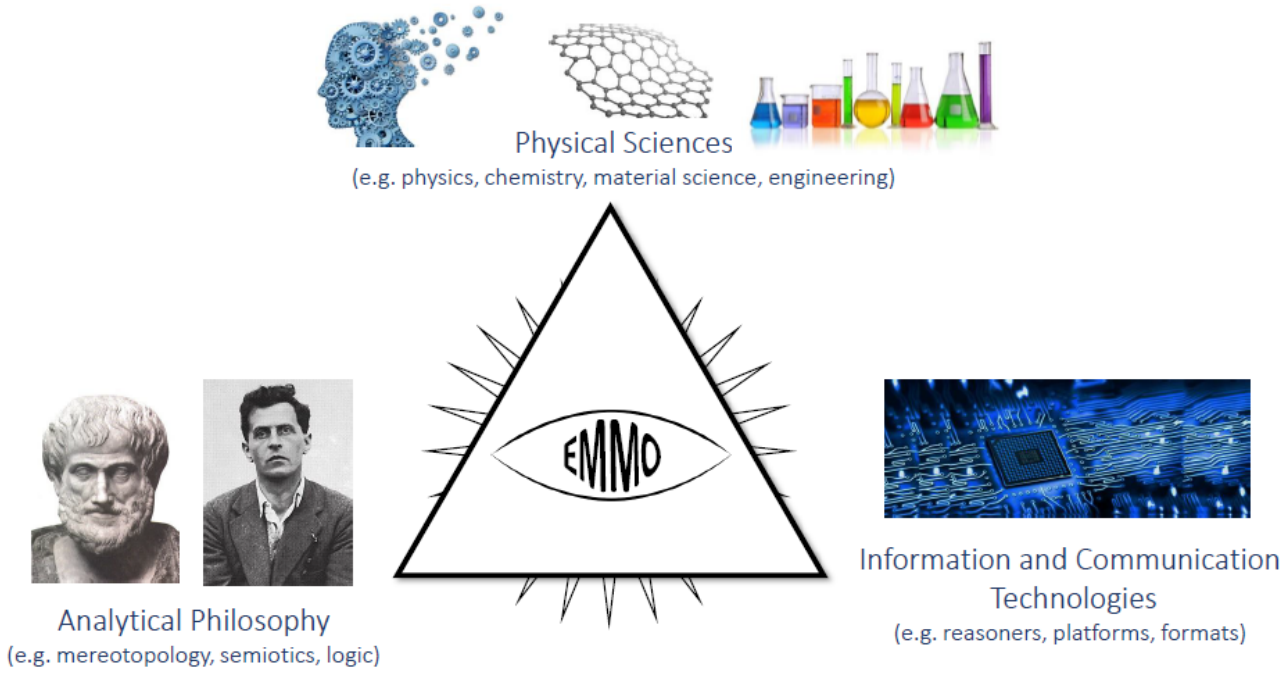
Europeean Materials Modelling Ontology

Version 1.0.0-alpha2

European Materials Modelling Counsil (EMMC)

September 08, 2020



Abstract

EMMO is an ontology that is created by the Europeean Materials Modelling Council (EMMC) to provide a formal way to describe the fundamental concepts of physics, chemistry and materials science. EMMO is designed to pave the road for semantic interoperability providing a generic common ground for describing materials, models and data that can be adapted by all domains.

It is a representational framework of predefined classes and axioms (ontology) provided by experts (EMMC) that enables end users (industry, research, academy) to represent real life physical entities (materials, devices), models and properties using ontological signs (individuals) in a standard way to facilitate interactions and exchanges (data, software, knowledge) between all involved material modelling and characterization communities and stakeholders.

Keywords: EMMO, materials science, modelling, characterisation, materials, ontology

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Contents

1 Introduction **2**
What is an ontology . . . 3
Primitive elements in EMMO . . . 4
Theoretical foundations . . . 5
The structure of EMMO . . . 9

2 EMMO Relations **12**
Root of EMMO relations . . . 13
Mereotopological branch . . . 13
Connected branch . . . 14
Has Part branch . . . 15
Semiotical branch . . . 19

3 EMMO Classes **22**
EMMO branch . . . 22
Elementary branch . . . 27
Perspective branch . . . 27
Holistic branch . . . 28
Semiotic branch . . . 29
Sign branch . . . 30
Interpreter branch . . . 32
Object branch . . . 32
Conventional branch . . . 33
Property branch . . . 35
Icon branch . . . 38
Process branch . . . 39
Perceptual branch . . . 41
Graphical branch . . . 43
Geometrical branch . . . 45
Symbol branch . . . 47
Mathematical branch . . . 49
Mathematical Symbol branch . . . 51
Mathematical Model branch . . . 52
Mathematical Operator branch . . . 54
Metrological branch . . . 56
Physics Dimension branch . . . 58
Physical Quantity branch . . . 64
Number branch . . . 74
Measurement Unit branch . . . 75
UTF8 branch . . . 79
SI Base Unit branch . . . 82
SI Special Unit branch . . . 84
Prefixed Unit branch . . . 91
Metric Prefix branch . . . 92
Quantity branch . . . 97
Base Quantity branch . . . 99
Derived Quantity branch . . . 103
Physical Constant branch . . . 110
Reductionistic branch . . . 112

Expression branch . . . 115
Formula branch . . . 116
Physicalistic branch . . . 118
Elementary Particle branch . . . 120
Material State branch . . . 122
Subatomic branch . . . 125

4 Individuals **127**

5 Appendix **128**
The complete taxonomy of EMMO relations . . . 128
The taxonomy of EMMO classes . . . 128

Chapter 1

Introduction

EMMO is a multidisciplinary effort to develop a standard representational framework (the ontology) based on current materials modelling knowledge, including physical sciences, analytical philosophy and information and communication technologies. This multidisciplinarity is illustrated by the figure on the title page. It provides the connection between the physical world, materials characterisation world and materials modelling world.

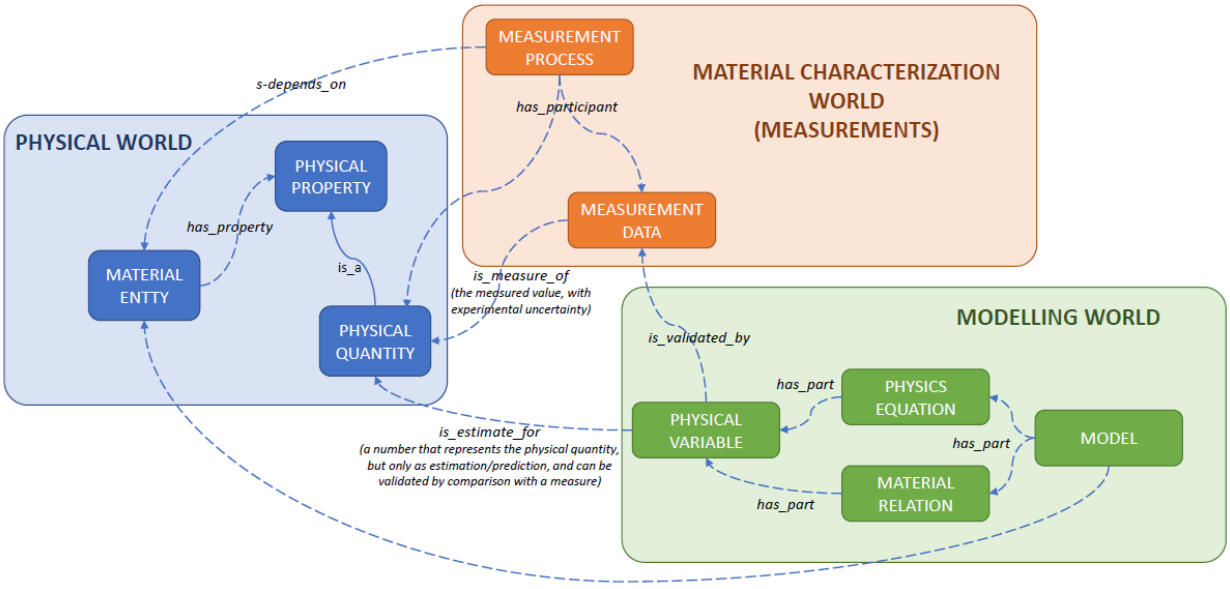

Figure 1.1: EMMO provides the connection between the physical world, materials characterisation world and materials modelling world.

EMMO is based on and is consistent with the Review of Materials Modelling, CEN Workshop Agreement and MODA template. However, while these efforts are written for humans, EMMO is defined using the Web Ontology Language (OWL), which is machine readable and allows for machine reasoning. In terms of semantic representation, EMMO brings everything to a much higher level than these foundations.

As illustrated in the figure below, EMMO covers all aspects of materials modelling and characterisation, including:

- the **material** itself, which must be described in a rigorous way
- the **observation process** involving an observer that percieves the real world (characterisation)
- the **properties** that are measured or modelled
- the **physics laws** that describe the material behaviour
- the **physical models** that approximate the physics laws
- the **solver** including the numerical discretisation method that leads to a solvable mathematical representation under certain simplifying assumptions
- the **numerical solver** that performs the calculations
- the **post processing** of experimental or simulated data

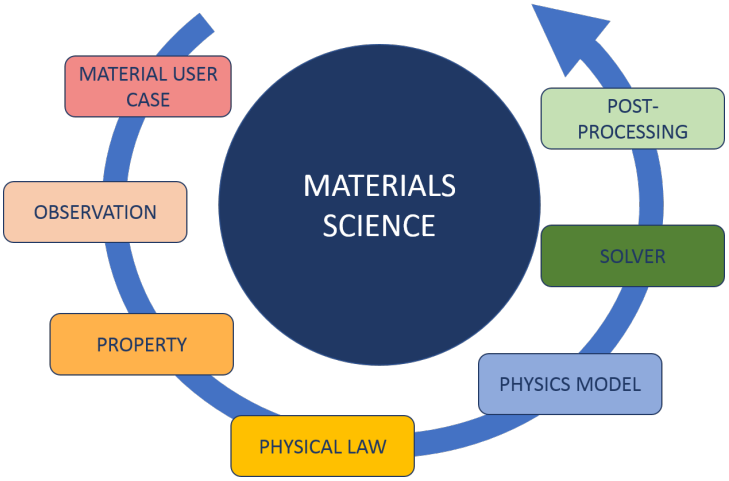

Figure 1.2: The aspects of materials modelling and characterisation covered by EMMO.

EMMO is released under the Creative Commons license and is available at emmo.info/. The OWL2-DL sources are available in RDF/XML format.

What is an ontology

In short, an ontology is a specification of a conceptualization. The word *ontology* has a long history in philosophy, in which it refers to the subject of existence. The so-called ontological argument for the existence of God was proposed by Anselm of Canterbury in 1078. He defined God as *"that than which nothing greater can be thought"*, and argued that *"if the greatest possible being exists in the mind, it must also exist in reality. If it only exists in the mind, then an even greater being must be possible – one which exists both in the mind and in reality"*. Even though this example has little to do with todays use of ontologies in e.g. computer science, it illustrates the basic idea; the ontology defines some basic premises (concepts and relations between them) from which it is possible reason to gain new knowledge.

For a more elaborated and modern definition of the ontology we refer the reader to the one provided by Tom Gruber (2009). Another useful introduction to ontologies is the paper Ontology Development 101: A Guide to Creating Your First Ontology by Noy and McGuinness (2001), which is based on the Protege sortware, with which EMMO has been developed.

A taxonomy is a hierarchical representation of classes and subclasses connected via `is_a` relations. Hence, it is a subset of the ontology excluding all but the `is_a` relations. The main use of taxonomies is for the organisation of classifications. The figure shows a simple example of a taxonomy illustrating a categorisation of four classes into a hierarchy of more higher of levels of generality.

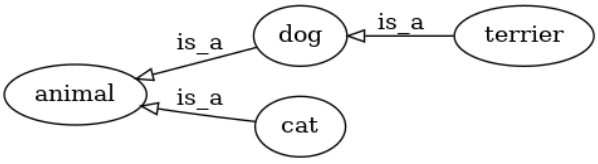

Figure 1.3: Example of a taxonomy.

In EMMO, the taxonomy is a rooted directed acyclic graph (DAG). This is important since many classification methods relies on this property, see e.g. Valentini (2014) and Robison et al (2015). Note, that EMMO is a DAG does not prevent some classes from having more than one parent. A `Variable` is for instance both a `Mathematical` and a `Symbol`. See appendix for the full EMMO taxonomy.

Primitive elements in EMMO

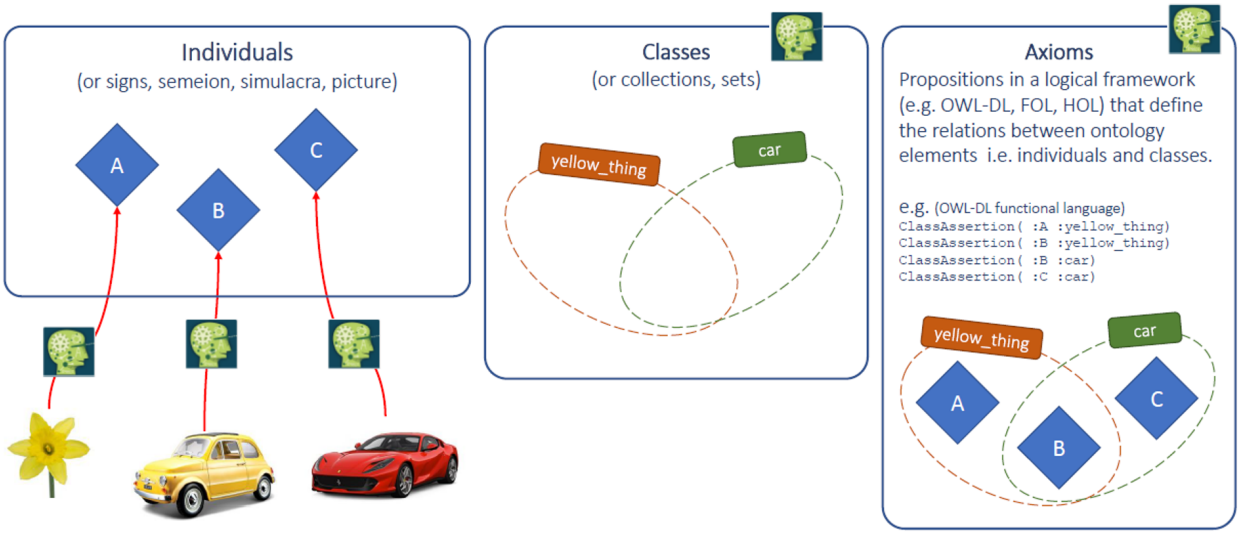

Figure 1.4: The primitive building blocks of EMMO.

Individuals

Individuals are the basic, "ground level" components of EMMO. They may include concrete objects such as cars, flowers, stars, persons and molecules, as well as abstract individuals such as a measured height, a specific equation and software programs.

Individuals possess attributes in form of axioms that are defined by the user (interpreter) upon declaration.

Classes

Classes represent concepts. They are the building blocks that we use to create an ontology as a representation of knowledge. We distinguish between *defined* and *non-defined* classes.

Defined classes are defined by the requirements for being a member of the class. In the graphical representations of EMMO, defined classes are orange. For instance, in the graph of the top-level entity branch below, The root `EMMO` and a defined class (defined to be the disjoint union of `Item` and `Collection`).

Non-defined classes are defined as an abstract group of objects, whose members are defined as belonging to the class. They are yellow in the graphical representations.

Axioms

Axioms are propositions in a logical framework that define the relations between the individuals and classes. They are used to categorise individuals in classes and to define the *defined* classes.

The simplest form of a class axiom is a class description that just states the existence of the class and gives it an unique identifier. In order to provide more knowledge about the class, class axioms typically contain additional components that state necessary and/or sufficient characteristics of the class. OWL contains three language constructs for combining class descriptions into class axioms:

- *Subclass* (`rdfs:subClassOf`) allows one to say that the class extension of a class description is a subset of the class extension of another class description.
- *Equivalence* (`owl:equivalentClass`) allows one to say that a class description has exactly the same class extension (i.e. the individuals associated with the class) as another class description.
- *Distjointness* (`owl:disjointWith`) allows one to say that the class extension of a class description has no members in common with the class extension of another class description.

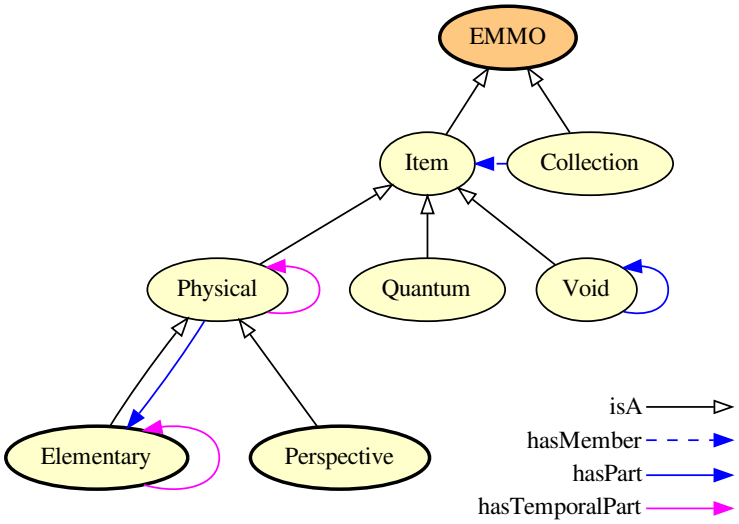

Figure 1.5: Example of the top-level branch of EMMO showing some classes and relationships between them.

See the section about Description logic for more information about these language constructs. Axioms are also used to define relations between relations. These are further detailed in the chapter on Relations.

Theoretical foundations

EMMO build upon several theoretical frameworks.

Semiotics

Semiotics is the study of meaning-making. It is the dicipline of formulating something that possibly can exist in a defined space and time in the real world.

Mereotopology

Mereotopology is the combination of **mereology** (science of parthood) and **topology** (mathematical study of the geometrical properties and conservation through deformations). It is introdused via the `Item` class and based on the `mereotopological` relations. Items in EMMO are always topologically connected in space and time. EMMO makes a strong distinction between membership and parthood relations. In contrast to collections, items can only have parts that are themselves items. For further information, see Casati and Varzi "Parts and Places" (1999).

Physics

EMMO is strongly based on physics, with the aim of being able to describe all aspects and all domains of physics, from quantum mechanics to continuum, engeneering, chemistry, etc. EMMO is compatible with both the De Broglie - Bohm and the Copenhagen interpretation of quantum mecanics (see `Physical` for more comments).

EMMO defines a physics-based parthood hierachy under `Physical` by introducing the following concepts (illustrated in the figure below):

- `Elementary` is the fundamental, non-divisible constituent of entities. In EMMO, elementaries are based on the standard model of physics.

- `State` is a `Physical` whose parts does not change during its life time (at the chosen level of granularity). This is consistent with a state within e.g. thermodynamics.
- `Existent` is a succession of states.

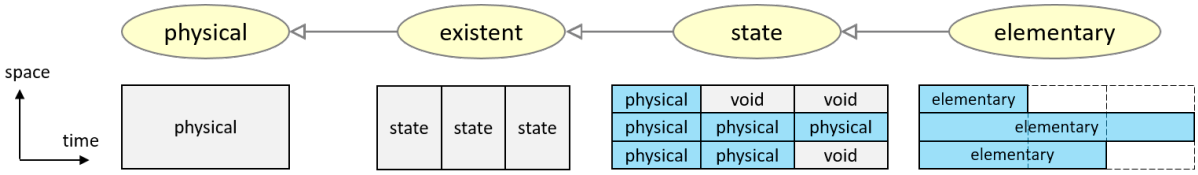

Figure 1.6: Parthood hierachy under `Physical`.

Metrology

Metrology is the science of measurements. It introduces units and links them to properties. The description of metrology in EMMO is based on the standards of International System of Quantities (ISQ) and International System of Units (SI).

Description logic

Description logic (DL) is a formal knowledge representation language in which the *axioms* are expressed. It is less expressive than first-order logic (FOL), but commonly used for providing the logical formalism for ontologies and semantic web. EMMO is expressed in the Web Ontology Language (OWL), which in turn is based on DL. This brings along features like reasoning.

Since it is essential to have a basic notion of OWL and DL, we include here a very brief overview. For a proper introduction to OWL and DL, we refer the reader to sources like Grau et.al. (2008), OWL2 Primer and OWL Reference.

OWL distinguishes between six types of class descriptions:

1. a class identifier (a IRI reference)
2. an exhaustive enumeration of individuals that together form the instances of a class (`owl:oneOf`)
3. a property restriction (`owl:someValuesFrom`, `owl:allValuesFrom`, `owl:hasValue`, `owl:cardinality`, `owl:minCardinality`, `owl:maxCardinality`)
4. the intersection of two or more class descriptions (`owl:intersectionOf`)
5. the union of two or more class descriptions (`owl:unionOf`)
6. the complement of a class description (`owl:complementOf`)

Except for the first, all of these refer to *defined classes*. The table below shows the notation in OWL, DL and the Manchester OWL syntax, all commonly used for the definitions. The Manchester syntax is used by Protege and is designed to not use DL symbols and to be easy and quick to read and write. Several other syntaxes exist for DL. An interesting example is the pure Python syntax proposed by Lamy (2017), which is used in the open source Owlready2 Python package. The Python API for EMMO is also based on Owlready2.

Table 1.1: Notation for DL and Protege. A and B are classes, R is an active relation, S is an passive relation, a and b are individuals and n is a literal. Inspired by the Great table of Description Logics.

DL	Manchester	Python + Owlready2	Read	Meaning
Constants				
$\top$		Thing	top	A special class with every individual as an instance
$\bot$		Nothing	bottom	The empty class
Axioms				
$A \doteq B$			A is defined to be equal to B	Class *definition*

DL	Manchester	Python + Owlready2	Read	Meaning
$A \sqsubseteq B$	A subclass_of B	class A(B): … issubclass(A, B)	all A are B	Class *inclusion* Test for *inclusion*
$A \equiv B$	A equivalent_to B	A.equivalent_to.append(B) B in A.equivalent_to	A is equivalent to B	Class *equivalence* Test for equivalence
$a : A$	a is_a A	a = A() isinstance(a, A)	a is a A	Class *assertion* (*instantiation*) Test for instance of
$(a, b) : R$	a object property assertion b	a.R.append(b)	a is R-related to b	Property *assertion*
$(a, n) : R$	a data property assertion n	a.R.append(n)	a is R-related to n	Data *assertion*
Constructions				
$A \sqcap B$	A and B	A & B	A and B	Class *intersection* (*conjunction*)
$A \sqcup B$	A or B	A | B	A or B	Class *union* (*disjunction*)
$\neg A$	not A	Not(A)	not A	Class *complement* (*negation*)
$\{a, b, ...\}$	{a, b, …}	OneOf([a, b, …])	one of a, b, …	Class *enumeration*
$S \equiv R^-$	S inverse_of R	Inverse(R) S.inverse == R	S is inverse of R	Property *inverse* Test for *inverse*
$\forall R.A$	R only A	R.only(A)	all A with R	*Universal restriction*
$\exists R.A$	R some A	R.some(A)	some A with R	*Existential restriction*
$= nR.A$	R exactly n A	R.exactly(n, A)		*Cardinality restriction*
$\leq nR.A$	R min n A	R.min(n, A)		*Minimum cardinality restriction*
$\geq nR.A$	R max n A	R.max(n, A)		*Minimum cardinality restriction*
$\exists R\{a\}$	R value a	R.value(a)		*Value restriction*
Decompositions				
$A \sqcup B \sqsubseteq \bot$	A disjoint with B	AllDisjoint([A, B]) B in A.disjoints()	A disjoint with B	Disjoint Test for disjointness
$\exists R.\top \sqsubseteq A$	R domain A	R.domain = [A]		Classes that the restriction applies to
$\top \sqsubseteq \forall R.B$	R range B	R.range = [B]		All classes that can be the value of the restriction

Examples

Here are some examples of different class descriptions using both the DL and Manchester notation.

Equivalence (`owl:equivalentTo`)

Equivalence (≡) defines necessary and sufficient conditions.

Parent is equivalent to mother or father

DL: `parent` $\equiv$ `mother` $\vee$ `father`

Manchester: `parent equivalent_to mother or father`

Inclusion (`rdf:subclassOf`)

Inclusion ($\sqsubseteq$) defines necessary conditions.

An employee is a person.

DL: `employee` $\sqsubseteq$ `person`

Manchester: `employee is_a person`

Enumeration (`owl:oneOf`)

The color of a wine is either white, rose or red:

DL: `wine_color` $\equiv$ {`white`, `rose`, `red`}

Manchester: `wine_color equivalent_to {white, rose, red}`

Existential restriction (`owl:someValuesFrom`)

A mother is a woman that has a child (some person):

DL: `mother` $\equiv$ `woman` $\sqcap$ $\exists$`has_child`.`person`

Manchester: `mother equivalent_to woman and has_child some person`

Universal restriction (`owl:allValuesFrom`)

All parents that only have daughters:

DL: `parents_with_only_daughters` $\equiv$ `person` $\sqcap$ $\forall$`has_child`.`woman`

Manchester: `parents_with_only_daughters equivalent_to person and has_child only woman`

Value restriction (`owl:hasValue`)

The owl:hasValue restriction allows to define classes based on the existence of particular property values. There must be at least one matching property value.

All children of Mary:

DL: `Marys_children` $\equiv$ `person` $\sqcap$ $\exists$`has_parent`.{`Mary`}

Manchester: `Marys_children equivalent_to person and has_parent value Mary`

Property cardinality (`owl:cardinality`)

The owl:cardinality restrictions ($\geq$, $\leq$ or $\equiv$) allow to define classes based on the maximum (owl:maxCardinality), minimum (owl:minCardinality) or exact (owl:cardinality) number of occurences.

A person with one parent:

DL: `half_orphant` $\equiv$ `person` and $=1$`has_parent`.`person`

Manchester: `half_orphant equivalent_to person and has_parent exactly 1 person`

Intersection (`owl:intersectionOf`)

Individuals of the intersection (⊓) of two classes, are simultaneously instances of both classes.

A man is a person that is male:

DL: `man` ≡ `person` ⊓ `male`

Manchester: `man equivalent_to person and male`

Union (`owl:unionOf`)

Individuals of the union (⊔) of two classes, are either instances of one or both classes.

A person is a man or woman:

DL: `person` ≡ `man` ⊔ `woman`

Manchester: `person equivalent_to man or woman`

Complement (`owl:complementOf`)

Individuals of the complement (¬) of a class, are all individuals that are not member of the class.

Not a man:

DL: `female` ≡ ¬ `male`

Manchester: `female equivalent_to not male`

The structure of EMMO

The EMMO ontology is structured in shells, expressed by specific ontology fragments, that extends from fundamental concepts to the application domains, following the dependency flow.

Top Level

The EMMO top level is the group of fundamental axioms that constitute the philosophical foundation of the EMMO. Adopting a physicalistic/nominalistic perspective, the EMMO defines real world objects as 4D objects that are always extended in space and time (i.e. real world objects cannot be spaceless nor timeless). For this reason abstract objects, i.e. objects that does not extend in space and time, are forbidden in the EMMO.

EMMO is strongly based on the analytical philosophy dicipline semiotic. The role of abstract objects are in EMMO fulfilled by semiotic objects, i.e. real world objects (e.g. symbol or sign) that stand for other real world objects that are to be interpreted by an agent. These symbols appear in actions (semiotic processes) meant to communicate meaning by establishing relationships between symbols (signs).

Another important building block of from analytical philosophy is atomistic mereology applied to 4D objects. The EMMO calls it 'quantum mereology', since the there is a epistemological limit to how fine we can resolve space and time due to the uncertainty principles.

The mereotopology module introduces the fundamental mereotopological concepts and their relations with the real world objects that they represent. The EMMO uses mereotopology as the ground for all the subsequent ontology modules. The concept of topological connection is used to define the first distinction between ontology entities namely the *Item* and *Collection* classes. Items are causally self-connected objects, while collections are causally disconnected. Quantum mereology is represented by the *Quantum* class. This module introduces also the fundamental mereotopological relations used to distinguish between space and time dimensions.

The physical module, defines the *Physical* objects and the concept of *Void* that plays a fundamental role in the description of multiscale objects and quantum systems. It also define the *Elementary* class, that restricts mereological atomism in space.

In EMMO, the only univocally defined real world object is the *Item* individual called **Universe** that stands for the universe. Every other real world object is a composition of elementaries up to the most comprehensive object; the **Universe**. Intermediate objects are not univocally defined, but their definition is provided according to some

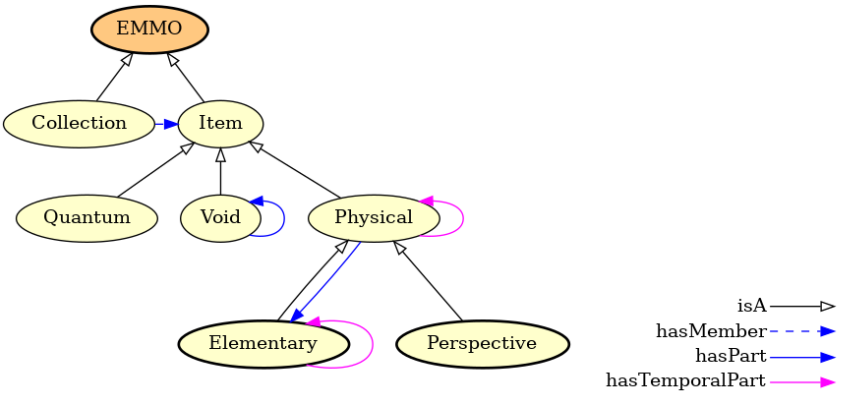

Figure 1.7: The EMMO top level.

specific philosophical perspectives. This is an expression of reductionism (i.e. objects are made of sub-objects) and epistemological pluralism (i.e. objects are always defined according to the perspective of an interpreter, or a class of interpreters).

The *Perspective* class collects the different ways to represent the objects that populate the conceptual region between the elementary and universe levels.

Middle Level

The middle level ontologies act as roots for extending the EMMO towards specific application domains.

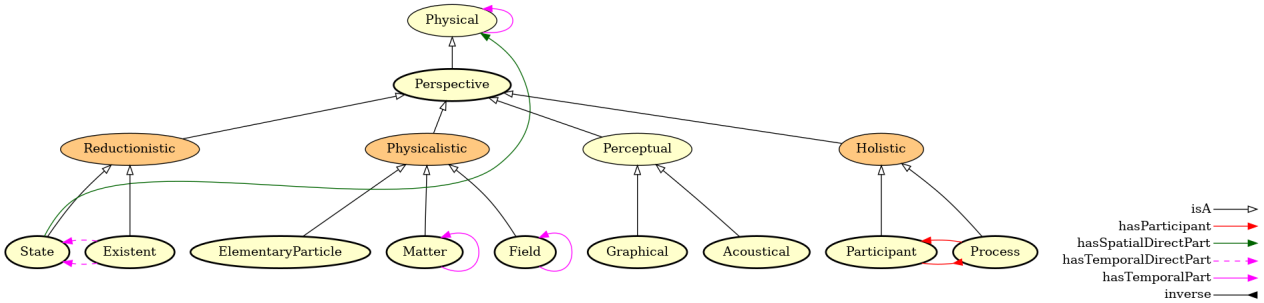

Figure 1.8: The EMMO perspectives.

The *Reductionistic* perspective class uses the fundamental non-transitive parthood relation, called direct parthood, to provide a powerful granularity description of multiscale real world objects. The EMMO can in principle represents the **Universe** with direct parthood relations as a direct rooted tree up to its elementary constituents.

The *Phenomenic* perspective class introduces the concept of real world objects that express of a recognisable pattern in space or time that impress the user. Under this class the EMMO categorises e.g. formal languages, pictures, geometry, mathematics and sounds. Phenomenic objects can be used in a semiotic process as signs.

The *Physicalistic* perspective class introduces the concept of real world objects that have a meaning for the under applied physics perspective.

The *Holistic* perspective class introduces the concept of real world objects that unfold in time in a way that has a meaning for the EMMO user, through the definition of the classes *Process* and *Participant*. The semiotics module introduces the concepts of semiotics and the *Semiosis* process that has a *Sign*, an *Object* and an *Interpreter* as participants. This forms the basis in EMMO to represent e.g. models, formal languages, theories, information and properties.

EMMO relations

All EMMO relations are subrelations of the relations found in the two roots: *mereotopological* and *semiotical*. The relation hierarchy extends more vertically (i.e. more subrelations) than horizontally (i.e. less sibling

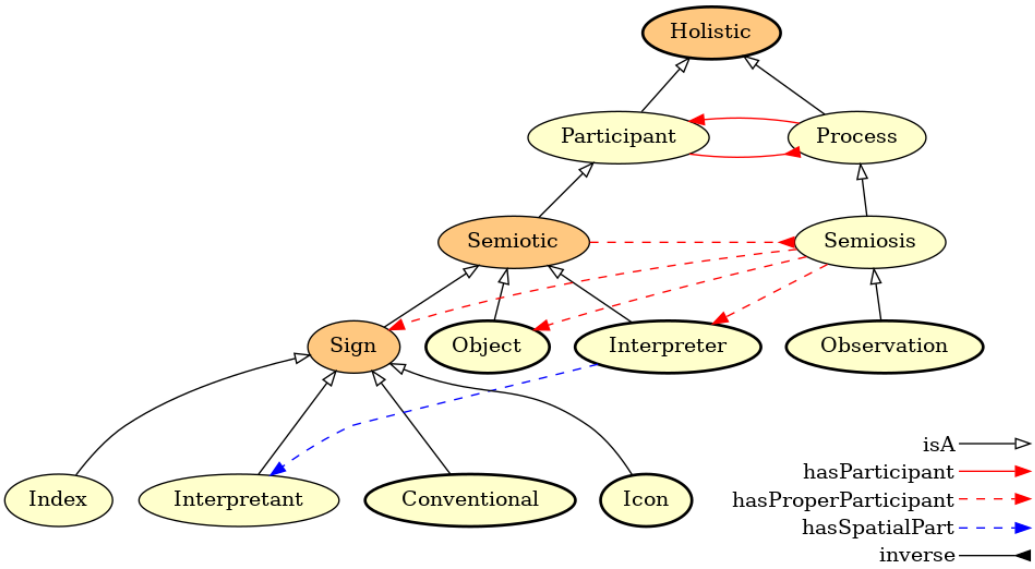

Figure 1.9: The semiotic level, showing both the taxonomy (open black arrows) and other relations as listed in the caption. The inverted arrows corresponds to inverse relations.

relations), facilitating the categorisation and inferencing of individuals. See also the chapter EMMO Relations.

Imposing all relations to fall under mereotopology or semiotics is how the EMMO force the developers to respect its perspectives. Two entities are related only by contact or parthood (mereotopology) or by standing one for another (semiosis): no other types of relation are possible within the EMMO.

