MMODS-O: A Modular Ontology for the Metadata Object Description Schema (MODS) – Documentation

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1 Overview

We are presenting the documentation for MMODS-O, an ontology derived from the Metadata Object Description Schema (MODS, version 3.8), which is an XML Schema by The Library of Congress. The XML Schema concerns metadata pertaining to bibliographic elements, however it is also used for other purposes, for instance LCACommons which is an interagency community that focues on Life Cycle Analysis, National Agricultural Library – require the metadata to be in MODS format. Our motivation for developing this ontology – including how it relates to previous attempts – will be described elsewhere. This documentation is intended for readers who are familiar with MODS XML schema.

The MMODS-O ontology was carried out following, in general terms, the Modular Ontology Modeling (MOMo) methodology [Shimizu et al., 2023], however with involvement of fewer people than usual. The intention is not to provide a final version, but to provide a first step towards developing a high-quality modular ontology for MODS.

The rest of the documentation is structured as follows: first, we provide a brief primer on Ontology Axioms. In section 2, we list all the modules of the ontology wherein each module we provide the schema-diagram, the axioms, followed by some explanations of the axioms.

For background regarding Semantic Web standards, in particular the Web Ontology Language OWL, including its relation to description logics, we refer the reader to [Hitzler et al., 2012, Hitzler et al., 2010].

Primer on Ontology Axioms

Logical axioms are presented (mostly) in description logic notation, which can be directly translated into the Web Ontology Language OWL [Hitzler et al., 2010]. We use description logic notation because it is, in the end, easier for humans to read than any of the other serializations.[1]

Logical axioms serve many purposes in ontology modeling and engineering [Hitzler and Krisnadhi, 2016]; in our context, the primary reason why we choose a strong axiomatization is to disambiguate the ontology.

Almost all axioms which are part of the ontology are of the straightforward and local types that go back to the investigations in [Sarker et al., 2016, Eberhart et al., 2021]. We will now describe these types in more detail, as it will make it much easier to understand the axiomatization of the ontology.

There is a systematic way to look at each node-edge-node triple in a schema diagram in order to decide on some of the axioms which should be added: Given a node-edge-node triple with nodes A and B and edge R from A to B, as depicted in Figure 1.1, we check all of the following axioms whether they should be included.[2] We list them in natural language, see Figure 1.2 for the formal versions in description logic notation, and Figure 1.3 for the same in Manchester syntax, where we also list our names for these axioms.

1. A is a subClass of B.
2. A and B are disjoint.
3. The domain of R is A.
4. For every B which has an inverse R-filler, this inverse R-filler is in A. In other words, the domain of R, scoped by B, is A.
5. The range of R is B.
6. For every A which has an R-filler, this R-filler is in B. In other words, the range of R, scoped by A, is B.
7. For every A there has to be an R-filler in B.
8. For every B there has to be an inverse R-filler in A.
9. R is functional.

[1] Preliminary results supporting this claim can be found in [Shimizu, 2017].

[2] The OWLAx Protégé plug-in [Sarker et al., 2016] provides a convenient interface for adding these axioms.

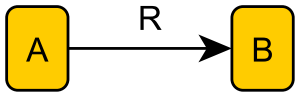

Figure 1.1: Generic node-edge-node schema diagram for explaining systematic axiomatization

1. $A \sqsubseteq B$
2. $A \sqcap B \sqsubseteq \bot$
3. $\exists R.\top \sqsubseteq A$
4. $\exists R.B \sqsubseteq A$
5. $\top \sqsubseteq \forall R.B$
6. $A \sqsubseteq \forall R.B$
7. $A \sqsubseteq R.B$
8. $B \sqsubseteq \exists R^{-}.A$
9. $\top \sqsubseteq \leq 1R.\top$
10. $\top \sqsubseteq \leq 1R.B$
11. $A \sqsubseteq \leq 1R.\top$
12. $A \sqsubseteq \leq 1R.B$
13. $\top \sqsubseteq \leq 1R^{-}.\top$
14. $\top \sqsubseteq \leq 1R^{-}.A$
15. $B \sqsubseteq \leq 1R^{-}.\top$
16. $B \sqsubseteq \leq 1R^{-}.A$
17. $A \sqsubseteq \geq 0R.B$

Figure 1.2: Most common axioms which could be produced from a single edge R between nodes A and B in a schema diagram: description logic notation.

1. A SubClassOf B (subClass)
2. A DisjointWith B (disjointness)
3. R some `owl:Thing` SubClassOf A (domain)
4. R some B SubClassOf A (scoped domain)
5. `owl:Thing` SubClassOf R only B (range)
6. A SubClassOf R only B (scoped range)
7. A SubClassOf R some B (existential)
8. B SubClassOf inverse R some A (inverse existential)
9. `owl:Thing` SubClassOf R max 1 `owl:Thing` (functionality)
10. `owl:Thing` SubClassOf R max 1 B (qualified functionality)
11. A SubClassOf R max 1 `owl:Thing` (scoped functionality)
12. A SubClassOf R max 1 B (qualified scoped functionality)
13. `owl:Thing` SubClassOf inverse R max 1 `owl:Thing` (inverse functionality)
14. `owl:Thing` SubClassOf inverse R max 1 A (inverse qualified functionality)
15. B SubClassOf inverse R max 1 `owl:Thing` (inverse scoped functionality)
16. B SubClassOf inverse R max 1 A (inverse qualified scoped functionality)
17. A SubClassOf R min 0 B (structural tautology)

Figure 1.3: Most common axioms which could be produced from a single edge R between nodes A and B in a schema diagram: Manchester syntax.

10. R has at most one filler in B.
11. For every A there is at most one R-filler.
12. For every A there is at most one R-filler in B.
13. R is inverse functional.
14. R has at most one inverse filler in A.
15. For every B there is at most one inverse R-filler.
16. For every B there is at most one inverse R-filler in A.
17. An A may have an R-filler in B.

Domain and range axoims are items 2–5 in this list. Items 6 and 7 are extistential axioms. Items 8–15 are about variants of functionality and inverse functionality. All axiom types except disjointness and those utilizing inverses also apply to datatype properties.

Structural tautologies are, indeed, tautologies, i.e., they do not carry any formal logical content. How-

ever as argued in [Hitzler and Krisnadhi, 2016] they can help humans to understand the ontology, by indicating *possible* relationships, i.e., relationships intended by the modeler which, however, cannot be cast into non-tautological axioms. We also exhaustively add structural tautologies to essentially capture the structure of the schema diagrams, essentially providing a machine-readable version of the schema diagram via the set of structural tautologies in the OWL file. See [Shimizu et al., 2023] for the importance of schema diagrams for the MOMo process.

Explanations Regarding Schema Diagrams

We utilize schema diagrams to visualize the ontology. In our experience, simple diagrams work best for this purpose. The reader needs to bear in mind, though, that these diagrams are ambiguous and incomplete visualizations of the ontology (or module), as the actual ontology (or module) is constituted by the set of axioms provided.

We use the following visuals in our diagrams:

rectangular box with solid frame and orange fill: a class
rectangual box with dashed frame and blue fill: a module, which is described in more detail elsewhere in the document
rectangular box with dashed frame and purple fill: a set of URIs constituting a controlled vocabulary
oval with solid frame and yellow fill: a data type
arrow with white head and no label: a subClass relationship
arrow with solid tip and label: a relationship (or property) other than a subClass relationship

2 Patterns

We list the individual modules of the ontology, together with their axioms and explanations thereof. Each axiom is listed only once (for now), i.e. some axioms pertaining to a module may be found in the axiom set listed for an earlier listed module. Schema diagrams are provided throughout, but the reader should keep in mind that while schema diagrams are very useful for understanding an ontology [Karima et al., 2017], they are also inherently ambiguous. In the end, it is the *axioms* together with the *documentation* that constitute the ontology.

We would like to note here that, we make use of a domain called *MODSItem*. It is used to reference a resource that may have the MODS top-level elements such as *TitleInfo*, *OriginInfo*, *Identifier*, etc.

2.1 Overview of All Modules

2.1.1 Overview

This section represents all the modules which are part of the ontology.

2.2 Title Info Module

2.2.1 Overview

Title Info Module is primarily used to express all the relevant information regarding the Title of the resource under description. Trivially, it is used to convey the title, Part Number/Name (e.g. *a book title may have multiple parts with different names*). Many of these sub-elements may have relevant Language Attributes. Other than these, Title Info can specify type of the Title (e.g. *abbreviated*, *translated*), Authority (*to dictate the range of values the Title Info can take on*), etc.

2.2.2 Formalization

2.2.2.1 Axioms

$$\top \sqsubseteq \forall \mathsf{hasTitleInfo}.\mathsf{TitleInfo} \tag{1}$$

$$\mathsf{MODSItem} \sqsubseteq \exists \mathsf{hasTitleInfo}.\mathsf{TitleInfo} \tag{2}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasTitleInfo}^{-}.\top \tag{3}$$

$$\mathsf{MODSItem} \sqsubseteq \geq 0 \mathsf{hasTitleInfo}.\mathsf{TitleInfo} \tag{4}$$

$$\exists \mathsf{hasTitle}.\top \sqsubseteq \mathsf{TitleInfo} \tag{5}$$

$$\top \sqsubseteq \forall \mathsf{hasTitle}.\mathsf{Title} \tag{6}$$

$$\mathsf{TitleInfo} \sqsubseteq \exists \mathsf{hasTitle}.\mathsf{Title} \tag{7}$$

$$\mathsf{Title} \sqsubseteq \exists \mathsf{hasTitle}^{-}.\mathsf{TitleInfo} \tag{8}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasTitle}^{-}.\top \tag{9}$$

$$\mathsf{TitleInfo} \sqsubseteq \geq 0 \mathsf{hasTitle}.\mathsf{Title} \tag{10}$$

$$\top \sqsubseteq \forall \mathsf{hasTitleValue}.\mathsf{xsd{:}string} \tag{11}$$

$$\mathsf{Title} \sqsubseteq \exists \mathsf{hasTitleValue}.\mathsf{xsd{:}string} \tag{12}$$

$$\mathsf{Title} \sqsubseteq \geq 0 \mathsf{hasTitleValue}.\mathsf{xsd{:}string} \tag{13}$$

$$\top \sqsubseteq \forall \mathsf{hasLanguageAttributes}.\mathsf{LanguageAttributes} \tag{14}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasLanguageAttributes}.\top \tag{15}$$

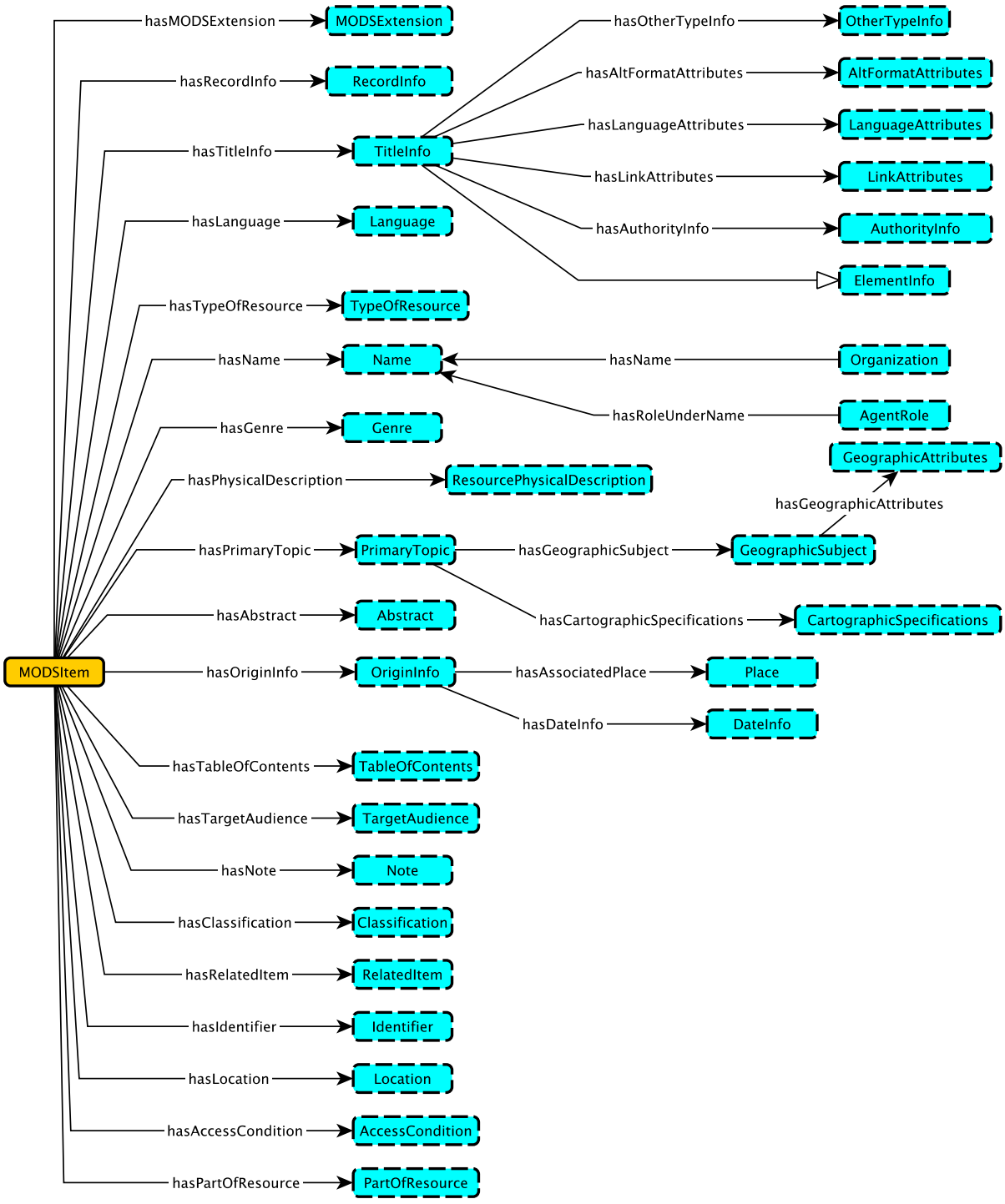

Figure 2.1: Overview of the Modules of the Ontology

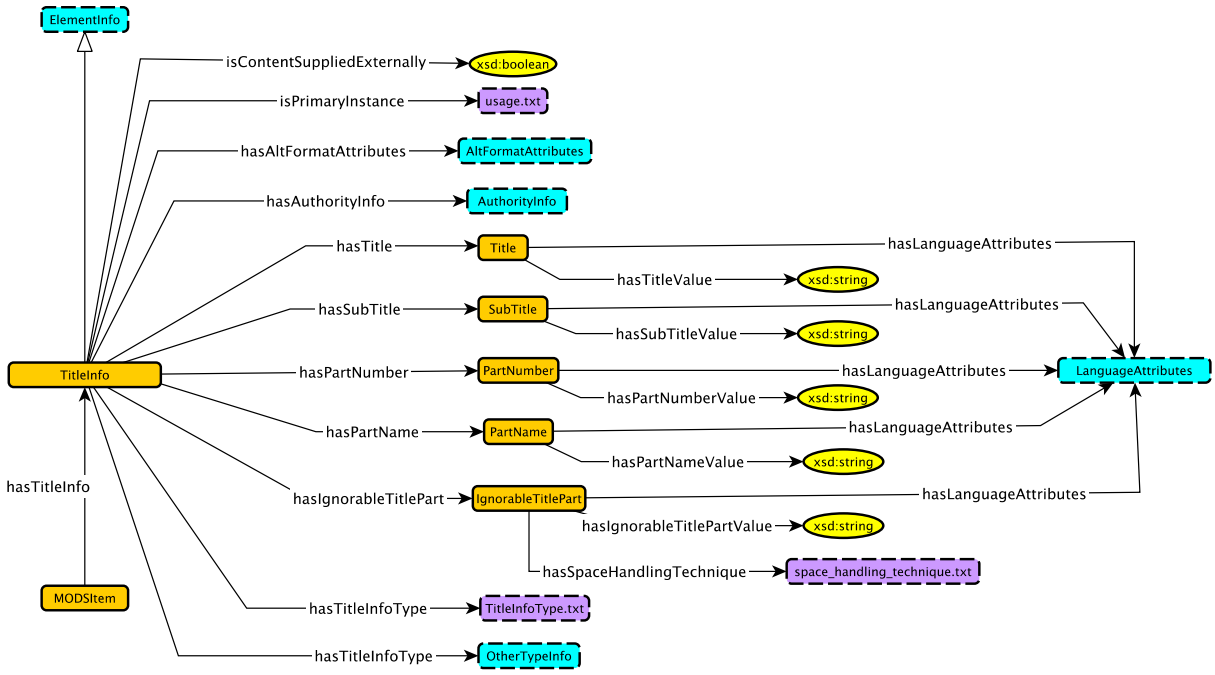

Figure 2.2: The schema diagram for the Title Info Module.

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{16}$$
$$\text{Title} \sqsubseteq \geq 0 \text{hasLanguageAttributes}.\text{LanguageAttributes} \tag{17}$$
$$\exists \text{hasSubTitle}.\top \sqsubseteq \text{TitleInfo} \tag{18}$$
$$\top \sqsubseteq \forall \text{hasSubTitle}.\text{SubTitle} \tag{19}$$
$$\text{SubTitle} \sqsubseteq \exists \text{hasSubTitle}^{-}.\text{TitleInfo} \tag{20}$$
$$\top \sqsubseteq \leq 1 \text{hasSubTitle}^{-}.\top \tag{21}$$
$$\text{TitleInfo} \sqsubseteq \geq 0 \text{hasSubTitle}.\text{SubTitle} \tag{22}$$
$$\top \sqsubseteq \forall \text{hasSubTitleValue}.\text{xsd:string} \tag{23}$$
$$\text{SubTitle} \sqsubseteq \exists \text{hasSubTitleValue}.\text{xsd:string} \tag{24}$$
$$\text{SubTitle} \sqsubseteq \geq 0 \text{hasSubTitleValue}.\text{xsd:string} \tag{25}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes}.\text{LanguageAttributes} \tag{26}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \tag{27}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{28}$$
$$\text{SubTitle} \sqsubseteq \geq 0 \text{hasLanguageAttributes}.\text{LanguageAttributes} \tag{29}$$
$$\exists \text{hasPartNumber}.\top \sqsubseteq \text{TitleInfo} \tag{30}$$
$$\top \sqsubseteq \forall \text{hasPartNumber}.\text{PartNumber} \tag{31}$$
$$\text{PartNumber} \sqsubseteq \exists \text{hasPartNumber}^{-}.\text{TitleInfo} \tag{32}$$
$$\top \sqsubseteq \leq 1 \text{hasPartNumber}^{-}.\top \tag{33}$$
$$\text{TitleInfo} \sqsubseteq \geq 0 \text{hasPartNumber}.\text{PartNumber} \tag{34}$$
$$\top \sqsubseteq \forall \text{hasPartNumberValue}.\text{xsd:string} \tag{35}$$
$$\text{PartNumber} \sqsubseteq \exists \text{hasPartNumberValue}.\text{xsd:string} \tag{36}$$

$$\text{PartNumber} \sqsubseteq \geq 0 \text{hasPartNumberValue.xsd:string} \tag{37}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{38}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \tag{39}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{40}$$
$$\text{PartNumber} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \tag{41}$$
$$\exists \text{hasPartName.}\top \sqsubseteq \text{TitleInfo} \tag{42}$$
$$\top \sqsubseteq \forall \text{hasPartName.PartName} \tag{43}$$
$$\text{PartName} \sqsubseteq \exists \text{hasPartName}^{-}.\text{TitleInfo} \tag{44}$$
$$\top \sqsubseteq \leq 1 \text{hasPartName}^{-}.\top \tag{45}$$
$$\text{TitleInfo} \sqsubseteq \geq 0 \text{hasPartName.PartName} \tag{46}$$
$$\top \sqsubseteq \forall \text{hasPartNameValue.xsd:string} \tag{47}$$
$$\text{PartName} \sqsubseteq \exists \text{hasPartNameValue.xsd:string} \tag{48}$$
$$\text{PartName} \sqsubseteq \geq 0 \text{hasPartNameValue.xsd:string} \tag{49}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{50}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \tag{51}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{52}$$
$$\text{PartName} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \tag{53}$$
$$\exists \text{hasIgnorableTitlePart.}\top \sqsubseteq \text{TitleInfo} \tag{54}$$
$$\top \sqsubseteq \forall \text{hasIgnorableTitlePart.IgnorableTitlePart} \tag{55}$$
$$\text{IgnorableTitlePart} \sqsubseteq \exists \text{hasIgnorableTitlePart}^{-}.\text{TitleInfo} \tag{56}$$
$$\top \sqsubseteq \leq 1 \text{hasIgnorableTitlePart}^{-}.\top \tag{57}$$
$$\text{TitleInfo} \sqsubseteq \geq 0 \text{hasIgnorableTitlePart.NonSort} \tag{58}$$
$$\top \sqsubseteq \forall \text{hasIgnorableTitlePartValue.xsd:string} \tag{59}$$
$$\text{IgnorableTitlePart} \sqsubseteq \exists \text{hasIgnorableTitlePartValue.xsd:string} \tag{60}$$
$$\text{IgnorableTitlePart} \sqsubseteq \geq 0 \text{hasIgnorableTitlePartValue.xsd:string} \tag{61}$$
$$\top \sqsubseteq \forall \text{hasSpaceHandlingTechnique.SpaceHandlingTechnique.txt} \tag{62}$$
$$\text{IgnorableTitlePart} \sqsubseteq \exists \text{hasSpaceHandlingTechnique.SpaceHandlingTechnique.txt} \tag{63}$$
$$\text{IgnorableTitlePart} \sqsubseteq \geq 0 \text{hasSpaceHandlingTechnique.SpaceHandlingTechnique.txt} \tag{64}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{65}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \tag{66}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{67}$$
$$\text{IgnorableTitlePart} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \tag{68}$$
$$\top \sqsubseteq \forall \text{isContentSuppliedExternally.xsd:boolean} \tag{69}$$
$$\text{TitleInfo} \sqsubseteq \geq 0 \text{isContentSuppliedExternally.xsd:boolean} \tag{70}$$
$$\top \sqsubseteq \forall \text{isPrimaryInstance.Usage.txt} \tag{71}$$
$$\text{TitleInfo} \sqsubseteq \geq 0 \text{isPrimaryInstance.Usage.txt} \tag{72}$$
$$\top \sqsubseteq \forall \text{hasAltFormatAttributes.AltFormatAttributes} \tag{73}$$
$$\top \sqsubseteq \leq 1 \text{hasAltFormatAttributes.}\top \tag{74}$$
$$\top \sqsubseteq \leq 1 \text{hasAltFormatAttributes}^{-}.\top \tag{75}$$
$$\text{TitleInfo} \sqsubseteq \geq 0 \text{hasAltFormatAttributes.AltFormatAttributes} \tag{76}$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \tag{77}$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo.}\top \tag{78}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasAuthorityInfo}^{-}.\top \quad (79)$$

$$\mathsf{TitleInfo} \sqsubseteq \geq 0 \mathsf{hasAuthorityInfo}.\mathsf{AuthorityInfo} \quad (80)$$

$$\top \sqsubseteq \forall \mathsf{hasTitleInfoType}.(\mathsf{TitleInfoType.txt} \sqcup \mathsf{OtherTypeInfo}) \quad (81)$$

$$\mathsf{TitleInfoType.txt} \sqsubseteq \exists \mathsf{hasTitleInfoType}^{-}.\mathsf{TitleInfo} \quad (82)$$

$$\mathsf{TitleInfo} \sqsubseteq \geq 0 \mathsf{hasTitleInfoType}.\mathsf{TitleInfoType.txt} \quad (83)$$

$$\mathsf{OtherTypeInfo} \sqsubseteq \exists \mathsf{hasTitleInfoType}^{-}.\mathsf{TitleInfo} \quad (84)$$

$$\mathsf{TitleInfo} \sqsubseteq \geq 0 \mathsf{hasTitleInfoType}.\mathsf{OtherTypeInfo} \quad (85)$$

$$\mathsf{TitleInfo} \sqsubseteq \mathsf{ElementInfo} \quad (86)$$

2.2.2.2 Explanations

1. Range
2. Existential
3. Inverse Functionality
4. Structural Tautology
5. Domain
6. Range
7. Existential
8. Inverse Existential
9. Inverse Functionality
10. Structural Tautology
11. Range
12. Existential
13. Structural Tautology
14. Range
15. Functionality
16. Inverse Functionality
17. Structural Tautology
18. Domain
19. Range
20. Inverse Existential
21. Inverse Functionality
22. Structural Tautology
23. Range
24. Existential
25. Structural Tautology
26. Range
27. Functionality
28. Inverse Functionality
29. Structural Tautology
30. Domain
31. Range
32. Inverse Existential
33. Inverse Functionality
34. Structural Tautology
35. Range
36. Existential
37. Structural Tautology
38. Range
39. Functionality
40. Inverse Functionality
41. Structural Tautology
42. Domain
43. Range
44. Inverse Existential
45. Inverse Functionality
46. Structural Tautology
47. Range
48. Existential
49. Structural Tautology
50. Range
51. Functionality
52. Inverse Functionality
53. Structural Tautology
54. Domain
55. Range
56. Inverse Existential
57. Inverse Functionality
58. Structural Tautology
59. Range
60. Existential
61. Structural Tautology
62. Range
63. Existential
64. Structural Tautology
65. Range
66. Functionality
67. Inverse Functionality
68. Structural Tautology
69. Range
70. Structural Tautology
71. Range
72. Structural Tautology
73. Range
74. Functionality
75. Inverse Functionality
76. Structural Tautology
77. Range
78. Functionality
79. Inverse Functionality
80. Structural Tautology
81. Range
82. Inverse Existential
83. Structural Tautology
84. Inverse Existential
85. Structural Tautology
86. TitleInfo is a sub-class of ElementInfo

2.3 Name Module

2.3.1 Overview

Name module is used to represent names of person, organization, or conference associated with the resource. There can be multiple names associated with a resource. Detailed information such as name part (First Name, Middle Name, Last Name), different display forms can also be specified.

Figure 2.3: The schema diagram for the Name Module.

2.3.2 Formalization

2.3.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasAssociatedName}.\text{Name} \tag{1}$$

$$\top \sqsubseteq \leq 1 \text{hasAssociatedName}^{-}.\top \tag{2}$$

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasAssociatedName}.\text{Name} \tag{3}$$

$$\top \sqsubseteq \forall \text{hasAssociatedPrimaryName}.\text{Name} \tag{4}$$

$$\top \sqsubseteq \leq 1 \text{hasAssociatedPrimaryName}.\top \tag{5}$$

$$\top \sqsubseteq \leq 1 \text{hasAssociatedPrimaryName}^{-}.\top \tag{6}$$

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasAssociatedPrimaryName.Name} \quad (7)$$
$$\exists \text{hasNamePart.}\top \sqsubseteq \text{Name} \quad (8)$$
$$\top \sqsubseteq \forall \text{hasNamePart.NamePart} \quad (9)$$
$$\text{Name} \sqsubseteq \exists \text{hasNamePart.NamePart} \quad (10)$$
$$\text{NamePart} \sqsubseteq \exists \text{hasNamePart}^{-}\text{.Name} \quad (11)$$
$$\top \sqsubseteq \leq 1 \text{hasNamePart}^{-}.\top \quad (12)$$
$$\text{Name} \sqsubseteq \geq 0 \text{hasNamePart.NamePart} \quad (13)$$
$$\top \sqsubseteq \forall \text{hasNamePartValue.xsd:string} \quad (14)$$
$$\text{NamePart} \sqsubseteq \exists \text{hasNamePartValue.xsd:string} \quad (15)$$
$$\text{NamePart} \sqsubseteq \geq 0 \text{hasNamePartValue.xsd:string} \quad (16)$$
$$\top \sqsubseteq \forall \text{hasNamePartType.NamePartType.txt} \quad (17)$$
$$\text{NamePart} \sqsubseteq \geq 0 \text{hasNamePartType.NamePartType.txt} \quad (18)$$
$$\exists \text{hasNameIdentifier.}\top \sqsubseteq \text{Name} \quad (19)$$
$$\top \sqsubseteq \forall \text{hasNameIdentifier.NameIdentifier} \quad (20)$$
$$\text{NameIdentifier} \sqsubseteq \exists \text{hasNameIdentifier}^{-}\text{.Name} \quad (21)$$
$$\top \sqsubseteq \leq 1 \text{hasNameIdentifier}^{-}.\top \quad (22)$$
$$\text{Name} \sqsubseteq \geq 0 \text{hasNameIdentifier.NameIdentifier} \quad (23)$$
$$\exists \text{hasDisplayForm.}\top \sqsubseteq \text{Name} \quad (24)$$
$$\top \sqsubseteq \forall \text{hasDisplayForm.DisplayForm} \quad (25)$$
$$\text{DisplayForm} \sqsubseteq \exists \text{hasDisplayForm}^{-}\text{.Name} \quad (26)$$
$$\top \sqsubseteq \leq 1 \text{hasDisplayForm.}\top \quad (27)$$
$$\top \sqsubseteq \leq 1 \text{hasDisplayForm}^{-}.\top \quad (28)$$
$$\text{Name} \sqsubseteq \geq 0 \text{hasDisplayForm.DisplayForm} \quad (29)$$
$$\top \sqsubseteq \forall \text{hasDisplayFormValue.xsd:string} \quad (30)$$
$$\text{DisplayForm} \sqsubseteq \exists \text{hasDisplayFormValue.xsd:string} \quad (31)$$
$$\text{DisplayForm} \sqsubseteq \geq 0 \text{hasDisplayFormValue.xsd:string} \quad (32)$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (33)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \quad (34)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (35)$$
$$\text{DisplayForm} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (36)$$
$$\top \sqsubseteq \forall \text{hasDescription.Description} \quad (37)$$
$$\top \sqsubseteq \leq 1 \text{hasDescription}^{-}.\top \quad (38)$$
$$\text{Name} \sqsubseteq \geq 0 \text{hasDescription.Description} \quad (39)$$
$$\top \sqsubseteq \forall \text{hasDescriptionValue.xsd:string} \quad (40)$$
$$\text{Description} \sqsubseteq \exists \text{hasDescriptionValue.xsd:string} \quad (41)$$
$$\text{Description} \sqsubseteq \geq 0 \text{hasDescriptionValue.xsd:string} \quad (42)$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (43)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \quad (44)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (45)$$
$$\text{Description} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (46)$$
$$\top \sqsubseteq \forall \text{hasEtal.Etal} \quad (47)$$
$$\text{Etal} \sqsubseteq \exists \text{hasEtal}^{-}\text{.Name} \quad (48)$$

$$\top \sqsubseteq \leq 1 \text{hasEtal}^{-}.\top \quad (49)$$
$$\text{Name} \sqsubseteq \geq 0 \text{hasEtal.Etal} \quad (50)$$
$$\top \sqsubseteq \forall \text{hasEtalValue.xsd:string} \quad (51)$$
$$\text{Etal} \sqsubseteq \exists \text{hasEtalValue.xsd:string} \quad (52)$$
$$\text{Etal} \sqsubseteq \geq 0 \text{hasEtalValue.xsd:string} \quad (53)$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (54)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \quad (55)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (56)$$
$$\text{Etal} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (57)$$
$$\top \sqsubseteq \forall \text{hasNameType.NameType.txt} \quad (58)$$
$$\text{Name} \sqsubseteq \geq 0 \text{hasNameType.NameType.txt} \quad (59)$$
$$\top \sqsubseteq \forall \text{isPrimaryInstance.Usage.txt} \quad (60)$$
$$\text{Name} \sqsubseteq \geq 0 \text{isPrimaryInstance.Usage.txt} \quad (61)$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \quad (62)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo.}\top \quad (63)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \quad (64)$$
$$\text{Name} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \quad (65)$$
$$\top \sqsubseteq \forall \text{hasName.Name} \quad (66)$$
$$\text{Organization} \sqsubseteq \exists \text{hasName.Name} \quad (67)$$
$$\top \sqsubseteq \leq 1 \text{hasName.}\top \quad (68)$$
$$\top \sqsubseteq \leq 1 \text{hasName}^{-}.\top \quad (69)$$
$$\text{Organization} \sqsubseteq \geq 0 \text{hasName.Name} \quad (70)$$
$$\top \sqsubseteq \forall \text{hasLinkAttributes.LinkAttributes} \quad (71)$$
$$\top \sqsubseteq \leq 1 \text{hasLinkAttributes.}\top \quad (72)$$
$$\top \sqsubseteq \leq 1 \text{hasLinkAttributes}^{-}.\top \quad (73)$$
$$\text{Organization} \sqsubseteq \geq 0 \text{hasLinkAttributes.LinkAttributes} \quad (74)$$
$$\top \sqsubseteq \forall \text{providesAgentRole.AgentRole} \quad (75)$$
$$\top \sqsubseteq \leq 1 \text{providesAgentRole}^{-}.\top \quad (76)$$
$$\text{Organization} \sqsubseteq \geq 0 \text{providesAgentRole.AgentRole} \quad (77)$$
$$\exists \text{hasRoleUnderName.Name} \sqsubseteq \text{AgentRole} \quad (78)$$
$$\top \sqsubseteq \forall \text{hasRoleUnderName.Name} \quad (79)$$
$$\text{AgentRole} \sqsubseteq \geq 0 \text{hasRoleUnderName.Name} \quad (80)$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (81)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \quad (82)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (83)$$
$$\text{AgentRole} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (84)$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \quad (85)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo.}\top \quad (86)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \quad (87)$$
$$\text{AgentRole} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \quad (88)$$
$$\top \sqsubseteq \forall \text{hasRoleType.RoleType.txt} \quad (89)$$
$$\text{AgentRole} \sqsubseteq \geq 0 \text{hasRoleType.RoleType.txt} \quad (90)$$

$$\mathsf{NamePart} \sqsubseteq \mathsf{ElementInfo} \tag{91}$$
$$\mathsf{NamePart} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasID}.\top) \tag{92}$$
$$\mathsf{NamePart} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasIDRef}.\top) \tag{93}$$
$$\mathsf{NamePart} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasXlink}.\top) \tag{94}$$
$$\mathsf{NamePart} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasNameTitleGroup}.\top) \tag{95}$$
$$\mathsf{NameIdentifier} \sqsubseteq \mathsf{Identifier} \tag{96}$$
$$\mathsf{Name} \sqsubseteq \mathsf{ElementInfo} \tag{97}$$

2.3.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Functionality
6. Inverse Functionality
7. Structural Tautology
8. Domain
9. Range
10. Existential
11. Inverse Existential
12. Inverse Functionality
13. Structural Tautology
14. Range
15. Existential
16. Structural Tautology
17. Range
18. Structural Tautology
19. Domain
20. Range
21. Inverse Existential
22. Inverse Functionality
23. Structural Tautology
24. Domain
25. Range
26. Inverse Existential
27. Functionality
28. Inverse Functionality
29. Structural Tautology
30. Range
31. Existential
32. Structural Tautology
33. Range
34. Functionality
35. Inverse Functionality
36. Structural Tautology
37. Range
38. Inverse Functionality
39. Structural Tautology
40. Range
41. Existential
42. Structural Tautology
43. Range
44. Functionality
45. Inverse Functionality
46. Structural Tautology
47. Range
48. Inverse Existential
49. Inverse Functionality
50. Structural Tautology
51. Range
52. Existential
53. Structural Tautology
54. Range
55. Functionality
56. Inverse Functionality
57. Structural Tautology
58. Range
59. Structural Tautology
60. Range
61. Structural Tautology
62. Range
63. Functionality
64. Inverse Functionality
65. Structural Tautology
66. Range
67. Existential
68. Functionality
69. Inverse Functionality
70. Structural Tautology
71. Range
72. Functionality
73. Inverse Functionality
74. Structural Tautology
75. Range
76. Inverse Functionality
77. Structural Tautology
78. Scoped Domain
79. Range
80. Structural Tautology
81. Range
82. Functionality
83. Inverse Functionality
84. Structural Tautology
85. Range
86. Functionality
87. Inverse Functionality

88. Structural Tautology
89. Range
90. Structural Tautology
91. NamePart is a sub-class of ElementInfo
92. NamePart does not have a hasLinkAttributes property which has a hasID property
93. NamePart does not have a hasLinkAttributes property which has a hasIDRef property
94. NamePart does not have a hasLinkAttributes property which has a hasXlink property
95. NamePart does not have a hasLinkAttributes property which has a hasNameTitleGroup property
96. NameIdentifier is a sub-class of Identifier
97. Name is a sub-class of ElementInfo

2.4 Classification Module

2.4.1 Overview

Classification Module is intended to take on values that uniquely refers to a scheme of coding and organizing resources which help to indicate the subject for the resource under description. There can be an Authority associated to dictate what values are to be taken on by the Classification module as well as a specification of what method is used to generate the unique classification value.

