The *open*EHR Archetype Model

Archetype Object Model

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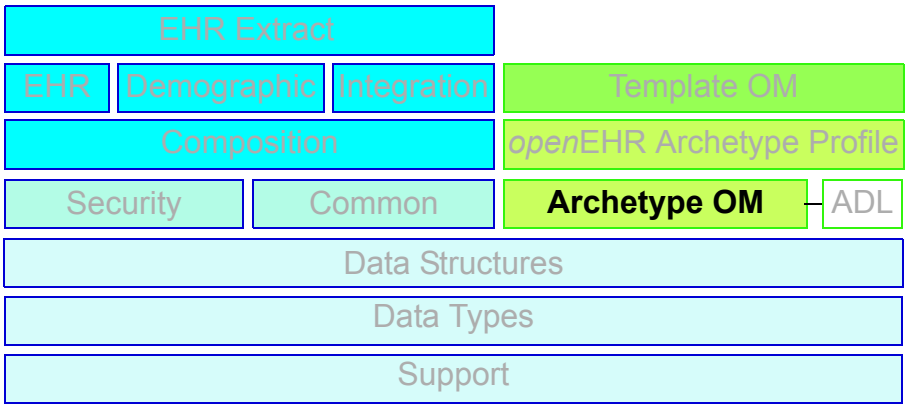

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Amendment Record

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1 Introduction

1.1 Purpose

This document contains the definitive statement of archetype semantics, in the form of an object model for archetypes. The model presented here can be used as a basis for building software that processes archetypes, independent of their persistent representation; equally, it can be used to develop the output side of parsers that process archetypes in a linguistic format, such as the *open*EHR Archetype Definition Language (ADL) [4], XML-instance and so on. As a specification, it can be treated as an API for archetypes.

It is recommended that the *open*EHR ADL document [4] be read in conjunction with this document, since it contains a detailed explanation of the semantics of archetypes, and many of the examples are more obvious in ADL, regardless of whether ADL is actually used with the object model presented here or not.

1.2 Related Documents

Prerequisite documents for reading this document include:

- The *open*EHR Architecture Overview

Related documents include:

- The *open*EHR Archetype Definition Language (ADL)
- The *open*EHR Archetype Profile (oAP)

1.3 Nomenclature

In this document, the term ‘attribute’ denotes any stored property of a type defined in an object model, including primitive attributes and any kind of relationship such as an association or aggregation. XML ‘attributes’ are always referred to explicitly as ‘XML attributes’.

1.4 Status

This document is under development, and is published as a proposal for input to standards processes and implementation works.

This document is available at http://svn.openehr.org/specification/TAGS/Release-1.0.1/publishing/architecture/am/aom.pdf.

The latest version of this document can be found at http://svn.openehr.org/specification/TRUNK/publishing/architecture/am/aom.pdf.

Blue text indicates sections under active development.

1.5 Tools

Various tools exist for creating and processing archetypes. The *open*EHR tools are available in source and binary form from the website (http://www.openEHR.org).

1.6 Changes from Previous Versions

1.6.1 Version 2.0 to 2.1

The changes in version 2.1 are made to better facilitate the representation of specialised archetypes. The key semantic capability for specialised archetypes is to be able to support a differential representation, i.e. to express a specialised archetype only in terms of the changed or new elements in its defnition, rather than including a copy of unchanged elements. Doing the latter is clearly unsustainable in terms of change management. The 2.0 model already supported differential representation, but somewhat inconveniently.

The changes are as follows.

- The addition of two new classes `DIFFERENTIAL_ARCHETYPE` and `FLAT_ARCHETYPE` which are variants of `ARCHETYPE` class, which is now abstract.
- The addition of two attributes to the `C_ATTRIBUTE` class, allowing the inclusion of a path and a flag including that the matches (∈) operator is to be negated for this attribute. The former allows for specialised archetype redefinitions deep within a structure to be stated with respect to a path rather than having to include the ADL blocks to descend from the top to the point of redefinition. The matches negation flag allows specialised archetypes to state constraints by value exclusion rather than inclusion, which experience has shown is very convenient for some kinds of constraints. All the changes in this version are found in the `constraint_model` and `primitive` packages.
- The `C_DEFINED_OBJECT` *default_value* function has been renamed to *prototype_value*, in order to properly represent its meaning (it is a generated value, not a set value) and to avoid a name clash with the *open*EHR Template *default_value* attribute defined in a descendant of the `C_DEFINED_OBJECT` class.
- The addition of two new classes `DIFFERENTIAL_ARCHETYPE_ONTOLOGY` and `FLAT_ARCHETYPE_ONTOLOGY`, which are variants of `ARCHETYPE_ONTOLOGY`, which is now abstract.
- The name of the *invariant* attribute has been changed to *rules*, to better reflect its purpose.

