

# **MMODS-O: A Modular Ontology for the Meta-data 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 focuses 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.<sup>1</sup>

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.<sup>2</sup> 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.

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

<sup>2</sup>The OWLAX Protégé plug-in [Sarker et al., 2016] provides a convenient interface for adding these axioms.

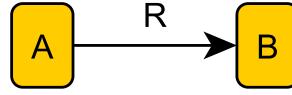


Figure 1.1: Generic node-edge-node schema diagram for explaining systematic axiomatization

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

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. $A \text{ SubClassOf } B$  | (subClass)                               |
| 2. $A \text{ DisjointWith } B$  | (disjointness)                           |
| 3. $R \text{ some } \text{owl:Thing} \text{ SubClassOf } A$                           | (domain)                                 |
| 4. $R \text{ some } B \text{ SubClassOf } A$  | (scoped domain)                          |
| 5. $\text{owl:Thing} \text{ SubClassOf } R \text{ only } B$                           | (range)                                  |
| 6. $A \text{ SubClassOf } R \text{ only } B$  | (scoped range)                           |
| 7. $A \text{ SubClassOf } R \text{ some } B$  | (existential)                            |
| 8. $B \text{ SubClassOf inverse } R \text{ some } A$                                  | (inverse existential)                    |
| 9. $\text{owl:Thing} \text{ SubClassOf } R \text{ max } 1 \text{ owl:Thing}$          | (functionality)                          |
| 10. $\text{owl:Thing} \text{ SubClassOf } R \text{ max } 1 B$                         | (qualified functionality)                |
| 11. $A \text{ SubClassOf } R \text{ max } 1 \text{ owl:Thing}$                        | (scoped functionality)                   |
| 12. $A \text{ SubClassOf } R \text{ max } 1 B$  | (qualified scoped functionality)         |
| 13. $\text{owl:Thing} \text{ SubClassOf inverse } R \text{ max } 1 \text{ owl:Thing}$ | (inverse functionality)                  |
| 14. $\text{owl:Thing} \text{ SubClassOf inverse } R \text{ max } 1 A$                 | (inverse qualified functionality)        |
| 15. $B \text{ SubClassOf inverse } R \text{ max } 1 \text{ owl:Thing}$                | (inverse scoped functionality)           |
| 16. $B \text{ SubClassOf inverse } R \text{ max } 1 A$                                | (inverse qualified scoped functionality) |
| 17. $A \text{ SubClassOf } R \text{ min } 0 B$  | (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 axioms are items 2–5 in this list. Items 6 and 7 are existential 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

$$T \sqsubseteq \forall \text{hasTitleInfo}. \text{TitleInfo} \quad (1)$$

$$\text{MODSItem} \sqsubseteq \exists \text{hasTitleInfo}. \text{TitleInfo} \quad (2)$$

$$T \sqsubseteq \leq 1 \text{hasTitleInfo}^{-}. T \quad (3)$$

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasTitleInfo}. \text{TitleInfo} \quad (4)$$

$$\exists \text{hasTitle}. T \sqsubseteq \text{TitleInfo} \quad (5)$$

$$T \sqsubseteq \forall \text{hasTitle}. \text{Title} \quad (6)$$

$$\text{TitleInfo} \sqsubseteq \exists \text{hasTitle}. \text{Title} \quad (7)$$

$$\text{Title} \sqsubseteq \exists \text{hasTitle}^{-}. \text{TitleInfo} \quad (8)$$

$$T \sqsubseteq \leq 1 \text{hasTitle}^{-}. T \quad (9)$$

$$\text{TitleInfo} \sqsubseteq \geq 0 \text{hasTitle}. \text{Title} \quad (10)$$

$$T \sqsubseteq \forall \text{hasTitleValue.xsd:string} \quad (11)$$

$$\text{Title} \sqsubseteq \exists \text{hasTitleValue.xsd:string} \quad (12)$$

$$\text{Title} \sqsubseteq \geq 0 \text{hasTitleValue.xsd:string} \quad (13)$$

$$T \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (14)$$

$$T \sqsubseteq \leq 1 \text{hasLanguageAttributes}. T \quad (15)$$

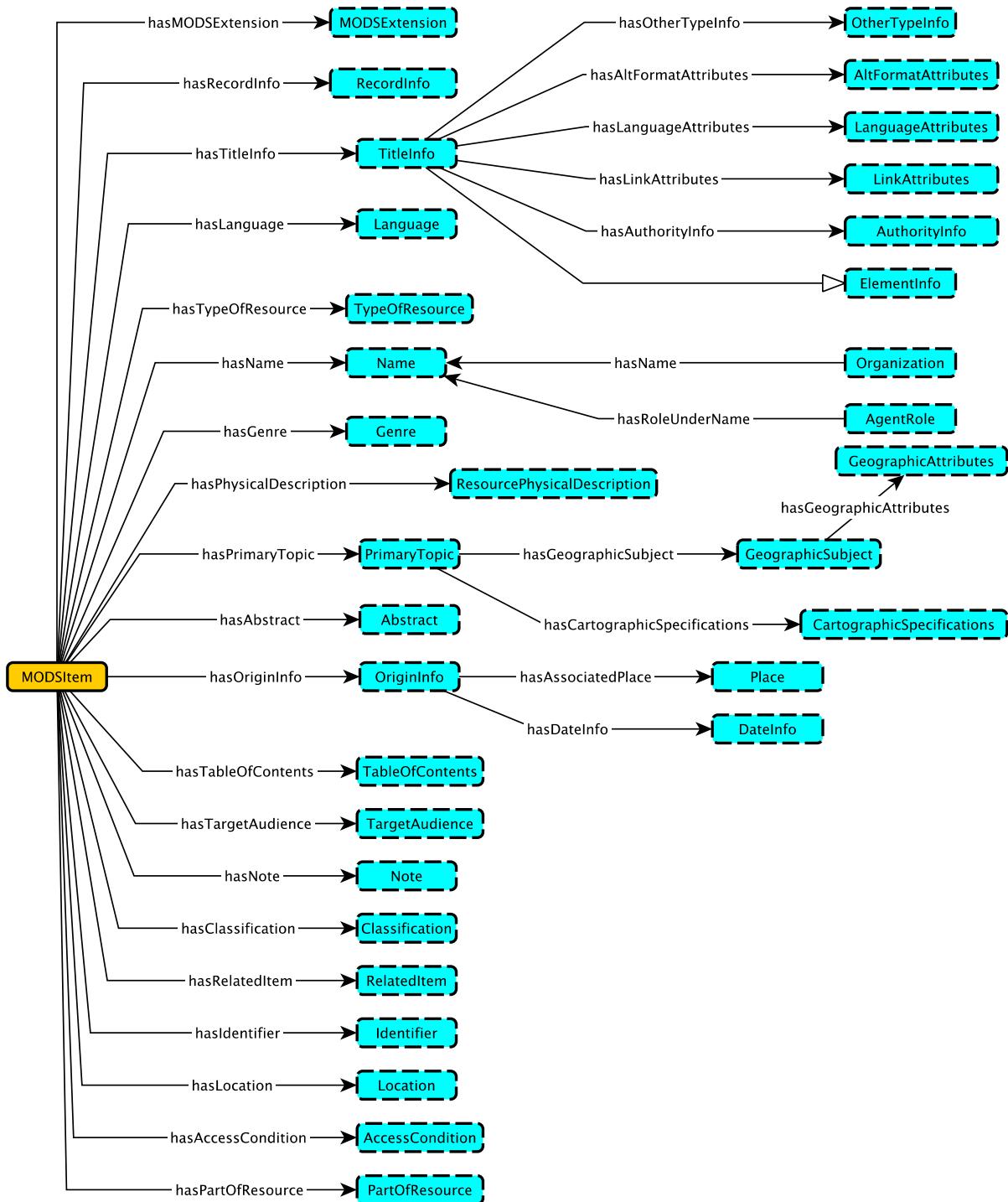


Figure 2.1: Overview of the Modules of the Ontology

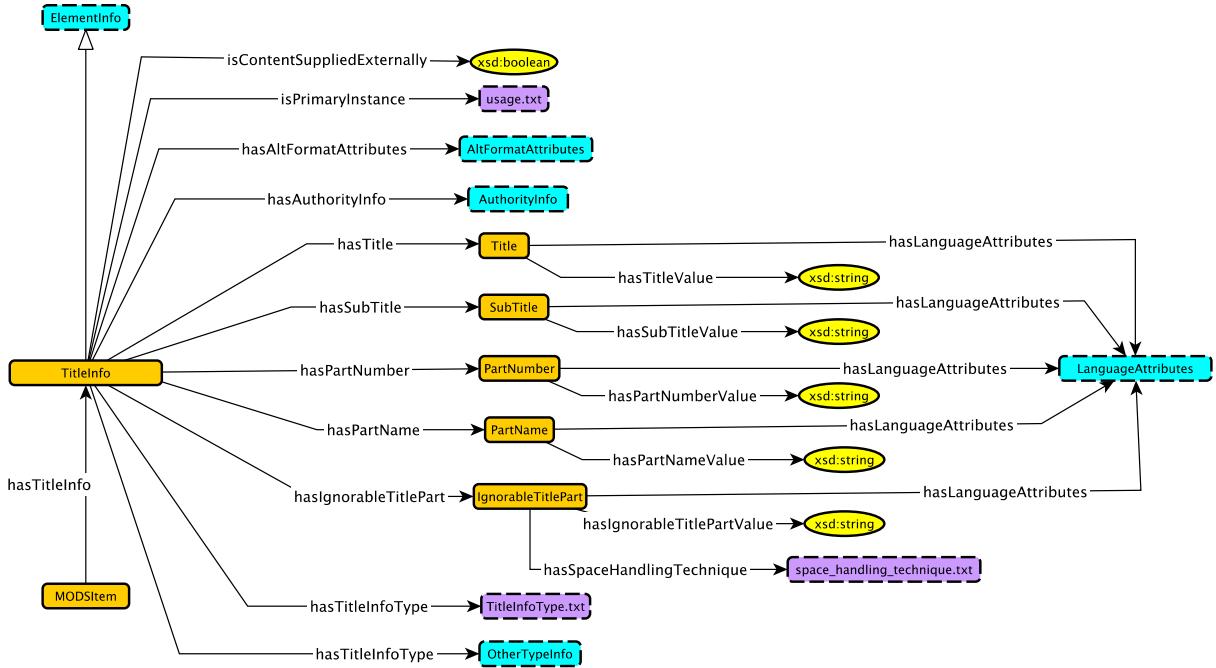


Figure 2.2: The schema diagram for the Title Info Module.

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^- . \top \quad (16)$$

$$\text{Title} \sqsubseteq \geq 0 \text{hasLanguageAttributes} . \text{LanguageAttributes} \quad (17)$$

$$\exists \text{hasSubTitle} . \top \sqsubseteq \text{TitleInfo} \quad (18)$$

$$\top \sqsubseteq \forall \text{hasSubTitle} . \text{SubTitle} \quad (19)$$

$$\text{SubTitle} \sqsubseteq \exists \text{hasSubTitle}^- . \text{TitleInfo} \quad (20)$$

$$\top \sqsubseteq \leq 1 \text{hasSubTitle}^- . \top \quad (21)$$

$$\text{TitleInfo} \sqsubseteq \geq 0 \text{hasSubTitle} . \text{SubTitle} \quad (22)$$

$$\top \sqsubseteq \forall \text{hasSubTitleValue} . \text{xsd:string} \quad (23)$$

$$\text{SubTitle} \sqsubseteq \exists \text{hasSubTitleValue} . \text{xsd:string} \quad (24)$$

$$\text{SubTitle} \sqsubseteq \geq 0 \text{hasSubTitleValue} . \text{xsd:string} \quad (25)$$

$$\top \sqsubseteq \forall \text{hasLanguageAttributes} . \text{LanguageAttributes} \quad (26)$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes} . \top \quad (27)$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}^- . \top \quad (28)$$

$$\text{SubTitle} \sqsubseteq \geq 0 \text{hasLanguageAttributes} . \text{LanguageAttributes} \quad (29)$$

$$\exists \text{hasPartNumber} . \top \sqsubseteq \text{TitleInfo} \quad (30)$$

$$\top \sqsubseteq \forall \text{hasPartNumber} . \text{PartNumber} \quad (31)$$

$$\text{PartNumber} \sqsubseteq \exists \text{hasPartNumber}^- . \text{TitleInfo} \quad (32)$$

$$\top \sqsubseteq \leq 1 \text{hasPartNumber}^- . \top \quad (33)$$

$$\text{TitleInfo} \sqsubseteq \geq 0 \text{hasPartNumber} . \text{PartNumber} \quad (34)$$

$$\top \sqsubseteq \forall \text{hasPartNumberValue} . \text{xsd:string} \quad (35)$$

$$\text{PartNumber} \sqsubseteq \exists \text{hasPartNumberValue} . \text{xsd:string} \quad (36)$$

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

$T \sqsubseteq \leq 1\text{hasAuthorityInfo}^- . T$	(79)
$\text{TitleInfo} \sqsubseteq \geq 0\text{hasAuthorityInfo} . \text{AuthorityInfo}$	(80)
$T \sqsubseteq \forall \text{hasTitleInfoType} . (\text{TitleInfoType.txt} \sqcup \text{OtherTypeInfo})$	(81)
$\text{TitleInfoType.txt} \sqsubseteq \exists \text{hasTitleInfoType}^- . \text{TitleInfo}$	(82)
$\text{TitleInfo} \sqsubseteq \geq 0\text{hasTitleInfoType} . \text{TitleInfoType.txt}$	(83)
$\text{OtherTypeInfo} \sqsubseteq \exists \text{hasTitleInfoType}^- . \text{TitleInfo}$	(84)
$\text{TitleInfo} \sqsubseteq \geq 0\text{hasTitleInfoType} . \text{OtherTypeInfo}$	(85)
$\text{TitleInfo} \sqsubseteq \text{ElementInfo}$	(86)

### 2.2.2.2 Explanations

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

## 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

$$\top \sqsubseteq \forall \text{hasAssociatedName}.\text{Name} \quad (1)$$

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

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasAssociatedName}.\text{Name} \quad (3)$$

$$\top \sqsubseteq \forall \text{hasAssociatedPrimaryName}.\text{Name} \quad (4)$$

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

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

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

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

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

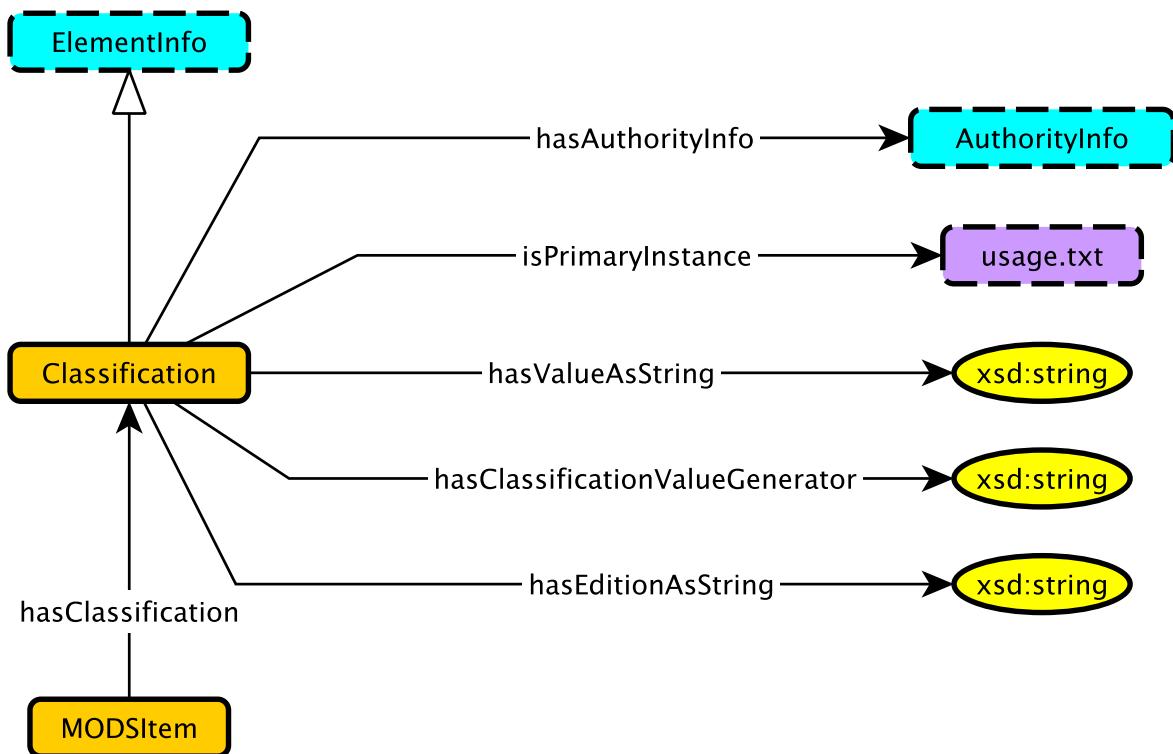


Figure 2.4: The schema diagram for the Classification.

