedSpace



Element	Description
Type	Class
Name	SharedSpace
IRI	http://ontology.asam.net/ontologies/Domain#SharedSpace
Subclass of	Road

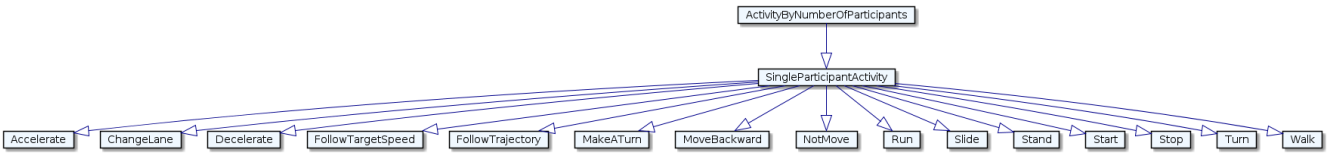
Element	Description
Comments	DEF: A Road that may be used equally by vehicles and pedestrians. Shared spaces are designed to minimize the segregation between traffic participants.This is done by reducing traffic management features that tend to encourge users of vehicles to assume priority, such as curbs and lane markings.

Sidewalk



Element	Description
Type	Class
Name	Sidewalk
IRI	http://ontology.asam.net/ontologies/Domain#Sidewalk
Subclass of	LaneForSpecificParticipants
Comments	DEF: Sidewalk is a LaneForSpecificParticipants that is designated for pedestrians or cyclist. Delimited from the road by some obstacles or poles, but not only by marking. Often elevated compared to the road and often located at the side of a road. Also includes walkable parts of traffic islands, but not pedestrian areas.

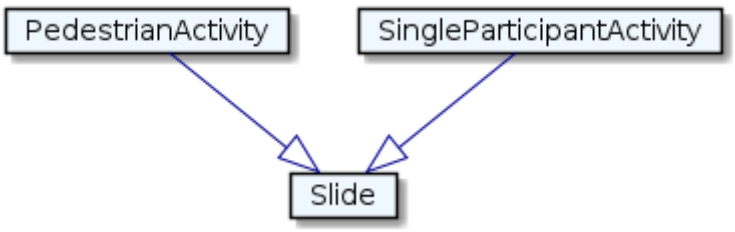
SingleParticipantActivity



Element	Description
Type	Class
Name	SingleParticipantActivity
IRI	http://ontology.asam.net/ontologies/Domain#SingleParticipantActivity
Subclass of	ActivityByNumberOfParticipants

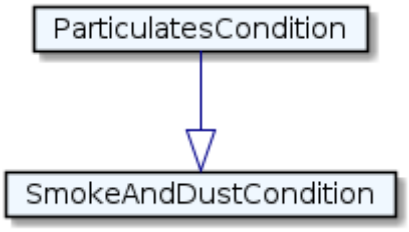
Element	Description
Comments	DEF: A set of activities which involve exactly one traffic participant.

Slide



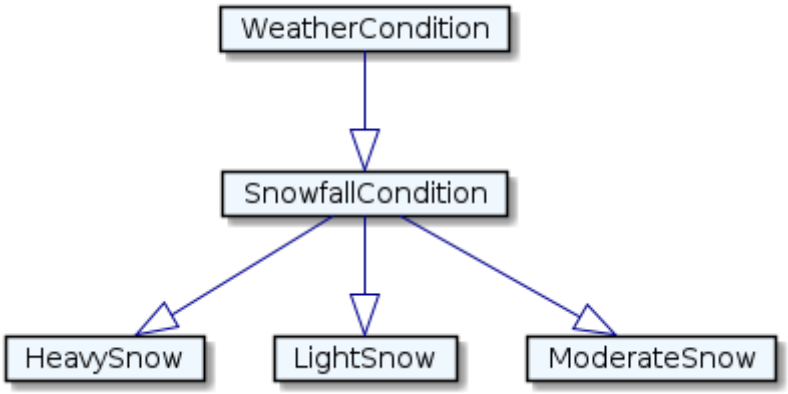
Element	Description
Type	Class
Name	Slide
IRI	http://ontology.asam.net/ontologies/Domain#Slide
Subclass of	PedestrianActivity
Subclass of	SingleParticipantActivity
Comments	DEF: A PedestrianActivity where the biological object moves in such a way that the feet always touch the ground.

SmokeAndDustCondition



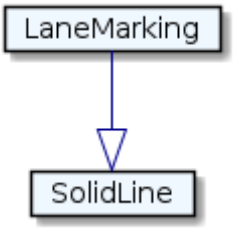
Element	Description
Type	Class
Name	SmokeAndDustCondition
IRI	http://ontology.asam.net/ontologies/Domain#SmokeAndDustCondition
Subclass of	ParticulatesCondition
Comments	DEF: A ParticulateCondition where the particles consist of smoke or pollution.

SnowfallCondition



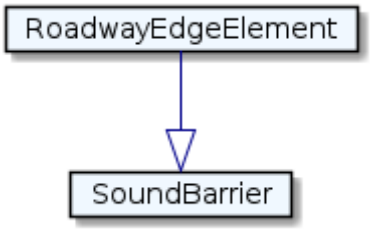
Element	Description
Type	Class
Name	SnowfallCondition
IRI	http://ontology.asam.net/ontologies/Domain#SnowfallCondition
Subclass of	WeatherCondition
Comments	DEF: A WeatherCondition where it snows. The intensity of the snowfall may be described by the SnowfallIntensity property.

SolidLine



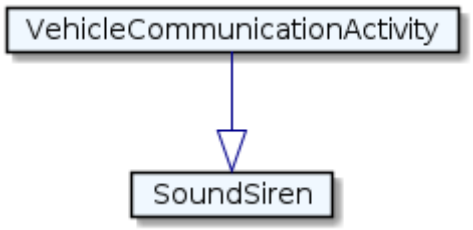
Element	Description
Type	Class
Name	SolidLine
IRI	http://ontology.asam.net/ontologies/Domain#SolidLine
Subclass of	LaneMarking
Comments	DEF: SolidLine is a LaneMarking that is drawn on a two-way road and it indicates that traffic participants cannot overtake the vehicle ahead, or are not allowed to change the lanes.

SoundBarrier



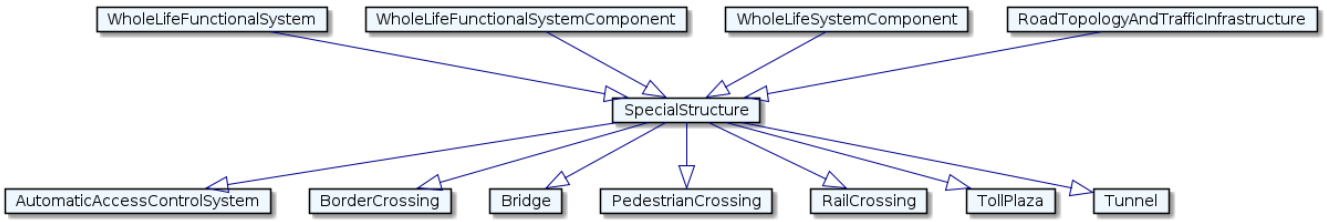
Element	Description
Type	Class
Name	SoundBarrier
IRI	http://ontology.asam.net/ontologies/Domain#SoundBarrier
Subclass of	RoadwayEdgeElement
Comments	DEF: A RoadwayEdgeElement that is an built structure designed to protect people in residential areas from noise pollution. Sound barriers are usually high walls next to roads.

SoundSiren



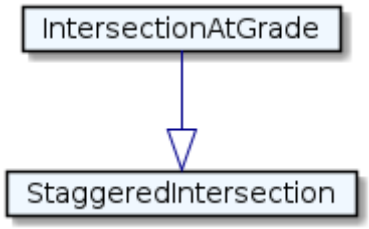
Element	Description
Type	Class
Name	SoundSiren
IRI	http://ontology.asam.net/ontologies/Domain#SoundSiren
Subclass of	VehicleCommunicationActivity
Comments	DEF: A VehicleCommunicatingActivity of an emergency vehicle that uses its siren to alert other traffic participants.

SpecialStructure



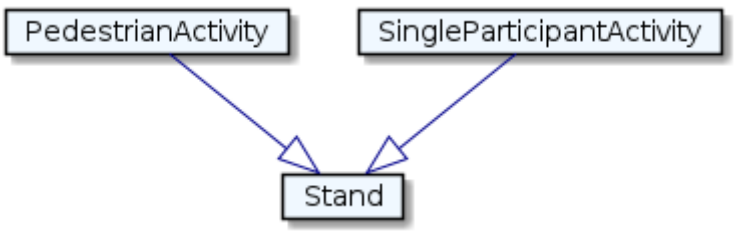
Element	Description
Type	Class
Name	SpecialStructure
IRI	http://ontology.asam.net/ontologies/Domain#SpecialStructure
Subclass of	WholeLifeFunctionalSystem
Subclass of	WholeLifeFunctionalSystemComponent
Subclass of	WholeLifeSystemComponent
Subclass of	RoadTopologyAndTrafficInfrastructure
Comments	DEF: A set of traffic infrastructure types that are installed on road or junctions and on/through which cars can travel.

StaggeredIntersection



Element	Description
Type	Class
Name	StaggeredIntersection
IRI	http://ontology.asam.net/ontologies/Domain#StaggeredIntersection
Subclass of	IntersectionAtGrade
Comments	DEF: An Intersection that consists of two T-junctions that directly follow each other. One intersection is vertically rotated by 180° in relation to the other intersection.

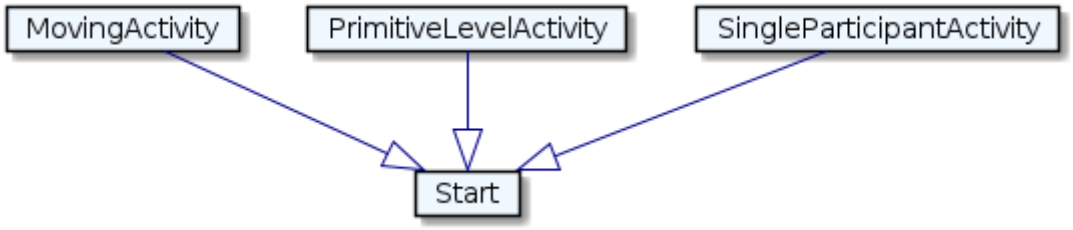
Stand



Element	Description
Type	Class

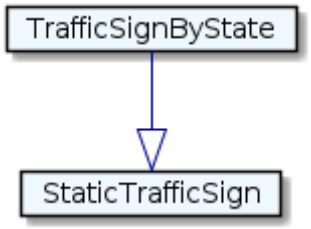
Element	Description
Name	Stand
IRI	http://ontology.asam.net/ontologies/Domain#Stand
Subclass of	PedestrianActivity
Subclass of	SingleParticipantActivity
Comments	DEF: A PedestrianActivity in which the biological object remains with both legs on the ground without moving in any direction.

Start



Element	Description
Type	Class
Name	Start
IRI	http://ontology.asam.net/ontologies/Domain#Start
Subclass of	MovingActivity
Subclass of	PrimitiveLevelActivity
Subclass of	SingleParticipantActivity
Comments	DEF: An Activity that starts with a speed of 0 for the subject traffic participant and ends with the traffic participant driving at a non-zero speed.

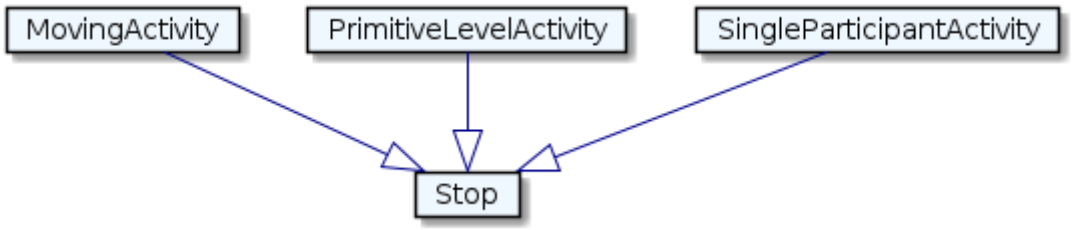
StaticTrafficSign



Element	Description
Type	Class
Name	StaticTrafficSign

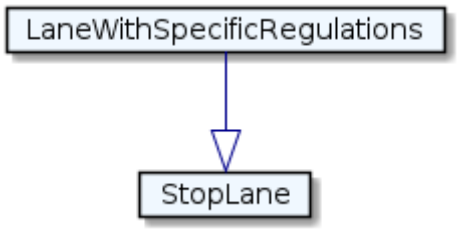
Element	Description
IRI	http://ontology.asam.net/ontologies/Domain#StaticTrafficSign
Subclass of	TrafficSignByState
Comments	DEF: A traffic sign whose content is static, meaning it does not change over time.