A unique feature in EMMO, is the introduction of *direct parthood*. As illustrated in the figure below, it is a mereological relation that lacks transitivity. This makes it possible to entities made of parts at different levels of granularity and to go between granularity levels in a well-defined manner. This is paramount for cross scale interoperability. Every material in EMMO is placed on a granularity level and the ontology gives information about the direct upper and direct lower level classes using the non-transitive direct parthood relations.

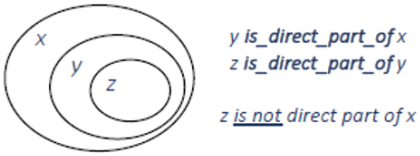

Figure 1.10: Direct parthood.

Annotations

All entities and relations in EMMO have some attributes, called *annotations*. In some cases, only the required *International Resource Identifier* (IRI) and *relations* are provided. However, descriptive annotations, like *elucidation* and *comment*, are planned to be added for all classes and relations. Possible annotations are:

- **Elucidation** is a human readable explanation and clearification of the documented class or relation.
- **Example** clearifies the elucidation through an example. A class may have several examples, each addressing different aspects.
- **Comment** is a clearifying note complementing the definition and elucidation. A class may have several comments, each clearifying different aspects.
- **IRI** stands for *international resource identifier*. It is an identifier that uniquely identifies the class or relation. IRIs are similar to URIs, but are not restricted to the ASCII character set. In EMMO, the IRIs are now valid URLs pointing to the stable version of EMMO.
- **Relations** is a list of relations applying to the current class or relation. The relations for relations are special and will be elaborated on in the introduction to chapter [Relations]. Some of the listed relations are defined in the OWL sources, while other are inferred by the reasoner. The relations are expressed using the Manchester OWL syntax introduced in section Description logic.

Chapter 2

EMMO Relations

In the language of OWL, relations are called *properties*. However, since relations describe relations between classes and individuals and since properties has an other meaning in EMMO, we only call them *relations*.

Resource Description Framework (RDF) is a W3C standard that is widely used for describing informations on the web and is one of the standards that OWL builds on. RDF expresses information in form of *subject-predicate-object* triplets. The subject and object are resources (aka items to describe) and the predicate expresses a relationship between the subject and the object.

In OWL are the subject and object classes or individuals (or data) while the predicate is a relation. An example of an relationship is the statement *dog is_a animal*. Here `dog` is the subject, `is_a` the predicate and `animal` the object.

OWL distingues between *object properties*, that link classes or individuals to classes or individuals, and *data properties* that link individuals to data values. Since EMMO only deals with classes, we will only be discussing object properties. However, in actual simulation or characterisation applications build on EMMO, datatype propertyes will be important.

The characteristics of the different properties are described by the following *property axioms*:

- `rdf:subPropertyOf` is used to define that a property is a subproperty of some other property. For instance, in the figure below showing the relation branch, we see that `active_relation` is a subproperty or `relation`. The `rdf:subPropertyOf` axioms forms a taxonomy-like tree for relations.
- `owl:equivalentProperty` states that two properties have the same property extension.
- `owl:inverseOf` axioms relate active relations to their corresponding passive relations, and vice versa. The root relation `relation` is its own inverse.
- `owl:FunctionalProperty` is a property that can have only one (unique) value y for each instance x, i.e. there cannot be two distinct values y1 and y2 such that the pairs (x,y1) and (x,y2) are both instances of this property. Both object properties and datatype properties can be declared as "functional".
- `owl:InverseFunctionalProperty`
- `owl:TransitiveProperty` states that if a pair (x,y) is an instance of P, and the pair (y,z) is instance of P, then we can infer that the pair (x,z) is also an instance of P.
- `owl:SymmetricProperty` states that if the pair (x,y) is an instance of P, then the pair (y,x) is also an instance of P. A popular example of a symmetric property is the `siblingOf` relation.
- `rdfs:domain` specifies which classes the property applies to. Or said differently, the valid values of the *subject* in a *subject-predicate-object* triplet.
- `rdfs:range` specifies the property extension, i.e. the valid values of the *object* in a *subject-predicate-object* triplet.

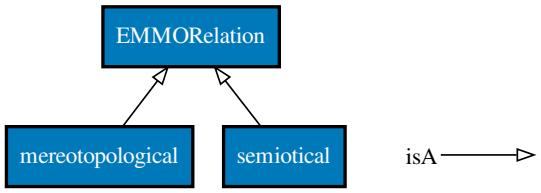

Figure 2.1: Top-level of the EMMO relation hierarchy.

Root of EMMO relations

EMMORelation

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_ec2472ae_cf4a_46a5_8555_1556f5a6c3c5

Elucidation: The superclass of all relations used by the EMMO.

Relations:

- is_a owl:ObjectProperty
- is_a owl:SymmetricProperty
- is_a owl:TransitiveProperty
- is_a owl:topObjectProperty
- inverse_of EMMORelation
- domain EMMO
- range EMMO

Mereotopological branch

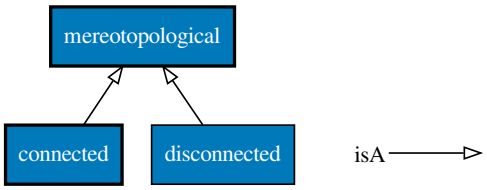

Figure 2.2: Mereotopological branch.

mereotopological

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_03212fd7_abfd_4828_9c8e_62c293052d4b

Elucidation: The superclass of all EMMO mereotopological relations.

Comment: Mereotopology merges mereological and topological concepts and provides relations between wholes, parts, boundaries, etc.

Relations:

- is_a owl:ObjectProperty
- is_a owl:SymmetricProperty
- is_a owl:TransitiveProperty

- is_a EMMORelation
- Inverse(mereotopology.EMMORelation)
- inverse_of mereotopological

disconnected

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_517dfaf9_4970_41ac_81ee_d031627d2c7c

Relations:

- is_a owl:ObjectProperty
- is_a owl:SymmetricProperty
- is_a mereotopological
- Inverse(mereotopology.mereotopological)
- inverse_of disconnected

Connected branch

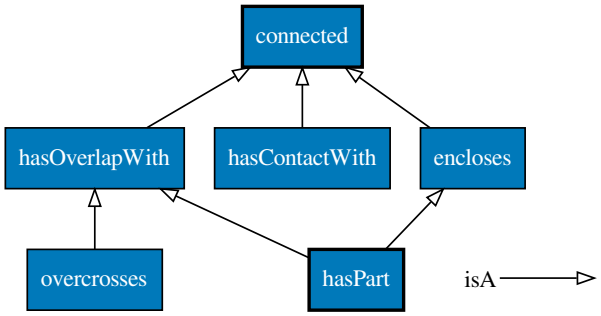

Figure 2.3: Connected branch.

overcrosses

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_9cb984ca_48ad_4864_b09e_50d3fff19420

Relations:

- is_a owl:ObjectProperty
- is_a owl:SymmetricProperty
- is_a hasOverlapWith
- Inverse(mereotopology.hasOverlapWith)
- inverse_of overcrosses

hasContactWith

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_4d6504f1_c470_4ce9_b941_bbbebc9ab05d

Relations:

- is_a owl:ObjectProperty
- is_a owl:SymmetricProperty
- is_a connected
- Inverse(mereotopology.connected)
- inverse_of hasContactWith

encloses

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_8c898653_1118_4682_9bbf_6cc334d16a99

Comment: Enclosure is reflexive and transitive.

Relations:

- is_a owl:ObjectProperty
- is_a owl:TransitiveProperty
- is_a connected
- Inverse(mereotopology.connected)

hasOverlapWith

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_d893d373_b579_4867_841e_1c2b31a8d2c6

Relations:

- is_a owl:ObjectProperty
- is_a owl:SymmetricProperty
- is_a connected
- Inverse(mereotopology.connected)
- inverse_of hasOverlapWith

connected

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_6703954e_34c4_4a15_a9e7_f313760ae1a8

Comment: Causality is a topological property between connected items.

Comment: Items being connected means that there is a topological contact or “interaction” between them.

Relations:

- is_a owl:ObjectProperty
- is_a owl:SymmetricProperty
- is_a mereotopological
- Inverse(mereotopology.mereotopological)
- inverse_of connected

Has Part branch

hasProperPart

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_9380ab64_0363_4804_b13f_3a8a94119a76

Relations:

- is_a owl:ObjectProperty
- is_a owl:TransitiveProperty
- is_a hasPart

hasTemporalDirectPart

IRI: http://emmo.info/emmo/middle/reductionistic#EMMO_65a2c5b8_e4d8_4a51_b2f8_e55effc0547d

Relations:

- is_a owl:ObjectProperty
- is_a owl:InverseFunctionalProperty
- is_a owl:AsymmetricProperty
- is_a owl:IrreflexiveProperty

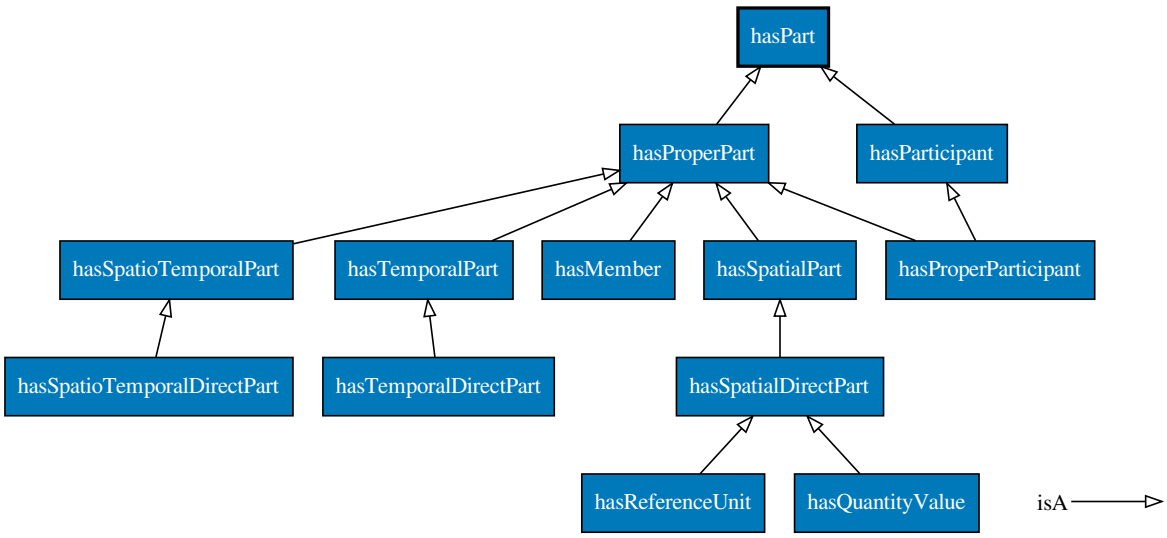

Figure 2.4: Has Part branch.

- is_a hasTemporalPart
- domain Existent
- range State

hasSpatioTemporalPart

IRI: http://emmo.info/emmo/top/physical#EMMO_6e046dd0_9634_4013_b2b1_9cc468087c83

Elucidation: A relation that isolates a proper part that extends itself in time through a portion of the lifetime whole.

Relations:

- is_a owl:ObjectProperty
- is_a owl:TransitiveProperty
- is_a hasProperPart
- domain Item
- range Item

hasSpatioTemporalDirectPart

IRI: http://emmo.info/emmo/middle/reductionistic#EMMO_663859e5_add3_4c9e_96fb_c99399de278d

Relations:

- is_a owl:ObjectProperty
- is_a owl:InverseFunctionalProperty
- is_a owl:AsymmetricProperty
- is_a owl:IrreflexiveProperty
- is_a hasSpatioTemporalPart

hasTemporalPart

IRI: http://emmo.info/emmo/top/physical#EMMO_7afbed84_7593_4a23_bd88_9d9c6b04e8f6

Elucidation: A relation that isolate a proper part that covers the total spatial extension of a whole within a time interval.

Relations:

- is_a owl:ObjectProperty
- is_a owl:TransitiveProperty
- is_a hasProperPart
- domain Item
- range Item

hasReferenceUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_67fc0a36_8dcb_4ffa_9a43_31074efa3296

Comment: Relates the physical quantity to its unit through spatial direct parthood.

Relations:

- is_a owl:ObjectProperty
- is_a owl:InverseFunctionalProperty
- is_a owl:AsymmetricProperty
- is_a owl:IrreflexiveProperty
- is_a hasSpatialDirectPart
- domain Quantity
- range ReferenceUnit

hasQuantityValue

IRI: http://emmo.info/emmo/middle/metrology#EMMO_8ef3cd6d_ae58_4a8d_9fc0_ad8f49015cd0

Comment: Relates a quantity to its reference unit through spatial direct parthood.

Relations:

- is_a owl:ObjectProperty
- is_a owl:InverseFunctionalProperty
- is_a owl:AsymmetricProperty
- is_a owl:IrreflexiveProperty
- is_a hasSpatialDirectPart
- domain Quantity
- range Numerical

hasPart

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_17e27c22_37e1_468c_9dd7_95e137f73e7f

Relations:

- is_a owl:ObjectProperty
- is_a owl:TransitiveProperty
- is_a encloses
- is_a hasOverlapWith
- Inverse(mereotopology.hasOverlapWith)

hasParticipant

IRI: http://emmo.info/emmo/middle/holistic#EMMO_ae2d1a96_bfa1_409a_a7d2_03d69e8a125a

Elucidation: The relation between a process and an object participating to it.

Comment: Participation is a parthood relation: you must be part (and then be connected) of the process to contribute to it.

Comment: Participation is not under direct parthood since a process is not strictly related to reductionism, but it's a way to categorize temporal regions by the interpreters.

Relations:

- is_a owl:ObjectProperty
- is_a hasPart
- domain Process
- range Participant

hasMember

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_6b7276a4_4b9d_440a_b577_0277539c0fc4

Relations:

- is_a owl:ObjectProperty
- is_a owl:AsymmetricProperty
- is_a owl:IrreflexiveProperty
- is_a hasProperPart
- domain Collection
- range Item

hasSpatialPart

IRI: http://emmo.info/emmo/top/physical#EMMO_f68030be_94b8_4c61_a161_886468558054

Elucidation: A relation that isolates a proper part that extends itself in time within the overall lifetime of the whole, without covering the full spatial extension of the 4D whole (i.e. is not a temporal part).

Relations:

- is_a owl:ObjectProperty
- is_a owl:TransitiveProperty
- is_a hasProperPart
- domain Item
- range Item

hasProperParticipant

IRI: http://emmo.info/emmo/middle/holistic#EMMO_c5aae418_1622_4d02_93c5_21159e28e6c1

Relations:

- is_a owl:ObjectProperty
- is_a hasParticipant
- is_a hasProperPart

hasSpatialDirectPart

IRI: http://emmo.info/emmo/middle/reductionistic#EMMO_b2282816_b7a3_44c6_b2cb_3feff1ceb7fe

Relations:

- is_a owl:ObjectProperty
- is_a owl:InverseFunctionalProperty
- is_a owl:AsymmetricProperty
- is_a owl:IrreflexiveProperty
- is_a hasSpatialPart
- domain State

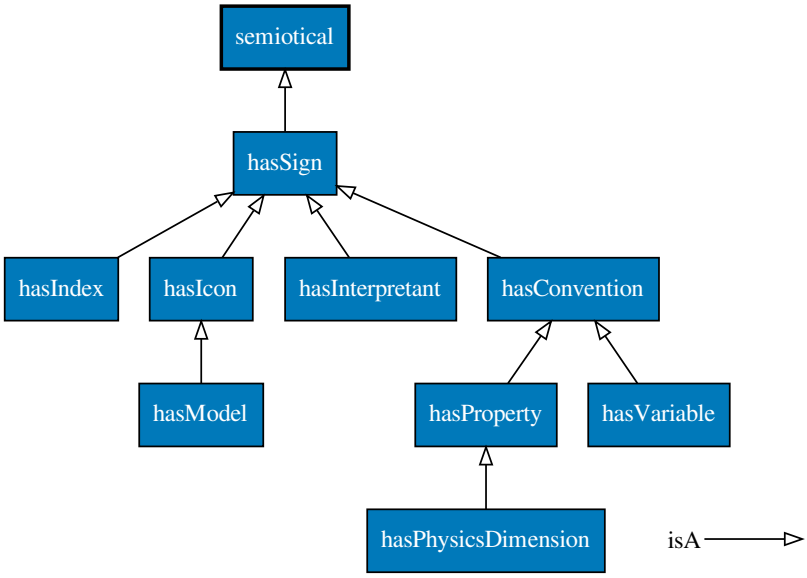

Figure 2.5: Semiotical branch.

Semiotical branch

hasIndex

IRI: http://emmo.info/emmo/middle/semiotics#EMMO_297999d6_c9e4_4262_9536_bd524d1c6e21

Relations:

- is_a owl:ObjectProperty
- is_a hasSign
- range Index

semiotical

IRI: http://emmo.info/emmo/middle/semiotics#EMMO_2337e25c_3c60_43fc_a8f9_b11a3f974291

Elucidation: The generic EMMO semiotical relation.

Relations:

- is_a owl:ObjectProperty
- is_a EMMORelation
- Inverse(mereotopology.EMMORelation)

hasIcon

IRI: http://emmo.info/emmo/middle/semiotics#EMMO_39c3815d_8cae_4c8f_b2ff_eeba24bec455

Relations:

- is_a owl:ObjectProperty
- is_a hasSign
- range Icon

hasModel

IRI: http://emmo.info/emmo/middle/models#EMMO_24c71baf_6db6_48b9_86c8_8c70cf36db0c

Relations:

- is_a owl:ObjectProperty
- is_a hasIcon

hasInterpretant

IRI: http://emmo.info/emmo/middle/semiotics#EMMO_7fb7fe7e_bdf9_4eeb_adad_e384dd5285c6

Relations:

- is_a owl:ObjectProperty
- is_a hasSign
- range Interpretant

hasSign

IRI: http://emmo.info/emmo/middle/semiotics#EMMO_60577dea_9019_4537_ac41_80b0fb563d41

Relations:

- is_a owl:ObjectProperty
- is_a semiotical
- domain Object
- range Sign

hasProperty

IRI: http://emmo.info/emmo/middle/properties#EMMO_e1097637_70d2_4895_973f_2396f04fa204

Relations:

- is_a owl:ObjectProperty
- is_a hasConvention
- domain Object
- range Property

hasConvention

IRI: http://emmo.info/emmo/middle/semiotics#EMMO_eb3518bf_f799_4f9e_8c3e_ce59af11453b

Relations:

- is_a owl:ObjectProperty
- is_a hasSign
- range Conventional

hasVariable

IRI: http://emmo.info/emmo/middle/math#EMMO_3446e167_c576_49d6_846c_215bb8878a55

Relations:

- is_a owl:ObjectProperty
- is_a hasConvention
- domain Mathematical
- range Variable

hasPhysicsDimension

IRI: http://emmo.info/emmo/middle/metrology#EMMO_bed1d005_b04e_4a90_94cf_02bc678a8569

Relations:

- is_a owl:ObjectProperty
- is_a hasProperty
- range PhysicsDimension

Chapter 3

EMMO Classes

emmo is a class representing the collection of all the individuals (signs) that are used in the ontology. Individuals are declared by the EMMO users when they want to apply the EMMO to represent the world.

EMMO branch

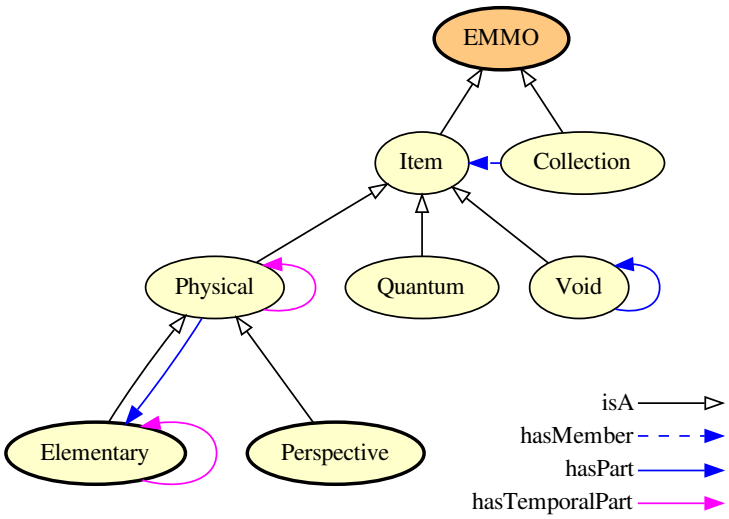

Figure 3.1: EMMO branch.

The root of all classes used to represent the world. It has two children; *collection* and *item*.

collection is the class representing the collection of all the individuals (signs) that represents a collection of non-connected real world objects.

item Is the class that collects all the individuals that are members of a set (it's the most comprehensive set individual). It is the branch of mereotopology.

Collection

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_2d2ecd97_067f_4d0e_950c_d746b7700a31

Elucidation: The class of all individuals that stand for a real world not self-connected object.

Comment: A 'Collection' individual stands for a non-self-connected real world object.

A ‘Collection’ individual is related to each ‘Item’ individuals of the collection (i.e. the members) through the membership relation.

An ‘Item’ individual stands for a real world self-connected object which can be represented as a whole made of connected parts (e.g. a car made of components).

Comment: Formally, ‘Collection’ is axiomatized as the class of individuals that hasMember some ‘Item’.

A ‘Collection’ cannot have as member another ‘Collection’.

Comment: From Latin collectio, from colligere ‘gather together’.

Comment: e.g. the collection of users of a particular software, the collection of atoms that have been part of that just dissociated molecule, or even the collection of atoms that are part of a molecule considered as single individual non-connected objects and not as a mereotopological self-connected fusion.

Relations:

- is_a EMMO
- hasMember some Item

Item

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_eb3a768e_d53e_4be9_a23b_0714833c36de

Comment: A real world object is self-connected if any two parts that make up the whole are connected to each other (here the concept of connection is primitive).

Alternatively, using the primitive path-connectivity concept we can define a self-connected real world object as an object for which each couple of points is path-connected.

Comment: An ‘Item’ individual stands for a real world self-connected object which can be represented as a whole made of connected parts (e.g. a car made of components).

In the EMMO, connectivity is the topological foundation of causality.

All physical systems, i.e. systems whose behaviour is explained by physics laws, are represented only by ‘Item’-s.

Members of a ‘Collection’ lack of causality connection, i.e. they do not constitute a physical system as a whole.

Comment: From Latin item, “likewise, just so, moreover”.

Relations:

- is_a EMMO
- disjoint_union_of Void, Physical

Quantum

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_3f9ae00e_810c_4518_aec2_7200e424cf68

Elucidation: The class of ‘EMMO’ individuals that stand for real world objects that can’t be further divided in time nor in space.

Example: For a physics based ontology the ‘Quantum’ can stand for the smallest identifiable portion of spacetime defined by the Planck limit in length (1.616e-35 m) and time (5.39e-44 s).

However, the quantum mereotopology approach is not restricted only to physics. For example, in a manpower management ontology, a ‘Quantum’ can stand for an hour (time) of a worker (space) activity.

Comment: A ‘Quantum’ is the most fundamental subclass of ‘Item’, since its individuals stand for the smallest possible self-connected 4D real world objects.

The quantum concept recalls the fact that there is lower epistemological limit to our knowledge of the universe, related to the uncertainity principle.

Comment: A ‘Quantum’ stands for a 4D real world object.

Comment: A quantum is the EMMO mereological 4D a-tomic entity.

To avoid confusion with the concept of atom coming from physics, we will use the expression quantum mereology, instead of a-tomistic mereology.

Comment: From Latin quantum (plural quanta) "as much as, so much as;", introduced in physics directly from Latin by Max Planck, 1900.

Relations:

- is_a Item
- is_a EMMO
- hasProperPart only owl:Nothing

Physical

IRI: http://emmo.info/emmo/top/physical#EMMO_c5ddfdba_c074_4aa4_ad6b_1ac4942d300d

Elucidation: A 'Item' that has part some 'Elementary' and whose temporal proper parts are only 'Physical'-s (i.e. it can be perceived without interruptions in time).

Comment: A 'Physical' is the class that contains all the individuals that stand for real world objects that interact physically with the ontologist, i.e. physical objects.

A physical object must be perceived through physical interaction by the ontologist. Then the ontologist can declare an individual standing for the physical object just perceived.

Perception is a subcategory of physical interactions. It is an interaction that stimulate a representation of the physical object within the ontologist (the agent).

Comment: A 'Physical' must include at least an 'Elementary' part, and can include 'Void' parts.

A 'Physical' may include as part also the 'Void' surrounding or enclosed by its 'Physical' sub parts.

There are no particular criteria for 'Physical'-s structure, except that is made of some 'Elementary'-s as proper parts and not only 'Void'.

This is done in order to take into account the quantum nature of physical systems, in which the actual position of sub-components (e.g. electrons in an atom) is not known except for its probability distribution function (according to the Copenhagen interpretation.)

e.g. a real world object that has spatial parts an atom and a cubic light year of void, extending for some time, can be a physical object.

Comment: A 'Physical' with dimensions other than 4D cannot exist, following the restriction of the parent 'EMMO' class.

It follows from the fact that perception is always unfolding in time.

e.g. you always have an aperture time when you take a picture or measure a property. Instantaneous perceptions are idealizations (abstractions) or a very small time measurement.

Comment: From Latin physica "study of nature" (and Ancient Greek φυσικός, "natural").

Here the word relates to things perceived through the senses as opposed to the mind; tangible or concrete.

Comment: In the EMMO there are no relations such as occupiesSpace, since 'Physical'-s are themselves the 4D regions.

Comment: The EMMO can be used to represent real world entities as 'Physical'-s that are easy to connect to classical or quantum mechanical based models.

Classical mechanics poses no representational issues, for the EMMO: the 4D representation of 'Physical'-s is consistent with classical physics systems.

However, the representation of 'Physical'-s that are typically analized through quantum mechanics (e.g. molecules, atoms, clusters), is not straightforward.

1) De Broglie - Bohm interpretation The most simple approach is to rely on Bohmian mechanics, in which each particle is supposed to exists in a specific position between measurements (hidden variables approach), while its trajectory is calculated using a Guiding Equation based on a quantum field calculated with the Schroedinger Equation.

While this approach is really easy to implement in an ontology, since each entity has its own well defined 4D region, its mathematical representation failed to receive large consensus due to the difficulties to include relativistic effects, to be extended to subnuclear scale and the strong non-locality assumtpion of the quantum field.

Nevertheless, the Bohmian mechanics is a numerical approach that is used in electronic models to reduce the computational effort of the solution of Schroedinger Equation.

In practice, an EMMO user can declare a 'physical' individual that stand for the whole quantum system to be described, and at the same time all sub-parts individuals can be declared, having them a well defined position in time, according to De Broglie - Bohm interpretation. The Hamiltonian can be calculated by considering the sub-part individuals.

'physical'-s are then made of 'physical' parts and 'void' parts that stand for the space between 'physical'-s (e.g. the void between electrons and nucleus in an atom).

2) Copenhagen interpretation In this interpretation the properties (e.g. energy level, position, spin) of a particle are not defined in the interval between two measurements and the quantum system is entangled (i.e. properties of particles in the sysyem are correlated) and described by a global wavefunction obtained solving the Schroedinger Equation.

Upon measurement, the wavefunction collapses to a combination of close eigenstates that provide information about bservables of the system components (e.g. position, energy).

The EMMO can be used to represent 'physical'-s that can be related to Copenhagen based models. In practice, the user should follow these steps:

a) define the quantum system as a 'physical' individual (e.g. an H2 molecule) under a specific class (e.g. 'h2_molecule'). This individual is the whole.

b) define the axioms of the class that describe how many sub-parts are expected for the whole and their class types (e.g. 'h2_molecule' has axioms 'has_proper_part exactly 2 electron' and 'has_proper_part exactly 2 nucleus)

c) the user can now connect the whole to a Schroedinger equation based model whose Hamiltonian is calculated trough the information coming only from the axioms. No individuals are declared for the subparts!

d) a measurement done on the quantum system that provides information on the sub-part observables is interpreted as wavefunction collapse and leads to the end of the whole and the declaration of the sub-parts individuals which can be themselves other quantum systems

e.g. if the outer electron of the H2 molecule interacts with another entity defining its state, then the whole that stands for the entangled H2 molecule becomes a 'physical' made of an electron individual, a quantum system made of one electron and two nuclei and the void between them.

e.g. in the Born-Oppenheimer approximation the user represent the atom by un-entangling nucleus and electronic cloud. The un-entanglement comes in the form of declaration of individual as parts.

e.g. the double slit experiment can be represent in the EMMO as: a) before the slit: a 'physical' that extend in space and has parts 'electron' and 'void', called 'single_electron_wave_function'. 'electron' and 'void' are only in the axioms and not decalred individuals. b) during slit passage: a 'physical' made of one declared individual, the 'electron'. c) after the slit: again 'single_electron_wave_function' d) upon collision with the detector: 'physical' made of one declared individual, the 'electron'.

Comment: The purpose of the 'Physical' branch is to provide a representation of the real world objects, while the models used to name, explain or predict the behaviour of the real world objects lay under the 'Semiotic' branch.

More than one semiotic representation can be connected to the same 'Physical'.

e.g. Navier-Stokes or Euler equation applied to the same fluid are an example of mathematical model used to represent a physical object for some specific interpreter.

Relations:

- is_a Item
- hasPart some Elementary
- hasTemporalPart only Physical

Individuals:

- Universe

Void

IRI: http://emmo.info/emmo/top/physical#EMMO_29072ec4_ffcb_42fb_bdc7_26f05a2e9873

Elucidation: A 'Item' that has no 'Physical' parts.

Comment: From Latin vacuus, "empty".

Relations:

- is_a Item
- hasPart only Void

EMMO

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_802d3e92_8770_4f98_a289_ccaaab7fdddf

Elucidation: The class representing the collection of all the individuals declared in this ontology standing for real world objects.

Comment: 'EMMO' is the disjoint union of 'Item' and 'Collection' (covering axiom).

The union implies that 'EMMO' individuals can only be 'Item' individuals (standing for self-connected real world objects) or 'Collection' individuals (standing for a collection of disconnected items).

Disjointness means that a 'Collection' individual cannot be an 'Item' individual and viceversa, representing the fact that a real world object cannot be self-connected and non-self connected at the same time.

Comment: For the EMMO ontologist the whole universe is represented as a 4D path-connected topological manifold (i.e. the spacetime).

A real world object is then a 4D topological sub-region of the universe.

A universe sub-region is isolated and defined as a real world object by the ontologist. Then, through a semiotic process that occurs at meta-ontological level (i.e. outside the ontology). an EMMO ontology entity (e.g. an OWL individual) is assigned to represent that real world object.

The fundamental distinction between real world objects, upon which the EMMO is based, is self-connectedness: a real world object can be self-connected xor not self-connected.

Comment: In the EMMO we will refer to the universe as a Minkowski space, restricting the ontology to special relativity only. However, exension to general relativity, will adding more complexity, should not change the overall approach.

Comment: Mereotopology is the fundamental logical representation used by the EMMO ontologist to characterize the universe and to provide the definitions to connect real world objects to the EMMO concepts.

Parthood relations do not change dimensionality of the real world object referred by an 'EMMO' individual, i.e. every part of a real world object always retains its 4D dimensionality.

The smallest part of a real world object (i.e. a part that has no proper parts) is referred in the EMMO by a 'Quantum' individual.

It follows that, for the EMMO, real world objects of dimensionality lower than 4D (e.g. surfaces, lines) do not exist.

Relations:

- is_a owl:Thing
- equivalent_to hasPart some Quantum
- equivalent_to Inverse(hasPart) value Universe
- disjoint_union_of Collection, Item

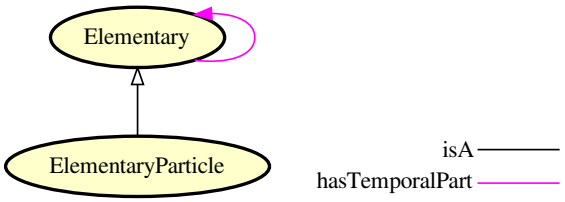

Figure 3.2: Elementary branch.

Elementary branch

Elementary

IRI: http://emmo.info/emmo/top/physical#EMMO_0f795e3e_c602_4577_9a43_d5a231aa1360

Elucidation: The basic constituent of 'item'-s that can be proper partitioned only in time up to quantum level.

Comment: According to mereology, this should be call 'a-tomistic' in the strict etimological sense of the word (from greek, a-tomos: un-divisible).

Mereology based on such items is called atomistic mereology.

However, in order not to confuse the lexicon between mereology and physics (in which an atom is a divisible physical entity) we prefer to call it 'elementary', recalling the concept of elementary particle coming from the standard particles model.

Comment: From Latin elementārius ("elementary"), from elementum ("one of the four elements of antiquity; fundamentals")

Comment: While a 'Quantum' is a-tomistic in time and space, an 'elementary' is a-tomistic only in space, recalling the concept of elementary particle.

Relations:

- is_a Physical
- hasTemporalPart only Elementary
- hasSpatialPart only owl:Nothing

Perspective branch

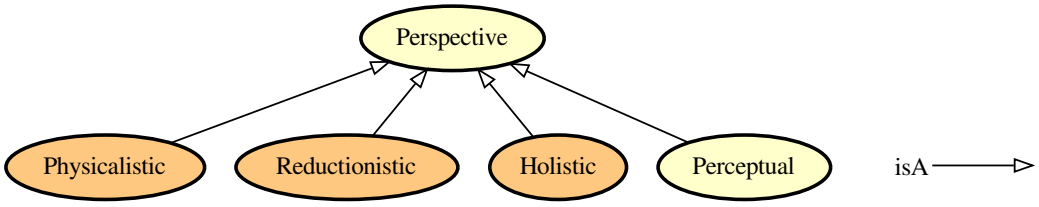

Figure 3.3: Perspective branch.

Perspective

IRI: http://emmo.info/emmo/top#EMMO_49267eba_5548_4163_8f36_518d65b583f9

Elucidation: The class of individuals that stand for real world objects according to a specific representational perspective.

Comment: This class is the practical implementation of the EMMO pluralistic approach for which that only objective categorization is provide by the Universe individual and all the 'Elementary' individuals.

Between these two extremes, there are several subjective ways to categorize real world objects, each one provide under a 'Perspective' subclass.