### 2.4.2 Formalization

#### 2.4.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasClassification}.\text{Classification} \quad (1)$$

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

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

#### 2.4.2.2 Explanations

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

## 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

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

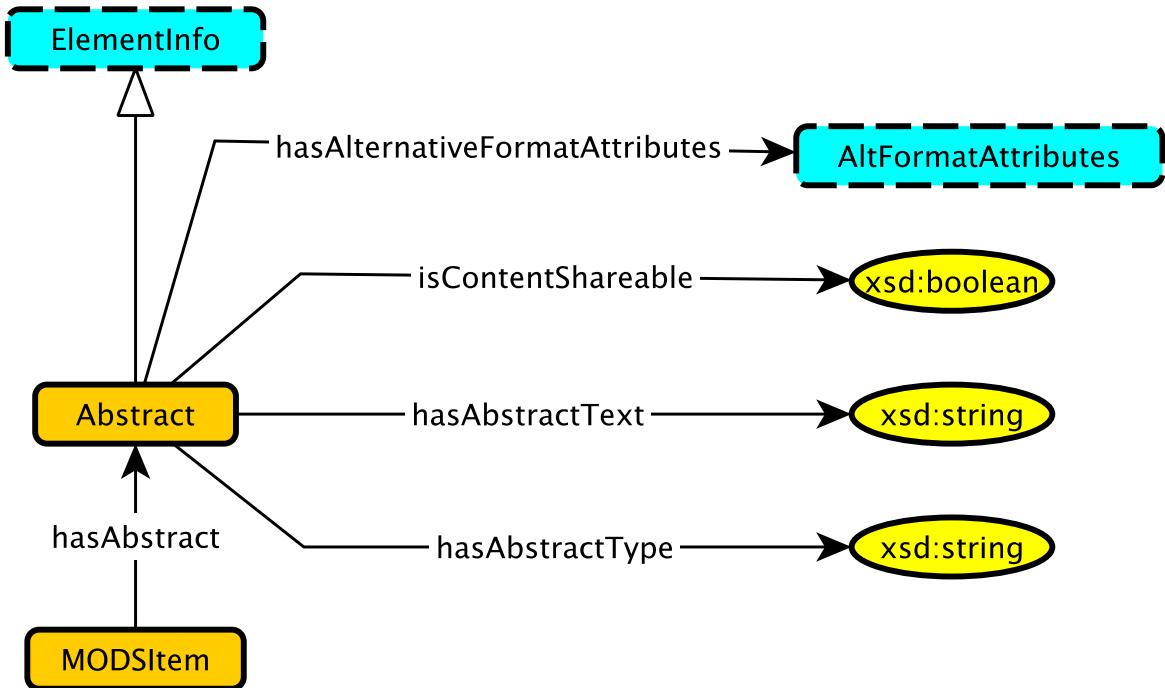


Figure 2.5: The schema diagram for the Abstract Module.

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

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

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

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

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

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

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

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

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

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

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

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

### 2.5.2.2 Explanations

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

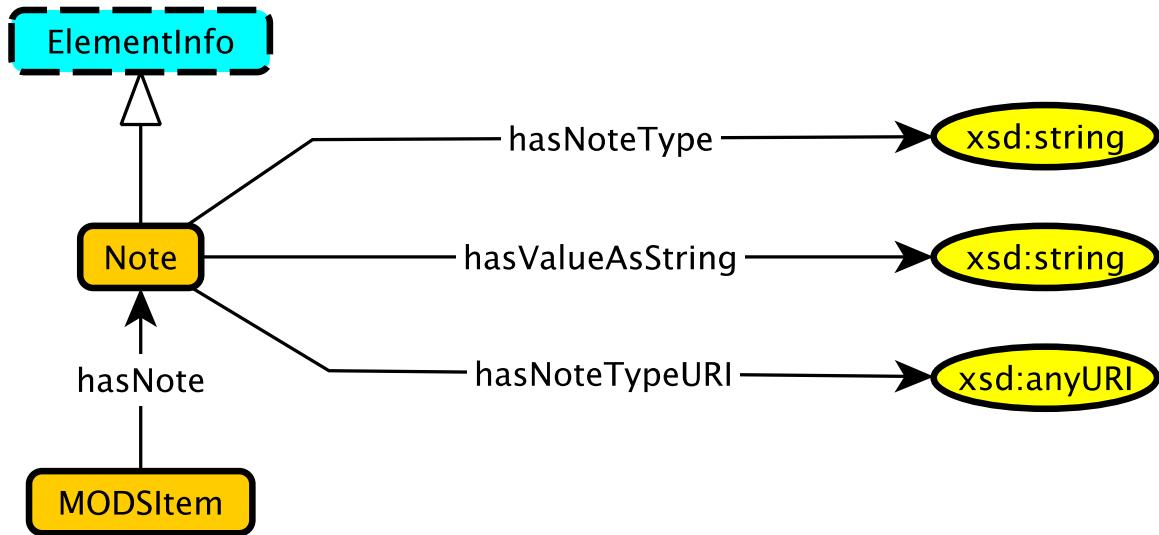


Figure 2.6: The schema diagram for the Note Module.

### 2.6.2 Formalization

#### 2.6.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasNote}.\text{Note} \quad (1)$$

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

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasNote}.\text{Note} \quad (3)$$

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

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

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

$$\text{Note} \sqsubseteq \exists \text{hasValueAsString}.\text{xsd:string} \quad (7)$$

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

$$\top \sqsubseteq \forall \text{hasNoteTypeURI}.\text{xsd:anyURI} \quad (9)$$

$$\text{Note} \sqsubseteq \geq 0 \text{hasNoteTypeURI}.\text{xsd:anyURI} \quad (10)$$

$$\text{Note} \sqsubseteq \text{ElementInfo} \quad (11)$$

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

### 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.

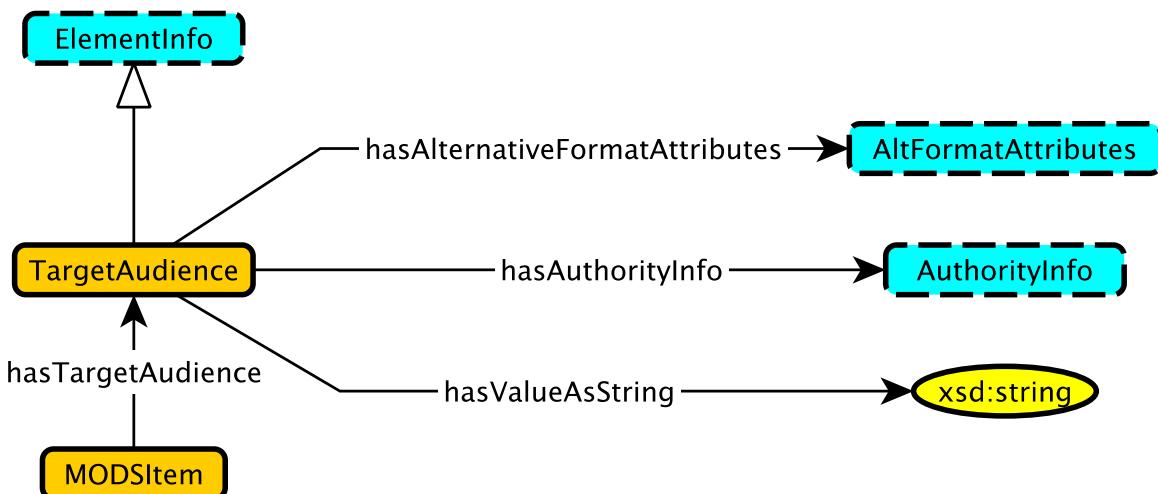


Figure 2.7: The schema diagram for the Target Audience Module.

### 2.7.2 Formalization

#### 2.7.2.1 Axioms

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

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

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

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

$$T \sqsubseteq \leq 1 \text{hasAlternativeFormatAttributes}^- \top \quad (5)$$

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

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

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

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

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

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

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

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

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

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

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

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

### 2.7.2.2 Explanations

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

## 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

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

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

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

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

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

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

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

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

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

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

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

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

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

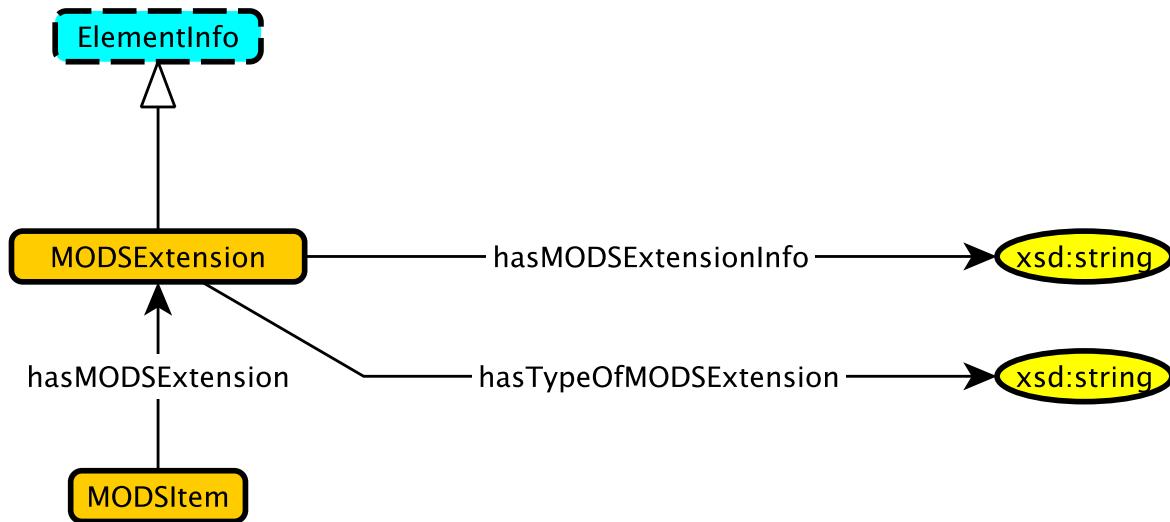


Figure 2.8: The schema diagram for the MODS Extension Module.

### 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.

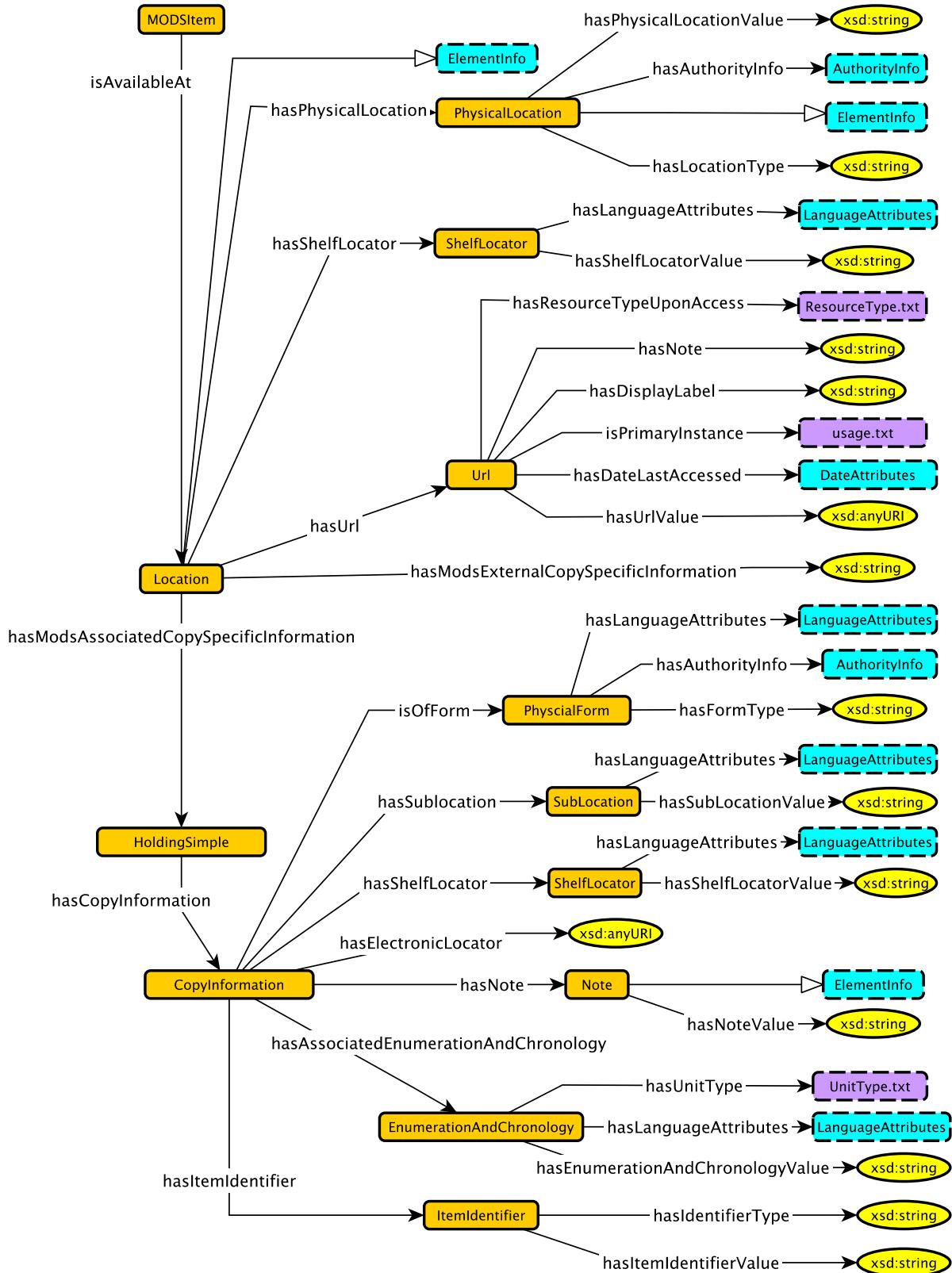


Figure 2.9: The schema diagram for the Location Module.

## 2.9.2 Formalization

### 2.9.2.1 Axioms

- $T \sqsubseteq \forall \text{isAvailableAt}.\text{Location}$  (1)
- $T \sqsubseteq \leq 1 \text{isAvailableAt}^-.\top$  (2)
- $\text{MODSItem} \sqsubseteq \geq 0 \text{isAvailableAt}.\text{Location}$  (3)
- $\exists \text{hasPhysicalLocation}.T \sqsubseteq \text{Location}$  (4)
- $T \sqsubseteq \forall \text{hasPhysicalLocation}.\text{PhysicalLocation}$  (5)
- $\text{PhysicalLocation} \sqsubseteq \exists \text{hasPhysicalLocation}^-.\text{Location}$  (6)
- $T \sqsubseteq \leq 1 \text{hasPhysicalLocation}^-.\top$  (7)
- $\text{Location} \sqsubseteq \geq 0 \text{hasPhysicalLocation}.\text{PhysicalLocation}$  (8)
- $T \sqsubseteq \forall \text{hasLocationType}.\text{xsd:string}$  (9)
- $\text{PhysicalLocation} \sqsubseteq \geq 0 \text{hasLocationType}.\text{xsd:string}$  (10)
- $T \sqsubseteq \forall \text{hasAuthorityInfo}.\text{AuthorityInfo}$  (11)
- $T \sqsubseteq \leq 1 \text{hasAuthorityInfo}.\top$  (12)
- $T \sqsubseteq \leq 1 \text{hasAuthorityInfo}^-.\top$  (13)
- $\text{PhysicalLocation} \sqsubseteq \geq 0 \text{hasAuthorityInfo}.\text{AuthorityInfo}$  (14)
- $T \sqsubseteq \forall \text{hasPhysicalLocationValue}.\text{xsd:string}$  (15)
- $\text{PhysicalLocation} \sqsubseteq \exists \text{hasPhysicalLocationValue}.\text{xsd:string}$  (16)
- $\text{PhysicalLocation} \sqsubseteq \geq 0 \text{hasPhysicalLocationValue}.\text{xsd:string}$  (17)
- $T \sqsubseteq \forall \text{hasShelfLocator}.\text{ShelfLocator}$  (18)
- $\text{ShelfLocator} \sqsubseteq \exists \text{hasShelfLocator}^-.\text{Location}$  (19)
- $T \sqsubseteq \leq 1 \text{hasShelfLocator}^-.\top$  (20)
- $\text{Location} \sqsubseteq \geq 0 \text{hasShelfLocator}.\text{ShelfLocator}$  (21)
- $T \sqsubseteq \forall \text{hasShelfLocatorValue}.\text{xsd:string}$  (22)
- $\text{ShelfLocator} \sqsubseteq \exists \text{hasShelfLocatorValue}.\text{xsd:string}$  (23)
- $\text{ShelfLocator} \sqsubseteq \geq 0 \text{hasShelfLocatorValue}.\text{xsd:string}$  (24)
- $T \sqsubseteq \forall \text{hasLanguageAttributes}.\text{LanguageAttributes}$  (25)
- $T \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top$  (26)
- $T \sqsubseteq \leq 1 \text{hasLanguageAttributes}^-.\top$  (27)
- $\text{ShelfLocator} \sqsubseteq \geq 0 \text{hasLanguageAttributes}.\text{LanguageAttributes}$  (28)
- $T \sqsubseteq \forall \text{hasUrl}.\text{Url}$  (29)
- $\text{Url} \sqsubseteq \exists \text{hasUrl}^-.\text{Location}$  (30)
- $T \sqsubseteq \leq 1 \text{hasUrl}^-.\top$  (31)
- $\text{Location} \sqsubseteq \geq 0 \text{hasUrl}.\text{Url}$  (32)
- $T \sqsubseteq \forall \text{has ResourceTypeUponAccess}.\text{ResourceType.txt}$  (33)
- $\text{Url} \sqsubseteq \geq 0 \text{has ResourceTypeUponAccess}.\text{ResourceType.txt}$  (34)
- $T \sqsubseteq \forall \text{has Note}.\text{xsd:string}$  (35)
- $\text{Url} \sqsubseteq \geq 0 \text{has Note}.\text{xsd:string}$  (36)
- $T \sqsubseteq \forall \text{has DisplayLabel}.\text{xsd:string}$  (37)
- $\text{Url} \sqsubseteq \geq 0 \text{has DisplayLabel}.\text{xsd:string}$  (38)