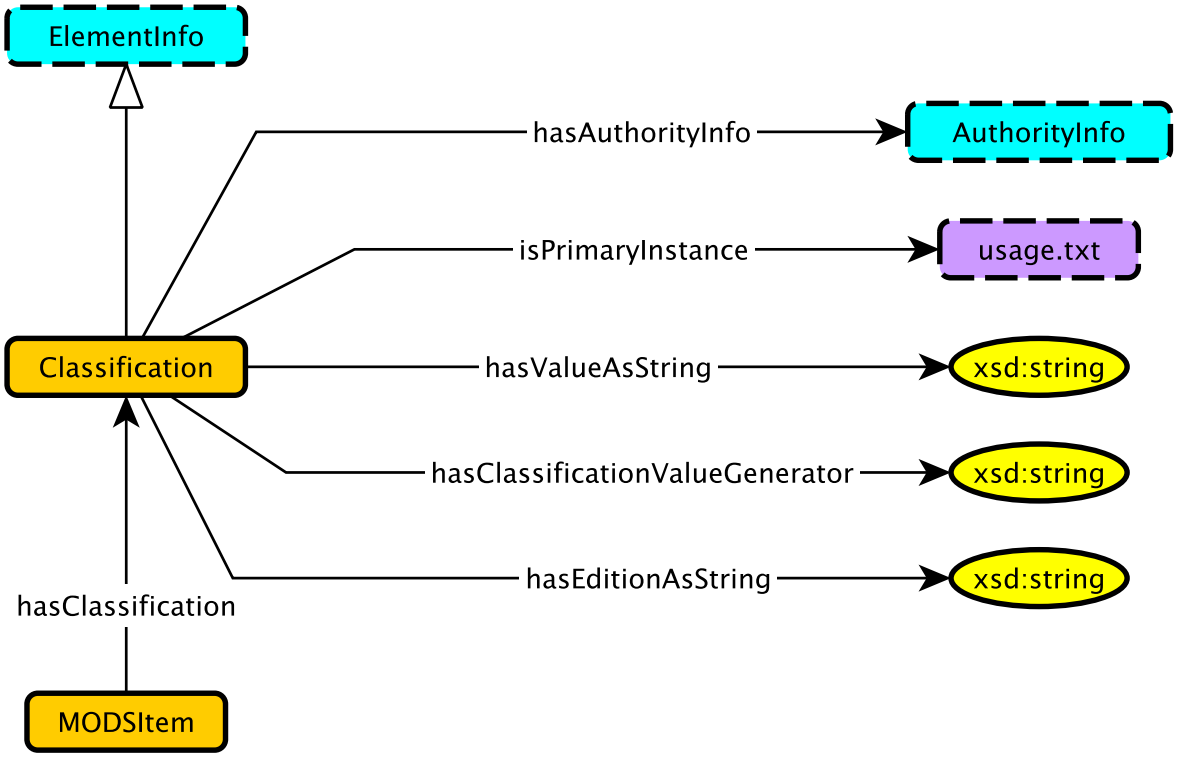

Figure 2.4: The schema diagram for the Classification.

2.4.2 Formalization

2.4.2.1 Axioms

$$\top \sqsubseteq \forall \mathsf{hasClassfication}.\mathsf{Classification} \tag{1}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasClassfication}^{-}.\top \tag{2}$$

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasClassfication.Classification} \quad (3)$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \quad (4)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo.}\top \quad (5)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \quad (6)$$
$$\text{Classification} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \quad (7)$$
$$\top \sqsubseteq \forall \text{isPrimaryInstance.Usage.txt} \quad (8)$$
$$\text{Classification} \sqsubseteq \geq 0 \text{isPrimaryInstance.Usage.txt} \quad (9)$$
$$\top \sqsubseteq \forall \text{hasEditionAsString.xsd:string} \quad (10)$$
$$\text{Classification} \sqsubseteq \geq 0 \text{hasEditionAsString.xsd:string} \quad (11)$$
$$\top \sqsubseteq \forall \text{hasValueAsString.xsd:string} \quad (12)$$
$$\text{Classification} \sqsubseteq \exists \text{hasValueAsString.xsd:string} \quad (13)$$
$$\text{Classification} \sqsubseteq \geq 0 \text{hasValueAsString.xsd:string} \quad (14)$$
$$\top \sqsubseteq \forall \text{hasClassificationValueGenerator.xsd:string} \quad (15)$$
$$\text{Classification} \sqsubseteq \geq 0 \text{hasClassificationValueGenerator.xsd:string} \quad (16)$$
$$\text{Classification} \sqsubseteq \text{ElementInfo} \quad (17)$$
$$\text{Classification} \sqsubseteq \neg(\exists \text{hasLinkAttributes.} \exists \text{hasXlink.} \top) \quad (18)$$
$$\text{Classification} \sqsubseteq \neg(\exists \text{hasLinkAttributes.} \exists \text{hasNameTitleGroup.} \top) \quad (19)$$

2.4.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Functionality
6. Inverse Functionality
7. Structural Tautology
8. Range
9. Structural Tautology
10. Range
11. Structural Tautology
12. Range
13. Existential
14. Structural Tautology
15. Range
16. Structural Tautology
17. Classification is a sub-class of ElementInfo
18. Classification does not have a hasLinkAttributes property which has a hasXlink property.
19. Classification does not have a hasLinkAttributes property which has a hasNameTitleGroup property.

2.5 Abstract Module

2.5.1 Overview

Abstract Module is intended to outline a summary of the resource (e.g. if the resource under description is a publication, then it refers to the Abstract section of the publication). Additionally, it may specify the Language Attributes, Type, and any other Alternative Format available within the resource.

2.5.2 Formalization

2.5.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasAbstract.Abstract} \quad (1)$$
$$\top \sqsubseteq \leq 1 \text{hasAbstract}^{-}.\top \quad (2)$$
$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasAbstract.Abstract} \quad (3)$$
$$\top \sqsubseteq \forall \text{hasAlternativeFormatAttributes.AltFormatAttributes} \quad (4)$$

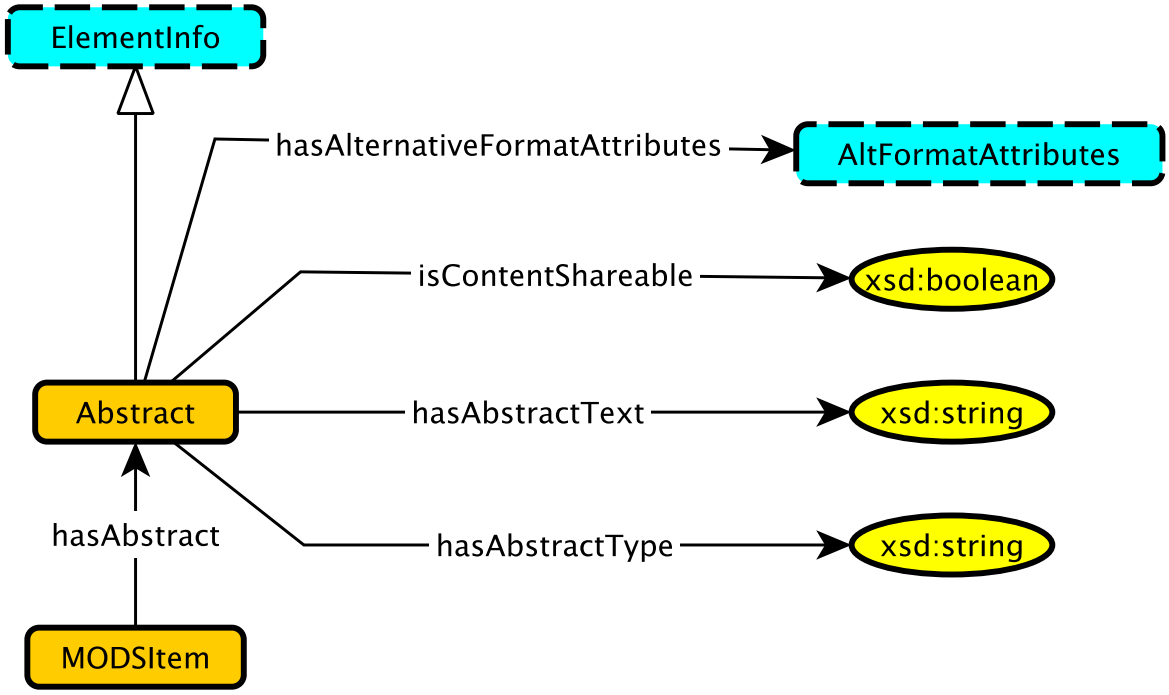

Figure 2.5: The schema diagram for the Abstract Module.

$$\top \sqsubseteq \leq 1 \text{hasAlternativeFormatAttributes}.\top \quad (5)$$

$$\top \sqsubseteq \leq 1 \text{hasAlternativeFormatAttributes}^{-}.\top \quad (6)$$

$$\text{Abstract} \sqsubseteq \geq 0 \text{hasAlternativeFormatAttributes}.\text{AltFormatAttributes} \quad (7)$$

$$\top \sqsubseteq \forall \text{isContentShareable}.\text{xsd:boolean} \quad (8)$$

$$\text{Abstract} \sqsubseteq \geq 0 \text{isContentShareable}.\text{xsd:boolean} \quad (9)$$

$$\top \sqsubseteq \forall \text{hasAbstractText}.\text{xsd:string} \quad (10)$$

$$\text{Abstract} \sqsubseteq \exists \text{hasAbstractText}.\text{xsd:string} \quad (11)$$

$$\text{Abstract} \sqsubseteq \geq 0 \text{hasAbstractText}.\text{xsd:string} \quad (12)$$

$$\top \sqsubseteq \forall \text{hasAbstractType}.\text{xsd:string} \quad (13)$$

$$\text{Abstract} \sqsubseteq \geq 0 \text{hasAbstractType}.\text{xsd:string} \quad (14)$$

$$\text{Abstract} \sqsubseteq \text{ElementInfo} \quad (15)$$

$$\text{Abstract} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.\top) \quad (16)$$

2.5.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Functionality
6. Inverse Functionality
7. Structural Tautology
8. Range
9. Structural Tautology
10. Range
11. Existential
12. Structural Tautology
13. Range
14. Structural Tautology

15. Abstract is a sub-class of ElementInfo
16. Abstract does not have a hasLinkAttributes property which has a hasNameTitleGroup property.

2.6 Note Module

2.6.1 Overview

This module is intended to outline any general textual information relating to the resource.

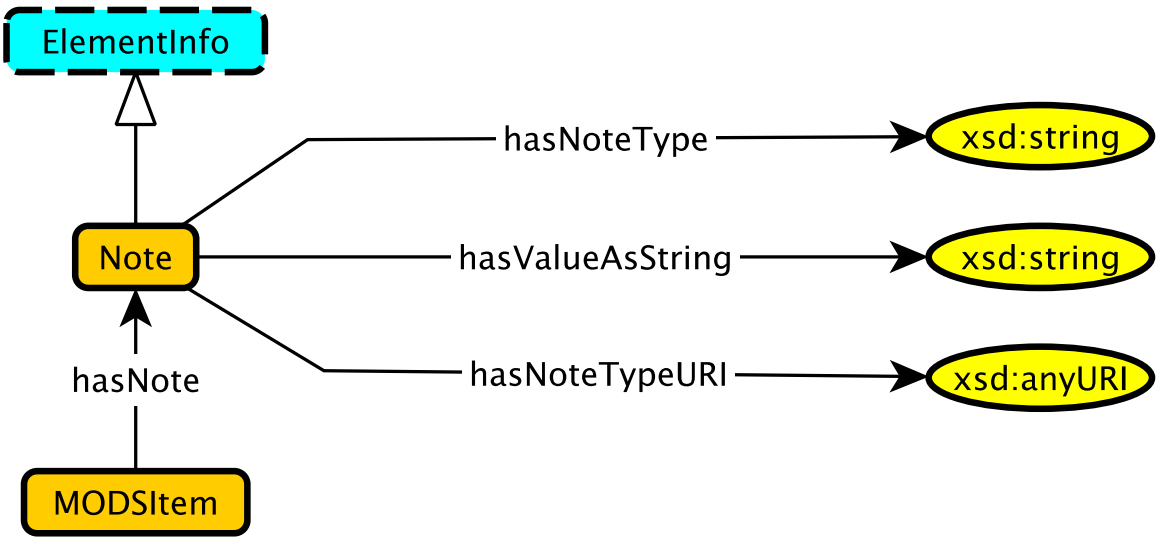

Figure 2.6: The schema diagram for the Note Module.

2.6.2 Formalization

2.6.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasNote.Note} \tag{1}$$
$$\top \sqsubseteq \leq 1 \text{hasNote}^{-}.\top \tag{2}$$
$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasNote.Note} \tag{3}$$
$$\top \sqsubseteq \forall \text{hasNoteType.xsd:string} \tag{4}$$
$$\text{Note} \sqsubseteq \geq 0 \text{hasNoteType.xsd:string} \tag{5}$$
$$\top \sqsubseteq \forall \text{hasValueAsString.xsd:string} \tag{6}$$
$$\text{Note} \sqsubseteq \exists \text{hasValueAsString.xsd:string} \tag{7}$$
$$\text{Note} \sqsubseteq \geq 0 \text{hasValueAsString.xsd:string} \tag{8}$$
$$\top \sqsubseteq \forall \text{hasNoteTypeURI.xsd:anyURI} \tag{9}$$
$$\text{Note} \sqsubseteq \geq 0 \text{hasNoteTypeURI.xsd:anyURI} \tag{10}$$
$$\text{Note} \sqsubseteq \text{ElementInfo} \tag{11}$$
$$\text{Note} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.\top) \tag{12}$$

2.6.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Structural Tautology
6. Range
7. Existential
8. Structural Tautology
9. Range
10. Structural Tautology
11. Note is a sub-class of ElementInfo
12. Note does not have a hasLinkAttributes property which has a hasNameTitleGroup property.

2.7 Target Audience Module

2.7.1 Overview

Target Audience Module is used to specify the intellectual level of the audience for which the resource is intended. The value (e.g. *adolescent*, *adult*, *kindergarten*) it takes on is dictated by an Authority.

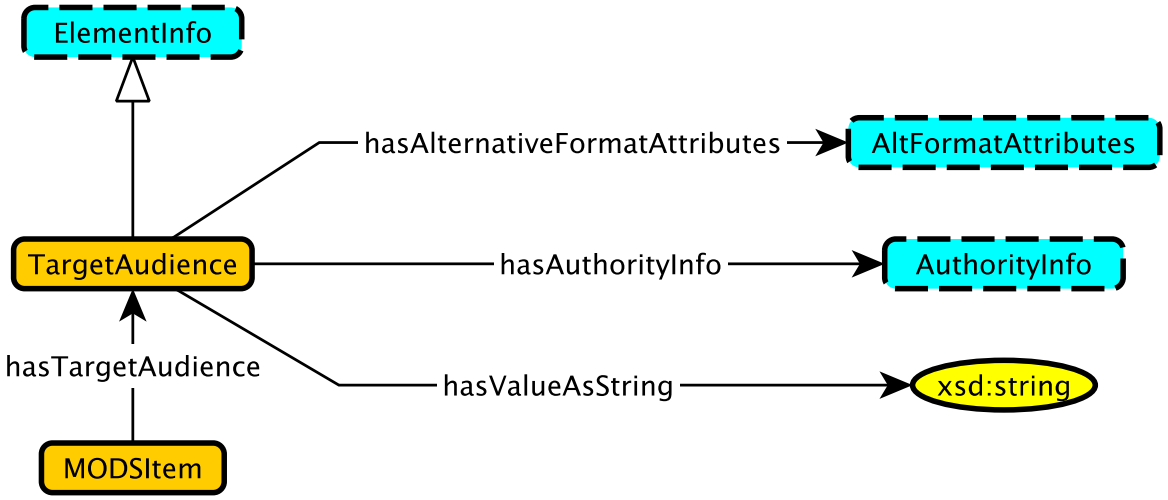

Figure 2.7: The schema diagram for the Target Audience Module.

2.7.2 Formalization

2.7.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasTargetAudience}.\text{TargetAudience} \quad (1)$$

$$\top \sqsubseteq \leq 1 \text{hasTargetAudience}^{-}.\top \quad (2)$$

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasTargetAudience}.\text{TargetAudience} \quad (3)$$

$$\top \sqsubseteq \forall \text{hasAlternativeFormatAttributes}.\text{AltFormatAttributes} \quad (4)$$

$$\top \sqsubseteq \leq 1 \text{hasAlternativeFormatAttributes}.\top \quad (5)$$

$$\top \sqsubseteq \leq 1 \text{hasAlternativeFormatAttributes}^{-}.\top \quad (6)$$

$$\text{TargetAudience} \sqsubseteq \geq 0 \text{hasAlternativeFormatAttributes}.\text{AltFormatAttributes} \quad (7)$$

$$\top \sqsubseteq \forall \text{hasAuthorityInfo}.\text{AuthorityInfo} \quad (8)$$

$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}.\top \quad (9)$$

$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \quad (10)$$

$$\text{TargetAudience} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \quad (11)$$

$$\top \sqsubseteq \forall \text{hasValueAsString.xsd:string} \quad (12)$$

$$\text{TargetAudience} \sqsubseteq \exists \text{hasValueAsString.xsd:string} \quad (13)$$

$$\text{TargetAudience} \sqsubseteq \geq 0 \text{hasValueAsString.xsd:string} \quad (14)$$

$$\text{TargetAudience} \sqsubseteq \text{ElementInfo} \quad (15)$$

$$\text{TargetAudience} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasXlink}.\top) \quad (16)$$

$$\text{TargetAudience} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.\top) \quad (17)$$

2.7.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Functionality
6. Inverse Functionality
7. Structural Tautology
8. Range
9. Functionality
10. Inverse Functionality
11. Structural Tautology
12. Range
13. Existential
14. Structural Tautology
15. TargetAudience is a sub-class of ElementInfo
16. TargetAudience does not have a hasLinkAttributes property which has a hasXlink property.
17. TargetAudience does not have a hasLinkAttributes property which has a hasNameTitleGroup property.

2.8 MODS Extension Module

2.8.1 Overview

To allow elements that are not part of MODS description, the MODS Extension Module is used - outlining the additional information as string.

2.8.2 Formalization

2.8.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasMODSExtension.MODSExtension} \quad (1)$$

$$\top \sqsubseteq \leq 1 \text{hasMODSExtension}^{-}.\top \quad (2)$$

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasMODSExtension.MODSExtension} \quad (3)$$

$$\top \sqsubseteq \forall \text{hasTypeOfMODSExtension.xsd:string} \quad (4)$$

$$\text{MODSExtension} \sqsubseteq \geq 0 \text{hasTypeOfMODSExtension.xsd:string} \quad (5)$$

$$\top \sqsubseteq \forall \text{hasMODSExtensionInfo.xsd:string} \quad (6)$$

$$\text{MODSExtension} \sqsubseteq \exists \text{hasMODSExtensionInfo.xsd:string} \quad (7)$$

$$\text{MODSExtension} \sqsubseteq \geq 0 \text{hasMODSExtensionInfo.xsd:string} \quad (8)$$

$$\text{MODSExtension} \sqsubseteq \text{ElementInfo} \quad (9)$$

$$\text{MODSExtension} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasXlink}.\top) \quad (10)$$

$$\text{MODSExtension} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasAltRepGroup}.\top) \quad (11)$$

$$\text{MODSExtension} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.\top) \quad (12)$$

$$\text{MODSExtension} \sqsubseteq \neg(\exists \text{hasLanguageAttributes}.\top) \quad (13)$$

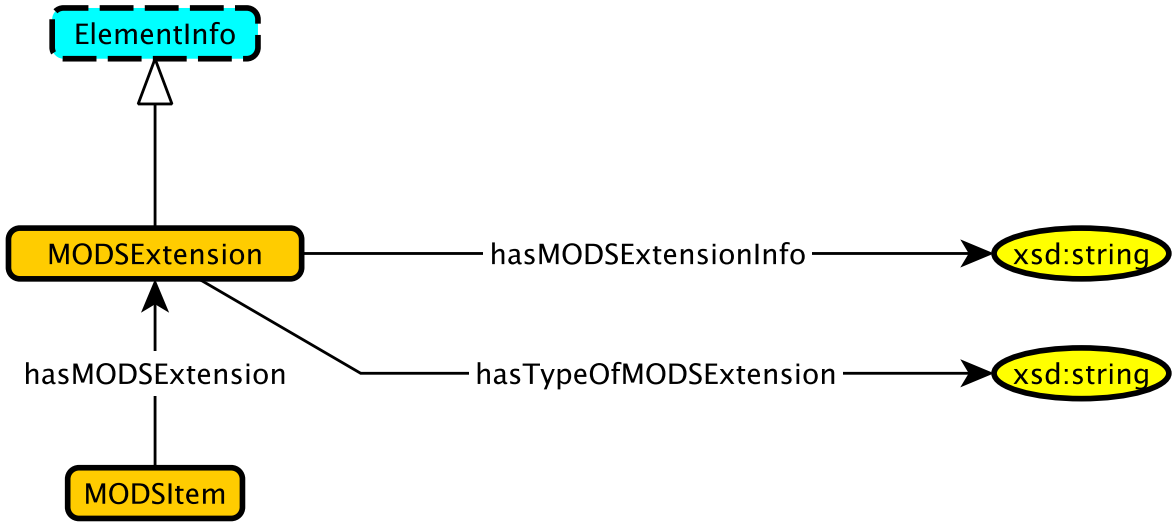

Figure 2.8: The schema diagram for the MODS Extension Module.

2.8.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Structural Tautology
6. Range
7. Existential
8. Structural Tautology
9. MODSExtension is a sub-class of ElementInfo
10. MODSExtension does not have a hasLinkAttributes property which has a hasXlink property.
11. MODSExtension does not have a hasLinkAttributes property which has a hasAltRepGroup property.
12. MODSExtension does not have a hasLinkAttributes property which has a hasNameTitleGroup property.
13. MODSExtension does not have a hasLanguageAttribute property.

2.9 Location Module

2.9.1 Overview

Location module is used to specify Physical and/or Electronic location of the resource under description. Sub-elements such as Physical Location, Shelf Locator is used to specify the institution/repository and shelfmark that indicates the location identifier of a copy. Holding Simple is used to convey additional information such as a specific tangible instance of a resource, physical form of resource, URL, etc. If it requires elements outside MODS description, then a property *hasModsExternalCopySpecificInformation* is used to express them as string.

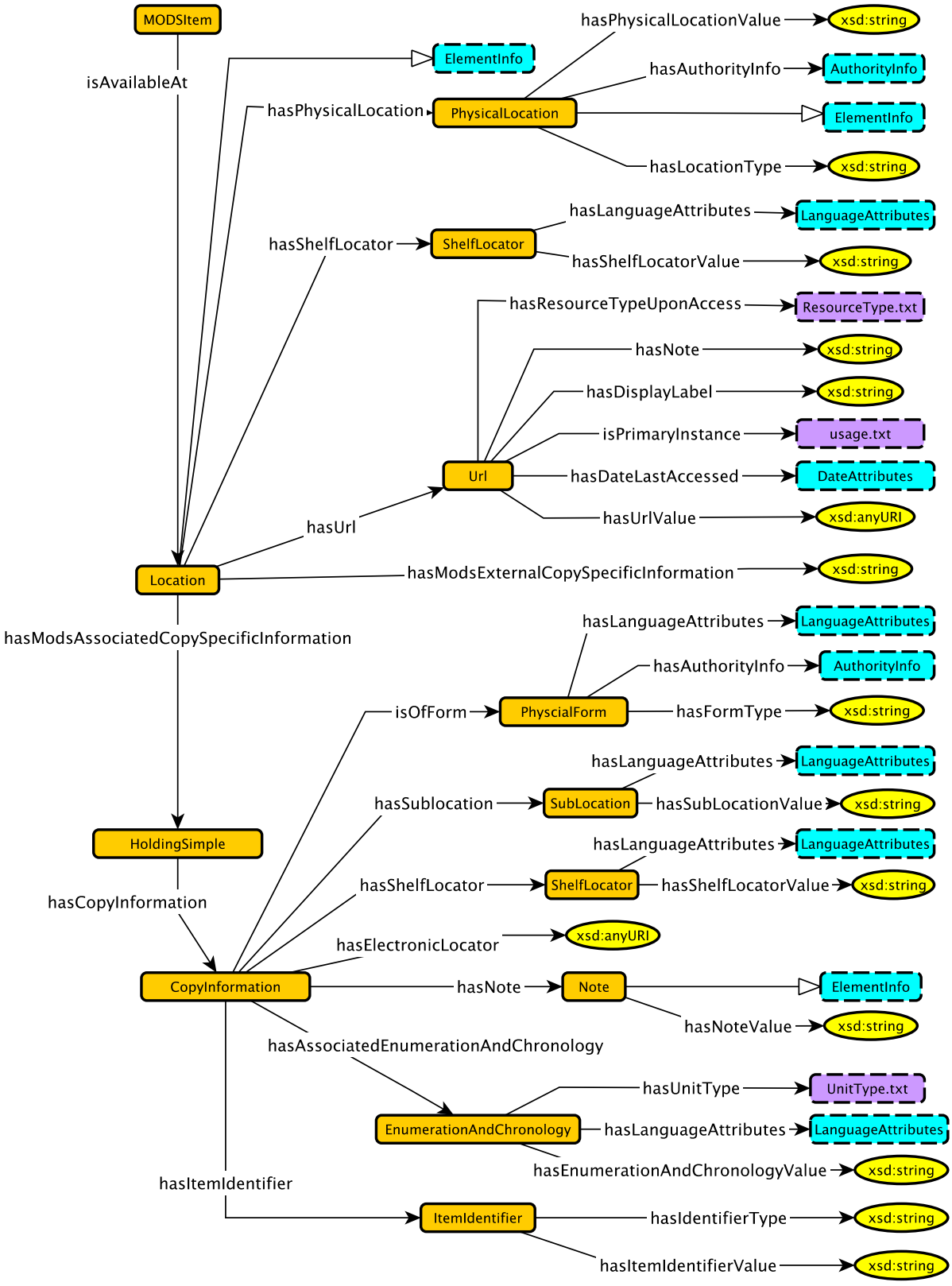

Figure 2.9: The schema diagram for the Location Module.