Relations:

- is_a Physical

Holistic branch

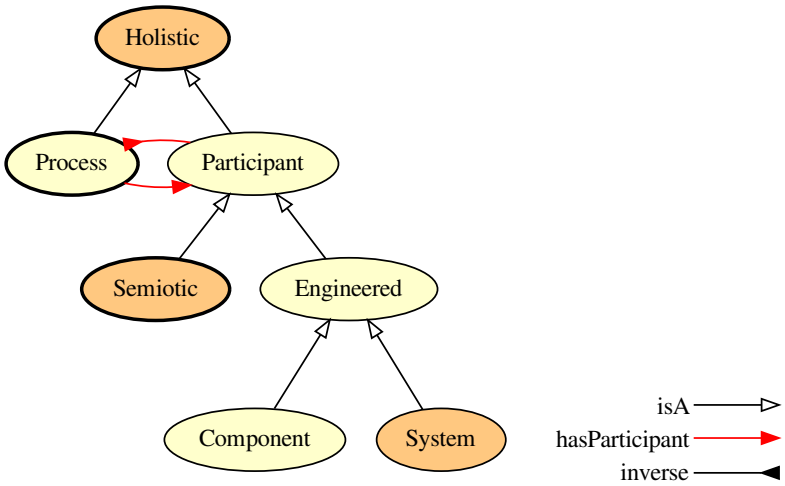

Figure 3.4: Holistic branch.

Holistic

IRI: http://emmo.info/emmo/middle/holistic#EMMO_0277f24a_ea7f_4917_81b7_fb0406c8fc62

Elucidation: A union of classes that categorize physicals under a holistic perspective, meaning that the interest is on the whole 4D object (process) and the role of its spatial parts (participants) without going further into its subparts.

Comment: An holistic perspective considers each part of the whole as equally important, without the need of a granularity hierarchy, assigning a role to the whole.

Meaning that a molecule of a body can have role in the body evolution, without caring if its part of a specific organ.

This class allows the picking of parts without necessarily going trough a rigid hierarchy of compositions (e.g. body → organ → cell → molecule).

Comment: Holism (from Greek *ὁλος* holos "all, whole, entire")

Relations:

- is_a Perspective

- equivalent_to Process or Participant

Component

IRI: http://emmo.info/emmo/middle/manufacturing#EMMO_494b372c_cfdf_47d3_a4de_5e037c540de8

Relations:

- is_a Engineered

Participant

IRI: http://emmo.info/emmo/middle/holistic#EMMO_49804605_c0fe_4538_abda_f70ba1dc8a5d

Elucidation: A portion of a 'Process' that participates to the process with a specific role.

Comment: In the EMMO the relation of participation to a process falls under mereotopology.

Since topological connection means causality, then the only way for a real world object to participate to a process is to be a part of it.

Relations:

- is_a Holistic
- is_a Physical
- Inverse(hasParticipant) some Process

Engineered

IRI: http://emmo.info/emmo/middle/manufacturing#EMMO_86ca9b93_1183_4b65_81b8_c0fcd3bba5ad

Elucidation: A 'physical' that stands for a real world object that has been manufacturedfor a particular purpose.

Example: Car, tire, composite material.

Comment: The 'Engineered' branch represents real world objects that show some level of complexity/heterogeneity in their composition, and are made for a specific use.

Relations:

- is_a Participant
- Inverse(hasProperParticipant) some Manufacturing

System

IRI: http://emmo.info/emmo/middle/manufacturing#EMMO_e775e341_5687_4d45_b50c_379b098a8c26

Relations:

- is_a Engineered
- equivalent_to hasSpatialPart some Component

Semiotic branch

Semiotic

IRI: http://emmo.info/emmo/middle/semiotics#EMMO_b803f122_4acb_4064_9d71_c1e5fd091fc9

Elucidation: The class of individuals that stands for semiotic objects, i.e. objects that take part on a semiotic process.

Comment: Semiotic subclasse are defined using Peirce's semiotic theory.

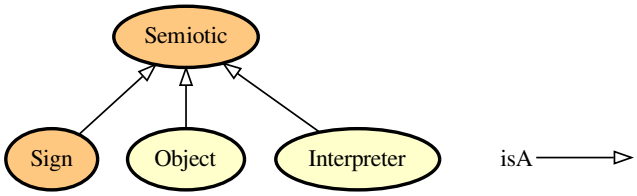

Figure 3.5: Semiotic branch.

"Namely, a sign is something, A, which brings something, B, its interpretant sign determined or created by it, into the same sort of correspondence with something, C, its object, as that in which itself stands to C." (Peirce 1902, NEM 4, 20–21).

The triadic elements: - 'sign': the sign A (e.g. a name) - 'interpretant': the sign B as the effects of the sign A on the interpreter (e.g. the mental concept of what a name means) - 'object': the object C (e.g. the entity to which the sign A and B refer to)

This class includes also the 'interpeter' i.e. the entity that connects the 'sign' to the 'object'

Relations:

- is_a Participant
- Inverse(hasProperParticipant) some Semiosis
- equivalent_to Interpreter or Object or Sign

Sign branch

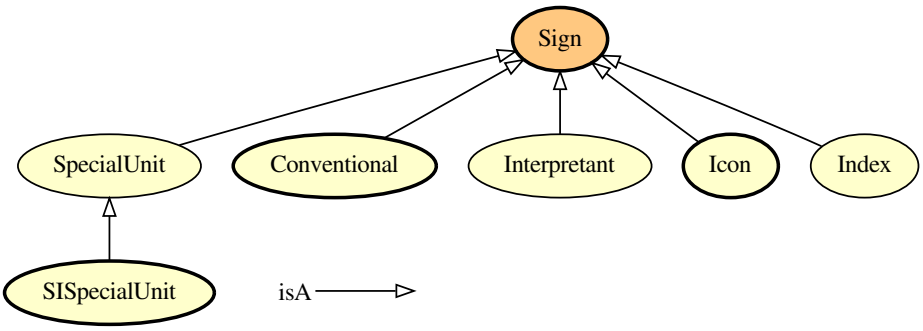

Figure 3.6: Sign branch.

Sign

IRI: http://emmo.info/emmo/middle/semiotics#EMMO_b21a56ed_f969_4612_a6ec_cb7766f7f31d

Elucidation: An 'Physical' that is used as sign ("semeion" in greek) that stands for another 'Physical' through an semiotic process.

Example: A novel is made of chapters, paragraphs, sentences, words and characters (in a direct parthood mereological hierarchy).

Each of them are 'sign'-s.

A character can be the a-tomistic ‘sign’ for the class of texts.

The horizontal segment in the character “A” is direct part of “A” but it is not a ‘sign’ itself.

For plain text we can propose the ASCII symbols, for math the fundamental math symbols.

Comment: A ‘Sign’ can have temporal-direct-parts which are ‘Sign’ themselves.

A ‘Sign’ usually have ‘sign’ spatial direct parts only up to a certain elementary semiotic level, in which the part is only a ‘Physical’ and no more a ‘Sign’ (i.e. it stands for nothing). This elementary semiotic level is peculiar to each particular system of signs (e.g. text, painting).

Just like an ‘Elementary’ in the ‘Physical’ branch, each ‘Sign’ branch should have an a-tomistic mereological part.

Comment: According to Peirce, ‘Sign’ includes three subcategories: - symbols: that stand for an object through convention - indeces: that stand for an object due to causal continguity - icon: that stand for an object due to similitudes e.g. in shape or composition

Relations:

- is_a Semiotic
- equivalent_to Index or Conventional or Icon

SpecialUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_3ee80521_3c23_4dd1_935d_9d522614a3e2

Elucidation: A unit symbol that stands for a derived unit.

Example: Pa stands for N/m2 J stands for N m

Comment: Special units are semiotic shortcuts to more complex composed symbolic objects.

Relations:

- is_a DerivedUnit
- is_a UnitSymbol
- is_a Sign
- Inverse(hasSign) some DerivedUnit

Interpretant

IRI: http://emmo.info/emmo/middle/semiotics#EMMO_054af807_85cd_4a13_8eba_119dfdaaf38b

Elucidation: The interpreter’s internal representation of the object in a semiosis process.

Relations:

- is_a Sign

Index

IRI: http://emmo.info/emmo/middle/semiotics#EMMO_0cd58641_824c_4851_907f_f4c3be76630c

Elucidation: A ‘Sign’ that stands for an ‘Object’ due to causal continguity.

Example: Smoke stands for a combustion process (a fire). My facial expression stands for my emotional status.

Relations:

- is_a Sign

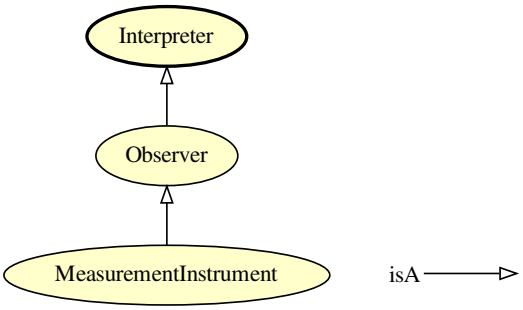

Figure 3.7: Interpreter branch.

Interpreter branch

Interpreter

IRI: http://emmo.info/emmo/middle/semiotics#EMMO_0527413c_b286_4e9c_b2d0_03fb2a038dee

Elucidation: The entity (or agent, or observer, or cognitive entity) who connects 'Sign', 'Interpretant' and 'Object'.

Relations:

- is_a Semiotic
- hasSpatialPart some Interpretant

Observer

IRI: http://emmo.info/emmo/middle/properties#EMMO_1b52ee70_121e_4d8d_8419_3f97cd0bd89c

Elucidation: An 'interpreter' that perceives another 'entity' (the 'object') through a specific perception mechanism and produces a 'property' (the 'sign') that stands for the result of that particular perception.

Relations:

- is_a Interpreter
- Inverse(hasParticipant) some Observation

MeasurementInstrument

IRI: http://emmo.info/emmo/middle/properties#EMMO_f2d5d3ad_2e00_417f_8849_686f3988d929

Relations:

- is_a Observer

Object branch

Object

IRI: http://emmo.info/emmo/middle/semiotics#EMMO_6f5af708_f825_4feb_a0d1_a8d813d3022b

Elucidation: The object, in Peirce semiotics.

Comment: Here is assumed that the concept of 'object' is always relative to a 'semiotic' process. An 'object' does not exists per se, but it's always part of an interpretation.

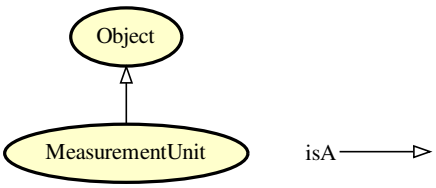

Figure 3.8: Object branch.

The EMMO relies on strong reductionism, i.e. everything real is a formless collection of elementary particles: we give a meaning to real world entities only by giving them boundaries and defining them using 'sign'-s.

In this way the 'sign'-ed entity become and 'object', and the 'object' is the basic entity needed in order to apply a logical formalism to the real world entities (i.e. we can speak of it through its sign, and use logics on it through its sign).

Relations:

- is_a Semiotic

Conventional branch

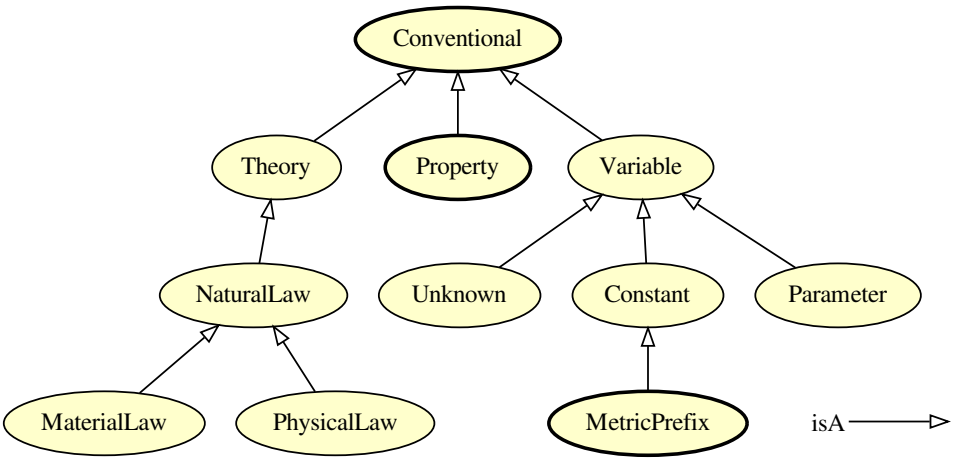

Figure 3.9: Conventional branch.

Unknown

IRI: http://emmo.info/emmo/middle/math#EMMO_fe7e56ce_118b_4243_9aad_20eb9f4f31f6

Elucidation: The dependent variable for which an equation has been written.

Example: Velocity, for the Navier-Stokes equation.

Relations:

- is_a Variable

MaterialLaw

IRI: http://emmo.info/emmo/middle/models#EMMO_f19ff3b4_6bfe_4c41_a2b2_9affd39c140b

Relations:

- is_a NaturalLaw

Constant

IRI: http://emmo.info/emmo/middle/math#EMMO_ae15fb4f_8e4d_41de_a0f9_3997f89ba6a2

Elucidation: A 'varaible' that stand for a well known constant.

Example: π refers to the constant number ~3.14

Relations:

- is_a Variable
- Inverse(hasVariable) only Numerical

NaturalLaw

IRI: http://emmo.info/emmo/middle/models#EMMO_db9a009e_f097_43f5_9520_6cbc07e7610b

Relations:

- is_a Theory

Variable

IRI: http://emmo.info/emmo/middle/math#EMMO_1eed0732_e3f1_4b2c_a9c4_b4e75eeb5895

Elucidation: A 'Variable' is a symbolic object that stands for a numerical defined 'Mathematical' object like e.g. a number, a vector, a matrix.

Example: x k

Relations:

- is_a Mathematical
- is_a Conventional
- Inverse(hasVariable) some Mathematical

Conventional

IRI: http://emmo.info/emmo/middle/semiotics#EMMO_35d2e130_6e01_41ed_94f7_00b333d46cf9

Elucidation: A 'Sign' that stands for an 'Object' through convention, norm or habit, without any resemblance to it.

Comment: In Peirce semiotics this kind of sign category is called symbol. However, since symbol is also used in formal languages, the name is changed in conventional.

Relations:

- is_a Sign

PhysicalLaw

IRI: http://emmo.info/emmo/middle/models#EMMO_9c32fd69_f480_4130_83b3_fb25d9face14

Relations:

- is_a NaturalLaw

Parameter

IRI: http://emmo.info/emmo/middle/math#EMMO_d1d436e7_72fc_49cd_863b_7bfb4ba5276a

Example: viscosity in the Navier-Stokes equation

Comment: A 'variable' whose value is assumed to be known independently from the equation, but whose value is not explicitated in the equation.

Relations:

- is_a Variable

Theory

IRI: http://emmo.info/emmo/middle/models#EMMO_8d2d9374_ef3a_47e6_8595_6bc208e07519

Elucidation: A 'conventional' that stand for a 'physical'.

Comment: The 'theory' is e.g. a proposition, a book or a paper whose sub-symbols suggest in the mind of the interpreter an interpretant structure that can represent a 'physical'.

It is not an 'icon' (like a math equation), because it has no common resemblance or logical structure with the 'physical'.

In Peirce semiotics: legisign-symbol-argument

Relations:

- is_a Conventional

Property branch

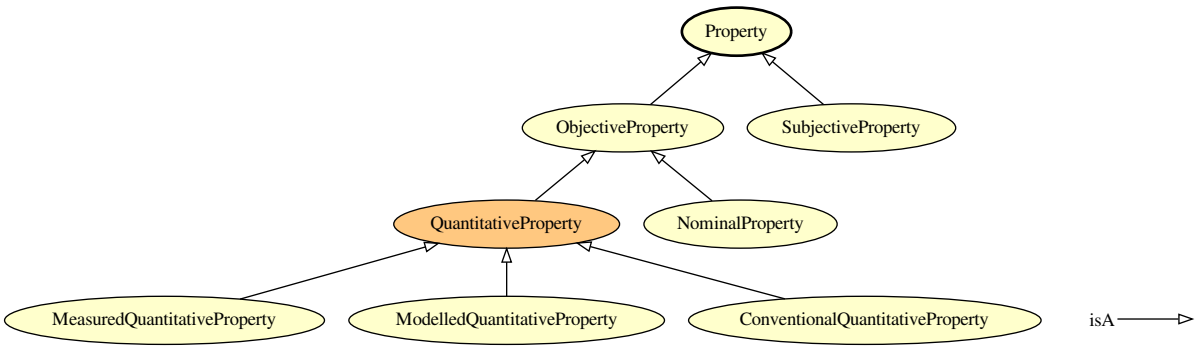

Figure 3.10: Property branch.

MeasuredQuantitativeProperty

IRI: http://emmo.info/emmo/middle/properties#EMMO_873b0ab3_88e6_4054_b901_5531e01f14a4

Relations:

- is_a QuantitativeProperty

NominalProperty

IRI: http://emmo.info/emmo/middle/properties#EMMO_909415d1_7c43_4d5e_bbeb_7e1910159f66

Elucidation: An 'ObjectiveProperty' that cannot be quantified.

Example: CFC is a 'sign' that stands for the fact that the morphology of atoms composing the microstructure of an entity is predominantly Cubic Face Centered

A color is a nominal property.

Sex of a human being.

Comment: "Property of a phenomenon, body, or substance, where the property has no magnitude."

"A nominal property has a value, which can be expressed in words, by alphanumerical codes, or by other means."

International vocabulary of metrology (VIM)

Relations:

- is_a ObjectiveProperty

ObjectiveProperty

IRI: http://emmo.info/emmo/middle/properties#EMMO_2a888cdf_ec4a_4ec5_af1c_0343372fc978

Elucidation: A 'Property' that is determined by each 'Observer' following a well defined 'Observation' procedure through a specific perception channel.

Comment: The word objective does not mean that each observation will provide the same results. It means that the observation followed a well defined procedure.

Comment: This class refers to what is commonly known as physical property, i.e. a measurable property of physical system, whether is quantifiable or not.

Relations:

- is_a Property

ModelledQuantitativeProperty

IRI: http://emmo.info/emmo/middle/properties#EMMO_d0200cf1_e4f4_45ae_873f_b9359daea3cd

Relations:

- is_a QuantitativeProperty

SubjectiveProperty

IRI: http://emmo.info/emmo/middle/properties#EMMO_251cfb4f_5c75_4778_91ed_6c8395212fd8

Elucidation: A 'Property' that cannot be univocally determined and depends on an agent (e.g. a human individual, a community) acting as black-box.

Example: The beauty of that girl. The style of your clothing.

Comment: The word subjective means that a non-well defined or an unknown procedure is used for the definition of the property.

This happens due to e.g. the complexity of the object, the lack of a underlying model for the representation of the object, the non-well specified meaning of the property symbols.

A 'SubjectiveProperty' cannot be used to univocally compare 'Object'-s.

e.g. you cannot evaluate the beauty of a person on objective basis.

Relations:

- is_a Property

Property

IRI: http://emmo.info/emmo/middle/properties#EMMO_b7bcff25_ffc3_474e_9ab5_01b1664bd4ba

Elucidation: A 'Perceptual' referring to a specific code that is used as 'Conventional' sign to represent an 'Object' according to a specific interaction mechanism by an 'Observer'.

(A property is always a partial representation of an 'Object' since it reflects the 'Object' capability to be part of a specific 'Observation' process)

Example: Hardness is a subclass of properties.

Vickers hardness is a subclass of hardness that involves the procedures and instruments defined by the standard hardness test.

Example: Let's define the class 'colour' as the subclass of the properties that involve photon emission and an electromagnetic radiation sensible observer.

An individual C of this class 'colour' can be defined be declaring the process individual (e.g. daylight illumination) and the observer (e.g. my eyes)

Stating that an entity E hasProperty C, we mean that it can be observed by such setup of process + observer (i.e. observed by my eyes under daylight).

This definition can be generalized by using a generic human eye, so that the observer can be a generic human.

This can be used in material characterization, to define exactly the type of measurement done, including the instrument type.

Comment: A 'Property' is a sort of name or label that we put upon objects that interact with an observer in the same specific way.

e.g. "hot" objects are objects that interact with an observer through a perception mechanism aimed to perceive an heat source.

Comment: We know real world entities through observation/perception.

A non-perceivable real world entity does not exist (or it exists on a plane of existance that has no intersection with us and we can say nothing about it).

Perception/observation of a real wolrd entity occurs when the entity stimulate an observer in a peculiar way through a well defined perception channel.

For this reason each property is related to a specific observation process which involves a specific observer with its own perception mechanisms.

The observation process (e.g. a look, a photo shot, a measurement) is performed by an observer (e.g. you, a camera, an instrument) through a specific perception mechanism (e.g. retina impression, CMOS excitation, piezoelectric sensor activation) and involves an observed entity.

An observation is a semiotic process, since it stimulate an interpretant within the interpreter who can communicate the perception result to other interpreters through a sign which is the property.

Property subclasses are specializations that depend on the type of observation processes.

e.g. the property 'colour' is related to a process that involves emission or interaction of photon and an observer who can perceive electromagnetic radiation in the visible frequency range.

Properties usually relies on symbolic systems (e.g. for colour it can be palette or RGB).

Relations:

- is_a Conventional
- Inverse(hasParticipant) some Observation
- Inverse(hasProperty) some Object
- disjoint_union_of SubjectiveProperty, ObjectiveProperty

QuantitativeProperty

IRI: http://emmo.info/emmo/middle/metrology#EMMO_dd4a7f3e_ef56_466c_ac1a_d2716b5f87ec

Elucidation: A 'Quantity' that can be quantified with respect to a standardized reference physical instance (e.g. the prototype meter bar, the kg prototype) or method (e.g. resilience) through a measurement process.

Comment: "A property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed by means of a number and a reference" ISO 80000-1

"A reference can be a measurement unit, a measurement procedure, a reference material, or a combination of such." International vocabulary of metrology (VIM)

Comment: A quantitative property is always expresssed as a quantity (i.e. a number and a reference unit). For the EMMO, a nominalistic ontology, there is no property as abstract object.

A property is a sign that stands for an object according to a specific code shared by some observers.

For quantititative properties, one possible code that is shared between the scientific community (the observers) is the SI system of units.

Comment: Subclasses of 'QuantitativeProperty' classify objects according to the type semiosis that is used to connect the property to the object (e.g. by measurement, by convention, by modelling).

Relations:

- is_a Quantity
- is_a ObjectiveProperty
- equivalent_to MeasuredQuantitativeProperty or ModelledQuantitativeProperty or ConventionalQuantitativeProperty

ConventionalQuantitativeProperty

IRI: http://emmo.info/emmo/middle/properties#EMMO_d8aa8e1f_b650_416d_88a0_5118de945456

Elucidation: A quantitative property attributed by agreement to a quantity for a given purpose.

Example: The thermal conductivity of a copper sample in my laboratory can be assumed to be the conductivity that appears in the vendor specification. This value has been obtained by measurement of a sample which is not the one I have in my laboratory. This conductivity value is then a conventional quantitiative property assigned to my sample through a semiotic process in which no actual measurement is done by my laboratory.

If I don't believe the vendor, then I can measure the actual thermal conductivity. I then perform a measurement process that semiotically assign another value for the conductivity, which is a measured property, since is part of a measurement process.

Then I have two different physical quantities that are properties thanks to two different semiotic processes.

Comment: A property that is associated to an object by convention, or assumption.

Relations:

- is_a QuantitativeProperty

Icon branch

Icon

IRI: http://emmo.info/emmo/middle/semiotics#EMMO_d7788d1a_020d_4c78_85a1_13563fcec168

Elucidation: A 'Sign' that stands for an 'Object' by resembling or imitating it, in shape or by sharing a similar logical structure.

Example: A picture that reproduces the aspect of a person.

An equation that reproduces the logical connection of the properties of a physical entity.

Comment: Three subtypes of icon are possible:

(a) the image, which depends on a simple quality (e.g. picture)

(b) the diagram, whose internal relations, mainly dyadic or so taken, represent by analogy the relations in something (e.g. math formula, geometric flowchart)

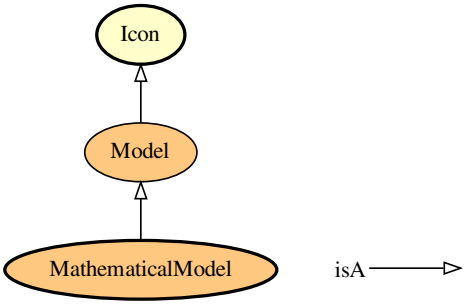

Figure 3.11: Icon branch.

(c) the metaphor, which represents the representative character of a sign by representing a parallelism in something else

[Wikipedia]

Relations:

- is_a Sign

Model

IRI: http://emmo.info/emmo/middle/models#EMMO_939483b1_0148_43d1_8b35_851d2cd5d939

Elucidation: A 'sign' that not only stands for a 'physical' or a 'process', but it is also a simplified representation, aimed to assist calculations for its description or for predictions of its behaviour.

A 'model' represents a 'physical' or a 'process' by direct similitude (e.g. small scale replica) or by capturing in a logical framework the relations between its properties (e.g. mathematical model).

Comment: A 'model' prediction is always a prediction of the properties of an entity, since an entity is known by an interpreter only through perception.

Relations:

- is_a Icon
- equivalent_to Inverse(hasModel) some Physical

Process branch

Manufacturing

IRI: http://emmo.info/emmo/middle/manufacturing#EMMO_a4d66059_5dd3_4b90_b4cb_10960559441b

Relations:

- is_a Process
- hasProperParticipant some Engineered

PhysicalPhenomenon

IRI: http://emmo.info/emmo/middle/models#EMMO_314d0bd5_67ed_437e_a609_36d46147cea7

Elucidation: A 'process' that is recognized by physical sciences and is catogrized accordingly.

Comment: While every 'process' in the EMMO involves physical objects, this class is devoted to represent real world objects that express a phenomena relevant for the ontologist.

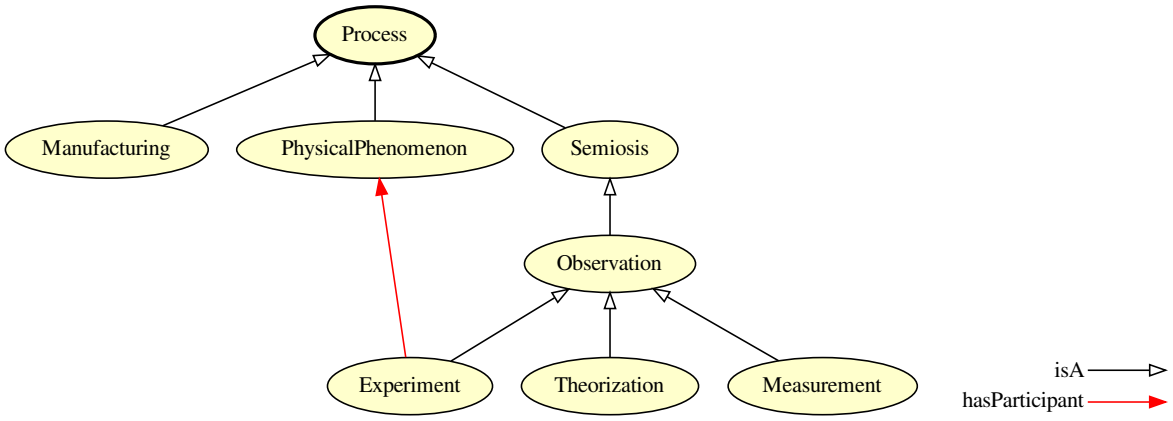

Figure 3.12: Process branch.

Relations:

- is_a Process

Experiment

IRI: http://emmo.info/emmo/middle/models#EMMO_22522299_4091_4d1f_82a2_3890492df6db

Elucidation: An experiment is a process that is intended to replicate a physical phenomenon in a controlled environment.

Relations:

- is_a Observation
- hasParticipant some PhysicalPhenomenon

Theorization

IRI: http://emmo.info/emmo/middle/models#EMMO_6c739b1a_a774_4416_bb31_1961486fa9ed

Elucidation: The 'semiosis' process of interpreting a 'physical' and provide a complec sign, 'theory' that stands for it and explain it to another interpreter.

Relations:

- is_a Observation

Observation

IRI: http://emmo.info/emmo/middle/properties#EMMO_10a5fd39_06aa_4648_9e70_f962a9cb2069

Elucidation: A 'Semiosis' that involves an 'Observer' that perceives another 'Physical' (the 'Object') through a specific perception mechanism and produces a 'Property' (the 'Sign') that stands for the result of that particular perception.

Relations:

- is_a Semiosis
- hasParticipant some Observer
- hasParticipant some Property

Measurement

IRI: http://emmo.info/emmo/middle/properties#EMMO_463bcfda_867b_41d9_a967_211d4d437cfb

Elucidation: An 'observation' that results in a quantitative comparison of a 'property' of an 'object' with a standard reference.

Relations:

- is_a Observation
- hasParticipant some MeasurementInstrument

Semiosis

IRI: http://emmo.info/emmo/middle/semiotics#EMMO_008fd3b2_4013_451f_8827_52bceab11841

Elucidation: A 'Process', that has participant an 'Interpreter', that is aimed to produce a 'Sign' representing another participant, the 'Object'.

Example: Me looking a cat and saying loud: "Cat!" → the semiosis process

me → interpreter cat → object (in Peirce semiotics) the cat perceived by my mind → interpretant "Cat!" → sign, the produced sign

Relations:

- is_a Process
- hasProperParticipant some Interpreter
- hasProperParticipant some Object
- hasProperParticipant some Sign

Process

IRI: http://emmo.info/emmo/middle/holistic#EMMO_43e9a05d_98af_41b4_92f6_00f79a09bfce

Elucidation: A temporal part of a 'physical' that identifies a particular type of evolution in time.

Comment: A 'Process' is always a 'Physical', since a 'Void' does not have elements that evolves in time.

Comment: A 'Process' is defined as a temporal part of a 'Physical' that is categorized according to an EMMO user that recognizes a particular type of evolution in time of the real world object.

Following the common definition of process, every 'Physical' should be a process, since every 4D object always has a time dimension.

However, in the EMMO we restrict the meaning of the word process to 'Physical'-s whose evolution in time have a particular meaning for the ontologist.

A 'Process' is not only something that unfolds in time (which is automatically represented in a 4D ontology), but something that has a meaning for the ontologist, i.e. that the ontologist can separate from the rest of the 4D physical for any reason.

Relations:

- is_a Holistic
- is_a Physical
- hasParticipant some Participant

Perceptual branch

Noise

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_91756568_8655_4060_8937_a1a906dad8c1

Relations:

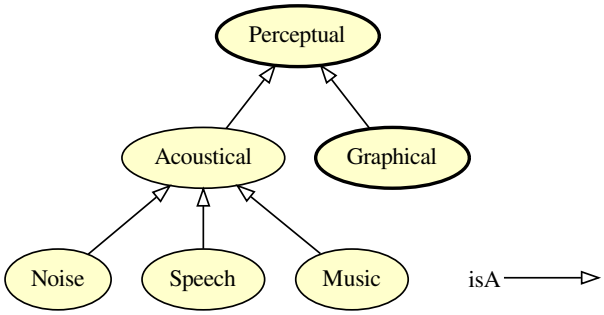

Figure 3.13: Perceptual branch.

- is_a Acoustical

Acoustical

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_4b3afb22_27cf_4ce3_88bc_492bfccb546b

Elucidation: A 'Perceptual' which stands for a real world object whose spatiotemporal pattern makes it identifiable by an observer as a sound.

Comment: 'acoustical' refers to the perception mechanism of the observer that can occur through a microphone, a ear.

Relations:

- is_a Perceptual

Perceptual

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_649bf97b_4397_4005_90d9_219755d92e34

Elucidation: A 'Physical' which stands for a real world object that can stimulate a perception (e.g. a mental impression, the excitation of a sensor) to an interpreter (human or non-human).

Example: A line scratched on a surface. A sound. A smell. The word 'cat' and the sound of the word 'cat' (the first one is graphical and the second acoustical).

Example: The meta-semiotic process: I see a cloud in the sky. Since I'm an EMMO ontologist, I create an individual named Cloud under the 'Impression' class. This semiotic process occurs at meta-level: it's how I use the EMMO as tool for a direct representation of the world.

The semiotic process within EMMO: My friend looks at the same cloud and says: "It is an elephant". I use the EMMO to record this experience by declaring: - my friend as MyFriend individual, belonging to 'Interpreter' classes - the sound of the word "elephant" as an acoustical impression individual named ElephantWord, belonging to 'Impression' - a relation hasSign between Cloud and ElephantWord, that makes ElephantWord also belonging to 'Sign' class and Cloud belonging also to 'Object' class - a 'Semiosis' individual called MyFriendElephantCloud that hasParticipant: Cloud, ElephantWord and MyFriend, respectively as object, sign and interpreter.

Comment: 'Perceptual' includes real world objects that: - are part of a communication system (e.g. words, speech, alphabets) - are not part of a communication system, but can be identified and referred by an interpreter

Comment: A 'Perceptual' is a meta-object, meaning that is addressed by the ontologist (the meta-interpreter) in a meta-semiotic process occurring outside the EMMO.

A 'Perceptual' becomes an 'Object', when it is part of a 'Semiotic' process described by the ontologist through the EMMO.

Comment: From Latin perceptiō (“a receiving or collecting, perception, comprehension”), from perceptus (“perceived, observed”).

Comment: This class is the most general superclass for the categorization of real world objects that are recognizable by an interpreter (agent).

A ‘Perceptual’ can stand for something else in a semiotic process (acting as sign or as object).

However, a perceptual is not necessarily a ‘Sign’ (e.g. a line sketched on a blackboard is a recognizable ‘Perceptual’ but it may stand for nothing).

Relations:

- is_a Perspective

Speech

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_660ef3b0_6692_4c51_8f69_763c7817b2e1

Relations:

- is_a Acoustical

Music

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_0d69f94a_f4fa_49d9_bf90_ace770eeab02

Elucidation: A ‘acoustical’ that can be categorized as music by the ontologist.

Comment: A music score is not a ‘music’ individual.

A music score is a ‘graphical’ that can stand for a ‘music’ (or vice versa) since it comes through a different perception mechanism.

The ‘music’ individual is the sound itself as produced and delivered by a source in the form of sound wave through a medium.

Relations:

- is_a Acoustical

Graphical branch

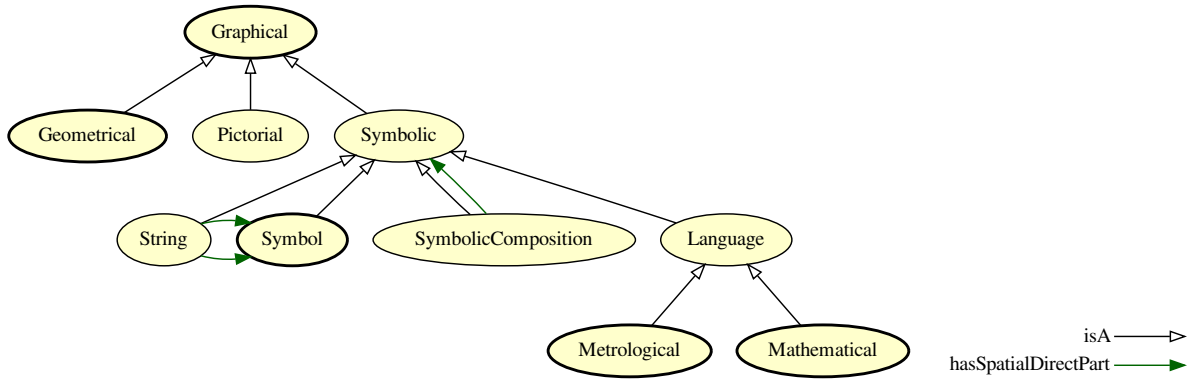

Figure 3.14: Graphical branch.