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

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

ItemIdentifier $\sqsubseteq \exists \text{hasItemIdentifierValue}.\text{xsd:string}$	(121)
ItemIdentifier $\sqsubseteq \geq 0 \text{hasItemIdentifierValue}.\text{xsd:string}$	(122)
Location $\sqsubseteq \geq 0 \text{hasModsExternalCopySpecificInformation}.\text{xsd:string}$	(123)
Location $\sqsubseteq \text{ElementInfo}$	(124)
Location $\sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasXlink}.\top)$	(125)
Location $\sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.\top)$	(126)
PhysicalLocation $\sqsubseteq \text{ElementInfo}$	(127)
PhysicalLocation $\sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasID}.\top)$	(128)
PhysicalLocation $\sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasIDRef}.\top)$	(129)
PhysicalLocation $\sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasAltRepGroup}.\top)$	(130)
PhysicalLocation $\sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.\top)$	(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   | 110. Range   |
| 79. Range                  | 111. Existential   |
| 80. Existential            | 112. Structural Tautology  |
| 81. Structural Tautology   | 113. Range   |
| 82. Range                  | 114. Inverse Existential   |
| 83. Inverse Existential    | 115. Functionality   |
| 84. Inverse Functionality  | 116. Inverse Functionality   |
| 85. Structural Tautology   | 117. Structural Tautology  |
| 86. Range                  | 118. Range   |
| 87. Existential            | 119. Structural Tautology  |
| 88. Structural Tautology   | 120. Range   |
| 89. Range                  | 121. Existential   |
| 90. Functionality          | 122. Structural Tautology  |
| 91. Inverse Functionality  | 123. Structural Tautology  |
| 92. Structural Tautology   | 124. Location is a sub-class of ElementInfo  |
| 93. Range                  | 125. Location does not have a hasLinkAttributes property which has a hasXlink property.                  |
| 94. Structural Tautology   | 126. Location does not have a hasLinkAttributes property which has a hasNameTitleGroup property.         |
| 95. Range                  | 127. PhysicalLocation is a sub-class of ElementInfo  |
| 96. Inverse Functionality  | 128. PhysicalLocation does not have a hasLinkAttributes property which has a hasID property.             |
| 97. Structural Tautology   | 129. PhysicalLocation does not have a hasLinkAttributes property which has a hasIDRef property.          |
| 98. Domain                 | 130. PhysicalLocation does not have a hasLinkAttributes property which has a hasAltRepGroup property.    |
| 99. Range                  | 131. PhysicalLocation does not have a hasLinkAttributes property which has a hasNameTitleGroup property. |
| 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  |  |

## 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

$$\top \sqsubseteq \forall \text{hasResourcePhysicalDescription}.\text{ResourcePhysicalDescription} \quad (1)$$

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

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasResourcePhysicalDescription}.\text{ResourcePhysicalDescription} \quad (3)$$

$$\exists \text{hasPhysicalRepresentationOf}.\top \sqsubseteq \text{ResourcePhysicalDescription} \quad (4)$$

$$\top \sqsubseteq \forall \text{hasPhysicalRepresentationOf}.\text{PhysicalForm} \quad (5)$$

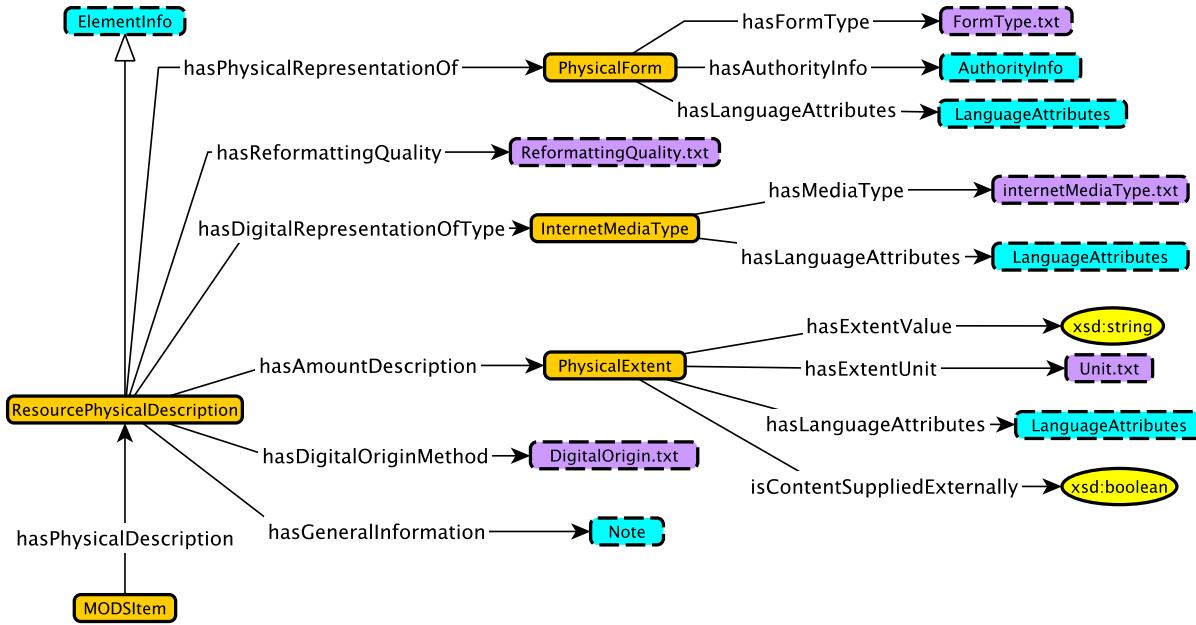


Figure 2.10: The schema diagram for the Resource Physical Description Module.

$\text{PhysicalForm} \sqsubseteq \exists \text{hasPhysicalRepresentationOf}^{-}.\text{ResourcePhysicalDescription}$  (6)

$T \sqsubseteq \leq 1 \text{hasPhysicalRepresentationOf}^{-}.T$  (7)

$\text{ResourcePhysicalDescription} \sqsubseteq \geq 0 \text{hasPhysicalRepresentationOf}.\text{PhysicalForm}$  (8)

$\exists \text{hasFormType}.T \sqsubseteq \text{PhysicalForm}$  (9)

$\text{PhysicalForm} \sqsubseteq \geq 0 \text{hasFormType}.\text{FormType.txt}$  (10)

$T \sqsubseteq \forall \text{hasAuthorityInfo}.\text{AuthorityInfo}$  (11)

$T \sqsubseteq \leq 1 \text{hasAuthorityInfo}.T$  (12)

$T \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.T$  (13)

$\text{PhysicalForm} \sqsubseteq \geq 0 \text{hasAuthorityInfo}.\text{AuthorityInfo}$  (14)

$T \sqsubseteq \forall \text{hasLanguageAttributes}.\text{LanguageAttributes}$  (15)

$T \sqsubseteq \leq 1 \text{hasLanguageAttributes}.T$  (16)

$T \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.T$  (17)

$\text{PhysicalForm} \sqsubseteq \geq 0 \text{hasLanguageAttributes}.\text{LanguageAttributes}$  (18)

$\exists \text{hasDigitalRepresentationOfType}.T \sqsubseteq \text{ResourcePhysicalDescription}$  (19)

$T \sqsubseteq \forall \text{hasDigitalRepresentationOfType}.\text{InternetMediaType}$  (20)

$\text{InternetMediaType} \sqsubseteq \exists \text{hasDigitalRepresentationOfType}^{-}.\text{ResourcePhysicalDescription}$  (21)

$T \sqsubseteq \leq 1 \text{hasDigitalRepresentationOfType}^{-}.T$  (22)

$\text{ResourcePhysicalDescription} \sqsubseteq \geq 0 \text{hasDigitalRepresentationOfType}.\text{InternetMediaType}$  (23)

$T \sqsubseteq \forall \text{hasMediaType}.\text{InternetMediaType.txt}$  (24)

$\text{InternetMediaType} \sqsubseteq \exists \text{hasMediaType}.\text{InternetMediaType.txt}$  (25)

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

### 2.10.2.2 Explanations

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

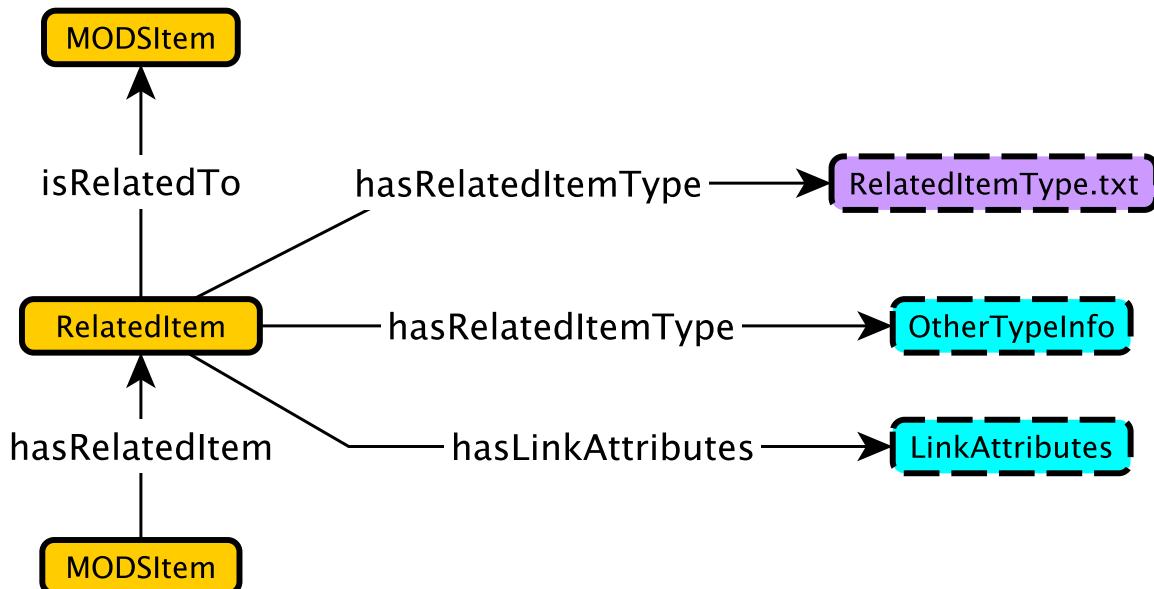


Figure 2.11: The schema diagram for the Related Item Module.

## 2.11.2 Formalization

### 2.11.2.1 Axioms

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

### 2.11.2.2 Explanations

- |   |   |
|---|---|
| <ul style="list-style-type: none"> <li>1. Range</li> <li>2. Structural Tautology</li> <li>3. Range</li> <li>4. Existential</li> <li>5. Inverse Existential</li> <li>6. Structural Tautology</li> <li>7. Range</li> <li>8. Structural Tautology</li> <li>9. Structural Tautology</li> <li>10. Range</li> </ul> | <ul style="list-style-type: none"> <li>11. Functionality</li> <li>12. Inverse Functionality</li> <li>13. Structural Tautology</li> <li>14. RelatedItem does not have a hasLinkAttributes property which has a hasAltRepGroup property.</li> <li>15. RelatedItem does not have a hasLinkAttributes property which has a hasNameTitleGroup property.</li> </ul> |
|---|---|

## 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

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

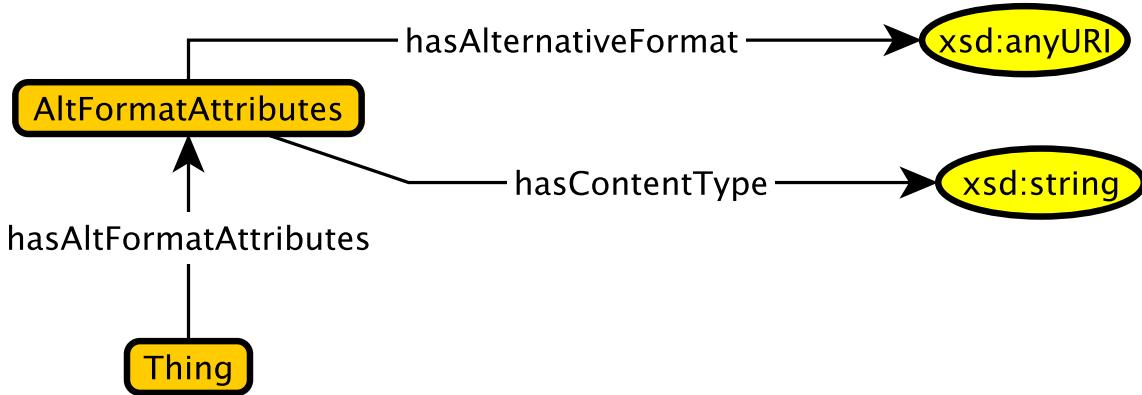


Figure 2.12: The schema diagram for the Alternative Format Attributes Module.

$$\text{AltFormatAttributes} \sqsubseteq \exists \text{hasAlternativeFormat}. \text{xsd}: \text{anyURI} \quad (5)$$

$$\text{AltFormatAttributes} \sqsubseteq \geq 0 \text{hasAlternativeFormat}. \text{xsd}: \text{anyURI} \quad (6)$$

$$\top \sqsubseteq \forall \text{hasContentType}. \text{xsd}: \text{string} \quad (7)$$

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

### 2.12.2.2 Explanations

- |   |  |
|---|--|
| 1. Range<br>2. Inverse Functionality<br>3. Structural Tautology<br>4. Range | 5. Existential<br>6. Structural Tautology<br>7. Range<br>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

$$\top \sqsubseteq \forall \text{hasLanguage}. \text{Language} \quad (1)$$

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

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasLanguage}. \text{Language} \quad (3)$$

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

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

$$\top \sqsubseteq \forall \text{hasLanguageTerm}. \text{Term} \quad (6)$$

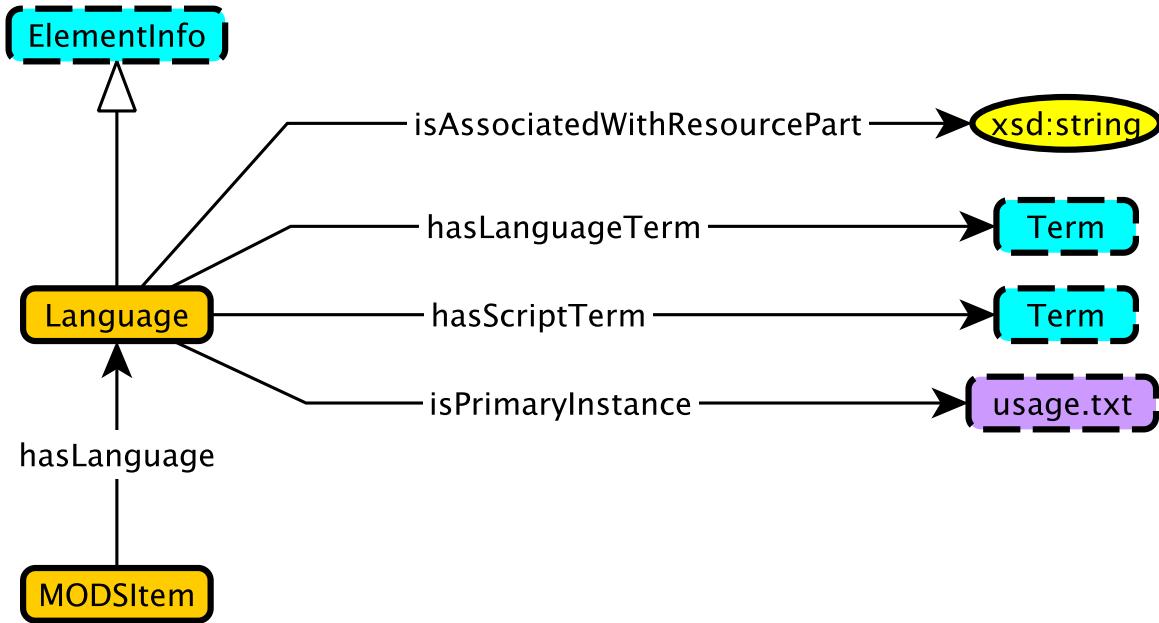


Figure 2.13: The schema diagram for the Language Module.

$\text{Language} \sqsubseteq \exists \text{hasLanguageTerm}.\text{Term}$  (7)

$\top \sqsubseteq \leq 1 \text{hasLanguageTerm}^-.\top$  (8)

$\text{Language} \sqsubseteq \geq 0 \text{hasLanguageTerm}.\text{Term}$  (9)

$\top \sqsubseteq \forall \text{hasScriptTerm}.\text{Term}$  (10)

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

$\text{Language} \sqsubseteq \geq 0 \text{hasScriptTerm}.\text{Term}$  (12)

$\top \sqsubseteq \forall \text{isPrimaryInstance}.\text{Usage.txt}$  (13)

$\text{Language} \sqsubseteq \geq 0 \text{isPrimaryInstance}.\text{Usage.txt}$  (14)

$\text{Language} \sqsubseteq \text{ElementInfo}$  (15)

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

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

$\text{Language} \sqsubseteq \neg(\exists \text{hasScriptTerm}.\exists \text{hasAltRepGroup}.\top)$  (18)

### 2.13.2.2 Explanations

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

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.