1.6.2 Version 0.6 to 2.0

As part of the changes carried out to ADL version 1.3, the archetype object model specified here is revised, also to version 2.0, to indicate that ADL and the AOM can be regarded as 100% synchronised specifications.

- added a new attribute *adl_version*: String to the `ARCHETYPE` class;
- changed name of `ARCHETYPE`.*concept_code* attribute to *concept*.

2 Overview

2.1 Context

Archetypes form the second layer of the *open*EHR semantic architecture. They provide a way of creating models of domain content, expressed in terms of constraints on a reference model. Archetype paths provide the basis of querying in *open*EHR as well as bindings to terminology.

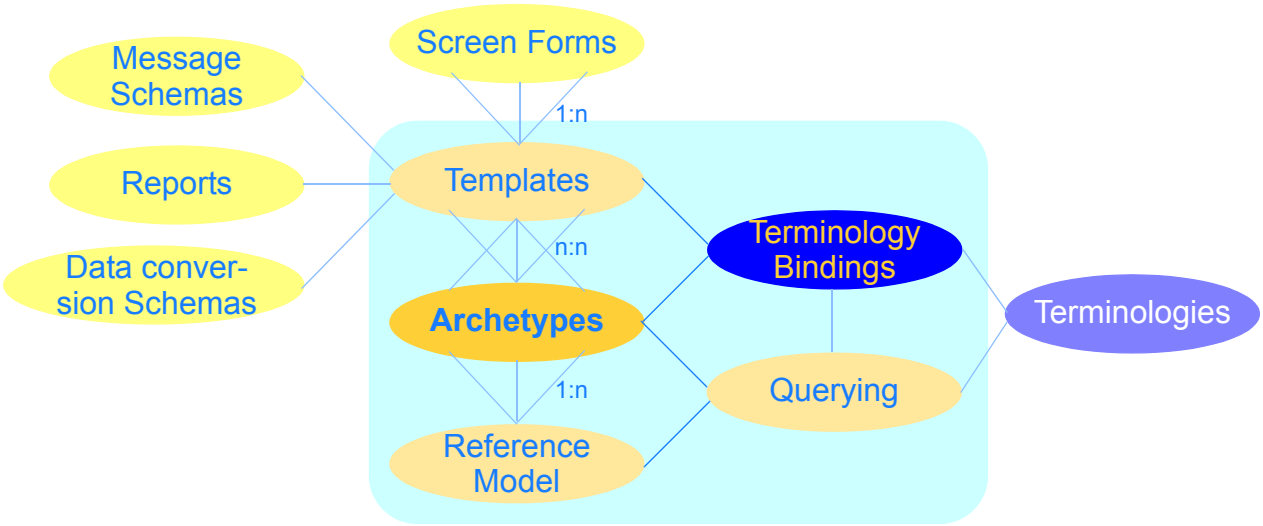


FIGURE 1 The *open*EHR Semantic Architecture

Archetypes are defined in terms of the following specifications:

- the Archetype Definition Language (ADL);
- the openEHR Archetype Object Model (AOM) - this specification;
- the openEHR Archetype Profile (oAP).

The AOM is the definitive expression of archetype semantics, and is independent of any particular syntax. The Archetype Definition Language is a formal abstract syntax for archetypes, used to provide a default serial expression of archetypes.

The purpose of the *open*EHR Archetype Profile is to define which classes and attributes of the *open*EHR RM can be sensibly archetyped, and to provide custom archetype classes. The *open*EHR archetype framework is described in terms of Archetype Definitions and Principles [6] and the Archetype System [7].

2.2 Basic Semantics

Archetypes are topic- or theme-based models of domain content, expressed in terms of constraints on a reference information model. Since each archetype constitutes an encapsulation of a set of data points pertaining to a topic, it is of a manageable, limited size, and has a clear boundary. For example an 'Apgar result' archetype of the *open*EHR reference model class `OBSERVATION` contains the data points relevant to Apgar score of a newborn, while a 'blood pressure measrement' archetype contains data points relevant to the result and measurement of blood pressure.