2.9.2 Formalization

2.9.2.1 Axioms

$$\top \sqsubseteq \forall \text{isAvailableAt.Location} \tag{1}$$

$$\top \sqsubseteq \leq 1 \text{isAvailableAt}^{-}.\top \tag{2}$$

$$\text{MODSItem} \sqsubseteq \geq 0 \text{isAvailableAt.Location} \tag{3}$$

$$\exists \text{hasPhysicalLocation}.\top \sqsubseteq \text{Location} \tag{4}$$

$$\top \sqsubseteq \forall \text{hasPhysicalLocation.PhysicalLocation} \tag{5}$$

$$\text{PhysicalLocation} \sqsubseteq \exists \text{hasPhysicalLocation}^{-}.\text{Location} \tag{6}$$

$$\top \sqsubseteq \leq 1 \text{hasPhysicalLocation}^{-}.\top \tag{7}$$

$$\text{Location} \sqsubseteq \geq 0 \text{hasPhysicalLocation.PhysicalLocation} \tag{8}$$

$$\top \sqsubseteq \forall \text{hasLocationType.xsd:string} \tag{9}$$

$$\text{PhysicalLocation} \sqsubseteq \geq 0 \text{hasLocationType.xsd:string} \tag{10}$$

$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \tag{11}$$

$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}.\top \tag{12}$$

$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \tag{13}$$

$$\text{PhysicalLocation} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \tag{14}$$

$$\top \sqsubseteq \forall \text{hasPhysicalLocationValue.xsd:string} \tag{15}$$

$$\text{PhysicalLocation} \sqsubseteq \exists \text{hasPhysicalLocationValue.xsd:string} \tag{16}$$

$$\text{PhysicalLocation} \sqsubseteq \geq 0 \text{hasPhysicalLocationValue.xsd:string} \tag{17}$$

$$\top \sqsubseteq \forall \text{hasShelfLocator.ShelfLocator} \tag{18}$$

$$\text{ShelfLocator} \sqsubseteq \exists \text{hasShelfLocator}^{-}.\text{Location} \tag{19}$$

$$\top \sqsubseteq \leq 1 \text{hasShelfLocator}^{-}.\top \tag{20}$$

$$\text{Location} \sqsubseteq \geq 0 \text{hasShelfLocator.ShelfLocator} \tag{21}$$

$$\top \sqsubseteq \forall \text{hasShelfLocatorValue.xsd:string} \tag{22}$$

$$\text{ShelfLocator} \sqsubseteq \exists \text{hasShelfLocatorValue.xsd:string} \tag{23}$$

$$\text{ShelfLocator} \sqsubseteq \geq 0 \text{hasShelfLocatorValue.xsd:string} \tag{24}$$

$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{25}$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \tag{26}$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{27}$$

$$\text{ShelfLocator} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \tag{28}$$

$$\top \sqsubseteq \forall \text{hasUrl.Url} \tag{29}$$

$$\text{Url} \sqsubseteq \exists \text{hasUrl}^{-}.\text{Location} \tag{30}$$

$$\top \sqsubseteq \leq 1 \text{hasUrl}^{-}.\top \tag{31}$$

$$\text{Location} \sqsubseteq \geq 0 \text{hasUrl.Url} \tag{32}$$

$$\top \sqsubseteq \forall \text{hasResourceTypeUponAccess.ResourceType.txt} \tag{33}$$

$$\text{Url} \sqsubseteq \geq 0 \text{hasResourceTypeUponAccess.ResourceType.txt} \tag{34}$$

$$\top \sqsubseteq \forall \text{hasNote.xsd:string} \tag{35}$$

$$\text{Url} \sqsubseteq \geq 0 \text{hasNote.xsd:string} \tag{36}$$

$$\top \sqsubseteq \forall \text{hasDiplayLabel.xsd:string} \tag{37}$$

$$\text{Url} \sqsubseteq \geq 0 \text{hasDiplayLabel.xsd:string} \tag{38}$$

$$\top \sqsubseteq \forall \text{isPrimaryInstance.Usage.txt} \tag{39}$$
$$\text{Url} \sqsubseteq \geq 0 \text{isPrimaryInstance.Usage.txt} \tag{40}$$
$$\top \sqsubseteq \forall \text{hasDateLastAccessed.xsd:string} \tag{41}$$
$$\text{Url} \sqsubseteq \geq 0 \text{hasDateLastAccessed.xsd:string} \tag{42}$$
$$\top \sqsubseteq \forall \text{hasUrlValue.xsd:anyURI} \tag{43}$$
$$\text{Url} \sqsubseteq \exists \text{hasUrlValue.xsd:anyURI} \tag{44}$$
$$\text{Url} \sqsubseteq \geq 0 \text{hasUrlValue.xsd:anyURI} \tag{45}$$
$$\top \sqsubseteq \forall \text{hasModsAssociatedCopySpecificInformation.HoldingSimple} \tag{46}$$
$$\text{HoldingSimple} \sqsubseteq \exists \text{hasModsAssociatedCopySpecificInformation}^{-}\text{.Location} \tag{47}$$
$$\top \sqsubseteq \leq 1 \text{hasModsAssociatedCopySpecificInformation}^{-}.\top \tag{48}$$
$$\text{Location} \sqsubseteq \geq 0 \text{hasModsAssociatedCopySpecificInformation.HoldingSimple} \tag{49}$$
$$\top \sqsubseteq \forall \text{hasCopyInformation.CopyInformation} \tag{50}$$
$$\text{HoldingSimple} \sqsubseteq \exists \text{hasCopyInformation.CopyInformation} \tag{51}$$
$$\text{CopyInformation} \sqsubseteq \exists \text{hasCopyInformation}^{-}\text{.HoldingSimple} \tag{52}$$
$$\top \sqsubseteq \leq 1 \text{hasCopyInformation}^{-}.\top \tag{53}$$
$$\text{HoldingSimple} \sqsubseteq \geq 0 \text{hasCopyInformation.CopyInformation} \tag{54}$$
$$\exists \text{isOfForm}.\top \sqsubseteq \text{CopyInformation} \tag{55}$$
$$\top \sqsubseteq \forall \text{isOfForm.PhysicalForm} \tag{56}$$
$$\text{PhysicalForm} \sqsubseteq \exists \text{isOfForm}^{-}\text{.CopyInformation} \tag{57}$$
$$\top \sqsubseteq \leq 1 \text{isOfForm}^{-}.\top \tag{58}$$
$$\text{CopyInformation} \sqsubseteq \geq 0 \text{isOfForm.PhysicalForm} \tag{59}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{60}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \tag{61}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{62}$$
$$\text{PhysicalForm} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \tag{63}$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \tag{64}$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}.\top \tag{65}$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \tag{66}$$
$$\text{PhysicalForm} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \tag{67}$$
$$\top \sqsubseteq \forall \text{hasFormType.xsd:string} \tag{68}$$
$$\text{PhysicalForm} \sqsubseteq \geq 0 \text{hasFormType.xsd:string} \tag{69}$$
$$\exists \text{hasSublocation}.\top \sqsubseteq \text{CopyInformation} \tag{70}$$
$$\top \sqsubseteq \forall \text{hasSublocation.SubLocation} \tag{71}$$
$$\text{SubLocation} \sqsubseteq \exists \text{hasSublocation}^{-}\text{.CopyInformation} \tag{72}$$
$$\top \sqsubseteq \leq 1 \text{hasSublocation}^{-}.\top \tag{73}$$
$$\text{CopyInformation} \sqsubseteq \geq 0 \text{hasSublocation.SubLocation} \tag{74}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{75}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \tag{76}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{77}$$
$$\text{SubLocation} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \tag{78}$$
$$\top \sqsubseteq \forall \text{hasSubLocationValue.xsd:string} \tag{79}$$
$$\text{SubLocation} \sqsubseteq \exists \text{hasSubLocationValue.xsd:string} \tag{80}$$

$$\text{SubLocation} \sqsubseteq \geq 0 \text{hasSubLocationValue.xsd:string} \quad (81)$$
$$\top \sqsubseteq \forall \text{hasShelfLocator.ShelfLocator} \quad (82)$$
$$\text{ShelfLocator} \sqsubseteq \exists \text{hasShelfLocator}^{-}.\text{CopyInformation} \quad (83)$$
$$\top \sqsubseteq \leq 1 \text{hasShelfLocator}^{-}.\top \quad (84)$$
$$\text{CopyInformation} \sqsubseteq \geq 0 \text{hasShelfLocator.ShelfLocator} \quad (85)$$
$$\top \sqsubseteq \forall \text{hasShelfLocatorValue.xsd:string} \quad (86)$$
$$\text{ShelfLocator} \sqsubseteq \exists \text{hasShelfLocatorValue.xsd:string} \quad (87)$$
$$\text{ShelfLocator} \sqsubseteq \geq 0 \text{hasShelfLocatorValue.xsd:string} \quad (88)$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (89)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \quad (90)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (91)$$
$$\text{ShelfLocator} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (92)$$
$$\top \sqsubseteq \forall \text{hasElectronicLocator.xsd:anyURI} \quad (93)$$
$$\text{CopyInformation} \sqsubseteq \geq 0 \text{hasElectronicLocator.xsd:anyURI} \quad (94)$$
$$\top \sqsubseteq \forall \text{hasNote.Note} \quad (95)$$
$$\top \sqsubseteq \leq 1 \text{hasNote}^{-}.\top \quad (96)$$
$$\text{CopyInformation} \sqsubseteq \geq 0 \text{hasNote.Note} \quad (97)$$
$$\exists \text{hasAssociatedEnumerationAndChronology.}\top \sqsubseteq \text{CopyInformation} \quad (98)$$
$$\top \sqsubseteq \forall \text{hasAssociatedEnumerationAndChronology.EnumerationAndChronology} \quad (99)$$
$$\text{EnumerationAndChronology} \sqsubseteq \exists \text{hasAssociatedEnumerationAndChronology}^{-}.\text{CopyInformation} \quad (100)$$
$$\top \sqsubseteq \leq 1 \text{hasAssociatedEnumerationAndChronology}^{-}.\top \quad (101)$$
$$\text{CopyInformation} \sqsubseteq \geq 0 \text{hasAssociatedEnumerationAndChronology.EnumerationAndChronology} \quad (102)$$
$$\top \sqsubseteq \forall \text{hasUnitType.UnitType.txt} \quad (103)$$
$$\text{EnumerationAndChronology} \sqsubseteq \exists \text{hasUnitType.UnitType.txt} \quad (104)$$
$$\text{EnumerationAndChronology} \sqsubseteq \geq 0 \text{hasUnitType.UnitType.txt} \quad (105)$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (106)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \quad (107)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (108)$$
$$\text{EnumerationAndChronology} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (109)$$
$$\top \sqsubseteq \forall \text{hasEnumerationAndChronologyValue.xsd:string} \quad (110)$$
$$\text{EnumerationAndChronology} \sqsubseteq \exists \text{hasEnumerationAndChronologyValue.xsd:string} \quad (111)$$
$$\text{EnumerationAndChronology} \sqsubseteq \geq 0 \text{hasEnumerationAndChronologyValue.xsd:string} \quad (112)$$
$$\top \sqsubseteq \forall \text{hasItemIdentifier.ItemIdentifier} \quad (113)$$
$$\text{ItemIdentifier} \sqsubseteq \exists \text{hasItemIdentifier}^{-}.\text{CopyInformation} \quad (114)$$
$$\top \sqsubseteq \leq 1 \text{hasItemIdentifier.}\top \quad (115)$$
$$\top \sqsubseteq \leq 1 \text{hasItemIdentifier}^{-}.\top \quad (116)$$
$$\text{CopyInformation} \sqsubseteq \geq 0 \text{hasItemIdentifier.ItemIdentifier} \quad (117)$$
$$\top \sqsubseteq \forall \text{hasIdentifierType.xsd:string} \quad (118)$$
$$\text{ItemIdentifier} \sqsubseteq \geq 0 \text{hasIdentifierType.xsd:string} \quad (119)$$
$$\top \sqsubseteq \forall \text{hasItemIdentifierValue.xsd:string} \quad (120)$$

$$\mathsf{ItemIdentifier} \sqsubseteq \exists \mathsf{hasItemIdentifierValue.xsd{:}string} \tag{121}$$
$$\mathsf{ItemIdentifier} \sqsubseteq \geq 0\,\mathsf{hasItemIdentifierValue.xsd{:}string} \tag{122}$$
$$\mathsf{Location} \sqsubseteq \geq 0\,\mathsf{hasModsExternalCopySpecificInformation.xsd{:}string} \tag{123}$$
$$\mathsf{Location} \sqsubseteq \mathsf{ElementInfo} \tag{124}$$
$$\mathsf{Location} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasXlink}.\top) \tag{125}$$
$$\mathsf{Location} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasNameTitleGroup}.\top) \tag{126}$$
$$\mathsf{PhysicalLocation} \sqsubseteq \mathsf{ElementInfo} \tag{127}$$
$$\mathsf{PhysicalLocation} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasID}.\top) \tag{128}$$
$$\mathsf{PhysicalLocation} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasIDRef}.\top) \tag{129}$$
$$\mathsf{PhysicalLocation} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasAltRepGroup}.\top) \tag{130}$$
$$\mathsf{PhysicalLocation} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasNameTitleGroup}.\top) \tag{131}$$

2.9.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Domain
5. Range
6. Inverse Existential
7. Inverse Functionality
8. Structural Tautology
9. Range
10. Structural Tautology
11. Range
12. Functionality
13. Inverse Functionality
14. Structural Tautology
15. Range
16. Existential
17. Structural Tautology
18. Range
19. Inverse Existential
20. Inverse Functionality
21. Structural Tautology
22. Range
23. Existential
24. Structural Tautology
25. Range
26. Functionality
27. Inverse Functionality
28. Structural Tautology
29. Range
30. Inverse Existential
31. Inverse Functionality
32. Structural Tautology
33. Range
34. Structural Tautology
35. Range
36. Structural Tautology
37. Range
38. Structural Tautology
39. Range
40. Structural Tautology
41. Range
42. Structural Tautology
43. Range
44. Existential
45. Structural Tautology
46. Range
47. Inverse Existential
48. Inverse Functionality
49. Structural Tautology
50. Range
51. Existential
52. Inverse Existential
53. Inverse Functionality
54. Structural Tautology
55. Domain
56. Range
57. Inverse Existential
58. Inverse Functionality
59. Structural Tautology
60. Range
61. Functionality
62. Inverse Functionality
63. Structural Tautology
64. Range
65. Functionality
66. Inverse Functionality
67. Structural Tautology
68. Range
69. Structural Tautology
70. Domain
71. Range
72. Inverse Existential
73. Inverse Functionality
74. Structural Tautology
75. Range
76. Functionality
77. Inverse Functionality

78. Structural Tautology
79. Range
80. Existential
81. Structural Tautology
82. Range
83. Inverse Existential
84. Inverse Functionality
85. Structural Tautology
86. Range
87. Existential
88. Structural Tautology
89. Range
90. Functionality
91. Inverse Functionality
92. Structural Tautology
93. Range
94. Structural Tautology
95. Range
96. Inverse Functionality
97. Structural Tautology
98. Domain
99. Range
100. Inverse Existential
101. Inverse Functionality
102. Structural Tautology
103. Range
104. Existential
105. Structural Tautology
106. Range
107. Functionality
108. Inverse Functionality
109. Structural Tautology
110. Range
111. Existential
112. Structural Tautology
113. Range
114. Inverse Existential
115. Functionality
116. Inverse Functionality
117. Structural Tautology
118. Range
119. Structural Tautology
120. Range
121. Existential
122. Structural Tautology
123. Structural Tautology
124. Location is a sub-class of ElementInfo
125. Location does not have a hasLinkAttributes property which has a hasXlink property.
126. Location does not have a hasLinkAttributes property which has a hasNameTitleGroup property.
127. PhysicalLocation is a sub-class of ElementInfo
128. PhysicalLocation does not have a hasLinkAttributes property which has a hasID property.
129. PhysicalLocation does not have a hasLinkAttributes property which has a hasIDRef property.
130. PhysicalLocation does not have a hasLinkAttributes property which has a hasAltRepGroup property.
131. PhysicalLocation does not have a hasLinkAttributes property which has a hasNameTitleGroup property.

2.10 Resource Physical Description Module

2.10.1 Overview

Resource Physical Description Module outlines physical characteristics of the resource such as physical form/medium (e.g. - *electronic*, *photoprint*), material, data representation using *ReformattingQuality* (e.g. *image/jpeg*, *text/xml*), measurements and units.

2.10.2 Formalization

2.10.2.1 Axioms

$$\top \sqsubseteq \forall \mathsf{hasResourcePhysicalDescription}.\mathsf{ResourcePhysicalDescription} \tag{1}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasResourcePhysicalDescription}^{-}.\top \tag{2}$$

$$\mathsf{MODSItem} \sqsubseteq \geq 0 \mathsf{hasResourcePhysicalDescription}.\mathsf{ResourcePhysicalDescription} \tag{3}$$

$$\exists \mathsf{hasPhysicalRepresentationOf}.\top \sqsubseteq \mathsf{ResourcePhysicalDescription} \tag{4}$$

$$\top \sqsubseteq \forall \mathsf{hasPhysicalRepresentationOf}.\mathsf{PhysicalForm} \tag{5}$$

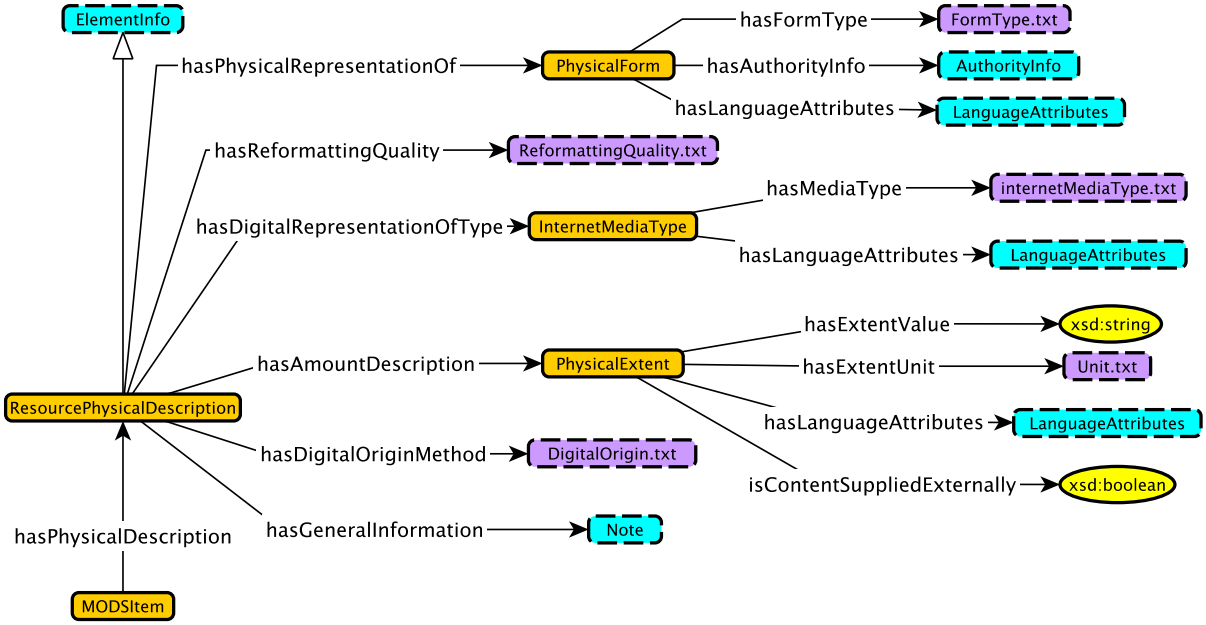

Figure 2.10: The schema diagram for the Resource Physical Description Module.

$$\mathsf{PhysicalForm} \sqsubseteq \exists \mathsf{hasPhysicalRepresentationOf}^{-}.\mathsf{ResourcePhysicalDescription} \tag{6}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasPhysicalRepresentationOf}^{-}.\top \tag{7}$$

$$\mathsf{ResourcePhysicalDescription} \sqsubseteq \geq 0 \mathsf{hasPhysicalRepresentationOf}.\mathsf{PhysicalForm} \tag{8}$$

$$\exists \mathsf{hasFormType}.\top \sqsubseteq \mathsf{PhysicalForm} \tag{9}$$

$$\mathsf{PhysicalForm} \sqsubseteq \geq 0 \mathsf{hasFormType}.\mathsf{FormType.txt} \tag{10}$$

$$\top \sqsubseteq \forall \mathsf{hasAuthorityInfo}.\mathsf{AuthorityInfo} \tag{11}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasAuthorityInfo}.\top \tag{12}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasAuthorityInfo}^{-}.\top \tag{13}$$

$$\mathsf{PhysicalForm} \sqsubseteq \geq 0 \mathsf{hasAuthorityInfo}.\mathsf{AuthorityInfo} \tag{14}$$

$$\top \sqsubseteq \forall \mathsf{hasLanguageAttributes}.\mathsf{LanguageAttributes} \tag{15}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasLanguageAttributes}.\top \tag{16}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasLanguageAttributes}^{-}.\top \tag{17}$$

$$\mathsf{PhysicalForm} \sqsubseteq \geq 0 \mathsf{hasLanguageAttributes}.\mathsf{LanguageAttributes} \tag{18}$$

$$\exists \mathsf{hasDigitalRepresentationOfType}.\top \sqsubseteq \mathsf{ResourcePhysicalDescription} \tag{19}$$

$$\top \sqsubseteq \forall \mathsf{hasDigitalRepresentationOfType}.\mathsf{InternetMediaType} \tag{20}$$

$$\mathsf{InternetMediaType} \sqsubseteq \exists \mathsf{hasDigitalRepresentationOfType}^{-}.\mathsf{ResourcePhysicalDescription} \tag{21}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasDigitalRepresentationOfType}^{-}.\top \tag{22}$$

$$\mathsf{ResourcePhysicalDescription} \sqsubseteq \geq 0 \mathsf{hasDigitalRepresentationOfType}.\mathsf{InternetMediaType} \tag{23}$$

$$\top \sqsubseteq \forall \mathsf{hasMediaType}.\mathsf{InternetMediaType.txt} \tag{24}$$

$$\mathsf{InternetMediaType} \sqsubseteq \exists \mathsf{hasMediaType}.\mathsf{InternetMediaType.txt} \tag{25}$$

$$\text{InternetMediaType} \sqsubseteq \geq 0\,\text{hasMediaType.InternetMediaType.txt} \tag{26}$$
$$\top \sqsubseteq \forall\,\text{hasLanguageAttributes.LanguageAttributes} \tag{27}$$
$$\top \sqsubseteq \leq 1\,\text{hasLanguageAttributes.}\top \tag{28}$$
$$\top \sqsubseteq \leq 1\,\text{hasLanguageAttributes}^{-}.\top \tag{29}$$
$$\text{InternetMediaType} \sqsubseteq \geq 0\,\text{hasLanguageAttributes.LanguageAttributes} \tag{30}$$
$$\top \sqsubseteq \forall\,\text{hasAmountDescription.PhysicalExtent} \tag{31}$$
$$\top \sqsubseteq \leq 1\,\text{hasAmountDescription}^{-}.\top \tag{32}$$
$$\text{ResourcePhysicalDescription} \sqsubseteq \geq 0\,\text{hasAmountDescription.PhysicalExtent} \tag{33}$$
$$\top \sqsubseteq \forall\,\text{hasExtentValue.xsd:string} \tag{34}$$
$$\text{PhysicalExtent} \sqsubseteq \exists\,\text{hasExtentValue.xsd:string} \tag{35}$$
$$\text{PhysicalExtent} \sqsubseteq \geq 0\,\text{hasExtentValue.xsd:string} \tag{36}$$
$$\top \sqsubseteq \forall\,\text{hasExtentUnit.Unit.txt} \tag{37}$$
$$\text{PhysicalExtent} \sqsubseteq \geq 0\,\text{hasExtentUnit.Unit.txt} \tag{38}$$
$$\top \sqsubseteq \forall\,\text{hasLanguageAttributes.LanguageAttributes} \tag{39}$$
$$\top \sqsubseteq \leq 1\,\text{hasLanguageAttributes.}\top \tag{40}$$
$$\top \sqsubseteq \leq 1\,\text{hasLanguageAttributes}^{-}.\top \tag{41}$$
$$\text{PhysicalExtent} \sqsubseteq \geq 0\,\text{hasLanguageAttributes.LanguageAttributes} \tag{42}$$
$$\top \sqsubseteq \forall\,\text{isContentSuppliedExternally.xsd:boolean} \tag{43}$$
$$\text{PhysicalExtent} \sqsubseteq \geq 0\,\text{isContentSuppliedExternally.xsd:boolean} \tag{44}$$
$$\exists\,\text{hasGeneralInformation.}\top \sqsubseteq \text{ResourcePhysicalDescription} \tag{45}$$
$$\top \sqsubseteq \forall\,\text{hasGeneralInformation.Note} \tag{46}$$
$$\text{Note} \sqsubseteq \exists\,\text{hasGeneralInformation}^{-}.\text{ResourcePhysicalDescription} \tag{47}$$
$$\top \sqsubseteq \leq 1\,\text{hasGeneralInformation}^{-}.\top \tag{48}$$
$$\text{ResourcePhysicalDescription} \sqsubseteq \geq 0\,\text{hasGeneralInformation.Note} \tag{49}$$
$$\top \sqsubseteq \forall\,\text{hasReformattingQuality.ReformattingQuality.txt} \tag{50}$$
$$\text{ResourcePhysicalDescription} \sqsubseteq \geq 0\,\text{hasReformattingQuality.ReformattingQuality.txt} \tag{51}$$
$$\top \sqsubseteq \forall\,\text{hasDigitalOriginMethod.DigitalOrigin.txt} \tag{52}$$
$$\text{ResourcePhysicalDescription} \sqsubseteq \geq 0\,\text{hasDigitalOriginMethod.DigitalOrigin.txt} \tag{53}$$
$$\text{ResourcePhysicalDescription} \sqsubseteq \text{ElementInfo} \tag{54}$$
$$\text{ResourcePhysicalDescription} \sqsubseteq \neg(\exists\,\text{hasLinkAttributes.}\exists\,\text{hasNameTitleGroup.}\top) \tag{55}$$

2.10.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Domain
5. Range
6. Inverse Existential
7. Inverse Functionality
8. Structural Tautology
9. Domain
10. Structural Tautology
11. Range
12. Functionality
13. Inverse Functionality
14. Structural Tautology
15. Range
16. Functionality
17. Inverse Functionality
18. Structural Tautology
19. Domain
20. Range
21. Inverse Existential
22. Inverse Functionality
23. Structural Tautology
24. Range

25. Existential
26. Structural Tautology
27. Range
28. Functionality
29. Inverse Functionality
30. Structural Tautology
31. Range
32. Inverse Functionality
33. Structural Tautology
34. Range
35. Existential
36. Structural Tautology
37. Range
38. Structural Tautology
39. Range
40. Functionality
41. Inverse Functionality
42. Structural Tautology
43. Range
44. Structural Tautology
45. Domain
46. Range
47. Inverse Existential
48. Inverse Functionality
49. Structural Tautology
50. Range
51. Structural Tautology
52. Range
53. Structural Tautology
54. ResourcePhysicalDescription is a sub-class of ElementInfo
55. ResourcePhysicalDescription does not have a hasLinkAttributes property which has a hasNameTitleGroup property

2.11 Related Item Module

2.11.1 Overview

This module is to be used when a MODS Item under description is needs to be referenced by other MODS Items (e.g. a publication may be related to another publication).

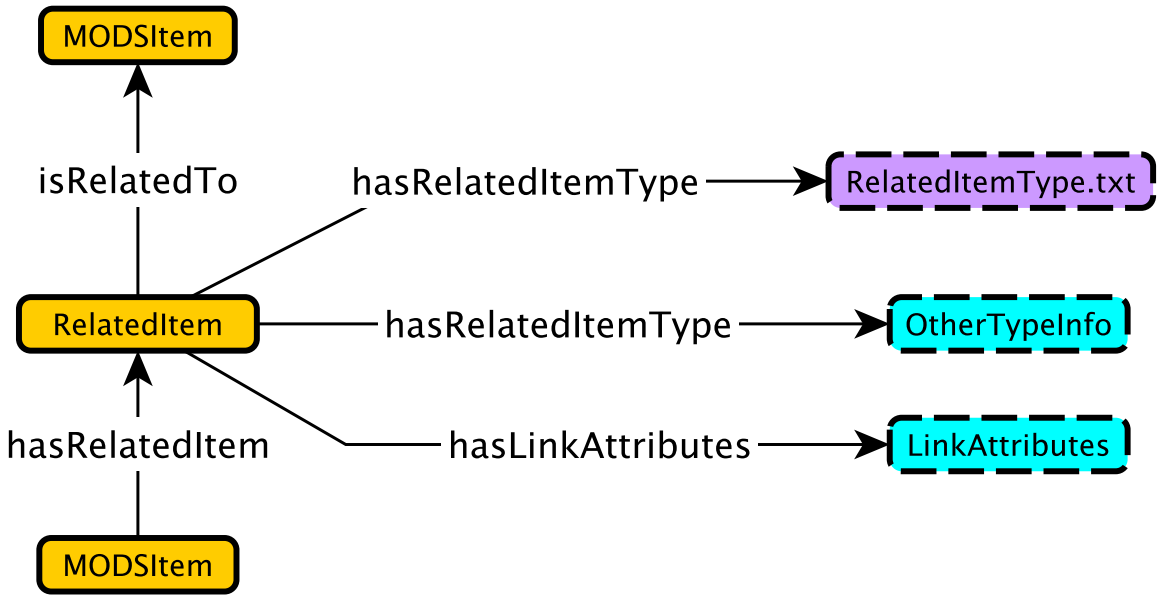

Figure 2.11: The schema diagram for the Related Item Module.

2.11.2 Formalization

2.11.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasRelatedItem.RelatedItem} \quad (1)$$
$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasRelatedItem.RelatedItem} \quad (2)$$
$$\top \sqsubseteq \forall \text{isRelatedTo.Item} \quad (3)$$
$$\text{RelatedItem} \sqsubseteq \exists \text{isRelatedTo.Item} \quad (4)$$
$$\text{MODSItem} \sqsubseteq \exists \text{isRelatedTo}^{-}\text{.RelatedItem} \quad (5)$$
$$\text{RelatedItem} \sqsubseteq \geq 0 \text{isRelatedTo.Item} \quad (6)$$
$$\top \sqsubseteq \forall \text{hasRelatedItemType.(RelatedItemType.txt} \sqcup \text{OtherTypeInfo)} \quad (7)$$
$$\text{RelatedItem} \sqsubseteq \geq 0 \text{hasRelatedItemType.RelatedItemType.txt} \quad (8)$$
$$\text{RelatedItem} \sqsubseteq \geq 0 \text{hasRelatedItemType.OtherTypeInfo} \quad (9)$$
$$\top \sqsubseteq \forall \text{hasLinkAttributes.LinkAttributes} \quad (10)$$
$$\top \sqsubseteq \leq 1 \text{hasLinkAttributes.} \top \quad (11)$$
$$\top \sqsubseteq \leq 1 \text{hasLinkAttributes}^{-}\text{.} \top \quad (12)$$
$$\text{RelatedItem} \sqsubseteq \geq 0 \text{hasLinkAttributes.LinkAttributes} \quad (13)$$
$$\text{RelatedItem} \sqsubseteq \neg(\exists \text{hasLinkAttributes.} \exists \text{hasAltRepGroup.} \top) \quad (14)$$
$$\text{RelatedItem} \sqsubseteq \neg(\exists \text{hasLinkAttributes.} \exists \text{hasNameTitleGroup.} \top) \quad (15)$$

2.11.2.2 Explanations

1. Range
2. Structural Tautology
3. Range
4. Existential
5. Inverse Existential
6. Structural Tautology
7. Range
8. Structural Tautology
9. Structural Tautology
10. Range
11. Functionality
12. Inverse Functionality
13. Structural Tautology
14. RelatedItem does not have a hasLinkAttributes property which has a hasAltRepGroup property.
15. RelatedItem does not have a hasLinkAttributes property which has a hasNameTitleGroup property.

2.12 Alternative Format Attributes Module

2.12.1 Overview

In cases where an alternative format of equivalent content is available elsewhere, AltFormatAttributes module is used to reference the alternative format using a URI, additionally it may also specify the content type that is being referenced.

2.12.2 Formalization

2.12.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasAltFormatAttributes.AltFormatAttributes} \quad (1)$$
$$\top \sqsubseteq \leq 1 \text{hasAltFormatAttributes}^{-}\text{.} \top \quad (2)$$
$$\top \sqsubseteq \geq 0 \text{hasAltFormatAttributes.AltFormatAttributes} \quad (3)$$
$$\top \sqsubseteq \forall \text{hasAlternativeFormat.xsd:anyURI} \quad (4)$$

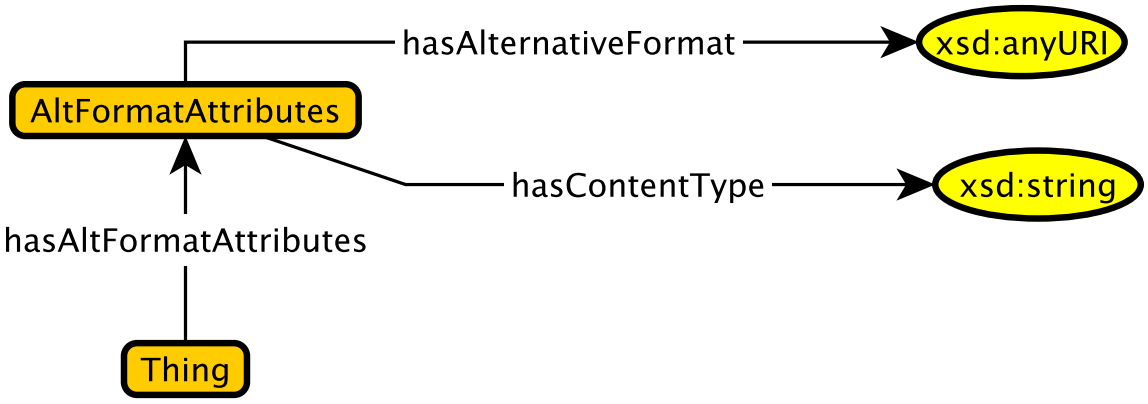

Figure 2.12: The schema diagram for the Alternative Format Attributes Module.

$$\text{AltFormatAttributes} \sqsubseteq \exists \text{hasAlternativeFormat.xsd:anyURI} \quad (5)$$
$$\text{AltFormatAttributes} \sqsubseteq \geq 0 \text{hasAlternativeFormat.xsd:anyURI} \quad (6)$$
$$\top \sqsubseteq \forall \text{hasContentType.xsd:string} \quad (7)$$
$$\text{AltFormatAttributes} \sqsubseteq \geq 0 \text{hasContentType.xsd:string} \quad (8)$$

2.12.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Existential
6. Structural Tautology
7. Range
8. Structural Tautology

2.13 Language Module

2.13.1 Overview

Language Module specifies the general Language and Script used to express the content of the resource. This is different from the Language Attributes in the sense that Language Attributes specifies language on elements and sub-elements level only whereas the Language Module references the language of the entire resource in general.