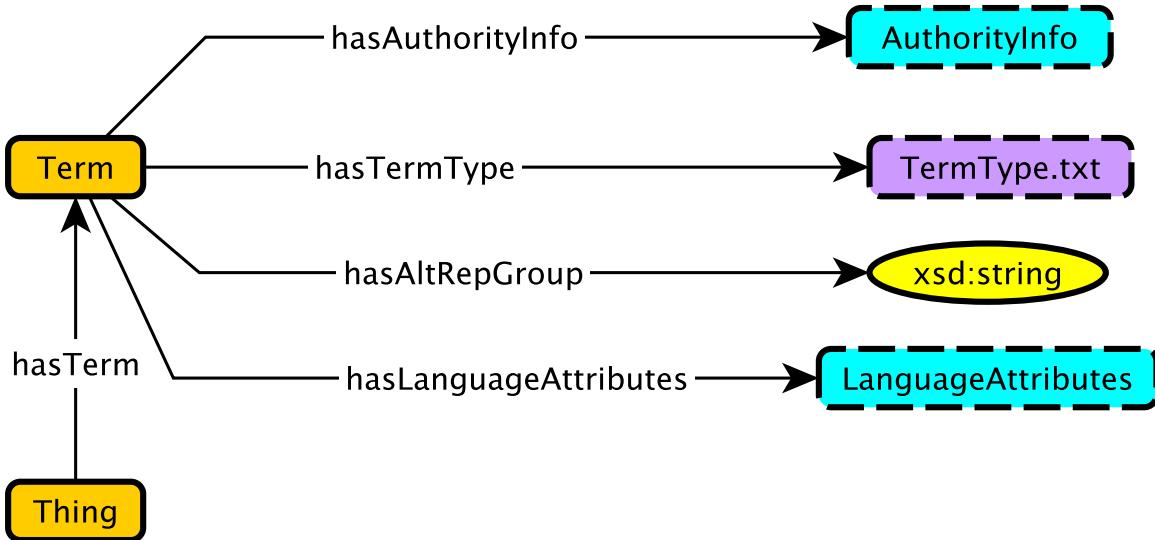


Figure 2.14: The schema diagram for the Term Module.

### 2.14.2 Formalization

#### 2.14.2.1 Axioms

$$T \sqsubseteq \forall \text{hasTerm}. \text{Term} \quad (1)$$

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

$$T \sqsubseteq \geq 0 \text{hasTerm}. \text{Term} \quad (3)$$

$$T \sqsubseteq \forall \text{hasTermType}. \text{TermType.txt} \quad (4)$$

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

$$\text{Term} \sqsubseteq \geq 0 \text{hasTermType}. \text{TermType.txt} \quad (6)$$

$$T \sqsubseteq \forall \text{hasAuthorityInfo}. \text{AuthorityInfo} \quad (7)$$

$$T \sqsubseteq \leq 1 \text{hasAuthorityInfo}. \top \quad (8)$$

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

$$\text{Term} \sqsubseteq \geq 0 \text{hasAuthorityInfo}. \text{AuthorityInfo} \quad (10)$$

$$T \sqsubseteq \forall \text{hasLanguageAttributes}. \text{LanguageAttributes} \quad (11)$$

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

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

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

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

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

### 2.14.2.2 Explanations

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

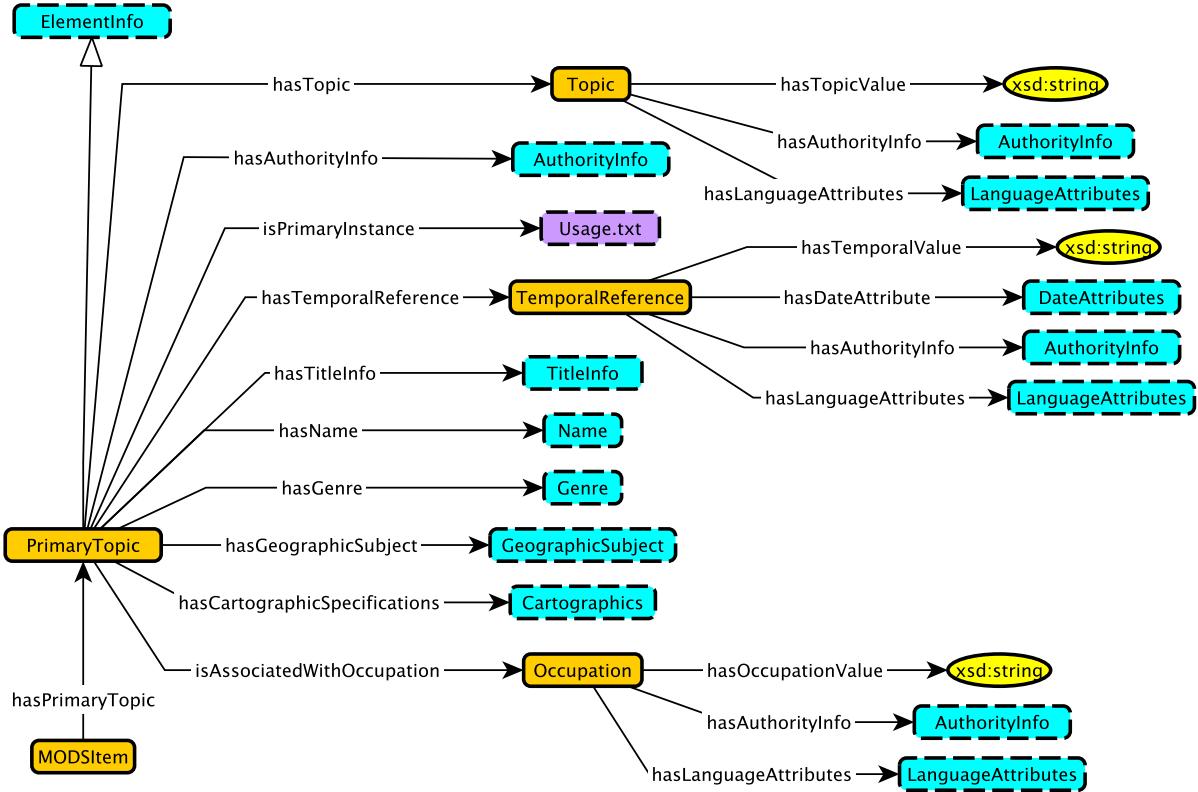


Figure 2.15: The schema diagram for the PrimaryTopic Module.

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

$$\exists \text{hasTemporalReference.T} \sqsubseteq \text{PrimaryTopic} \quad (20)$$

$$\quad T \sqsubseteq \forall \text{hasTemporalReference.TemporalReference} \quad (21)$$

$$\text{TemporalReference} \sqsubseteq \exists \text{hasTemporalReference}^{-}.\text{PrimaryTopic} \quad (22)$$

$$\quad T \sqsubseteq \leq 1 \text{hasTemporalReference}^{-}.T \quad (23)$$

$$\text{PrimaryTopic} \sqsubseteq \geq 0 \text{hasTemporalReference.TemporalReference} \quad (24)$$

$$\quad T \sqsubseteq \forall \text{hasDateAttribute.DateAttributes} \quad (25)$$

$$\quad T \sqsubseteq \leq 1 \text{hasDateAttribute.T} \quad (26)$$

$$\quad T \sqsubseteq \leq 1 \text{hasDateAttribute}^{-}.T \quad (27)$$

$$\text{TemporalReference} \sqsubseteq \geq 0 \text{hasDateAttribute.DateAttributes} \quad (28)$$

$$\quad T \sqsubseteq \forall \text{hasAuthorityInfo.AuthorityInfo} \quad (29)$$

$$\quad T \sqsubseteq \leq 1 \text{hasAuthorityInfo.T} \quad (30)$$

$$\quad T \sqsubseteq \leq 1 \text{hasAuthorityInfo}^{-}.T \quad (31)$$

$$\text{TemporalReference} \sqsubseteq \geq 0 \text{hasAuthorityInfo.AuthorityInfo} \quad (32)$$

$$\quad T \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes} \quad (33)$$

$$\quad T \sqsubseteq \leq 1 \text{hasLanguageAttributes.T} \quad (34)$$

$$\quad T \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}.T \quad (35)$$

$$\text{TemporalReference} \sqsubseteq \geq 0 \text{hasLanguageAttributes.LanguageAttributes} \quad (36)$$

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

$T \sqsubseteq \leq_1 \text{isPrimaryInstance}.T$	(79)
$\text{TitleInfo} \sqsubseteq \neg(\exists \text{isPrimaryInstance}.T)$	(80)
$\text{TitleInfo} \sqsubseteq \neg(\exists \text{isContentSuppliedExternally}.T)$	(81)
$\text{TitleInfo} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasAltRepGroup}.T)$	(82)
$\text{TitleInfo} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.T)$	(83)
$\text{Name} \sqsubseteq \neg(\exists \text{hasAssociatedName}.T)$	(84)
$\text{Name} \sqsubseteq \neg(\exists \text{hasEtal}.T)$	(85)
$\text{PrimaryTopic} \sqsubseteq \text{ElementInfo}$	(86)
$\text{PrimaryTopic} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.T)$	(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.

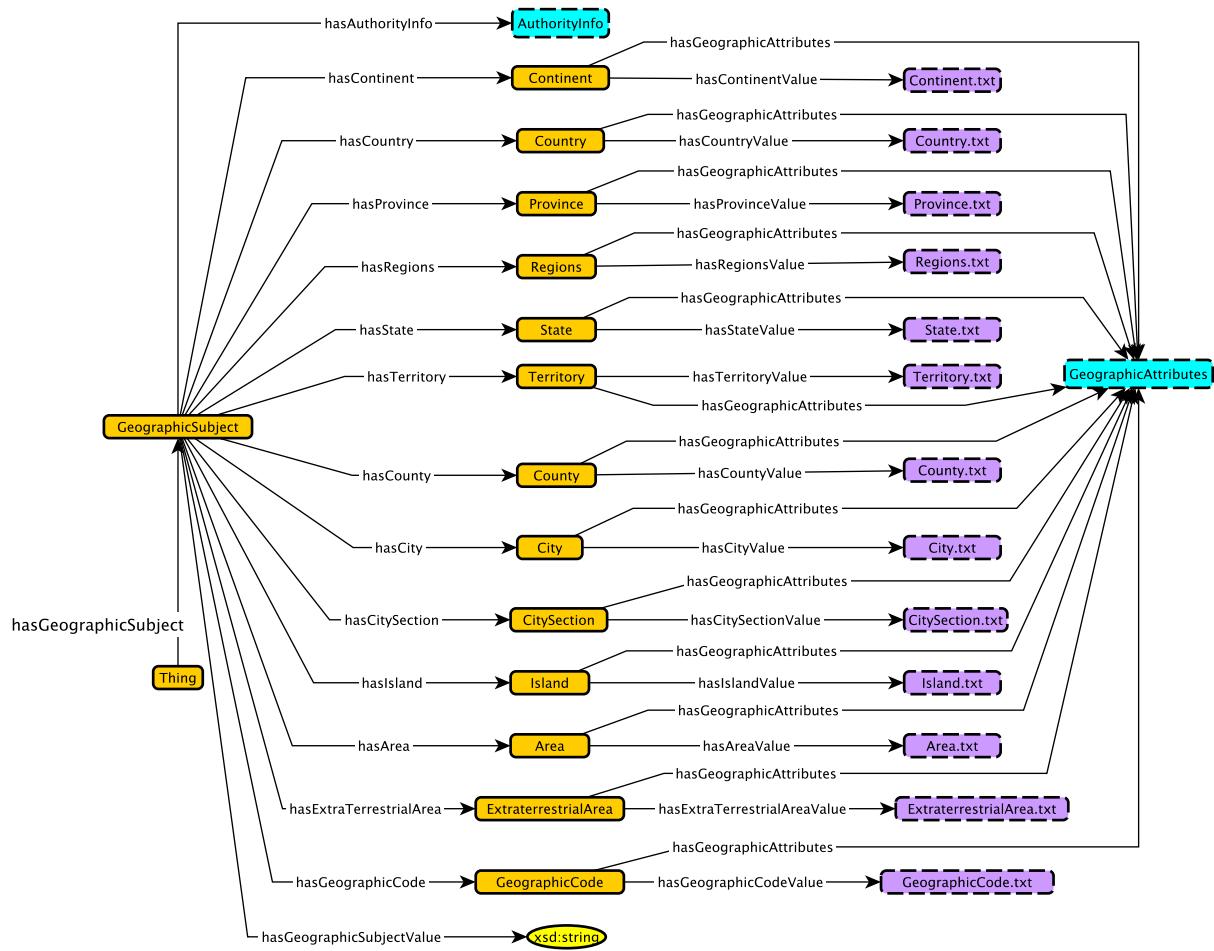


Figure 2.16: The schema diagram for the Geographic Subject Module.

## 2.16.2 Formalization

### 2.16.2.1 Axioms

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

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

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

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

$$\text{T} \sqsubseteq \leq 1\text{hasAuthorityInfo}^-. \text{T} \quad (164)$$

$$\text{GeographicSubject} \sqsubseteq \geq 0\text{hasAuthorityInfo}.\text{AuthorityInfo} \quad (165)$$

### 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

$$\top \sqsubseteq \forall \text{hasGeographicAttributes}.\text{GeographicAttributes} \quad (1)$$

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

$$\top \sqsubseteq \geq 0 \text{hasGeographicAttributes}.\text{GeographicAttributes} \quad (3)$$

$$\top \sqsubseteq \forall \text{hasAuthorityInfo}.\text{AuthorityInfo} \quad (4)$$

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

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

$$\text{GeographicAttributes} \sqsubseteq \geq 0 \text{hasAuthorityInfo}.\text{AuthorityInfo} \quad (7)$$

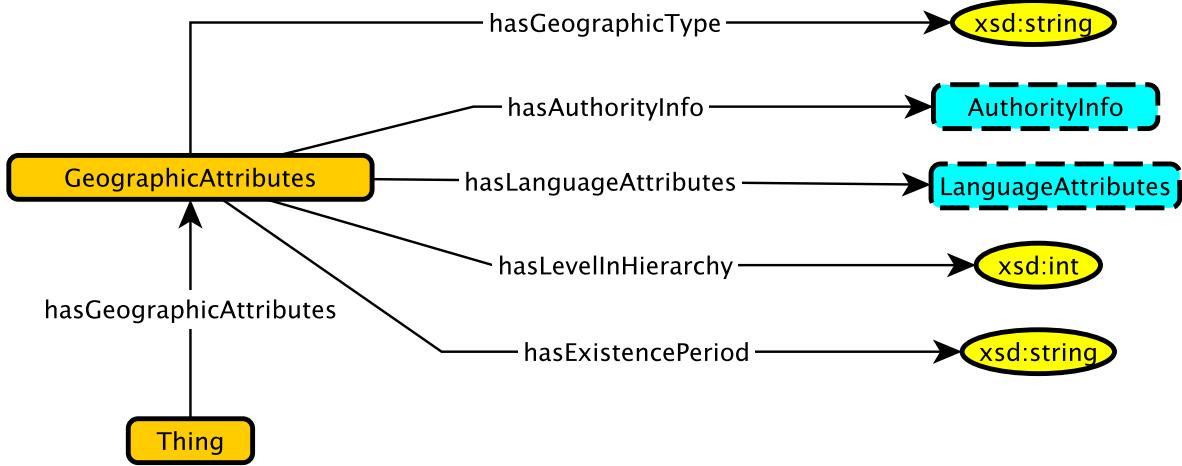


Figure 2.17: The schema diagram for the Geographic Attributes Module.

$$T \sqsubseteq \forall \text{hasLanguageAttributes}. \text{LanguageAttributes} \quad (8)$$

$$T \sqsubseteq \leq 1 \text{hasLanguageAttributes}. T \quad (9)$$

$$T \sqsubseteq \leq 1 \text{hasLanguageAttributes}^{-}. T \quad (10)$$

$$\text{GeographicAttributes} \sqsubseteq \geq 0 \text{hasLanguageAttributes}. \text{LanguageAttributes} \quad (11)$$

$$T \sqsubseteq \forall \text{hasLevelInHierarchy}. \text{xsd:int} \quad (12)$$

$$\text{GeographicAttributes} \sqsubseteq \geq 0 \text{hasLevelInHierarchy}. \text{xsd:int} \quad (13)$$

$$T \sqsubseteq \forall \text{hasExistencePeriod}. \text{xsd:string} \quad (14)$$

$$\text{GeographicAttributes} \sqsubseteq \geq 0 \text{hasExistencePeriod}. \text{xsd:string} \quad (15)$$

$$T \sqsubseteq \forall \text{hasGeographicType}. \text{xsd:string} \quad (16)$$

$$\text{GeographicAttributes} \sqsubseteq \geq 0 \text{hasGeographicType}. \text{xsd:string} \quad (17)$$

### 2.17.2.2 Explanations

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

## 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.

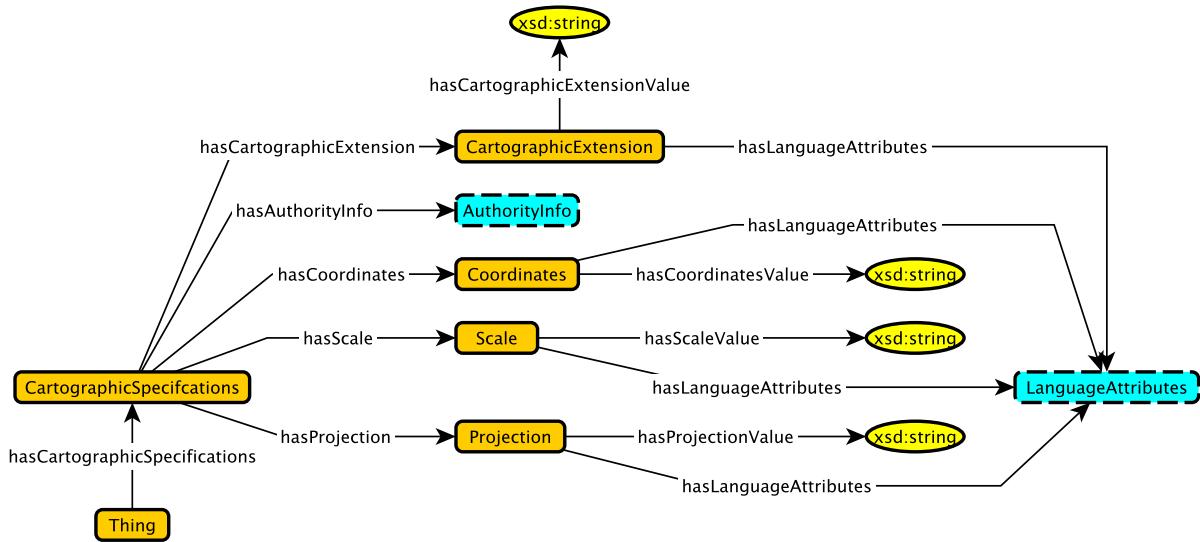


Figure 2.18: The schema diagram for the Cartographic Specifications Module.