Stop



Element	Description
Type	Class
Name	Stop
IRI	http://ontology.asam.net/ontologies/Domain#Stop
Subclass of	MovingActivity
Subclass of	PrimitiveLevelActivity
Subclass of	SingleParticipantActivity
Comments	DEF: An Activity that starts with the subject traffic participant driving at a non-zero speed and ends with a speed of 0 for the subject.

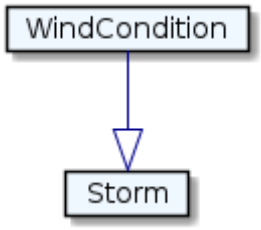
StopLane



Element	Description
Type	Class
Name	StopLane
IRI	http://ontology.asam.net/ontologies/Domain#StopLane
Subclass of	LaneWithSpecificRegulations

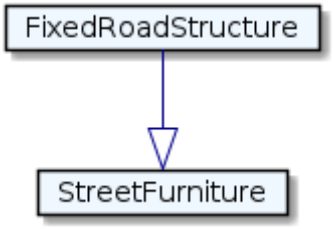
Element	Description
Comments	DEF: StopLane is a LaneWithSpecificRegulations that is on the side of a highway (typically paved). This lane is only allowed for emergency stopping.

Storm



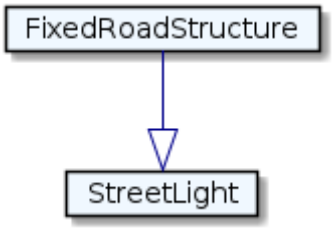
Element	Description
Type	Class
Name	Storm
IRI	http://ontology.asam.net/ontologies/Domain#Storm
Subclass of	WindCondition
Comments	DEF: Storm is a WindCondition, is it described by the WindSpeed property using m/s, Storm is when the WindSpeed is 24.5-28.4 m/s.

StreetFurniture



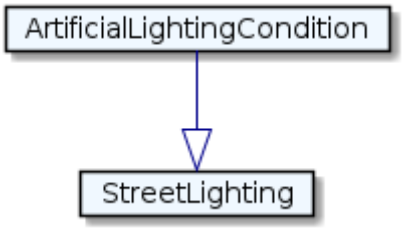
Element	Description
Type	Class
Name	StreetFurniture
IRI	http://ontology.asam.net/ontologies/Domain#StreetFurniture
Subclass of	FixedRoadStructure
Comments	DEF: A FixedRoadStructure installed at or along a road. Street furniture may have different purposes, such as providing resting places, creating obstacles for traffic, or decorating.

StreetLight



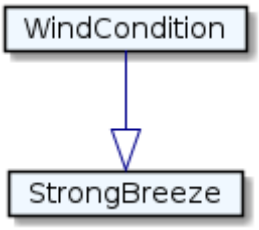
Element	Description
Type	Class
Name	StreetLight
IRI	http://ontology.asam.net/ontologies/Domain#StreetLight
Subclass of	FixedRoadStructure
Comments	DEF: A FixedRoadStructure that is a manufactured source of light on the edge of the road.

StreetLighting



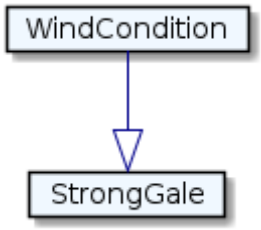
Element	Description
Type	Class
Name	StreetLighting
IRI	http://ontology.asam.net/ontologies/Domain#StreetLighting
Subclass of	ArtificialLightingCondition
Comments	DEF: An ArtificialLightingCondition where the area in question is illuminated by lighting equipment installed along the road, typically mounted on tall posts.

StrongBreeze



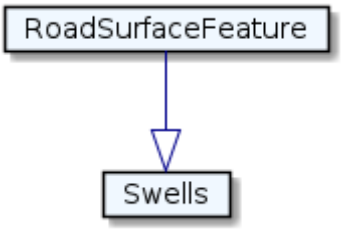
Element	Description
Type	Class
Name	StrongBreeze
IRI	http://ontology.asam.net/ontologies/Domain#StrongBreeze
Subclass of	WindCondition
Comments	DEF: StrongBreeze is a WindCondition, is it described by the WindSpeed property using m/s, StrongBreeze is when the WindSpeed is 10.8-13.8 m/s.

StrongGale



Element	Description
Type	Class
Name	StrongGale
IRI	http://ontology.asam.net/ontologies/Domain#StrongGale
Subclass of	WindCondition
Comments	DEF: StrongGale is a WindCondition, is it described by the WindSpeed property using m/s, StrongGale is when the WindSpeed is 20.8-24.4 m/s.

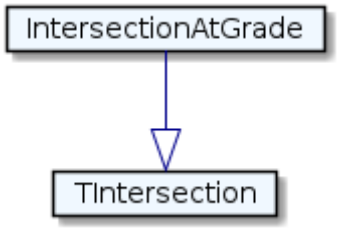
Swells



Element	Description
Type	Class
Name	Swells
IRI	http://ontology.asam.net/ontologies/Domain#Swells

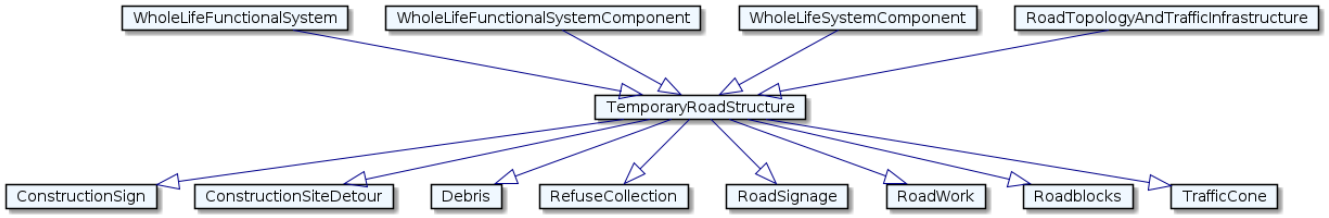
Element	Description
Subclass of	RoadSurfaceFeature
Comments	DEF:Swells is a RoadSurfaceFeature that indicates a raised or elevated surface that was not part of the original road designs and can often be caused by the environmental conditions.

TIntersection



Element	Description
Type	Class
Name	TIntersection
IRI	http://ontology.asam.net/ontologies/Domain#TIntersection
Subclass of	IntersectionAtGrade
Comments	DEF: An Intersection that consists of three roads. Two of the roads form a straight line, the third road meets the others at 90°. The resulting shape is similar to the capital letter T.

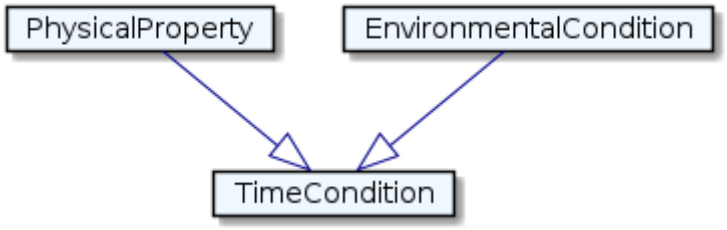
TemporaryRoadStructure



Element	Description
Type	Class
Name	TemporaryRoadStructure
IRI	http://ontology.asam.net/ontologies/Domain#TemporaryRoadStructure
Subclass of	WholeLifeFunctionalSystem
Subclass of	WholeLifeFunctionalSystemComponent
Subclass of	WholeLifeSystemComponent

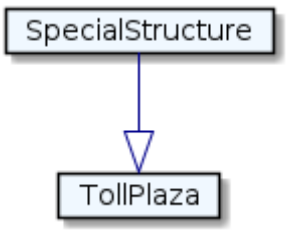
Element	Description
Subclass of	RoadTopologyAndTrafficInfrastructure
Comments	DEF: A traffic infrastructure that is located on a road for limited period of time and because of specific situations, such as accidents, traffic guidance, or construction works

TimeCondition



Element	Description
Type	Class
Name	TimeCondition
IRI	http://ontology.asam.net/ontologies/Domain#TimeCondition
Subclass of	PhysicalProperty
Subclass of	EnvironmentalCondition
Comments	DEF: An EnvironmentalCondition that gives information about the time when a specific traffic situation occurs. Time may be give as time of day, day of week, or date of year.

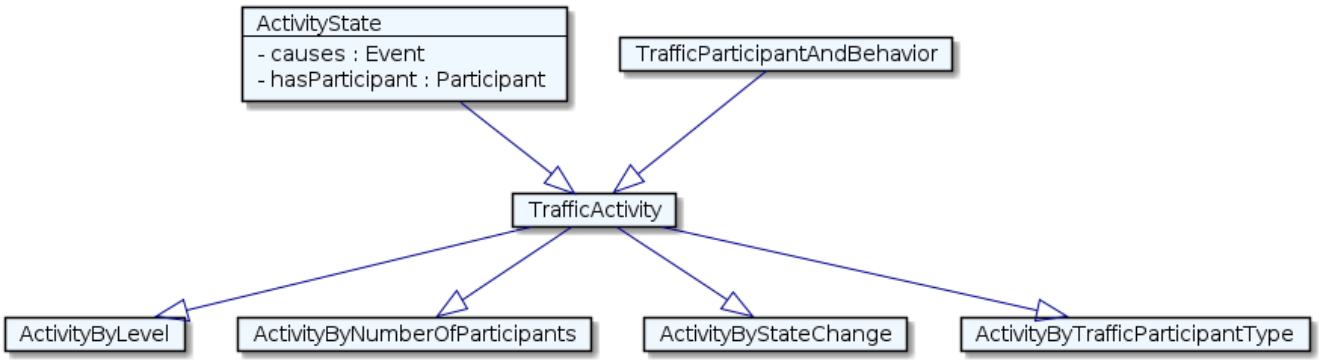
TollPlaza



Element	Description
Type	Class
Name	TollPlaza
IRI	http://ontology.asam.net/ontologies/Domain#TollPlaza
Subclass of	SpecialStructure

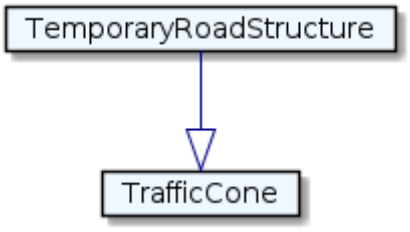
Element	Description
Comments	DEF: A SpecialStructure that contains toll roads, toll boths, and other structures for toll collection.

TrafficActivity



Element	Description
Type	Class
Name	TrafficActivity
IRI	http://ontology.asam.net/ontologies/Domain#TrafficActivity
Subclass of	ActivityState
Subclass of	TrafficParticipantAndBehavior
Comments	DEF: An activity implies actions performed by traffic participants during a traffic situation, typically to achieve a specific goal, like changing a lane.

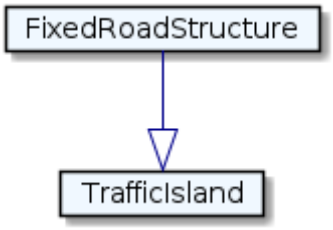
TrafficCone



Element	Description
Type	Class
Name	TrafficCone
IRI	http://ontology.asam.net/ontologies/Domain#TrafficCone
Subclass of	TemporaryRoadStructure

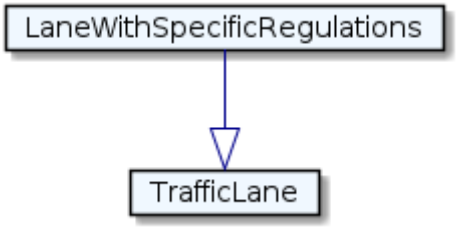
Element	Description
Comments	DEF: A TemporaryRoadStructure that is a solid or hollow cone-shaped marker that is place on roads or sidewalks to temporarily redirect the traffic.

TrafficIsland



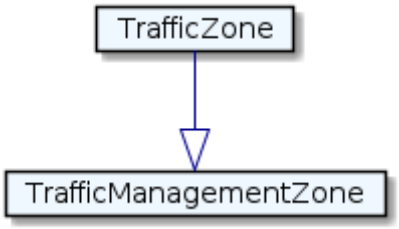
Element	Description
Type	Class
Name	TrafficIsland
IRI	http://ontology.asam.net/ontologies/Domain#TrafficIsland
Subclass of	FixedRoadStructure
Comments	DEF: A FixedRoadStructure that is located on the surface of a road and that serves to guide the traffic flow or protect pedestrians at crosswalks.