2.13.2 Formalization

2.13.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasLanguage.Language} \quad (1)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguage}^{-}.\top \quad (2)$$
$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasLanguage.Language} \quad (3)$$
$$\top \sqsubseteq \forall \text{isAssociatedWithResourcePart.xsd:string} \quad (4)$$
$$\text{Language} \sqsubseteq \geq 0 \text{isAssociatedWithResourcePart.xsd:string} \quad (5)$$
$$\top \sqsubseteq \forall \text{hasLanguageTerm.Term} \quad (6)$$

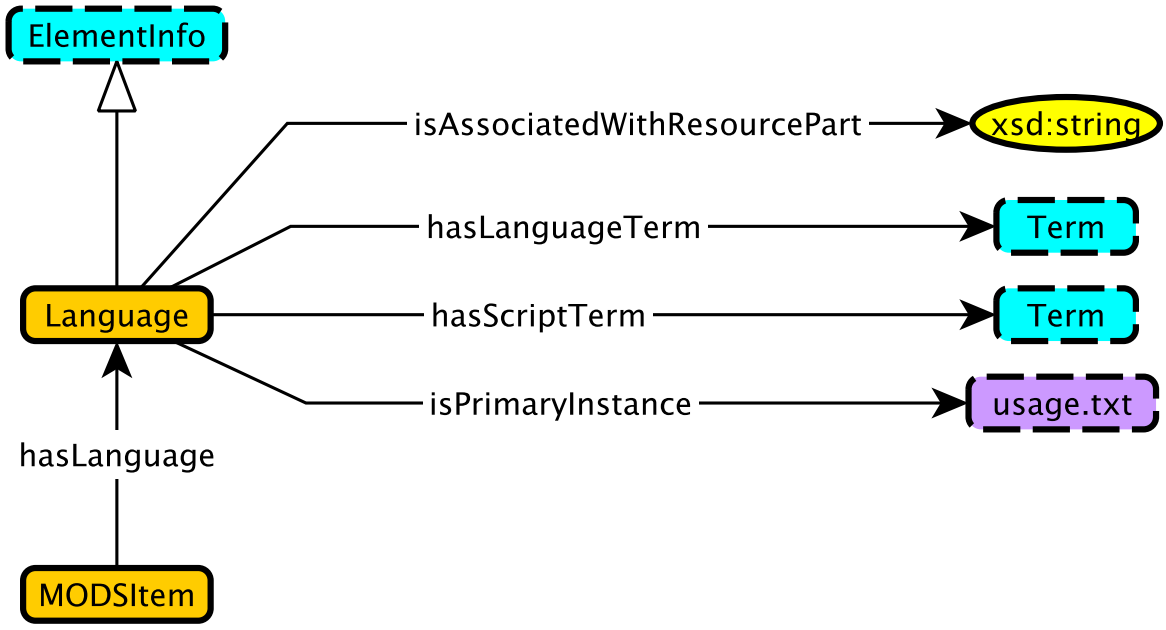

Figure 2.13: The schema diagram for the Language Module.

$$\mathsf{Language} \sqsubseteq \exists \mathsf{hasLanguageTerm}.\mathsf{Term} \tag{7}$$
$$\top \sqsubseteq \leq 1 \mathsf{hasLanguageTerm}^{-}.\top \tag{8}$$
$$\mathsf{Language} \sqsubseteq \geq 0 \mathsf{hasLanguageTerm}.\mathsf{Term} \tag{9}$$
$$\top \sqsubseteq \forall \mathsf{hasScriptTerm}.\mathsf{Term} \tag{10}$$
$$\top \sqsubseteq \leq 1 \mathsf{hasScriptTerm}^{-}.\top \tag{11}$$
$$\mathsf{Language} \sqsubseteq \geq 0 \mathsf{hasScriptTerm}.\mathsf{Term} \tag{12}$$
$$\top \sqsubseteq \forall \mathsf{isPrimaryInstance}.\mathsf{Usage.txt} \tag{13}$$
$$\mathsf{Language} \sqsubseteq \geq 0 \mathsf{isPrimaryInstance}.\mathsf{Usage.txt} \tag{14}$$
$$\mathsf{Language} \sqsubseteq \mathsf{ElementInfo} \tag{15}$$
$$\mathsf{Language} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasXlink}.\top) \tag{16}$$
$$\mathsf{Language} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasNameTitleGroup}.\top) \tag{17}$$
$$\mathsf{Language} \sqsubseteq \neg(\exists \mathsf{hasScripTerm}.\exists \mathsf{hasAltRepGroup}.\top) \tag{18}$$

2.13.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Structural Tautology
6. Range
7. Existential
8. Inverse Functionality
9. Structural Tautology
10. Range
11. Inverse Functionality
12. Structural Tautology
13. Range
14. Structural Tautology
15. Language is a sub-class of ElementInfo
16. Language does not have a hasLinkAttributes property which has a hasXlink property

17. Language does not have a hasLinkAttributes property which has a hasNameTitleGroup property
18. Language does not have a hasLinkAttributes property which has a hasAltRepGroup property

2.14 Term Module

2.14.1 Overview

This is a helper module to be used in conjunction with the Language Module which represents the Authority, Term Type (*Language Term* or *Script Term*) primarily.

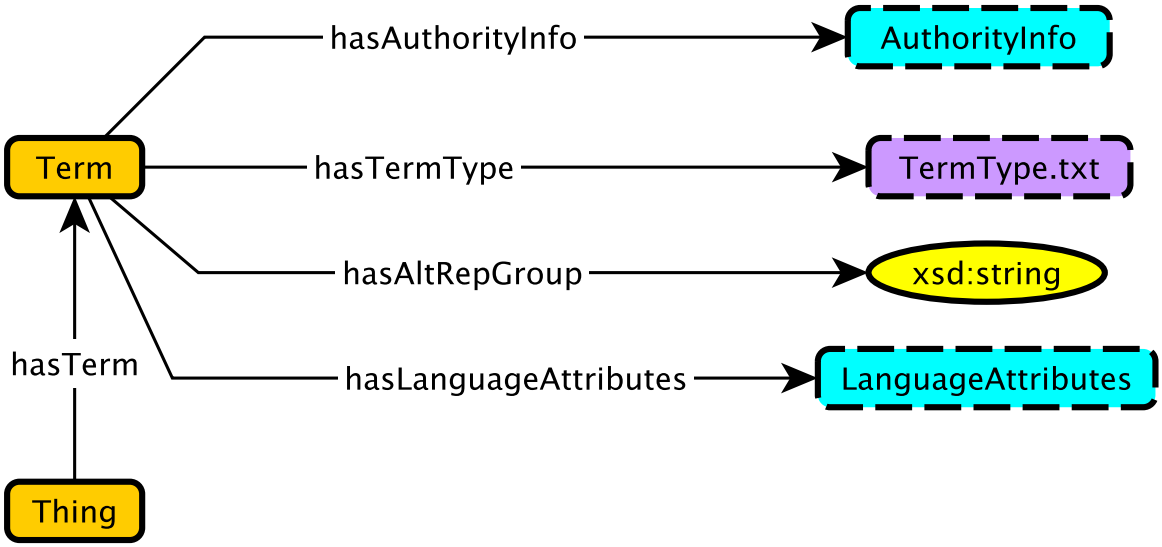

Figure 2.14: The schema diagram for the Term Module.

2.14.2 Formalization

2.14.2.1 Axioms

$$\top \sqsubseteq \forall \mathsf{hasTerm}.\mathsf{Term} \tag{1}$$
$$\top \sqsubseteq \leq 1 \mathsf{hasTerm}^{-}.\top \tag{2}$$
$$\top \sqsubseteq \geq 0 \mathsf{hasTerm}.\mathsf{Term} \tag{3}$$
$$\top \sqsubseteq \forall \mathsf{hasTermType}.\mathsf{TermType.txt} \tag{4}$$
$$\top \sqsubseteq \leq 1 \mathsf{hasTermType}.\top \tag{5}$$
$$\mathsf{Term} \sqsubseteq \geq 0 \mathsf{hasTermType}.\mathsf{TermType.txt} \tag{6}$$
$$\top \sqsubseteq \forall \mathsf{hasAuthorityInfo}.\mathsf{AuthorityInfo} \tag{7}$$
$$\top \sqsubseteq \leq 1 \mathsf{hasAuthorityInfo}.\top \tag{8}$$
$$\top \sqsubseteq \leq 1 \mathsf{hasAuthorityInfo}^{-}.\top \tag{9}$$
$$\mathsf{Term} \sqsubseteq \geq 0 \mathsf{hasAuthorityInfo}.\mathsf{AuthorityInfo} \tag{10}$$
$$\top \sqsubseteq \forall \mathsf{hasLanguageAttributes}.\mathsf{LanguageAttributes} \tag{11}$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \quad (12)$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (13)$$

$$\text{Term} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (14)$$

$$\top \sqsubseteq \forall \text{hasAltRepGroup.xsd:string} \quad (15)$$

$$\text{Term} \sqsubseteq \geq 0 \text{hasAltRepGroup.xsd:string} \quad (16)$$

2.14.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Functionality
6. Structural Tautology
7. Range
8. Functionality
9. Inverse Functionality
10. Structural Tautology
11. Range
12. Functionality
13. Inverse Functionality
14. Structural Tautology
15. Range
16. Structural Tautology

2.15 Primary Topic Module

2.15.1 Overview

The Primary Topic module refers to the top-level-element Subject in the MODS XML Schema. It is used to represent the focus of a work which may range across multiple topics. A subject may be relevant within certain period of time which is expressed using *TemporalReference*. It may also have Title Information, Genre, Geographic Information (*GeographicSubject*), map data indicating spatial coverage (*Cartographics*).

2.15.1.1 Axioms

$$\top \sqsubseteq \forall \text{hasPrimaryTopic.PrimaryTopic} \quad (1)$$

$$\top \sqsubseteq \leq 1 \text{hasPrimaryTopic}^{-}.\top \quad (2)$$

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasPrimaryTopic.PrimaryTopic} \quad (3)$$

$$\exists \text{hasTopic}.\top \sqsubseteq \text{Topic} \quad (4)$$

$$\top \sqsubseteq \forall \text{hasTopic.Topic} \quad (5)$$

$$\text{Topic} \sqsubseteq \exists \text{hasTopic}^{-}.\text{PrimaryTopic} \quad (6)$$

$$\top \sqsubseteq \leq 1 \text{hasTopic}^{-}.\top \quad (7)$$

$$\text{PrimaryTopic} \sqsubseteq \geq 0 \text{hasTopic.Topic} \quad (8)$$

$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \quad (9)$$

$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}.\top \quad (10)$$

$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \quad (11)$$

$$\text{Topic} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \quad (12)$$

$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (13)$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \quad (14)$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (15)$$

$$\text{Topic} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (16)$$

$$\top \sqsubseteq \forall \text{hasTopicValue.xsd:string} \quad (17)$$

$$\text{Topic} \sqsubseteq \exists \text{hasTopicValue.xsd:string} \quad (18)$$

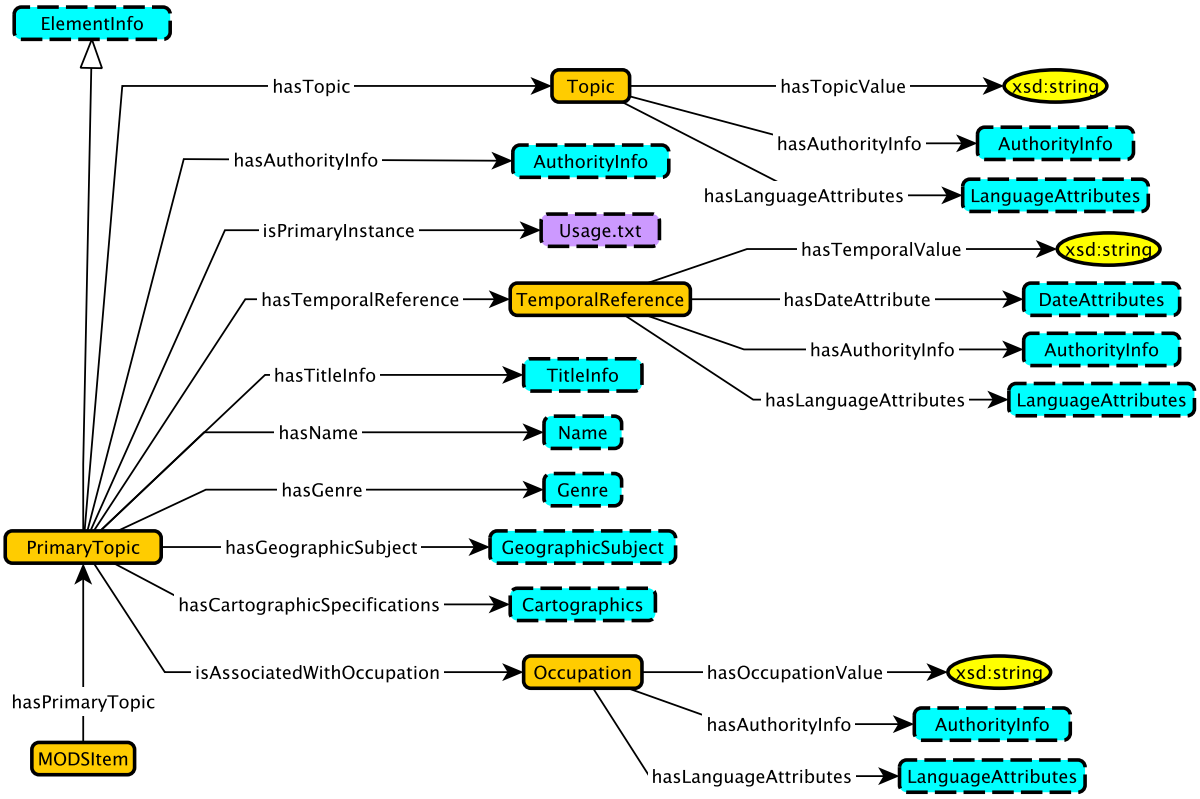

Figure 2.15: The schema diagram for the PrimaryTopic Module.

$$\text{Topic} \sqsubseteq \geq 0 \text{hasTopicValue.xsd:string} \tag{19}$$
$$\exists \text{hasTemporalReference}.\top \sqsubseteq \text{PrimaryTopic} \tag{20}$$
$$\top \sqsubseteq \forall \text{hasTemporalReference.TemporalReference} \tag{21}$$
$$\text{TemporalReference} \sqsubseteq \exists \text{hasTemporalReference}^{-}.\text{PrimaryTopic} \tag{22}$$
$$\top \sqsubseteq \leq 1 \text{hasTemporalReference}^{-}.\top \tag{23}$$
$$\text{PrimaryTopic} \sqsubseteq \geq 0 \text{hasTemporalReference.TemporalReference} \tag{24}$$
$$\top \sqsubseteq \forall \text{hasDateAttribute.DateAttributes} \tag{25}$$
$$\top \sqsubseteq \leq 1 \text{hasDateAttribute}.\top \tag{26}$$
$$\top \sqsubseteq \leq 1 \text{hasDateAttribute}^{-}.\top \tag{27}$$
$$\text{TemporalReference} \sqsubseteq \geq 0 \text{hasDateAttribute.DateAttributes} \tag{28}$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \tag{29}$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}.\top \tag{30}$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \tag{31}$$
$$\text{TemporalReference} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \tag{32}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{33}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \tag{34}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{35}$$
$$\text{TemporalReference} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \tag{36}$$

$$\top \sqsubseteq \forall \text{hasTemporalValue.xsd:string} \tag{37}$$
$$\text{TemporalReference} \sqsubseteq \exists \text{hasTemporalValue.xsd:string} \tag{38}$$
$$\text{TemporalReference} \sqsubseteq \geq 0 \text{hasTemporalValue.xsd:string} \tag{39}$$
$$\exists \text{isAssociatedWithOccupation}.\top \sqsubseteq \text{PrimaryTopic} \tag{40}$$
$$\top \sqsubseteq \forall \text{isAssociatedWithOccupation.Occupation} \tag{41}$$
$$\text{Occupation} \sqsubseteq \exists \text{isAssociatedWithOccupation}^{-}.\text{PrimaryTopic} \tag{42}$$
$$\top \sqsubseteq \leq 1 \text{isAssociatedWithOccupation}^{-}.\top \tag{43}$$
$$\text{PrimaryTopic} \sqsubseteq \geq 0 \text{isAssociatedWithOccupation.Occupation} \tag{44}$$
$$\top \sqsubseteq \forall \text{hasOccupationValue.xsd:string} \tag{45}$$
$$\text{Occupation} \sqsubseteq \exists \text{hasOccupationValue.xsd:string} \tag{46}$$
$$\text{Occupation} \sqsubseteq \geq 0 \text{hasOccupationValue.xsd:string} \tag{47}$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \tag{48}$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}.\top \tag{49}$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \tag{50}$$
$$\text{Occupation} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \tag{51}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{52}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \tag{53}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{54}$$
$$\text{Occupation} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \tag{55}$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \tag{56}$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}.\top \tag{57}$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \tag{58}$$
$$\text{PrimaryTopic} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \tag{59}$$
$$\exists \text{hasTitleInfo}.\top \sqsubseteq \text{PrimaryTopic} \tag{60}$$
$$\top \sqsubseteq \forall \text{hasTitleInfo.TitleInfo} \tag{61}$$
$$\text{TitleInfo} \sqsubseteq \exists \text{hasTitleInfo}^{-}.\text{PrimaryTopic} \tag{62}$$
$$\top \sqsubseteq \leq 1 \text{hasTitleInfo}^{-}.\top \tag{63}$$
$$\text{PrimaryTopic} \sqsubseteq \geq 0 \text{hasTitleInfo.TitleInfo} \tag{64}$$
$$\top \sqsubseteq \forall \text{hasName.Name} \tag{65}$$
$$\top \sqsubseteq \leq 1 \text{hasName}^{-}.\top \tag{66}$$
$$\text{PrimaryTopic} \sqsubseteq \geq 0 \text{hasName.Name} \tag{67}$$
$$\top \sqsubseteq \forall \text{hasGenre.Genre} \tag{68}$$
$$\top \sqsubseteq \leq 1 \text{hasGenre}^{-}.\top \tag{69}$$
$$\text{PrimaryTopic} \sqsubseteq \geq 0 \text{hasGenre.Genre} \tag{70}$$
$$\top \sqsubseteq \forall \text{hasGeographicSubject.GeographicSubject} \tag{71}$$
$$\top \sqsubseteq \leq 1 \text{hasGeographicSubject}^{-}.\top \tag{72}$$
$$\text{PrimaryTopic} \sqsubseteq \geq 0 \text{hasGeographicSubject.GeographicSubject} \tag{73}$$
$$\top \sqsubseteq \forall \text{hasCartographicSpecifications.Carographics} \tag{74}$$
$$\top \sqsubseteq \leq 1 \text{hasCartographicSpecifications}^{-}.\top \tag{75}$$
$$\text{PrimaryTopic} \sqsubseteq \geq 0 \text{hasCartographicSpecifications.Carographics} \tag{76}$$
$$\top \sqsubseteq \forall \text{isPrimaryInstance.Usage.txt} \tag{77}$$
$$\text{PrimaryTopic} \sqsubseteq \geq 0 \text{isPrimaryInstance.Usage.txt} \tag{78}$$

$$\top \sqsubseteq \leq 1 \mathsf{isPrimaryInstance}.\top \quad (79)$$
$$\mathsf{TitleInfo} \sqsubseteq \neg(\exists \mathsf{isPrimaryInstance}.\top) \quad (80)$$
$$\mathsf{TitleInfo} \sqsubseteq \neg(\exists \mathsf{isContentSuppliedExternally}.\top) \quad (81)$$
$$\mathsf{TitleInfo} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasAltRepGroup}.\top) \quad (82)$$
$$\mathsf{TitleInfo} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasNameTitleGroup}.\top) \quad (83)$$
$$\mathsf{Name} \sqsubseteq \neg(\exists \mathsf{hasAssociatedName}.\top) \quad (84)$$
$$\mathsf{Name} \sqsubseteq \neg(\exists \mathsf{hasEtal}.\top) \quad (85)$$
$$\mathsf{PrimaryTopic} \sqsubseteq \mathsf{ElementInfo} \quad (86)$$
$$\mathsf{PrimaryTopic} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasNameTitleGroup}.\top) \quad (87)$$

2.15.1.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Domain
5. Range
6. Inverse Existential
7. Inverse Functionality
8. Structural Tautology
9. Range
10. Functionality
11. Inverse Functionality
12. Structural Tautology
13. Range
14. Functionality
15. Inverse Functionality
16. Structural Tautology
17. Range
18. Existential
19. Structural Tautology
20. Domain
21. Range
22. Inverse Existential
23. Inverse Functionality
24. Structural Tautology
25. Range
26. Functionality
27. Inverse Functionality
28. Structural Tautology
29. Range
30. Functionality
31. Inverse Functionality
32. Structural Tautology
33. Range
34. Functionality
35. Inverse Functionality
36. Structural Tautology
37. Range
38. Existential
39. Structural Tautology
40. Domain
41. Range
42. Inverse Existential
43. Inverse Functionality
44. Structural Tautology
45. Range
46. Existential
47. Structural Tautology
48. Range
49. Functionality
50. Inverse Functionality
51. Structural Tautology
52. Range
53. Functionality
54. Inverse Functionality
55. Structural Tautology
56. Range
57. Functionality
58. Inverse Functionality
59. Structural Tautology
60. Domain
61. Range
62. Inverse Existential
63. Inverse Functionality
64. Structural Tautology
65. Range
66. Inverse Functionality
67. Structural Tautology
68. Range
69. Inverse Functionality
70. Structural Tautology
71. Range
72. Inverse Functionality
73. Structural Tautology
74. Range
75. Inverse Functionality
76. Structural Tautology
77. Range
78. Structural Tautology
79. Functionality
80. TitleInfo does not have a isPrimaryInstance property

81. TitleInfo does not have a isContentSuppliedExternally property
82. TitleInfo does not have a hasLinkAttributes property which has a hasAltRepGroup property
83. TitleInfo does not have a hasLinkAttributes property which has a hasNameTitleGroup property
84. Name does not have a hasAssociatedName property
85. Name does not have a hasEtal property
86. PrimaryTopic is a sub-class of ElementInfo
87. PrimaryTopic does not have a hasLinkAttributes property which has a hasNameTitleGroup property

2.16 Geographic Subject Module

2.16.1 Overview

Geographic Subject refers to the element *Hierarchical Geographic* within the top-level element Subject. It contains elements which may describe the details about a place such as continent, country, state, etc.

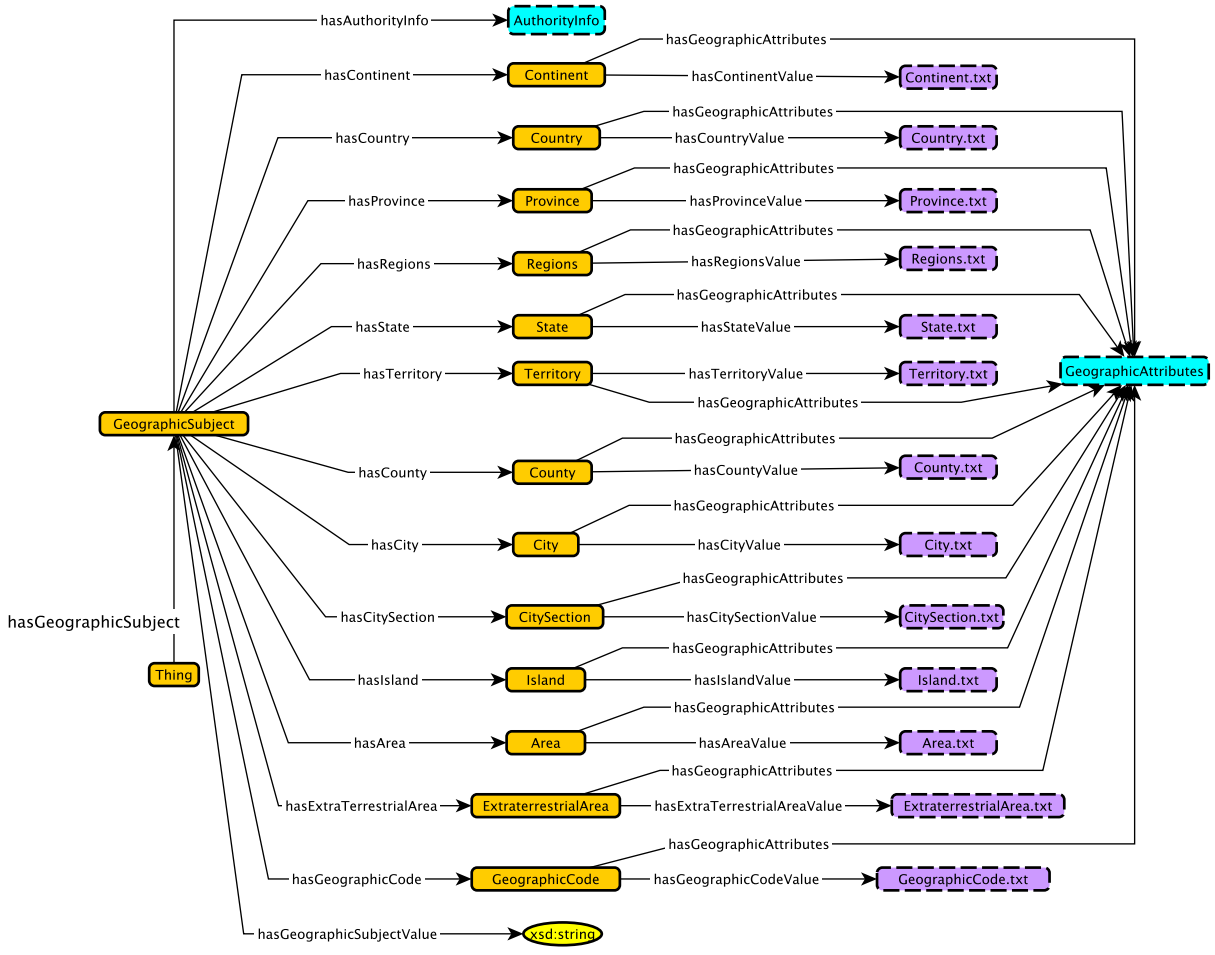

Figure 2.16: The schema diagram for the Geographic Subject Module.

2.16.2 Formalization

2.16.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasGeographicSubject.GeographicSubject} \tag{1}$$
$$\top \sqsubseteq \leq 1 \text{hasGeographicSubject}^{-}.\top \tag{2}$$
$$\top \sqsubseteq \geq 0 \text{hasGeographicSubject.GeographicSubject} \tag{3}$$
$$\exists \text{hasContinent.}\top \sqsubseteq \text{GeographicSubject} \tag{4}$$
$$\top \sqsubseteq \forall \text{hasContinent.Continent} \tag{5}$$
$$\text{Continent} \sqsubseteq \exists \text{hasContinent}^{-}.\text{GeographicSubject} \tag{6}$$
$$\top \sqsubseteq \leq 1 \text{hasContinent}^{-}.\top \tag{7}$$
$$\text{GeographicSubject} \sqsubseteq \geq 0 \text{hasContinent.Continent} \tag{8}$$
$$\top \sqsubseteq \forall \text{hasContinentValue.Continent.txt} \tag{9}$$
$$\text{Continent} \sqsubseteq \exists \text{hasContinentValue.Continent.txt} \tag{10}$$
$$\text{Continent} \sqsubseteq \geq 0 \text{hasContinentValue.Continent.txt} \tag{11}$$
$$\top \sqsubseteq \forall \text{hasGeographicAttributes.GeographicAttributes} \tag{12}$$
$$\text{GeographicAttributes} \sqsubseteq \exists \text{hasGeographicAttributes}^{-}.\text{Continent} \tag{13}$$
$$\top \sqsubseteq \leq 1 \text{hasGeographicAttributes}^{-}.\top \tag{14}$$
$$\text{Continent} \sqsubseteq \geq 0 \text{hasGeographicAttributes.GeographicAttributes} \tag{15}$$
$$\exists \text{hasCountry.}\top \sqsubseteq \text{GeographicSubject} \tag{16}$$
$$\top \sqsubseteq \forall \text{hasCountry.Country} \tag{17}$$
$$\text{Country} \sqsubseteq \exists \text{hasCountry}^{-}.\text{GeographicSubject} \tag{18}$$
$$\top \sqsubseteq \leq 1 \text{hasCountry}^{-}.\top \tag{19}$$
$$\text{GeographicSubject} \sqsubseteq \geq 0 \text{hasCountry.Country} \tag{20}$$
$$\top \sqsubseteq \forall \text{hasCountryValue.Country.txt} \tag{21}$$
$$\text{Country} \sqsubseteq \exists \text{hasCountryValue.Country.txt} \tag{22}$$
$$\text{Country} \sqsubseteq \geq 0 \text{hasCountryValue.Country.txt} \tag{23}$$
$$\top \sqsubseteq \forall \exists \text{hasGeographicAttributes.GeographicAttributes} \tag{24}$$
$$\text{GeographicAttributes} \sqsubseteq \text{hasGeographicAttributes}^{-}.\text{Country} \tag{25}$$
$$\top \sqsubseteq \leq 1 \text{hasGeographicAttributes}^{-}.\top \tag{26}$$
$$\text{Country} \sqsubseteq \geq 0 \text{hasGeographicAttributes.GeographicAttributes} \tag{27}$$
$$\exists \text{hasProvince.}\top \sqsubseteq \text{GeographicSubject} \tag{28}$$
$$\top \sqsubseteq \forall \text{hasProvince.Province} \tag{29}$$
$$\text{Province} \sqsubseteq \exists \text{hasProvince}^{-}.\text{GeographicSubject} \tag{30}$$
$$\top \sqsubseteq \leq 1 \text{hasProvince}^{-}.\top \tag{31}$$
$$\text{GeographicSubject} \sqsubseteq \geq 0 \text{hasProvince.Province} \tag{32}$$
$$\top \sqsubseteq \forall \text{hasProvinceValue.Province.txt} \tag{33}$$
$$\text{Province} \sqsubseteq \exists \text{hasProvinceValue.Province.txt} \tag{34}$$
$$\text{Province} \sqsubseteq \geq 0 \text{hasProvinceValue.Province.txt} \tag{35}$$
$$\top \sqsubseteq \forall \text{hasGeographicAttributes.GeographicAttributes} \tag{36}$$
$$\text{GeographicAttributes} \sqsubseteq \exists \text{hasGeographicAttributes}^{-}.\text{Province} \tag{37}$$
$$\top \sqsubseteq \leq 1 \text{hasGeographicAttributes}^{-}.\top \tag{38}$$
$$\text{Province} \sqsubseteq \geq 0 \text{hasGeographicAttributes.GeographicAttributes} \tag{39}$$

$$\exists \text{hasRegions}.\top \sqsubseteq \text{GeographicSubject} \tag{40}$$
$$\top \sqsubseteq \forall \text{hasRegions}.\text{Regions} \tag{41}$$
$$\text{Regions} \sqsubseteq \exists \text{hasRegions}^{-}.\text{GeographicSubject} \tag{42}$$
$$\top \sqsubseteq \leq 1 \text{hasRegions}^{-}.\top \tag{43}$$
$$\text{GeographicSubject} \sqsubseteq \geq 0 \text{hasRegions}.\text{Regions} \tag{44}$$
$$\top \sqsubseteq \forall \text{hasRegionsValue}.\text{Regions.txt} \tag{45}$$
$$\text{Regions} \sqsubseteq \exists \text{hasRegionsValue}.\text{Regions.txt} \tag{46}$$
$$\text{Regions} \sqsubseteq \geq 0 \text{hasRegionsValue}.\text{Regions.txt} \tag{47}$$
$$\top \sqsubseteq \forall \text{hasGeographicAttributes}.\text{GeographicAttributes} \tag{48}$$
$$\text{GeographicAttributes} \sqsubseteq \exists \text{hasGeographicAttributes}^{-}.\text{Regions} \tag{49}$$
$$\top \sqsubseteq \leq 1 \text{hasGeographicAttributes}^{-}.\top \tag{50}$$
$$\text{Regions} \sqsubseteq \geq 0 \text{hasGeographicAttributes}.\text{GeographicAttributes} \tag{51}$$
$$\exists \text{hasState}.\top \sqsubseteq \text{GeographicSubject} \tag{52}$$
$$\top \sqsubseteq \forall \text{hasState}.\text{State} \tag{53}$$
$$\text{State} \sqsubseteq \exists \text{hasState}^{-}.\text{GeographicSubject} \tag{54}$$
$$\top \sqsubseteq \leq 1 \text{hasState}^{-}.\top \tag{55}$$
$$\text{GeographicSubject} \sqsubseteq \geq 0 \text{hasState}.\text{State} \tag{56}$$
$$\top \sqsubseteq \forall \text{hasStateValue}.\text{State.txt} \tag{57}$$
$$\text{State} \sqsubseteq \exists \text{hasStateValue}.\text{State.txt} \tag{58}$$
$$\text{State} \sqsubseteq \geq 0 \text{hasStateValue}.\text{State.txt} \tag{59}$$
$$\top \sqsubseteq \forall \text{hasGeographicAttributes}.\text{GeographicAttributes} \tag{60}$$
$$\text{GeographicAttributes} \sqsubseteq \exists \text{hasGeographicAttributes}^{-}.\text{State} \tag{61}$$
$$\top \sqsubseteq \leq 1 \text{hasGeographicAttributes}^{-}.\top \tag{62}$$
$$\text{State} \sqsubseteq \geq 0 \text{hasGeographicAttributes}.\text{GeographicAttributes} \tag{63}$$
$$\exists \text{hasTerritory}.\top \sqsubseteq \text{GeographicSubject} \tag{64}$$
$$\top \sqsubseteq \forall \text{hasTerritory}.\text{Territory} \tag{65}$$
$$\text{Territory} \sqsubseteq \exists \text{hasTerritory}^{-}.\text{GeographicSubject} \tag{66}$$
$$\top \sqsubseteq \leq 1 \text{hasTerritory}^{-}.\top \tag{67}$$
$$\text{GeographicSubject} \sqsubseteq \geq 0 \text{hasTerritory}.\text{Territory} \tag{68}$$
$$\top \sqsubseteq \forall \text{hasTerritoryValue}.\text{Territory.txt} \tag{69}$$
$$\text{Territory} \sqsubseteq \exists \text{hasTerritoryValue}.\text{Territory.txt} \tag{70}$$
$$\text{Territory} \sqsubseteq \geq 0 \text{hasTerritoryValue}.\text{Territory.txt} \tag{71}$$
$$\top \sqsubseteq \forall \text{hasGeographicAttributes}.\text{GeographicAttributes} \tag{72}$$
$$\text{GeographicAttributes} \sqsubseteq \exists \text{hasGeographicAttributes}^{-}.\text{Territory} \tag{73}$$
$$\top \sqsubseteq \leq 1 \text{hasGeographicAttributes}^{-}.\top \tag{74}$$
$$\text{Territory} \sqsubseteq \geq 0 \text{hasGeographicAttributes}.\text{GeographicAttributes} \tag{75}$$
$$\exists \text{hasCountry}.\top \sqsubseteq \text{GeographicSubject} \tag{76}$$
$$\top \sqsubseteq \forall \text{hasCountry}.\text{County} \tag{77}$$
$$\text{County} \sqsubseteq \exists \text{hasCountry}^{-}.\text{GeographicSubject} \tag{78}$$
$$\top \sqsubseteq \leq 1 \text{hasCountry}^{-}.\top \tag{79}$$
$$\text{GeographicSubject} \sqsubseteq \geq 0 \text{hasCountry}.\text{County} \tag{80}$$