## 2.18.2 Formalization

### 2.18.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasCartographicSpecifications}.\text{CartographicSpecifications} \quad (1)$$

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

$$\top \sqsubseteq \geq 0 \text{hasCartographicSpecifications}.\text{CartographicSpecifications} \quad (3)$$

$$\exists \text{hasCoordinates}.\top \sqsubseteq \text{CartographicSpecifications} \quad (4)$$

$$\top \sqsubseteq \forall \text{hasCoordinates}.\text{Coordinates} \quad (5)$$

$$\text{CartographicSpecifications} \sqsubseteq \exists \text{hasCoordinates}.\text{Coordinates} \quad (6)$$

$$\text{Coordinates} \sqsubseteq \exists \text{hasCoordinates}^-.\text{Cartographics} \quad (7)$$

$$\top \sqsubseteq \leq 1 \text{hasCoordinates}^-.\top \quad (8)$$

$$\text{CartographicSpecifications} \sqsubseteq \geq 0 \text{hasCoordinates}.\text{Coordinates} \quad (9)$$

$$\top \sqsubseteq \forall \text{hasLanguageAttributes}.\text{LanguageAttributes} \quad (10)$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \quad (11)$$

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

$$\text{Coordinates} \sqsubseteq \geq 0 \text{hasLanguageAttributes}.\text{LanguageAttributes} \quad (13)$$

$$\top \sqsubseteq \forall \text{hasCoordinatesValue}.\text{xsd:string} \quad (14)$$

$$\text{Coordinates} \sqsubseteq \exists \text{hasCoordinatesValue}.\text{xsd:string} \quad (15)$$

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

$$\exists \text{hasScale}.\top \sqsubseteq \text{CartographicSpecifications} \quad (17)$$

$$\top \sqsubseteq \forall \text{hasScale}.\text{Scale} \quad (18)$$

$$\text{Scale} \sqsubseteq \exists \text{hasScale}^-.\text{CartographicSpecifications} \quad (19)$$

$$\top \sqsubseteq \leq 1 \text{hasScale}^-.\top \quad (20)$$

$$\text{CartographicSpecifications} \sqsubseteq \geq 0 \text{hasScale}.\text{Scale} \quad (21)$$

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

### 2.18.2.2 Explanations

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

$$T \sqsubseteq \forall \text{hasGenre}.\text{Genre} \quad (1)$$

$$T \sqsubseteq \leq 1 \text{hasGenre}^- . T \quad (2)$$

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasGenre}.\text{Genre} \quad (3)$$

$$T \sqsubseteq \forall \text{isPrimaryInstance}.\text{Usage.txt} \quad (4)$$

$$\text{Genre} \sqsubseteq \geq 0 \text{isPrimaryInstance}.\text{Usage.txt} \quad (5)$$

$$T \sqsubseteq \forall \text{hasAuthorityInfo}.\text{AuthorityInfo} \quad (6)$$

$$T \sqsubseteq \leq 1 \text{hasAuthorityInfo}.T \quad (7)$$

$$T \sqsubseteq \leq 1 \text{hasAuthorityInfo}^- . T \quad (8)$$

$$\text{Genre} \sqsubseteq \geq 0 \text{hasAuthorityInfo}.\text{AuthorityInfo} \quad (9)$$

$$T \sqsubseteq \forall \text{hasGenreValue}.\text{xsd:string} \quad (10)$$

$$\text{Genre} \sqsubseteq \exists \text{hasGenreValue}.\text{xsd:string} \quad (11)$$

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

$$T \sqsubseteq \forall \text{hasGenreType}.\text{xsd:string} \quad (13)$$

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

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

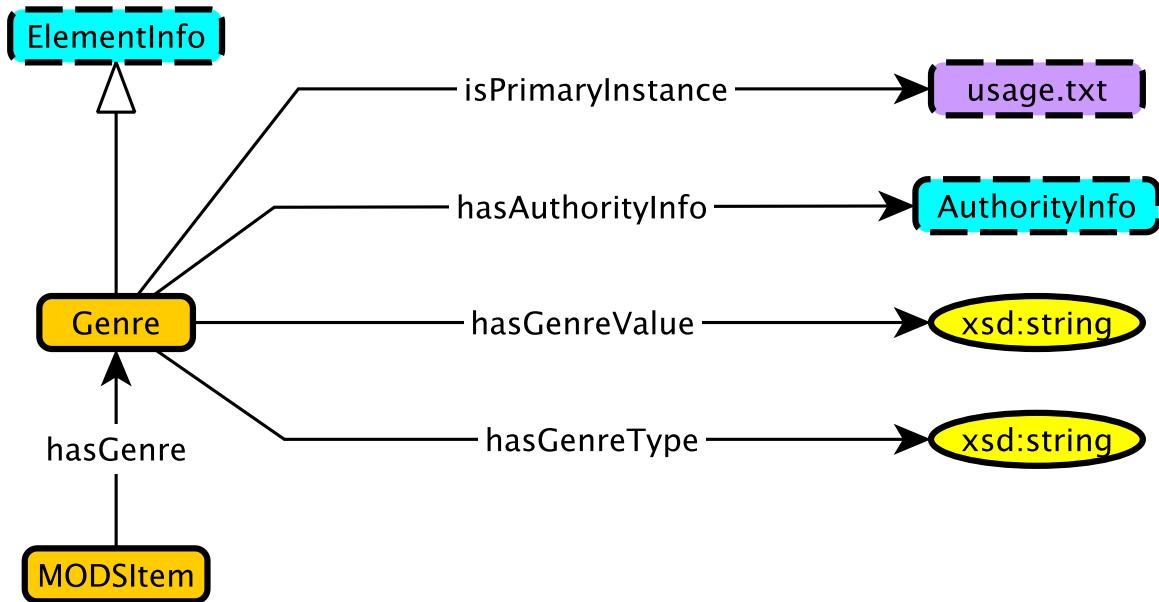


Figure 2.19: The schema diagram for the Genre Module.

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

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

### 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.

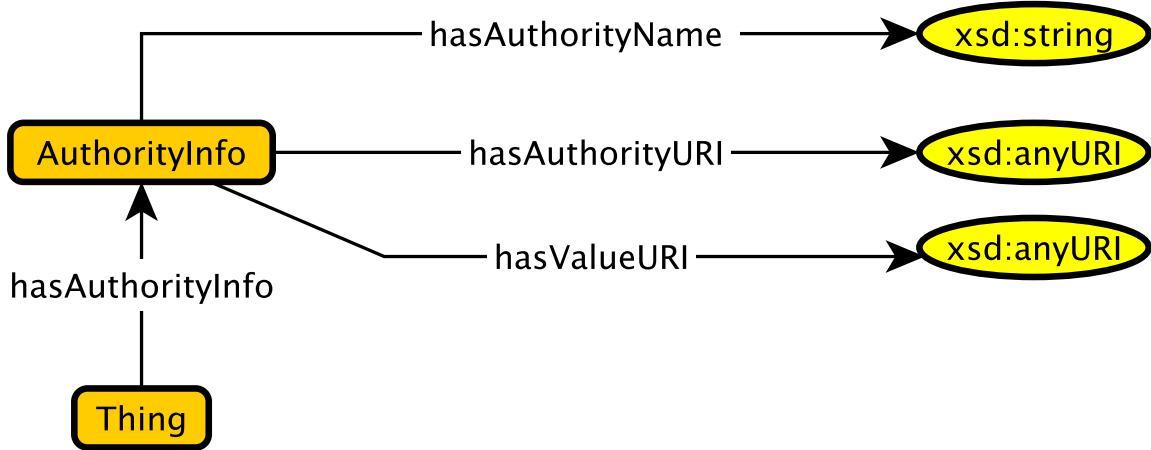


Figure 2.20: The schema diagram for the Authority Info Module.

## 2.20.2 Formalization

### 2.20.2.1 Axioms

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

### 2.20.2.2 Explanations

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

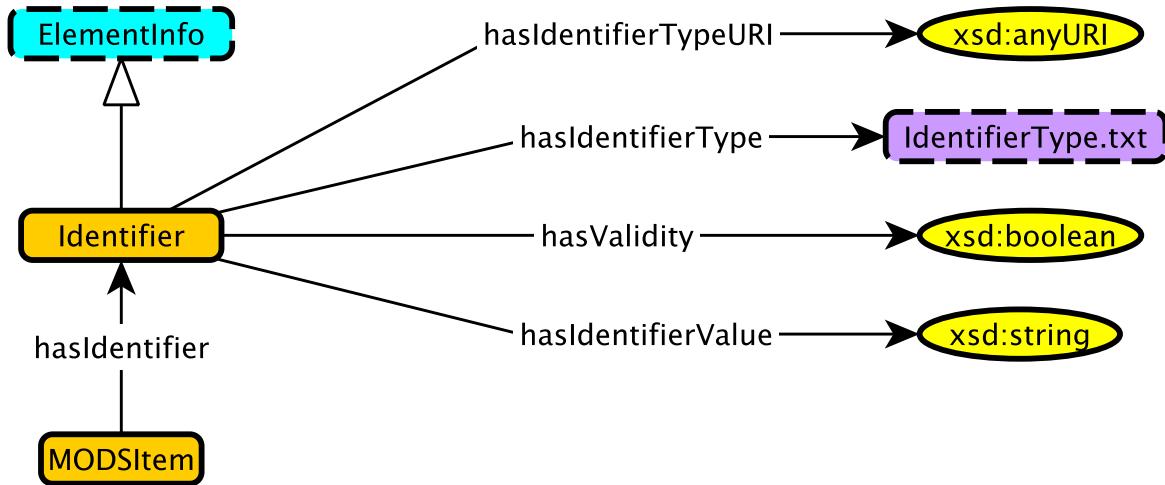


Figure 2.21: The schema diagram for the Identifier Module.

## 2.21.2 Formalization

### 2.21.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasIdentifier}.\text{Identifier} \quad (1)$$

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

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasIdentifier}.\text{Identifier} \quad (3)$$

$$\top \sqsubseteq \forall \text{hasIdentifierTypeURI}.\text{xsd}:anyURI \quad (4)$$

$$\text{Identifier} \sqsubseteq \geq 0 \text{hasIdentifierTypeURI}.\text{xsd}:anyURI \quad (5)$$

$$\top \sqsubseteq \forall \text{hasIdentifierType}.\text{IdentifierType}.txt \quad (6)$$

$$\text{Identifier} \sqsubseteq \geq 0 \text{hasIdentifierType}.\text{IdentifierType}.txt \quad (7)$$

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

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

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

$$\text{Identifier} \sqsubseteq \exists \text{hasIdentifierValue}.\text{xsd}:string \quad (11)$$

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

$$\text{Identifier} \sqsubseteq \text{ElementInfo} \quad (13)$$

$$\text{Identifier} \sqsubseteq \neg (\exists \text{hasLinkAttributes}.\exists \text{hasXlink}.\top) \quad (14)$$

$$\text{Identifier} \sqsubseteq \neg (\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.\top) \quad (15)$$

### 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.

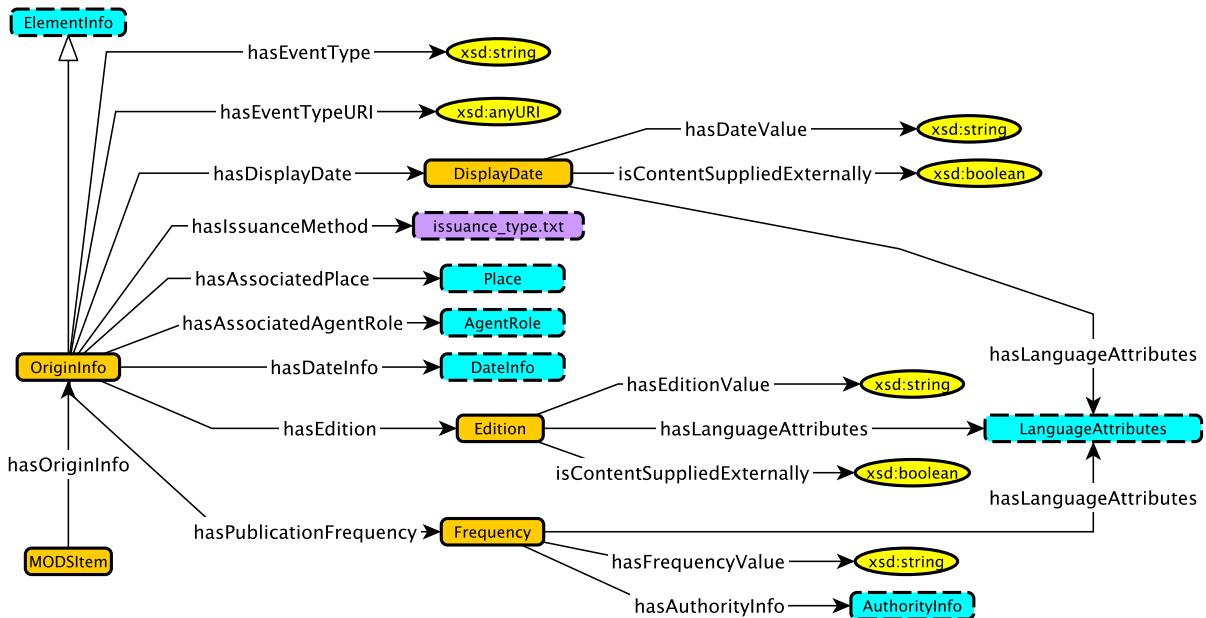


Figure 2.22: The schema diagram for the Origin Info Module.

### 2.22.2 Formalization

#### 2.22.2.1 Axioms

$$T \sqsubseteq \forall \text{hasOriginInfo}.\text{OriginInfo} \quad (1)$$

$$T \sqsubseteq \leq 1 \text{hasOriginInfo}^- . T \quad (2)$$

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasOriginInfo}.\text{OriginInfo} \quad (3)$$

$$T \sqsubseteq \forall \text{hasEdition}.\text{Edition} \quad (4)$$

$$\text{Edition} \sqsubseteq \exists \text{hasEdition}^- . \text{OriginInfo} \quad (5)$$

$$T \sqsubseteq \leq 1 \text{hasEdition} . T \quad (6)$$

$$T \sqsubseteq \leq 1 \text{hasEdition}^- . T \quad (7)$$

$$\text{OriginInfo} \sqsubseteq \geq 0 \text{hasEdition}.\text{Edition} \quad (8)$$

$$T \sqsubseteq \forall \text{hasEditionValue}.\text{xsd:string} \quad (9)$$

$$\text{Edition} \sqsubseteq \exists \text{hasEditionValue}.\text{xsd:string} \quad (10)$$

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

$T \sqsubseteq \forall \text{hasDateInfo}.\text{DateInfo}$	(53)
$T \sqsubseteq \leq 1\text{hasDateInfo}^-.\top$	(54)
$\text{OriginInfo} \sqsubseteq \geq 0\text{hasDateInfo}.\text{DateInfo}$	(55)
$T \sqsubseteq \forall \text{hasEventType.xsd:string}$	(56)
$\text{OriginInfo} \sqsubseteq \geq 0\text{hasEventType.xsd:string}$	(57)
$T \sqsubseteq \forall \text{hasEventTypeURI.xsd:anyURI}$	(58)
$\text{OriginInfo} \sqsubseteq \geq 0\text{hasEventTypeURI.xsd:anyURI}$	(59)
$T \sqsubseteq \forall \text{hasIssuanceMethod.IssuanceType.txt}$	(60)
$\text{OriginInfo} \sqsubseteq \geq 0\text{hasIssuanceMethod.IssuanceType.txt}$	(61)
$\text{OriginInfo} \sqsubseteq \text{ElementInfo}$	(62)
$\text{OriginInfo} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasXlink}.\top)$	(63)
$\text{OriginInfo} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.\top)$	(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.  $\text{OriginInfo}$  is a sub-class of  $\text{ElementInfo}$
- 63.  $\text{OriginInfo}$  does not have a  $\text{hasLinkAttributes}$  property which has a  $\text{hasXlink}$  property
- 64.  $\text{OriginInfo}$  does not have a  $\text{hasLinkAttributes}$  property which has a  $\text{hasNameTitleGroup}$  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.

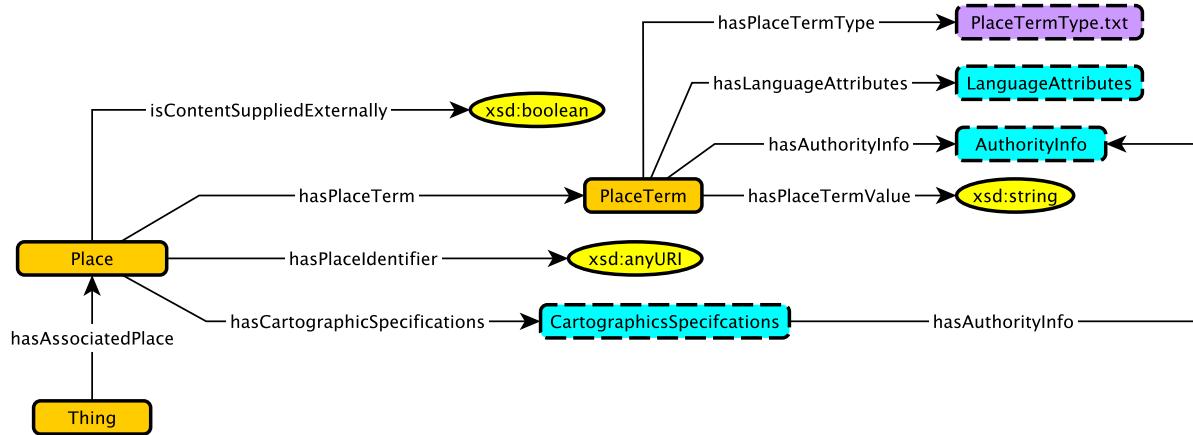


Figure 2.23: The schema diagram for the Place Module.