TrafficLane



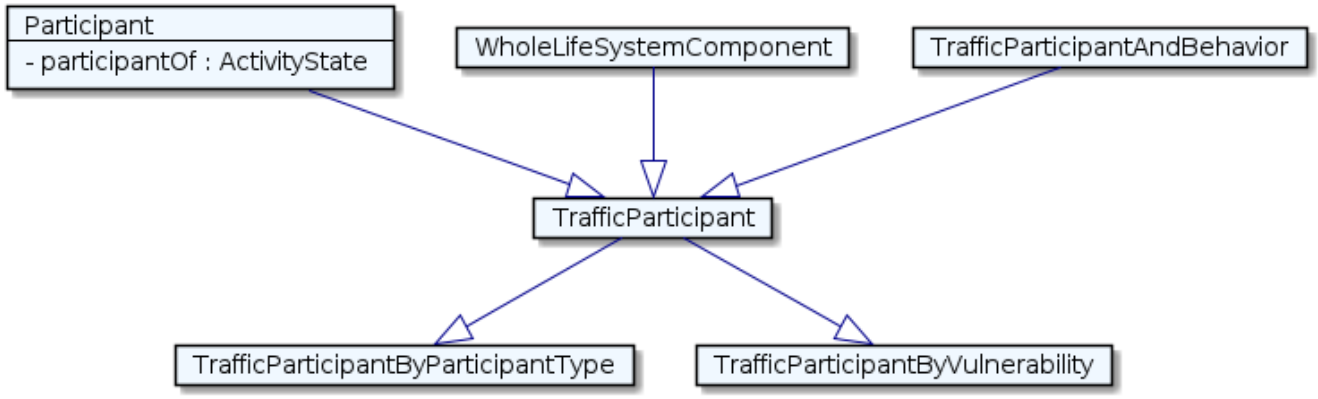
Element	Description
Type	Class
Name	TrafficLane
IRI	http://ontology.asam.net/ontologies/Domain#TrafficLane
Subclass of	LaneWithSpecificRegulations
Comments	DEF: TrafficLane is a type of LaneWithSpecificRegulations. It is intended for motorist to use and not suitable for pedestrians, traffic stream is marked off on a road.

TrafficManagementZone



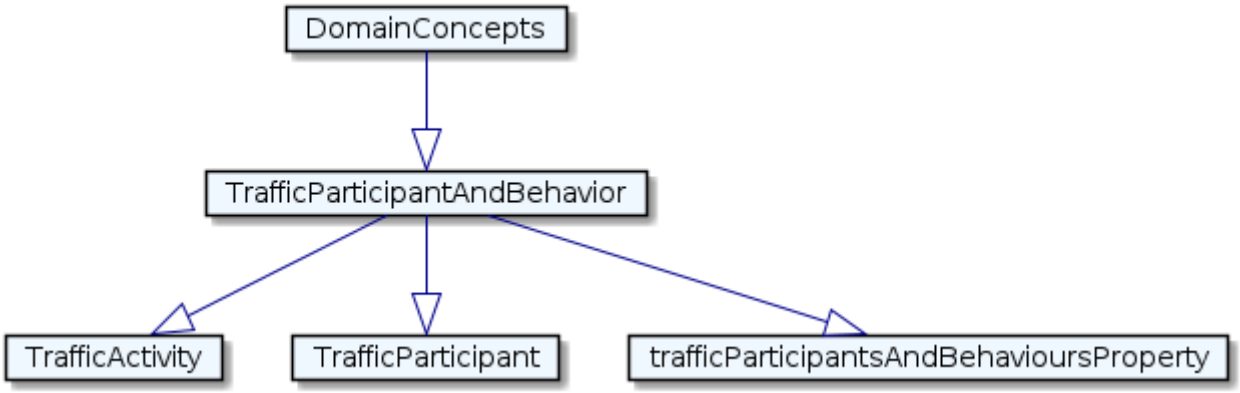
Element	Description
Type	Class
Name	TrafficManagementZone
IRI	http://ontology.asam.net/ontologies/Domain#TrafficManagementZone
Subclass of	TrafficZone
Comments	DEF: A Zone that features infrastructure elements and measures to avoid peaks in the traffic density and create a smooth traffic flow on busy major traffic routes.

TrafficParticipant



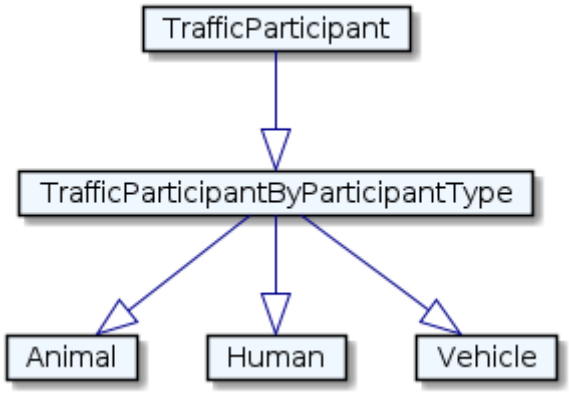
Element	Description
Type	Class
Name	TrafficParticipant
IRI	http://ontology.asam.net/ontologies/Domain#TrafficParticipant
Subclass of	Participant
Subclass of	WholeLifeSystemComponent
Subclass of	TrafficParticipantAndBehavior
Comments	DEF: Traffic participant is A state of a physical object that is participating actively in some traffic activity

TrafficParticipantAndBehavior



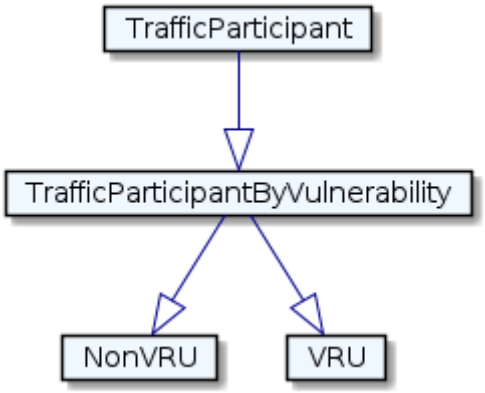
Element	Description
Type	Class
Name	TrafficParticipantAndBehavior
IRI	http://ontology.asam.net/ontologies/Domain#TrafficParticipantAndBehavior
Subclass of	DomainConcepts
Comments	DEF: A set of activities, physical objects, and functional objects that describe traffic participants and their dynamic behavior.

TrafficParticipantByParticipantType



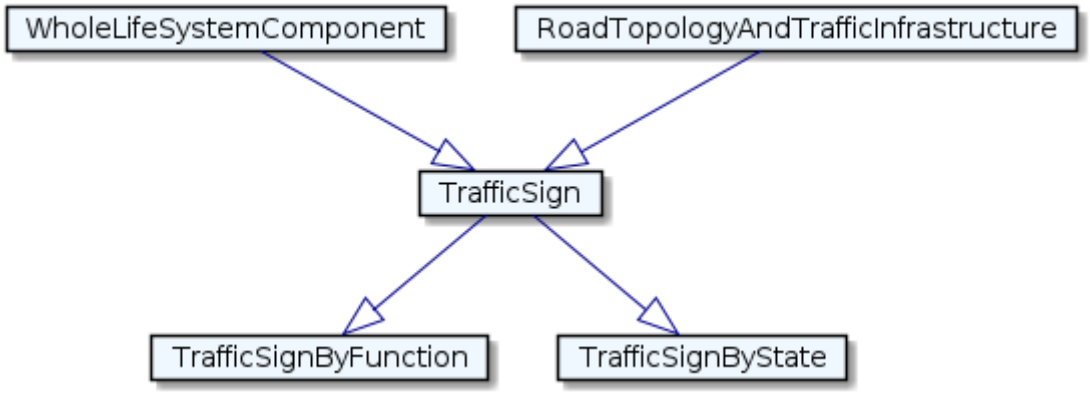
Element	Description
Type	Class
Name	TrafficParticipantByParticipantType
IRI	http://ontology.asam.net/ontologies/Domain#TrafficParticipantByParticipantType
Subclass of	TrafficParticipant
Comments	DEF: A set of traffic participants which are categorized by the individuals that participate in road traffic, such as vehicles or pedestrians.

TrafficParticipantByVulnerability



Element	Description
Type	Class
Name	TrafficParticipantByVulnerability
IRI	http://ontology.asam.net/ontologies/Domain#TrafficParticipantByVulnerability
Subclass of	TrafficParticipant
Comments	DEF: A set of traffic participants categorized by the probability and severity of injuries to people involved in a particular traffic situation.

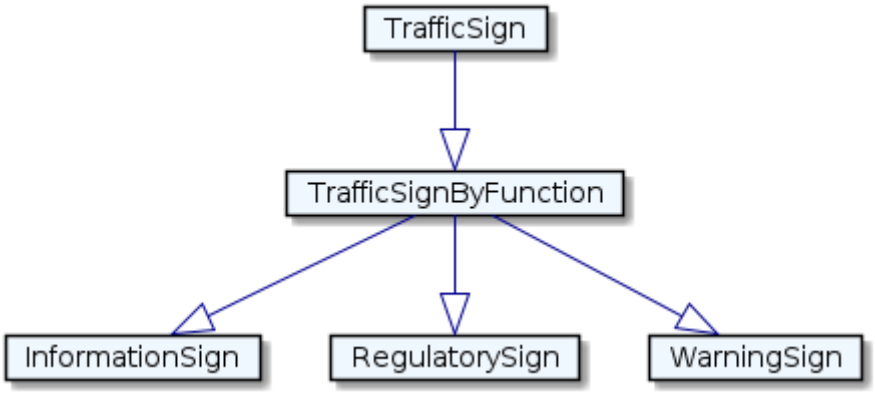
TrafficSign



Element	Description
Type	Class
Name	TrafficSign
IRI	http://ontology.asam.net/ontologies/Domain#TrafficSign
Subclass of	WholeLifeSystemComponent
Subclass of	RoadTopologyAndTrafficInfrastructure

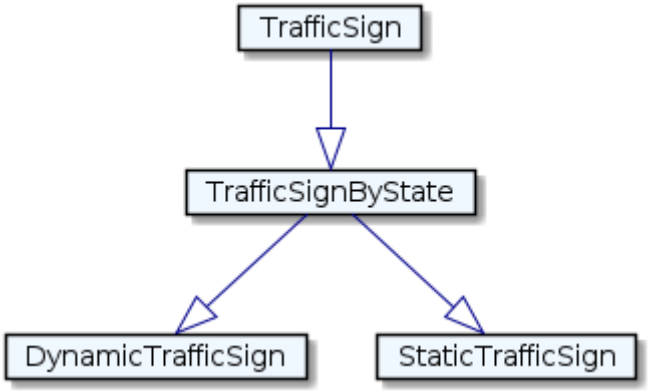
Element	Description
Comments	DEF: A traffic infrastructure element that is a sign located at the side or above a road to provide information or instructions to traffic participants.

TrafficSignByFunction



Element	Description
Type	Class
Name	TrafficSignByFunction
IRI	http://ontology.asam.net/ontologies/Domain#TrafficSignByFunction
Subclass of	TrafficSign
Comments	DEF: A set of traffic signs that groups signs according to type of content that they contain or which purpose they fulfil.

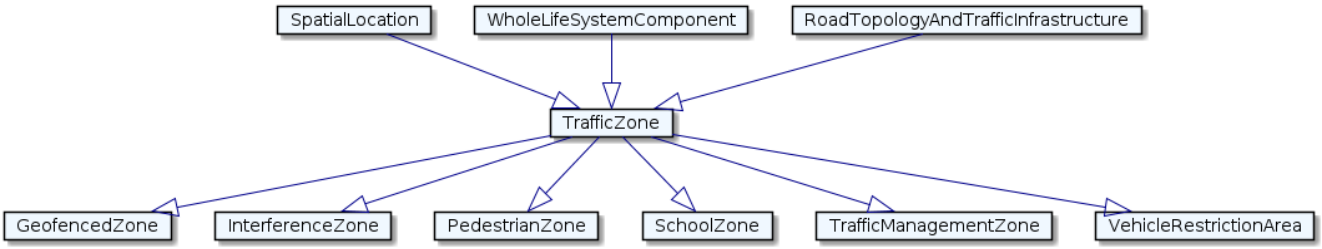
TrafficSignByState



Element	Description
Type	Class
Name	TrafficSignByState

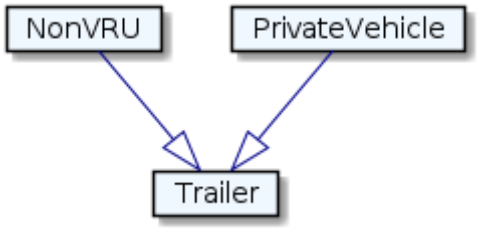
Element	Description
IRI	http://ontology.asam.net/ontologies/Domain#TrafficSignByState
Subclass of	TrafficSign
Comments	DEF: A set of traffic signs that groups signs depending on whether their content can be changed dynamically or is static.

TrafficZone



Element	Description
Type	Class
Name	TrafficZone
IRI	http://ontology.asam.net/ontologies/Domain#TrafficZone
Subclass of	SpatialLocation
Subclass of	WholeLifeSystemComponent
Subclass of	RoadTopologyAndTrafficInfrastructure
Comments	DEF: A geographic area with special road configurations, driving regulations, or environmental conditions. The boundaries of a zone may be fixed or dynamic. The conditions that define a zone may be based on complexity, operating procedures, or other factors.