$$\top \sqsubseteq \forall \text{hasCountyValue.County.txt} \tag{81}$$
$$\text{County} \sqsubseteq \exists \text{hasCountyValue.County.txt} \tag{82}$$
$$\text{County} \sqsubseteq \geq 0 \text{hasCountyValue.County.txt} \tag{83}$$
$$\top \sqsubseteq \forall \text{hasGeographicAttributes.GeographicAttributes} \tag{84}$$
$$\text{GeographicAttributes} \sqsubseteq \exists \text{hasGeographicAttributes}^{-}\text{.County} \tag{85}$$
$$\top \sqsubseteq \leq 1 \text{hasGeographicAttributes}^{-}.\top \tag{86}$$
$$\text{County} \sqsubseteq \geq 0 \text{hasGeographicAttributes.GeographicAttributes} \tag{87}$$
$$\exists \text{hasCity}.\top \sqsubseteq \text{GeographicSubject} \tag{88}$$
$$\top \sqsubseteq \forall \text{hasCity.City} \tag{89}$$
$$\text{City} \sqsubseteq \exists \text{hasCity}^{-}\text{.GeographicSubject} \tag{90}$$
$$\top \sqsubseteq \leq 1 \text{hasCity}^{-}.\top \tag{91}$$
$$\text{GeographicSubject} \sqsubseteq \geq 0 \text{hasCity.City} \tag{92}$$
$$\top \sqsubseteq \forall \text{hasCityValue.City.txt} \tag{93}$$
$$\text{City} \sqsubseteq \exists \text{hasCityValue.City.txt} \tag{94}$$
$$\text{City} \sqsubseteq \geq 0 \text{hasCityValue.City.txt} \tag{95}$$
$$\top \sqsubseteq \forall \text{hasGeographicAttributes.GeographicAttributes} \tag{96}$$
$$\text{GeographicAttributes} \sqsubseteq \exists \text{hasGeographicAttributes}^{-}\text{.City} \tag{97}$$
$$\top \sqsubseteq \leq 1 \text{hasGeographicAttributes}^{-}.\top \tag{98}$$
$$\text{City} \sqsubseteq \geq 0 \text{hasGeographicAttributes.GeographicAttributes} \tag{99}$$
$$\exists \text{hasCitySection}.\top \sqsubseteq \text{GeographicSubject} \tag{100}$$
$$\top \sqsubseteq \forall \text{hasCitySection.CitySection} \tag{101}$$
$$\text{CitySection} \sqsubseteq \exists \text{hasCitySection}^{-}\text{.GeographicSubject} \tag{102}$$
$$\top \sqsubseteq \leq 1 \text{hasCitySection}^{-}.\top \tag{103}$$
$$\text{GeographicSubject} \sqsubseteq \geq 0 \text{hasCitySection.CitySection} \tag{104}$$
$$\top \sqsubseteq \forall \text{hasCitySectionValue.CitySection.txt} \tag{105}$$
$$\text{CitySection} \sqsubseteq \exists \text{hasCitySectionValue.CitySection.txt} \tag{106}$$
$$\text{CitySection} \sqsubseteq \geq 0 \text{hasCitySectionValue.CitySection.txt} \tag{107}$$
$$\top \sqsubseteq \forall \text{hasGeographicAttributes.GeographicAttributes} \tag{108}$$
$$\text{GeographicAttributes} \sqsubseteq \exists \text{hasGeographicAttributes}^{-}\text{.CitySection} \tag{109}$$
$$\top \sqsubseteq \leq 1 \text{hasGeographicAttributes}^{-}.\top \tag{110}$$
$$\text{CitySection} \sqsubseteq \geq 0 \text{hasGeographicAttributes.GeographicAttributes} \tag{111}$$
$$\exists \text{hasIsland}.\top \sqsubseteq \text{GeographicSubject} \tag{112}$$
$$\top \sqsubseteq \forall \text{hasIsland.Island} \tag{113}$$
$$\text{Island} \sqsubseteq \exists \text{hasIsland}^{-}\text{.GeographicSubject} \tag{114}$$
$$\top \sqsubseteq \leq 1 \text{hasIsland}^{-}.\top \tag{115}$$
$$\text{GeographicSubject} \sqsubseteq \geq 0 \text{hasIsland.Island} \tag{116}$$
$$\top \sqsubseteq \forall \text{hasIslandValue.Island.txt} \tag{117}$$
$$\text{Island} \sqsubseteq \exists \text{hasIslandValue.Island.txt} \tag{118}$$
$$\text{Island} \sqsubseteq \geq 0 \text{hasIslandValue.Island.txt} \tag{119}$$
$$\top \sqsubseteq \forall \text{hasGeographicAttributes.GeographicAttributes} \tag{120}$$
$$\text{GeographicAttributes} \sqsubseteq \exists \text{hasGeographicAttributes}^{-}\text{.Island} \tag{121}$$

$$\top \sqsubseteq \leq 1 \text{hasGeographicAttributes}^{-}.\top \tag{122}$$
$$\text{Island} \sqsubseteq \geq 0 \text{hasGeographicAttributes.GeographicAttributes} \tag{123}$$
$$\exists \text{hasArea}.\top \sqsubseteq \text{GeographicSubject} \tag{124}$$
$$\top \sqsubseteq \forall \text{hasArea.Area} \tag{125}$$
$$\text{Area} \sqsubseteq \exists \text{hasArea}^{-}.\text{GeographicSubject} \tag{126}$$
$$\top \sqsubseteq \leq 1 \text{hasArea}^{-}.\top \tag{127}$$
$$\text{GeographicSubject} \sqsubseteq \geq 0 \text{hasArea.Area} \tag{128}$$
$$\top \sqsubseteq \forall \text{hasAreaValue.Area.txt} \tag{129}$$
$$\text{Area} \sqsubseteq \exists \text{hasAreaValue.Area.txt} \tag{130}$$
$$\text{Area} \sqsubseteq \geq 0 \text{hasAreaValue.Area.txt} \tag{131}$$
$$\top \sqsubseteq \forall \text{hasGeographicAttributes.GeographicAttributes} \tag{132}$$
$$\text{GeographicAttributes} \sqsubseteq \exists \text{hasGeographicAttributes}^{-}.\text{Area} \tag{133}$$
$$\top \sqsubseteq \leq 1 \text{hasGeographicAttributes}^{-}.\top \tag{134}$$
$$\text{Area} \sqsubseteq \geq 0 \text{hasGeographicAttributes.GeographicAttributes} \tag{135}$$
$$\exists \text{hasExtraTerrestrialArea}.\top \sqsubseteq \text{GeographicSubject} \tag{136}$$
$$\top \sqsubseteq \forall \text{hasExtraTerrestrialArea.ExtraTerrestrialArea} \tag{137}$$
$$\text{ExtraTerrestrialArea} \sqsubseteq \exists \text{hasExtraTerrestrialArea}^{-}.\text{GeographicSubject} \tag{138}$$
$$\top \sqsubseteq \leq 1 \text{hasExtraTerrestrialArea}^{-}.\top \tag{139}$$
$$\text{GeographicSubject} \sqsubseteq \geq 0 \text{hasExtraTerrestrialArea.ExtraTerrestrialArea} \tag{140}$$
$$\top \sqsubseteq \forall \text{hasExtraTerrestrialAreaValue.ExtraTerrestrialArea.txt} \tag{141}$$
$$\text{ExtraTerrestrialArea} \sqsubseteq \exists \text{hasExtraTerrestrialAreaValue.ExtraTerrestrialArea.txt} \tag{142}$$
$$\text{ExtraTerrestrialArea} \sqsubseteq \geq 0 \text{hasExtraTerrestrialAreaValue.ExtraTerrestrialArea.txt} \tag{143}$$
$$\top \sqsubseteq \forall \text{hasGeographicAttributes.GeographicAttributes} \tag{144}$$
$$\text{GeographicAttributes} \sqsubseteq \exists \text{hasGeographicAttributes}^{-}.\text{ExtraTerrestrialArea} \tag{145}$$
$$\top \sqsubseteq \leq 1 \text{hasGeographicAttributes}^{-}.\top \tag{146}$$
$$\text{ExtraTerrestrialArea} \sqsubseteq \geq 0 \text{hasGeographicAttributes.GeographicAttributes} \tag{147}$$
$$\exists \text{hasGeographicCode}.\top \sqsubseteq \text{GeographicSubject} \tag{148}$$
$$\top \sqsubseteq \forall \text{hasGeographicCode.GeographicCode} \tag{149}$$
$$\text{GeographicCode} \sqsubseteq \exists \text{hasGeographicCode}^{-}.\text{GeographicSubject} \tag{150}$$
$$\top \sqsubseteq \leq 1 \text{hasGeographicCode}^{-}.\top \tag{151}$$
$$\text{GeographicSubject} \sqsubseteq \geq 0 \text{hasGeographicCode.GeographicCode} \tag{152}$$
$$\top \sqsubseteq \forall \text{hasGeographicCodeValue.xsd:string} \tag{153}$$
$$\text{GeographicCode} \sqsubseteq \exists \text{hasGeographicCodeValue.xsd:string} \tag{154}$$
$$\text{GeographicCode} \sqsubseteq \geq 0 \text{hasGeographicCodeValue.xsd:string} \tag{155}$$
$$\top \sqsubseteq \forall \text{hasGeographicAttributes.GeographicAttributes} \tag{156}$$
$$\text{GeographicAttributes} \sqsubseteq \exists \text{hasGeographicAttributes}^{-}.\text{GeographicCode} \tag{157}$$
$$\top \sqsubseteq \leq 1 \text{hasGeographicAttributes}^{-}.\top \tag{158}$$
$$\text{GeographicCode} \sqsubseteq \geq 0 \text{hasGeographicAttributes.GeographicAttributes} \tag{159}$$
$$\top \sqsubseteq \forall \text{hasGeographicSubjectValue.xsd:string} \tag{160}$$
$$\text{GeographicSubject} \sqsubseteq \exists \text{hasGeographicSubjectValue.xsd:string} \tag{161}$$
$$\text{GeographicSubject} \sqsubseteq \geq 0 \text{hasGeographicSubjectValue.xsd:string} \tag{162}$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \tag{163}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasAuthorityInfo}^{-}.\top \tag{164}$$

$$\mathsf{GeographicSubject} \sqsubseteq \geq 0 \mathsf{hasAuthorityInfo}.\mathsf{AuthorityInfo} \tag{165}$$

2.16.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Domain
5. Range
6. Inverse Existential
7. Inverse Functionality
8. Structural Tautology
9. Range
10. Existential
11. Structural Tautology
12. Range
13. Inverse Existential
14. Inverse Functionality
15. Structural Tautology
16. Domain
17. Range
18. Inverse Existential
19. Inverse Functionality
20. Structural Tautology
21. Range
22. Existential
23. Structural Tautology
24. Range
25. Inverse Existential
26. Inverse Functionality
27. Structural Tautology
28. Domain
29. Range
30. Inverse Existential
31. Inverse Functionality
32. Structural Tautology
33. Range
34. Existential
35. Structural Tautology
36. Range
37. Inverse Existential
38. Inverse Functionality
39. Structural Tautology
40. Domain
41. Range
42. Inverse Existential
43. Inverse Functionality
44. Structural Tautology
45. Range
46. Existential
47. Structural Tautology
48. Range
49. Inverse Existential
50. Inverse Functionality
51. Structural Tautology
52. Domain
53. Range
54. Inverse Existential
55. Inverse Functionality
56. Structural Tautology
57. Range
58. Existential
59. Structural Tautology
60. Range
61. Inverse Existential
62. Inverse Functionality
63. Structural Tautology
64. Domain
65. Range
66. Inverse Existential
67. Inverse Functionality
68. Structural Tautology
69. Range
70. Existential
71. Structural Tautology
72. Range
73. Inverse Existential
74. Inverse Functionality
75. Structural Tautology
76. Domain
77. Range
78. Inverse Existential
79. Inverse Functionality
80. Structural Tautology
81. Range
82. Existential
83. Structural Tautology
84. Range
85. Inverse Existential
86. Inverse Functionality
87. Structural Tautology
88. Domain
89. Range
90. Inverse Existential
91. Inverse Functionality
92. Structural Tautology
93. Range
94. Existential
95. Structural Tautology
96. Range
97. Inverse Existential
98. Inverse Functionality
99. Structural Tautology
100. Domain

101. Range
102. Inverse Existential
103. Inverse Functionality
104. Structural Tautology
105. Range
106. Existential
107. Structural Tautology
108. Range
109. Inverse Existential
110. Inverse Functionality
111. Structural Tautology
112. Domain
113. Range
114. Inverse Existential
115. Inverse Functionality
116. Structural Tautology
117. Range
118. Existential
119. Structural Tautology
120. Range
121. Inverse Existential
122. Inverse Functionality
123. Structural Tautology
124. Domain
125. Range
126. Inverse Existential
127. Inverse Functionality
128. Structural Tautology
129. Range
130. Existential
131. Structural Tautology
132. Range
133. Inverse Existential
134. Inverse Functionality
135. Structural Tautology
136. Domain
137. Range
138. Inverse Existential
139. Inverse Functionality
140. Structural Tautology
141. Range
142. Existential
143. Structural Tautology
144. Range
145. Inverse Existential
146. Inverse Functionality
147. Structural Tautology
148. Domain
149. Range
150. Inverse Existential
151. Inverse Functionality
152. Structural Tautology
153. Range
154. Existential
155. Structural Tautology
156. Range
157. Inverse Existential
158. Inverse Functionality
159. Structural Tautology
160. Range
161. Existential
162. Structural Tautology
163. Range
164. Inverse Functionality
165. Structural Tautology

2.17 Geographic Attributes Module

2.17.1 Overview

Geographic Attributes Module is created to group together the common attributes which is shared by all elements within Geographic Subject Module.

2.17.2 Formalization

2.17.2.1 Axioms

$$\top \sqsubseteq \forall \mathsf{hasGeographicAttributes}.\mathsf{GeographicAttributes} \tag{1}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasGeographicAttributes}^{-}.\top \tag{2}$$

$$\top \sqsubseteq \geq 0 \mathsf{hasGeographicAttributes}.\mathsf{GeographicAttributes} \tag{3}$$

$$\top \sqsubseteq \forall \mathsf{hasAuthorityInfo}.\mathsf{AuthorityInfo} \tag{4}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasAuthorityInfo}.\top \tag{5}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasAuthorityInfo}^{-}.\top \tag{6}$$

$$\mathsf{GeographicAttributes} \sqsubseteq \geq 0 \mathsf{hasAuthorityInfo}.\mathsf{AuthorityInfo} \tag{7}$$

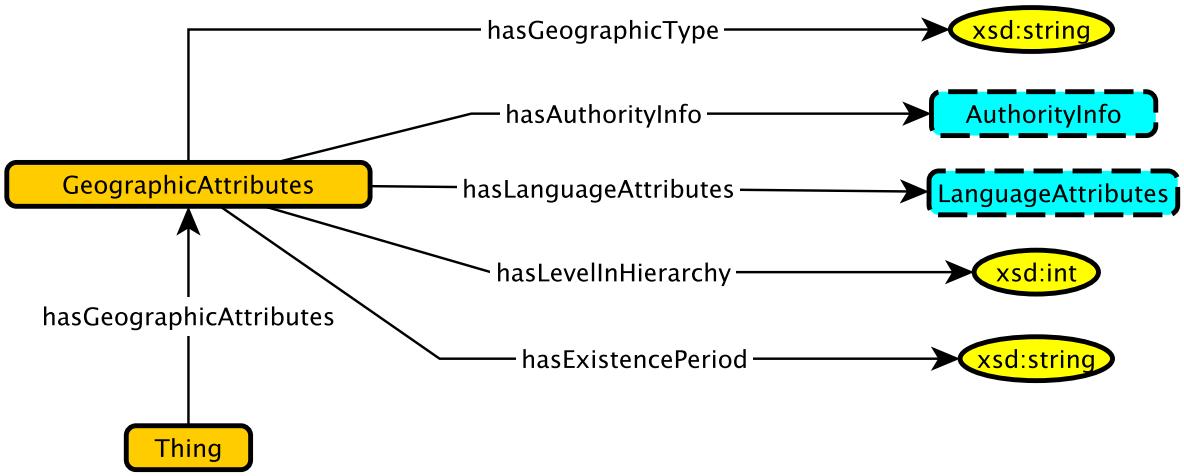

Figure 2.17: The schema diagram for the Geographic Attributes Module.

$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{8}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \tag{9}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{10}$$
$$\text{GeographicAttributes} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \tag{11}$$
$$\top \sqsubseteq \forall \text{hasLevelInHierarchy.xsd:int} \tag{12}$$
$$\text{GeographicAttributes} \sqsubseteq \geq 0 \text{hasLevelInHierarchy.xsd:int} \tag{13}$$
$$\top \sqsubseteq \forall \text{hasExistencePeriod.xsd:string} \tag{14}$$
$$\text{GeographicAttributes} \sqsubseteq \geq 0 \text{hasExistencePeriod.xsd:string} \tag{15}$$
$$\top \sqsubseteq \forall \text{hasGeographicType.xsd:string} \tag{16}$$
$$\text{GeographicAttributes} \sqsubseteq \geq 0 \text{hasGeographicType.xsd:string} \tag{17}$$

2.17.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Functionality
6. Inverse Functionality
7. Structural Tautology
8. Range
9. Functionality
10. Inverse Functionality
11. Structural Tautology
12. Range
13. Structural Tautology
14. Range
15. Structural Tautology
16. Range
17. Structural Tautology

2.18 Cartographic Specifications Module

2.18.1 Overview

Cartographic Specification Module is used when information pertaining to map needs to be expressed. The module may specify the scale, coordinates, projection method.

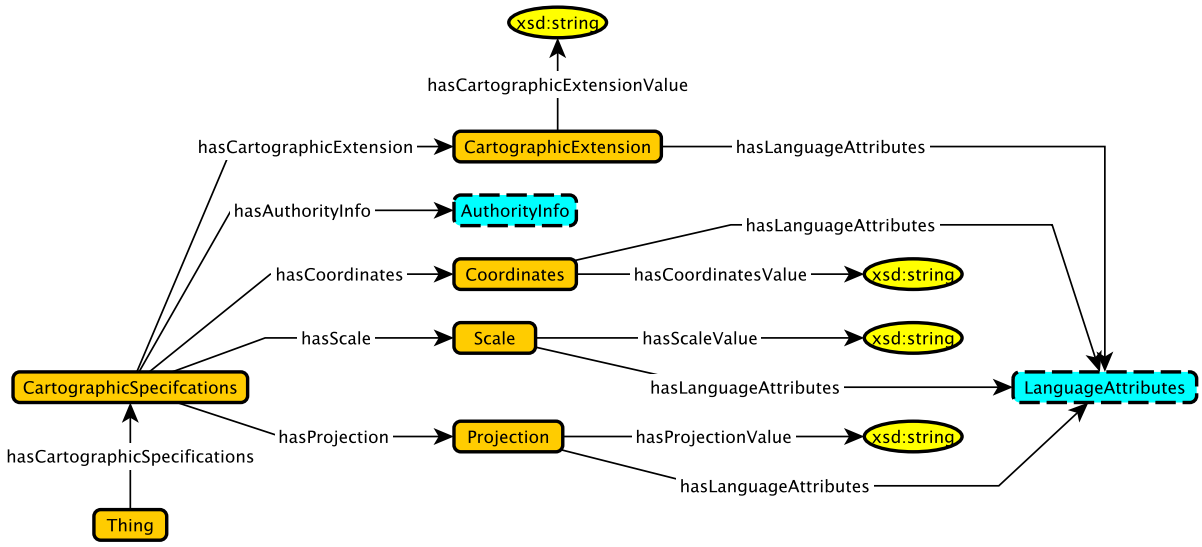

Figure 2.18: The schema diagram for the Cartographic Specifications Module.

2.18.2 Formalization

2.18.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasCartographicSpecifications}.\text{CartographicSpecifcations} \quad (1)$$
$$\top \sqsubseteq \leq 1\,\text{hasCartographicSpecifications}^{-}.\top \quad (2)$$
$$\top \sqsubseteq \geq 0\,\text{hasCartographicSpecifications}.\text{CartographicSpecifcations} \quad (3)$$
$$\exists \text{hasCoordinates}.\top \sqsubseteq \text{CartographicSpecifcations} \quad (4)$$
$$\top \sqsubseteq \forall \text{hasCoordinates}.\text{Coordinates} \quad (5)$$
$$\text{CartographicSpecifcations} \sqsubseteq \exists \text{hasCoordinates}.\text{Coordinates} \quad (6)$$
$$\text{Coordinates} \sqsubseteq \exists \text{hasCoordinates}^{-}.\text{Cartographics} \quad (7)$$
$$\top \sqsubseteq \leq 1\,\text{hasCoordinates}^{-}.\top \quad (8)$$
$$\text{CartographicSpecifcations} \sqsubseteq \geq 0\,\text{hasCoordinates}.\text{Coordinates} \quad (9)$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes}.\text{LanguageAttributes} \quad (10)$$
$$\top \sqsubseteq \leq 1\,\text{hasLanguageAttributes}.\top \quad (11)$$
$$\top \sqsubseteq \leq 1\,\text{hasLanguageAttributes}^{-}.\top \quad (12)$$
$$\text{Coordinates} \sqsubseteq \geq 0\,\text{hasLanguageAttributes}.\text{LanguageAttributes} \quad (13)$$
$$\top \sqsubseteq \forall \text{hasCoordinatesValue}.\text{xsd:string} \quad (14)$$
$$\text{Coordinates} \sqsubseteq \exists \text{hasCoordinatesValue}.\text{xsd:string} \quad (15)$$
$$\text{Coordinates} \sqsubseteq \geq 0\,\text{hasCoordinatesValue}.\text{xsd:string} \quad (16)$$
$$\exists \text{hasScale}.\top \sqsubseteq \text{CartographicSpecifcations} \quad (17)$$
$$\top \sqsubseteq \forall \text{hasScale}.\text{Scale} \quad (18)$$
$$\text{Scale} \sqsubseteq \exists \text{hasScale}^{-}.\text{CartographicSpecifcations} \quad (19)$$
$$\top \sqsubseteq \leq 1\,\text{hasScale}^{-}.\top \quad (20)$$
$$\text{CartographicSpecifcations} \sqsubseteq \geq 0\,\text{hasScale}.\text{Scale} \quad (21)$$

$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (22)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \quad (23)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (24)$$
$$\text{Scale} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (25)$$
$$\top \sqsubseteq \forall \text{hasScaleValue.xsd:string} \quad (26)$$
$$\text{Scale} \sqsubseteq \exists \text{hasScaleValue.xsd:string} \quad (27)$$
$$\text{Scale} \sqsubseteq \geq 0 \text{hasScaleValue.xsd:string} \quad (28)$$
$$\exists \text{hasProjection}.\top \sqsubseteq \text{CartographicSpecifcations} \quad (29)$$
$$\top \sqsubseteq \forall \text{hasProjection.Projection} \quad (30)$$
$$\text{Projection} \sqsubseteq \exists \text{hasProjection}^{-}.\text{Cartographics} \quad (31)$$
$$\top \sqsubseteq \leq 1 \text{hasProjection}^{-}.\top \quad (32)$$
$$\text{CartographicSpecifcations} \sqsubseteq \geq 0 \text{hasProjection.Projection} \quad (33)$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (34)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \quad (35)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (36)$$
$$\text{Projection} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (37)$$
$$\top \sqsubseteq \forall \text{hasProjectionValue.xsd:string} \quad (38)$$
$$\text{Projection} \sqsubseteq \exists \text{hasProjectionValue.xsd:string} \quad (39)$$
$$\text{Projection} \sqsubseteq \geq 0 \text{hasProjectionValue.xsd:string} \quad (40)$$
$$\exists \text{hasCartographicExtension}.\top \sqsubseteq \text{CartographicSpecifcations} \quad (41)$$
$$\top \sqsubseteq \forall \text{hasCartographicExtension.CartographicExtension} \quad (42)$$
$$\text{CartographicExtension} \sqsubseteq \exists \text{hasCartographicExtension}^{-}.\text{CartographicSpecifcations} \quad (43)$$
$$\top \sqsubseteq \leq 1 \text{hasCartographicMODSExtension}^{-}.\top \quad (44)$$
$$\text{CartographicSpecifcations} \sqsubseteq \geq 0 \text{hasCartographicExtension.CartographicExtension} \quad (45)$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (46)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \quad (47)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (48)$$
$$\text{CartographicExtension} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (49)$$
$$\top \sqsubseteq \forall \text{hasCartographicExtensionValue.xsd:string} \quad (50)$$
$$\text{CartographicExtension} \sqsubseteq \exists \text{hasCartographicExtensionValue.xsd:string} \quad (51)$$
$$\text{CartographicExtension} \sqsubseteq \geq 0 \text{hasCartographicExtensionValue.xsd:string} \quad (52)$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \quad (53)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}.\top \quad (54)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \quad (55)$$
$$\text{CartographicSpecifcations} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \quad (56)$$

2.18.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Domain
5. Range
6. Existential
7. Inverse Existential
8. Inverse Functionality
9. Structural Tautology
10. Range
11. Functionality
12. Inverse Functionality

13. Structural Tautology
14. Range
15. Existential
16. Structural Tautology
17. Domain
18. Range
19. Inverse Existential
20. Inverse Functionality
21. Structural Tautology
22. Range
23. Functionality
24. Inverse Functionality
25. Structural Tautology
26. Range
27. Existential
28. Structural Tautology
29. Domain
30. Range
31. Inverse Existential
32. Inverse Functionality
33. Structural Tautology
34. Range
35. Functionality
36. Inverse Functionality
37. Structural Tautology
38. Range
39. Existential
40. Structural Tautology
41. Domain
42. Range
43. Inverse Existential
44. Inverse Functionality
45. Structural Tautology
46. Range
47. Functionality
48. Inverse Functionality
49. Structural Tautology
50. Range
51. Existential
52. Structural Tautology
53. Range
54. Functionality
55. Inverse Functionality
56. Structural Tautology

2.19 Genre Module

2.19.1 Overview

Genre Module is used to assign a category to the contents of the resource that is helpful in characterizing the style or form of the content. The value may be controlled in which case the Authority is specified, as well as can be uncontrolled.

2.19.2 Formalization

2.19.2.1 Axioms

$$\top \sqsubseteq \forall \mathsf{hasGenre.Genre} \tag{1}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasGenre}^{-}.\top \tag{2}$$

$$\mathsf{MODSItem} \sqsubseteq \geq 0 \mathsf{hasGenre.Genre} \tag{3}$$

$$\top \sqsubseteq \forall \mathsf{isPrimaryInstance.Usage.txt} \tag{4}$$

$$\mathsf{Genre} \sqsubseteq \geq 0 \mathsf{isPrimaryInstance.Usage.txt} \tag{5}$$

$$\top \sqsubseteq \forall \mathsf{hasAuthorityInfo.AuthorityInfo} \tag{6}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasAuthorityInfo}.\top \tag{7}$$

$$\top \sqsubseteq \leq 1 \mathsf{hasAuthorityInfo}^{-}.\top \tag{8}$$

$$\mathsf{Genre} \sqsubseteq \geq 0 \mathsf{hasAuthorityInfo.AuthorityInfo} \tag{9}$$

$$\top \sqsubseteq \forall \mathsf{hasGenreValue.xsd:string} \tag{10}$$

$$\mathsf{Genre} \sqsubseteq \exists \mathsf{hasGenreValue.xsd:string} \tag{11}$$

$$\mathsf{Genre} \sqsubseteq \geq 0 \mathsf{hasGenreValue.xsd:string} \tag{12}$$

$$\top \sqsubseteq \forall \mathsf{hasGenreType.xsd:string} \tag{13}$$

$$\mathsf{Genre} \sqsubseteq \geq 0 \mathsf{hasGenreType.xsd:string} \tag{14}$$

$$\mathsf{Genre} \sqsubseteq \mathsf{ElementInfo} \tag{15}$$

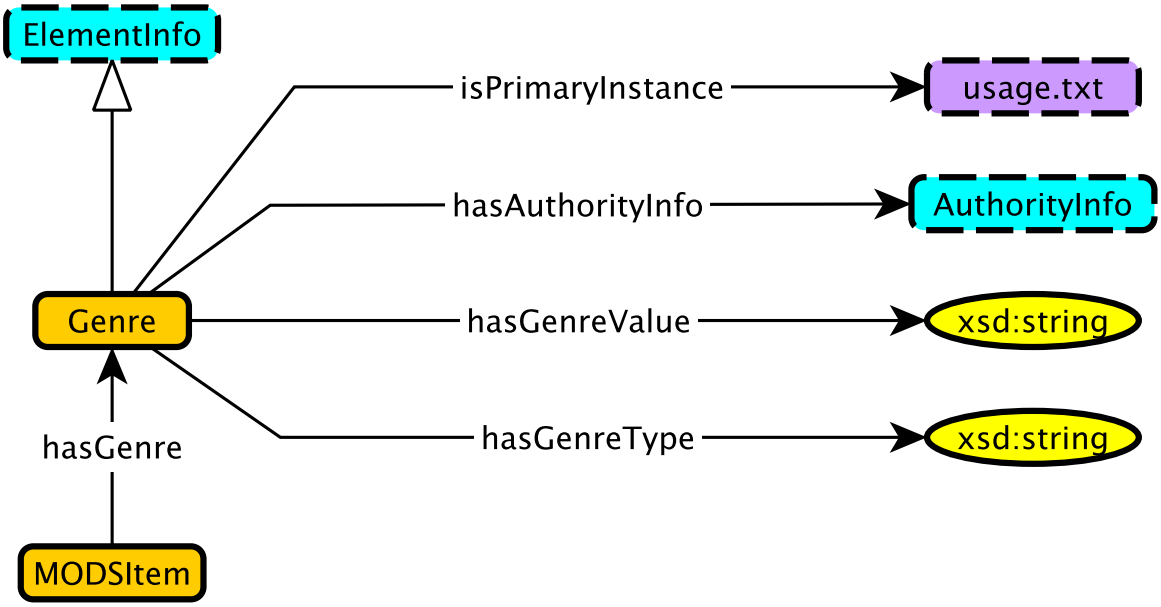

Figure 2.19: The schema diagram for the Genre Module.

$$\mathsf{Genre} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasXlink}.\top) \tag{16}$$

$$\mathsf{Genre} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasNameTitleGroup}.\top) \tag{17}$$

2.19.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Structural Tautology
6. Range
7. Functionality
8. Inverse Functionality
9. Structural Tautology
10. Range
11. Existential
12. Structural Tautology
13. Range
14. Structural Tautology
15. Genre is a sub-class of ElementInfo
16. Genre does not have a hasLinkAttributes property which has a hasXlink property
17. Genre does not have a hasLinkAttributes property which has a hasNameTitleGroup property

2.20 Authority Info Module

2.20.1 Overview

Authority module specifies the Authority which dictates which values are allowed for a specific entity. It can be specified with any combinations of *hasAuthorityName*, *hasAuthorityURI*, and *hasValueURI* properties.