### 2.23.2 Formalization

#### 2.23.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasAssociatedPlace}.\text{Place} \quad (1)$$

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

$$\top \sqsubseteq \geq 0 \text{hasAssociatedPlace}.\text{Place} \quad (3)$$

$$\exists \text{hasPlaceTerm}.\top \sqsubseteq \text{Place} \quad (4)$$

$$\top \sqsubseteq \forall \text{hasPlaceTerm}.\text{PlaceTerm} \quad (5)$$

$$\text{Place} \sqsubseteq \exists \text{hasPlaceTerm}.\text{PlaceTerm} \quad (6)$$

$$\text{PlaceTerm} \sqsubseteq \exists \text{hasPlaceTerm}^-.\text{Place} \quad (7)$$

$$\text{PlaceTerm} \sqsubseteq \leq 1 \text{hasPlaceTerm}^-.\text{Place} \quad (8)$$

$$\text{Place} \sqsubseteq \geq 0 \text{hasPlaceTerm}.\text{PlaceTerm} \quad (9)$$

$$\top \sqsubseteq \forall \text{hasPlaceTermType}.\text{PlaceTermType.txt} \quad (10)$$

$$\text{PlaceTerm} \sqsubseteq \geq 0 \text{hasPlaceTermType}.\text{PlaceTermType.txt} \quad (11)$$

$$\top \sqsubseteq \forall \text{hasLanguageAttributes}.\text{LanguageAttributes} \quad (12)$$

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

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

$$\text{PlaceTerm} \sqsubseteq \geq 0 \text{hasLanguageAttributes}.\text{LanguageAttributes} \quad (15)$$

$$\top \sqsubseteq \forall \text{hasAuthorityInfo}.\text{AuthorityInfo} \quad (16)$$

$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}.\top \quad (17)$$

$$\top \sqsubseteq \leq 1 \text{hasAuthorityInfo}^-.\top \quad (18)$$

PlaceTerm $\sqsubseteq \geq 0$ hasAuthorityInfo.AuthorityInfo	(19)
T $\sqsubseteq \forall$ hasPlaceTermValue.xsd:string	(20)
PlaceTerm $\sqsubseteq \exists$ hasPlaceTermValue.xsd:string	(21)
PlaceTerm $\sqsubseteq \geq 0$ hasPlaceTermValue.xsd:string	(22)
T $\sqsubseteq \forall$ hasCartographicSpecifications.CartographicSpecifications	(23)
CartographicSpecifications $\sqsubseteq \leq 1$ hasCartographicSpecifications <sup>-</sup> .Place	(24)
Place $\sqsubseteq \geq 0$ hasCartographicSpecifications.CartographicSpecifications	(25)
T $\sqsubseteq \forall$ hasAuthorityInfo.AuthorityInfo	(26)
T $\sqsubseteq \leq 1$ hasAuthorityInfo.T	(27)
T $\sqsubseteq \leq 1$ hasAuthorityInfo <sup>-</sup> .T	(28)
CartographicSpecifications $\sqsubseteq \geq 0$ hasAuthorityInfo.AuthorityInfo	(29)
T $\sqsubseteq \forall$ hasPlaceIdentifier.xsd:anyURI	(30)
Place $\sqsubseteq \geq 0$ hasPlaceIdentifier.xsd:anyURI	(31)
T $\sqsubseteq \forall$ isContentSuppliedExternally.xsd:boolean	(32)
Place $\sqsubseteq \geq 0$ isContentSuppliedExternally.xsd:boolean	(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

T $\sqsubseteq \forall$ hasTypeOfResource.TypeOfResource	(1)
T $\sqsubseteq \leq 1$ hasTypeOfResource <sup>-</sup> .T	(2)

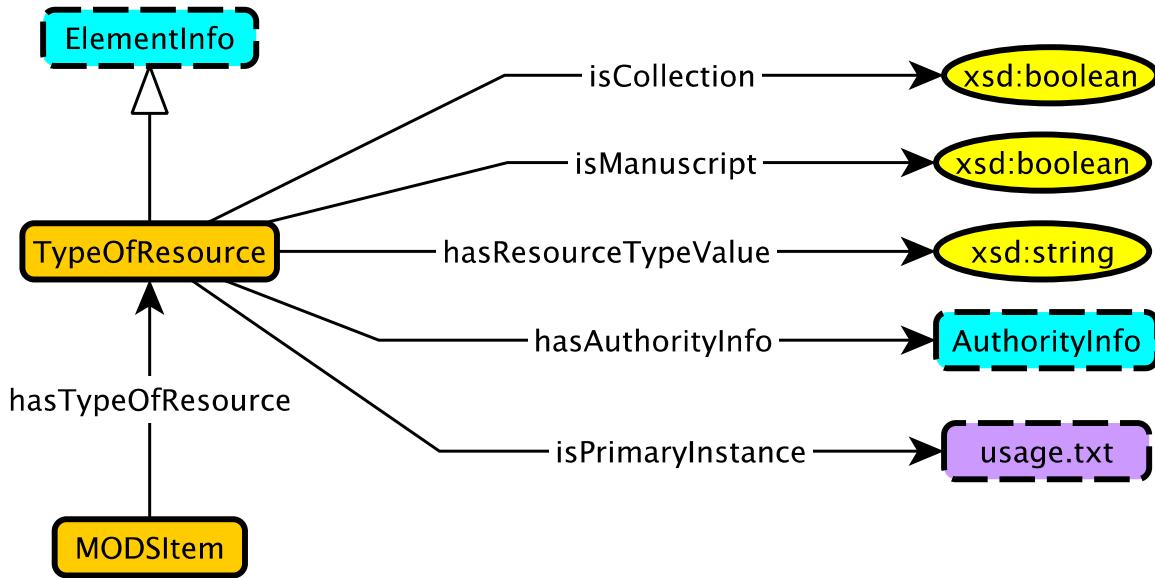


Figure 2.24: The schema diagram for the Type of Resource Module.

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

### 2.24.2.2 Explanations

- |                          |                          |
|--------------------------|--------------------------|
| 1. Range                 | 5. Functionality         |
| 2. Inverse Functionality | 6. Inverse Functionality |
| 3. Structural Tautology  | 7. Structural Tautology  |
| 4. Range                 | 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 resource.

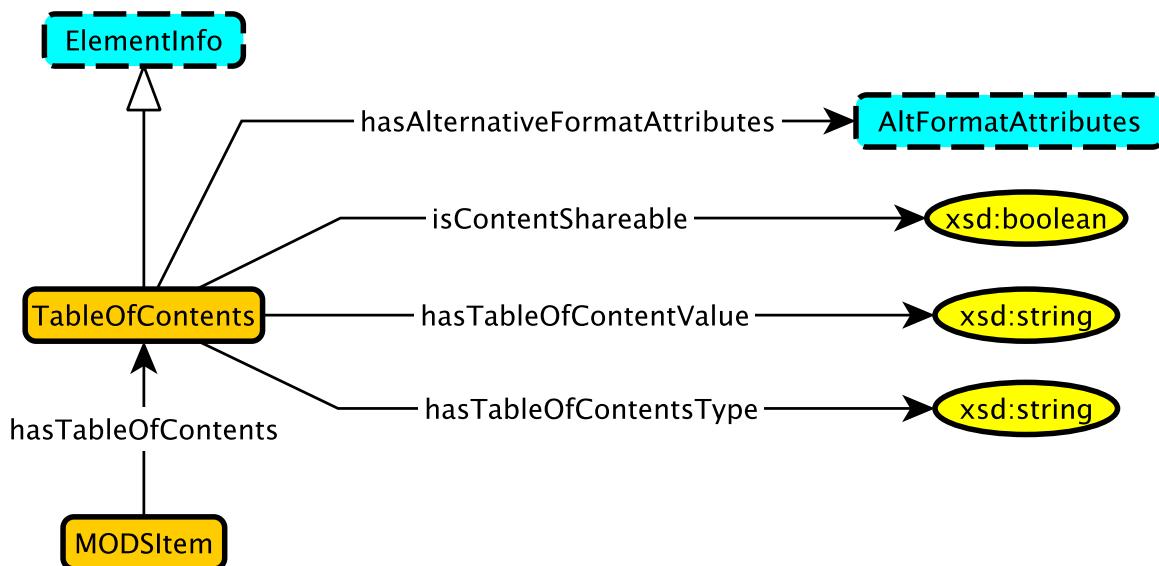


Figure 2.25: The schema diagram for the Table of Contents Module.

### 2.25.2 Formalization

#### 2.25.2.1 Axioms

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

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

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

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

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

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

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

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

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

### 2.25.2.2 Explanations

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

## 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.

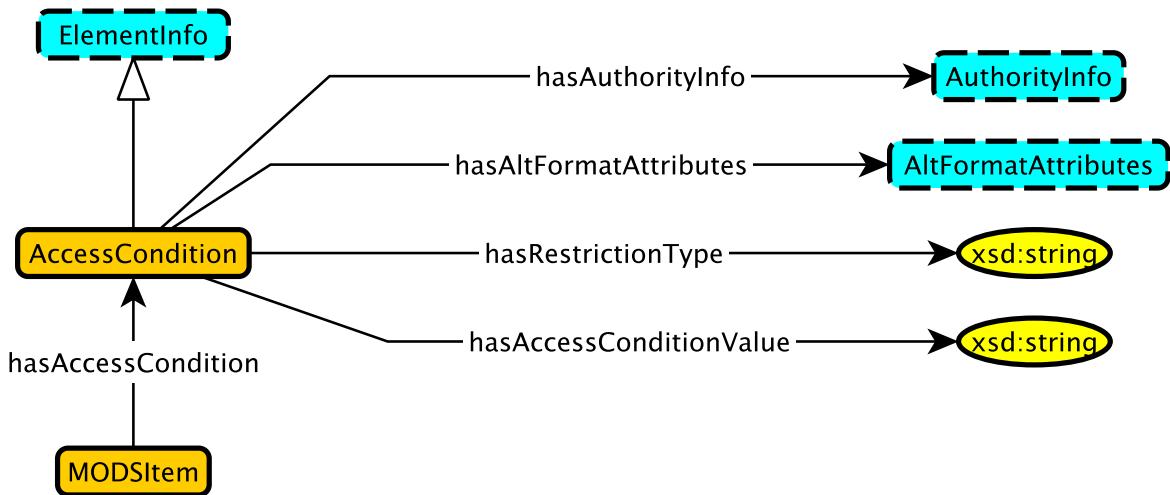


Figure 2.26: The schema diagram for the Access Condition Module.

## 2.26.2 Formalization

### 2.26.2.1 Axioms

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

### 2.26.2.2 Explanations

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

## 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.

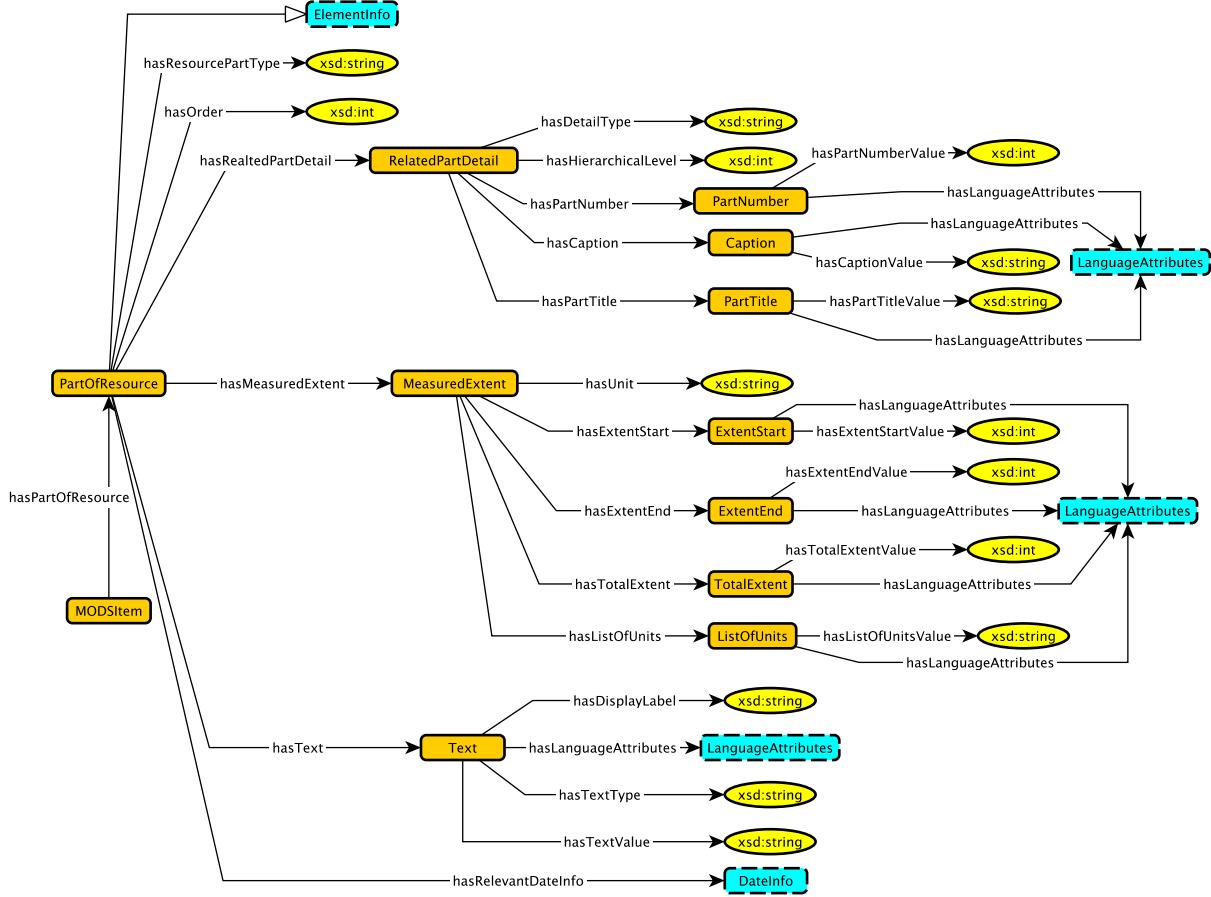


Figure 2.27: The schema diagram for the Part of Resource Module.

## 2.27.2 Formalization

### 2.27.2.1 Axioms

$$T \sqsubseteq \forall \text{hasPartOfResource}.\text{PartOfResource} \quad (1)$$

$$T \sqsubseteq \leq 1 \text{hasPartOfResource}^- . T \quad (2)$$

$$\text{MODSItem} \sqsubseteq \geq 0 \text{hasPartOfResource}.\text{PartOfResource} \quad (3)$$

$$T \sqsubseteq \forall \text{hasRelatedPartDetail}.\text{RelatedPartDetail} \quad (4)$$

$$T \sqsubseteq \leq 1 \text{RelatedPartDetail}^- . T \quad (5)$$

$$\text{PartOfResource} \sqsubseteq \geq 0 \text{hasRelatedPartDetail}.\text{RelatedPartDetail} \quad (6)$$

$$T \sqsubseteq \forall \text{hasDetailType}.\text{xsd:string} \quad (7)$$

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

$$T \sqsubseteq \forall \text{hasHierarchicalLevel}.\text{xsd:int} \quad (9)$$

$$\text{RelatedPartDetail} \sqsubseteq \geq 0 \text{hasHierarchicalLevel}.\text{xsd:int} \quad (10)$$

$$T \sqsubseteq \forall \text{hasPartNumber}.\text{PartNumber} \quad (11)$$

$$T \sqsubseteq \leq 1 \text{hasPartNumber}^- . T \quad (12)$$

$$\text{RelatedPartDetail} \sqsubseteq \geq 0 \text{hasPartNumber}.\text{PartNumber} \quad (13)$$