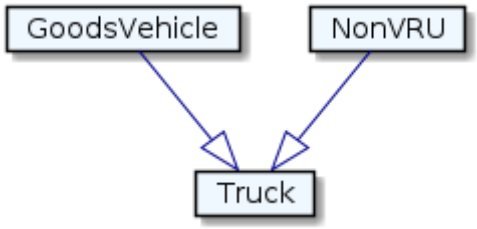
Trailer



Element	Description
Type	Class
Name	Trailer

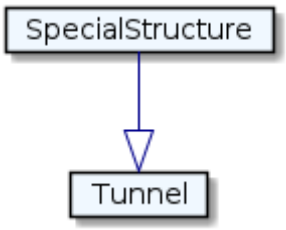
Element	Description
IRI	http://ontology.asam.net/ontologies/Domain#Trailer
Subclass of	NonVRU
Subclass of	PrivateVehicle
Comments	DEF: An unpowered Vehicle that is designed for being towed by another Vehicle.

Truck



Element	Description
Type	Class
Name	Truck
IRI	http://ontology.asam.net/ontologies/Domain#Truck
Subclass of	GoodsVehicle
Subclass of	NonVRU
Comments	DEF: A large and heavy road Vehicle designed and used for carrying goods and materials.

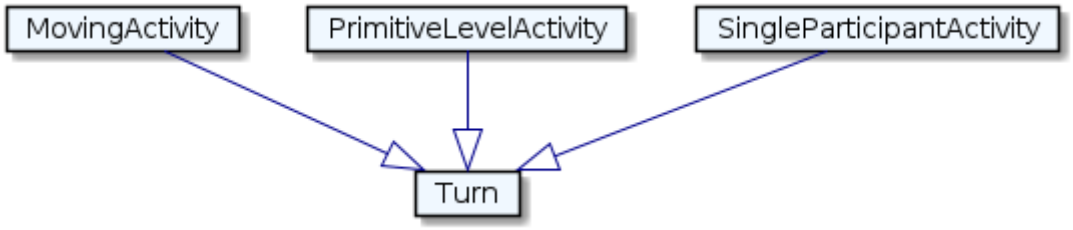
Tunnel



Element	Description
Type	Class
Name	Tunnel
IRI	http://ontology.asam.net/ontologies/Domain#Tunnel
Subclass of	SpecialStructure

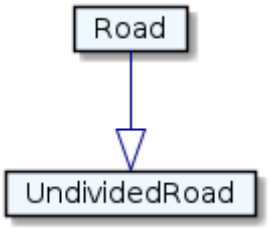
Element	Description
Comments	DEF: A SpecialStructure that is a built underground passage through or below a natural or built structure.

Turn



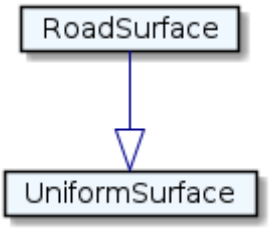
Element	Description
Type	Class
Name	Turn
IRI	http://ontology.asam.net/ontologies/Domain#Turn
Subclass of	MovingActivity
Subclass of	PrimitiveLevelActivity
Subclass of	SingleParticipantActivity
Comments	DEF: An Activity during which the subject traffic participant changes its orientation.

UndividedRoad



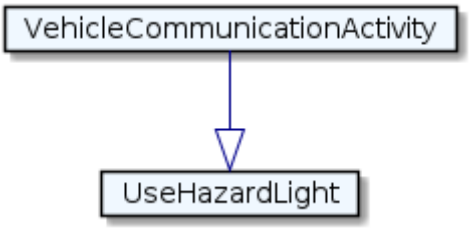
Element	Description
Type	Class
Name	UndividedRoad
IRI	http://ontology.asam.net/ontologies/Domain#UndividedRoad
Subclass of	Road
Comments	DEF: A type of road where traffic travels in both directions; the directions are not separated by a central reservation.

UniformSurface



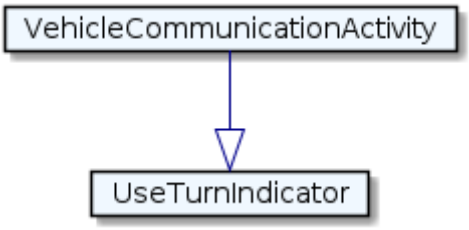
Element	Description
Type	Class
Name	UniformSurface
IRI	http://ontology.asam.net/ontologies/Domain#UniformSurface
Subclass of	RoadSurface
Comments	DEF:UniformSurface is a RoadSurface where the surface material is distributed evenly.

UseHazardLight



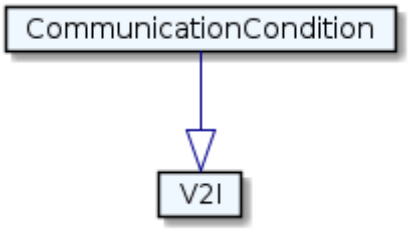
Element	Description
Type	Class
Name	UseHazardLight
IRI	http://ontology.asam.net/ontologies/Domain#UseHazardLight
Subclass of	VehicleCommunicationActivity
Comments	DEF: A VehicleCommunicatingActivity where a vehicle uses its hazard warning lights to warn other traffic participants of a dangerous situation or malfunction of the vehicle.

UseTurnIndicator



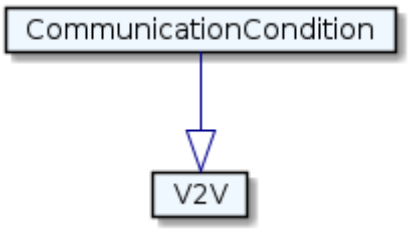
Element	Description
Type	Class
Name	UseTurnIndicator
IRI	http://ontology.asam.net/ontologies/Domain#UseTurnIndicator
Subclass of	VehicleCommunicationActivity
Comments	DEF: A VehicleCommunicatingActivity in which the subject vehicle uses its direction indicator light to indicate its intention of turning, changing lane, or similar.

V2I



Element	Description
Type	Class
Name	V2I
IRI	http://ontology.asam.net/ontologies/Domain#V2I
Subclass of	CommunicationCondition
Comments	DEF: A CommunicationCondition that enables communication between a vehicle and the surrounding infrastructure.

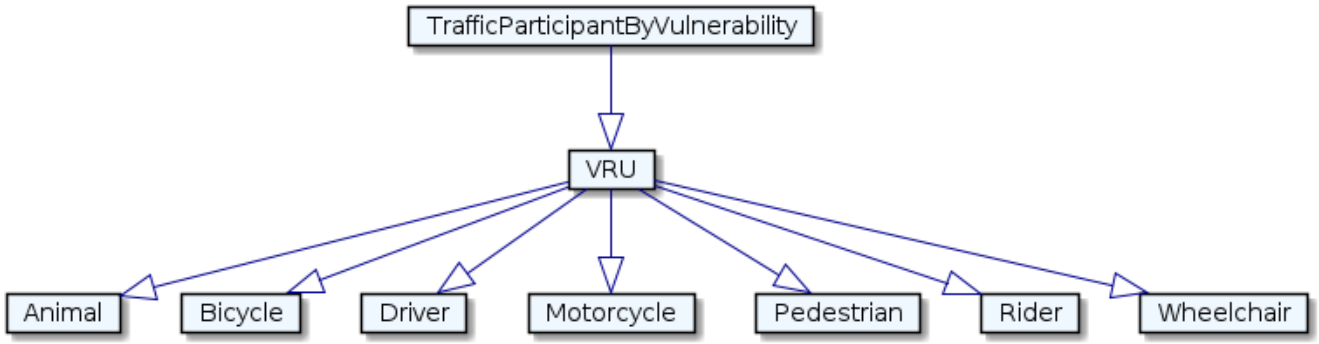
V2V



Element	Description
Type	Class
Name	V2V
IRI	http://ontology.asam.net/ontologies/Domain#V2V
Subclass of	CommunicationCondition

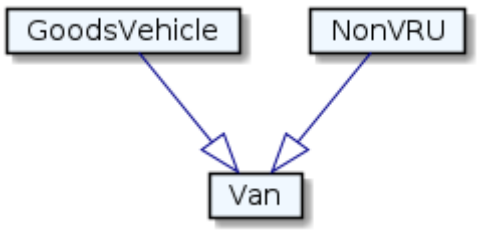
Element	Description
Comments	DEF: A CommunicationCondition that enables communication between a vehicle and other vehicles in a traffic situation.

VRU



Element	Description
Type	Class
Name	VRU
IRI	http://ontology.asam.net/ontologies/Domain#VRU
Subclass of	TrafficParticipantByVulnerability
Comments	DEF: Set of vulnerable road users (VRU) which are non-motorized traffic participants with reduce mobilities and orientation. A VRU includes both the mobility device (if applicable) and the human that controls it.

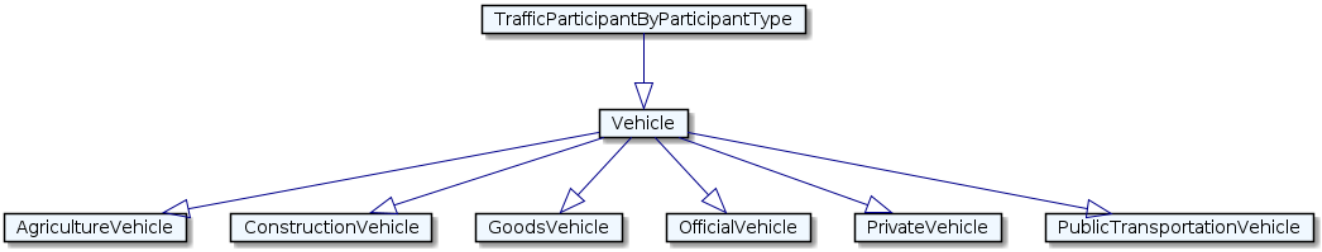
Van



Element	Description
Type	Class
Name	Van
IRI	http://ontology.asam.net/ontologies/Domain#Van
Subclass of	GoodsVehicle
Subclass of	NonVRU

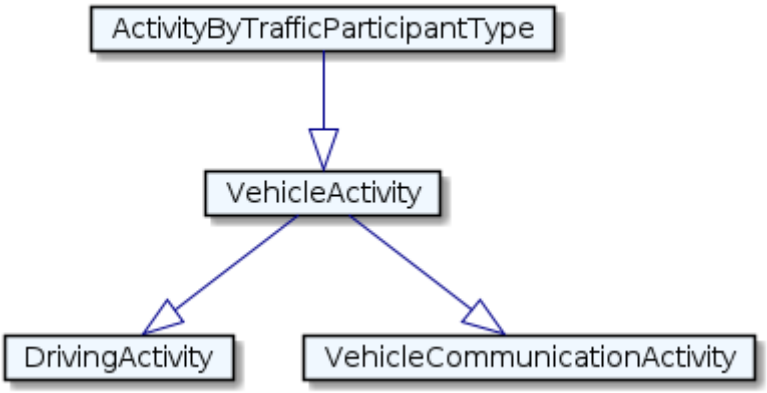
Element	Description
Comments	DEF: A medium sized, motor-powered Vehicle, usually without rear side windows, that is used for transporting goods.

Vehicle



Element	Description
Type	Class
Name	Vehicle
IRI	http://ontology.asam.net/ontologies/Domain#Vehicle
Subclass of	TrafficParticipantByParticipantType
Comments	DEF: A machine that is a TrafficFunctionalObject which has the intended role of transporting things like goods, humans, or animals. Vehicles are participants in traffic-related activities.

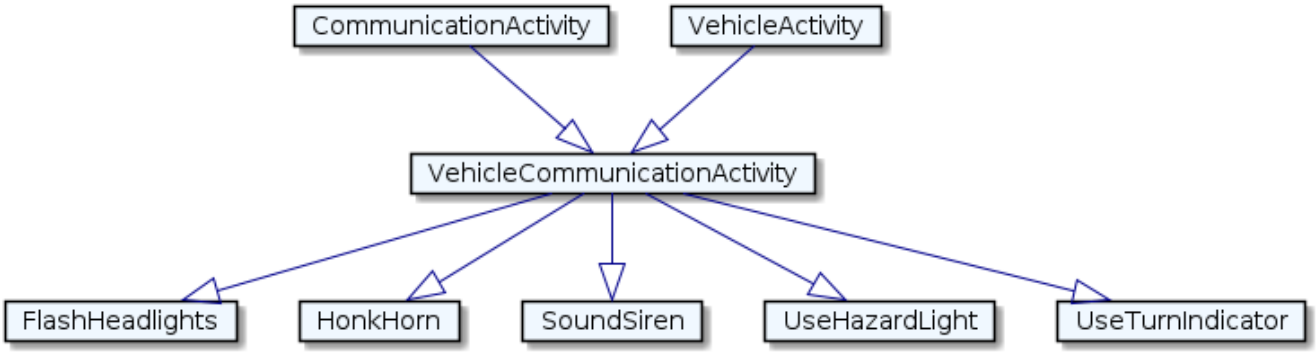
VehicleActivity



Element	Description
Type	Class
Name	VehicleActivity
IRI	http://ontology.asam.net/ontologies/Domain#VehicleActivity
Subclass of	ActivityByTrafficParticipantType

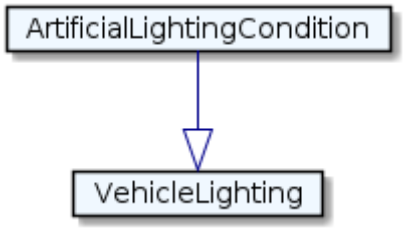
Element	Description
Comments	DEF: A set of activities performed by vehicles.