Symbolic

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_057e7d57_aff0_49de_911a_8861d85cef40

Elucidation: An 'Graphical' that stands for a token or a composition of tokens from one or more alphabets, without necessarily respecting syntactic rules.

Example: fe780 emmo !5*a cat

Relations:

- is_a Graphical

Pictorial

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_1da53c06_9577_4008_8652_272fa3b62be7

Elucidation: A 'Graphical' that stands for a real world object that shows a recognizable pictorial pattern without being necessarily associated to a symbolic language.

Example: A drawing of a cat. A circle on a paper sheet. The Mona Lisa.

Relations:

- is_a Graphical

Graphical

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_c74da218_9147_4f03_92d1_8894abca55f3

Elucidation: A 'Perceptual' which stands for a real world object whose spatial configuration shows a pattern identifiable by an observer.

Example: 'Graphical' objects include writings, pictures, sketches ...

Comment: From the Ancient Greek γραφή (graphḗ) which means drawing, painting, writing, a writing, description, and from γράφω (gráphō) which means scratch, carve.

Relations:

- is_a Perceptual

String

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_50ea1ec5_f157_41b0_b46b_a9032f17ca10

Elucidation: A physical made of more than one symbol sequentially arranged.

Example: The word "cat" considered as a collection of 'symbol'-s respecting the rules of english language.

In this example the 'symbolic' entity "cat" is not related to the real cat, but it is only a word (like it would be to an italian person that ignores the meaning of this english word).

If an 'interpreter' skilled in english language is involved in a 'semiotic' process with this word, that "cat" became also a 'sign' i.e. it became for the 'interpreter' a representation for a real cat.

Comment: A string is made of concatenated symbols whose arrangement is one-dimensional. Each symbol can have only one previous and one next neighborhood (bidirectional list).

Comment: A string is not requested to respect any syntactic rule: it's simply directly made of symbols.

Relations:

- is_a Symbolic
- is_a State
- hasSpatialDirectPart some Symbol
- hasSpatialDirectPart only Symbol

SymbolicComposition

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_89a0c87c_0804_4013_937a_6fe234d9499c

Elucidation: A symbolic entity made of other symbolic entities according to a specific spatial configuration.

Relations:

- is_a Symbolic
- is_a State
- hasSpatialDirectPart some Symbolic

Language

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_d8d2144e_5c8d_455d_a643_5caf4d8d9df8

Elucidation: A language object is a symbolic object respecting a specific language syntactic rules (a well-formed formula).

Relations:

- is_a Symbolic

Geometrical branch

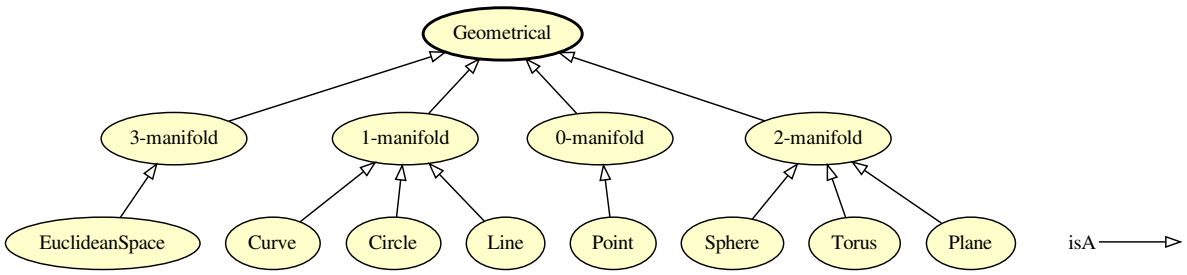

Figure 3.15: Geometrical branch.

EuclideanSpace

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_5f278af9_8593_4e27_a717_ccc9e07a0ddf

Relations:

- is_a 3-manifold

Geometrical

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_b5957cef_a287_442d_a3ce_fd39f20ba1cd

Elucidation: A 'graphical' aimed to represent a geometrical concept.

Comment: A 'geometrical' stands for real world objects that express a geometrical concept.

This can be achieved in many different ways. For example, a line can be expressed by: a) an equation like y=mx+q, which is both an 'equation' and a 'geometrical' b) a line drawn with a pencil on a paper, which is simply a 'graphical' object c) a set of axioms, when the properties of a line are inferred by the interpreter reading them, that are both 'graphical' and also 'formula'

The case a) is a geometrical and mathematical, b) is geometrical and pictorial, while c) is geometrical and a composition of idiomatic strings.

Relations:

- is_a Graphical

Sphere

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_d7bf784a_db94_4dd9_861c_54f262846fbf

Relations:

- is_a 2-manifold

Curve

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_0ef4ff4a_5458_4f2a_b51f_4689d472a3f2

Relations:

- is_a 1-manifold

3-manifold

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_46f0f8df_4dc6_418f_8036_10427a3a288e

Relations:

- is_a Geometrical

Circle

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_b2a234a8_579a_422c_9305_b8f7e72c76cd

Relations:

- is_a 1-manifold

Line

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_3e309118_e8b7_4021_80f4_642d2df65d94

Relations:

- is_a 1-manifold

Point

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_39362460_2a97_4367_8f93_0418c2ac9a08

Relations:

- is_a 0-manifold

Torus

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_86060335_31c2_4820_b433_27c64aea0366

Relations:

- is_a 2-manifold

1-manifold

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_0c576e13_4ee7_4f3d_bfe9_1614243df018

Relations:

- is_a Geometrical

Plane

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_25f5ca8e_8f7f_44d8_a392_bd3fe8894458

Relations:

- is_a 2-manifold

0-manifold

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_0ab0485c_9e5b_4257_a679_90a2dfba5c7c

Relations:

- is_a Geometrical

2-manifold

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_9268958f_7f54_48ab_a693_febe2645892b

Relations:

- is_a Geometrical

Symbol branch

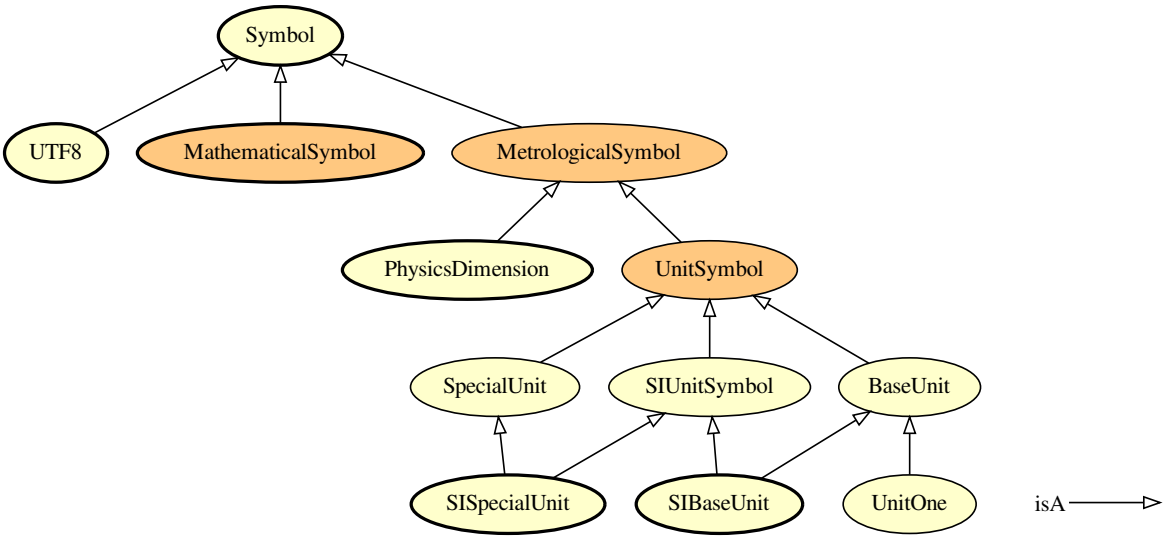

Figure 3.16: Symbol branch.

BaseUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_db716151_6b73_45ff_910c_d182fdcbb4f5

Elucidation: A set of units that correspond to the base quantities in a system of units.

Relations:

- is_a UnitSymbol

UnitSymbol

IRI: http://emmo.info/emmo/middle/metrology#EMMO_216f448e_cdbc_4aeb_a529_7a5fe7fc38bb

Elucidation: A symbol that stands for a single unit.

Example: Some examples are “Pa”, “m” and “J”.

Relations:

- is_a MetrologicalSymbol
- is_a NonPrefixedUnit
- equivalent_to MeasurementUnit and Symbol
- disjoint_union_of SpecialUnit, BaseUnit

SIUnitSymbol

IRI: http://emmo.info/emmo/middle/siunits#EMMO_32129fb5_df25_48fd_a29c_18a2f22a2dd5

Relations:

- is_a UnitSymbol
- is_a SICoherentUnit
- disjoint_union_of SIBaseUnit, SISpecialUnit

Symbol

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_a1083d0a_c1fb_471f_8e20_a98f881ad527

Elucidation: The class of individuals that stand for an elementary mark of a specific symbolic code (alphabet).

Example: The class of letter “A” is the symbol as idea and the letter A that you see on the screen is the mark.

Comment: Subclasses of ‘Symbol’ are alphabets, in formal languages terminology.

A ‘Symbol’ is atomic for that alphabet, i.e. it has no parts that are symbols for the same alphabet. e.g. a math symbol is not made of other math symbols

A Symbol may be a String in another language. e.g. “Bq” is the symbol for Becquerel units when dealing with metrology, or a string of “B” and “q” symbols when dealing with characters.

Comment: Symbols of a formal language need not be symbols of anything. For instance there are logical constants which do not refer to any idea, but rather serve as a form of punctuation in the language (e.g. parentheses).

Symbols of a formal language must be capable of being specified without any reference to any interpretation of them. (Wikipedia)

Comment: The class is the idea of the symbol, while the individual of that class stands for a specific mark (or token) of that idea.

Relations:

- is_a Symbolic
- hasSymbolData exactly 1 type

MetrologicalSymbol

IRI: http://emmo.info/emmo/middle/metrology#EMMO_50a3552e_859a_4ff7_946d_76d537cabce6

Elucidation: A symbol that stands for a concept in the language of the meterological domain of ISO 80000.

Relations:

- is_a Metrological
- is_a Symbol
- hasProperPart only not Metrological
- equivalent_to Metrological and Symbol

SpecialUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_3ee80521_3c23_4dd1_935d_9d522614a3e2

Elucidation: A unit symbol that stands for a derived unit.

Example: Pa stands for N/m2 J stands for N m

Comment: Special units are semiotic shortcuts to more complex composed symbolic objects.

Relations:

- is_a DerivedUnit
- is_a UnitSymbol
- is_a Sign
- Inverse(hasSign) some DerivedUnit

UnitOne

IRI: http://emmo.info/emmo/middle/metrology#EMMO_5ebd5e01_0ed3_49a2_a30d_cd05cbe72978

Elucidation: Represents the number 1, used as an explicit unit to say something has no units.

Example: Refractive index or volume fraction.

Example: Typically used for ratios of two units whos dimensions cancels out.

Qudtmatch: http://qudt.org/vocab/unit/UNITLESS

Relations:

- is_a BaseUnit
- hasPhysicsDimension only DimensionOne

Mathematical branch

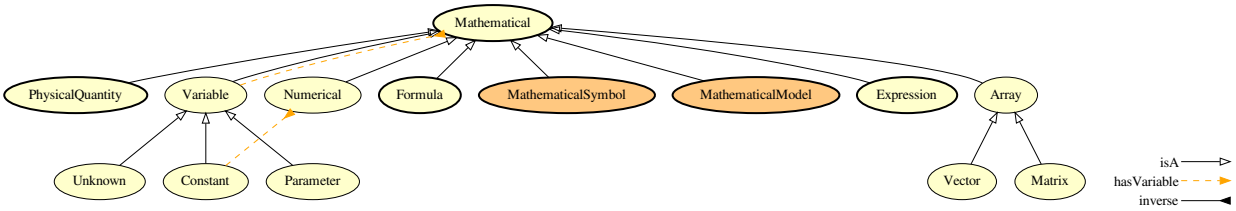

Figure 3.17: Mathematical branch.

Array

IRI: http://emmo.info/emmo/middle/math#EMMO_28fbea28_2204_4613_87ff_6d877b855fcd%20

Relations:

- is_a Mathematical

Unknown

IRI: http://emmo.info/emmo/middle/math#EMMO_fe7e56ce_118b_4243_9aad_20eb9f4f31f6

Elucidation: The dependent variable for which an equation has been written.

Example: Velocity, for the Navier-Stokes equation.

Relations:

- is_a Variable

Constant

IRI: http://emmo.info/emmo/middle/math#EMMO_ae15fb4f_8e4d_41de_a0f9_3997f89ba6a2

Elucidation: A 'varaible' that stand for a well known constant.

Example: π refers to the constant number ~3.14

Relations:

- is_a Variable
- Inverse(hasVariable) only Numerical

Vector

IRI: http://emmo.info/emmo/middle/math#EMMO_06658d8d_dcde_4fc9_aae1_17f71c0bcdec

Relations:

- is_a Array

Variable

IRI: http://emmo.info/emmo/middle/math#EMMO_1eed0732_e3f1_4b2c_a9c4_b4e75eeb5895

Elucidation: A 'Variable' is a symbolic object that stands for a numerical defined 'Mathematical' object like e.g. a number, a vector, a matrix.

Example: x k

Relations:

- is_a Mathematical
- is_a Conventional
- Inverse(hasVariable) some Mathematical

Matrix

IRI: http://emmo.info/emmo/middle/math#EMMO_1cba0b27_15d0_4326_933f_379d0b3565b6

Relations:

- is_a Array

Mathematical

IRI: http://emmo.info/emmo/middle/math#EMMO_54ee6b5e_5261_44a8_86eb_5717e7fdb9d0

Elucidation: The class of general mathematical symbolic objects respecting mathematical syntactic rules.

Relations:

- is_a Language

Parameter

IRI: http://emmo.info/emmo/middle/math#EMMO_d1d436e7_72fc_49cd_863b_7bfb4ba5276a

Example: viscosity in the Navier-Stokes equation

Comment: A 'variable' whose value is assumed to be known independently from the equation, but whose value is not explicitated in the equation.

Relations:

- is_a Variable

Numerical

IRI: http://emmo.info/emmo/middle/math#EMMO_4ce76d7f_03f8_45b6_9003_90052a79bfaa

Elucidation: A 'Mathematical' that has no unknown value, i.e. all its 'Variable"-s parts refers to a 'Number' (for scalars that have a built-in datatype) or to another 'Numerical' (for complex numerical data structures that should rely on external implementations).

Relations:

- is_a Mathematical

Mathematical Symbol branch

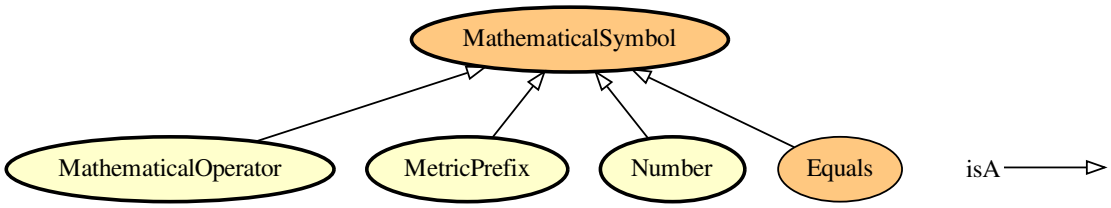

Figure 3.18: Mathematical Symbol branch.

Equals

IRI: http://emmo.info/emmo/middle/math#EMMO_535d75a4_1972_40bc_88c6_ca566386934f

Elucidation: The equals symbol.

Relations:

- is_a MathematicalSymbol
- is_a Mathematical
- is_a Symbol
- equivalent_to hasSymbolData value "="

MathematicalSymbol

IRI: http://emmo.info/emmo/middle/math#EMMO_5be83f9c_a4ba_4b9a_be1a_5bfc6e891231

Relations:

- is_a Mathematical
- is_a Symbol
- hasProperPart only not Mathematical
- equivalent_to Mathematical and Symbol

Mathematical Model branch

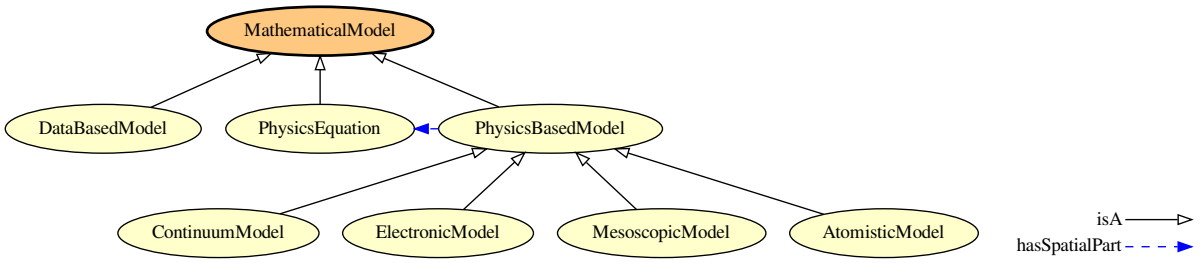

Figure 3.19: Mathematical Model branch.

DataBasedModel

IRI: http://emmo.info/emmo/middle/models#EMMO_a4b14b83_9392_4a5f_a2e8_b2b58793f59b

Elucidation: A computational model that uses data to create new insight into the behaviour of a system.

Relations:

- is_a MathematicalModel

PhysicsEquation

IRI: http://emmo.info/emmo/middle/models#EMMO_27c5d8c6_8af7_4d63_beb1_ec37cd8b3fa3

Elucidation: An 'equation' that stands for a 'physical_law' by mathematically defining the relations between physics_quantities.

Comment: The Newton's equation of motion.

The Schrodinger equation.

The Navier-Stokes equation.

Relations:

- is_a Equation
- is_a MathematicalModel
- hasSpatialDirectPart some PhysicalQuantity
- Inverse(hasModel) some PhysicalPhenomenon

ContinuumModel

IRI: http://emmo.info/emmo/middle/models#EMMO_4456a5d2_16a6_4ee1_9a8e_5c75956b28ea

Elucidation: A physics-based model based on a physics equation describing the behaviour of continuum volume.

Relations:

- is_a PhysicsBasedModel

ElectronicModel

IRI: http://emmo.info/emmo/middle/models#EMMO_6eca09be_17e9_445e_abc9_000aa61b7a11

Elucidation: A physics-based model based on a physics equation describing the behaviour of electrons.

Example: Density functional theory. Hartree-Fock.

Relations:

- is_a PhysicsBasedModel

PhysicsBasedModel

IRI: http://emmo.info/emmo/middle/models#EMMO_b29fd350_39aa_4af7_9459_3faa0544cba6

Elucidation: A solvable set of one Physics Equation and one or more Materials Relations.

Relations:

- is_a MathematicalModel
- hasSpatialPart some PhysicsEquation
- hasSpatialPart some MaterialRelation

MathematicalModel

IRI: http://emmo.info/emmo/middle/models#EMMO_f7ed665b_c2e1_42bc_889b_6b42ed3a36f0

Comment: A mathematical model can be defined as a description of a system using mathematical concepts and language to facilitate proper explanation of a system or to study the effects of different components and to make predictions on patterns of behaviour.

Abramowitz and Stegun, 1968

Relations:

- is_a Mathematical
- is_a Model
- equivalent_to Mathematical and Model

MesoscopicModel

IRI: http://emmo.info/emmo/middle/models#EMMO_53935db0_af45_4426_b9e9_244a0d77db00

Elucidation: A physics-based model based on a physics equation describing the behaviour of mesoscopic entities, i.e. a set of bounded atoms like a molecule, bead or nanoparticle.

Relations:

- is_a PhysicsBasedModel

AtomisticModel

IRI: http://emmo.info/emmo/middle/models#EMMO_84cadc45_6758_46f2_ba2a_5ead65c70213

Elucidation: A physics-based model based on a physics equation describing the behaviour of atoms.

Relations:

- is_a PhysicsBasedModel

Mathematical Operator branch

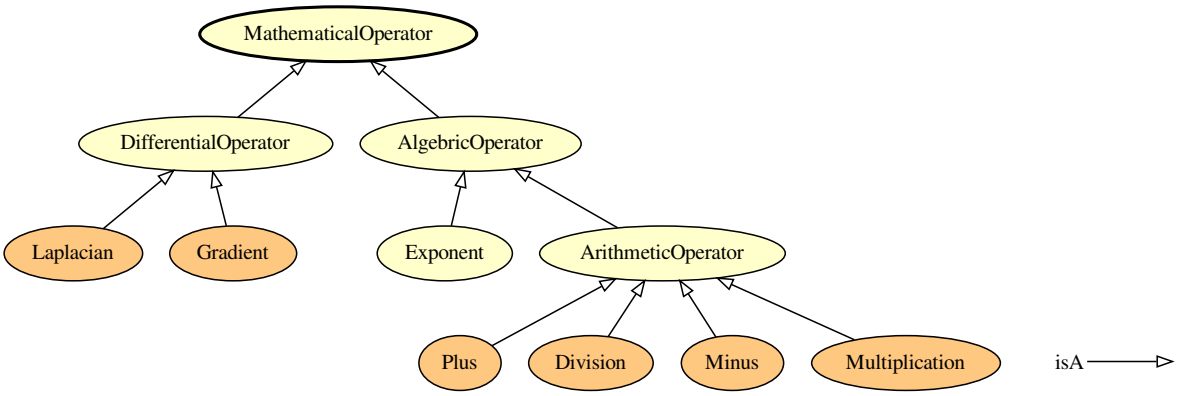

Figure 3.20: Mathematical Operator branch.

ArithmeticOperator

IRI: http://emmo.info/emmo/middle/math#EMMO_707f0cd1_941c_4b57_9f20_d0ba30cd6ff3

Relations:

- is_a AlgebricOperator

Plus

IRI: http://emmo.info/emmo/middle/math#EMMO_8de14a59_660b_454f_aff8_76a07ce185f4

Relations:

- is_a ArithmeticOperator
- equivalent_to hasSymbolData value “+”

Laplacian

IRI: http://emmo.info/emmo/middle/math#EMMO_048a14e3_65fb_457d_8695_948965c89492

Relations:

- is_a DifferentialOperator
- equivalent_to hasSymbolData value “Δ”

Exponent

IRI: http://emmo.info/emmo/middle/math#EMMO_223d9523_4169_4ecd_b8af_acad1215e1ff

Relations:

- is_a AlgebricOperator

DifferentialOperator

IRI: http://emmo.info/emmo/middle/math#EMMO_f8a2fe9f_458b_4771_9aba_a50e76afc52d

Relations:

- is_a MathematicalOperator

AlgebricOperator

IRI: http://emmo.info/emmo/middle/math#EMMO_3c424d37_cf62_41b1_ac9d_a316f8d113d6

Relations:

- is_a MathematicalOperator

MathematicalOperator

IRI: http://emmo.info/emmo/middle/math#EMMO_f6d0c26a_98b6_4cf8_8632_aa259131faaa

Relations:

- is_a MathematicalSymbol
- is_a Mathematical
- is_a Symbol

Division

IRI: http://emmo.info/emmo/middle/math#EMMO_a365b3c1_7bde_41d7_a15b_2820762e85f4

Relations:

- is_a ArithmeticOperator
- equivalent_to hasSymbolData value “/”

Minus

IRI: http://emmo.info/emmo/middle/math#EMMO_46d5643b_9706_4b67_8bea_ed77d6026539

Relations:

- is_a ArithmeticOperator
- equivalent_to hasSymbolData value “-”

Multiplication

IRI: http://emmo.info/emmo/middle/math#EMMO_2b1303e8_d4c3_453b_9918_76f1d009543f

Relations:

- is_a ArithmeticOperator
- equivalent_to hasSymbolData value “*”

Gradient

IRI: http://emmo.info/emmo/middle/math#EMMO_b5c58790_fb2d_42eb_b184_2a3f6ca60acb

Relations:

- is_a DifferentialOperator
- equivalent_to hasSymbolData value "∇"

Metrological branch

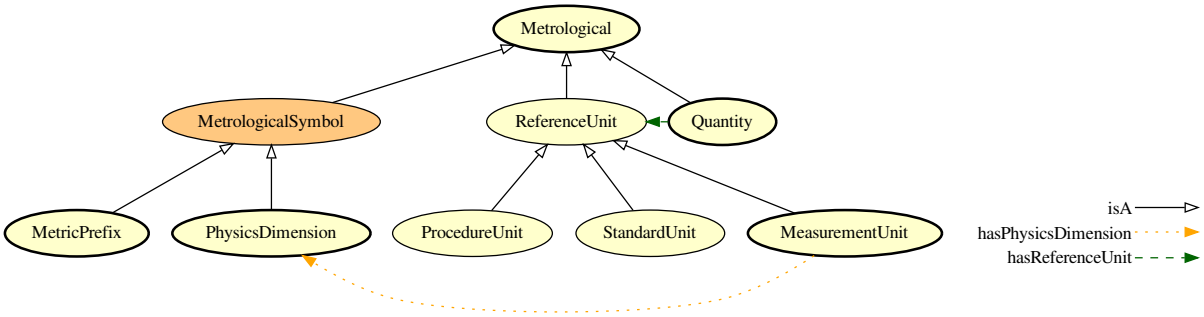

Figure 3.21: Metrological branch.

ReferenceUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_18ce5200_00f5_45bb_8c6f_6fb128cd41ae

Comment: A reference can be a measurement unit, a measurement procedure, a reference material, or a combination of such. International vocabulary of metrology (VIM)

Comment: A symbolic is recognized as reference unit also if it is not part of a quatity (e.g. as in the sentence "the Bq is the reference unit of Becquerel").

For this reason we can't declare the axiom: ReferenceUnit SubClassOf: inverse(hasReferenceUnit) some Quantity because there exist reference units without being part of a quantity.

This is peculiar to EMMO, where quantities (symbolic) are distinct with properties (semiotics).

Relations:

- is_a Metrological

BaseUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_db716151_6b73_45ff_910c_d182fdcbb4f5

Elucidation: A set of units that correspond to the base quantities in a system of units.

Relations:

- is_a UnitSymbol

UnitSymbol

IRI: http://emmo.info/emmo/middle/metrology#EMMO_216f448e_cdbc_4aeb_a529_7a5fe7fc38bb

Elucidation: A symbol that stands for a single unit.

Example: Some examples are “Pa”, “m” and “J”.

Relations:

- is_a MetrologicalSymbol
- is_a NonPrefixedUnit
- equivalent_to MeasurementUnit and Symbol
- disjoint_union_of SpecialUnit, BaseUnit

ProcedureUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_c9c8f824_9127_4f93_bc21_69fe78a7f6f2

Elucidation: A reference unit provided by a measurement procedure.

Example: Rockwell C hardness of a given sample (150 kg load): 43.5HRC(150 kg)

Relations:

- is_a ReferenceUnit

Metrological

IRI: http://emmo.info/emmo/middle/metrology#EMMO_985bec21_989f_4b9e_a4b3_735d88099c3c

Elucidation: A symbolic object used in metrology.

Comment: This language domain makes use of ISO 80000 concepts.

Relations:

- is_a Language

SIUnitSymbol

IRI: http://emmo.info/emmo/middle/siunits#EMMO_32129fb5_df25_48fd_a29c_18a2f22a2dd5

Relations:

- is_a UnitSymbol
- is_a SICoherentUnit
- disjoint_union_of SIBaseUnit, SISpecialUnit

MetrologicalSymbol

IRI: http://emmo.info/emmo/middle/metrology#EMMO_50a3552e_859a_4ff7_946d_76d537cabce6

Elucidation: A symbol that stands for a concept in the language of the meterological domain of ISO 80000.

Relations:

- is_a Metrological
- is_a Symbol
- hasProperPart only not Metrological
- equivalent_to Metrological and Symbol

SpecialUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_3ee80521_3c23_4dd1_935d_9d522614a3e2

Elucidation: A unit symbol that stands for a derived unit.

Example: Pa stands for N/m2 J stands for N m

Comment: Special units are semiotic shortcuts to more complex composed symbolic objects.

Relations:

- is_a DerivedUnit
- is_a UnitSymbol
- is_a Sign
- Inverse(hasSign) some DerivedUnit

StandardUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_acd1a504_ca32_4f30_86ad_0b62cea5bc02

Elucidation: A reference unit provided by a reference material. International vocabulary of metrology (VIM)

Example: Arbitrary amount-of-substance concentration of lutropin in a given sample of plasma (WHO international standard 80/552): 5.0 International Unit/l

Relations:

- is_a ReferenceUnit

UnitOne

IRI: http://emmo.info/emmo/middle/metrology#EMMO_5ebd5e01_0ed3_49a2_a30d_cd05cbe72978

Elucidation: Represents the number 1, used as an explicit unit to say something has no units.

Example: Refractive index or volume fraction.

Example: Typically used for ratios of two units whos dimensions cancels out.

Qudtmatch: http://qudt.org/vocab/unit/UNITLESS

Relations:

- is_a BaseUnit
- hasPhysicsDimension only DimensionOne

Physics Dimension branch

AmountPerTimeDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_ce7d4720_aa20_4a8c_93e8_df41a35b6723

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T-1 L0 M0 I0 Θ0 N+1 J0”

QuarticTimeSquareCurrentPerMassSquareLengthDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_b14d9be5_f81e_469b_abca_379c2e83feab

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T+4 L-2 M-1 I+2 Θ0 N0 J0”

TimeDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_02e894c3_b793_4197_b120_3442e08f58d1

Relations:

- is_a PhysicsDimension

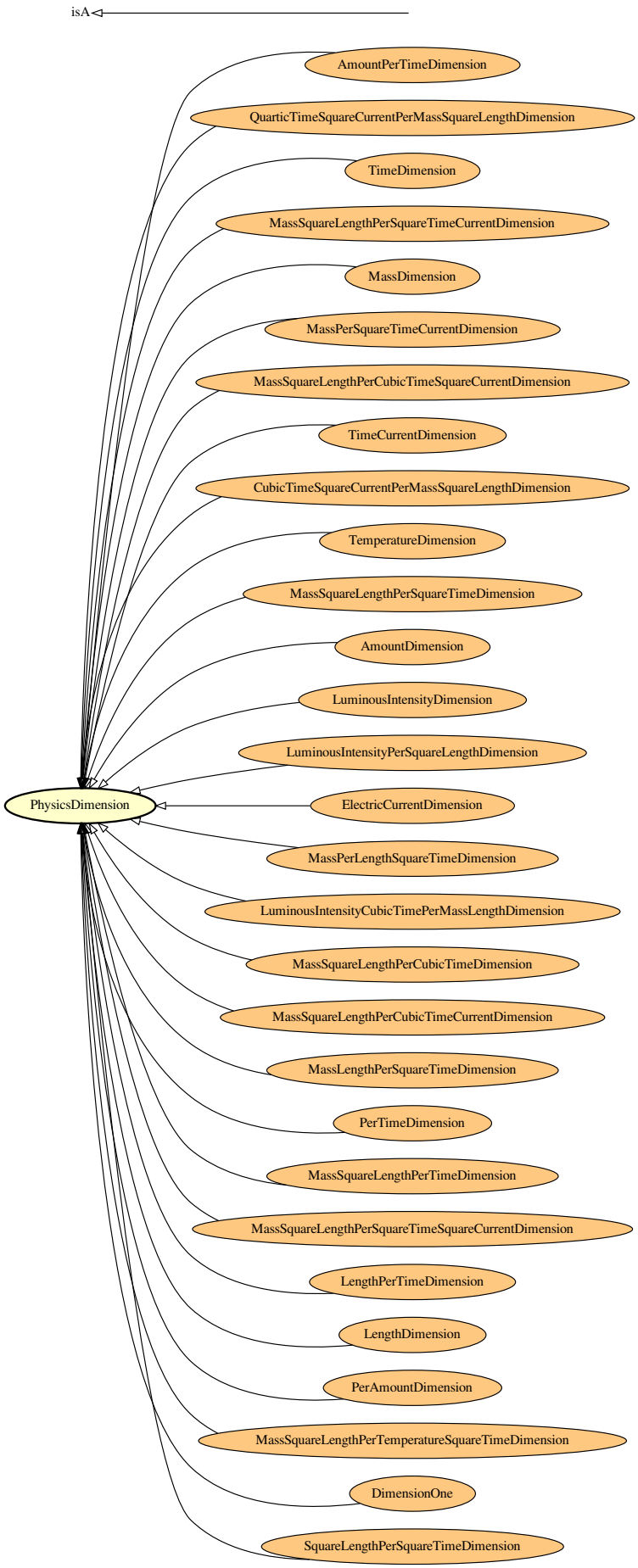

Figure 3.22: Physics Dimension branch.

- equivalent_to hasSymbolData value “T+1 L0 M0 I0 Θ0 N0 J0”

MassSquareLengthPerSquareTimeCurrentDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_4c49ab58_a6f6_409e_b849_f873ae1dcbee

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T-2 L+2 M+1 I-1 Θ0 N0 J0”

MassDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_77e9dc31_5b19_463e_b000_44c6e79f98aa

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T0 L0 M+1 I0 Θ0 N0 J0”

MassPerSquareTimeCurrentDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_ec903946_ddc9_464a_903c_7373e0d1eeb5

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T-2 L0 M+1 I-1 Θ0 N0 J0”

MassSquareLengthPerCubicTimeSquareCurrentDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_7610efb8_c7c6_4684_abc1_774783c62472

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T-3 L+2 M+1 I-2 Θ0 N0 J0”

TimeCurrentDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_ab79e92b_5377_454d_be06_d61b50db295a

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T+1 L0 M0 I+1 Θ0 N0 J0”

CubicTimeSquareCurrentPerMassSquareLengthDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_321af35f_f0cc_4a5c_b4fe_8c2c0303fb0c

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T+3 L-2 M-1 I+2 Θ0 N0 J0”

TemperatureDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_a77a0a4b_6bd2_42b2_be27_4b63cebbb59e

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value "T0 L0 M0 I0 Θ+1 N0 J0"

PhysicsDimension

IRI: http://emmo.info/emmo/middle/metrology#EMMO_9895a1b4_f0a5_4167_ac5e_97db40b8bfcc

Elucidation: A symbol that, following SI specifications, describe the physical dimensionality of a physical quantity and the exponents of the base units in a measurement unit.