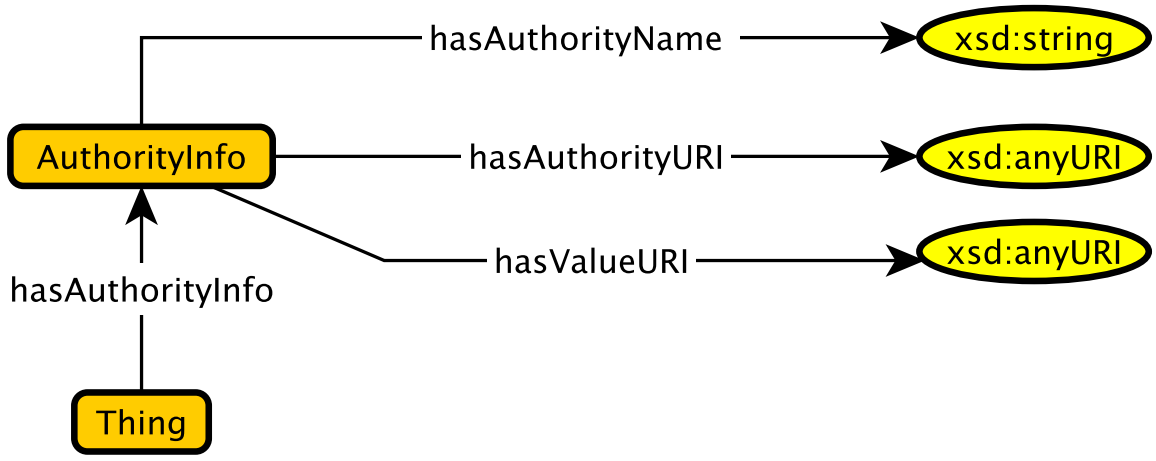

Figure 2.20: The schema diagram for the Authority Info Module.

2.20.2 Formalization

2.20.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \quad (1)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo.}\top \quad (2)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \quad (3)$$
$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \quad (4)$$
$$\top \sqsubseteq \forall \text{hasAuthorityName.xsd:string} \quad (5)$$
$$\text{AuthorityInfo} \sqsubseteq \geq 0 \text{hasAuthorityName.xsd:string} \quad (6)$$
$$\top \sqsubseteq \forall \text{hasAuthorityURI.xsd:anyURI} \quad (7)$$
$$\text{AuthorityInfo} \sqsubseteq \geq 0 \text{hasAuthorityURI.xsd:anyURI} \quad (8)$$
$$\top \sqsubseteq \forall \text{hasValueURI.xsd:anyURI} \quad (9)$$
$$\text{AuthorityInfo} \sqsubseteq \geq 0 \text{hasValueURI.xsd:anyURI} \quad (10)$$

2.20.2.2 Explanations

1. Range
2. Functionality
3. Inverse Functionality
4. Structural Tautology
5. Range
6. Structural Tautology
7. Range
8. Structural Tautology
9. Range
10. Structural Tautology

2.21 Identifier Module

2.21.1 Overview

Identifier Module is used to convey a unique standard number or code such as *DOI* or *ISBN* which identifies a resource. As value it expresses the identifier, in addition it specifies identifier type and its validity.

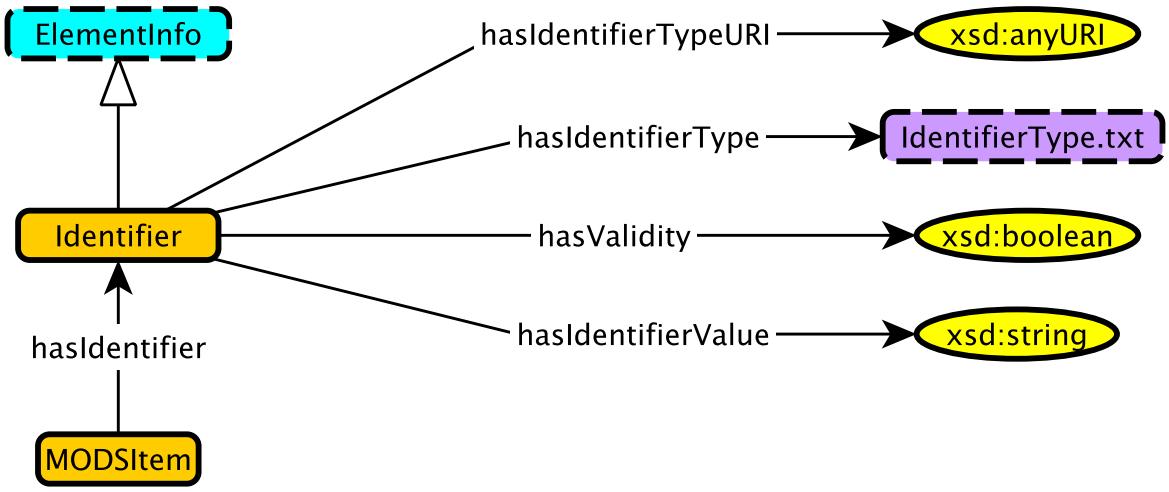

Figure 2.21: The schema diagram for the Identifier Module.

2.21.2 Formalization

2.21.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasIdentifier}.\text{Identifier} \tag{1}$$
$$\top \sqsubseteq \leq 1 \text{hasIdentifier}^{-}.\top \tag{2}$$
$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasIdentifier}.\text{Identifier} \tag{3}$$
$$\top \sqsubseteq \forall \text{hasIdentifierTypeURI}.\text{xsd:anyURI} \tag{4}$$
$$\text{Identifier} \sqsubseteq \geq 0 \text{hasIdentifierTypeURI}.\text{xsd:anyURI} \tag{5}$$
$$\top \sqsubseteq \forall \text{hasIdentifierType}.\text{IdentifierType.txt} \tag{6}$$
$$\text{Identifier} \sqsubseteq \geq 0 \text{hasIdentifierType}.\text{IdentifierType.txt} \tag{7}$$
$$\top \sqsubseteq \forall \text{hasValidity}.\text{xsd:boolean} \tag{8}$$
$$\text{Identifier} \sqsubseteq \geq 0 \text{hasValidity}.\text{xsd:boolean} \tag{9}$$
$$\top \sqsubseteq \forall \text{hasIdentifierValue}.\text{xsd:string} \tag{10}$$
$$\text{Identifier} \sqsubseteq \exists \text{hasIdentifierValue}.\text{xsd:string} \tag{11}$$
$$\text{Identifier} \sqsubseteq \geq 0 \text{hasIdentifierValue}.\text{xsd:string} \tag{12}$$
$$\text{Identifier} \sqsubseteq \text{ElementInfo} \tag{13}$$
$$\text{Identifier} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasXlink}.\top) \tag{14}$$
$$\text{Identifier} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.\top) \tag{15}$$

2.21.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Structural Tautology
6. Range
7. Structural Tautology
8. Range
9. Structural Tautology
10. Range
11. Existential
12. Structural Tautology

13. Identifier is a sub-class of ElementInfo
14. Identifier does not have a hasLinkAttributes property which has a hasXlink property
15. Identifier does not have a hasLinkAttributes property which has a hasNameTitleGroup property

2.22 Origin Info Module

2.22.1 Overview

To specify the details regarding the origin such as Place, Edition, relevant Dates, the Origin Info Module is used. In addition, it is also used to convey information regarding the creator/publisher agent associated with the resource.

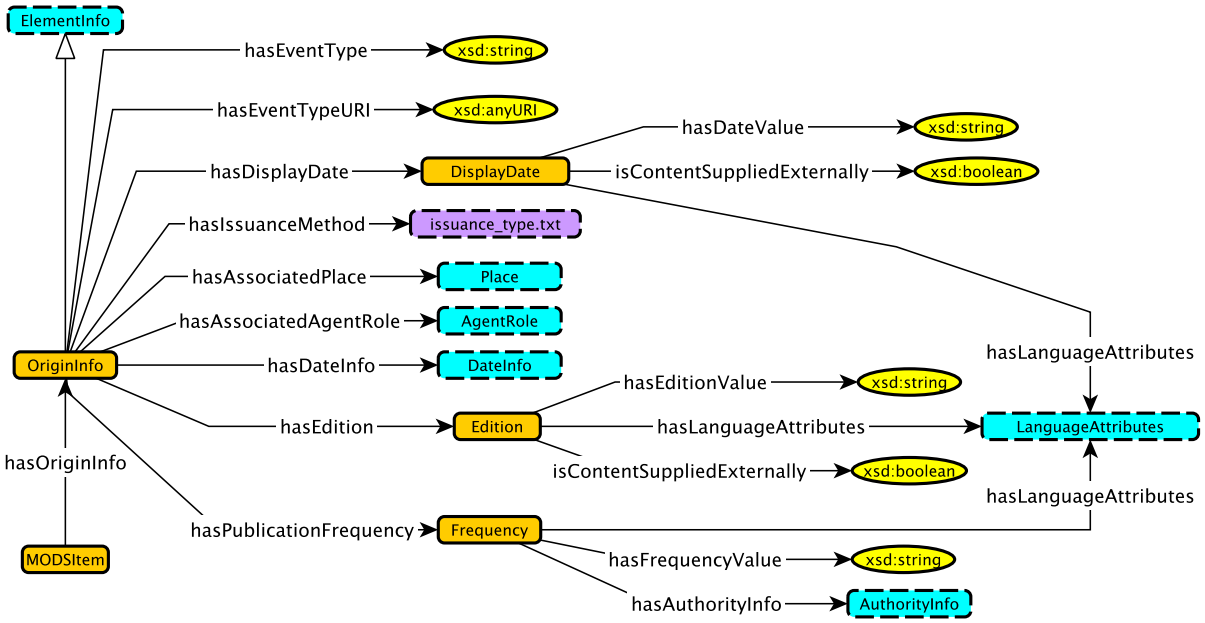

Figure 2.22: The schema diagram for the Origin Info Module.

2.22.2 Formalization

2.22.2.1 Axioms

$$\top \sqsubseteq \forall \mathsf{hasOriginInfo}.\mathsf{OriginInfo} \tag{1}$$
$$\top \sqsubseteq \leq 1\,\mathsf{hasOriginInfo}^{-}.\top \tag{2}$$
$$\mathsf{MODSItem} \sqsubseteq \geq 0\,\mathsf{hasOriginInfo}.\mathsf{OriginInfo} \tag{3}$$
$$\top \sqsubseteq \forall \mathsf{hasEdition}.\mathsf{Edition} \tag{4}$$
$$\mathsf{Edition} \sqsubseteq \exists \mathsf{hasEdition}^{-}.\mathsf{OriginInfo} \tag{5}$$
$$\top \sqsubseteq \leq 1\,\mathsf{hasEdition}.\top \tag{6}$$
$$\top \sqsubseteq \leq 1\,\mathsf{hasEdition}^{-}.\top \tag{7}$$
$$\mathsf{OriginInfo} \sqsubseteq \geq 0\,\mathsf{hasEdition}.\mathsf{Edition} \tag{8}$$
$$\top \sqsubseteq \forall \mathsf{hasEditionValue}.\mathsf{xsd{:}string} \tag{9}$$
$$\mathsf{Edition} \sqsubseteq \exists \mathsf{hasEditionValue}.\mathsf{xsd{:}string} \tag{10}$$

$$\text{Edition} \sqsubseteq \geq 0 \text{hasEditionValue.xsd:string} \tag{11}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{12}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \tag{13}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{14}$$
$$\text{Edition} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \tag{15}$$
$$\top \sqsubseteq \forall \text{isContentSuppliedExternally.xsd:boolean} \tag{16}$$
$$\text{Edition} \sqsubseteq \geq 0 \text{isContentSuppliedExternally.xsd:boolean} \tag{17}$$
$$\top \sqsubseteq \forall \text{hasPublicationFrequency.Frequency} \tag{18}$$
$$\text{Frequency} \sqsubseteq \exists \text{hasPublicationFrequency}^{-}.\text{OriginInfo} \tag{19}$$
$$\top \sqsubseteq \leq 1 \text{hasPublicationFrequency}^{-}.\top \tag{20}$$
$$\text{OriginInfo} \sqsubseteq \geq 0 \text{hasPublicationFrequency.Frequency} \tag{21}$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \tag{22}$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo.}\top \tag{23}$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \tag{24}$$
$$\text{Frequency} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \tag{25}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{26}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \tag{27}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{28}$$
$$\text{Frequency} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \tag{29}$$
$$\top \sqsubseteq \forall \text{hasFrequencyValue.xsd:string} \tag{30}$$
$$\text{Frequency} \sqsubseteq \exists \text{hasFrequencyValue.xsd:string} \tag{31}$$
$$\text{Frequency} \sqsubseteq \geq 0 \text{hasFrequencyValue.xsd:string} \tag{32}$$
$$\top \sqsubseteq \forall \text{hasDisplayDate.DisplayDate} \tag{33}$$
$$\top \sqsubseteq \leq 1 \text{hasDisplayDate.}\top \tag{34}$$
$$\top \sqsubseteq \leq 1 \text{hasDisplayDate}^{-}.\top \tag{35}$$
$$\text{OriginInfo} \sqsubseteq \geq 0 \text{hasDisplayDate.DisplayDate} \tag{36}$$
$$\top \sqsubseteq \forall \text{hasDateValue.xsd:string} \tag{37}$$
$$\text{DisplayDate} \sqsubseteq \exists \text{hasDateValue.xsd:string} \tag{38}$$
$$\text{DisplayDate} \sqsubseteq \geq 0 \text{hasDateValue.xsd:string} \tag{39}$$
$$\top \sqsubseteq \forall \text{isContentSuppliedExternally.xsd:boolean} \tag{40}$$
$$\text{DisplayDate} \sqsubseteq \geq 0 \text{isContentSuppliedExternally.xsd:boolean} \tag{41}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{42}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \tag{43}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{44}$$
$$\text{DisplayDate} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \tag{45}$$
$$\top \sqsubseteq \forall \text{hasAssoicatedPlace.Place} \tag{46}$$
$$\text{Place} \sqsubseteq \exists \text{hasAssoicatedPlace}^{-}.\text{OriginInfo} \tag{47}$$
$$\top \sqsubseteq \leq 1 \text{hasAssoicatedPlace}^{-}.\top \tag{48}$$
$$\text{OriginInfo} \sqsubseteq \geq 0 \text{hasAssoicatedPlace.Place} \tag{49}$$
$$\top \sqsubseteq \forall \text{hasAssociatedAgentRole.AgentRole} \tag{50}$$
$$\top \sqsubseteq \leq 1 \text{hasAssociatedAgentRole}^{-}.\top \tag{51}$$
$$\text{OriginInfo} \sqsubseteq \geq 0 \text{hasAssociatedAgentRole.AgentRole} \tag{52}$$

$$\top \sqsubseteq \forall \text{hasDateInfo.DateInfo} \tag{53}$$

$$\top \sqsubseteq \leq 1 \text{hasDateInfo}^{-}.\top \tag{54}$$

$$\text{OriginInfo} \sqsubseteq \geq 0 \text{hasDateInfo.DateInfo} \tag{55}$$

$$\top \sqsubseteq \forall \text{hasEventType.xsd:string} \tag{56}$$

$$\text{OriginInfo} \sqsubseteq \geq 0 \text{hasEventType.xsd:string} \tag{57}$$

$$\top \sqsubseteq \forall \text{hasEventTypeURI.xsd:anyURI} \tag{58}$$

$$\text{OriginInfo} \sqsubseteq \geq 0 \text{hasEventTypeURI.xsd:anyURI} \tag{59}$$

$$\top \sqsubseteq \forall \text{hasIssuanceMethod.IssuanceType.txt} \tag{60}$$

$$\text{OriginInfo} \sqsubseteq \geq 0 \text{hasIssuanceMethod.IssuanceType.txt} \tag{61}$$

$$\text{OriginInfo} \sqsubseteq \text{ElementInfo} \tag{62}$$

$$\text{OriginInfo} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasXlink}.\top) \tag{63}$$

$$\text{OriginInfo} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.\top) \tag{64}$$

2.22.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Inverse Existential
6. Functionality
7. Inverse Functionality
8. Structural Tautology
9. Range
10. Existential
11. Structural Tautology
12. Range
13. Functionality
14. Inverse Functionality
15. Structural Tautology
16. Range
17. Structural Tautology
18. Range
19. Inverse Existential
20. Inverse Functionality
21. Structural Tautology
22. Range
23. Functionality
24. Inverse Functionality
25. Structural Tautology
26. Range
27. Functionality
28. Inverse Functionality
29. Structural Tautology
30. Range
31. Existential
32. Structural Tautology
33. Range
34. Functionality
35. Inverse Functionality
36. Structural Tautology
37. Range
38. Existential
39. Structural Tautology
40. Range
41. Structural Tautology
42. Range
43. Functionality
44. Inverse Functionality
45. Structural Tautology
46. Range
47. Inverse Existential
48. Inverse Functionality
49. Structural Tautology
50. Range
51. Inverse Functionality
52. Structural Tautology
53. Range
54. Inverse Functionality
55. Structural Tautology
56. Range
57. Structural Tautology
58. Range
59. Structural Tautology
60. Range
61. Structural Tautology
62. OriginInfo is a sub-class of ElementInfo
63. OriginInfo does not have a hasLinkAttributes property which has a hasXlink property
64. OriginInfo does not have a hasLinkAttributes property which has a hasNameTitleGroup property

2.23 Place Module

2.23.1 Overview

Place Module describes any place associated with the resource. In MODS, it comes as a part of the Origin Info Module.

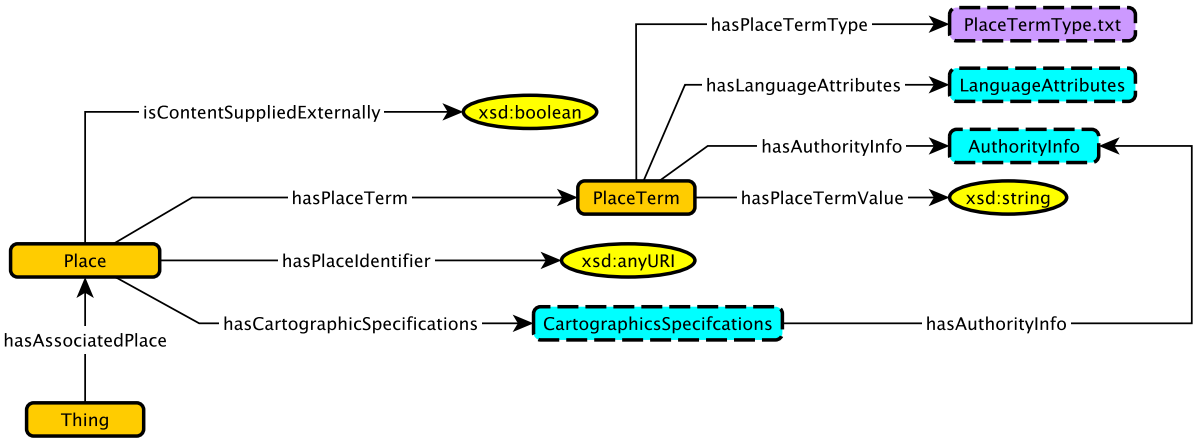

Figure 2.23: The schema diagram for the Place Module.

2.23.2 Formalization

2.23.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasAssociatedPlace}.\text{Place} \tag{1}$$
$$\top \sqsubseteq \leq 1\,\text{hasAssociatedPlace}^{-}.\top \tag{2}$$
$$\top \sqsubseteq \geq 0\,\text{hasAssociatedPlace}.\text{Place} \tag{3}$$
$$\exists \text{hasPlaceTerm}.\top \sqsubseteq \text{Place} \tag{4}$$
$$\top \sqsubseteq \forall \text{hasPlaceTerm}.\text{PlaceTerm} \tag{5}$$
$$\text{Place} \sqsubseteq \exists \text{hasPlaceTerm}.\text{PlaceTerm} \tag{6}$$
$$\text{PlaceTerm} \sqsubseteq \exists \text{hasPlaceTerm}^{-}.\text{Place} \tag{7}$$
$$\text{PlaceTerm} \sqsubseteq \leq 1\,\text{hasPlaceTerm}^{-}.\text{Place} \tag{8}$$
$$\text{Place} \sqsubseteq \geq 0\,\text{hasPlaceTerm}.\text{PlaceTerm} \tag{9}$$
$$\top \sqsubseteq \forall \text{hasPlaceTermType}.\text{PlaceTermType.txt} \tag{10}$$
$$\text{PlaceTerm} \sqsubseteq \geq 0\,\text{hasPlaceTermType}.\text{PlaceTermType.txt} \tag{11}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes}.\text{LanguageAttributes} \tag{12}$$
$$\top \sqsubseteq \leq 1\,\text{hasLanguageAttributes}.\top \tag{13}$$
$$\top \sqsubseteq \leq 1\,\text{hasLanguageAttributes}^{-}.\top \tag{14}$$
$$\text{PlaceTerm} \sqsubseteq \geq 0\,\text{hasLanguageAttributes}.\text{LanguageAttributes} \tag{15}$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo}.\text{AuthorityInfo} \tag{16}$$
$$\top \sqsubseteq \leq 1\,\text{hasAuthorityInfo}.\top \tag{17}$$
$$\top \sqsubseteq \leq 1\,\text{hasAuthorityInfo}^{-}.\top \tag{18}$$

$$\text{PlaceTerm} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \quad (19)$$
$$\top \sqsubseteq \forall \text{hasPlaceTermValue.xsd:string} \quad (20)$$
$$\text{PlaceTerm} \sqsubseteq \exists \text{hasPlaceTermValue.xsd:string} \quad (21)$$
$$\text{PlaceTerm} \sqsubseteq \geq 0 \text{hasPlaceTermValue.xsd:string} \quad (22)$$
$$\top \sqsubseteq \forall \text{hasCartographicSpecifications.CartographicSpecifications} \quad (23)$$
$$\text{CartographicSpecifications} \sqsubseteq \leq 1 \text{hasCartographicSpecifications}^{-}\text{.Place} \quad (24)$$
$$\text{Place} \sqsubseteq \geq 0 \text{hasCartographicSpecifications.CartographicSpecifications} \quad (25)$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \quad (26)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo.} \top \quad (27)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}\text{.} \top \quad (28)$$
$$\text{CartographicSpecifications} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \quad (29)$$
$$\top \sqsubseteq \forall \text{hasPlaceIdentifier.xsd:anyURI} \quad (30)$$
$$\text{Place} \sqsubseteq \geq 0 \text{hasPlaceIdentifier.xsd:anyURI} \quad (31)$$
$$\top \sqsubseteq \forall \text{isContentSuppliedExternally.xsd:boolean} \quad (32)$$
$$\text{Place} \sqsubseteq \geq 0 \text{isContentSuppliedExternally.xsd:boolean} \quad (33)$$

2.23.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Domain
5. Range
6. Existential
7. Inverse Existential
8. Inverse Qualified Scoped Functionality
9. Structural Tautology
10. Range
11. Structural Tautology
12. Range
13. Functionality
14. Inverse Functionality
15. Structural Tautology
16. Range
17. Functionality
18. Inverse Functionality
19. Structural Tautology
20. Range
21. Existential
22. Structural Tautology
23. Range
24. Inverse Qualified Scoped Functionality
25. Structural Tautology
26. Range
27. Functionality
28. Inverse Functionality
29. Structural Tautology
30. Range
31. Structural Tautology
32. Range
33. Structural Tautology

2.24 Type of Resource Module

2.24.1 Overview

Type of Resource Module is used to express information pertaining to the characteristics and general type of content of the resource. A resource can be a still image, moving image, music notation, etc.

2.24.2 Formalization

2.24.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasTypeOfResource.TypeOfResource} \quad (1)$$
$$\top \sqsubseteq \leq 1 \text{hasTypeOfResource}^{-}\text{.} \top \quad (2)$$

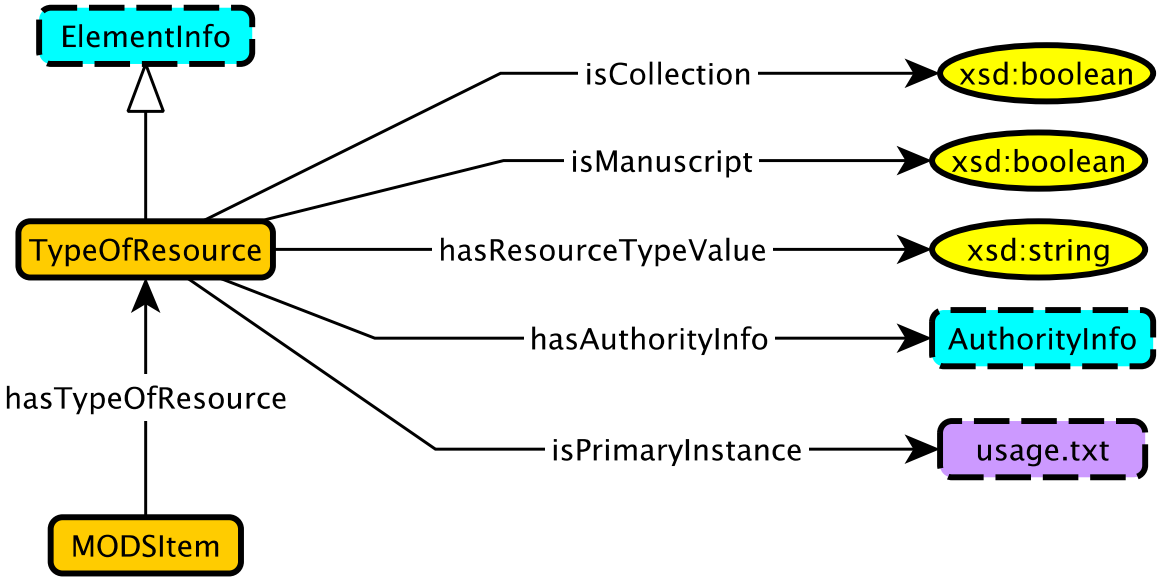

Figure 2.24: The schema diagram for the Type of Resource Module.

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasTypeOfResource.TypeOfResource} \quad (3)$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \quad (4)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo.}\top \quad (5)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \quad (6)$$
$$\text{TypeOfResource} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \quad (7)$$
$$\top \sqsubseteq \forall \text{isPrimaryInstance.Usage.txt} \quad (8)$$
$$\text{TypeOfResource} \sqsubseteq \geq 0 \text{isPrimaryInstance.Usage.txt} \quad (9)$$
$$\top \sqsubseteq \forall \text{isCollection.xsd:boolean} \quad (10)$$
$$\text{TypeOfResource} \sqsubseteq \geq 0 \text{isCollection.xsd:boolean} \quad (11)$$
$$\top \sqsubseteq \forall \text{isManuscript.xsd:boolean} \quad (12)$$
$$\text{TypeOfResource} \sqsubseteq \geq 0 \text{isManuscript.xsd:boolean} \quad (13)$$
$$\top \sqsubseteq \forall \text{hasResourceTypeValue.xsd:string} \quad (14)$$
$$\text{TypeOfResource} \sqsubseteq \exists \text{hasResourceTypeValue.xsd:string} \quad (15)$$
$$\text{TypeOfResource} \sqsubseteq \geq 0 \text{hasResourceTypeValue.xsd:string} \quad (16)$$
$$\text{TypeOfResource} \sqsubseteq \text{ElementInfo} \quad (17)$$
$$\text{TypeOfResource} \sqsubseteq \neg(\exists \text{hasLinkAttributes.}\exists \text{hasXlink.}\top) \quad (18)$$
$$\text{TypeOfResource} \sqsubseteq \neg(\exists \text{hasLinkAttributes.}\exists \text{hasNameTitleGroup.}\top) \quad (19)$$

2.24.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Functionality
6. Inverse Functionality
7. Structural Tautology
8. Range

9. Structural Tautology
10. Range
11. Structural Tautology
12. Range
13. Structural Tautology
14. Range
15. Existential
16. Structural Tautology
17. TypeOfResource is a sub-class of ElementInfo
18. TypeOfResource does not have a hasLinkAttributes property which has a hasXlink property
19. TypeOfResource does not have a hasLinkAttributes property which has a hasNameTitleGroup property

2.25 Table of Contents Module

2.25.1 Overview

Table of Contents module is simply used to represent the table of contents of the actual resouce.

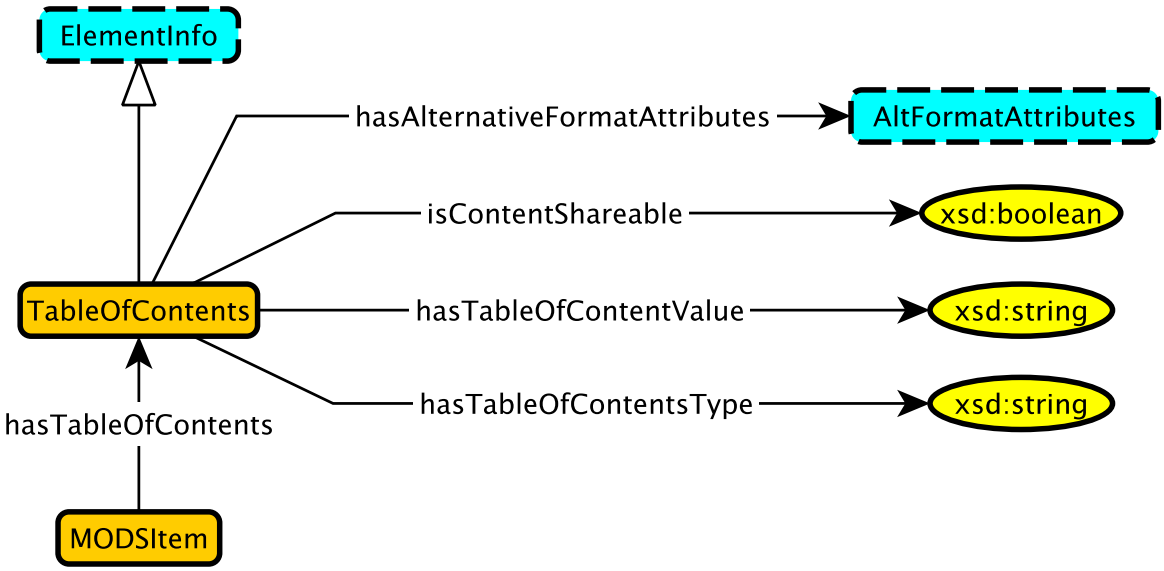

Figure 2.25: The schema diagram for the Table of Contents Module.

2.25.2 Formalization

2.25.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasTableOfContent}.\text{TableOfContents} \quad (1)$$

$$\top \sqsubseteq \leq 1 \text{hasTableOfContent}^{-}.\top \quad (2)$$

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasTableOfContent}.\text{TableOfContents} \quad (3)$$

$$\top \sqsubseteq \forall \text{hasAlternativeFormatAttributes}.\text{AlternativeFormatAttributes} \quad (4)$$

$$\top \sqsubseteq \leq 1 \text{hasAlternativeFormatAttributes}.\top \quad (5)$$

$$\top \sqsubseteq \leq 1 \text{hasAlternativeFormatAttributes}^{-}.\top \quad (6)$$

$$\text{TableOfContents} \sqsubseteq \geq 0 \text{hasAlternativeFormatAttributes}.\text{AlternativeFormatAttributes} \quad (7)$$

$$\top \sqsubseteq \forall \text{isContentShareable}.\text{xsd:boolean} \quad (8)$$

$$\text{TableOfContents} \sqsubseteq \geq 0 \text{isContentShareable.xsd:boolean} \quad (9)$$
$$\top \sqsubseteq \forall \text{hasTableOfContentValue.xsd:string} \quad (10)$$
$$\text{TableOfContents} \sqsubseteq \exists \text{hasTableOfContentValue.xsd:string} \quad (11)$$
$$\text{TableOfContents} \sqsubseteq \geq 0 \text{hasTableOfContentValue.xsd:string} \quad (12)$$
$$\top \sqsubseteq \forall \text{hasTableOfContentsType.xsd:string} \quad (13)$$
$$\text{TableOfContents} \sqsubseteq \geq 0 \text{hasTableOfContentsType.xsd:string} \quad (14)$$
$$\text{TableOfContents} \sqsubseteq \text{ElementInfo} \quad (15)$$
$$\text{TableOfContents} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.\top) \quad (16)$$

2.25.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Functionality
6. Inverse Functionality
7. Structural Tautology
8. Range
9. Structural Tautology
10. Range
11. Existential
12. Structural Tautology
13. Range
14. Structural Tautology
15. TableOfContents is sub-class of ElementInfo
16. TableOfContents does not have a hasLinkAttributes property which has a hasNameTitleGroup property

2.26 Access Condition Module

2.26.1 Overview

Various restrictions, rights to edit or publish copies of the resource are expressed through the Access Condition Module.