VehicleCommunicationActivity



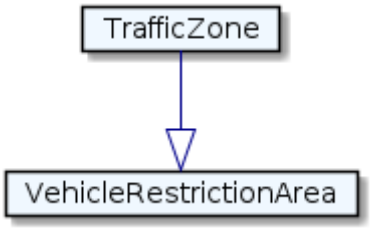
Element	Description
Type	Class
Name	VehicleCommunicationActivity
IRI	http://ontology.asam.net/ontologies/Domain#VehicleCommunicationActivity
Subclass of	CommunicationActivity
Subclass of	VehicleActivity
Comments	DEF: A CommunicatingActivity where the subject is a vehicle.

VehicleLighting



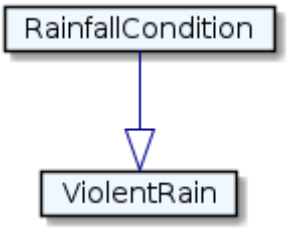
Element	Description
Type	Class
Name	VehicleLighting
IRI	http://ontology.asam.net/ontologies/Domain#VehicleLighting
Subclass of	ArtificialLightingCondition
Comments	DEF: An ArtificialLightingCondition where the area in question is illuminated by lighting or signaling equipment installed on vehicles, for example, headlights.

VehicleRestrictionArea



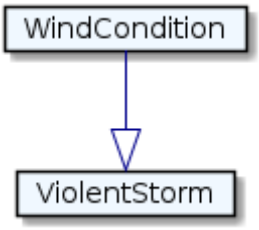
Element	Description
Type	Class
Name	VehicleRestrictionArea
IRI	http://ontology.asam.net/ontologies/Domain#VehicleRestrictionArea
Subclass of	TrafficZone
Comments	DEF: A Zone where specific types of traffic participants are not allowed to travel.

ViolentRain



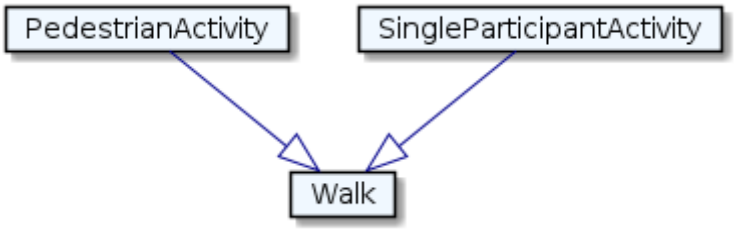
Element	Description
Type	Class
Name	ViolentRain
IRI	http://ontology.asam.net/ontologies/Domain#ViolentRain
Subclass of	RainfallCondition
Comments	DEF: ViolentRain is a RainfallCondition, is it described by the precipitationIntensity property using mm/hr, ViolentRain is when the precipitationIntensity is < 50 -100 mm/hr.

ViolentStorm



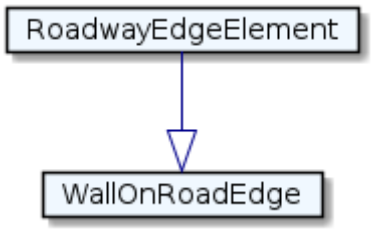
Element	Description
Type	Class
Name	ViolentStorm
IRI	http://ontology.asam.net/ontologies/Domain#ViolentStorm
Subclass of	WindCondition
Comments	DEF: ViolentStorm is a WindCondition, is it described by the WindSpeed property using m/s, ViolentStorm is when the WindSpeed is 28.5-32.6 m/s.

Walk



Element	Description
Type	Class
Name	Walk
IRI	http://ontology.asam.net/ontologies/Domain#Walk
Subclass of	PedestrianActivity
Subclass of	SingleParticipantActivity
Comments	DEF: A PedestrianActivity where the biological object moves in such a way that at least one foot is always on the ground.

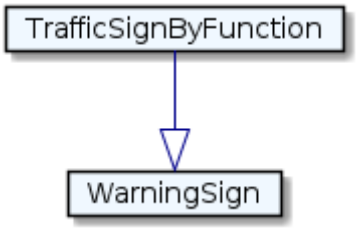
WallOnRoadEdge



Element	Description
Type	Class
Name	WallOnRoadEdge
IRI	http://ontology.asam.net/ontologies/Domain#WallOnRoadEdge

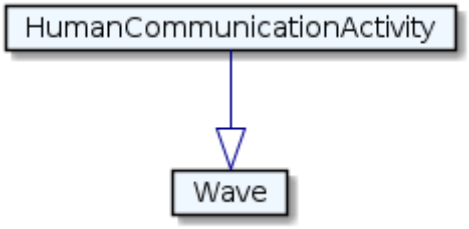
Element	Description
Subclass of	RoadwayEdgeElement
Comments	DEF: A RoadwayEdgeElement that is a vertical structure built from brick or stone and that separates the road from the surrounding area of land.

WarningSign



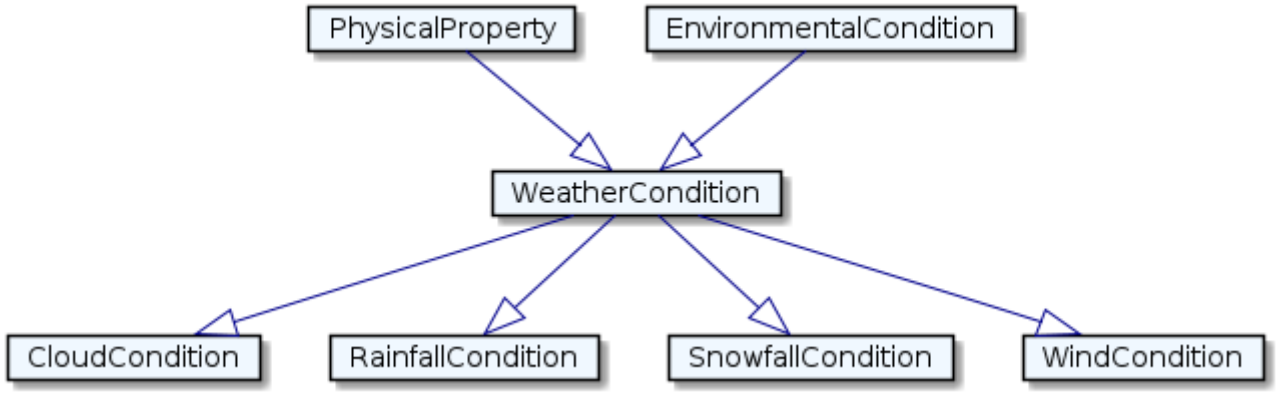
Element	Description
Type	Class
Name	WarningSign
IRI	http://ontology.asam.net/ontologies/Domain#WarningSign
Subclass of	TrafficSignByFunction
Comments	DEF: A traffic sign that warns traffic participants of potential dangers ahead so that these can react accordingly, for example, reduce speed.

Wave



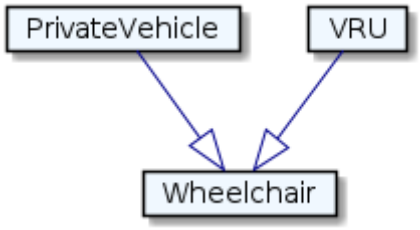
Element	Description
Type	Class
Name	Wave
IRI	http://ontology.asam.net/ontologies/Domain#Wave
Subclass of	HumanCommunicationActivity
Comments	DEF: An Activity of a human traffic participant which waves a hand to indicate their intention.

WeatherCondition



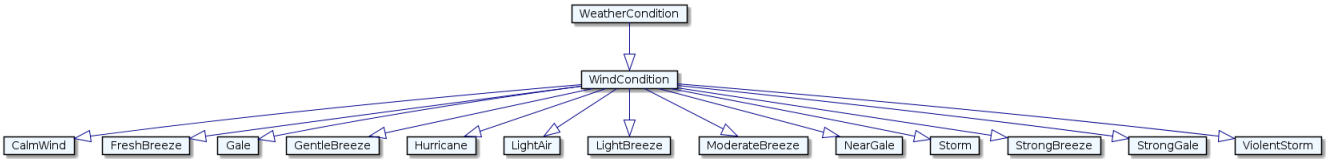
Element	Description
Type	Class
Name	WeatherCondition
IRI	http://ontology.asam.net/ontologies/Domain#WeatherCondition
Subclass of	PhysicalProperty
Subclass of	EnvironmentalCondition
Comments	DEF: An EnvironmentalCondition that comprises the characteristics of the atmosphere in terms of wind, rain, fog, snowfall and other natural phenomena.

Wheelchair



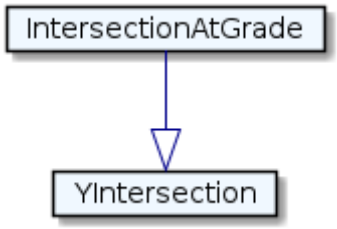
Element	Description
Type	Class
Name	Wheelchair
IRI	http://ontology.asam.net/ontologies/Domain#Wheelchair
Subclass of	PrivateVehicle
Subclass of	VRU
Comments	DEF: A traffic participant which consists of a (handicapped) person sitting in a chair that is equipped with wheels. The person uses the chair as means of transport.

WindCondition



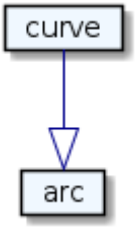
Element	Description
Type	Class
Name	WindCondition
IRI	http://ontology.asam.net/ontologies/Domain#WindCondition
Subclass of	WeatherCondition
Comments	DEF: A WeatherCondition that defines the wind properties within a traffic situation. Properties can include speed, direction, and other characteristics.

YIntersection



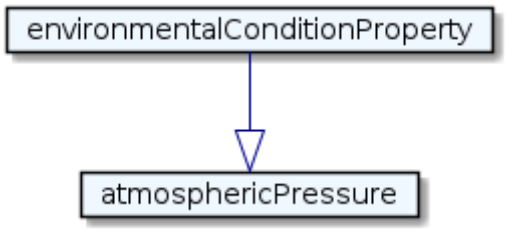
Element	Description
Type	Class
Name	YIntersection
IRI	http://ontology.asam.net/ontologies/Domain#YIntersection
Subclass of	IntersectionAtGrade
Comments	DEF: An Intersection with three roads that has the shape of the capital letter Y.

arc



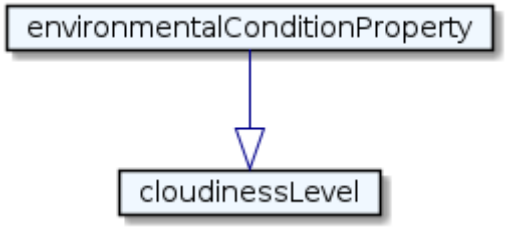
Element	Description
Type	Class
Name	arc
IRI	http://ontology.asam.net/ontologies/Domain#arc
Subclass of	curve
Comments	DEF: A Curve with a constant curvature.

atmosphericPressure



Element	Description
Type	Class
Name	atmosphericPressure
IRI	http://ontology.asam.net/ontologies/Domain#atmosphericPressure
Subclass of	environmentalConditionProperty
Comments	DEF: An ambientConditionProperty that specifies the force per given area unit exerted by the atmosphere. Pascal is used as unit of measurement; values may range from 0 to infinity.