Comment: All physical quantities, with the exception of counts, are derived quantities, which may be written in terms of base quantities according to the equations of physics. The dimensions of the derived quantities are written as products of powers of the dimensions of the base quantities using the equations that relate the derived quantities to the base quantities. In general the dimension of any quantity Q is written in the form of a dimensional product,

dim Q = T^α L^β M^γ I^δ Θ^ϵ N^ζ J^η

where the exponents α, β, γ, δ, ϵ, ζ and η, which are generally small integers, which can be positive, negative, or zero, are called the dimensional exponents. (SI brochure)

Comment: The conventional symbolic representation of the dimension of a base quantity is a single upper case letter in roman (upright) type. The conventional symbolic representation of the dimension of a derived quantity is the product of powers of the dimensions of the base quantities according to the definition of the derived quantity. The dimension of a quantity Q is denoted by dim Q. ISO 80000-1

Comment: The expression used by the EMMO for physical dimensions is a metrological symbol (but a string at meta level, i.e. the ontologist level) like this:

Ta Lb Mc Id Θe Nf Jg

where a, b, c, d, e, f and g are 0 or signed integers.

Regex for the physical dimension symbol for the EMMO is: ^T([+-][1-9]|0) L([+-][1-9]|0) M([+-][1-9]|0) I([+-][1-9]|0) Θ([+-][1-9]|0) N([+-][1-9]|0) J([+-][1-9]|0)$

Examples of correspondance between base units and physical dimensions are: mol → T0 L0 M0 I0 Θ0 N+1 J0 s → T+1 L0 M0 I0 Θ0 N0 J0 A/m2 → T0 L0 M-2 I+1 Θ0 N0 J0

Relations:

- is_a MetrologicalSymbol
- is_a Metrological
- is_a Symbol

MassSquareLengthPerSquareTimeDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_f6070071_d054_4b17_9d2d_f446f7147d0f

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value "T-2 L+2 M+1 I0 Θ0 N0 J0"

AmountDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_e501069c_34d3_4dc7_ac87_c90c7342192b

Comment: "In the name "amount of substance", the word "substance" will typically be replaced by words to specify the substance concerned in any particular application, for example "amount of hydrogen chloride, HCl",

or “amount of benzene, C6H6”. It is important to give a precise definition of the entity involved (as emphasized in the definition of the mole); this should preferably be done by specifying the molecular chemical formula of the material involved. Although the word “amount” has a more general dictionary definition, the abbreviation of the full name “amount of substance” to “amount” may be used for brevity.” SI Brochure

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T0 L0 M0 I0 Θ0 N+1 J0”

LuminousIntensityDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_14ff4393_0f28_4fb4_abc7_c2cc00bc761d

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T0 L0 M0 I0 Θ0 N0 J+1”

LuminousIntensityPerSquareLengthDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_668e6ead_1530_40cc_ad5e_24b880edff50

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T0 L-2 M0 I0 Θ0 N0 J+1”

ElectricCurrentDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_d5f3e0e5_fc7d_4e64_86ad_555e74aaff84

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T0 L0 M0 I+1 Θ0 N0 J0”

MassPerLengthSquareTimeDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_53bd0c90_41c3_46e2_8779_cd2a80f7e18b

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T-2 L-1 M+1 I0 Θ0 N0 J0”

LuminousIntensityCubicTimePerMassLengthDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_5c003f53_20a2_4bd7_8445_58187e582578

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T+3 L-1 M-1 I0 Θ0 N0 J+1”

MassSquareLengthPerCubicTimeDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_c8d084ad_f88e_4596_8e4d_982c6655ce6f

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T-3 L+2 M+1 I0 Θ0 N0 J0”

MassSquareLengthPerCubicTimeCurrentDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_2e7e5796_4a80_4d73_bb84_f31138446c0c

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T-3 L+2 M+1 I-1 Θ0 N0 J0”

MassLengthPerSquareTimeDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_53e825d9_1a09_483c_baa7_37501ebfbe1c

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T-2 L+1 M+1 I0 Θ0 N0 J0”

PerTimeDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_515b5579_d526_4842_9e6f_ecc34db6f368

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T-1 L0 M0 I0 Θ0 N0 J0”

MassSquareLengthPerTimeDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_501f9b3a_c469_48f7_9281_2e6a8d805d7a

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T-1 L+2 M+1 I0 Θ0 N0 J0”

MassSquareLengthPerSquareTimeSquareCurrentDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_585e0ff0_9429_4d3c_b578_58abb1ba21d1

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T-2 L+2 M+1 I-2 Θ0 N0 J0”

LengthPerTimeDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_4f5c7c54_1c63_4d17_b12b_ea0792c2b187

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T-1 L+1 M0 I0 Θ0 N0 J0”

LengthDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_b3600e73_3e05_479d_9714_c041c3acf5cc

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T0 L+1 M0 I0 Θ0 N0 J0”

PerAmountDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_af24ae20_8ef2_435a_86a1_2ea44488b318

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T0 L0 M0 I0 Θ0 N-1 J0”

MassSquareLengthPerTemperatureSquareTimeDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_3ecff38b_b3cf_4a78_b49f_8580abf8715b

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T-2 L+2 M+1 I0 Θ-1 N0 J0”

DimensionOne

IRI: http://emmo.info/emmo/middle/metrology#EMMO_3227b821_26a5_4c7c_9c01_5c24483e0bd0

Comment: “The unit one is the neutral element of any system of units – necessary and present automatically.” SI Brochure

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T0 L0 M0 I0 Θ0 N0 J0”

SquareLengthPerSquareTimeDimension

IRI: http://emmo.info/emmo/middle/isq#EMMO_847f1d9f_205e_46c1_8cb6_a9e479421f88

Relations:

- is_a PhysicsDimension
- equivalent_to hasSymbolData value “T-2 L+2 M0 I0 Θ0 N0 J0”

Physical Quantity branch

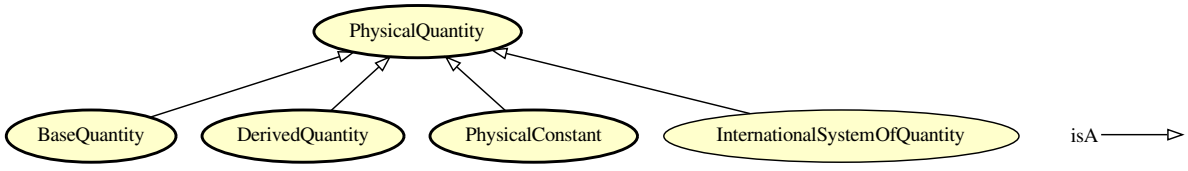

Figure 3.23: Physical Quantity branch.

DoseEquivalent

IRI: http://emmo.info/emmo/middle/isq#EMMO_3df10765_f6ff_4c9e_be3d_10b1809d78bd

Elucidation: A dose quantity used in the International Commission on Radiological Protection (ICRP) system of radiological protection.

Dbpediamatch: http://dbpedia.org/page/Energy

Iupacdoi: https://doi.org/10.1351/goldbook.E02101

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only SquareLengthPerSquareTimeDimension

LuminousIntensity

IRI: http://emmo.info/emmo/middle/isq#EMMO_50bf79a6_a48b_424d_9d2c_813bd631231a

Elucidation: A measure of the wavelength-weighted power emitted by a light source in a particular direction per unit solid angle. It is based on the luminosity function, which is a standardized model of the sensitivity of the human eye.

Dbpediamatch: http://dbpedia.org/page/Luminous_intensity

Relations:

- is_a ISQBaseQuantity
- hasReferenceUnit only hasPhysicsDimension only LuminousIntensityDimension

Capacitance

IRI: http://emmo.info/emmo/middle/isq#EMMO_99dba333_0dbd_4f75_8841_8c0f97fd58e2

Elucidation: The derivative of the electric charge of a system with respect to the electric potential.

Altlabel: ElectricCapacitance

Dbpediamatch: http://dbpedia.org/page/Capacitance

Iupacdoi: https://doi.org/10.1351/goldbook.C00791

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only QuarticTimeSquareCurrentPerMassSquareLengthDimension

ElectricResistance

IRI: http://emmo.info/emmo/middle/isq#EMMO_e88f75d6_9a17_4cfc_bdf7_43d7cea5a9a1

Elucidation: Measure of the difficulty to pass an electric current through a material.

Altlabel: Resistance

Comment: Inverse of 'ElectricalConductance'.

Dbpediamatch: http://dbpedia.org/page/Electrical_resistance_and_conductance

Iupacdoi: https://doi.org/10.1351/goldbook.E01936

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassSquareLengthPerCubicTimeSquareCurrentDimension

MagneticFlux

IRI: http://emmo.info/emmo/middle/isq#EMMO_3b931698_937e_49be_ab1b_36fa52d91181

Elucidation: Measure of magnetism, taking account of the strength and the extent of a magnetic field.

Dbpediamatch: http://dbpedia.org/page/Magnetic_flux

Iupacdoi: https://doi.org/10.1351/goldbook.M03684

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassSquareLengthPerSquareTimeCurrentDimension

MagneticFluxDensity

IRI: http://emmo.info/emmo/middle/isq#EMMO_961d1aba_f75e_4411_aaa4_457f7516ed6b

Elucidation: Strength of the magnetic field.

Comment: Often denoted B.

Dbpediamatch: http://dbpedia.org/page/Magnetic_field

Iupacdoi: https://doi.org/10.1351/goldbook.M03686

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassPerSquareTimeCurrentDimension

RatioQuantity

IRI: http://emmo.info/emmo/middle/isq#EMMO_faab3f84_e475_4a46_af9c_7d249f0b9aef

Elucidation: The class of quantities that are the ratio of two quantities with the same physical dimensionality.

Example: refractive index, volume fraction, fine structure constant

Comment: Quantities defined as ratios `Q=A/B` having equal dimensions in numerator and denominator are dimensionless quantities but still have a physical dimension defined as dim(A)/dim(B).

Johansson, Ingvar (2010). "Metrological thinking needs the notions of parametric quantities, units and dimensions". Metrologia. 47 (3): 219–230. doi:10.1088/0026-1394/47/3/012. ISSN 0026-1394.

Seealso: https://iopscience.iop.org/article/10.1088/0026-1394/47/3/012

Relations:

- is_a ISQDimensionlessQuantity

ElectricCharge

IRI: http://emmo.info/emmo/middle/isq#EMMO_1604f495_328a_4f28_9962_f4cc210739dd

Elucidation: The physical property of matter that causes it to experience a force when placed in an electromagnetic field.

Altlabel: Charge

Dbpediamatch: http://dbpedia.org/page/Electric_charge

Iupacdoi: https://doi.org/10.1351/goldbook.E01923

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only TimeCurrentDimension

Radioactivity

IRI: http://emmo.info/emmo/middle/isq#EMMO_8d3da9ac_2265_4382_bee5_db72046722f8

Elucidation: Decays per unit time.

Iupacdoi: https://doi.org/10.1351/goldbook.A00114

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only PerTimeDimension

ElementaryCharge

IRI: http://emmo.info/emmo/middle/siunits#EMMO_58a650f0_a638_4743_8439_535a325e5c4c

Elucidation: The magnitude of the electric charge carried by a single electron.

Comment: The DBpedia definition (http://dbpedia.org/page/Elementary_charge) is outdated as May 20, 2019. It is now an exact quantity.

Dbpediamatch: http://dbpedia.org/page/Elementary_charge

Iupacdoi: https://doi.org/10.1351/goldbook.E02032

Qudtmatch: http://physics.nist.gov/cuu/CODATA-Value_ElementaryCharge

Relations:

- is_a ElectricCharge
- is_a SIExactConstant

PureNumberQuantity

IRI: http://emmo.info/emmo/middle/isq#EMMO_ba882f34_0d71_4e4f_9d92_0c076c633a2c

Elucidation: A pure number, typically the number of something.

Example: 1, i, π, the number of protons in the nucleus of an atom

Comment: According to the SI brochure counting does not automatically qualify a quantity as an amount of substance.

This quantity is used only to describe the outcome of a counting process, without regard of the type of entities.

"There are also some quantities that cannot be described in terms of the seven base quantities of the SI, but have the nature of a count. Examples are a number of molecules, a number of cellular or biomolecular entities (for example copies of a particular nucleic acid sequence), or degeneracy in quantum mechanics. Counting quantities are also quantities with the associated unit one."

Relations:

- is_a ISQDimensionlessQuantity

Time

IRI: http://emmo.info/emmo/middle/isq#EMMO_d4f7d378_5e3b_468a_baa1_a7e98358cda7

Definition: One-dimensional subspace of space-time, which is locally orthogonal to space.

Elucidation: The indefinite continued progress of existence and events that occur in apparently irreversible succession from the past through the present to the future.

Iecentry: http://www.electropedia.org/iev/iev.nsf/display?openform&ievref=113-01-03

Comment: Time can be seen as the duration of an event or, more operationally, as "what clocks read".

Dbpediamatch: http://dbpedia.org/page/Time

Iupacdoi: https://doi.org/10.1351/goldbook.T06375

Relations:

- is_a ISQBaseQuantity
- hasReferenceUnit only hasPhysicsDimension only TimeDimension

Force

IRI: http://emmo.info/emmo/middle/isq#EMMO_1f087811_06cb_42d5_90fb_25d0e7e068ef

Elucidation: Any interaction that, when unopposed, will change the motion of an object.

Dbpediamatch: http://dbpedia.org/page/Force

Iupacdoi: https://doi.org/10.1351/goldbook.F02480

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassLengthPerSquareTimeDimension

ElectricPotential

IRI: http://emmo.info/emmo/middle/isq#EMMO_4f2d3939_91b1_4001_b8ab_7d19074bf845

Elucidation: Energy required to move a unit charge through an electric field from a reference point.

Altlabel: Voltage

Dbpediamatch: http://dbpedia.org/page/Voltage

Iupacdoi: https://doi.org/10.1351/goldbook.A00424

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassSquareLengthPerCubicTimeCurrentDimension

ISQDerivedQuantity

IRI: http://emmo.info/emmo/middle/isq#EMMO_2946d40b_24a1_47fa_8176_e3f79bb45064

Elucidation: Derived quantities defined in the International System of Quantities (ISQ).

Relations:

- is_a InternationalSystemOfQuantity
- is_a DerivedQuantity

ElectricCurrent

IRI: http://emmo.info/emmo/middle/isq#EMMO_c995ae70_3b84_4ebb_bcfc_69e6a281bb88

Elucidation: A flow of electric charge.

Dbpediamatch: http://dbpedia.org/page/Electric_current

Iupacdoi: https://doi.org/10.1351/goldbook.E01927

Relations:

- is_a ISQBaseQuantity
- hasReferenceUnit only hasPhysicsDimension only ElectricCurrentDimension

Angle

IRI: http://emmo.info/emmo/middle/isq#EMMO_f3dd74c0_f480_49e8_9764_33b78638c235

Definition: Ratio of circular arc length to radius.

Altlabel: PlaneAngle

Dbpediamatch: http://dbpedia.org/page/Angle

Iupacdoi: https://doi.org/10.1351/goldbook.A00346

Relations:

- is_a RatioQuantity
- hasReferenceUnit only hasPhysicsDimension only DimensionOne

AmountOfSubstance

IRI: http://emmo.info/emmo/middle/isq#EMMO_8159c26a_494b_4fa0_9959_10888f152298

Elucidation: The number of elementary entities present.

Dbpediamatch: http://dbpedia.org/page/Amount_of_substance

Iupacdoi: https://doi.org/10.1351/goldbook.A00297

Relations:

- is_a ISQBaseQuantity
- hasReferenceUnit only hasPhysicsDimension only AmountDimension

ISQDimensionlessQuantity

IRI: http://emmo.info/emmo/middle/isq#EMMO_a66427d1_9932_4363_9ec5_7d91f2bfda1e

Elucidation: A quantity to which no physical dimension is assigned and with a corresponding unit of measurement in the SI of the unit one.

Dbpediamatch: http://dbpedia.org/page/Dimensionless_quantity

Iupacdoi: https://doi.org/10.1351/goldbook.D01742

Wikipediaentry: https://en.wikipedia.org/wiki/Dimensionless_quantity

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only DimensionOne

InternationalSystemOfQuantity

IRI: http://emmo.info/emmo/middle/isq#EMMO_f35cff4d_dc09_44cf_a729_22fb79e3bfb2

Elucidation: Quantities declared under the ISO 80000.

Seealso: https://www.iso.org/obp/ui/#iso:std:iso:80000:-1:ed-1:v1:en:sec:3.1

Wikipediaentry: https://en.wikipedia.org/wiki/International_System_of_Quantities

Relations:

- is_a PhysicalQuantity

ISQBaseQuantity

IRI: http://emmo.info/emmo/middle/isq#EMMO_1a4c1a97_88a7_4d8e_b2f9_2ca58e92dde4

Elucidation: Base quantities defined in the International System of Quantities (ISQ).

Wikipediaentry: https://en.wikipedia.org/wiki/International_System_of_Quantities

Relations:

- is_a InternationalSystemOfQuantity
- is_a BaseQuantity
- disjoint_union_of LuminousIntensity, AmountOfSubstance, ThermodynamicTemperature, ElectricCurrent, Length, Time, Mass

SolidAngle

IRI: http://emmo.info/emmo/middle/isq#EMMO_e7c9f7fd_e534_4441_88fe_1fec6cb20f26

Elucidation: Ratio of area on a sphere to its radius squared.

Dbpediamatch: http://dbpedia.org/page/Solid_angle

Iupacdoi: https://doi.org/10.1351/goldbook.S05732

Relations:

- is_a RatioQuantity
- hasReferenceUnit only hasPhysicsDimension only DimensionOne

AbsorbedDose

IRI: http://emmo.info/emmo/middle/isq#EMMO_8e5dd473_808b_4a8a_b7cd_63068c12ff57

Definition: Energy imparted to matter by ionizing radiation in a suitable small element of volume divided by the mass of that element of volume.

Dbpediamatch: http://dbpedia.org/page/Absorbed_dose

Iupacdoi: https://doi.org/10.1351/goldbook.A00031

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only SquareLengthPerSquareTimeDimension

CelsiusTemperature

IRI: http://emmo.info/emmo/middle/isq#EMMO_66bc9029_f473_45ff_bab9_c3509ff37a22

Elucidation: An objective comparative measure of hot or cold.

Temperature is a relative quantity that can be used to express temperature differences. Unlike ThermodynamicTemperature, it cannot express absolute temperatures.

Dbpediamatch: http://dbpedia.org/page/Temperature

Iupacdoi: https://doi.org/10.1351/goldbook.T06261

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only TemperatureDimension

HyperfineTransitionFrequencyOfCs

IRI: http://emmo.info/emmo/middle/siunits#EMMO_f96feb3f_4438_4e43_aa44_7458c4d87fc2

Elucidation: The frequency standard in the SI system in which the photon absorption by transitions between the two hyperfine ground states of caesium-133 atoms are used to control the output frequency.

Relations:

- is_a Frequency
- is_a SIExactConstant

LuminousFlux

IRI: http://emmo.info/emmo/middle/isq#EMMO_e2ee1c98_497a_4f66_b4ed_5711496a848e

Elucidation: Perceived power of light.

Dbpediamatch: http://dbpedia.org/page/Luminous_flux

Iupacdoi: https://doi.org/10.1351/goldbook.L03646

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only LuminousIntensityDimension

Energy

IRI: http://emmo.info/emmo/middle/isq#EMMO_31ec09ba_1713_42cb_83c7_b38bf6f9ced2

Elucidation: A property of objects which can be transferred to other objects or converted into different forms.

Comment: Energy is often defined as “ability of a system to perform work”, but it might be misleading since is not necessarily available to do work.

Dbpediamatch: http://dbpedia.org/page/Energy

Iupacdoi: https://doi.org/10.1351/goldbook.E02101

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassSquareLengthPerSquareTimeDimension

Frequency

IRI: http://emmo.info/emmo/middle/isq#EMMO_852b4ab8_fc29_4749_a8c7_b92d4fca7d5a

Elucidation: Number of periods per time interval.

Dbpediamatch: http://dbpedia.org/page/Frequency

Iupacdoi: https://doi.org/10.1351/goldbook.FT07383

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only PerTimeDimension

CatalyticActivity

IRI: http://emmo.info/emmo/middle/isq#EMMO_bd67d149_24c2_4bc9_833a_c2bc26f98fd3

Elucidation: Increase in the rate of reaction of a specified chemical reaction that an enzyme produces in a specific assay system.

Iupacdoi: https://doi.org/10.1351/goldbook.C00881

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only AmountPerTimeDimension

Pressure

IRI: http://emmo.info/emmo/middle/isq#EMMO_50a44256_9dc5_434b_bad4_74a4d9a29989

Elucidation: The force applied perpendicular to the surface of an object per unit area over which that force is distributed.

Dbpediamatch: http://dbpedia.org/page/Pressure

Iupacdoi: https://doi.org/10.1351/goldbook.P04819

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassPerLengthSquareTimeDimension

Power

IRI: http://emmo.info/emmo/middle/isq#EMMO_09b9021b_f97b_43eb_b83d_0a764b472bc2

Elucidation: Rate of transfer of energy per unit time.

Dbpediamatch: http://dbpedia.org/page/Power_(physics)

Iupacdoi: https://doi.org/10.1351/goldbook.P04792

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassSquareLengthPerCubicTimeDimension

Mass

IRI: http://emmo.info/emmo/middle/isq#EMMO_ed4af7ae_63a2_497e_bb88_2309619ea405

Elucidation: Property of a physical body that express its resistance to acceleration (a change in its state of motion) when a force is applied.

Dbpediamatch: http://dbpedia.org/page/Mass

Iupacdoi: https://doi.org/10.1351/goldbook.M03709

Relations:

- is_a ISQBaseQuantity
- hasReferenceUnit only hasPhysicsDimension only MassDimension
- Inverse(hasProperty) only Matter

Illuminance

IRI: http://emmo.info/emmo/middle/isq#EMMO_b51fbd00_a857_4132_9711_0ef70e7bdd20

Definition: The total luminous flux incident on a surface, per unit area.

Dbpediamatch: http://dbpedia.org/page/Illuminance

Iupacdoi: https://doi.org/10.1351/goldbook.I02941

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only LuminousIntensityPerSquareLengthDimension

PhysicalQuantity

IRI: http://emmo.info/emmo/middle/metrology#EMMO_02c0621e_a527_4790_8a0f_2bb51973c819

Elucidation: A 'Mathematical' entity that is made of a 'Number' and a 'MeasurementUnit' defined by a physical law, connected to a physical entity through a model perspective. Measurement is done according to the same model.

Comment: In the same system of quantities, dim ρB = ML-3 is the quantity dimension of mass concentration of component B, and ML-3 is also the quantity dimension of mass density, ρ. ISO 80000-1

Comment: Measured or simulated 'physical propertiy'-s are always defined by a physical law, connected to a physical entity through a model perspective and measurement is done according to the same model.

Systems of units suggests that this is the correct approach, since except for the fundamental units (length, time, charge) every other unit is derived by mathematical relations between these fundamental units, implying a physical laws or definitions.

Comment: Measurement units of quantities of the same quantity dimension may be designated by the same name and symbol even when the quantities are not of the same kind.

For example, joule per kelvin and J/K are respectively the name and symbol of both a measurement unit of heat capacity and a measurement unit of entropy, which are generally not considered to be quantities of the same kind.

However, in some cases special measurement unit names are restricted to be used with quantities of specific kind only.

For example, the measurement unit 'second to the power minus one' (1/s) is called hertz (Hz) when used for frequencies and becquerel (Bq) when used for activities of radionuclides.

As another example, the joule (J) is used as a unit of energy, but never as a unit of moment of force, i.e. the newton metre (N · m).

Comment: — quantities of the same kind have the same quantity dimension, — quantities of different quantity dimensions are always of different kinds, and — quantities having the same quantity dimension are not necessarily of the same kind. ISO 80000-1

Relations:

- is_a Mathematical
- is_a Quantity
- hasReferenceUnit only MeasurementUnit
- disjoint_union_of DerivedQuantity, BaseQuantity

Length

IRI: http://emmo.info/emmo/middle/isq#EMMO_cd2cd0de_e0cc_4ef1_b27e_2e88db027bac

Elucidation: Extend of a spatial dimension.

Iecentry: http://www.electropedia.org/iev/iev.nsf/display?openform&ievref=113-01-19

Comment: Length is a non-negative additive quantity attributed to a one-dimensional object in space.

Dbpediamatch: http://dbpedia.org/page/Length

Iupacdoi: https://doi.org/10.1351/goldbook.L03498

Relations:

- is_a ISQBaseQuantity
- hasReferenceUnit only hasPhysicsDimension only LengthDimension

Inductance

IRI: http://emmo.info/emmo/middle/isq#EMMO_04cc9451_5306_45d0_8554_22cee4d6e785

Elucidation: A property of an electrical conductor by which a change in current through it induces an electromotive force in both the conductor itself and in any nearby conductors by mutual inductance.

Altlabel: ElectricInductance

Dbpediamatch: http://dbpedia.org/page/Inductance

Iupacdoi: https://doi.org/10.1351/goldbook.M04076

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassSquareLengthPerSquareTimeSquareCurrentDimension

ElectricConductance

IRI: http://emmo.info/emmo/middle/isq#EMMO_ffb73b1e_5786_43e4_a964_cb32ac7affb7

Elucidation: Measure of the ease for electric current to pass through a material.

Altlabel: Conductance

Comment: Inverse of 'ElectricalResistance'.

Dbpediamatch: http://dbpedia.org/page/Electrical_resistance_and_conductance

Iupacdoi: https://doi.org/10.1351/goldbook.E01925

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only CubicTimeSquareCurrentPerMassSquareLengthDimension

ThermodynamicTemperature

IRI: http://emmo.info/emmo/middle/isq#EMMO_affe07e4_e9bc_4852_86c6_69e26182a17f

Elucidation: Thermodynamic temperature is the absolute measure of temperature. It is defined by the third law of thermodynamics in which the theoretically lowest temperature is the null or zero point.

Dbpediamatch: http://dbpedia.org/page/Thermodynamic_temperature

Iupacdoi: https://doi.org/10.1351/goldbook.T06321

Relations:

- is_a ISQBaseQuantity
- hasReferenceUnit only hasPhysicsDimension only TemperatureDimension

Number branch

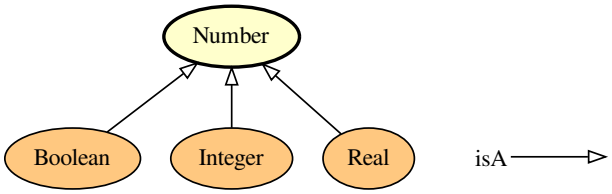

Figure 3.24: Number branch.

Boolean

IRI: http://emmo.info/emmo/middle/math#EMMO_54dc83cb_06e1_4739_9e45_bc09cead7f48

Relations:

- is_a Number
- hasNumericalData only type
- hasNumericalData exactly 1 type
- equivalent_to hasNumericalData some type

Number

IRI: http://emmo.info/emmo/middle/math#EMMO_21f56795_ee72_4858_b571_11cfaa59c1a8

Elucidation: A numerical data value.

Comment: A number is actually a string (e.g. 1.4, 1e-8) of numerical digits and other symbols. However, in order not to increase complexity of the taxonomy and relations, here we take a number as an "atomic" object (i.e. we do not include digits in the EMMO as alphabet for numbers).

A 'Number' individual provide the link between the ontology and the actual data, through the data property hasNumericalValue.

Relations:

- is_a Numerical
- is_a MathematicalSymbol
- is_a Symbol

Integer

IRI: http://emmo.info/emmo/middle/math#EMMO_f8bd64d5_5d3e_4ad4_a46e_c30714fecb7f

Relations:

- is_a Number
- hasNumericalData only type
- hasNumericalData exactly 1 type
- equivalent_to hasNumericalData some type

Real

IRI: http://emmo.info/emmo/middle/math#EMMO_18d180e4_5e3e_42f7_820c_e08951223486

Relations:

- is_a Number
- hasNumericalData only type
- hasNumericalData exactly 1 type
- equivalent_to hasNumericalData some type

Measurement Unit branch

SIUnit

IRI: http://emmo.info/emmo/middle/siunits#EMMO_feb03a8a_bbb6_4918_a891_46713ef557f4

Elucidation: The set of units provided by the SI referring to the ISQ.

Comment: The complete set of SI units includes both the coherent set and the multiples and sub-multiples formed by using the SI prefixes.

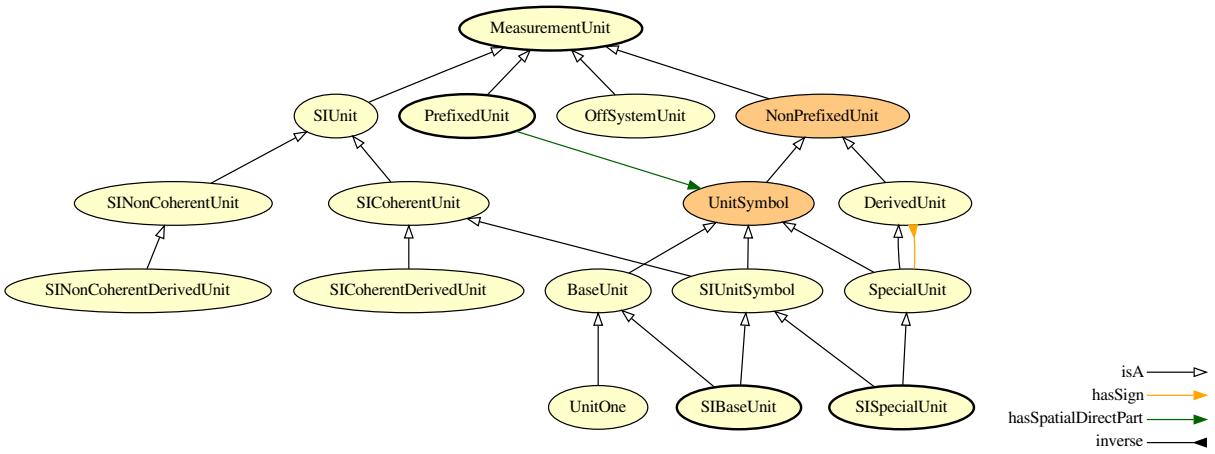

Figure 3.25: Measurement Unit branch.

Comment: The names, symbols and prefixes of SI units are defined by the General Conference on Weights and Measures (CGPM).

https://en.wikipedia.org/wiki/General_Conference_on_Weights_and_Measures

Relations:

- is_a MeasurementUnit
- disjoint_union_of SICoherentDerivedUnit, SIBaseUnit, SINonCoherentDerivedUnit, SIPrefixedUnit, SISpecialUnit

SINonCoherentDerivedUnit

IRI: http://emmo.info/emmo/middle/siunits#EMMO_60b78cc3_6011_4134_95ab_956f56d4bdc1

Elucidation: A derived unit whos numerical factor in front of the product of base units is NOT equal to one.

Relations:

- is_a SINonCoherentUnit

BaseUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_db716151_6b73_45ff_910c_d182fdcbb4f5

Elucidation: A set of units that correspond to the base quantities in a system of units.

Relations:

- is_a UnitSymbol

UnitSymbol

IRI: http://emmo.info/emmo/middle/metrology#EMMO_216f448e_cdbc_4aeb_a529_7a5fe7fc38bb

Elucidation: A symbol that stands for a single unit.

Example: Some examples are “Pa”, “m” and “J”.

Relations:

- is_a MetrologicalSymbol
- is_a NonPrefixedUnit
- equivalent_to MeasurementUnit and Symbol

- disjoint_union_of SpecialUnit, BaseUnit

OffSystemUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_591e02fd_8d37_45a6_9d11_bb21cef391a0

Elucidation: A unit that does not belong to any system of units.

Example: eV barn

Relations:

- is_a MeasurementUnit

SINonCoherentUnit

IRI: http://emmo.info/emmo/middle/siunits#EMMO_8246541a_f1f6_4d03_8bd7_fc6b76d17375

Relations:

- is_a SIUnit
- disjoint_union_of SINonCoherentDerivedUnit, SIPrefixedUnit

SICoherentDerivedUnit

IRI: http://emmo.info/emmo/middle/siunits#EMMO_1273eb34_de48_43a9_925f_104110469dd2

Elucidation: A SI derived unit whos numerical factor in front of the product of SI base units is one.

Example: m/s kg/m^3

Comment: This class collects all units that are products or powers of SI base or SI special units only.

Relations:

- is_a SICoherentUnit

SICoherentUnit

IRI: http://emmo.info/emmo/middle/siunits#EMMO_707c6032_e272_4a20_98b5_d35c4f67be68

Comment: Derived units are defined as products of powers of the base units. When the numerical factor of this product is one, the derived units are called coherent derived units. The base and coherent derived units of the SI form a coherent set, designated the set of coherent SI units.

Relations:

- is_a SIUnit
- disjoint_union_of SICoherentDerivedUnit, SIBaseUnit, SISpecialUnit

DerivedUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_08b308d4_31cd_4779_a784_aa92fc730f39

Elucidation: Derived units are defined as products of powers of the base units corresponding to the relations defining the derived quantities in terms of the base quantities.

Relations:

- is_a NonPrefixedUnit

SIUnitSymbol

IRI: http://emmo.info/emmo/middle/siunits#EMMO_32129fb5_df25_48fd_a29c_18a2f22a2dd5

Relations:

- is_a UnitSymbol
- is_a SICoherentUnit
- disjoint_union_of SIBaseUnit, SISpecialUnit

NonPrefixedUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_868ae137_4d25_493e_b270_21ea3d94849e

Elucidation: A measurement unit symbol that do not have a metric prefix as a direct spatial part.

Relations:

- is_a MeasurementUnit
- hasSpatialDirectPart only not MetricPrefix
- equivalent_to DerivedUnit or UnitSymbol

SpecialUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_3ee80521_3c23_4dd1_935d_9d522614a3e2

Elucidation: A unit symbol that stands for a derived unit.

Example: Pa stands for N/m2 J stands for N m

Comment: Special units are semiotic shortcuts to more complex composed symbolic objects.

Relations:

- is_a DerivedUnit
- is_a UnitSymbol
- is_a Sign
- Inverse(hasSign) some DerivedUnit

SIPrefixedUnit

IRI: http://emmo.info/emmo/middle/siunits#EMMO_d41ce84b_4317_41fb_a5d1_6cd281fca106

Elucidation: A SI base or special unit with a metric prefix.

Comment: The presence of the prefix makes this units non-coherent with SI system.

Relations:

- is_a PrefixedUnit
- is_a SINonCoherentUnit

MeasurementUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_b081b346_7279_46ef_9a3d_2c088fcd79f4

Elucidation: A 'Quantity' that stands for the standard reference magnitude of a specific class of measurement processes, defined and adopted by convention or by law.

The numerical quantity value of the 'MeasurementUnit' is conventionally 1 and does not appear.

Quantitative measurement results are expressed as a multiple of the 'MeasurementUnit'.

Comment: "Real scalar quantity, defined and adopted by convention, with which any other quantity of the same kind can be compared to express the ratio of the second quantity to the first one as a number" ISO 80000-1

Comment: "Unit symbols are mathematical entities and not abbreviations."