2.2.1 Archetype Relationships

A 'system' of archetypes is a collection of archetypes covering all or part of a domain, such as clinical medicine. The constraint and object-oriented semantics of archetypes allow two kinds of relationships to be expressed between archetypes in the system: specialisation and composition. The specialisation relationship in particular affects the parsing and validation of archetypes in the system.

Archetype Specialisation

Specialised archetypes are expressed in a differential form with respect to the parent archetype (i.e. in a similar way to how specialised classes are expressed in an object-oriented model). Differential form is a necessary pre-requisite to sustainable management of specialised archetypes. An archetype is a specialisation of another archetype if it mentions that archetype as its parent, and only makes changes to its definition such that its constraints are 'narrower' than those of the parent. The chain of archetypes from a specialised archetype back through all its parents the top-level ultimate parent is known as an *archetype lineage*. For non-specialised (i.e. top-level) archetypes, the lineage is just itself.

Every archetype has a 'specialisation depth'. Archetypes with no specialisation parent are depth 0, and specialised archetypes add one level to their depth for each step down a hierarchy required to reach them.

In order for specialised archetypes to be usable, the differential form used for authoring has to be compressed through the archetype lineage to create *flat-form archetypes*, i.e. the standalone equivalent of a given archetype, as if it had been constructed on its own. A flattened archetype is expressed in the same serial and object form as a differential form archetype, although there are some differences in the semantics.

Any data created via the use of an archetype conforms to the flat form of an archetype, and to the flat form of every archetype up the lineage. This notion of specialisation thus corresponds to the idea of *substitubility*, applied to data.

Archetype Composition

It the interests of re-use and clarity of modelling, archetypes can be composed to form larger structures semantically equivalent to a single large archetype. Composition allows two things to occur: for archetypes to be defined according to natural 'levels' or encapsulations of information, and for the re-use of smaller archetypes by higher-level archetypes. Archetype *slots* are the means of composition, and are defined in terms of constraints. Thus, unlike an object model, an archetype composition relationship is not with one fixed archetype, but instead defines a pattern for matching other suitable archetypes. Depending on what archetypes are available within the system, the archetypes matched can vary.

2.3 Computational Environment

2.3.1 Model / Language Relationship

The object model described in this document relates to the syntax form of archetypes as shown in FIGURE 2. The object model (upper right in the figure) is the object-oriented equivalent of the ADL the Archetype Definition Language BNF language specification, and of any other syntax used to express archetypes. Instances of the model (lower right on the figure) are archetypes, and correspond one-to-one with archetype documents expressed in ADL or an equivalent language.

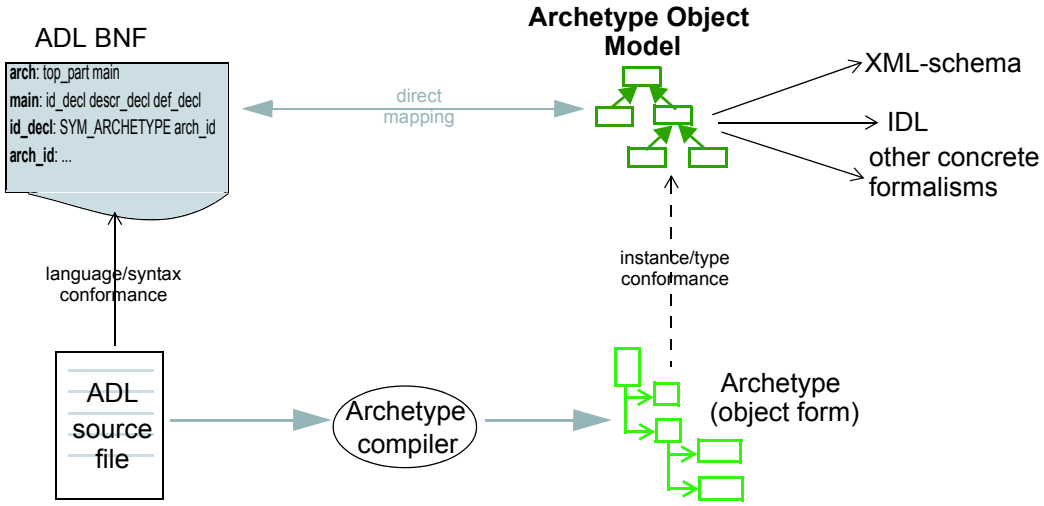


FIGURE 2 Relationship of Archetype Object Model to Archetype Languages

2.3.2 Archetypes as Computable Structures

An archetype object structure can be created in various ways. It may be created programmatically in memory inside an archetype authoring tool, or it may be converted from a serial form such as ADL or XML. Due to the possibility of archetype specialisation, the object structures of archetype lineages rather than just single archetypes must be created. For the same reason, archetypes have to be constructed in differential and flat form (explained in detail in the ADL specification). The former is the 'source' form of an archetype, in which specialised archetypes express only redefined and added elements with respect to the parent, and the latter is the result of any archetype compressed through its inheritance lineage, i.e. as if it had been defined stand-alone.