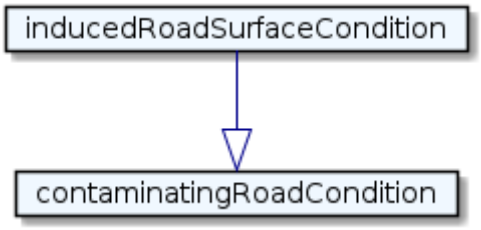
cloudinessLevel



Element	Description
Type	Class
Name	cloudinessLevel
IRI	http://ontology.asam.net/ontologies/Domain#cloudinessLevel
Subclass of	environmentalConditionProperty

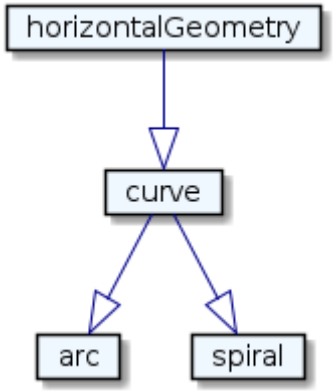
Element	Description
Comments	DEF: An ambientConditionProperty that determines the amount of sky covered in clouds. Okta is used as unit of measurement.

contaminatingRoadCondition



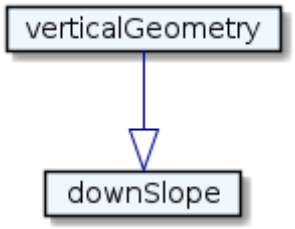
Element	Description
Type	Class
Name	contaminatingRoadCondition
IRI	http://ontology.asam.net/ontologies/Domain#contaminatingRoadCondition
Subclass of	inducedRoadSurfaceCondition
Comments	DEF: An InducedRoadSurfaceCondition where the road surface is covered with substances or a mix of substances and other materials.

curve



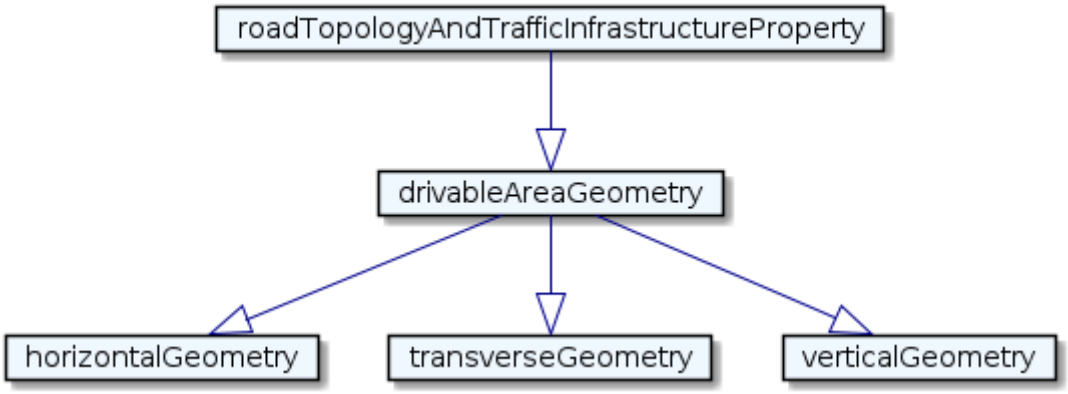
Element	Description
Type	Class
Name	curve
IRI	http://ontology.asam.net/ontologies/Domain#curve
Subclass of	horizontalGeometry
Comments	DEF: A HorizontalGeometry that is not straight.

downSlope



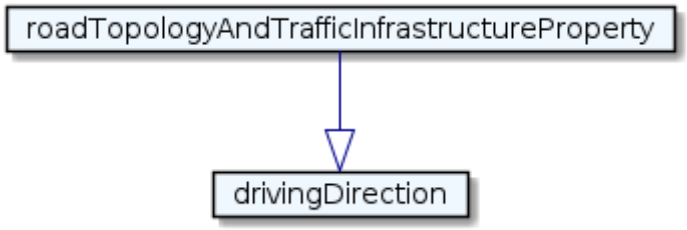
Element	Description
Type	Class
Name	downSlope
IRI	http://ontology.asam.net/ontologies/Domain#downSlope
Subclass of	verticalGeometry
Comments	DEF: A VerticalGeometry that is a plane with negative gradient. It represents a descending elevation of the road in driving direction.

drivableAreaGeometry



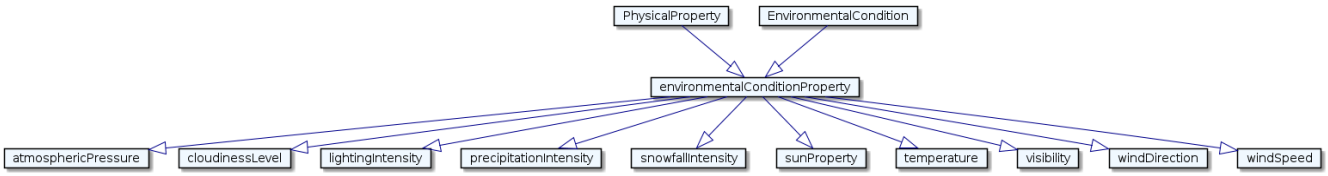
Element	Description
Type	Class
Name	drivableAreaGeometry
IRI	http://ontology.asam.net/ontologies/Domain#drivableAreaGeometry
Subclass of	roadTopologyAndTrafficInfrastructureProperty
Comments	DEF: Shape of a drivable area described as geometry.

drivingDirection



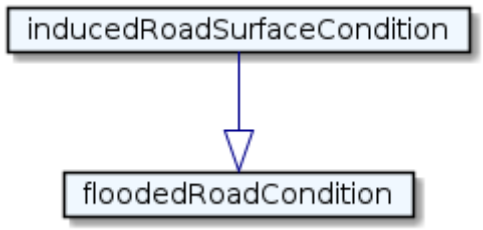
Element	Description
Type	Class
Name	drivingDirection
IRI	http://ontology.asam.net/ontologies/Domain#drivingDirection
Subclass of	roadTopologyAndTrafficInfrastructureProperty
Comments	DEF: A traffic infrastructure property that indicates whether traffic participants keep on the left or right side of the road in birectional travel.

environmentalConditionProperty



Element	Description
Type	Class
Name	environmentalConditionProperty
IRI	http://ontology.asam.net/ontologies/Domain#environmentalConditionProperty
Subclass of	PhysicalProperty
Subclass of	EnvironmentalCondition

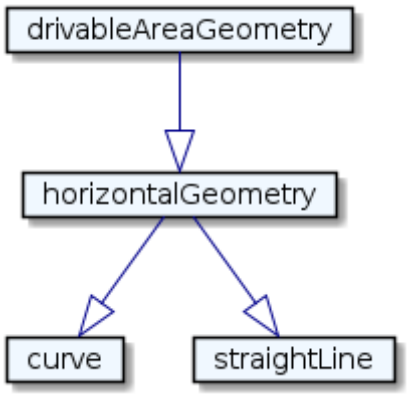
floodedRoadCondition



Element	Description
Type	Class
Name	floodedRoadCondition

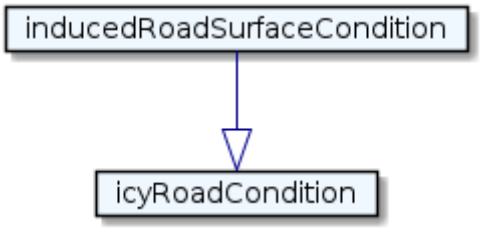
Element	Description
IRI	http://ontology.asam.net/ontologies/Domain#floodedRoadCondition
Subclass of	inducedRoadSurfaceCondition
Comments	DEF: An InducedRoadSurfaceCondition where the road is covered with flowing water, especially from rain.

horizontalGeometry



Element	Description
Type	Class
Name	horizontalGeometry
IRI	http://ontology.asam.net/ontologies/Domain#horizontalGeometry
Subclass of	drivableAreaGeometry
Comments	DEF: A DrivableAreaGeometry in the horizontal plane

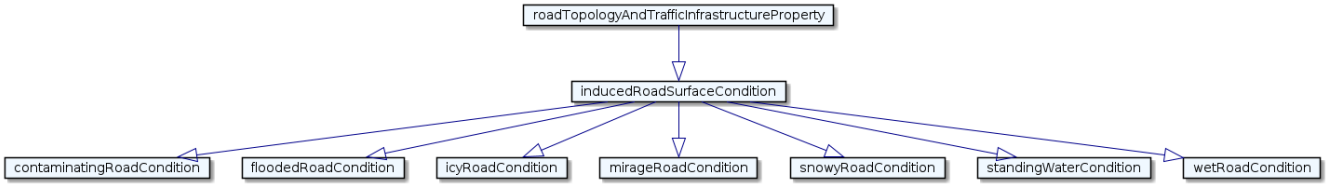
icyRoadCondition



Element	Description
Type	Class
Name	icyRoadCondition
IRI	http://ontology.asam.net/ontologies/Domain#icyRoadCondition

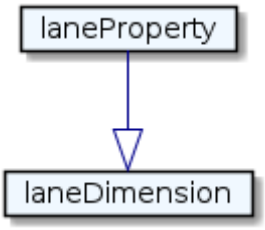
Element	Description
Subclass of	inducedRoadSurfaceCondition
Comments	DEF: An InducedRoadSurfaceCondition where the road is completely or partially covered with ice.

inducedRoadSurfaceCondition



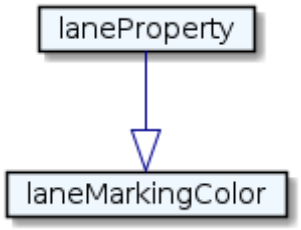
Element	Description
Type	Class
Name	inducedRoadSurfaceCondition
IRI	http://ontology.asam.net/ontologies/Domain#inducedRoadSurfaceCondition
Subclass of	roadTopologyAndTrafficInfrastructureProperty
Comments	DEF: A traffic infrastructure property that describes the conditions on the road surface caused by environmental influences, such as rain or snow.

laneDimension



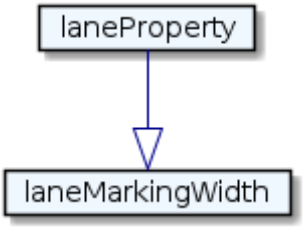
Element	Description
Type	Class
Name	laneDimension
IRI	http://ontology.asam.net/ontologies/Domain#laneDimension
Subclass of	laneProperty
Comments	DEF: A LaneProperty that is the width of the lane.

laneMarkingColor



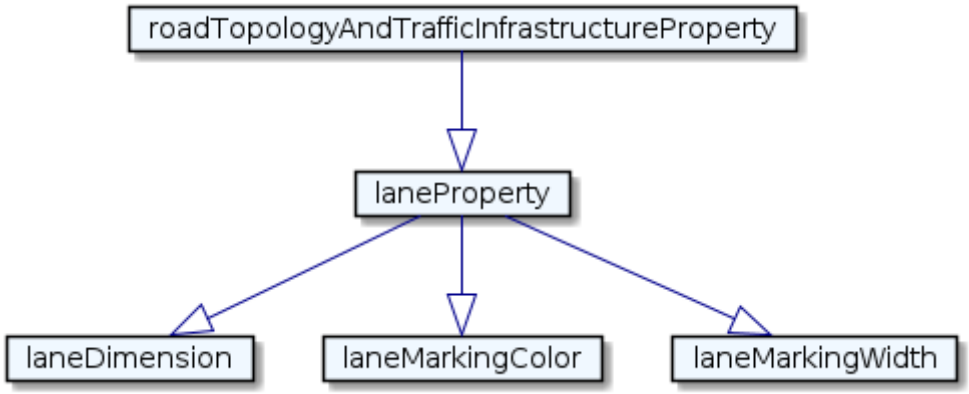
Element	Description
Type	Class
Name	laneMarkingColor
IRI	http://ontology.asam.net/ontologies/Domain#laneMarkingColor
Subclass of	laneProperty
Comments	DEF: A LaneProperty that is the colour of the lane marking.

laneMarkingWidth



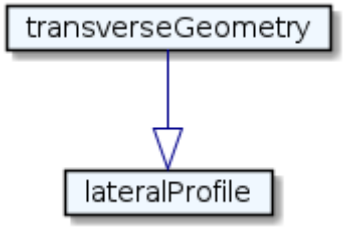
Element	Description
Type	Class
Name	laneMarkingWidth
IRI	http://ontology.asam.net/ontologies/Domain#laneMarkingWidth
Subclass of	laneProperty
Comments	DEF: A LaneProperty that is the width of the lane marking.

laneProperty



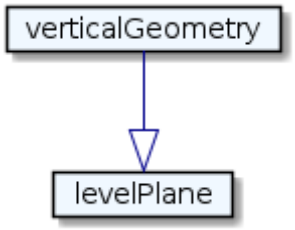
Element	Description
Type	Class
Name	laneProperty
IRI	http://ontology.asam.net/ontologies/Domain#laneProperty
Subclass of	roadTopologyAndTrafficInfrastructureProperty
Comments	DEF: A traffic infrastructure property that describes the characteristics of a lane.

lateralProfile



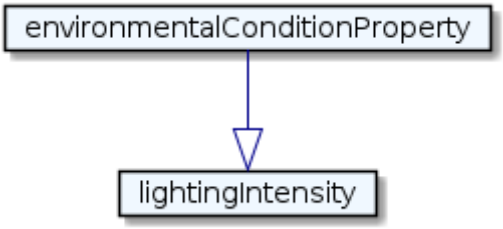
Element	Description
Type	Class
Name	lateralProfile
IRI	http://ontology.asam.net/ontologies/Domain#lateralProfile
Subclass of	transverseGeometry
Comments	DEF: A TransverseGeometry that specifies the elevation of a road orthogonally to a reference line.

levelPlane



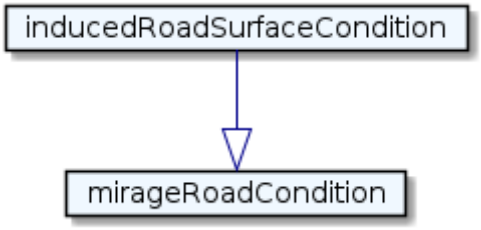
Element	Description
Type	Class
Name	levelPlane
IRI	http://ontology.asam.net/ontologies/Domain#levelPlane
Subclass of	verticalGeometry
Comments	DEF: A VerticalGeometry that is a plane with a gradient of 0. All points of the plane are on the same vertical level.

lightingIntensity



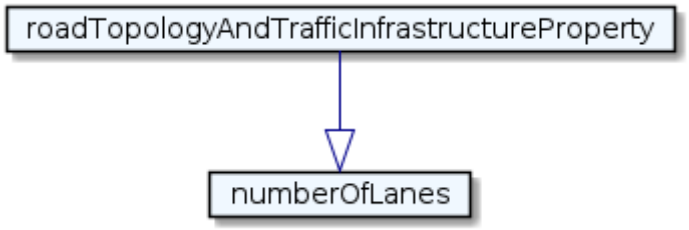
Element	Description
Type	Class
Name	lightingIntensity
IRI	http://ontology.asam.net/ontologies/Domain#lightingIntensity
Subclass of	environmentalConditionProperty
Comments	DEF: An ambientConditionProperty that describes the intensity of illumination by a lighting source. Lux is used as unit of measurement.

mirageRoadCondition



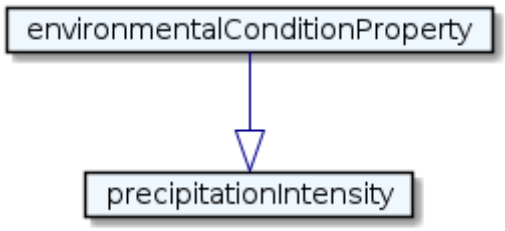
Element	Description
Type	Class
Name	mirageRoadCondition
IRI	http://ontology.asam.net/ontologies/Domain#mirageRoadCondition
Subclass of	inducedRoadSurfaceCondition
Comments	DEF: An InducedRoadSurfaceCondition where displaced images of distant objects or the sky appear. A mirage is a natural optical phenomenon caused by the bending of light rays via refraction.

numberOfLanes



Element	Description
Type	Class
Name	numberOfLanes
IRI	http://ontology.asam.net/ontologies/Domain#numberOfLanes
Subclass of	roadTopologyAndTrafficInfrastructureProperty
Comments	DEF: A traffic infrastructure property that indicates how many lanes a road has.