"Symbols for units are treated as mathematical entities. In expressing the value of a quantity as the product of a numerical value and a unit, both the numerical value and the unit may be treated by the ordinary rules of algebra."

https://www.bipm.org/utils/common/pdf/si-brochure/SI-Brochure-9-EN.pdf

Comment: While the SI brochure treats 'MeasurementUnit' as a 'PhysicalQuantity', in the EMMO this is not possible since the latter always has two direct parts, a 'Numerical' and a 'MeasurementUnit', while the former a single 'Symbol'.

SI distinguishes between a quantity (an abstract concept) and the quantity value (a number and a reference). The EMMO, following strict nominalism, considers a SI quantity as a SI quantity value, collapsing the two concepts into one: the 'Quantity'.

So, for the EMMO the symbol "kg" is not a physical quantity but a 'MeasurementUnit', while the string "1 kg" is 'Physical Quantity'.

Relations:

- is_a ReferenceUnit
- is_a Object
- hasPhysicsDimension exactly 1 PhysicsDimension
- disjoint_union_of NonPrefixedUnit, PrefixedUnit

UnitOne

IRI: http://emmo.info/emmo/middle/metrology#EMMO_5ebd5e01_0ed3_49a2_a30d_cd05cbe72978

Elucidation: Represents the number 1, used as an explicit unit to say something has no units.

Example: Refractive index or volume fraction.

Example: Typically used for ratios of two units whos dimensions cancels out.

Qudtmatch: http://qudt.org/vocab/unit/UNITLESS

Relations:

- is_a BaseUnit
- hasPhysicsDimension only DimensionOne

UTF8 branch

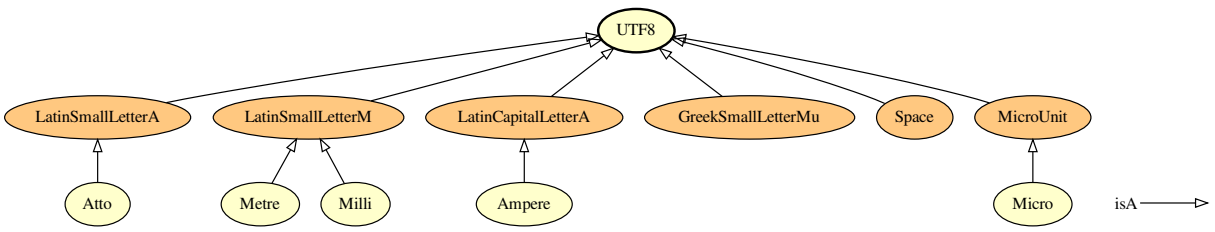

Figure 3.26: UTF8 branch.

Atto

IRI: http://emmo.info/emmo/middle/siunits#EMMO_42955b2d_b465_4666_86cc_ea3c2d685753

Relations:

- is_a LatinSmallLetterA
- is_a SIMetricPrefix

- Inverse(hasVariable) only hasNumericalData value 1e-18
- hasSymbolData value “a”

LatinSmallLetterM

IRI: http://emmo.info/emmo/middle/metrology#EMMO_aa0d5cde_cbdc_4815_b46d_2f76b00a6bde

Altlabel: m

Relations:

- is_a UTF8
- equivalent_to hasSymbolData value “m”

LatinCapitalLetterA

IRI: http://emmo.info/emmo/middle/metrology#EMMO_2125f2d0_5050_49e3_a579_4c74bc9fd02e

Altlabel: A

Relations:

- is_a UTF8
- equivalent_to hasSymbolData value “A”

Micro

IRI: http://emmo.info/emmo/middle/siunits#EMMO_9ff3bf8e_2168_406e_8251_1d158fc948ae

Relations:

- is_a MicroUnit
- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 1e-06
- hasSymbolData value “μ”

GreekSmallLetterMu

IRI: http://emmo.info/emmo/middle/metrology#EMMO_1e9c2a4b_abb9_4b27_bd9c_e31aac337a04

Altlabel: μ

Relations:

- is_a UTF8
- equivalent_to hasSymbolData value “μ”

Ampere

IRI: http://emmo.info/emmo/middle/siunits#EMMO_db5dd38d_ac79_4af6_8782_fee7e7150ae8

Definition: The ampere, symbol A, is the SI unit of electric current. It is defined by taking the fixed numerical value of the elementary charge e to be 1.602176634×10-19 when expressed in the unit C, which is equal to A s, where the second is defined in terms of $\nabla\nu$Cs.

Iupacdoi: https://doi.org/10.1351/goldbook.A00300

Qudtmatch: http://qudt.org/vocab/unit/A

Relations:

- is_a LatinCapitalLetterA
- is_a SIBaseUnit
- hasPhysicsDimension only ElectricCurrentDimension

- hasSymbolData value “A”

UTF8

IRI: http://emmo.info/emmo/middle/metrology#EMMO_e13b2173_1dec_4b97_9ac1_1dc4b418612a

Relations:

- is_a Symbol

LatinSmallLetterA

IRI: http://emmo.info/emmo/middle/metrology#EMMO_cfcf0f48_09ac_4770_a06a_684a42b4a14c

Altlabel: a

Relations:

- is_a UTF8
- equivalent_to hasSymbolData value “a”

Space

IRI: http://emmo.info/emmo/middle/metrology#EMMO_ea192c80_6029_4410_863c_8eed7ea52037

Altlabel:

Comment: U+0020

Relations:

- is_a UTF8
- equivalent_to hasSymbolData value ” ”

MicroUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_2cfdcca6_6231_48aa_81b5_388b464bfe80

Altlabel: µ

Relations:

- is_a UTF8
- equivalent_to hasSymbolData value “µ”

Metre

IRI: http://emmo.info/emmo/middle/siunits#EMMO_7db11dbf_a643_464a_9b56_07eabcc3e9c5

Definition: The metre, symbol m, is the SI unit of length. It is defined by taking the fixed numerical value of the speed of light in vacuum c to be 299792458 when expressed in the unit m s-1, where the second is defined in terms of ∇νCs.

Iupacdoi: https://doi.org/10.1351/goldbook.M03884

Qudtmatch: http://qudt.org/vocab/unit/M

Relations:

- is_a LatinSmallLetterM
- is_a SIBaseUnit
- hasPhysicsDimension only LengthDimension
- hasSymbolData value “m”

Milli

IRI: http://emmo.info/emmo/middle/siunits#EMMO_a3a701ed_6f7d_4a10_9aee_dfa1961fc7b7

Relations:

- is_a LatinSmallLetterM
- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 0.001
- hasSymbolData value “m”

SI Base Unit branch

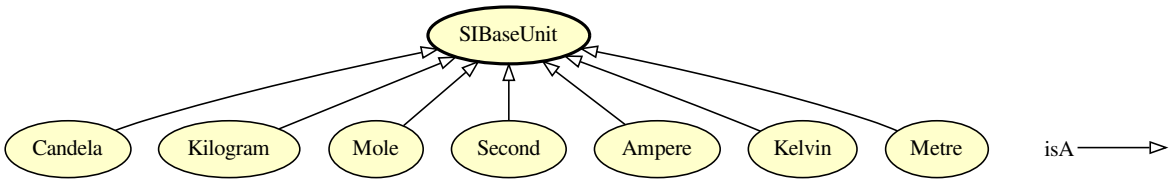

Figure 3.27: SI Base Unit branch.

SIBaseUnit

IRI: http://emmo.info/emmo/middle/siunits#EMMO_3a185e6c_9e19_4776_b583_19c978156aa0

Elucidation: The base units in the SI system.

Seealso: https://www.bipm.org/utils/common/pdf/si-brochure/SI-Brochure-9-EN.pdf

Relations:

- is_a BaseUnit
- is_a SIUnitSymbol
- disjoint_union_of Kelvin, Second, Metre, Candela, Kilogram, Ampere, Mole

Candela

IRI: http://emmo.info/emmo/middle/siunits#EMMO_8d00f093_3f45_4ea3_986c_b3545c3c2f4c

Definition: The candela, symbol cd, is the SI unit of luminous intensity in a given direction. It is defined by taking the fixed numerical value of the luminous efficacy of monochromatic radiation of frequency 540×1012 Hz, Kcd, to be 683 when expressed in the unit lm W-1, which is equal to cd sr W-1, or cd sr kg-1 m-2 s3, where the kilogram, metre and second are defined in terms of h, c and ∇νCs.

Iupacdoi: https://doi.org/10.1351/goldbook.C00787

Qudtmatch: http://qudt.org/vocab/unit/CD

Relations:

- is_a SIBaseUnit
- hasPhysicsDimension only LuminousIntensityDimension
- hasSymbolData value “cd”

Kilogram

IRI: http://emmo.info/emmo/middle/siunits#EMMO_9bfd6f1e_b0ce_459c_beb7_8f1f41708bba

Definition: The kilogram, symbol kg, is the SI unit of mass. It is defined by taking the fixed numerical value of the Planck constant h to be 6.62607015×10-34 when expressed in the unit J s, which is equal to kg m2 s-1, where the metre and the second are defined in terms of c and ∇νCs.

Iupacdoi: https://doi.org/10.1351/goldbook.K03391

Qudtmatch: http://qudt.org/vocab/unit/KiloGM

Relations:

- is_a SIBaseUnit
- hasPhysicsDimension only MassDimension
- hasSymbolData value “kg”

Mole

IRI: http://emmo.info/emmo/middle/siunits#EMMO_df6eeb01_1b41_4bd8_9257_a04fbd7cf000

Definition: The mole, symbol mol, is the SI unit of amount of substance. One mole contains exactly 6.022 140 76 × 1023 elementary entities. This number is the fixed numerical value of the Avogadro constant, NA, when expressed in the unit mol-1 and is called the Avogadro number. The amount of substance, symbol n, of a system is a measure of the number of specified elementary entities. An elementary entity may be an atom, a molecule, an ion, an electron, any other particle or specified group of particles.

Iupacdoi: https://doi.org/10.1351/goldbook.M03980

Qudtmatch: http://qudt.org/vocab/unit/MOL

Relations:

- is_a SIBaseUnit
- hasPhysicsDimension only AmountDimension
- hasSymbolData value “mol”

Second

IRI: http://emmo.info/emmo/middle/siunits#EMMO_314ba716_2d3d_4462_9a4f_d3419ae1df43

Definition: The second, symbol s, is the SI unit of time. It is defined by taking the fixed numerical value of the caesium frequency ∇νCs, the unperturbed ground-state hyperfine transition frequency of the caesium 133 atom, to be 9192631770 when expressed in the unit Hz, which is equal to s-1.

Iupacdoi: https://doi.org/10.1351/goldbook.S05513

Qudtmatch: http://qudt.org/vocab/unit/SEC

Relations:

- is_a SIBaseUnit
- hasPhysicsDimension only TimeDimension
- hasSymbolData value “s”

Ampere

IRI: http://emmo.info/emmo/middle/siunits#EMMO_db5dd38d_ac79_4af6_8782_fee7e7150ae8

Definition: The ampere, symbol A, is the SI unit of electric current. It is defined by taking the fixed numerical value of the elementary charge e to be 1.602176634×10-19 when expressed in the unit C, which is equal to A s, where the second is defined in terms of ∇νCs.

Iupacdoi: https://doi.org/10.1351/goldbook.A00300

Qudtmatch: http://qudt.org/vocab/unit/A

Relations:

- is_a LatinCapitalLetterA
- is_a SIBaseUnit
- hasPhysicsDimension only ElectricCurrentDimension
- hasSymbolData value “A”

Kelvin

IRI: http://emmo.info/emmo/middle/siunits#EMMO_2e5e45fc_f52c_4294_bdc2_5ed7a06dfce7

Definition: The kelvin, symbol K, is the SI unit of thermodynamic temperature. It is defined by taking the fixed numerical value of the Boltzmann constant k to be 1.380649×10-23 when expressed in the unit J K-1, which is equal to kg m2 s-2 K-1, where the kilogram, metre and second are defined in terms of h, c and ∇νCs.

Iupacdoi: https://doi.org/10.1351/goldbook.K03374

Qudtmatch: http://qudt.org/vocab/unit/K

Relations:

- is_a SIBaseUnit
- hasPhysicsDimension only TemperatureDimension
- hasSymbolData value “K”

Metre

IRI: http://emmo.info/emmo/middle/siunits#EMMO_7db11dbf_a643_464a_9b56_07eabcc3e9c5

Definition: The metre, symbol m, is the SI unit of length. It is defined by taking the fixed numerical value of the speed of light in vacuum c to be 299792458 when expressed in the unit m s-1, where the second is defined in terms of ∇νCs.

Iupacdoi: https://doi.org/10.1351/goldbook.M03884

Qudtmatch: http://qudt.org/vocab/unit/M

Relations:

- is_a LatinSmallLetterM
- is_a SIBaseUnit
- hasPhysicsDimension only LengthDimension
- hasSymbolData value “m”

SI Special Unit branch

Farad

IRI: http://emmo.info/emmo/middle/siunits#EMMO_a9201b2f_e6de_442a_b3a6_d291.0.0-alpha2a582

Comment: Measurement unit for electric capacitance.

Iupacdoi: https://doi.org/10.1351/goldbook.F02320

Qudtmatch: http://qudt.org/vocab/unit/FARAD

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only QuarticTimeSquareCurrentPerMassSquareLengthDimension
- hasSymbolData value “F”

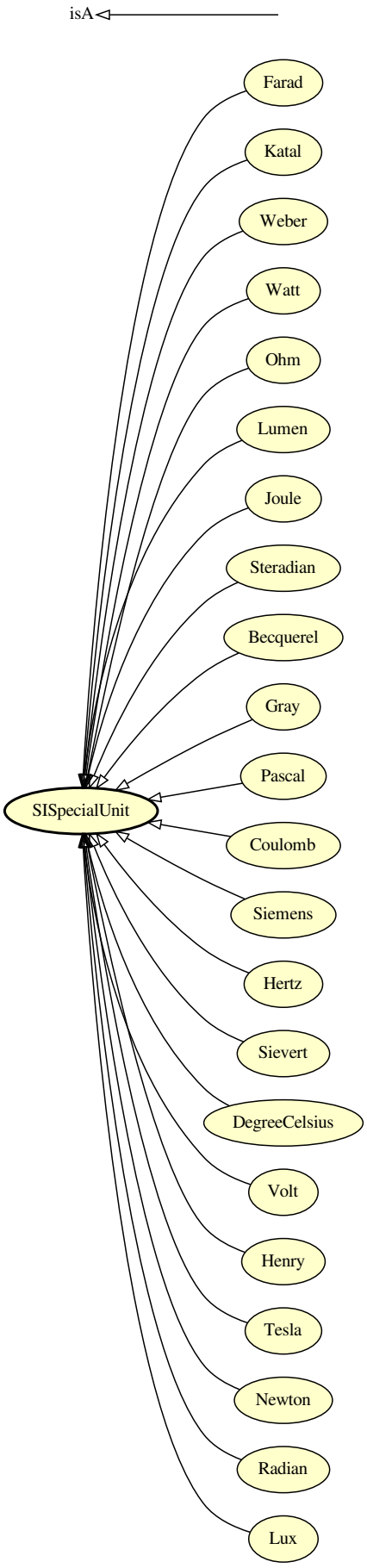

Figure 3.28: SI Special Unit branch.

Katal

IRI: http://emmo.info/emmo/middle/siunits#EMMO_33b67e69_3645_4c73_b100_5ea6759221b4

Comment: Measurement unit for catalytic activity.

Iupacdoi: https://doi.org/10.1351/goldbook.K03372

Qudtmatch: http://qudt.org/vocab/unit/KAT

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only AmountPerTimeDimension
- hasSymbolData value “kat”

Weber

IRI: http://emmo.info/emmo/middle/siunits#EMMO_d7f11b34_a121_4519_87c0_aa754f1c4737

Comment: Measurement unit for magnetic flux.

Iupacdoi: https://doi.org/10.1351/goldbook.W06666

Qudtmatch: http://qudt.org/vocab/unit/WB

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only MassSquareLengthPerSquareTimeCurrentDimension
- hasSymbolData value “Wb”

Watt

IRI: http://emmo.info/emmo/middle/siunits#EMMO_080052a1_f295_44be_a60f_1326ce13f1ba

Comment: Measurement unit for power.

Iupacdoi: https://doi.org/10.1351/goldbook.W06656

Qudtmatch: http://qudt.org/vocab/unit/W

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only MassSquareLengthPerCubicTimeDimension
- hasSymbolData value “W”

Ohm

IRI: http://emmo.info/emmo/middle/siunits#EMMO_59c10c5c_47bd_4348_ba39_38836607dfa1

Comment: Measurement unit for resistance.

Iupacdoi: https://doi.org/10.1351/goldbook.O04280

Qudtmatch: http://qudt.org/vocab/unit/OHM

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only MassSquareLengthPerCubicTimeSquareCurrentDimension
- hasSymbolData value “Ω”

Lumen

IRI: http://emmo.info/emmo/middle/siunits#EMMO_d7b7fd1e_645a_42cb_8f40_85f0d034d3ae

Comment: Measurement unit for luminous flux.

Iupacdoi: https://doi.org/10.1351/goldbook.L03639

Qudtmatch: http://qudt.org/vocab/unit/LM

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only LuminousIntensityDimension
- hasSymbolData value “lm”

Joule

IRI: http://emmo.info/emmo/middle/siunits#EMMO_8a70dea4_d6ab_4260_b931_a3e990982416

Comment: Measurement unit for energy.

Iupacdoi: https://doi.org/10.1351/goldbook.J03363

Qudtmatch: http://qudt.org/vocab/unit/J

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only MassSquareLengthPerSquareTimeDimension
- hasSymbolData value “J”

Steradian

IRI: http://emmo.info/emmo/middle/siunits#EMMO_cf3dd6cc_c5d6_4b3d_aef4_82f3b7a361af

Elucidation: Dimensionless measurement unit for solid angle.

Iupacdoi: https://doi.org/10.1351/goldbook.S05971

Qudtmatch: http://qudt.org/vocab/unit/SR

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only DimensionOne
- hasSymbolData value “sr”

Becquerel

IRI: http://emmo.info/emmo/middle/siunits#EMMO_b71e4ba5_8f73_4199_8c96_7ea7f94d9e2a

Definition: Radioactive decays per second.

Comment: Unit for radioactive activity.

Iupacdoi: https://doi.org/10.1351/goldbook.B00624

Qudtmatch: http://qudt.org/vocab/unit/BQ

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only PerTimeDimension
- hasSymbolData value “Bq”

Gray

IRI: http://emmo.info/emmo/middle/siunits#EMMO_00199e76_69dc_45b6_a9c6_98cc90cdc0f5

Comment: Measurement unit for absorbed dose.

Iupacdoi: https://doi.org/10.1351/goldbook.G02696

Qudtmatch: http://qudt.org/vocab/unit/GRAY

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only SquareLengthPerSquareTimeDimension
- hasSymbolData value “Gy”

SISpecialUnit

IRI: http://emmo.info/emmo/middle/siunits#EMMO_e9ffc696_5228_4ff9_8a60_0f5e05e9931b

Elucidation: The 22 derived units that are given a special name in the SI system that stands for units derived by SI base units.

Comment: These units are SI coherent by definition.

Wikipediaentry: https://en.wikipedia.org/wiki/International_System_of_Units#Derived_units

Relations:

- is_a SpecialUnit
- is_a SIUnitSymbol
- disjoint_union_of Gray, Watt, Katal, Ohm, Coulomb, Joule, Radian, Pascal, Farad, Newton, Tesla, DegreeCelsius, Becquerel, Steradian, Lumen, Weber, Lux, Sievert, Volt, Hertz, Siemens, Henry

Pascal

IRI: http://emmo.info/emmo/middle/siunits#EMMO_a80dc6f5_b1aa_41a7_a3a8_cd5040da2162

Comment: Measurement unit for pressure.

Iupacdoi: https://doi.org/10.1351/goldbook.P04442

Qudtmatch: http://qudt.org/vocab/unit/PA

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only MassPerLengthSquareTimeDimension
- hasSymbolData value “Pa”

Coulomb

IRI: http://emmo.info/emmo/middle/siunits#EMMO_696ed548_9477_45ea_993c_6a8f5271914a

Comment: Measurement unit for electric charge.

Iupacdoi: https://doi.org/10.1351/goldbook.C01365

Qudtmatch: http://qudt.org/vocab/unit/C

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only TimeCurrentDimension
- hasSymbolData value “C”

Siemens

IRI: http://emmo.info/emmo/middle/siunits#EMMO_f2523820_04a6_44ab_bb67_8237dda2b0c2

Comment: Measurement unit for electrical conductance.

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only CubicTimeSquareCurrentPerMassSquareLengthDimension
- hasSymbolData value “S”

Hertz

IRI: http://emmo.info/emmo/middle/siunits#EMMO_e75f580e_52bf_4dd5_af70_df409cec08fd

Comment: Measurement unit for frequence.

Iupacdoi: https://doi.org/10.1351/goldbook.H02785

Qudtmatch: http://qudt.org/vocab/unit/HZ

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only PerTimeDimension
- hasSymbolData value “Hz”

Sievert

IRI: http://emmo.info/emmo/middle/siunits#EMMO_dc232f53_8ed8_4ddd_9f41_cc057985eadb

Comment: Measurement unit for equivalent doseof ionizing radiation.

Sievert is derived from absorbed dose, but takes into account the biological effectiveness of the radiation, which is dependent on the radiation type and energy.

Iupacdoi: https://doi.org/10.1351/goldbook.S05658

Qudtmatch: http://qudt.org/vocab/unit/SV

Wikipediaentry: https://en.wikipedia.org/wiki/Equivalent_dose

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only SquareLengthPerSquareTimeDimension
- hasSymbolData value “Sv”

DegreeCelsius

IRI: http://emmo.info/emmo/middle/siunits#EMMO_b20be325_8bfd_4237_bee7_201ab0fd9c75

Comment: Measurement unit for Celsius temperature. This unit can only be used for expressing temperature differences.

Iupacdoi: https://doi.org/10.1351/goldbook.D01561

Qudtmatch: http://qudt.org/vocab/unit/DEG_C

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only TemperatureDimension
- hasSymbolData value “°C”

Volt

IRI: http://emmo.info/emmo/middle/siunits#EMMO_e2207e91_02b0_4a8a_b13e_61d2a2a839f1

Comment: Measurement unit for voltage.

Iupacdoi: https://doi.org/10.1351/goldbook.V06634

Qudtmatch: http://qudt.org/vocab/unit/V

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only MassSquareLengthPerCubicTimeCurrentDimension
- hasSymbolData value “V”

Henry

IRI: http://emmo.info/emmo/middle/siunits#EMMO_fab003c8_f7a6_4346_9988_7161325ed7a3

Comment: Measurement unit for electrical inductance.

Iupacdoi: https://doi.org/10.1351/goldbook.H02782

Qudtmatch: http://qudt.org/vocab/unit/H

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only MassSquareLengthPerSquareTimeSquareCurrentDimension
- hasSymbolData value “H”

Tesla

IRI: http://emmo.info/emmo/middle/siunits#EMMO_acb50123_87a2_4753_b36c_f87114ad4de2

Comment: Measurement unit for magnetic flux density or induction.

Iupacdoi: https://doi.org/10.1351/goldbook.T06283

Qudtmatch: http://qudt.org/vocab/unit/T

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only MassPerSquareTimeCurrentDimension
- hasSymbolData value “T”

Newton

IRI: http://emmo.info/emmo/middle/siunits#EMMO_a979c531_f9fa_4a6e_93c1.0.0-alpha2960241ca6

Comment: Measurement unit for force.

Iupacdoi: https://doi.org/10.1351/goldbook.N04135

Qudtmatch: http://qudt.org/vocab/unit/N

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only MassLengthPerSquareTimeDimension
- hasSymbolData value “N”

Radian

IRI: http://emmo.info/emmo/middle/siunits#EMMO_a121bb1d_5225_4c78_809b_0268c3012208

Elucidation: Measure of plane angle.

Comment: Dimensionless measurement unit for plane angle.

Iupacdoi: https://doi.org/10.1351/goldbook.R05036

Qudtmatch: http://qudt.org/vocab/unit/RAD

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only DimensionOne
- hasSymbolData value “rad”

Lux

IRI: http://emmo.info/emmo/middle/siunits#EMMO_da1dd4a7_c611_4ad4_bef6_7646f28aa598

Comment: Measurement unit for illuminance.

Iupacdoi: https://doi.org/10.1351/goldbook.L03651

Qudtmatch: http://qudt.org/vocab/unit/LUX

Relations:

- is_a SISpecialUnit
- hasPhysicsDimension only LuminousIntensityPerSquareLengthDimension
- hasSymbolData value “lx”

Prefixed Unit branch

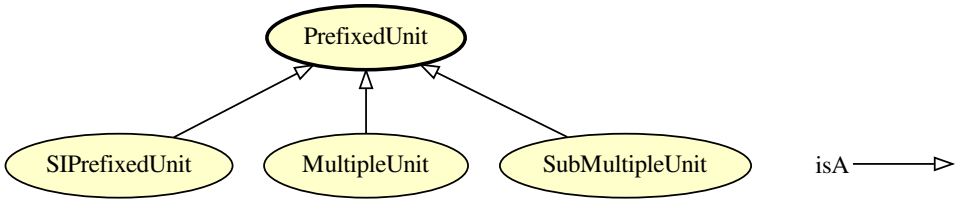

Figure 3.29: Prefixed Unit branch.

SIPrefixedUnit

IRI: http://emmo.info/emmo/middle/siunits#EMMO_d41ce84b_4317_41fb_a5d1_6cd281fca106

Elucidation: A SI base or special unit with a metric prefix.

Comment: The presence of the prefix makes this units non-coherent with SI system.

Relations:

- is_a PrefixedUnit
- is_a SINonCoherentUnit

PrefixedUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_c6d4a5e0_7e95_44df_a6db_84ee0a8bbc8e

Elucidation: A measurement unit that is made of a metric prefix and a unit symbol.

Relations:

- is_a MeasurementUnit
- is_a State
- hasSpatialDirectPart only (UnitSymbol or MetricPrefix)
- hasSpatialDirectPart exactly 1 UnitSymbol
- hasSpatialDirectPart exactly 1 MetricPrefix
- disjoint_union_of MultipleUnit, SubMultipleUnit

MultipleUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_62f0d847_3603_45b4_bfc4_dd4511355ff2

Elucidation: Measurement unit obtained by multiplying a given measurement unit by an integer greater than one.

Relations:

- is_a PrefixedUnit

SubMultipleUnit

IRI: http://emmo.info/emmo/middle/metrology#EMMO_a2f94f33_71fa_443c_a1fb_d1685fc537ec

Elucidation: Measurement unit obtained by dividing a given measurement unit by an integer greater than one.

Relations:

- is_a PrefixedUnit

Metric Prefix branch

Mega

IRI: http://emmo.info/emmo/middle/siunits#EMMO_5eaecadc_4f0d_4a3a_afc7_1fc0b83cc928

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 1000000.0
- hasSymbolData value “M”

Yocto

IRI: http://emmo.info/emmo/middle/siunits#EMMO_f5769206_9257_4b08_bf7b_dad7868c6afc

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 1e-24
- hasSymbolData value “y”

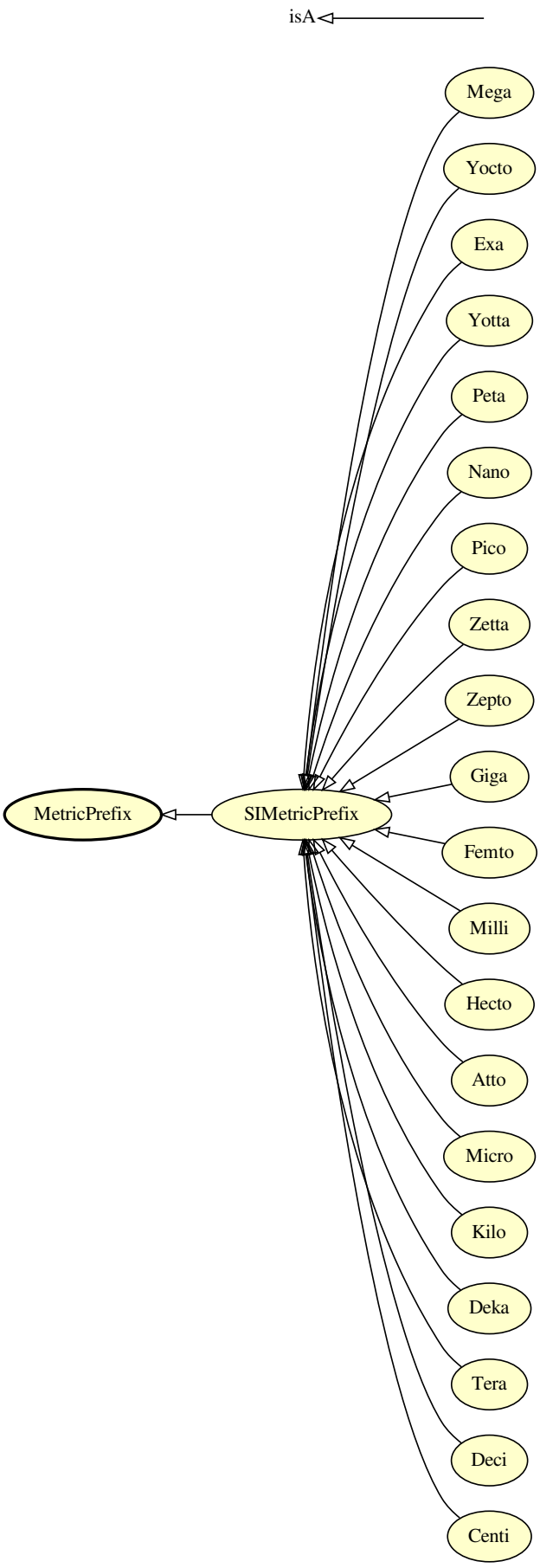

Figure 3.30: Metric Prefix branch.

Exa

IRI: http://emmo.info/emmo/middle/siunits#EMMO_5cf9f86c_86f5_40c4_846d_60371f670e0a

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 1e+18
- hasSymbolData value “E”

Yotta

IRI: http://emmo.info/emmo/middle/siunits#EMMO_e79c62ff_10ad_4ec0_baba_c19ddd4eaa11

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 1e+24
- hasSymbolData value “Y”

Peta

IRI: http://emmo.info/emmo/middle/siunits#EMMO_43a6b269_da31_4bb6_a537_c97df4fff32a

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 1000000000000000.0
- hasSymbolData value “P”

MetricPrefix

IRI: http://emmo.info/emmo/middle/metrology#EMMO_7d2afa66_ae9e_4095_a9bf_421d0be401b6

Elucidation: Dimensionless multiplicative unit prefix.

Seealso: https://en.wikipedia.org/wiki/Metric_prefix

Relations:

- is_a MathematicalSymbol
- is_a Constant
- is_a MetrologicalSymbol
- is_a Metrological
- is_a Symbol

Nano

IRI: http://emmo.info/emmo/middle/siunits#EMMO_e1981c25_7c55_4020_aa7a_d2e14ced86d4

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 1e-09
- hasSymbolData value “n”

Pico

IRI: http://emmo.info/emmo/middle/siunits#EMMO_068c4e58_2470_4b1c_8454_010dd4906100

Relations:

- is_a SIMetricPrefix

- Inverse(hasVariable) only hasNumericalData value 1e-12
- hasSymbolData value “p”

Zetta

IRI: http://emmo.info/emmo/middle/siunits#EMMO_daa9ee97_4c5f_42e5_918c_44d7523e8958

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 1e+21
- hasSymbolData value “Z”

Zepto

IRI: http://emmo.info/emmo/middle/siunits#EMMO_254472c6_3dbd_4f02_bc43_571389cd281f

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 1e-21
- hasSymbolData value “z”

SIMetricPrefix

IRI: http://emmo.info/emmo/middle/siunits#EMMO_471cb92b_edca_4cf9_bce8_a75084d876b8

Relations:

- is_a MetricPrefix
- disjoint_union_of Pico, Deci, Deka, Hecto, Femto, Zepto, Tera, Atto, Peta, Exa, Mega, Kilo, Micro, Milli, Giga, Centi, Zetta, Nano, Yotta, Yocto

Giga

IRI: http://emmo.info/emmo/middle/siunits#EMMO_a8eb4bbb_1bd3_4ad4_b114_2789bcbd2134

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 1000000000.0
- hasSymbolData value “G”

Femto

IRI: http://emmo.info/emmo/middle/siunits#EMMO_23bfe79a_cade_48f1_9a8c_fd96e6bac8ba

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 1e-15
- hasSymbolData value “f”

Milli

IRI: http://emmo.info/emmo/middle/siunits#EMMO_a3a701ed_6f7d_4a10_9aee_dfa1961fc7b7

Relations:

- is_a LatinSmallLetterM
- is_a SIMetricPrefix

- Inverse(hasVariable) only hasNumericalData value 0.001
- hasSymbolData value “m”

Hecto

IRI: http://emmo.info/emmo/middle/siunits#EMMO_21aaefc1_3f86_4208_b7db_a755f31f0f8c

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 100.0
- hasSymbolData value “h”

Atto

IRI: http://emmo.info/emmo/middle/siunits#EMMO_42955b2d_b465_4666_86cc_ea3c2d685753

Relations:

- is_a LatinSmallLetterA
- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 1e-18
- hasSymbolData value “a”

Micro

IRI: http://emmo.info/emmo/middle/siunits#EMMO_9ff3bf8e_2168_406e_8251_1d158fc948ae

Relations:

- is_a MicroUnit
- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 1e-06
- hasSymbolData value “μ”

Kilo

IRI: http://emmo.info/emmo/middle/siunits#EMMO_74931b1b_c133_4e59_9a75_1bf0e1626201

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 1000.0
- hasSymbolData value “k”

Deka

IRI: http://emmo.info/emmo/middle/siunits#EMMO_1d8b370b_c672_4d0c_964e_eaafcbf2f51f

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 10.0
- hasSymbolData value “da”

Tera

IRI: http://emmo.info/emmo/middle/siunits#EMMO_3a204900_2b33_47d1_b444_815cc4c8cffa

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 1000000000000.0
- hasSymbolData value “T”

Deci

IRI: http://emmo.info/emmo/middle/siunits#EMMO_1181c938_c8f0_4ad6_bc7a_2bfdc0903d29

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 0.1
- hasSymbolData value “d”

Centi

IRI: http://emmo.info/emmo/middle/siunits#EMMO_b55cd09a_e54d_4eb1_81dd_03c29d1b878e

Relations:

- is_a SIMetricPrefix
- Inverse(hasVariable) only hasNumericalData value 0.01
- hasSymbolData value “c”

Quantity branch

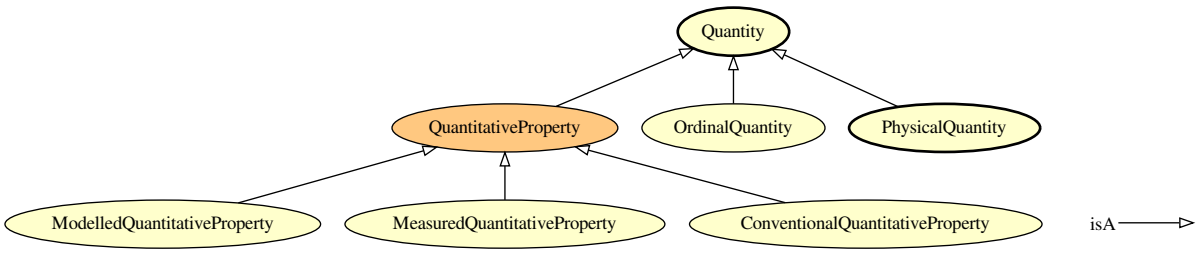

Figure 3.31: Quantity branch.