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

$T \sqsubseteq \leq 1\text{hasLanguageAttributes.}T$	(56)
$T \sqsubseteq \leq 1\text{hasLanguageAttributes}^-.\top$	(57)
$\text{ExtentStart} \sqsubseteq \geq 0\text{hasLanguageAttributes.LanguageAttributes}$	(58)
$T \sqsubseteq \forall \text{hasExtentEnd.}T$	(59)
$\text{MeasuredExtent} \sqsubseteq \exists \text{hasExtentEnd.}T$	(60)
$T \sqsubseteq \exists \text{hasExtentEndValue}^-.\text{MeasuredExtent}$	(61)
$T \sqsubseteq \leq 1\text{hasExtentEndValue.}\top$	(62)
$T \sqsubseteq \leq 1\text{hasExtentEndValue}^-.\top$	(63)
$\text{MeasuredExtent} \sqsubseteq \geq 0\text{hasExtentEnd.}T$	(64)
$T \sqsubseteq \forall \text{hasExtentEndValue.xsd:int}$	(65)
$T \sqsubseteq \exists \text{hasExtentEndValue.xsd:int}$	(66)
$T \sqsubseteq \geq 0\text{hasExtentEndValue.xsd:int}$	(67)
$T \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes}$	(68)
$T \sqsubseteq \leq 1\text{hasLanguageAttributes.}\top$	(69)
$T \sqsubseteq \leq 1\text{hasLanguageAttributes}^-.\top$	(70)
$\text{ExtentEnd} \sqsubseteq \geq 0\text{hasLanguageAttributes.LanguageAttributes}$	(71)
$T \sqsubseteq \forall \text{hasTotalExtent.TotalExtent}$	(72)
$\text{TotalExtent} \sqsubseteq \exists \text{hasTotalExtentValue}^-.\text{MeasuredExtent}$	(73)
$T \sqsubseteq \leq 1\text{hasTotalExtentValue.}\top$	(74)
$T \sqsubseteq \leq 1\text{hasTotalExtentValue}^-.\top$	(75)
$\text{MeasuredExtent} \sqsubseteq \geq 0\text{hasTotalExtent.TotalExtent}$	(76)
$T \sqsubseteq \forall \text{hasTotalExtentValue.xsd:int}$	(77)
$\text{TotalExtent} \sqsubseteq \exists \text{hasTotalExtentValue.xsd:int}$	(78)
$\text{TotalExtent} \sqsubseteq \geq 0\text{hasTotalExtentValue.xsd:int}$	(79)
$T \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes}$	(80)
$T \sqsubseteq \leq 1\text{hasLanguageAttributes.}\top$	(81)
$T \sqsubseteq \leq 1\text{hasLanguageAttributes}^-.\top$	(82)
$\text{TotalExtent} \sqsubseteq \geq 0\text{hasLanguageAttributes.LanguageAttributes}$	(83)
$T \sqsubseteq \forall \text{hasListOfUnits.ListOfUnits}$	(84)
$\text{ListOfUnits} \sqsubseteq \exists \text{hasListOfUnits}^-.\text{Extent}$	(85)
$T \sqsubseteq \leq 1\text{hasListOfUnits}^-.\top$	(86)
$\text{PhysicalExtent} \sqsubseteq \geq 0\text{hasListOfUnits.ListOfUnits}$	(87)
$T \sqsubseteq \forall \text{hasListOfUnitsValue.xsd:string}$	(88)
$\text{ListOfUnits} \sqsubseteq \exists \text{hasListOfUnitsValue.xsd:string}$	(89)
$\text{ListOfUnits} \sqsubseteq \geq 0\text{hasListOfUnitsValue.xsd:string}$	(90)
$T \sqsubseteq \forall \text{hasLanguageAttributes.LanguageAttributes}$	(91)
$T \sqsubseteq \leq 1\text{hasLanguageAttributes.}\top$	(92)
$T \sqsubseteq \leq 1\text{hasLanguageAttributes}^-.\top$	(93)
$\text{ListOfUnits} \sqsubseteq \geq 0\text{hasLanguageAttributes.LanguageAttributes}$	(94)
$T \sqsubseteq \forall \text{hasRelevantDateInfo.DateInfo}$	(95)
$T \sqsubseteq \leq 1\text{hasRelevantDateInfo}^-.\top$	(96)
$\text{PartOfResource} \sqsubseteq \geq 0\text{hasRelevantDateInfo.DateInfo}$	(97)

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

$$T \sqsubseteq \forall \text{providesAgentRole}.\text{AgentRole} \quad (1)$$

$$T \sqsubseteq \leq 1 \text{providesAgentRole}^- . T \quad (2)$$

$$T \sqsubseteq \geq 0 \text{providesAgentRole}.\text{AgentRole} \quad (3)$$

$$\exists \text{hasRoleUnderName}.\text{Name} \sqsubseteq \text{AgentRole} \quad (4)$$

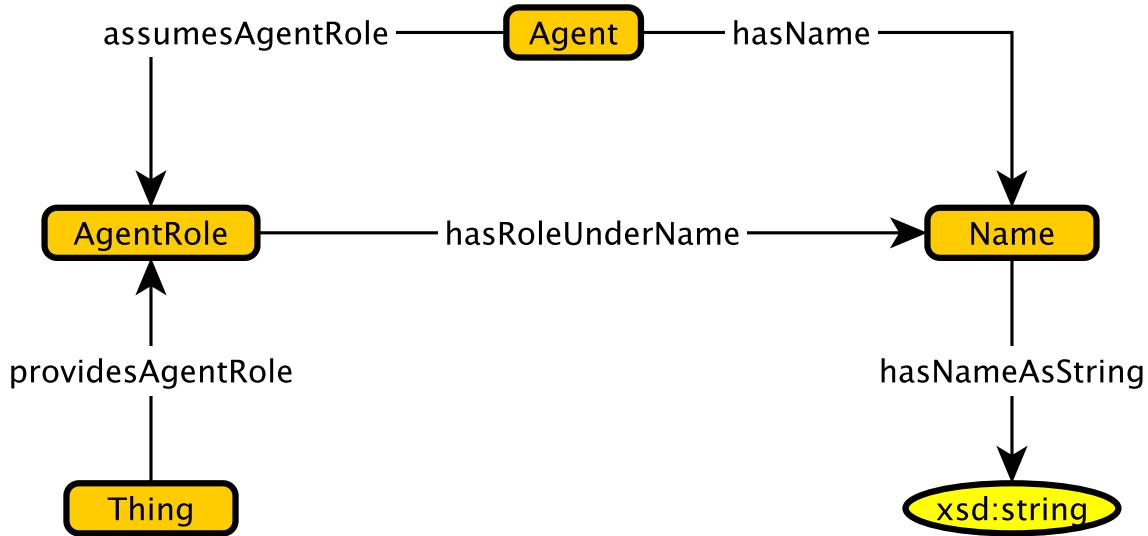


Figure 2.28: The schema diagram for the Agent Role Module.

$$T \sqsubseteq \forall \text{hasRoleUnderName}.Name \quad (5)$$

$$\text{AgentRole} \sqsubseteq \geq 0 \text{hasRoleUnderName}.Name \quad (6)$$

$$\exists \text{assumesAgentRole}.AgentRole \sqsubseteq \text{Agent} \quad (7)$$

$$T \sqsubseteq \forall \text{assumesAgentRole}.AgentRole \quad (8)$$

$$\text{AgentRole} \sqsubseteq \exists \text{assumesAgentRole}^{-}.\text{Agent} \quad (9)$$

$$\text{AgentRole} \sqsubseteq \leq 1 \text{assumesAgentRole}^{-}.\text{Agent} \quad (10)$$

$$\text{Agent} \sqsubseteq \geq 0 \text{assumesAgentRole}.AgentRole \quad (11)$$

$$\exists \text{hasName}.T \sqsubseteq \text{Agent} \quad (12)$$

$$T \sqsubseteq \forall \text{hasName}.Name \quad (13)$$

$$\text{Agent} \sqsubseteq \exists \text{hasName}.Name \quad (14)$$

$$\text{Name} \sqsubseteq \exists \text{hasName}^{-}.\text{Agent} \quad (15)$$

$$\text{Name} \sqsubseteq \leq 1 \text{hasName}^{-}.\text{Agent} \quad (16)$$

$$\text{Agent} \sqsubseteq \geq 0 \text{hasName}.Name \quad (17)$$

$$T \sqsubseteq \forall \text{hasNameAsString}.xsd:string \quad (18)$$

$$\text{Name} \sqsubseteq \exists \text{hasNameAsString}.xsd:string \quad (19)$$

$$\text{Name} \sqsubseteq \geq 0 \text{hasNameAsString}.xsd:string \quad (20)$$

$$\text{assumesAgentRole} \circ \text{hasRoleUnderName} \sqsubseteq \text{hasName} \quad (21)$$

$$\text{hasName} \circ \text{hasRoleUnderName}^{-} \sqsubseteq \text{assumesAgentRole} \quad (22)$$

### 2.28.2.2 Explanations

- |   |   |
|---|---|
| 1. Range<br>2. Inverse Functionality<br>3. Structural Tautology | 4. Scoped Domain<br>5. Range<br>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.

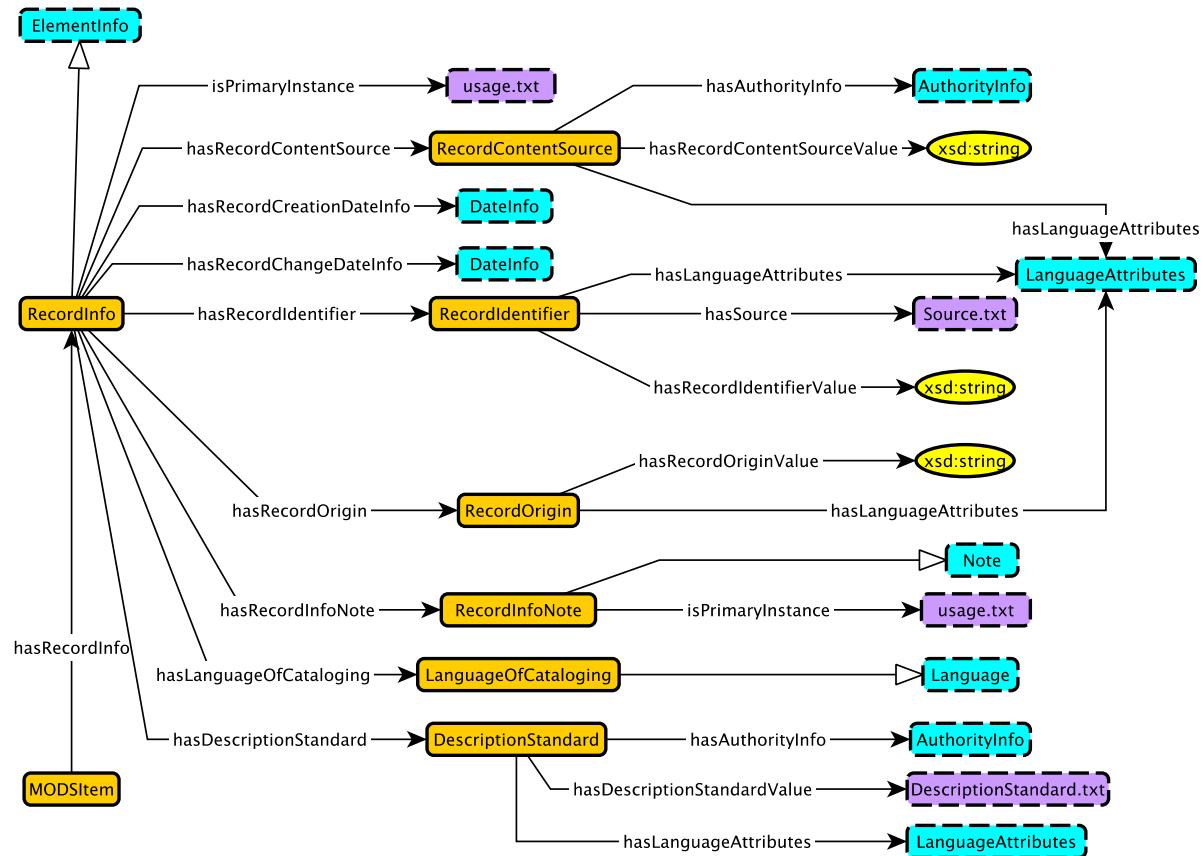


Figure 2.29: The schema diagram for the Record Info Module.

### 2.29.2 Formalization

#### 2.29.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasRecordInfo}.\text{RecordInfo} \quad (1)$$

$T \sqsubseteq \leq 1 hasRecordInfo^- . T$	(2)
$MODSItem \sqsubseteq \geq 0 hasRecordInfo . RecordInfo$	(3)
$\exists hasRecordContentSource . T \sqsubseteq RecordInfo$	(4)
$T \sqsubseteq \forall hasRecordContentSource . RecordContentSource$	(5)
$RecordContentSource \sqsubseteq \exists B hasRecordContentSource^- . RecordInfo$	(6)
$T \sqsubseteq \leq 1 hasRecordContentSource^- . T$	(7)
$RecordInfo \sqsubseteq \geq 0 hasRecordContentSource . RecordContentSource$	(8)
$T \sqsubseteq \forall hasAuthorityInfo . AuthorityInfo$	(9)
$T \sqsubseteq \leq 1 hasAuthorityInfo . T$	(10)
$T \sqsubseteq \leq 1 hasAuthorityInfo^- . T$	(11)
$RecordContentSource \sqsubseteq \geq 0 hasAuthorityInfo . AuthorityInfo$	(12)
$T \sqsubseteq \forall hasLanguageAttributes . LanguageAttributes$	(13)
$T \sqsubseteq \leq 1 hasLanguageAttributes . T$	(14)
$T \sqsubseteq \leq 1 hasLanguageAttributes^- . T$	(15)
$RecordContentSource \sqsubseteq \geq 0 hasLanguageAttributes . LanguageAttributes$	(16)
$T \sqsubseteq \forall hasRecordContentSourceValue . xsd:string$	(17)
$RecordContentSource \sqsubseteq \exists hasRecordContentSourceValue . xsd:string$	(18)
$RecordContentSource \sqsubseteq \geq 0 hasRecordContentSourceValue . xsd:string$	(19)
$\exists hasRecordCreationDateInfo . T \sqsubseteq RecordInfo$	(20)
$T \sqsubseteq \forall hasRecordCreationDateInfo . DateInfo$	(21)
$DateInfo \sqsubseteq \exists hasRecordCreationDateInfo^- . RecordInfo$	(22)
$T \sqsubseteq \leq 1 hasRecordCreationDateInfo . T$	(23)
$T \sqsubseteq \leq 1 hasRecordCreationDateInfo^- . T$	(24)
$RecordInfo \sqsubseteq \geq 0 hasRecordCreationDateInfo . DateInfo$	(25)
$\exists hasRecordChangeDateInfo . T \sqsubseteq RecordInfo$	(26)
$T \sqsubseteq \forall hasRecordChangeDateInfo . DateInfo$	(27)
$DateInfo \sqsubseteq \exists hasRecordChangeDateInfo^- . RecordInfo$	(28)
$T \sqsubseteq \leq 1 hasRecordChangeDateInfo^- . T$	(29)
$RecordInfo \sqsubseteq \geq 0 hasRecordChangeDateInfo . DateInfo$	(30)
$\exists hasRecordIdentifier . T \sqsubseteq RecordInfo$	(31)
$T \sqsubseteq \forall hasRecordIdentifier . RecordIdentifier$	(32)
$RecordIdentifier \sqsubseteq \exists hasRecordIdentifier^- . Record$	(33)
$T \sqsubseteq \leq 1 hasRecordIdentifier^- . T$	(34)
$Record \sqsubseteq \geq 0 hasRecordIdentifier . RecordIdentifier$	(35)
$T \sqsubseteq \forall hasLanguageAttributes . LanguageAttributes$	(36)
$T \sqsubseteq \leq 1 hasLanguageAttributes . T$	(37)
$T \sqsubseteq \leq 1 hasLanguageAttributes^- . T$	(38)
$RecordIdentifier \sqsubseteq \geq 0 hasLanguageAttributes . LanguageAttributes$	(39)
$T \sqsubseteq \forall hasSource . Source.txt$	(40)
$RecordIdentifier \sqsubseteq \geq 0 hasSource . Source.txt$	(41)
$T \sqsubseteq \forall hasRecordIdentifierValue . xsd:string$	(42)
$RecordIdentifier \sqsubseteq \exists hasRecordIdentifierValue . xsd:string$	(43)

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

$\text{RecordInfo} \sqsubseteq \geq 0 \text{hasLanguageOfCataloging}.\text{LanguageOfCataloging}$	(86)
$\text{RecordInfo} \sqsubseteq \text{ElementInfo}$	(87)
$\text{LanguageOfCataloging} \sqsubseteq \text{Language}$	(88)
$\text{LanguageOfCataloging} \sqsubseteq \neg(\exists \text{hasLanguageAttributes}.\top)$	(89)
$\text{RecordInfo} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasXlink}.\top)$	(90)
$\text{RecordInfo} \sqsubseteq \neg(\exists \text{hasLinkAttributes}.\exists \text{hasNameTitleGroup}.\top)$	(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.

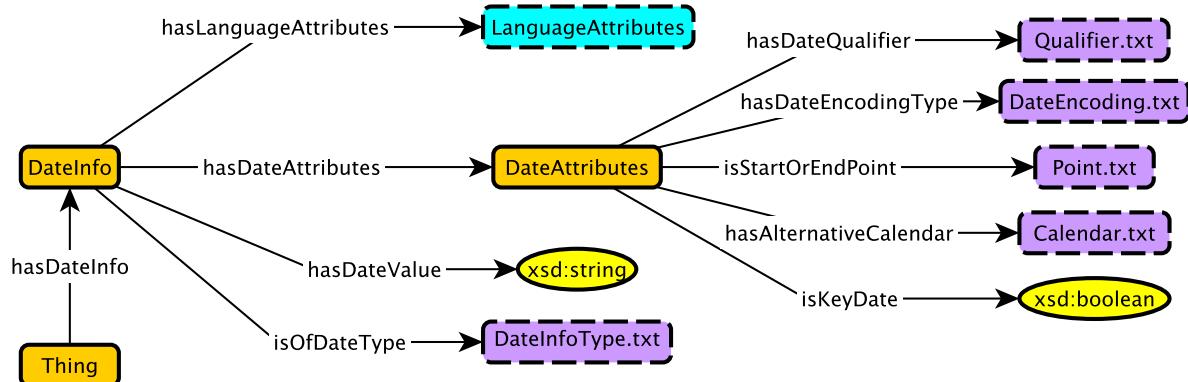


Figure 2.30: The schema diagram for the Date Info Module.