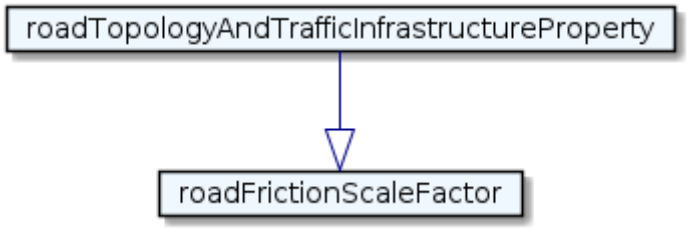
precipitationIntensity



Element	Description
Type	Class
Name	precipitationIntensity
IRI	http://ontology.asam.net/ontologies/Domain#precipitationIntensity
Subclass of	environmentalConditionProperty

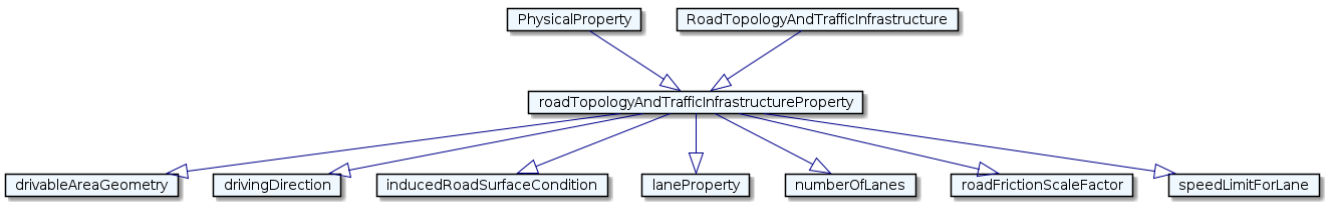
Element	Description
Comments	DEF: An ambientProperty that measures the level of rainfall. mm/hr is used as unit of measurement. It gives the amount or volume of water per fixed amount of time (hour).

roadFrictionScaleFactor



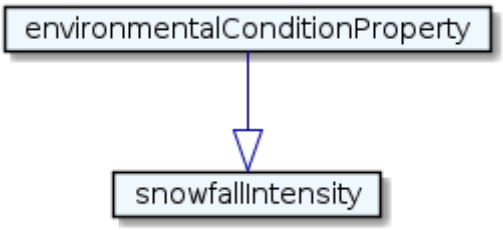
Element	Description
Type	Class
Name	roadFrictionScaleFactor
IRI	http://ontology.asam.net/ontologies/Domain#roadFrictionScaleFactor
Subclass of	roadTopologyAndTrafficInfrastructureProperty
Comments	DEF: RoadFrictionScaleFactor is a RoadTopologyAndTrafficInfrastructureProperty that describes the Friction scale factor

roadTopologyAndTrafficInfrastructureProperty



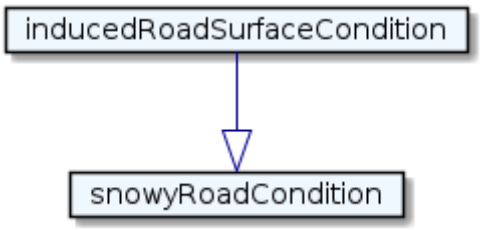
Element	Description
Type	Class
Name	roadTopologyAndTrafficInfrastructureProperty
IRI	http://ontology.asam.net/ontologies/Domain#roadTopologyAndTrafficInfrastructureProperty
Subclass of	PhysicalProperty
Subclass of	RoadTopologyAndTrafficInfrastructure

snowfallIntensity



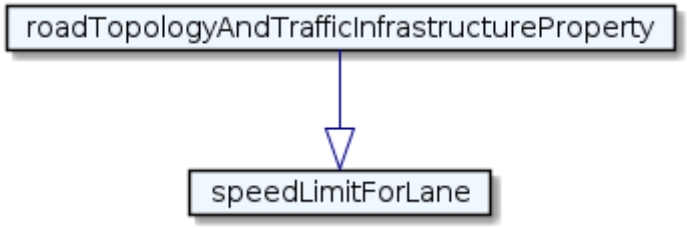
Element	Description
Type	Class
Name	snowfallIntensity
IRI	http://ontology.asam.net/ontologies/Domain#snowfallIntensity
Subclass of	environmentalConditionProperty
Comments	DEF: An ambientProperty that quantifies the amount of snow that falls within an area. mm/hr is used as unit of measurement. It gives the amount or volume of water per fixed amount of time (hour).

snowyRoadCondition



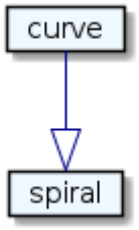
Element	Description
Type	Class
Name	snowyRoadCondition
IRI	http://ontology.asam.net/ontologies/Domain#snowyRoadCondition
Subclass of	inducedRoadSurfaceCondition
Comments	DEF: An InducedRoadSurfaceCondition where snow covers the surface of the road. Snow on the surface lowers the friction coefficent and can obscure lane markings.

speedLimitForLane



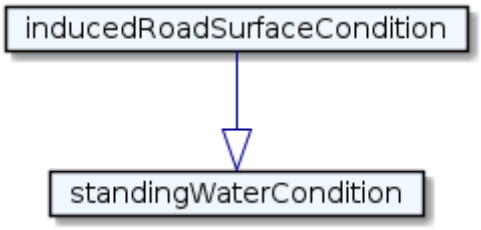
Element	Description
Type	Class
Name	speedLimitForLane
IRI	http://ontology.asam.net/ontologies/Domain#speedLimitForLane
Subclass of	roadTopologyAndTrafficInfrastructureProperty

spiral



Element	Description
Type	Class
Name	spiral
IRI	http://ontology.asam.net/ontologies/Domain#spiral
Subclass of	curve
Comments	DEF: A Curve with a changing curvature that is described as a clothoid. Spirals may be used to describe the transitions between geometric shapes and help avoiding leaps and gaps in the curvature.

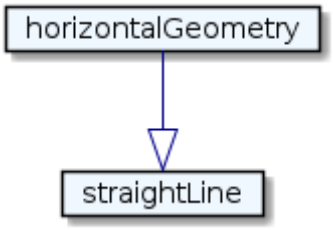
standingWaterCondition



Element	Description
Type	Class
Name	standingWaterCondition
IRI	http://ontology.asam.net/ontologies/Domain#standingWaterCondition
Subclass of	inducedRoadSurfaceCondition

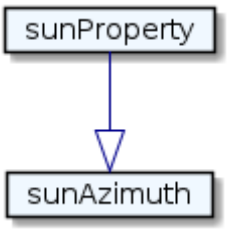
Element	Description
Comments	DEF: An InducedRoadSurfaceCondition where the road is covered with non-flowing (standing) water. Standing water often occurs in road sinks.

straightLine



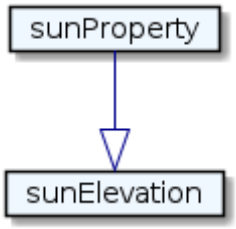
Element	Description
Type	Class
Name	straightLine
IRI	http://ontology.asam.net/ontologies/Domain#straightLine
Subclass of	horizontalGeometry
Comments	DEF: A HorizontalGeometry that runs as a straight line in the associated coordinate system.

sunAzimuth



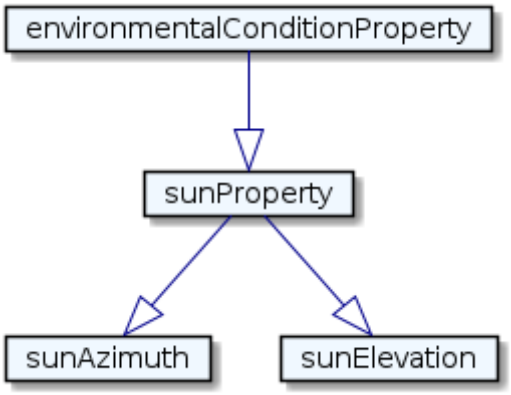
Element	Description
Type	Class
Name	sunAzimuth
IRI	http://ontology.asam.net/ontologies/Domain#sunAzimuth
Subclass of	sunProperty
Comments	DEF: A sunProperty that is the azimuth angle of the sun's position. It is defined as the angle between a line due south and the shadow cast by a vertical rod on Earth.

sunElevation



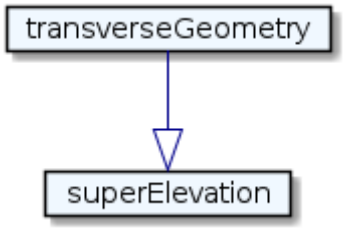
Element	Description
Type	Class
Name	sunElevation
IRI	http://ontology.asam.net/ontologies/Domain#sunElevation
Subclass of	sunProperty
Comments	DEF: A sunProperty that is the solar zenith angle, which is defined as the angle between the sun's rays and the vertical direction. It is complementary to the solar altitude angle, which is the angle between the sun's rays and a horizontal plane.

sunProperty



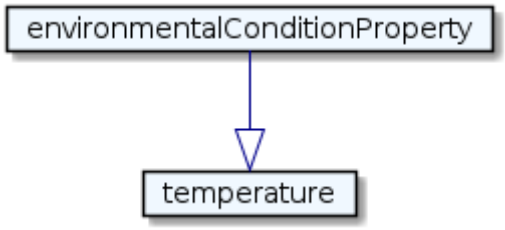
Element	Description
Type	Class
Name	sunProperty
IRI	http://ontology.asam.net/ontologies/Domain#sunProperty
Subclass of	environmentalConditionProperty
Comments	DEF: An ambientConditionProperty that defines characteristics of the sun, for example, azimuth and elevation.

superElevation



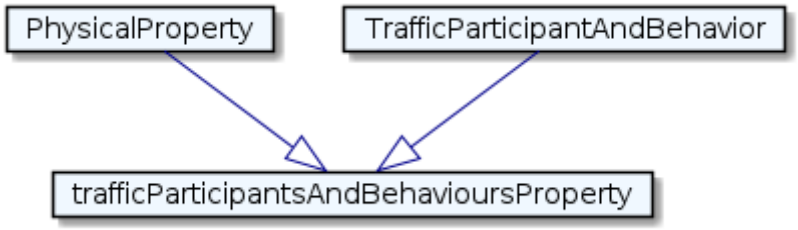
Element	Description
Type	Class
Name	superElevation
IRI	http://ontology.asam.net/ontologies/Domain#superElevation
Subclass of	transverseGeometry
Comments	DEF: A TransverseGeometry the specifies the cross slope of a road, meaning the roll angle of the road cross section around a reference line.

temperature



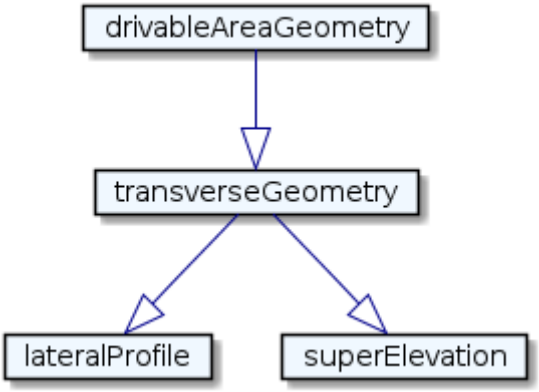
Element	Description
Type	Class
Name	temperature
IRI	http://ontology.asam.net/ontologies/Domain#temperature
Subclass of	environmentalConditionProperty
Comments	DEF: An ambientConditionProperty that describes how warm or cold it is. Temperature is given in one of the following units: Kelvin [K], Celsius[⊠] or Fahrenheit [⊠].