ModelledQuantitativeProperty

IRI: http://emmo.info/emmo/middle/properties#EMMO_d0200cf1_e4f4_45ae_873f_b9359daea3cd

Relations:

- is_a QuantitativeProperty

Quantity

IRI: http://emmo.info/emmo/middle/metrology#EMMO_f658c301_ce93_46cf_9639_4eace2c5d1d5

Elucidation: A symbolic that has parts a reference unit and a numerical object separated by a space expressing the value of a quantitative property (expressed as the product of the numerical and the unit).

Example: 6.8 m 0.9 km 8 K 6 MeV 43.5 HRC(150 kg)

Comment: A quantity is not necessarily a property, since it is possible to write “10 kg”, without assigning this quantity to a specific object.

However, a quantitative property is always a quantity.

Comment: Referred as Quantity Value in International vocabulary of metrology (VIM)

Comment: SI distinguishes between a quantity (an abstract concept) and the quantity value (a number and a reference).

The EMMO, following strict nominalism, denies the existence of abstract objects and then collapses the two concepts of SI quantity and SI quantity value into a single one: the 'Quantity'.

So, for the EMMO the symbol "kg" is not a physical quantity but simply a 'Symbolic' object categorized as a 'MeasurementUnit'.

While the string "1 kg" is a 'Physical Quantity'.

Relations:

- is_a Metrological
- is_a State
- hasReferenceUnit exactly 1 ReferenceUnit
- hasQuantityValue exactly 1 Numerical
- disjoint_union_of PhysicalQuantity, OrdinalQuantity

OrdinalQuantity

IRI: http://emmo.info/emmo/middle/metrology#EMMO_c46f091c_0420_4c1a_af30_0a2c8ebcf7d7

Elucidation: "Quantity, defined by a conventional measurement procedure, for which a total ordering relation can be established, according to magnitude, with other quantities of the same kind, but for which no algebraic operations among those quantities exist" International vocabulary of metrology (VIM)

Example: Hardness Resilience

Comment: "Ordinal quantities, such as Rockwell C hardness, are usually not considered to be part of a system of quantities because they are related to other quantities through empirical relations only." International vocabulary of metrology (VIM)

Relations:

- is_a Quantity

MeasuredQuantitativeProperty

IRI: http://emmo.info/emmo/middle/properties#EMMO_873b0ab3_88e6_4054_b901_5531e01f14a4

Relations:

- is_a QuantitativeProperty

QuantitativeProperty

IRI: http://emmo.info/emmo/middle/metrology#EMMO_dd4a7f3e_ef56_466c_ac1a_d2716b5f87ec

Elucidation: A 'Quantity' that can be quantified with respect to a standardized reference physical instance (e.g. the prototype meter bar, the kg prototype) or method (e.g. resilience) through a measurement process.

Comment: "A property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed by means of a number and a reference" ISO 80000-1

"A reference can be a measurement unit, a measurement procedure, a reference material, or a combination of such." International vocabulary of metrology (VIM)

Comment: A quantitative property is always expresssed as a quantity (i.e. a number and a reference unit). For the EMMO, a nominalistic ontology, there is no property as abstract object.

A property is a sign that stands for an object according to a specific code shared by some observers.

For quantititative properties, one possible code that is shared between the scientific community (the observers) is the SI system of units.

Comment: Subclasses of 'QuantitativeProperty' classify objects according to the type semiosis that is used to connect the property to the object (e.g. by measurement, by convention, by modelling).

Relations:

- is_a Quantity
- is_a ObjectiveProperty
- equivalent_to MeasuredQuantitativeProperty or ModelledQuantitativeProperty or ConventionalQuantitativeProperty

ConventionalQuantitativeProperty

IRI: http://emmo.info/emmo/middle/properties#EMMO_d8aa8e1f_b650_416d_88a0_5118de945456

Elucidation: A quantitative property attributed by agreement to a quantity for a given purpose.

Example: The thermal conductivity of a copper sample in my laboratory can be assumed to be the conductivity that appears in the vendor specification. This value has been obtained by measurement of a sample which is not the one I have in my laboratory. This conductivity value is then a conventional quantitiative property assigned to my sample through a semiotic process in which no actual measurement is done by my laboratory.

If I don't believe the vendor, then I can measure the actual thermal conductivity. I then perform a measurement process that semiotically assign another value for the conductivity, which is a measured property, since is part of a measurement process.

Then I have two different physical quantities that are properties thanks to two different semiotic processes.

Comment: A property that is associated to an object by convention, or assumption.

Relations:

- is_a QuantitativeProperty

Base Quantity branch

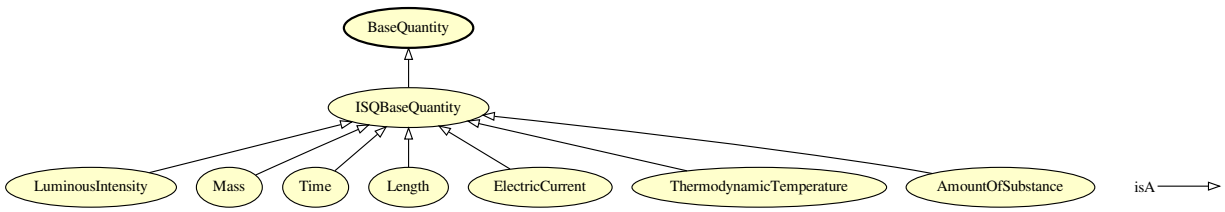

Figure 3.32: Base Quantity branch.

LuminousIntensity

IRI: http://emmo.info/emmo/middle/isq#EMMO_50bf79a6_a48b_424d_9d2c_813bd631231a

Elucidation: A measure of the wavelength-weighted power emitted by a light source in a particular direction per unit solid angle. It is based on the luminosity function, which is a standardized model of the sensitivity of the human eye.

Dbpediamatch: http://dbpedia.org/page/Luminous_intensity

Relations:

- is_a ISQBaseQuantity
- hasReferenceUnit only hasPhysicsDimension only LuminousIntensityDimension

Mass

IRI: http://emmo.info/emmo/middle/isq#EMMO_ed4af7ae_63a2_497e_bb88_2309619ea405

Elucidation: Property of a physical body that express its resistance to acceleration (a change in its state of motion) when a force is applied.

Dbpediamatch: http://dbpedia.org/page/Mass

Iupacdoi: https://doi.org/10.1351/goldbook.M03709

Relations:

- is_a ISQBaseQuantity
- hasReferenceUnit only hasPhysicsDimension only MassDimension
- Inverse(hasProperty) only Matter

ISQBaseQuantity

IRI: http://emmo.info/emmo/middle/isq#EMMO_1a4c1a97_88a7_4d8e_b2f9_2ca58e92dde4

Elucidation: Base quantities defined in the International System of Quantities (ISQ).

Wikipediaentry: https://en.wikipedia.org/wiki/International_System_of_Quantities

Relations:

- is_a InternationalSystemOfQuantity
- is_a BaseQuantity
- disjoint_union_of LuminousIntensity, AmountOfSubstance, ThermodynamicTemperature, ElectricCurrent, Length, Time, Mass

Time

IRI: http://emmo.info/emmo/middle/isq#EMMO_d4f7d378_5e3b_468a_baa1_a7e98358cda7

Definition: One-dimensional subspace of space-time, which is locally orthogonal to space.

Elucidation: The indefinite continued progress of existence and events that occur in apparently irreversible succession from the past through the present to the future.

Iecentry: http://www.electropedia.org/iev/iev.nsf/display?openform&ievref=113-01-03

Comment: Time can be seen as the duration of an event or, more operationally, as “what clocks read”.

Dbpediamatch: http://dbpedia.org/page/Time

Iupacdoi: https://doi.org/10.1351/goldbook.T06375

Relations:

- is_a ISQBaseQuantity
- hasReferenceUnit only hasPhysicsDimension only TimeDimension

BaseQuantity

IRI: http://emmo.info/emmo/middle/metrology#EMMO_acaaa124_3dde_48b6_86e6_6ec6f364f408

Elucidation: “Quantity in a conventionally chosen subset of a given system of quantities, where no quantity in the subset can be expressed in terms of the other quantities within that subset” ISO 80000-1

Relations:

- is_a PhysicalQuantity
- hasReferenceUnit only BaseUnit

Length

IRI: http://emmo.info/emmo/middle/isq#EMMO_cd2cd0de_e0cc_4ef1_b27e_2e88db027bac

Elucidation: Extend of a spatial dimension.

Iecentry: http://www.electropedia.org/iev/iev.nsf/display?openform&ievref=113-01-19

Comment: Length is a non-negative additive quantity attributed to a one-dimensional object in space.

Dbpediamatch: http://dbpedia.org/page/Length

Iupacdoi: https://doi.org/10.1351/goldbook.L03498

Relations:

- is_a ISQBaseQuantity
- hasReferenceUnit only hasPhysicsDimension only LengthDimension

ElectricCurrent

IRI: http://emmo.info/emmo/middle/isq#EMMO_c995ae70_3b84_4ebb_bcfc_69e6a281bb88

Elucidation: A flow of electric charge.

Dbpediamatch: http://dbpedia.org/page/Electric_current

Iupacdoi: https://doi.org/10.1351/goldbook.E01927

Relations:

- is_a ISQBaseQuantity
- hasReferenceUnit only hasPhysicsDimension only ElectricCurrentDimension

ThermodynamicTemperature

IRI: http://emmo.info/emmo/middle/isq#EMMO_affe07e4_e9bc_4852_86c6_69e26182a17f

Elucidation: Thermodynamic temperature is the absolute measure of temperature. It is defined by the third law of thermodynamics in which the theoretically lowest temperature is the null or zero point.

Dbpediamatch: http://dbpedia.org/page/Thermodynamic_temperature

Iupacdoi: https://doi.org/10.1351/goldbook.T06321

Relations:

- is_a ISQBaseQuantity
- hasReferenceUnit only hasPhysicsDimension only TemperatureDimension

AmountOfSubstance

IRI: http://emmo.info/emmo/middle/isq#EMMO_8159c26a_494b_4fa0_9959_10888f152298

Elucidation: The number of elementary entities present.

Dbpediamatch: http://dbpedia.org/page/Amount_of_substance

Iupacdoi: https://doi.org/10.1351/goldbook.A00297

Relations:

- is_a ISQBaseQuantity
- hasReferenceUnit only hasPhysicsDimension only AmountDimension

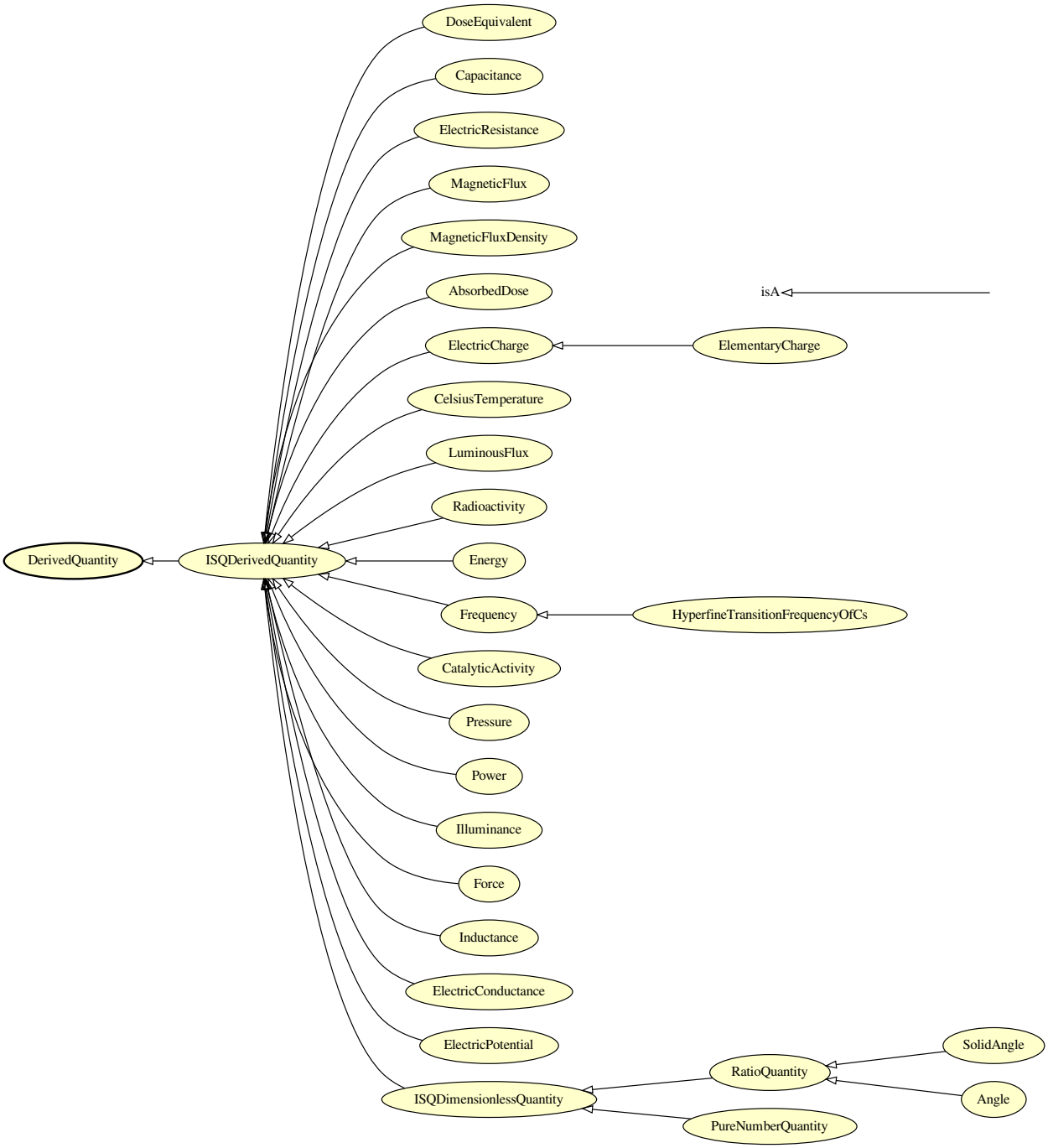

Figure 3.33: Derived Quantity branch.

Derived Quantity branch

DoseEquivalent

IRI: http://emmo.info/emmo/middle/isq#EMMO_3df10765_f6ff_4c9e_be3d_10b1809d78bd

Elucidation: A dose quantity used in the International Commission on Radiological Protection (ICRP) system of radiological protection.

Dbpediamatch: http://dbpedia.org/page/Energy

Iupacdoi: https://doi.org/10.1351/goldbook.E02101

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only SquareLengthPerSquareTimeDimension

Capacitance

IRI: http://emmo.info/emmo/middle/isq#EMMO_99dba333_0dbd_4f75_8841_8c0f97fd58e2

Elucidation: The derivative of the electric charge of a system with respect to the electric potential.

Altlabel: ElectricCapacitance

Dbpediamatch: http://dbpedia.org/page/Capacitance

Iupacdoi: https://doi.org/10.1351/goldbook.C00791

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only QuarticTimeSquareCurrentPerMassSquareLengthDimension

ElectricResistance

IRI: http://emmo.info/emmo/middle/isq#EMMO_e88f75d6_9a17_4cfc_bdf7_43d7cea5a9a1

Elucidation: Measure of the difficulty to pass an electric current through a material.

Altlabel: Resistance

Comment: Inverse of 'ElectricalConductance'.

Dbpediamatch: http://dbpedia.org/page/Electrical_resistance_and_conductance

Iupacdoi: https://doi.org/10.1351/goldbook.E01936

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassSquareLengthPerCubicTimeSquareCurrentDimension

SolidAngle

IRI: http://emmo.info/emmo/middle/isq#EMMO_e7c9f7fd_e534_4441_88fe_1fec6cb20f26

Elucidation: Ratio of area on a sphere to its radius squared.

Dbpediamatch: http://dbpedia.org/page/Solid_angle

Iupacdoi: https://doi.org/10.1351/goldbook.S05732

Relations:

- is_a RatioQuantity

- hasReferenceUnit only hasPhysicsDimension only DimensionOne

MagneticFlux

IRI: http://emmo.info/emmo/middle/isq#EMMO_3b931698_937e_49be_ab1b_36fa52d91181

Elucidation: Measure of magnetism, taking account of the strength and the extent of a magnetic field.

Dbpediamatch: http://dbpedia.org/page/Magnetic_flux

Iupacdoi: https://doi.org/10.1351/goldbook.M03684

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassSquareLengthPerSquareTimeCurrentDimension

MagneticFluxDensity

IRI: http://emmo.info/emmo/middle/isq#EMMO_961d1aba_f75e_4411_aaa4_457f7516ed6b

Elucidation: Strength of the magnetic field.

Comment: Often denoted B.

Dbpediamatch: http://dbpedia.org/page/Magnetic_field

Iupacdoi: https://doi.org/10.1351/goldbook.M03686

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassPerSquareTimeCurrentDimension

RatioQuantity

IRI: http://emmo.info/emmo/middle/isq#EMMO_faab3f84_e475_4a46_af9c_7d249f0b9aef

Elucidation: The class of quantities that are the ratio of two quantities with the same physical dimensionality.

Example: refractive index, volume fraction, fine structure constant

Comment: Quantities defined as ratios `Q=A/B` having equal dimensions in numerator and denominator are dimensionless quantities but still have a physical dimension defined as dim(A)/dim(B).

Johansson, Ingvar (2010). “Metrological thinking needs the notions of parametric quantities, units and dimensions”. Metrologia. 47 (3): 219–230. doi:10.1088/0026-1394/47/3/012. ISSN 0026-1394.

Seealso: https://iopscience.iop.org/article/10.1088/0026-1394/47/3/012

Relations:

- is_a ISQDimensionlessQuantity

AbsorbedDose

IRI: http://emmo.info/emmo/middle/isq#EMMO_8e5dd473_808b_4a8a_b7cd_63068c12ff57

Definition: Energy imparted to matter by ionizing radiation in a suitable small element of volume divided by the mass of that element of volume.

Dbpediamatch: http://dbpedia.org/page/Absorbed_dose

Iupacdoi: https://doi.org/10.1351/goldbook.A00031

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only SquareLengthPerSquareTimeDimension

ElectricCharge

IRI: http://emmo.info/emmo/middle/isq#EMMO_1604f495_328a_4f28_9962_f4cc210739dd

Elucidation: The physical property of matter that causes it to experience a force when placed in an electromagnetic field.

Altlabel: Charge

Dbpediamatch: http://dbpedia.org/page/Electric_charge

Iupacdoi: https://doi.org/10.1351/goldbook.E01923

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only TimeCurrentDimension

CelsiusTemperature

IRI: http://emmo.info/emmo/middle/isq#EMMO_66bc9029_f473_45ff_bab9_c3509ff37a22

Elucidation: An objective comparative measure of hot or cold.

Temperature is a relative quantity that can be used to express temperature differences. Unlike ThermodynamicTemperature, it cannot express absolute temperatures.

Dbpediamatch: http://dbpedia.org/page/Temperature

Iupacdoi: https://doi.org/10.1351/goldbook.T06261

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only TemperatureDimension

HyperfineTransitionFrequencyOfCs

IRI: http://emmo.info/emmo/middle/siunits#EMMO_f96feb3f_4438_4e43_aa44_7458c4d87fc2

Elucidation: The frequency standard in the SI system in which the photon absorption by transitions between the two hyperfine ground states of caesium-133 atoms are used to control the output frequency.

Relations:

- is_a Frequency
- is_a SIExactConstant

LuminousFlux

IRI: http://emmo.info/emmo/middle/isq#EMMO_e2ee1c98_497a_4f66_b4ed_5711496a848e

Elucidation: Perceived power of light.

Dbpediamatch: http://dbpedia.org/page/Luminous_flux

Iupacdoi: https://doi.org/10.1351/goldbook.L03646

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only LuminousIntensityDimension

Radioactivity

IRI: http://emmo.info/emmo/middle/isq#EMMO_8d3da9ac_2265_4382_bee5_db72046722f8

Elucidation: Decays per unit time.

Iupacdoi: https://doi.org/10.1351/goldbook.A00114

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only PerTimeDimension

Energy

IRI: http://emmo.info/emmo/middle/isq#EMMO_31ec09ba_1713_42cb_83c7_b38bf6f9ced2

Elucidation: A property of objects which can be transferred to other objects or converted into different forms.

Comment: Energy is often defined as "ability of a system to perform work", but it might be misleading since is not necessarily available to do work.

Dbpediamatch: http://dbpedia.org/page/Energy

Iupacdoi: https://doi.org/10.1351/goldbook.E02101

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassSquareLengthPerSquareTimeDimension

ElementaryCharge

IRI: http://emmo.info/emmo/middle/siunits#EMMO_58a650f0_a638_4743_8439_535a325e5c4c

Elucidation: The magnitude of the electric charge carried by a single electron.

Comment: The DBpedia definition (http://dbpedia.org/page/Elementary_charge) is outdated as May 20, 2019. It is now an exact quantity.

Dbpediamatch: http://dbpedia.org/page/Elementary_charge

Iupacdoi: https://doi.org/10.1351/goldbook.E02032

Qudtmatch: http://physics.nist.gov/cuu/CODATA-Value_ElementaryCharge

Relations:

- is_a ElectricCharge
- is_a SIExactConstant

Frequency

IRI: http://emmo.info/emmo/middle/isq#EMMO_852b4ab8_fc29_4749_a8c7_b92d4fca7d5a

Elucidation: Number of periods per time interval.

Dbpediamatch: http://dbpedia.org/page/Frequency

Iupacdoi: https://doi.org/10.1351/goldbook.FT07383

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only PerTimeDimension

CatalyticActivity

IRI: http://emmo.info/emmo/middle/isq#EMMO_bd67d149_24c2_4bc9_833a_c2bc26f98fd3

Elucidation: Increase in the rate of reaction of a specified chemical reaction that an enzyme produces in a specific assay system.

Iupacdoi: https://doi.org/10.1351/goldbook.C00881

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only AmountPerTimeDimension

Pressure

IRI: http://emmo.info/emmo/middle/isq#EMMO_50a44256_9dc5_434b_bad4_74a4d9a29989

Elucidation: The force applied perpendicular to the surface of an object per unit area over which that force is distributed.

Dbpediamatch: http://dbpedia.org/page/Pressure

Iupacdoi: https://doi.org/10.1351/goldbook.P04819

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassPerLengthSquareTimeDimension

Power

IRI: http://emmo.info/emmo/middle/isq#EMMO_09b9021b_f97b_43eb_b83d_0a764b472bc2

Elucidation: Rate of transfer of energy per unit time.

Dbpediamatch: http://dbpedia.org/page/Power_(physics)

Iupacdoi: https://doi.org/10.1351/goldbook.P04792

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassSquareLengthPerCubicTimeDimension

PureNumberQuantity

IRI: http://emmo.info/emmo/middle/isq#EMMO_ba882f34_0d71_4e4f_9d92_0c076c633a2c

Elucidation: A pure number, typically the number of something.

Example: 1, i, π, the number of protons in the nucleus of an atom

Comment: According to the SI brochure counting does not automatically qualify a quantity as an amount of substance.

This quantity is used only to describe the outcome of a counting process, without regard of the type of entities.

"There are also some quantities that cannot be described in terms of the seven base quantities of the SI, but have the nature of a count. Examples are a number of molecules, a number of cellular or biomolecular entities (for example copies of a particular nucleic acid sequence), or degeneracy in quantum mechanics. Counting quantities are also quantities with the associated unit one."

Relations:

- is_a ISQDimensionlessQuantity

Illuminance

IRI: http://emmo.info/emmo/middle/isq#EMMO_b51fbd00_a857_4132_9711_0ef70e7bdd20

Definition: The total luminous flux incident on a surface, per unit area.

Dbpediamatch: http://dbpedia.org/page/Illuminance

Iupacdoi: https://doi.org/10.1351/goldbook.I02941

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only LuminousIntensityPerSquareLengthDimension

Force

IRI: http://emmo.info/emmo/middle/isq#EMMO_1f087811_06cb_42d5_90fb_25d0e7e068ef

Elucidation: Any interaction that, when unopposed, will change the motion of an object.

Dbpediamatch: http://dbpedia.org/page/Force

Iupacdoi: https://doi.org/10.1351/goldbook.F02480

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassLengthPerSquareTimeDimension

Inductance

IRI: http://emmo.info/emmo/middle/isq#EMMO_04cc9451_5306_45d0_8554_22cee4d6e785

Elucidation: A property of an electrical conductor by which a change in current through it induces an electromotive force in both the conductor itself and in any nearby conductors by mutual inductance.

Altlabel: ElectricInductance

Dbpediamatch: http://dbpedia.org/page/Inductance

Iupacdoi: https://doi.org/10.1351/goldbook.M04076

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassSquareLengthPerSquareTimeSquareCurrentDimension

ElectricConductance

IRI: http://emmo.info/emmo/middle/isq#EMMO_ffb73b1e_5786_43e4_a964_cb32ac7affb7

Elucidation: Measure of the ease for electric current to pass through a material.

Altlabel: Conductance

Comment: Inverse of 'ElectricalResistance'.

Dbpediamatch: http://dbpedia.org/page/Electrical_resistance_and_conductance

Iupacdoi: https://doi.org/10.1351/goldbook.E01925

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only CubicTimeSquareCurrentPerMassSquareLengthDimension

ElectricPotential

IRI: http://emmo.info/emmo/middle/isq#EMMO_4f2d3939_91b1_4001_b8ab_7d19074bf845

Elucidation: Energy required to move a unit charge through an electric field from a reference point.

Altlabel: Voltage

Dbpediamatch: http://dbpedia.org/page/Voltage

Iupacdoi: https://doi.org/10.1351/goldbook.A00424

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only MassSquareLengthPerCubicTimeCurrentDimension

ISQDerivedQuantity

IRI: http://emmo.info/emmo/middle/isq#EMMO_2946d40b_24a1_47fa_8176_e3f79bb45064

Elucidation: Derived quantities defined in the International System of Quantities (ISQ).

Relations:

- is_a InternationalSystemOfQuantity
- is_a DerivedQuantity

Angle

IRI: http://emmo.info/emmo/middle/isq#EMMO_f3dd74c0_f480_49e8_9764_33b78638c235

Definition: Ratio of circular arc length to radius.

Altlabel: PlaneAngle

Dbpediamatch: http://dbpedia.org/page/Angle

Iupacdoi: https://doi.org/10.1351/goldbook.A00346

Relations:

- is_a RatioQuantity
- hasReferenceUnit only hasPhysicsDimension only DimensionOne

DerivedQuantity

IRI: http://emmo.info/emmo/middle/metrology#EMMO_71f6ab56_342c_484b_bbe0_de86b7367cb3

Elucidation: “Quantity, in a system of quantities, defined in terms of the base quantities of that system”.

Relations:

- is_a PhysicalQuantity

ISQDimensionlessQuantity

IRI: http://emmo.info/emmo/middle/isq#EMMO_a66427d1_9932_4363_9ec5_7d91f2bfda1e

Elucidation: A quantity to which no physical dimension is assigned and with a corresponding unit of measurement in the SI of the unit one.

Dbpediamatch: http://dbpedia.org/page/Dimensionless_quantity

Iupacdoi: https://doi.org/10.1351/goldbook.D01742

Wikipediaentry: https://en.wikipedia.org/wiki/Dimensionless_quantity

Relations:

- is_a ISQDerivedQuantity
- hasReferenceUnit only hasPhysicsDimension only DimensionOne

Physical Constant branch

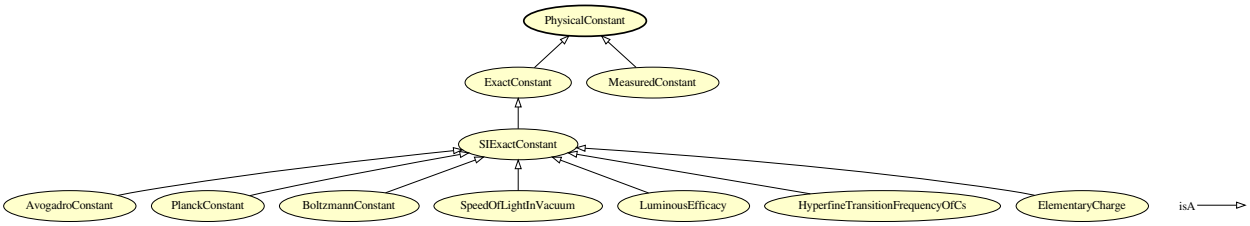

Figure 3.34: Physical Constant branch.

AvogadroConstant

IRI: http://emmo.info/emmo/middle/siunits#EMMO_176cae33_b83e_4cd2_a6bc_281f42f0ccc8

Elucidation: The number of constituent particles, usually atoms or molecules, that are contained in the amount of substance given by one mole.

Comment: The DBpedia definition (http://dbpedia.org/page/Avogadro_constant) is outdated as May 20, 2019. It is now an exact quantity.

Dbpediamatch: http://dbpedia.org/page/Avogadro_constant

Iupacdoi: https://doi.org/10.1351/goldbook.A00543

Qudtmatch: http://physics.nist.gov/cuu/CODATA-Value_AvogadroConstant

Relations:

- is_a SIExactConstant
- hasReferenceUnit only hasPhysicsDimension only PerAmountDimension

SIExactConstant

IRI: http://emmo.info/emmo/middle/siunits#EMMO_f2ca6dd0_0e5f_4392_a92d_cafdae6cfc95

Elucidation: Physical constant that by definition (after the latest revision of the SI system that was enforsed May 2019) has a known exact numerical value when expressed in SI units.

Relations:

- is_a ExactConstant

PlanckConstant

IRI: http://emmo.info/emmo/middle/siunits#EMMO_76cc4efc_231e_42b4_be83_2547681caed6

Elucidation: The quantum of action.

Dbpediamatch: http://dbpedia.org/page/Planck_constant

Iupacdoi: https://doi.org/10.1351/goldbook.P04685

Qudtmatch: http://physics.nist.gov/cuu/CODATA-Value_PlankConstant

Relations:

- is_a SIExactConstant

- hasReferenceUnit only hasPhysicsDimension only MassSquareLengthPerTimeDimension

ExactConstant

IRI: http://emmo.info/emmo/middle/metrology#EMMO_89762966_8076_4f7c_b745_f718d653e8e2

Comment: Physical constant used to define a unit system. Hence, when expressed in that unit system they have an exact value with no associated uncertainty.

Relations:

- is_a PhysicalConstant

BoltzmannConstant

IRI: http://emmo.info/emmo/middle/siunits#EMMO_ffc7735f_c177_46a4_98e9_a54440d29209

Elucidation: A physical constant relating energy at the individual particle level with temperature. It is the gas constant R divided by the Avogadro constant.

Comment: The DBpedia definition (http://dbpedia.org/page/Boltzmann_constant) is outdated as May 20, 2019. It is now an exact quantity.

Dbpediamatch: http://dbpedia.org/page/Boltzmann_constant

Iupacdoi: https://doi.org/10.1351/goldbook.B00695

Qudtmatch: http://physics.nist.gov/cuu/CODATA-Value_BoltzmannConstant

Relations:

- is_a SIExactConstant
- hasReferenceUnit only hasPhysicsDimension only MassSquareLengthPerTemperatureSquareTimeDimension

SpeedOfLightInVacuum

IRI: http://emmo.info/emmo/middle/siunits#EMMO_99296e55_53f7_4333_9e06_760ad175a1b9

Elucidation: The speed of light in vacuum.

Dbpediamatch: http://dbpedia.org/page/Speed_of_light

Iupacdoi: https://doi.org/10.1351/goldbook.S05854

Qudtmatch: http://physics.nist.gov/cuu/CODATA-Value_SpeedOfLightInVacuum

Relations:

- is_a SIExactConstant
- hasReferenceUnit only hasPhysicsDimension only LengthPerTimeDimension

LuminousEfficacy

IRI: http://emmo.info/emmo/middle/siunits#EMMO_506f7823_52bc_40cb_be07_b3b1e10cce13

Elucidation: The luminous efficacy of monochromatic radiation of frequency 540 × 10 12 Hz, K cd , is a technical constant that gives an exact numerical relationship between the purely physical characteristics of the radiant power stimulating the human eye (W) and its photobiological response defined by the luminous flux due to the spectral responsivity of a standard observer (lm) at a frequency of 540 × 10 12 hertz.

Relations:

- is_a SIExactConstant
- hasReferenceUnit only hasPhysicsDimension only LuminousIntensityCubicTimePerMassLengthDimension

MeasuredConstant

IRI: http://emmo.info/emmo/middle/metrology#EMMO_3f15d200_c97b_42c8_8ac0_d81d150361e2

Elucidation: For a given unit system, measured constants are physical constants that are not used to define the unit system. Hence, these constants have to be measured and will therefore be associated with an uncertainty.

Relations:

- is_a PhysicalConstant

HyperfineTransitionFrequencyOfCs

IRI: http://emmo.info/emmo/middle/siunits#EMMO_f96feb3f_4438_4e43_aa44_7458c4d87fc2

Elucidation: The frequency standard in the SI system in which the photon absorption by transitions between the two hyperfine ground states of caesium-133 atoms are used to control the output frequency.

Relations:

- is_a Frequency
- is_a SIExactConstant

PhysicalConstant

IRI: http://emmo.info/emmo/middle/metrology#EMMO_b953f2b1_c8d1_4dd9_b630_d3ef6580c2bb

Comment: Physical constants are categorised into “exact” and measured constants.

With “exact” constants, we refer to physical constants that have an exact numerical value after the revision of the SI system that was enforsed May 2019.

Wikipediaentry: https://en.wikipedia.org/wiki/List_of_physical_constants

Relations:

- is_a PhysicalQuantity
- disjoint_union_of MeasuredConstant, ExactConstant

ElementaryCharge

IRI: http://emmo.info/emmo/middle/siunits#EMMO_58a650f0_a638_4743_8439_535a325e5c4c

Elucidation: The magnitude of the electric charge carried by a single electron.

Comment: The DBpedia definition (http://dbpedia.org/page/Elementary_charge) is outdated as May 20, 2019. It is now an exact quantity.