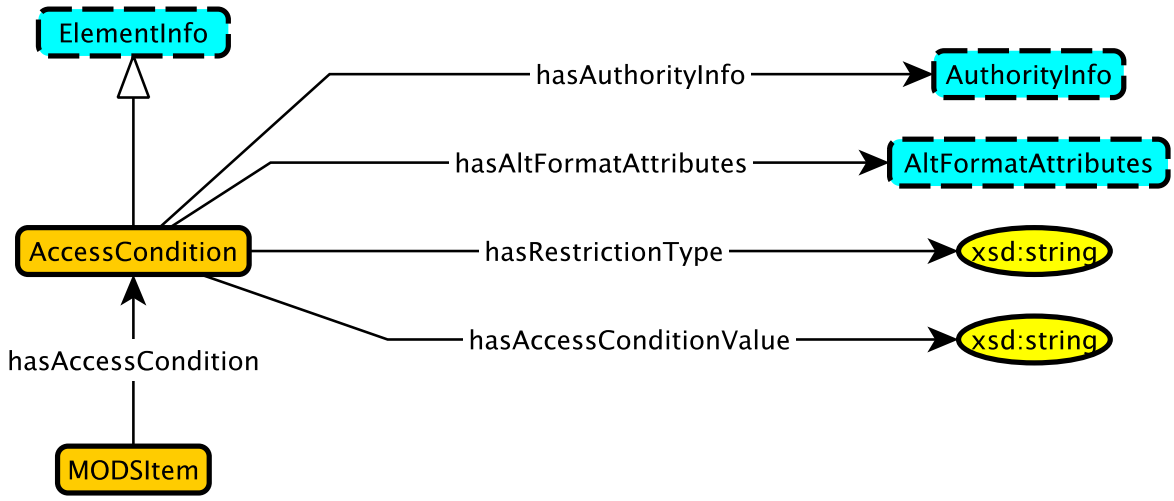

Figure 2.26: The schema diagram for the Access Condition Module.

2.26.2 Formalization

2.26.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasAccessCondition.AccessCondition} \quad (1)$$
$$\top \sqsubseteq \leq 1 \text{hasAccessCondition}^{-}.\top \quad (2)$$
$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasAccessCondition.AccessCondition} \quad (3)$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \quad (4)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}.\top \quad (5)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \quad (6)$$
$$\text{AccessCondition} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \quad (7)$$
$$\top \sqsubseteq \forall \text{hasAltFormatAttributes.AltFormatAttributes} \quad (8)$$
$$\top \sqsubseteq \leq 1 \text{hasAltFormatAttributes}.\top \quad (9)$$
$$\top \sqsubseteq \leq 1 \text{hasAltFormatAttributes}^{-}.\top \quad (10)$$
$$\text{AccessCondition} \sqsubseteq \geq 0 \text{hasAltFormatAttributes.AltFormatAttributes} \quad (11)$$
$$\top \sqsubseteq \forall \text{hasRestrictionType.xsd:string} \quad (12)$$
$$\text{AccessCondition} \sqsubseteq \geq 0 \text{hasRestrictionType.xsd:string} \quad (13)$$
$$\top \sqsubseteq \forall \text{hasAccessConditionValue.xsd:string} \quad (14)$$
$$\text{AccessCondition} \sqsubseteq \exists \text{hasAccessConditionValue.xsd:string} \quad (15)$$
$$\text{AccessCondition} \sqsubseteq \geq 0 \text{hasAccessConditionValue.xsd:string} \quad (16)$$
$$\text{AccessCondition} \sqsubseteq \text{ElementInfo} \quad (17)$$
$$\text{AccessCondition} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.\top) \quad (18)$$

2.26.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Functionality
6. Inverse Functionality
7. Structural Tautology
8. Range
9. Functionality
10. Inverse Functionality
11. Structural Tautology
12. Range
13. Structural Tautology
14. Range
15. Existential
16. Structural Tautology
17. AccessCondition is a sub-class of ElementInfo
18. AccessCondition does not have a hasLinkAttributes property which has a hasNameTitleGroup property

2.27 Part of Resource Module

2.27.1 Overview

Part of Resource Module is used when the goal is to describe a part of a larger resource. For instance, if the resource under description is a book, this module can be used to refer to a chapter with the starting and ending page numbers as extent.

Figure 2.27: The schema diagram for the Part of Resource Module.

2.27.2 Formalization

2.27.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasPartOfReource}.\text{PartOfReource} \tag{1}$$

$$\top \sqsubseteq \leq 1\,\text{hasPartOfReource}^{-}.\top \tag{2}$$

$$\text{MODSItem} \sqsubseteq \geq 0\,\text{hasPartOfReource}.\text{PartOfReource} \tag{3}$$

$$\top \sqsubseteq \forall \text{hasRelatedPartDetail}.\text{RelatedPartDetail} \tag{4}$$

$$\top \sqsubseteq \leq 1\,\text{RelatedPartDetail}^{-}.\top \tag{5}$$

$$\text{PartOfReource} \sqsubseteq \geq 0\,\text{hasRelatedPartDetail}.\text{RelatedPartDetail} \tag{6}$$

$$\top \sqsubseteq \forall \text{hasDetailType}.\text{xsd:string} \tag{7}$$

$$\text{RelatedPartDetail} \sqsubseteq \geq 0\,\text{hasDetailType}.\text{xsd:string} \tag{8}$$

$$\top \sqsubseteq \forall \text{hasHierarchicalLevel}.\text{xsd:int} \tag{9}$$

$$\text{RelatedPartDetail} \sqsubseteq \geq 0\,\text{hasHierarchicalLevel}.\text{xsd:int} \tag{10}$$

$$\top \sqsubseteq \forall \text{hasPartNumber}.\text{PartNumber} \tag{11}$$

$$\top \sqsubseteq \leq 1\,\text{hasPartNumber}^{-}.\top \tag{12}$$

$$\text{RelatedPartDetail} \sqsubseteq \geq 0\,\text{hasPartNumber}.\text{PartNumber} \tag{13}$$

$$\top \sqsubseteq \forall \text{hasPartNumberValue.xsd:int} \tag{14}$$
$$\text{PartNumber} \sqsubseteq \exists \text{hasPartNumberValue.xsd:int} \tag{15}$$
$$\text{PartNumber} \sqsubseteq \geq 0 \text{hasPartNumberValue.xsd:int} \tag{16}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{17}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \tag{18}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{19}$$
$$\text{PartNumber} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \tag{20}$$
$$\top \sqsubseteq \forall \text{hasCaption.Caption} \tag{21}$$
$$\top \sqsubseteq \leq 1 \text{hasCaption}^{-}.\top \tag{22}$$
$$\text{RelatedPartDetail} \sqsubseteq \geq 0 \text{hasCaption.Caption} \tag{23}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{24}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \tag{25}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{26}$$
$$\text{Caption} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \tag{27}$$
$$\top \sqsubseteq \forall \text{hasCaptionValue.xsd:string} \tag{28}$$
$$\text{Caption} \sqsubseteq \exists \text{hasCaptionValue.xsd:string} \tag{29}$$
$$\text{Caption} \sqsubseteq \geq 0 \text{hasCaptionValue.xsd:string} \tag{30}$$
$$\top \sqsubseteq \forall \text{hasPartTitle.PartTitle} \tag{31}$$
$$\top \sqsubseteq \leq 1 \text{hasPartTitle}^{-}.\top \tag{32}$$
$$\text{RelatedPartDetail} \sqsubseteq \geq 0 \text{hasPartTitle.PartTitle} \tag{33}$$
$$\top \sqsubseteq \forall \text{hasPartTitleValue.xsd:string} \tag{34}$$
$$\text{PartTitle} \sqsubseteq \exists \text{hasPartTitleValue.xsd:string} \tag{35}$$
$$\text{PartTitle} \sqsubseteq \geq 0 \text{hasPartTitleValue.xsd:string} \tag{36}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{37}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes.}\top \tag{38}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{39}$$
$$\text{PartTitle} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \tag{40}$$
$$\top \sqsubseteq \forall \text{hasMeasuredExtent.MeasuredExtentExtent} \tag{41}$$
$$\top \sqsubseteq \leq 1 \text{hasMeasuredExtent}^{-}.\top \tag{42}$$
$$\text{PartOfReource} \sqsubseteq \geq 0 \text{hasMeasuredExtent.MeasuredExtent} \tag{43}$$
$$\top \sqsubseteq \forall \text{hasUnit.xsd:string} \tag{44}$$
$$\text{MeasuredExtent} \sqsubseteq \geq 0 \text{hasUnit.xsd:string} \tag{45}$$
$$\top \sqsubseteq \forall \text{hasExtentStart.ExtentStart} \tag{46}$$
$$\text{MeasuredExtent} \sqsubseteq \exists \text{hasExtentStart.ExtentStart} \tag{47}$$
$$\text{ExtentStart} \sqsubseteq \exists \text{hasExtentStartValue}^{-}.\text{ExtentStart} \tag{48}$$
$$\top \sqsubseteq \leq 1 \text{hasExtentStartValue.}\top \tag{49}$$
$$\top \sqsubseteq \leq 1 \text{hasExtentStartValue}^{-}.\top \tag{50}$$
$$\text{MeasuredExtent} \sqsubseteq \geq 0 \text{hasExtentStart.ExtentStart} \tag{51}$$
$$\top \sqsubseteq \forall \text{hasExtentStartValue.xsd:int} \tag{52}$$
$$\text{ExtentStart} \sqsubseteq \exists \text{hasExtentStartValue.xsd:int} \tag{53}$$
$$\text{ExtentStart} \sqsubseteq \geq 0 \text{hasExtentStartValue.xsd:int} \tag{54}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \tag{55}$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \tag{56}$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{57}$$

$$\text{ExtentStart} \sqsubseteq \geq 0 \text{hasLanguageAttributes}.\text{LanguageAttributes} \tag{58}$$

$$\top \sqsubseteq \forall \text{hasExtentEnd}.\text{ExtentEnd} \tag{59}$$

$$\text{MeasuredExtent} \sqsubseteq \exists \text{hasExtentEnd}.\text{ExtentEnd} \tag{60}$$

$$\text{ExtentEnd} \sqsubseteq \exists \text{hasExtentEndValue}^{-}.\text{MeasuredExtent} \tag{61}$$

$$\top \sqsubseteq \leq 1 \text{hasExtentEndValue}.\top \tag{62}$$

$$\top \sqsubseteq \leq 1 \text{hasExtentEndValue}^{-}.\top \tag{63}$$

$$\text{MeasuredExtent} \sqsubseteq \geq 0 \text{hasExtentEnd}.\text{ExtentEnd} \tag{64}$$

$$\top \sqsubseteq \forall \text{hasExtentEndValue.xsd:int} \tag{65}$$

$$\text{ExtentEnd} \sqsubseteq \exists \text{hasExtentEndValue.xsd:int} \tag{66}$$

$$\text{ExtentEnd} \sqsubseteq \geq 0 \text{hasExtentEndValue.xsd:int} \tag{67}$$

$$\top \sqsubseteq \forall \text{hasLanguageAttributes}.\text{LanguageAttributes} \tag{68}$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \tag{69}$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{70}$$

$$\text{ExtentEnd} \sqsubseteq \geq 0 \text{hasLanguageAttributes}.\text{LanguageAttributes} \tag{71}$$

$$\top \sqsubseteq \forall \text{hasTotalExtent}.\text{TotalExtent} \tag{72}$$

$$\text{TotalExtent} \sqsubseteq \exists \text{hasTotalExtentValue}^{-}.\text{MeasuredExtent} \tag{73}$$

$$\top \sqsubseteq \leq 1 \text{hasTotalExtentValue}.\top \tag{74}$$

$$\top \sqsubseteq \leq 1 \text{hasTotalExtentValue}^{-}.\top \tag{75}$$

$$\text{MeasuredExtent} \sqsubseteq \geq 0 \text{hasTotalExtent}.\text{TotalExtent} \tag{76}$$

$$\top \sqsubseteq \forall \text{hasTotalExtentValue.xsd:int} \tag{77}$$

$$\text{TotalExtent} \sqsubseteq \exists \text{hasTotalExtentValue.xsd:int} \tag{78}$$

$$\text{TotalExtent} \sqsubseteq \geq 0 \text{hasTotalExtentValue.xsd:int} \tag{79}$$

$$\top \sqsubseteq \forall \text{hasLanguageAttributes}.\text{LanguageAttributes} \tag{80}$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \tag{81}$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{82}$$

$$\text{TotalExtent} \sqsubseteq \geq 0 \text{hasLanguageAttributes}.\text{LanguageAttributes} \tag{83}$$

$$\top \sqsubseteq \forall \text{hasListOfUnits}.\text{ListOfUnits} \tag{84}$$

$$\text{ListOfUnits} \sqsubseteq \exists \text{hasListOfUnits}^{-}.\text{Extent} \tag{85}$$

$$\top \sqsubseteq \leq 1 \text{hasListOfUnits}^{-}.\top \tag{86}$$

$$\text{PhysicalExtent} \sqsubseteq \geq 0 \text{hasListOfUnits}.\text{ListOfUnits} \tag{87}$$

$$\top \sqsubseteq \forall \text{hasListOfUnitsValue.xsd:string} \tag{88}$$

$$\text{ListOfUnits} \sqsubseteq \exists \text{hasListOfUnitsValue.xsd:string} \tag{89}$$

$$\text{ListOfUnits} \sqsubseteq \geq 0 \text{hasListOfUnitsValue.xsd:string} \tag{90}$$

$$\top \sqsubseteq \forall \text{hasLanguageAttributes}.\text{LanguageAttributes} \tag{91}$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \tag{92}$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{93}$$

$$\text{ListOfUnits} \sqsubseteq \geq 0 \text{hasLanguageAttributes}.\text{LanguageAttributes} \tag{94}$$

$$\top \sqsubseteq \forall \text{hasRelevantDateInfo}.\text{DateInfo} \tag{95}$$

$$\top \sqsubseteq \leq 1 \text{hasRelevantDateInfo}^{-}.\top \tag{96}$$

$$\text{PartOfReource} \sqsubseteq \geq 0 \text{hasRelevantDateInfo}.\text{DateInfo} \tag{97}$$

$$\top \sqsubseteq \forall \mathsf{hasText}.\mathsf{Text} \tag{98}$$
$$\top \sqsubseteq \leq 1\,\mathsf{hasText}^{-}.\top \tag{99}$$
$$\mathsf{PartOfReource} \sqsubseteq \geq 0\,\mathsf{hasText}.\mathsf{Text} \tag{100}$$
$$\top \sqsubseteq \forall \mathsf{hasDisplayLabel}.\mathsf{xsd{:}string} \tag{101}$$
$$\mathsf{Text} \sqsubseteq \geq 0\,\mathsf{hasDisplayLabel}.\mathsf{xsd{:}string} \tag{102}$$
$$\top \sqsubseteq \forall \mathsf{hasLanguageAttributes}.\mathsf{LanguageAttributes} \tag{103}$$
$$\top \sqsubseteq \leq 1\,\mathsf{hasLanguageAttributes}.\top \tag{104}$$
$$\top \sqsubseteq \leq 1\,\mathsf{hasLanguageAttributes}^{-}.\top \tag{105}$$
$$\mathsf{Text} \sqsubseteq \geq 0\,\mathsf{hasLanguageAttributes}.\mathsf{LanguageAttributes} \tag{106}$$
$$\top \sqsubseteq \forall \mathsf{hasTextType}.\mathsf{xsd{:}string} \tag{107}$$
$$\mathsf{Text} \sqsubseteq \geq 0\,\mathsf{hasTextType}.\mathsf{xsd{:}string} \tag{108}$$
$$\top \sqsubseteq \forall \mathsf{hasTextValue}.\mathsf{xsd{:}string} \tag{109}$$
$$\mathsf{Text} \sqsubseteq \exists \mathsf{hasTextValue}.\mathsf{xsd{:}string} \tag{110}$$
$$\mathsf{Text} \sqsubseteq \geq 0\,\mathsf{hasTextValue}.\mathsf{xsd{:}string} \tag{111}$$
$$\top \sqsubseteq \forall \mathsf{hasResourcePartType}.\mathsf{xsd{:}string} \tag{112}$$
$$\mathsf{PartOfReource} \sqsubseteq \geq 0\,\mathsf{hasResourcePartType}.\mathsf{xsd{:}string} \tag{113}$$
$$\top \sqsubseteq \forall \mathsf{hasOrder}.\mathsf{xsd{:}int} \tag{114}$$
$$\mathsf{PartOfReource} \sqsubseteq \geq 0\,\mathsf{hasOrder}.\mathsf{xsd{:}int} \tag{115}$$
$$\mathsf{PartOfReource} \sqsubseteq \mathsf{ElementInfo} \tag{116}$$
$$\mathsf{PartOfReource} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasXlink}.\top) \tag{117}$$
$$\mathsf{PartOfReource} \sqsubseteq \neg(\exists \mathsf{hasLinkAttributes}.\exists \mathsf{hasNameTitleGroup}.\top) \tag{118}$$

2.27.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Inverse Functionality
6. Structural Tautology
7. Range
8. Structural Tautology
9. Range
10. Structural Tautology
11. Range
12. Inverse Functionality
13. Structural Tautology
14. Range
15. Existential
16. Structural Tautology
17. Range
18. Functionality
19. Inverse Functionality
20. Structural Tautology
21. Range
22. Inverse Functionality
23. Structural Tautology
24. Range
25. Functionality
26. Inverse Functionality
27. Structural Tautology
28. Range
29. Existential
30. Structural Tautology
31. Range
32. Inverse Functionality
33. Structural Tautology
34. Range
35. Existential
36. Structural Tautology
37. Range
38. Functionality
39. Inverse Functionality
40. Structural Tautology
41. Range
42. Inverse Functionality
43. Structural Tautology
44. Range
45. Structural Tautology
46. Range
47. Existential
48. Inverse Existential
49. Functionality
50. Inverse Functionality
51. Structural Tautology

52. Range
53. Existential
54. Structural Tautology
55. Range
56. Functionality
57. Inverse Functionality
58. Structural Tautology
59. Range
60. Existential
61. Inverse Existential
62. Functionality
63. Inverse Functionality
64. Structural Tautology
65. Range
66. Existential
67. Structural Tautology
68. Range
69. Functionality
70. Inverse Functionality
71. Structural Tautology
72. Range
73. Inverse Existential
74. Functionality
75. Inverse Functionality
76. Structural Tautology
77. Range
78. Existential
79. Structural Tautology
80. Range
81. Functionality
82. Inverse Functionality
83. Structural Tautology
84. Range
85. Inverse Existential
86. Inverse Functionality
87. Structural Tautology
88. Range
89. Existential
90. Structural Tautology
91. Range
92. Functionality
93. Inverse Functionality
94. Structural Tautology
95. Range
96. Inverse Functionality
97. Structural Tautology
98. Range
99. Inverse Functionality
100. Structural Tautology
101. Range
102. Structural Tautology
103. Range
104. Functionality
105. Inverse Functionality
106. Structural Tautology
107. Range
108. Structural Tautology
109. Range
110. Existential
111. Structural Tautology
112. Range
113. Structural Tautology
114. Range
115. Structural Tautology
116. PartOfResource is a sub-class of ElementInfo
117. AccessCondition does not have a hasLinkAttributes property which has a hasXlink property
118. AccessCondition does not have a hasLinkAttributes property which has a hasNameTitleGroup property

2.28 Agent Role Module

2.28.1 Overview

The Agent Role Module conveys information regarding the Agent Roles which an Agent can assume. It is designed such that it can capture an Agent performing different roles under different names with the *hasRoleUnderName* property.

2.28.2 Formalization

2.28.2.1 Axioms

$$\top \sqsubseteq \forall \mathsf{providesAgentRole.AgentRole} \tag{1}$$

$$\top \sqsubseteq \leq 1 \mathsf{providesAgentRole}^{-}.\top \tag{2}$$

$$\top \sqsubseteq \geq 0 \mathsf{providesAgentRole.AgentRole} \tag{3}$$

$$\exists \mathsf{hasRoleUnderName.Name} \sqsubseteq \mathsf{AgentRole} \tag{4}$$

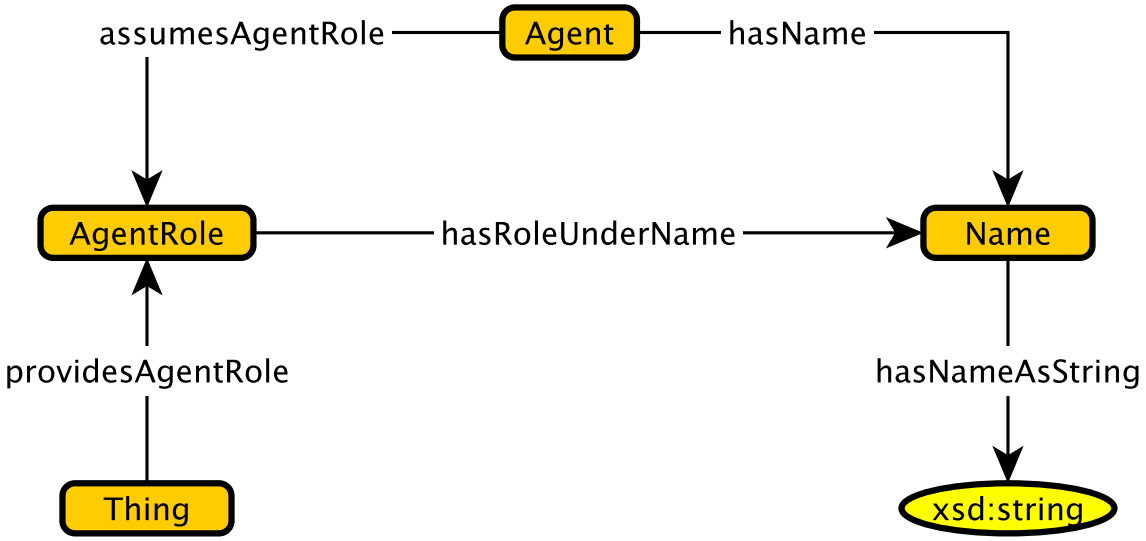

Figure 2.28: The schema diagram for the Agent Role Module.

$$\top \sqsubseteq \forall \text{hasRoleUnderName.Name} \tag{5}$$
$$\text{AgentRole} \sqsubseteq \geq 0 \text{hasRoleUnderName.Name} \tag{6}$$
$$\exists \text{assumesAgentRole.AgentRole} \sqsubseteq \text{Agent} \tag{7}$$
$$\top \sqsubseteq \forall \text{assumesAgentRole.AgentRole} \tag{8}$$
$$\text{AgentRole} \sqsubseteq \exists \text{assumesAgentRole}^{-}\text{.Agent} \tag{9}$$
$$\text{AgentRole} \sqsubseteq \leq 1 \text{assumesAgentRole}^{-}\text{.Agent} \tag{10}$$
$$\text{Agent} \sqsubseteq \geq 0 \text{assumesAgentRole.AgentRole} \tag{11}$$
$$\exists \text{hasName.} \top \sqsubseteq \text{Agent} \tag{12}$$
$$\top \sqsubseteq \forall \text{hasName.Name} \tag{13}$$
$$\text{Agent} \sqsubseteq \exists \text{hasName.Name} \tag{14}$$
$$\text{Name} \sqsubseteq \exists \text{hasName}^{-}\text{.Agent} \tag{15}$$
$$\text{Name} \sqsubseteq \leq 1 \text{hasName}^{-}\text{.Agent} \tag{16}$$
$$\text{Agent} \sqsubseteq \geq 0 \text{hasName.Name} \tag{17}$$
$$\top \sqsubseteq \forall \text{hasNameAsString.xsd:string} \tag{18}$$
$$\text{Name} \sqsubseteq \exists \text{hasNameAsString.xsd:string} \tag{19}$$
$$\text{Name} \sqsubseteq \geq 0 \text{hasNameAsString.xsd:string} \tag{20}$$
$$\text{assumesAgentRole} \circ \text{hasRoleUnderName} \sqsubseteq \text{hasName} \tag{21}$$
$$\text{hasName} \circ \text{hasRoleUnderName}^{-} \sqsubseteq \text{assumesAgentRole} \tag{22}$$

2.28.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Scoped Domain
5. Range
6. Structural Tautology

7. Scoped Domain
8. Range
9. Inverse Existential
10. Inverse Qualified Scoped Functionality
11. Structural Tautology
12. Domain
13. Range
14. Existential
15. Inverse Existential
16. Inverse Qualified Scoped Functionality
17. Structural Tautology
18. Range
19. Existential
20. Structural Tautology
21. Role Chain
22. Role Chain

2.29 Record Info Module

2.29.1 Overview

Record Info Module primarily describes the provenance of metadata such as source, creation date, last change date etc.

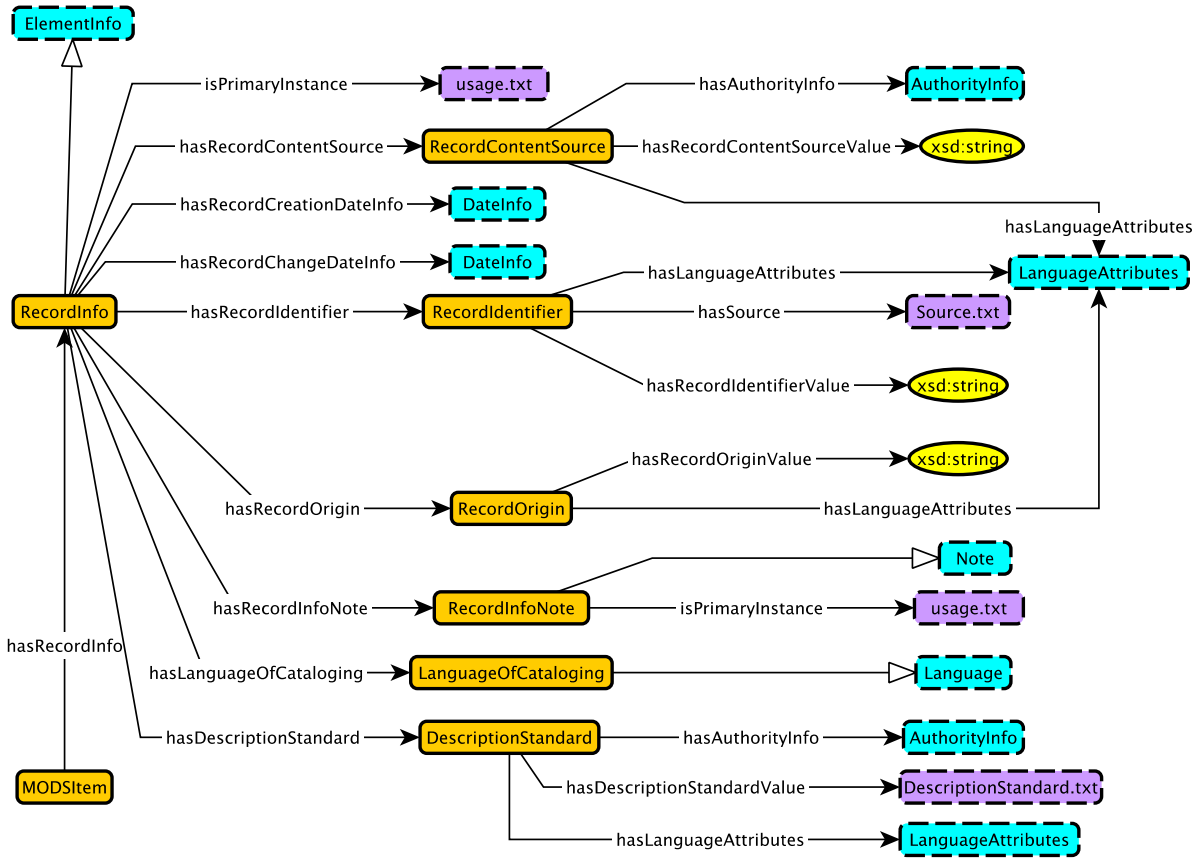

Figure 2.29: The schema diagram for the Record Info Module.

2.29.2 Formalization

2.29.2.1 Axioms

$$\top \sqsubseteq \forall \mathsf{hasRecordInfo}.\mathsf{RecordInfo} \tag{1}$$

$$\top \sqsubseteq \leq 1 \text{hasRecordInfo}^{-}.\top \quad (2)$$

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasRecordInfo.RecordInfo} \quad (3)$$

$$\exists \text{hasRecordContentSource}.\top \sqsubseteq \text{RecordInfo} \quad (4)$$

$$\top \sqsubseteq \forall \text{hasRecordContentSource.RecordContentSource} \quad (5)$$

$$\text{RecordContentSource} \sqsubseteq \exists B \text{hasRecordContentSource}^{-}.\text{RecordInfo} \quad (6)$$

$$\top \sqsubseteq \leq 1 \text{hasRecordContentSource}^{-}.\top \quad (7)$$

$$\text{RecordInfo} \sqsubseteq \geq 0 \text{hasRecordContentSource.RecordContentSource} \quad (8)$$

$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \quad (9)$$

$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}.\top \quad (10)$$

$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \quad (11)$$

$$\text{RecordContentSource} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \quad (12)$$

$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (13)$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \quad (14)$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (15)$$

$$\text{RecordContentSource} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (16)$$

$$\top \sqsubseteq \forall \text{hasRecordContentSourceValue.xsd:string} \quad (17)$$

$$\text{RecordContentSource} \sqsubseteq \exists \text{hasRecordContentSourceValue.xsd:string} \quad (18)$$

$$\text{RecordContentSource} \sqsubseteq \geq 0 \text{hasRecordContentSourceValue.xsd:string} \quad (19)$$

$$\exists \text{hasRecordCreationDateInfo}.\top \sqsubseteq \text{RecordInfo} \quad (20)$$

$$\top \sqsubseteq \forall \text{hasRecordCreationDateInfo.DateInfo} \quad (21)$$

$$\text{DateInfo} \sqsubseteq \exists \text{hasRecordCreationDateInfo}^{-}.\text{RecordInfo} \quad (22)$$

$$\top \sqsubseteq \leq 1 \text{hasRecordCreationDateInfo}.\top \quad (23)$$

$$\top \sqsubseteq \leq 1 \text{hasRecordCreationDateInfo}^{-}.\top \quad (24)$$

$$\text{RecordInfo} \sqsubseteq \geq 0 \text{hasRecordCreationDateInfo.DateInfo} \quad (25)$$

$$\exists \text{hasRecordChangeDateInfo}.\top \sqsubseteq \text{RecordInfo} \quad (26)$$

$$\top \sqsubseteq \forall \text{hasRecordChangeDateInfo.DateInfo} \quad (27)$$

$$\text{DateInfo} \sqsubseteq \exists \text{hasRecordChangeDateInfo}^{-}.\text{RecordInfo} \quad (28)$$

$$\top \sqsubseteq \leq 1 \text{hasRecordChangeDateInfo}^{-}.\top \quad (29)$$

$$\text{RecordInfo} \sqsubseteq \geq 0 \text{hasRecordChangeDateInfo.DateInfo} \quad (30)$$

$$\exists \text{hasRecordIdentifier}.\top \sqsubseteq \text{RecordInfo} \quad (31)$$

$$\top \sqsubseteq \forall \text{hasRecordIdentifier.RecordIdentifier} \quad (32)$$

$$\text{RecordIdentifier} \sqsubseteq \exists \text{hasRecordIdentifier}^{-}.\text{Record} \quad (33)$$

$$\top \sqsubseteq \leq 1 \text{hasRecordIdentifier}^{-}.\top \quad (34)$$

$$\text{Record} \sqsubseteq \geq 0 \text{hasRecordIdentifier.RecordIdentifier} \quad (35)$$