trafficParticipantsAndBehavioursProperty



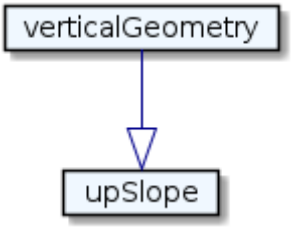
Element	Description
Type	Class
Name	trafficParticipantsAndBehavioursProperty
IRI	http://ontology.asam.net/ontologies/Domain#trafficParticipantsAndBehavioursProperty
Subclass of	PhysicalProperty
Subclass of	TrafficParticipantAndBehavior

transverseGeometry



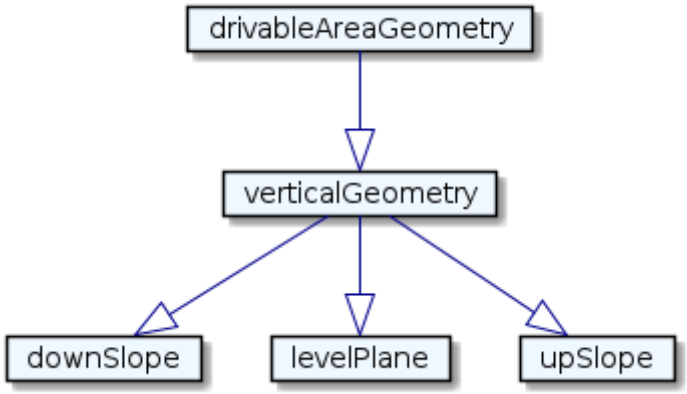
Element	Description
Type	Class
Name	transverseGeometry
IRI	http://ontology.asam.net/ontologies/Domain#transverseGeometry
Subclass of	drivableAreaGeometry
Comments	DEF: A DrivableAreaGeometry in the cross-section plane; the transverse profile

upSlope



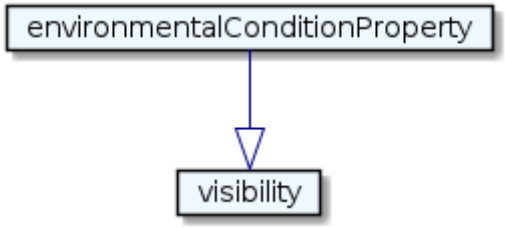
Element	Description
Type	Class
Name	upSlope
IRI	http://ontology.asam.net/ontologies/Domain#upSlope
Subclass of	verticalGeometry
Comments	DEF: A VerticalGeometry that is a plane with positive gradient. It represents an ascending elevation of the road in driving direction.

verticalGeometry



Element	Description
Type	Class
Name	verticalGeometry
IRI	http://ontology.asam.net/ontologies/Domain#verticalGeometry
Subclass of	drivableAreaGeometry
Comments	DEF: A DrivableAreaGeometry in the vertical (longitudinal) plane

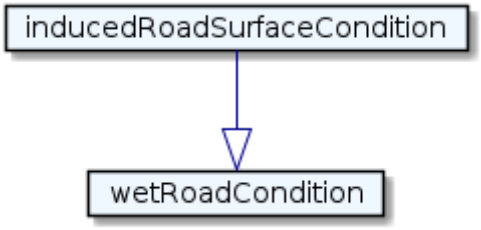
visibility



Element	Description
Type	Class
Name	visibility

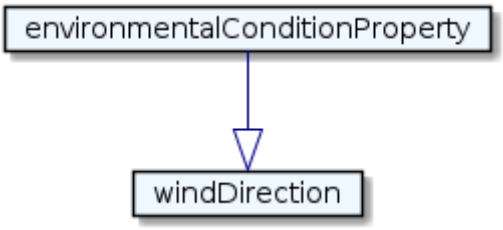
Element	Description
IRI	http://ontology.asam.net/ontologies/Domain#visibility
Subclass of	environmentalConditionProperty
Comments	DEF: An ambientConditionProperty type that specifies the distance at which a thing can be clearly discerned. The distance may be specified in meters, kilometers, or miles.

wetRoadCondition



Element	Description
Type	Class
Name	wetRoadCondition
IRI	http://ontology.asam.net/ontologies/Domain#wetRoadCondition
Subclass of	inducedRoadSurfaceCondition
Comments	DEF: An InducedRoadSurfaceCondition where the road is covered with a thin layer of water. This can lower the friction coefficent.

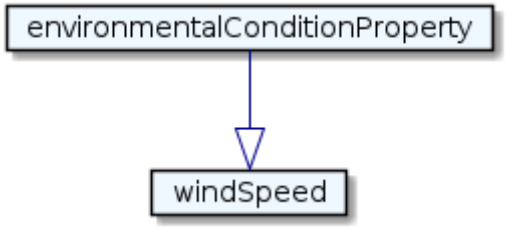
windDirection



Element	Description
Type	Class
Name	windDirection
IRI	http://ontology.asam.net/ontologies/Domain#windDirection
Subclass of	environmentalConditionProperty

Element	Description
Comments	DEF: An ambientConditionProperty that characterizes the direction from which the wind is coming. The direction may be specified as cardinal direction or in degrees. Example: Wind coming from the North is defined as a wind direction of 0° or 360°.

windSpeed



Element	Description
Type	Class
Name	windSpeed
IRI	http://ontology.asam.net/ontologies/Domain#windSpeed
Subclass of	environmentalConditionProperty
Comments	DEF: An ambientConditionProperty that defines how strong the wind is blowing. Wind speed is given in m/s.

A.2.2. Properties

Appendix B: Evaluation of ontology languages and rule languages for ASAM OpenXOntology

Different modeling and rule languages are available for ontologies. This topic gives a short summary of the considerations behind the decisions for OWL and SWRL that ASAM OpenXOntology uses.

B.1. Requirements of ASAM OpenXOntology

ASAM OpenXOntology has the goal to ensure semantic interoperability between OpenX standards. This interoperability must address the various differences in data models, information sources, and world views present within the OpenX standards. Also, the modeling principles must match the underlying nature of the things involved, for example, in the road traffic domain.

In order to realize such an ontology, the ontology modeling language must be capable of:

- Forming a conceptual representation of the knowledge domain, in this case the traffic domain.
- Formalizing the knowledge domain by means of logic.
- Generating structured data that is machine-interpretable.
- Representing both qualitative and quantitative data.
- Representing hierarchies of classes.

B.2. Evaluation of ontology languages

There are several ontology languages that are in wide use within the context of the Semantic Web and Linked Open Data.

Ontology languages can be classified in two ways:

- By structure
- By syntax

Structure

The structure of ontology languages can be categorized as follows:

Frame-based structure	Based on description logic	Based on first-order logic
F-Logic (Frame Logic)	Web Ontology Language (OWL)	Common Logic (CL)
KM programming language	RDF Schema (RDFS)	CycL
Simple Knowledge Organization System (SKOS)	OntoUML and UFO	Knowledge Interchange Format (KIF)

Table 7. Overview of ontology-based languages

Syntax

In terms of syntax, ontology languages can be divided into languages having some form of specialized syntax, usually predating the widespread use of XML and other markup languages, and languages expressed as markup languages, usually XML or UML.

Traditional syntax ontology languages	Markup ontology languages
Common Logic (CL)	Web Ontology Language (OWL)
CycL	Resource Description Framework (RDF)
F-Logic (Frame Logic)	RDF Schema (RDFS)
Knowledge Interchange Format (KIF)	Simple Knowledge Organization System (SKOS)
KM programming language	OntoUML and UFO

Table 8. Overview of the syntax of ontology languages

Regarding ASAM OpenXOntology, a markup ontology language is a good choice for knowledge representation because it provides:

- Both human-readable and machine-readable annotations of the relationships, classes, and individuals.
- A clear representation of the data models and data structures.
- A clear ordering method for the syntax.
- A possibility to easily check the validity of the model by means of rules and reasoning.
- A selection from many existing standards and schemas to facilitate the structure.

The following ontology languages have been compared:

- Resource Description Framework (RDF) [25]
- RDF Schema (RDFS) [26]
- Web Ontology Language (OWL) [19]
- Simple Knowledge Organization System (SKOS) [27]
- OntoUML [28] and UFO [29]

Resource Description Framework (RDF)

The W3C Recommendation RDF is a standard model for data interchange on the Web. RDF makes statements with the help of triples, that is, in the form *subject–predicate–object*. RDF triples state that a relationship, indicated by the predicate, holds between the things denoted by subject and object of the triple. When talking about RDF concepts, the term *property* is used synonymous to the term *predicate*.

For the expression of RDF, different serialization formats may be used. The most common are RDF/XML and Turtle.

RDF Schema (RDFS)

The W3C Recommendation RDFS is a semantic extension of the basic RDF vocabulary. RDFS enables the assignment of resources to classes. Classes can have subclasses, so that the things described can be organized hierarchically. A relationship can then be drawn between classes of things or individuals. RDFS also provides a mechanism for limiting the scope of a relationship. RDFS thus enables simple deduction and reasoning mechanisms.

Simple Knowledge Organization System (SKOS)

SKOS is another W3C Recommendation and ontology language based on RDF and RDFS. It provides a standard way to represent knowledge organization systems using RDF.

SKOS is intended to create a simple ontology language, which can fulfill simple semantic queries. This is suitable for simple classifications, but it cannot handle the complex logical relationships required in OpenXOntology.

Web Ontology Language (OWL)

OWL is a semantic markup language for publishing and sharing ontologies on the Web. OWL builds on RDF and RDFS and is part of the W3C recommendations related to the Semantic Web.

OWL goes beyond the basic semantics that can be expressed with RDF Schema. The data described by an ontology in the OWL family is interpreted as a set of individuals and a set of property assertions that relate these individuals to each other. An ontology consists of a set of axioms which place constraints on sets of individuals, meaning classes, and the types of relationships permitted between them. These axioms provide semantics by allowing computers to infer additional information based on the data explicitly provided.

OntoUML and Unified Foundational Ontology (UFO)

OntoUML and UFO were created independent of all the other languages described here as language for ontology-driven conceptual modeling. OntoUML is built as an UML extension and is based on UFO. Because UML is applied in many industries, OntoUML is popular in industrial usage.

B.3. Decision to use OWL for OpenXOntology

In ASAM OpenXOntology, knowledge expressions, such as descriptions of traffic scenarios, involve complex temporal dynamics that benefit from a basis in formalized logic. Some of the languages that were reviewed support some form of formalized logic. OWL is the most widely used language of those, in addition to being well-developed and well-documented. OWL is supported by a variety of tools.

ASAM OpenXOntology contains an interoperable domain ontology, which needs to be built on an interoperable, industry-accepted format. This is enabled by OWL, which also allows for easy conversion to other ontological formats.

B.4. Evaluation of rule languages

In OpenXOntology, many important logical assertions, for example, regarding concept definition and inference of the consequences of antecedent conditions, cannot be easily expressed solely with logic. In many of these cases, a rule language can provide the expressiveness required to make these assertions.

The following rule languages have been evaluated:

- RIF [30]
- RuleML [31]
- R2ML [32]
- SWRL [20]

Rule interchange format (RIF)

RIF is part of the Semantic Web stack, along with, for example, SPARQL, RDF, and OWL. RIF facilitates the exchange and sharing of rules. RIF has three dialects: the Core dialect, the Basic Logic Dialect that is equivalent to a Horn rule language, and a Product Rule Dialect (PRD).

Rule markup language (RuleML)

RuleML is a markup language for forward and backward rules for deduction, rewriting, and further inferential-transformational tasks. RuleML is defined by the Rule Markup Initiative that has the goal to develop a canonical web language for rules in XML markup and transformations to and from other rule standards. RIF and SWRL belong to the standards related to RuleML.

REWERSE rule markup language (R2ML)

The XML-based rule language R2ML is developed by the REWERSE working group and facilitates rule interchange between systems and tools.

R2ML bases on concepts from RuleML and SWRL. It is modeled using model-driven architecture (MDA). Rule concepts are defined using the Meta-Object Facility (MOF) standard and UML.

R2ML integrates functional languages, such as OCL, with datalog languages, such as SWRL.

Semantic web rule language (SWRL)

SWRL combines OWL with a subset of the Rule Markup Language (RuleML). It is a proposed rule language for the Semantic Web. SWRL adds rules at the cost of undecidability and lack of complete implementation. A SWRL rule consists of an antecedent (body) and a consequent (head).

B.4.1. Decision to use SWRL as rule language

The OpenXOntology project decided to use SWRL as rule language, because SWRL meets the basic requirements and is compatible with OWL.

Appendix C: List of figures

Appendix D: List of tables