Dbpediamatch: http://dbpedia.org/page/Elementary_charge

Iupacdoi: https://doi.org/10.1351/goldbook.E02032

Qudtmatch: http://physics.nist.gov/cuu/CODATA-Value_ElementaryCharge

Relations:

- is_a ElectricCharge
- is_a SIExactConstant

Reductionistic branch

Reductionistic

IRI: http://emmo.info/emmo/middle/reductionistic#EMMO_15db234d_ecaf_4715_9838_4b4ec424fb13

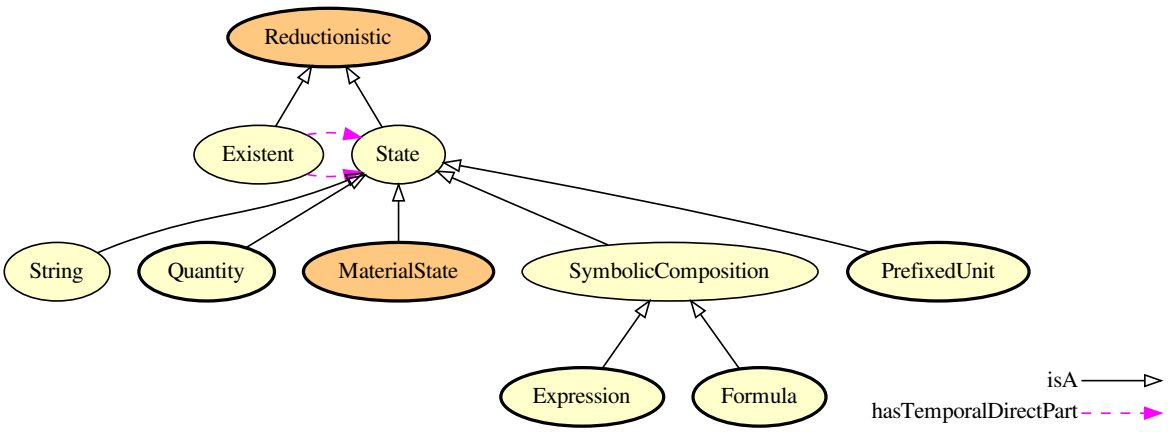

Figure 3.35: Reductionistic branch.

Elucidation: A class devoted to categorize 'Physical'-s according to their granularity relations, first in terms of time evolution (Existent) and then in terms of their composition (State), up to the spatial a-tomistic element (Elementary).

Direct parthood is the relation used to build the class hierarchy (and the granularity hierarchy).

Relations:

- is_a Perspective
- equivalent_to State or Existent

Existent

IRI: http://emmo.info/emmo/middle/reductionistic#EMMO_52211e5e_d767_4812_845e_eb6b402c476a

Elucidation: A 'Physical' which is a tessellation of 'State' temporal direct parts.

Comment: 'Existent' is the EMMO class to be used for representing real world physical objects under a reductionistic perspective (i.e. objects come from the composition of sub-part objects, both in time and space).

'Existent' class collects all individuals that stand for physical objects that can be structured in well defined temporal sub-parts called states, through the temporal direct parthood relation.

This class provides a first granularity hierarchy in time, and a way to axiomatize tessellation principles for a specific whole with a non-transitivity relation (direct parthood) that helps to retain the granularity levels.

e.g. a car, a supersaturated gas with nucleating nanoparticles, an atom that becomes ionized and then recombines with an electron.

Comment: An 'Existent' individual stands for a real world object for which the ontologist can provide univocal tessellation in time.

By definition, the tiles are represented by 'State'-s individual.

Tiles are related to the 'Existent' through temporal direct parthood, enforcing non-transitivity and inverse-functionality.

Comment: Being hasTemporalDirectPart a proper parthood relation, there cannot be 'Existent' made of a single 'State'.

Moreover, due to inverse functionality, a 'State' can be part of only one 'Existent', preventing overlapping between 'Existent'-s.

Comment: ex-sistere (latin): to stay (to persist through time) outside others of the same type (to be distinct from the rest).

Relations:

- is_a Reductionistic
- hasTemporalDirectPart some State
- hasTemporalDirectPart only State

String

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_50ea1ec5_f157_41b0_b46b_a9032f17ca10

Elucidation: A physical made of more than one symbol sequentially arranged.

Example: The word "cat" considered as a collection of 'symbol'-s respecting the rules of english language.

In this example the 'symbolic' entity "cat" is not related to the real cat, but it is only a word (like it would be to an italian person that ignores the meaning of this english word).

If an 'interpreter' skilled in english language is involved in a 'semiotic' process with this word, that "cat" became also a 'sign' i.e. it became for the 'interpreter' a representation for a real cat.

Comment: A string is made of concatenated symbols whose arrangement is one-dimensional. Each symbol can have only one previous and one next neighborhood (bidirectional list).

Comment: A string is not requested to respect any syntactic rule: it's simply directly made of symbols.

Relations:

- is_a Symbolic
- is_a State
- hasSpatialDirectPart some Symbol
- hasSpatialDirectPart only Symbol

SymbolicComposition

IRI: http://emmo.info/emmo/middle/perceptual#EMMO_89a0c87c_0804_4013_937a_6fe234d9499c

Elucidation: A symbolic entity made of other symbolic entities according to a specific spatial configuration.

Relations:

- is_a Symbolic
- is_a State
- hasSpatialDirectPart some Symbolic

State

IRI: http://emmo.info/emmo/middle/reductionistic#EMMO_36c79456_e29c_400d_8bd3_0eedddb82652

Elucidation: A 'Physical' which is a tessellation of spatial direct parts.

Example: e.g. the existent in my glass is declared at t = t_start as made of two direct parts: the ice and the water. It will continue to exists as state as long as the ice is completely melt at t = t_end. The new state will be completely made of water. Between t_start and t_end there is an exchange of molecules between the ice and the water, but this does not affect the existence of the two states.

If we partition the existent in my glass as ice surrounded by several molecules (we do not use the object water as direct part) then the appearance of a molecule coming from the ice will cause a state to end and another state to begin.

Comment: Direct partitions declaration is a choice of the ontologist that choses the classes to be used as direct parts, according to its own world view.

A 'State' can always be direct partitioned in 'Elementary'-s and 'Void' or 'Physical'.

e.g. the water in my glass can be seen as a single object without declaring direct parts, or as made of H2O molecules direct parts.

Comment: The definition of 'State' implies that its spatial direct parts (i.e. 'physicals') are not gained or lost during its temporal extension (they exist from the left to the right side of the time interval), so that the cardinality of spatial direct parts in a 'State' is constant.

This does not mean that there cannot be a change in the internal structure of the 'State' direct parts. It means only that this change must not affect the existence of the direct part itself.

There is no change in granularity or cardinality of direct parts of a 'State'.

The use of spatial direct parthood in 'State' definition means that a 'State' cannot overlap in space another 'State'.

Comment: The usefulness of 'State' is that it makes it possible to describe the evolution in time of an 'Existent' in terms of series of 'State'-s that can take into account the disappearance or appearance of parts within a 'Physical'.

A 'State' is a recognizable granularity level of matter, in the sense that its direct parts do not appear or disappear within its lifetime as it can be for a generic 'Existent'.

Comment: There is no change in granularity or cardinality of parts within a state.

The use of spatial direct parthood in state definition means that a state cannot overlap in space another state that is direct part of the same whole.

Relations:

- is_a Reductionistic
- hasSpatialDirectPart some Physical

Expression branch

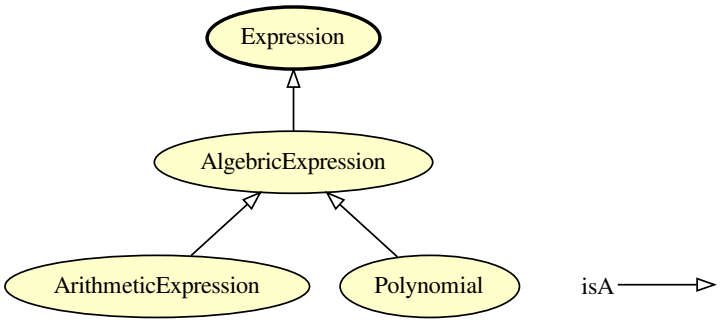

Figure 3.36: Expression branch.

ArithmeticExpression

IRI: http://emmo.info/emmo/middle/math#EMMO_89083bab_f69c_4d06_bf6d_62973b56cdc7

Example: 2+2

Relations:

- is_a AlgebricExpression
- is_a not hasSpatialDirectPart some Variable

Expression

IRI: http://emmo.info/emmo/middle/math#EMMO_f9bc8b52_85e9_4b53_b969_dd7724d5b8e4

Elucidation: A well-formed finite combination of mathematical symbols according to some specific rules.

Relations:

- is_a Mathematical
- is_a SymbolicComposition

AlgebricExpression

IRI: http://emmo.info/emmo/middle/math#EMMO_1aed91a3_d00c_48af_8f43_a0c958b2512a

Example: 2x+3

Comment: An expression that has parts only integer constants, variables, and the algebraic operations (addition, subtraction, multiplication, division and exponentiation by an exponent that is a rational number)

Relations:

- is_a Expression

Polynomial

IRI: http://emmo.info/emmo/middle/math#EMMO_91447ec0_fb55_49f2_85a5_3172dff6482c

Example: 2 * x^2 + x + 3

Relations:

- is_a AlgebricExpression

Formula branch

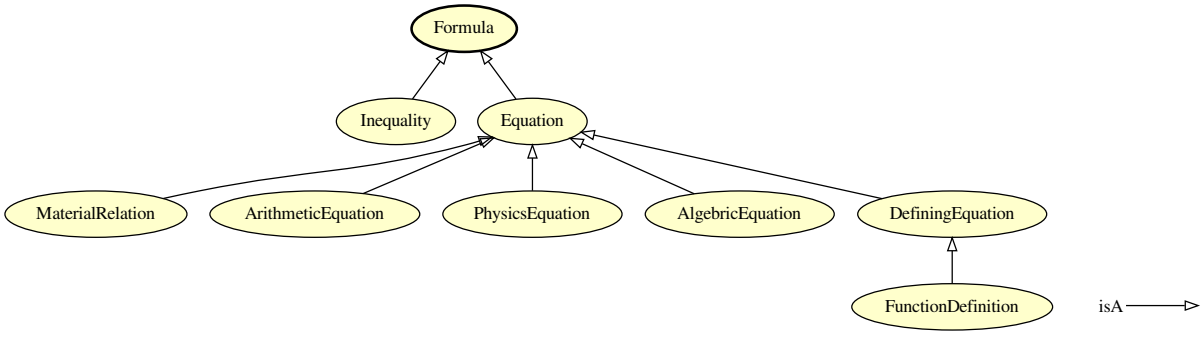

Figure 3.37: Formula branch.

DefiningEquation

IRI: http://emmo.info/emmo/middle/math#EMMO_29afdf54_90ae_4c98_8845_fa9ea3f143a8

Elucidation: An equation that define a new variable in terms of other mathematical entities.

Example: The definition of velocity as v = dx/dt.

The definition of density as mass/volume.

y = f(x)

Relations:

- is_a Equation

Equation

IRI: http://emmo.info/emmo/middle/math#EMMO_e56ee3eb_7609_4ae1_8bed_51974f0960a6

Elucidation: The class of 'mathematical'-s that stand for a statement of equality between two mathematical expressions.

Example: 2+3 = 5 x^2 +3x = 5x dv/dt = a sin(x) = y

Comment: An equation with variables can always be represented as:

f(v0, v1, ..., vn) = g(v0, v1, ..., vn)

where f is the left hand and g the right hand side expressions and v0, v1, ..., vn are the variables.

Relations:

- is_a Formula
- is_a Mathematical
- hasSpatialDirectPart some Expression

MaterialRelation

IRI: http://emmo.info/emmo/middle/models#EMMO_e5438930_04e7_4d42_ade5_3700d4a52ab7

Elucidation: An 'equation' that stands for a physical assumption specific to a material, and provides an expression for a 'physics_quantity' (the dependent variable) as function of other variables, physics_quantity or data (independent variables).

Example: The Lennard-Jones potential.

A force field.

An Hamiltonian.

Comment: A material_relation can e.g. return a predefined number, return a database query, be an equation that depends on other physics_quantities.

Relations:

- is_a Equation
- hasSpatialDirectPart some PhysicalQuantity

Inequality

IRI: http://emmo.info/emmo/middle/math#EMMO_0b6ebe5a_0026_4bef_a1c1_5be00df9f98e

Elucidation: A relation which makes a non-equal comparison between two numbers or other mathematical expressions.

Example: f(x) > 0

Relations:

- is_a Formula

ArithmeticEquation

IRI: http://emmo.info/emmo/middle/math#EMMO_a6138ba7_e365_4f2d_b6b4_fe5a5918d403

Example: 1 + 1 = 2

Relations:

- is_a Equation

Formula

IRI: http://emmo.info/emmo/middle/math#EMMO_88470739_03d3_4c47_a03e_b30a1288d50c

Elucidation: A mathematica string that can be evaluated as true or false.

Relations:

- is_a Mathematical
- is_a SymbolicComposition

FunctionDefinition

IRI: http://emmo.info/emmo/middle/math#EMMO_4bc29b0f_8fcc_4026_a291_f9774a66d9b8

Elucidation: A function defined using functional notation.

Example: y = f(x)

Relations:

- is_a DefiningEquation

PhysicsEquation

IRI: http://emmo.info/emmo/middle/models#EMMO_27c5d8c6_8af7_4d63_beb1_ec37cd8b3fa3

Elucidation: An 'equation' that stands for a 'physical_law' by mathematically defining the relations between physics_quantities.

Comment: The Newton's equation of motion.

The Schrodinger equation.

The Navier-Stokes equation.

Relations:

- is_a Equation
- is_a MathematicalModel
- hasSpatialDirectPart some PhysicalQuantity
- Inverse(hasModel) some PhysicalPhenomenon

AlgebricEquation

IRI: http://emmo.info/emmo/middle/math#EMMO_98d65021_4574_4890_b2fb_46430841077f

Example: 2 * a - b = c

Comment: An 'equation' that has parts two 'polynomial'-s

Relations:

- is_a Equation
- hasSpatialDirectPart some AlgebricExpression

Physicalistic branch

Physicalistic

IRI: http://emmo.info/emmo/middle/physicalistic#EMMO_98ada9d8_f1c8_4f13_99b5_d890f5354152

Elucidation: The perspective for which physical objects are categorized only by concepts coming from physics.

Relations:

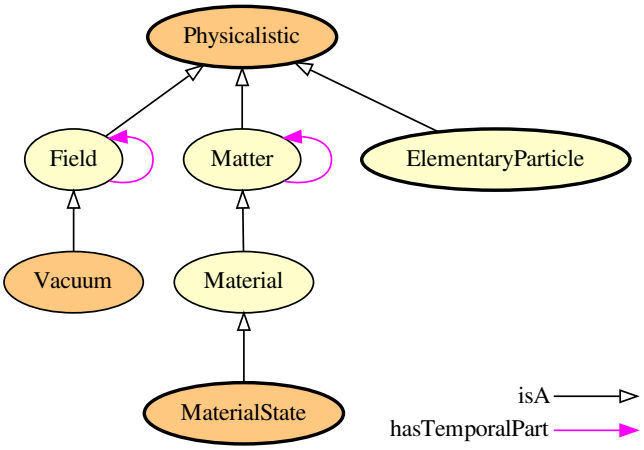

Figure 3.38: Physicalistic branch.

- is_a Perspective
- equivalent_to Matter or Field

Field

IRI: http://emmo.info/emmo/middle/physicalistic#EMMO_70dac51e_bddd_48c2_8a98_7d8395e91fc2

Elucidation: A 'Physical' with 'Massless' parts that are mediators of interactions.

Comment: The concepts of matter and field for classical physics, upon which we can categorize physical entities, are replaced in quantum physics by the more general concepts of quantum field.

Here the class 'Field' refers to the quantum field of massless bosonic particles (i.e. photons, gluons), while the class 'Matter' refers to the quantum field of massive fermionic or bosonic particles (e.g. quarks, electrons).

Relations:

- is_a Physicalistic
- is_a Physical
- hasPart some Massless
- hasTemporalPart only Field

Material

IRI: http://emmo.info/emmo/middle/physicalistic#EMMO_4207e895_8b83_4318_996a_72cfb32acd94

Elucidation: A 'Physical' that stands for a real world object that represents an amount of a physical substance (or mixture of substances) that constitute (is part of) a more comprehensive real world object.

Comment: The definition states that a 'Material' is a portion of a real world object, being that a full functional device or component, or a sample made of that material (or the sample itself).

Relations:

- is_a Matter

Vacuum

IRI: http://emmo.info/emmo/middle/physicalistic#EMMO_3c218fbe_60c9_4597_8bcf_41eb1773af1f

Elucidation: A 'Physical' with no 'Massive' parts.

Relations:

- is_a Field
- equivalent_to Field and not Matter

Matter

IRI: http://emmo.info/emmo/middle/physicalistic#EMMO_5b2222df_4da6_442f_8244_96e9e45887d1

Elucidation: A 'Physical' that possesses some 'Massive' parts.

Relations:

- is_a Physicalistic
- is_a Physical
- hasPart some Massive
- hasTemporalPart only Matter

Elementary Particle branch

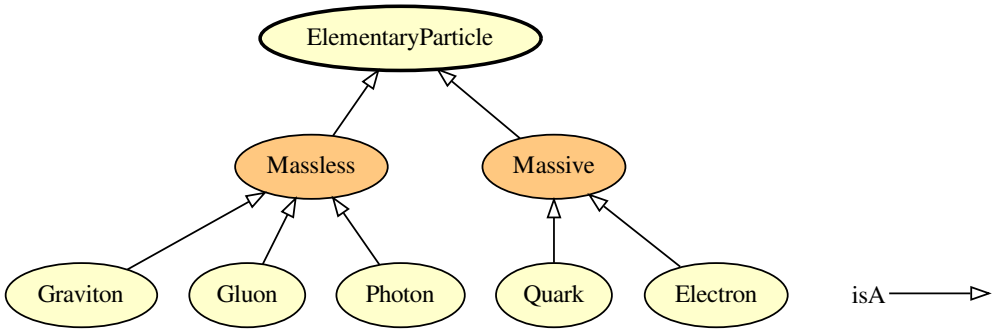

Figure 3.39: Elementary Particle branch.

Graviton

IRI: http://emmo.info/emmo/middle/physicalistic#EMMO_eb3c61f0_3983_4346_a0c6_e7f6b90a67a8

Elucidation: The class of individuals that stand for gravitons elementary particles.

Comment: While this particle is only supposed to exist, the EMMO approach to classical and quantum systems represents fields as made of particles.

For this reason graviton is an useful concept to homogenize the approach between different fields.

Relations:

- is_a Massless
- is_a Elementary

Massless

IRI: http://emmo.info/emmo/middle/physicalistic#EMMO_e5488299_8dab_4ebb_900a_26d2abed8396

Elucidation: The union of classes of elementary particles that do not possess mass.

Relations:

- is_a ElementaryParticle
- equivalent_to Photon or Gluon or Graviton

Quark

IRI: http://emmo.info/emmo/middle/physicalistic#EMMO_72d53756_7fb1_46ed_980f_83f47efbe105

Elucidation: The class of individuals that stand for quarks elementary particles.

Relations:

- is_a Massive
- is_a Elementary

Gluon

IRI: http://emmo.info/emmo/middle/physicalistic#EMMO_7db59e56_f68b_48b7_ae99_891c35ae5c3b

Elucidation: The class of individuals that stand for gluons elementary particles.

Relations:

- is_a Massless
- is_a Elementary

Electron

IRI: http://emmo.info/emmo/middle/physicalistic#EMMO_8043d3c6_a4c1_4089_ba34_9744e28e5b3d

Elucidation: The class of individuals that stand for electrons elemntary particles.

Relations:

- is_a Massive
- is_a Elementary

Massive

IRI: http://emmo.info/emmo/middle/physicalistic#EMMO_385b8f6e_43ac_4596_ad76_ac322c68b7ca

Elucidation: The union of classes of elementary particles that possess mass.

Relations:

- is_a ElementaryParticle
- equivalent_to Quark or Electron

Photon

IRI: http://emmo.info/emmo/middle/physicalistic#EMMO_25f8b804_9a0b_4387_a3e7_b35bce5365ee

Comment: The class of individuals that stand for photons elementary particles.

Relations:

- is_a Massless
- is_a Elementary

ElementaryParticle

IRI: http://emmo.info/emmo/middle/physicalistic#EMMO_c26a0340_d619_4928_b1a1_1a04e88bb89d

Elucidation: The union of all classes categorizing elementary particles according to the Standard Model.

Comment: Only a subset of elementary particles from the Standard Model are here included for the sake of simplicity.

Relations:

- is_a Physicalistic
- is_a Elementary
- disjoint_union_of Photon, Quark, Gluon, Electron, Graviton

Material State branch

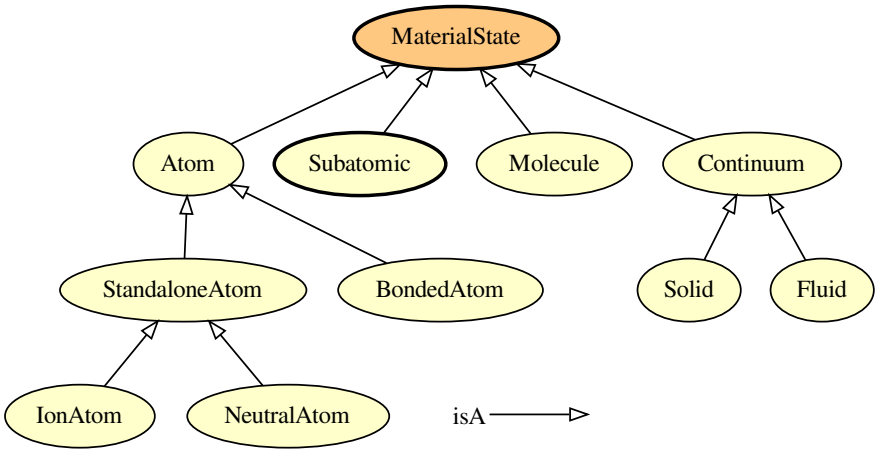

Figure 3.40: Material State branch.

IonAtom

IRI: http://emmo.info/emmo/middle/materials#EMMO_db03061b_db31_4132_a47a_6a634846578b

Elucidation: A standalone atom with an unbalanced number of electrons with respect to its atomic number.

Comment: The ion_atom is the basic part of a pure ionic bonded compound i.e. without eclectron sharing,

Relations:

- is_a StandaloneAtom

BondedAtom

IRI: http://emmo.info/emmo/middle/materials#EMMO_8303a247_f9d9_4616_bdcd_f5cbd7b298e3

Elucidation: An bonded atom that shares at least one electron to the atom-based entity of which is part of.

Comment: A real bond between atoms is always something hybrid between covalent, metallic and ionic.

In general, metallic and ionic bonds have atoms sharing electrons.

Comment: The bond types that are covered by this definition are the strong electonic bonds: covalent, metallic and ionic.

Comment: This class can be used to represent molecules as simplified quantum systems, in which outer molecule shared electrons are un-entangled with the inner shells of the atoms composing the molecule.

Relations:

- is_a Atom

NeutralAtom

IRI: http://emmo.info/emmo/middle/materials#EMMO_4588526f_8553_4f4d_aa73_a483e88d599b

Elucidation: A standalone atom that has no net charge.

Relations:

- is_a StandaloneAtom

StandaloneAtom

IRI: http://emmo.info/emmo/middle/materials#EMMO_2fd3f574_5e93_47fe_afca_ed80b0a21ab4

Elucidation: An atom that does not share electrons with other atoms.

Comment: A standalone atom can be bonded with other atoms by intermolecular forces (i.e. dipole–dipole, London dispersion force, hydrogen bonding), since this bonds does not involve electron sharing.

Relations:

- is_a Atom
- disjoint_union_of NeutralAtom, IonAtom

Atom

IRI: http://emmo.info/emmo/middle/materials#EMMO_eb77076b_a104_42ac_a065_798b2d2809ad

Elucidation: A standalone atom has direct part one 'nucleus' and one 'electron_cloud'.

An O 'atom' within an O2 'molecule' is an 'e-bonded_atom'.

In this material branch, H atom is a particular case, with respect to higher atomic number atoms, since as soon as it shares its electron it has no nucleus entangled electron cloud.

We cannot say that H2 molecule has direct part two H atoms, but has direct part two H nucleus.

Comment: An 'atom' is a 'nucleus' surrounded by an 'electron_cloud', i.e. a quantum system made of one or more bounded electrons.

Relations:

- is_a MaterialState
- is_a Material
- is_a State
- hasSpatialDirectPart some ElectronCloud
- hasSpatialDirectPart some Nucleus

MaterialState

IRI: http://emmo.info/emmo/middle/materials#EMMO_20fff605_465f_4034_8696_e53e90ec83f4

Elucidation: A union of the four base classes for the classification of materials according to the DG-RTD Review of Materials Modelling.

Seealso: https://op.europa.eu/en/publication-detail/-/publication/e0845ae1-1b60-11e7-aeb3-01aa75ed71a1

Relations:

- is_a Material

- is_a State
- equivalent_to Material and State

Solid

IRI: http://emmo.info/emmo/middle/materials#EMMO_a2b006f2_bbfd_4dba_bcaa_3fca20cd6be1

Elucidation: A continuum characterized by structural rigidity and resistance to changes of shape or volume, that retains its shape and density when not confined.

Relations:

- is_a Continuum

Fluid

IRI: http://emmo.info/emmo/middle/materials#EMMO_87ac88ff_8379_4f5a_8c7b_424a8fff1ee8

Elucidation: A continuum that has no fixed shape and yields easily to external pressure.

Example: Gas, liquid, plasma,

Relations:

- is_a Continuum

Molecule

IRI: http://emmo.info/emmo/middle/materials#EMMO_3397f270_dfc1_4500_8f6f_4d0d85ac5f71

Elucidation: An atom_based state defined by an exact number of e-bonded atomic species and an electron cloud made of the shared electrons.

Example: H20, C6H12O6, CH4

Comment: An entity is called essential if removing one direct part will lead to a change in entity class.

An entity is called redundand if removing one direct part will not lead to a change in entity class.

Comment: This definition states that this object is a non-periodic set of atoms or a set with a finite periodicity.

Removing an atom from the state will result in another type of atom_based state.

e.g. you cannot remove H from H20 without changing the molecule type (essential). However, you can remove a C from a nanotube (redundant). C60 fullerene is a molecule, since it has a finite periodicity and is made of a well defined number of atoms (essential). A C nanotube is not a molecule, since it has an infinite periodicity (redundant).

Relations:

- is_a MaterialState
- is_a Material
- is_a State

Continuum

IRI: http://emmo.info/emmo/middle/materials#EMMO_8b0923ab_b500_477b_9ce9_8b3a3e4dc4f2

Elucidation: A state that is a collection of sufficiently large number of other parts such that: - it is the bearer of qualities that can exists only by the fact that it is a sum of parts - the smallest partition dV of the state volume in which we are interested in, contains enough parts to be statistically consistent: n [#/m3] x dV [m3] >> 1

Comment: A continuum is made of a sufficient number of parts that it continues to exists as continuum individual even after the loss of one of them i.e. a continuum is a redundant.

Comment: A continuum is not necessarily small (i.e. composed by the minimum amount of sates to fulfill the definition).

A single continuum individual can be the whole fluid in a pipe.

Comment: A continuum is the bearer of properties that are generated by the interactions of parts such as viscosity and thermal or electrical conductivity.

Relations:

- is_a MaterialState
- is_a Material
- is_a State

Subatomic branch

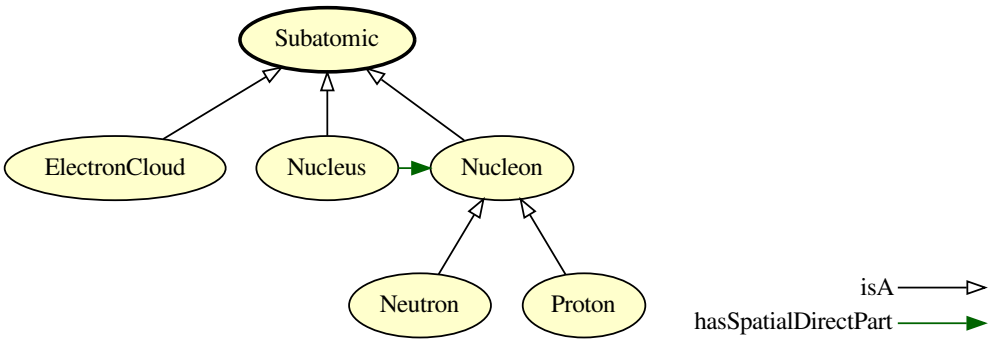

Figure 3.41: Subatomic branch.

Nucleon

IRI: http://emmo.info/emmo/middle/materials#EMMO_50781fd9_a9e4_46ad_b7be_4500371d188d

Relations:

- is_a Subatomic
- hasSpatialDirectPart some Quark
- disjoint_union_of Proton, Neutron

Neutron

IRI: http://emmo.info/emmo/middle/materials#EMMO_df808271_df91_4f27_ba59_fa423c51896c

Relations:

- is_a Nucleon

ElectronCloud

IRI: http://emmo.info/emmo/middle/materials#EMMO_1067b97a_84f8_4d22_8ace_b842b8ce355c

Elucidation: A 'spacetime' that stands for a quantum system made of electrons.

Relations:

- is_a Subatomic

- hasSpatialDirectPart some Electron

Proton

IRI: http://emmo.info/emmo/middle/materials#EMMO_8f87e700_99a8_4427_8ffb_e493de05c217

Relations:

- is_a Nucleon

Subatomic

IRI: http://emmo.info/emmo/middle/materials#EMMO_7d66bde4_b68d_41cc_b5fc_6fd98c5e2ff0

Relations:

- is_a MaterialState
- is_a Material
- is_a State

Nucleus

IRI: http://emmo.info/emmo/middle/materials#EMMO_f835f4d4_c665_403d_ab25_dca5cc74be52

Relations:

- is_a Subatomic
- hasSpatialDirectPart some Nucleon

Chapter 4

Individuals

Universe

IRI: http://emmo.info/emmo/top/mereotopology#EMMO_08cb807c_e626_447b_863f_e2835540e918

Relations:

- is_a Physical

Chapter 5

Appendix

The complete taxonomy of EMMO relations

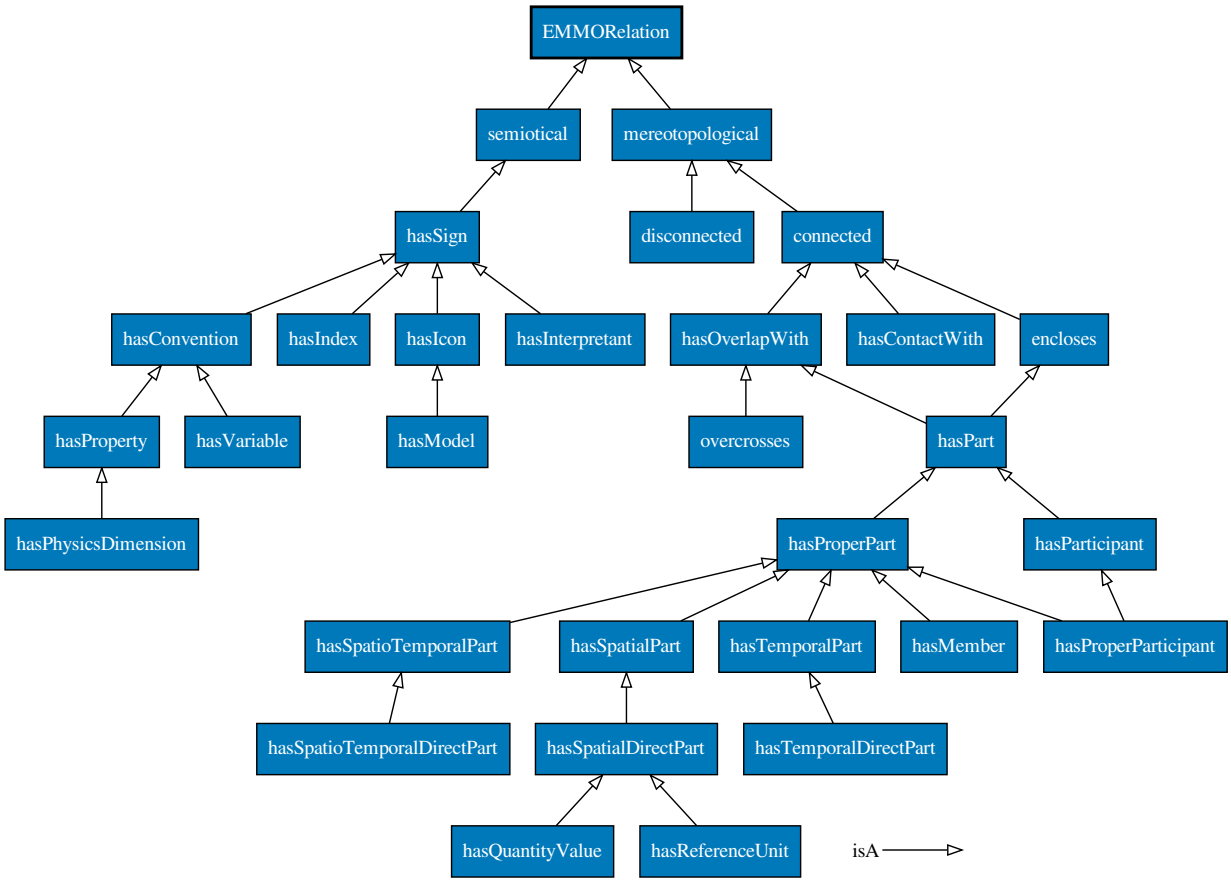

Figure 5.1: The complete taxonomy of EMMO relations.

The taxonomy of EMMO classes

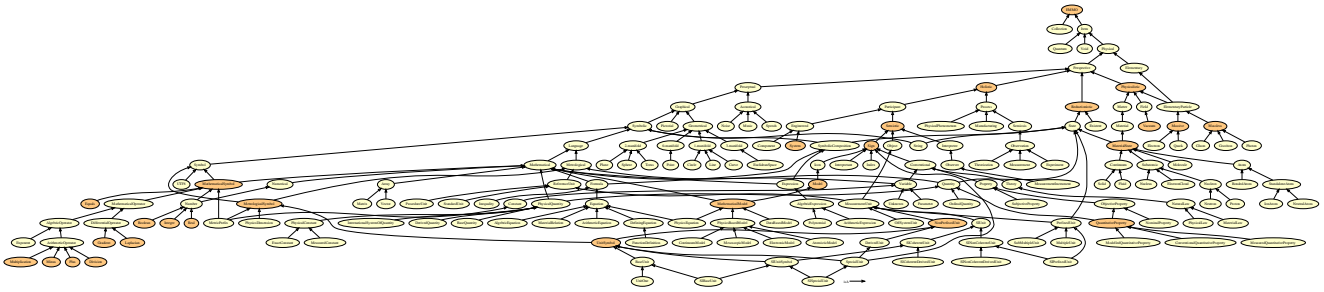

Figure 5.2: The almost complete taxonomy of EMMO classes. Only physical quantities and constants are left out.