$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (36)$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \quad (37)$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (38)$$

$$\text{RecordIdentifier} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (39)$$

$$\top \sqsubseteq \forall \text{hasSource.Source.txt} \quad (40)$$

$$\text{RecordIdentifier} \sqsubseteq \geq 0 \text{hasSource.Source.txt} \quad (41)$$

$$\top \sqsubseteq \forall \text{hasRecordIdentifierValue.xsd:string} \quad (42)$$

$$\text{RecordIdentifier} \sqsubseteq \exists \text{hasRecordIdentifierValue.xsd:string} \quad (43)$$

$$\text{RecordIdentifier} \sqsubseteq \geq 0 \text{hasRecordIdentifierValue.xsd:string} \quad (44)$$
$$\exists \text{hasRecordOrigin}.\top \sqsubseteq \text{RecordInfo} \quad (45)$$
$$\top \sqsubseteq \forall \text{hasRecordOrigin.RecordOrigin} \quad (46)$$
$$\text{RecordOrigin} \sqsubseteq \exists \text{hasRecordOrigin}^{-}.\text{RecordInfo} \quad (47)$$
$$\top \sqsubseteq \leq 1 \text{hasRecordOrigin}^{-}.\top \quad (48)$$
$$\text{RecordInfo} \sqsubseteq \geq 0 \text{hasRecordOrigin.RecordOrigin} \quad (49)$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (50)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \quad (51)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (52)$$
$$\text{RecordOrigin} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (53)$$
$$\top \sqsubseteq \forall \text{hasRecordOriginValue.xsd:string} \quad (54)$$
$$\text{RecordOrigin} \sqsubseteq \exists \text{hasRecordOriginValue.xsd:string} \quad (55)$$
$$\text{RecordOrigin} \sqsubseteq \geq 0 \text{hasRecordOriginValue.xsd:string} \quad (56)$$
$$\exists \text{hasRecordInfoNote}.\top \sqsubseteq \text{RecordInfo} \quad (57)$$
$$\top \sqsubseteq \forall \text{hasRecordInfoNote.RecordInfoNote} \quad (58)$$
$$\text{RecordInfoNote} \sqsubseteq \exists \text{hasRecordInfoNote}^{-}.\text{RecordInfo} \quad (59)$$
$$\top \sqsubseteq \leq 1 \text{hasRecordInfoNote}^{-}.\top \quad (60)$$
$$\text{RecordInfo} \sqsubseteq \geq 0 \text{hasRecordInfoNote.RecordInfoNote} \quad (61)$$
$$\top \sqsubseteq \forall \text{isPrimaryInstance.Usage.txt} \quad (62)$$
$$\text{RecordInfoNote} \sqsubseteq \geq 0 \text{isPrimaryInstance.Usage.txt} \quad (63)$$
$$\exists \text{hasDescriptionStandard}.\top \sqsubseteq \text{RecordInfo} \quad (64)$$
$$\top \sqsubseteq \forall \text{hasDescriptionStandard.DescriptionStandard} \quad (65)$$
$$\text{DescriptionStandard} \sqsubseteq \exists \text{hasDescriptionStandard}^{-}.\text{RecordInfo} \quad (66)$$
$$\top \sqsubseteq \leq 1 \text{hasDescriptionStandard}^{-}.\top \quad (67)$$
$$\text{RecordInfo} \sqsubseteq \geq 0 \text{hasDescriptionStandard.DescriptionStandard} \quad (68)$$
$$\top \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \quad (69)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}.\top \quad (70)$$
$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.\top \quad (71)$$
$$\text{DescriptionStandard} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \quad (72)$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (73)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \quad (74)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (75)$$
$$\text{DescriptionStandard} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (76)$$
$$\top \sqsubseteq \forall \text{hasDescriptionStandardValue.DescriptionStandard.txt} \quad (77)$$
$$\text{DescriptionStandard} \sqsubseteq \exists \text{hasDescriptionStandardValue.DescriptionStandard.txt} \quad (78)$$
$$\text{DescriptionStandard} \sqsubseteq \geq 0 \text{hasDescriptionStandardValue.DescriptionStandard.txt} \quad (79)$$
$$\top \sqsubseteq \forall \text{isPrimaryInstance.Usage.txt} \quad (80)$$
$$\text{RecordInfo} \sqsubseteq \geq 0 \text{isPrimaryInstance.Usage.txt} \quad (81)$$
$$\top \sqsubseteq \forall \text{hasLanguageOfCataloging.LanguageOfCataloging} \quad (82)$$
$$\text{LanguageOfCataloging} \sqsubseteq \exists \text{hasLanguageOfCataloging}^{-}.\text{RecordInfo} \quad (83)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageOfCataloging}.\top \quad (84)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageOfCataloging}^{-}.\top \quad (85)$$

$$\text{RecordInfo} \sqsubseteq \geq 0\,\text{hasLanguageOfCataloging.LanguageOfCataloging} \quad (86)$$

$$\text{RecordInfo} \sqsubseteq \text{ElementInfo} \quad (87)$$

$$\text{LanguageOfCataloging} \sqsubseteq \text{Language} \quad (88)$$

$$\text{LanguageOfCataloging} \sqsubseteq \neg(\exists \text{hasLanguageAttributes}.\top) \quad (89)$$

$$\text{RecordInfo} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasXlink}.\top) \quad (90)$$

$$\text{RecordInfo} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.\top) \quad (91)$$

2.29.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Domain
5. Range
6. Inverse Existential
7. Inverse Functionality
8. Structural Tautology
9. Range
10. Functionality
11. Inverse Functionality
12. Structural Tautology
13. Range
14. Functionality
15. Inverse Functionality
16. Structural Tautology
17. Range
18. Existential
19. Structural Tautology
20. Domain
21. Range
22. Inverse Existential
23. Functionality
24. Inverse Functionality
25. Structural Tautology
26. Domain
27. Range
28. Inverse Existential
29. Inverse Functionality
30. Structural Tautology
31. Domain
32. Range
33. Inverse Existential
34. Inverse Functionality
35. Structural Tautology
36. Range
37. Functionality
38. Inverse Functionality
39. Structural Tautology
40. Range
41. Structural Tautology
42. Range
43. Existential
44. Structural Tautology
45. Domain
46. Range
47. Inverse Existential
48. Inverse Functionality
49. Structural Tautology
50. Range
51. Functionality
52. Inverse Functionality
53. Structural Tautology
54. Range
55. Existential
56. Structural Tautology
57. Domain
58. Range
59. Inverse Existential
60. Inverse Functionality
61. Structural Tautology
62. Range
63. Structural Tautology
64. Domain
65. Range
66. Inverse Existential
67. Inverse Functionality
68. Structural Tautology
69. Range
70. Functionality
71. Inverse Functionality
72. Structural Tautology
73. Range
74. Functionality
75. Inverse Functionality
76. Structural Tautology
77. Range
78. Existential
79. Structural Tautology
80. Range
81. Structural Tautology
82. Range
83. Inverse Existential
84. Functionality
85. Inverse Functionality
86. Structural Tautology
87. RecordInfo is a sub-class of ElementInfo
88. LanguageOfCataloging is a sub-class of Language
89. LanguageOfCataloging does not have a hasLanguageAttributes property
90. RecordInfo does not have a hasLinkAttributes property which has a hasXlink property
91. RecordInfo does not have a hasLinkAttributes property which has a hasNameTitleGroup property

2.30 Date Info Module

2.30.1 Overview

Date Info Module is created to capture all type of dates throughout the MODS schema such as Date Modified, Date Created, Display Date. The module is intended to be used for any date, where the type of date under description is specified as a controlled vocabulary.

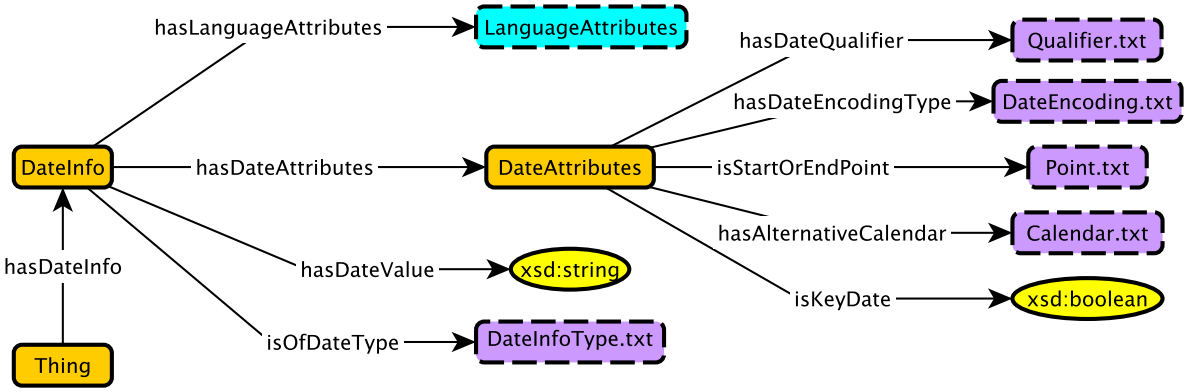

Figure 2.30: The schema diagram for the Date Info Module.

2.30.2 Formalization

2.30.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasDateInfo}.\text{DateInfo} \tag{1}$$
$$\text{DateInfo} \sqsubseteq \exists \text{hasDateInfo}^{-}.\text{Thing} \tag{2}$$
$$\top \sqsubseteq \leq 1 \text{hasDateInfo}^{-}.\top \tag{3}$$
$$\top \sqsubseteq \geq 0 \text{hasDateInfo}.\text{DateInfo} \tag{4}$$
$$\top \sqsubseteq \forall \text{hasDateAttributes}.\text{DateAttributes} \tag{5}$$
$$\text{DateInfo} \sqsubseteq \exists \text{hasDateAttributes}.\text{DateAttributes} \tag{6}$$
$$\top \sqsubseteq \leq 1 \text{hasDateAttributes}.\top \tag{7}$$
$$\top \sqsubseteq \leq 1 \text{hasDateAttributes}^{-}.\top \tag{8}$$
$$\text{DateInfo} \sqsubseteq \geq 0 \text{hasDateAttributes}.\text{DateAttributes} \tag{9}$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes}.\text{LanguageAttributes} \tag{10}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \tag{11}$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \tag{12}$$
$$\text{DateInfo} \sqsubseteq \geq 0 \text{hasLanguageAttributes}.\text{LanguageAttributes} \tag{13}$$
$$\top \sqsubseteq \forall \text{isOfDateType}.\text{DateInfoType.txt} \tag{14}$$
$$\text{DateInfo} \sqsubseteq \exists \text{isOfDateType}.\text{DateInfoType.txt} \tag{15}$$
$$\text{DateInfo} \sqsubseteq \geq 0 \text{isOfDateType}.\text{DateInfoType.txt} \tag{16}$$
$$\top \sqsubseteq \forall \text{hasDateValue}.\text{xsd:string} \tag{17}$$
$$\text{DateInfo} \sqsubseteq \exists \text{hasDateValue}.\text{xsd:string} \tag{18}$$

$$\text{DateInfo} \sqsubseteq \geq 0 \text{hasDateValue.xsd:string} \quad (19)$$
$$\top \sqsubseteq \forall \text{hasDateQualifier.Qualifier.txt} \quad (20)$$
$$\text{DateAttributes} \sqsubseteq \geq 0 \text{hasDateQualifier.Qualifier.txt} \quad (21)$$
$$\top \sqsubseteq \forall \text{hasDateEncodingType.DateEncoding.txt} \quad (22)$$
$$\text{DateAttributes} \sqsubseteq \geq 0 \text{hasDateEncodingType.DateEncoding.txt} \quad (23)$$
$$\top \sqsubseteq \forall \text{isKeyDate.xsd:boolean} \quad (24)$$
$$\text{DateAttributes} \sqsubseteq \geq 0 \text{isKeyDate.xsd:boolean} \quad (25)$$
$$\top \sqsubseteq \forall \text{isStartOrEndPoint.Point.txt} \quad (26)$$
$$\text{DateAttributes} \sqsubseteq \geq 0 \text{isStartOrEndPoint.Point.txt} \quad (27)$$
$$\top \sqsubseteq \forall \text{hasAlternativeCalendar.Calendar.txt} \quad (28)$$
$$\text{DateAttributes} \sqsubseteq \geq 0 \text{hasAlternativeCalendar.Calendar.txt} \quad (29)$$

2.30.2.2 Explanations

1. Range
2. Inverse Existential
3. Inverse Functionality
4. Structural Tautology
5. Range
6. Existential
7. Functionality
8. Inverse Functionality
9. Structural Tautology
10. Range
11. Functionality
12. Inverse Functionality
13. Structural Tautology
14. Range
15. Existential
16. Structural Tautology
17. Range
18. Existential
19. Structural Tautology
20. Range
21. Structural Tautology
22. Range
23. Structural Tautology
24. Range
25. Structural Tautology
26. Range
27. Structural Tautology
28. Range
29. Structural Tautology

2.31 Other Type Info Module

2.31.1 Overview

Other Type Info Module describes the type of an entity when the type is different from the enumerated types.

2.31.2 Formalization

2.31.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasOtherTypeInfo.OtherTypeInfo} \quad (1)$$
$$\top \sqsubseteq \leq 1 \text{hasOtherTypeInfo}^{-}.\top \quad (2)$$
$$\top \sqsubseteq \geq 0 \text{hasOtherTypeInfo.OtherTypeInfo} \quad (3)$$
$$\top \sqsubseteq \forall \text{hasTypeAsString.xsd:string} \quad (4)$$
$$\text{OtherTypeInfo} \sqsubseteq \exists \text{hasTypeAsString.xsd:string} \quad (5)$$
$$\text{OtherTypeInfo} \sqsubseteq \geq 0 \text{hasTypeAsString.xsd:string} \quad (6)$$
$$\top \sqsubseteq \forall \text{hasTypeAuthority.xsd:string} \quad (7)$$
$$\text{OtherTypeInfo} \sqsubseteq \geq 0 \text{hasTypeAuthority.xsd:string} \quad (8)$$

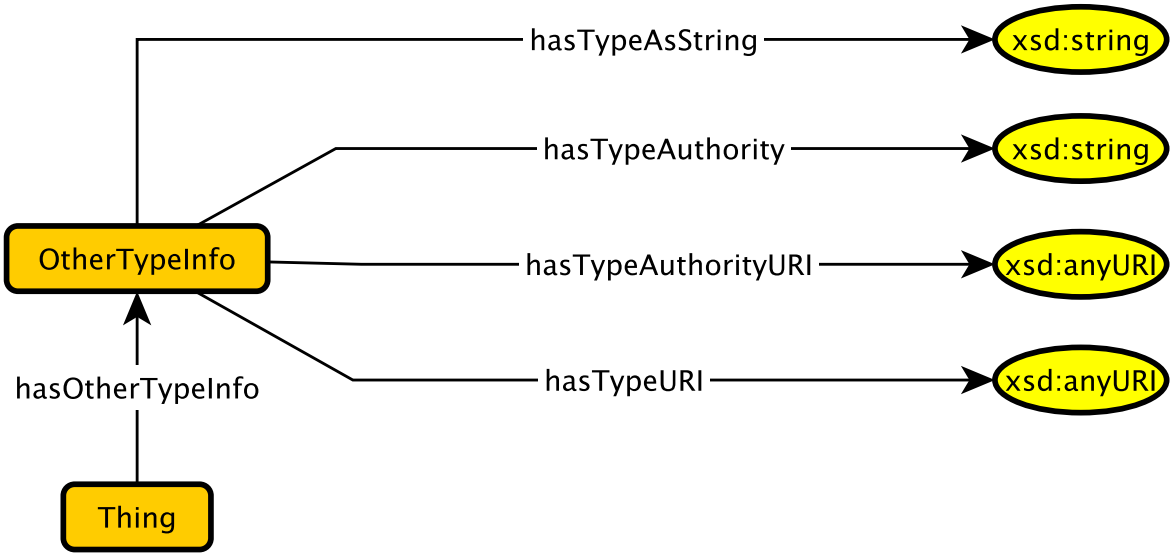

Figure 2.31: The schema diagram for the Other Type Info Module.

$$\top \sqsubseteq \forall \text{hasTypeAuthorityURI.xsd:anyURI} \tag{9}$$
$$\text{OtherTypeInfo} \sqsubseteq \geq 0 \text{hasTypeAuthorityURI.xsd:anyURI} \tag{10}$$
$$\top \sqsubseteq \forall \text{hasTypeURI.xsd:anyURI} \tag{11}$$
$$\text{OtherTypeInfo} \sqsubseteq \geq 0 \text{hasTypeURI.xsd:anyURI} \tag{12}$$

2.31.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Existential
6. Structural Tautology
7. Range
8. Structural Tautology
9. Range
10. Structural Tautology
11. Range
12. Structural Tautology

2.32 Language Attributes Module

2.32.1 Overview

Language Attributes Module is shared across many different modules. Any element withing the MODS can have Language Attributes. The attributes of the module may identify what language (e.g. - *fr*, *de*, *en*) has been used to express content in a particular element. In addition, it may also specify what type of script (e.g. - *Chinese*, *Latin*, *English*) has been used.

2.32.2 Formalization

Here, we would like to note the usage of the controlled vocabularies. Namely, the ranges of values for the property hasLanguage is an example of a controlled vocabulary wherein language.txt contains the language names such as *eng*, *fre* etc governed by codes from ISO 639-2/b. Similarly, XMLLanguage.txt

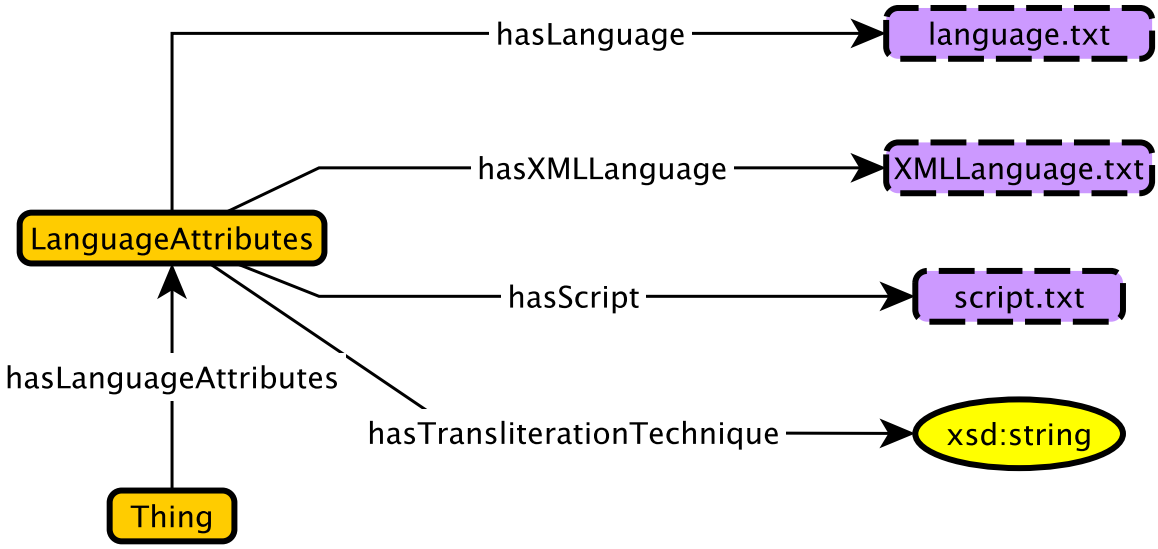

Figure 2.32: The schema diagram for the Language Attributes Module.

contains language codes that follows the W3C documentation that indicates using the IANA Language Subtag Registry. In case of script.txt, it contains the scripts used in writing an element, using codes from ISO 15924.

2.32.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasLanguageAttributes}.\text{LanguageAttributes} \quad (1)$$
$$\top \sqsubseteq \leq 1\text{hasLanguageAttributes}.\top \quad (2)$$
$$\top \sqsubseteq \leq 1\text{hasLanguageAttributes}^{-}.\top \quad (3)$$
$$\top \sqsubseteq \geq 0\text{hasLanguageAttributes}.\text{LanguageAttributes} \quad (4)$$
$$\exists \text{hasLanguage}.\top \sqsubseteq \text{LanguageAttributes} \quad (5)$$
$$\text{language.txt} \sqsubseteq \exists \text{hasLanguage}^{-}.\text{LanguageAttributes} \quad (6)$$
$$\text{LanguageAttributes} \sqsubseteq \geq 0\text{hasLanguage}.\text{language.txt} \quad (7)$$
$$\exists \text{hasXMLLanguage}.\top \sqsubseteq \text{LanguageAttributes} \quad (8)$$
$$\text{XMLLanguage.txt} \sqsubseteq \exists \text{hasXMLLanguage}^{-}.\text{LanguageAttributes} \quad (9)$$
$$\text{LanguageAttributes} \sqsubseteq \geq 0\text{hasXMLLang}.\text{XMLLanguage.txt} \quad (10)$$
$$\exists \text{hasScript}.\top \sqsubseteq \text{LanguageAttributes} \quad (11)$$
$$\text{script.txt} \sqsubseteq \exists \text{hasScript}^{-}.\text{LanguageAttributes} \quad (12)$$
$$\text{LanguageAttributes} \sqsubseteq \geq 0\text{hasScript}.\text{script.txt} \quad (13)$$
$$\exists \text{hasTransliterationTechnique}.\top \sqsubseteq \text{LanugageAttributes} \quad (14)$$
$$\text{xsd:string} \sqsubseteq \exists \text{hasTransliterationTechnique}^{-}.\text{LanguageAttributes} \quad (15)$$
$$\top \sqsubseteq \leq 1\text{hasTransliterationTechnique}^{-}.\top \quad (16)$$
$$\text{LanguageAttributes} \sqsubseteq \geq 0\text{hasTransliterationTechnique}.\text{xsd:string} \quad (17)$$

2.32.2.2 Explanations

1. Range
2. Functionality
3. Inverse Functionality
4. Structural Tautology
5. Domain
6. Inverse Existential
7. Structural Tautology
8. Domain
9. Inverse Existential
10. Structural Tautology
11. Domain
12. Inverse Existential
13. Structural Tautology
14. Domain
15. Inverse Existential
16. Inverse Functionality
17. Structural Tautology

2.33 Link Attributes Module

2.33.1 Overview

Link Attributes module consists of attributes which can be used to add references to related content/information within or outside MODS resource. An ID can be assigned to an element in the MODS resource which can be used to anchor the element within MODS resource but outside of the particular element. Any external information can also be tagged with an element through the *hasXlink* property. If there are alternative representations of the same content (e.g. different language, script, translation) that can be referenced using *hasAltRepGroup* property.

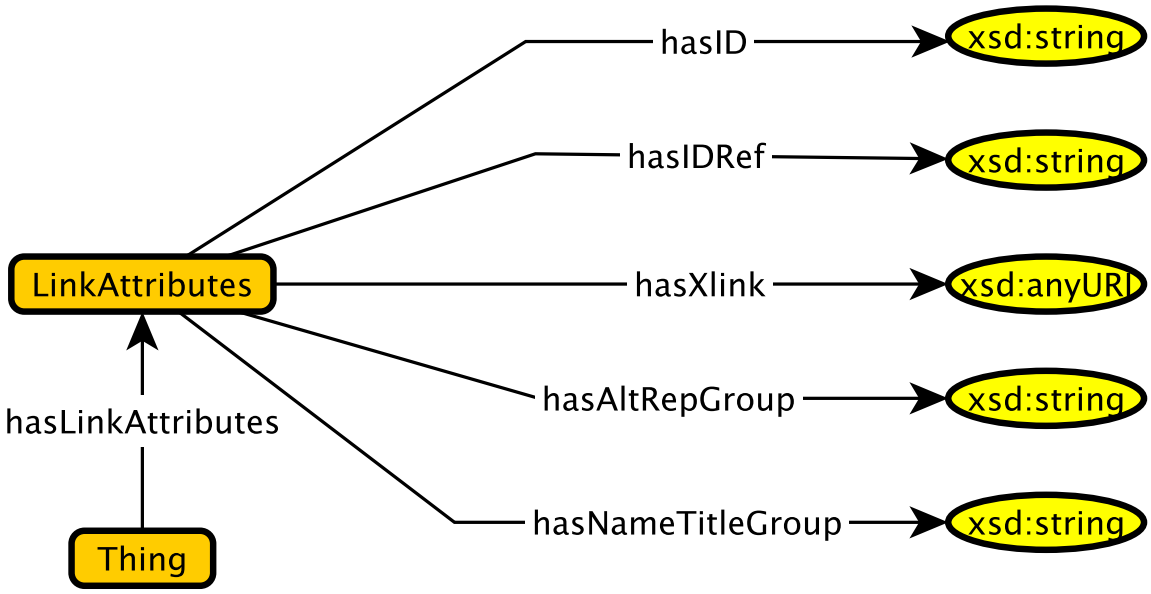

Figure 2.33: The schema diagram for the Link Attributes Module.

2.33.2 Formalization

2.33.2.1 Axioms

$$\top \sqsubseteq \forall \mathsf{hasLinkAttributes}.\mathsf{LinkAttributes} \tag{1}$$

$$\top \sqsubseteq \leq 1 \text{hasLinkAttributes}.\top \quad (2)$$
$$\top \sqsubseteq \leq 1 \text{hasLinkAttributes}^{-}.\top \quad (3)$$
$$\top \sqsubseteq \geq 0 \text{hasLinkAttributes.LinkAttributes} \quad (4)$$
$$\top \sqsubseteq \forall \text{hasID.xsd:string} \quad (5)$$
$$\text{LinkAttributes} \sqsubseteq \geq 0 \text{hasID.xsd:string} \quad (6)$$
$$\top \sqsubseteq \forall \text{hasIDRef.xsd:string} \quad (7)$$
$$\text{LinkAttributes} \sqsubseteq \geq 0 \text{hasIDRef.xsd:string} \quad (8)$$
$$\top \sqsubseteq \forall \text{hasXlink.xsd:anyURI} \quad (9)$$
$$\text{LinkAttributes} \sqsubseteq \geq 0 \text{hasXlink.xsd:anyURI} \quad (10)$$
$$\top \sqsubseteq \forall \text{hasAltRepGroup.xsd:string} \quad (11)$$
$$\text{LinkAttributes} \sqsubseteq \geq 0 \text{hasAltRepGroup.xsd:string} \quad (12)$$
$$\top \sqsubseteq \forall \text{hasNameTitleGroup.xsd:string} \quad (13)$$
$$\text{LinkAttributes} \sqsubseteq \geq 0 \text{hasNameTitleGroup.xsd:string} \quad (14)$$

2.33.2.2 Explanations

1. Range
2. Functionality
3. Inverse Functionality
4. Structural Tautology
5. Range
6. Structural Tautology
7. Range
8. Structural Tautology
9. Range
10. Structural Tautology
11. Range
12. Structural Tautology
13. Range
14. Structural Tautology

2.34 Element Info Module

2.34.1 Overview

Element Info Module is one of the modules which are created to aid modular design. There are many instances where an element can have a *Display Label*, *Link Attributes*, *Language Attributes*. This becomes repetitive to have the same connections across almost all of the elements. Therefore, we use a generic module Element Info and leverage a *subClassOf* relationship whenever Element Info is required.

2.34.2 Formalization

2.34.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasDisplayLabel.xsd:string} \quad (1)$$
$$\text{ElementInfo} \sqsubseteq \geq 0 \text{hasDisplayLabel.xsd:string} \quad (2)$$
$$\top \sqsubseteq \forall \text{hasLinkAttributes.LinkAttributes} \quad (3)$$
$$\top \sqsubseteq \leq 1 \text{hasLinkAttributes}.\top \quad (4)$$
$$\top \sqsubseteq \leq 1 \text{hasLinkAttributes}^{-}.\top \quad (5)$$
$$\text{ElementInfo} \sqsubseteq \geq 0 \text{hasLinkAttributes.LinkAttributes} \quad (6)$$
$$\top \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (7)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \quad (8)$$
$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.\top \quad (9)$$
$$\text{ElementInfo} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (10)$$

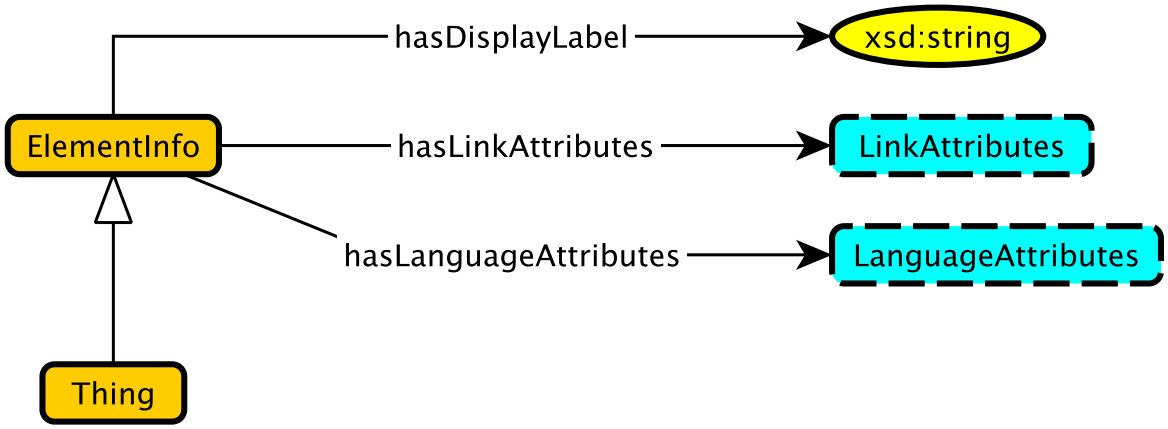

Figure 2.34: The schema diagram for the Element Info Module.

$$\top \sqsubseteq \text{ElementInfo} \tag{11}$$

(12)

2.34.2.2 Explanations

1. Range
2. Structural Tautology
3. Range
4. Functionality
5. Inverse Functionality
6. Structural Tautology
7. Range
8. Functionality
9. Inverse Functionality
10. Structural Tautology
11. Thing is a sub-class of ElementInfo

2.35 Organization Module

2.35.1 Overview

Organization module's primary job is to specify an organization entity (e.g. *university*, *factory*). An Organization can usually provide Agent Roles which is assumed by Agents (e.g. A *university* may provide the role of a professor). Organization naturally has a Name, here, the property *hasStandardizedName* is intended to be used when an organization has multiple name forms and a particular one is considered primary.

2.35.2 Formalization

2.35.2.1 Axioms

$$\top \sqsubseteq \forall \text{providesAgentRole.AgentRole} \tag{1}$$
$$\top \sqsubseteq \leq 1 \text{providesAgentRole}^{-}.\top \tag{2}$$
$$\text{Organization} \sqsubseteq \geq 0 \text{providesAgentRole.AgentRole} \tag{3}$$
$$\top \sqsubseteq \forall \text{hasName.Name} \tag{4}$$
$$\text{Organization} \sqsubseteq \exists \text{hasName.Name} \tag{5}$$
$$\top \sqsubseteq \leq 1 \text{hasName}.\top \tag{6}$$

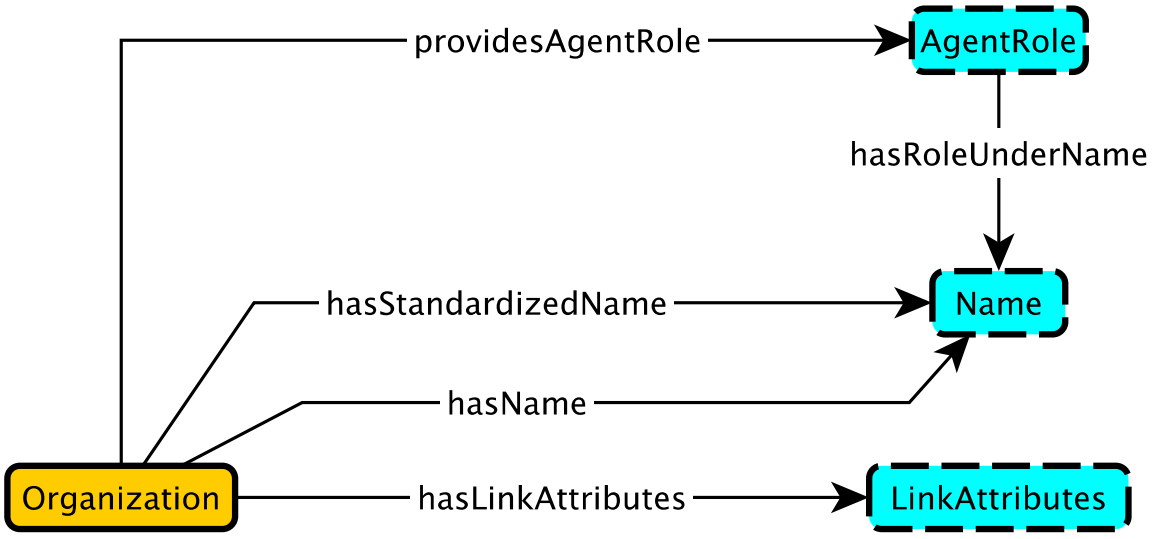

Figure 2.35: The schema diagram for the Organization Module.

$$\top \sqsubseteq \leq 1 \text{hasName}^{-}.\top \quad (7)$$
$$\text{Organization} \sqsubseteq \geq 0 \text{hasName.Name} \quad (8)$$
$$\top \sqsubseteq \forall \text{hasStandardizedName.Name} \quad (9)$$
$$\top \sqsubseteq \leq 1 \text{hasStandardizedName}.\top \quad (10)$$
$$\top \sqsubseteq \leq 1 \text{hasStandardizedName}^{-}.\top \quad (11)$$
$$\text{Organization} \sqsubseteq \geq 0 \text{hasStandardizedName.Name} \quad (12)$$
$$\top \sqsubseteq \forall \text{hasLinkAttributes.LinkAttributes} \quad (13)$$
$$\top \sqsubseteq \leq 1 \text{hasLinkAttributes}.\top \quad (14)$$
$$\top \sqsubseteq \leq 1 \text{hasLinkAttributes}^{-}.\top \quad (15)$$
$$\text{Organization} \sqsubseteq \geq 0 \text{hasLinkAttributes.LinkAttributes} \quad (16)$$
$$\exists \text{hasRoleUnderName.Name} \sqsubseteq \text{AgentRole} \quad (17)$$
$$\top \sqsubseteq \forall \text{hasRoleUnderName.Name} \quad (18)$$
$$\text{AgentRole} \sqsubseteq \geq 0 \text{hasRoleUnderName.Name} \quad (19)$$

2.35.2.2 Explanations

1. Range
2. Inverse Functionality
3. Structural Tautology
4. Range
5. Existential
6. Functionality
7. Inverse Functionality
8. Structural Tautology
9. Range
10. Functionality
11. Inverse Functionality
12. Structural Tautology
13. Range
14. Functionality
15. Inverse Functionality
16. Structural Tautology
17. Scoped Domain
18. Range
19. Structural Tautology

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