### 2.30.2 Formalization

#### 2.30.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasDateInfo}.\text{DateInfo} \quad (1)$$

$$\text{DateInfo} \sqsubseteq \exists \text{hasDateInfo}^-.\text{Thing} \quad (2)$$

$$\top \sqsubseteq \leq 1 \text{hasDateInfo}^-.\top \quad (3)$$

$$\top \sqsubseteq \geq 0 \text{hasDateInfo}.\text{DateInfo} \quad (4)$$

$$\top \sqsubseteq \forall \text{hasDateAttributes}.\text{DateAttributes} \quad (5)$$

$$\text{DateInfo} \sqsubseteq \exists \text{hasDateAttributes}.\text{DateAttributes} \quad (6)$$

$$\top \sqsubseteq \leq 1 \text{hasDateAttributes}.\top \quad (7)$$

$$\top \sqsubseteq \leq 1 \text{hasDateAttributes}^-.\top \quad (8)$$

$$\text{DateInfo} \sqsubseteq \geq 0 \text{hasDateAttributes}.\text{DateAttributes} \quad (9)$$

$$\top \sqsubseteq \forall \text{hasLanguageAttributes}.\text{LanguageAttributes} \quad (10)$$

$$\top \sqsubseteq \leq 1 \text{hasLanguageAttributes}.\top \quad (11)$$

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

$$\text{DateInfo} \sqsubseteq \geq 0 \text{hasLanguageAttributes}.\text{LanguageAttributes} \quad (13)$$

$$\top \sqsubseteq \forall \text{isOfDateType}.\text{DateInfoType.txt} \quad (14)$$

$$\text{DateInfo} \sqsubseteq \exists \text{isOfDateType}.\text{DateInfoType.txt} \quad (15)$$

$$\text{DateInfo} \sqsubseteq \geq 0 \text{isOfDateType}.\text{DateInfoType.txt} \quad (16)$$

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

$$\text{DateInfo} \sqsubseteq \exists \text{hasDateValue}.\text{xsd:string} \quad (18)$$

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

### 2.30.2.2 Explanations

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

## 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

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

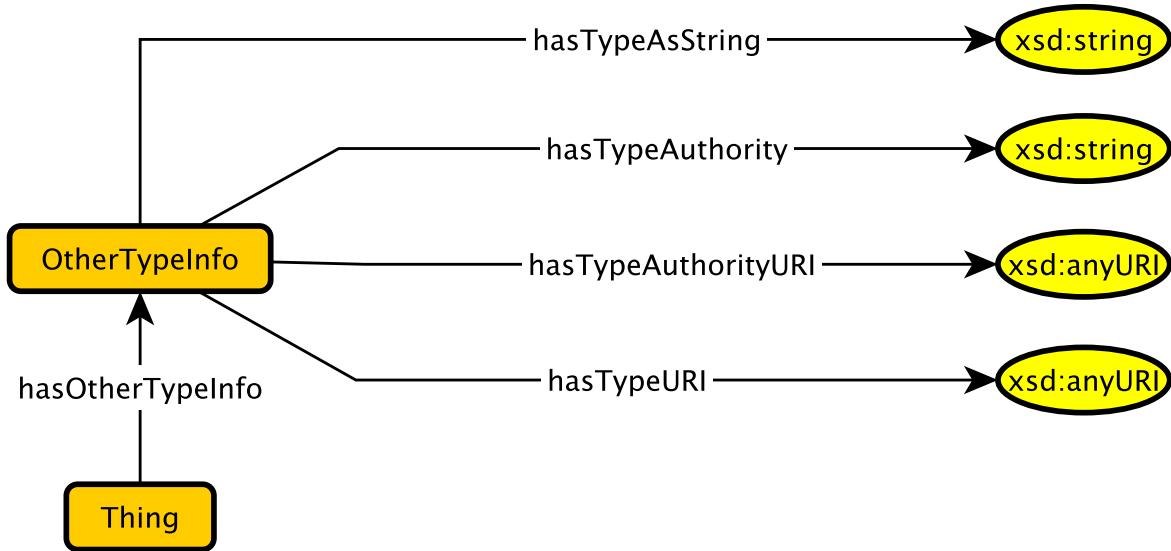


Figure 2.31: The schema diagram for the Other Type Info Module.

$$\top \sqsubseteq \forall \text{hasTypeAuthorityURI}. \text{xsd}:anyURI \quad (9)$$

$$\text{OtherTypeInfo} \sqsubseteq \geq 0 \forall \text{hasTypeAuthorityURI}. \text{xsd}:anyURI \quad (10)$$

$$\top \sqsubseteq \forall \text{hasTypeURI}. \text{xsd}:anyURI \quad (11)$$

$$\text{OtherTypeInfo} \sqsubseteq \geq 0 \forall \text{hasTypeURI}. \text{xsd}:anyURI \quad (12)$$

### 2.31.2.2 Explanations

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

## 2.32 Language Attributes Module

### 2.32.1 Overview

Language Attributes Module is shared across many different modules. Any element within 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`

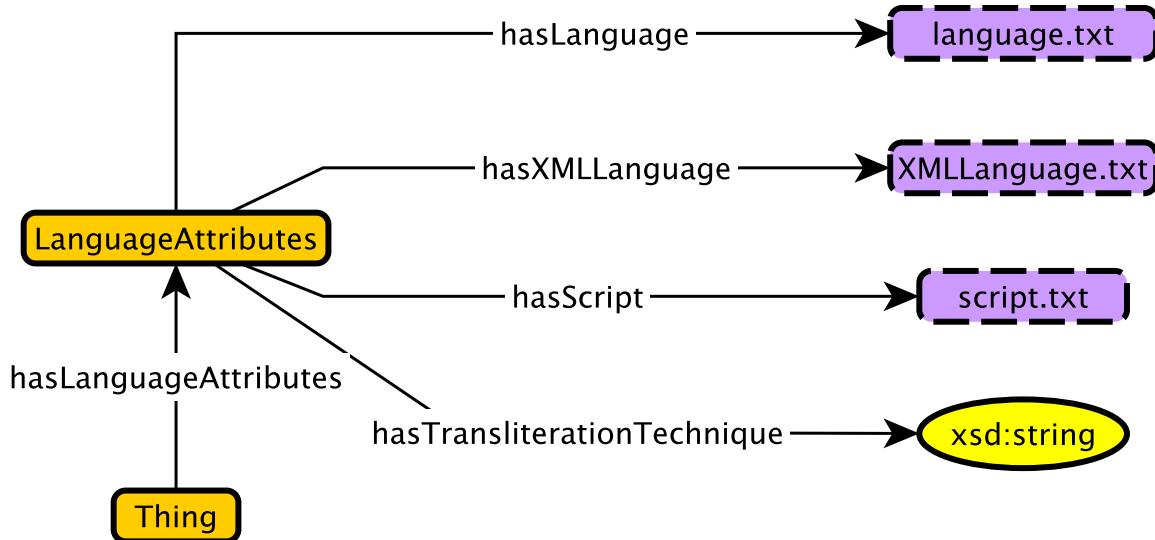


Figure 2.32: The schema diagram for the Language Attributes Module.

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

$$T \sqsubseteq \forall \text{hasLanguageAttributes}. \text{LanguageAttributes} \quad (1)$$

$$T \sqsubseteq \leq 1 \text{hasLanguageAttributes}. T \quad (2)$$

$$T \sqsubseteq \leq 1 \text{hasLanguageAttributes}^-. T \quad (3)$$

$$T \sqsubseteq \geq 0 \text{hasLanguageAttributes}. \text{LanguageAttributes} \quad (4)$$

$$\exists \text{hasLanguage}. T \sqsubseteq \text{LanguageAttributes} \quad (5)$$

$$\text{language.txt} \sqsubseteq \exists \text{hasLanguage}^-. \text{LanguageAttributes} \quad (6)$$

$$\text{LanguageAttributes} \sqsubseteq \geq 0 \text{hasLanguage}. \text{language.txt} \quad (7)$$

$$\exists \text{hasXMLLanguage}. T \sqsubseteq \text{LanguageAttributes} \quad (8)$$

$$\text{XMLLanguage.txt} \sqsubseteq \exists \text{hasXMLLanguage}^-. \text{LanguageAttributes} \quad (9)$$

$$\text{LanguageAttributes} \sqsubseteq \geq 0 \text{hasXMLLang}. \text{XMLLanguage.txt} \quad (10)$$

$$\exists \text{hasScript}. T \sqsubseteq \text{LanguageAttributes} \quad (11)$$

$$\text{script.txt} \sqsubseteq \exists \text{hasScript}^-. \text{LanguageAttributes} \quad (12)$$

$$\text{LanguageAttributes} \sqsubseteq \geq 0 \text{hasScript}. \text{script.txt} \quad (13)$$

$$\exists \text{hasTransliterationTechnique}. T \sqsubseteq \text{LanguageAttributes} \quad (14)$$

$$\text{xsd:string} \sqsubseteq \exists \text{hasTransliterationTechnique}^-. \text{LanguageAttributes} \quad (15)$$

$$T \sqsubseteq \leq 1 \text{hasTransliterationTechnique}^-. T \quad (16)$$

$$\text{LanguageAttributes} \sqsubseteq \geq 0 \text{hasTransliterationTechnique}. \text{xsd:string} \quad (17)$$

### 2.32.2.2 Explanations

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

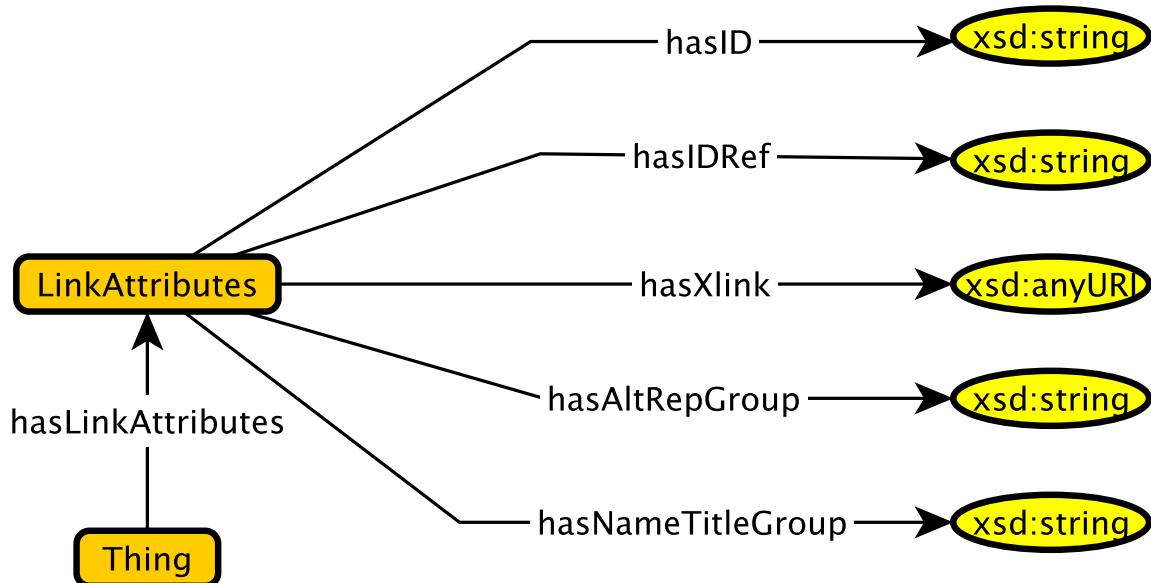


Figure 2.33: The schema diagram for the Link Attributes Module.

### 2.33.2 Formalization

#### 2.33.2.1 Axioms

$$\top \sqsubseteq \forall \text{hasLinkAttributes}.\text{LinkAttributes} \quad (1)$$

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

### 2.33.2.2 Explanations

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

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

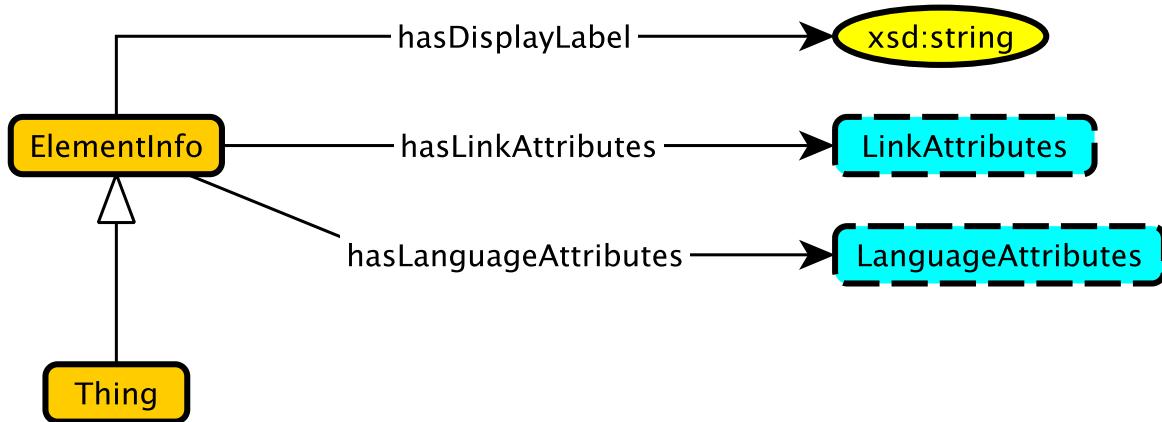


Figure 2.34: The schema diagram for the Element Info Module.

$$T \sqsubseteq \text{ElementInfo} \quad (11)$$

(12)

### 2.34.2.2 Explanations

- |  |   |
|--|---|
| 1. Range<br>2. Structural Tautology<br>3. Range<br>4. Functionality<br>5. Inverse Functionality<br>6. Structural Tautology | 7. Range<br>8. Functionality<br>9. Inverse Functionality<br>10. Structural Tautology<br>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

$$T \sqsubseteq \forall \text{providesAgentRole}.\text{AgentRole} \quad (1)$$

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

$$\text{Organization} \sqsubseteq \geq 0 \text{providesAgentRole}.\text{AgentRole} \quad (3)$$

$$T \sqsubseteq \forall \text{hasName}.\text{Name} \quad (4)$$

$$\text{Organization} \sqsubseteq \exists \text{hasName}.\text{Name} \quad (5)$$

$$T \sqsubseteq \leq 1 \text{hasName}.\top \quad (6)$$

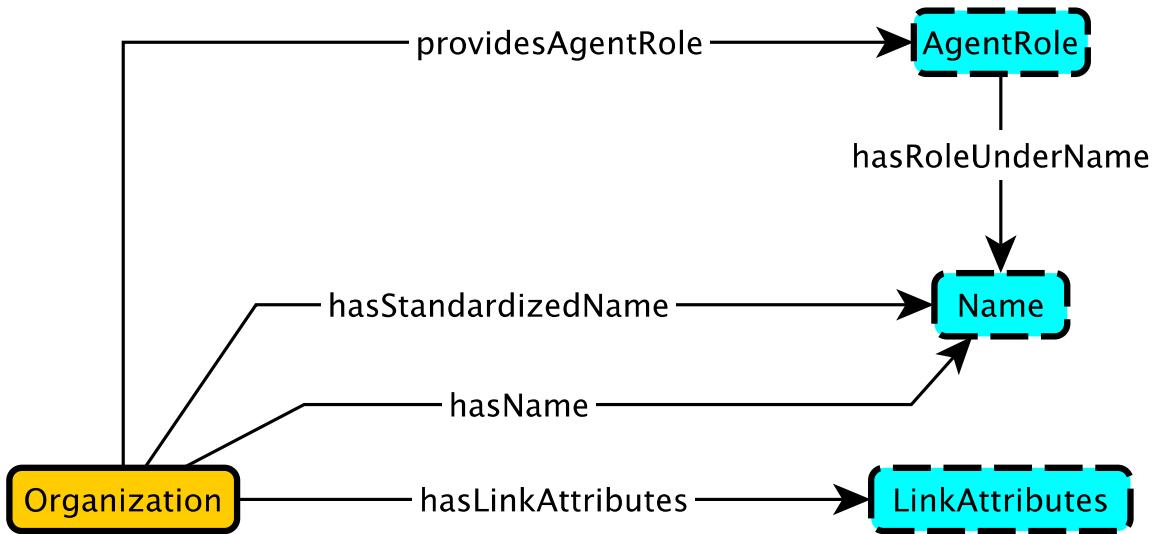


Figure 2.35: The schema diagram for the Organization Module.

$$T \sqsubseteq \leq 1 \text{hasName}^- . T \quad (7)$$

$$\text{Organization} \sqsubseteq \geq 0 \text{hasName}.Name \quad (8)$$

$$T \sqsubseteq \forall \text{hasStandardizedName}.Name \quad (9)$$

$$T \sqsubseteq \leq 1 \text{hasStandardizedName}.T \quad (10)$$

$$T \sqsubseteq \leq 1 \text{hasStandardizedName}^- . T \quad (11)$$

$$\text{Organization} \sqsubseteq \geq 0 \text{hasStandardizedName}.Name \quad (12)$$

$$T \sqsubseteq \forall \text{hasLinkAttributes}.LinkAttributes \quad (13)$$

$$T \sqsubseteq \leq 1 \text{hasLinkAttributes}.T \quad (14)$$

$$T \sqsubseteq \leq 1 \text{hasLinkAttributes}^- . T \quad (15)$$

$$\text{Organization} \sqsubseteq \geq 0 \text{hasLinkAttributes}.LinkAttributes \quad (16)$$

$$\exists \text{hasRoleUnderName}.Name \sqsubseteq \text{AgentRole} \quad (17)$$

$$T \sqsubseteq \forall \text{hasRoleUnderName}.Name \quad (18)$$

$$\text{AgentRole} \sqsubseteq \geq 0 \text{hasRoleUnderName}.Name \quad (19)$$

### 2.35.2.2 Explanations

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

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