FIGURE 3 illustrates the object structures for an archetype lineage as created by a compilation process, with the elements corresponding to the top-level archetype bolded. Differential input file(s) are converted by the parser into differential object parse trees, shown at the right of the figure. The same structures would be created by an editor application.

The differential in-memory representation is validated by the semantic checker, which verifies numerous things, such as that term codes referenced in the definition section are defined in the ontology section. It can also validate the classes and attributes mentioned in the archetype against a specification for the relevant reference model (e.g. in XMI or some equivalent). As part of the validation process, a flattener is used to generate the flat form at any given level of specialisation from the flat from from the previous level, and the differential form at the current level. For a top-level archetype, this is a null transform.

Both the differential and flat form archetypes can be serialised to various file forms. Differential form files serve as the source form for editing tools, while flat-form files are used in the *open*EHR templating environment and for generating other components, such as for screen forms. The semantics of both object forms are defined in this specification.

The results of the compilation process can be seen in the archetype visualisations in the *open*EHR ADL Workbench[1].

1. See http://www.openehr.org/svn/ref_impl_eiffel/TRUNK/apps/doc/adl_workbench_help.htm

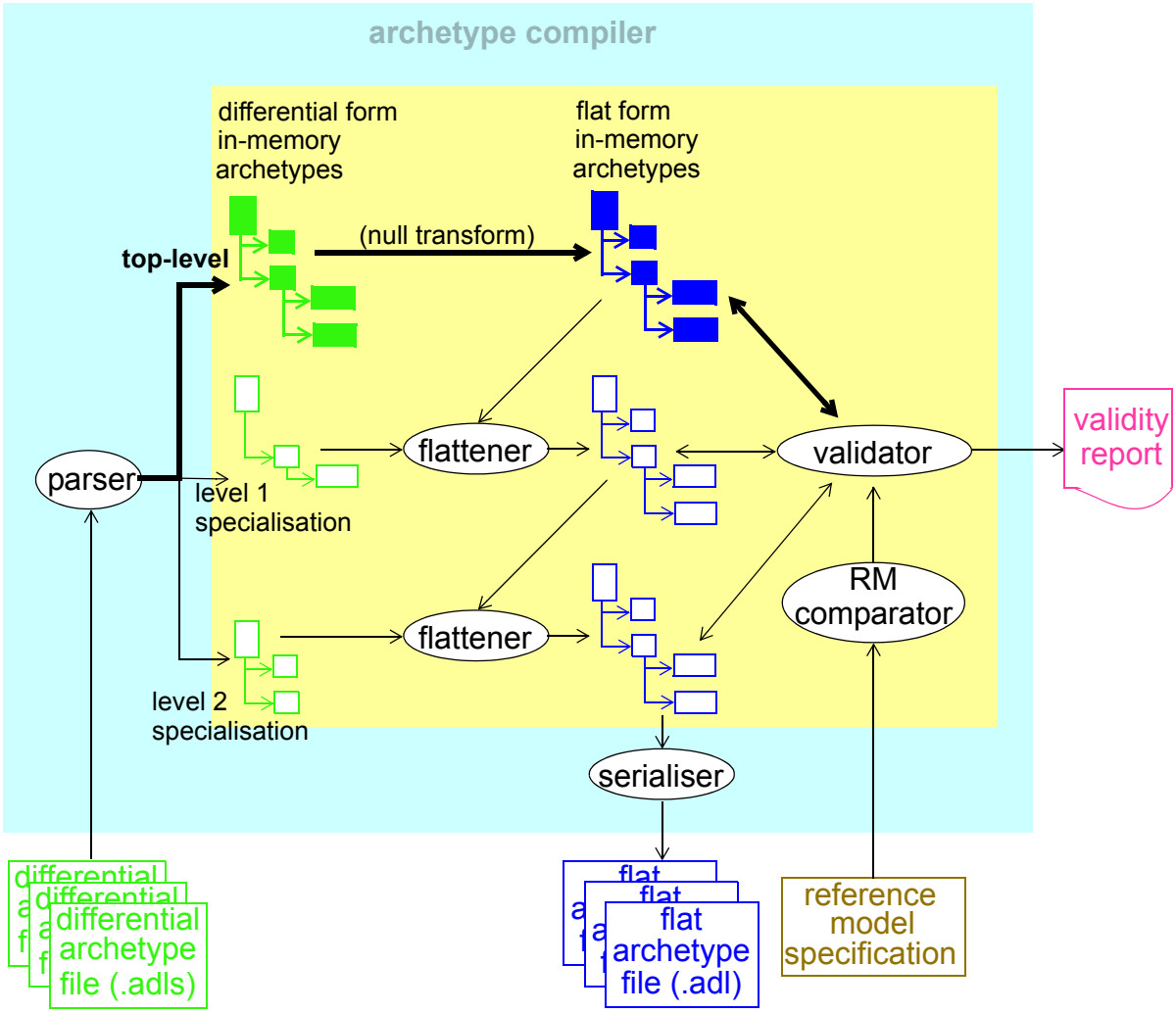


FIGURE 3 Object Structure of an Archetype Lineage

2.4 Model Overview

The model described here is a pure object-oriented model that can be used with archetype parsers and software that manipulates archetypes. It is independent of any particular linguistic expression of an archetype, such as ADL or OWL, and can therefore be used with any kind of parser.

It is dependent on the *open*EHR Support model (assumed types and identifiers), as small number of the *open*EHR Data types IM, and the `AUTHORED_RESOURCE` classes from the *open*EHR Common IM.

2.4.1 Package Structure

The *open*EHR Archetype Object Model is defined as the package `am.archetype`, as illustrated in FIGURE 4. It is shown in the context of the *open*EHR `am.archetype` packages.

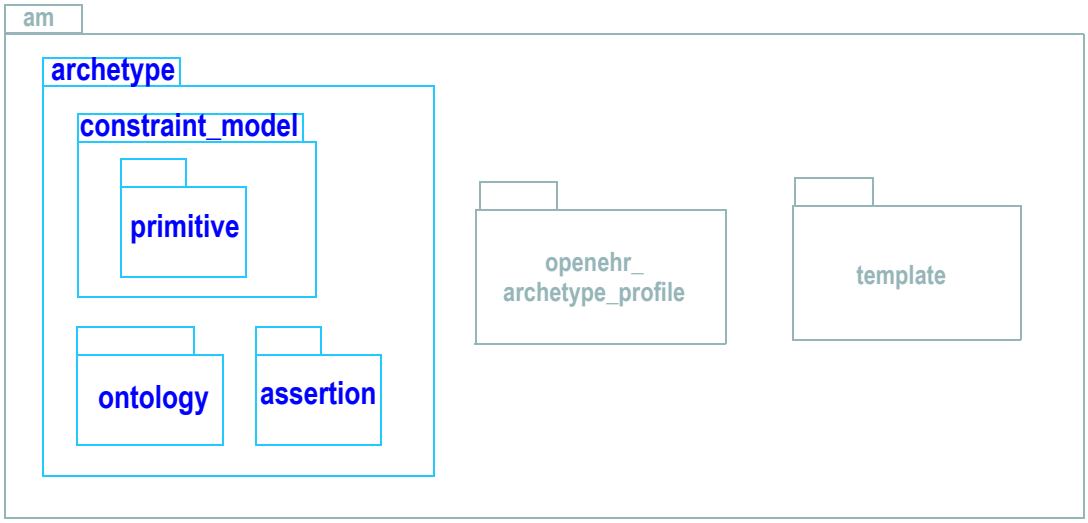


FIGURE 4 openehr.am.archetype Package

3 The Archetype Package

3.1 Overview

The model of an archetype, illustrated in FIGURE 5, is straightforward at an abstract level, mimicking the structure of an archetype document as defined in the *open*EHR Archetype Definition Language (ADL) document. An archetype is a modelled as a particular kind of AUTHORED_RESOURCE, and as such, includes descriptive meta-data, language information and revision history. The ARCHETYPE class adds *identifying information*, a *definition* - expressed in terms of constraints on instances of an object model, and an *ontology*. The archetype definition, the 'main' part of an archetype, is an

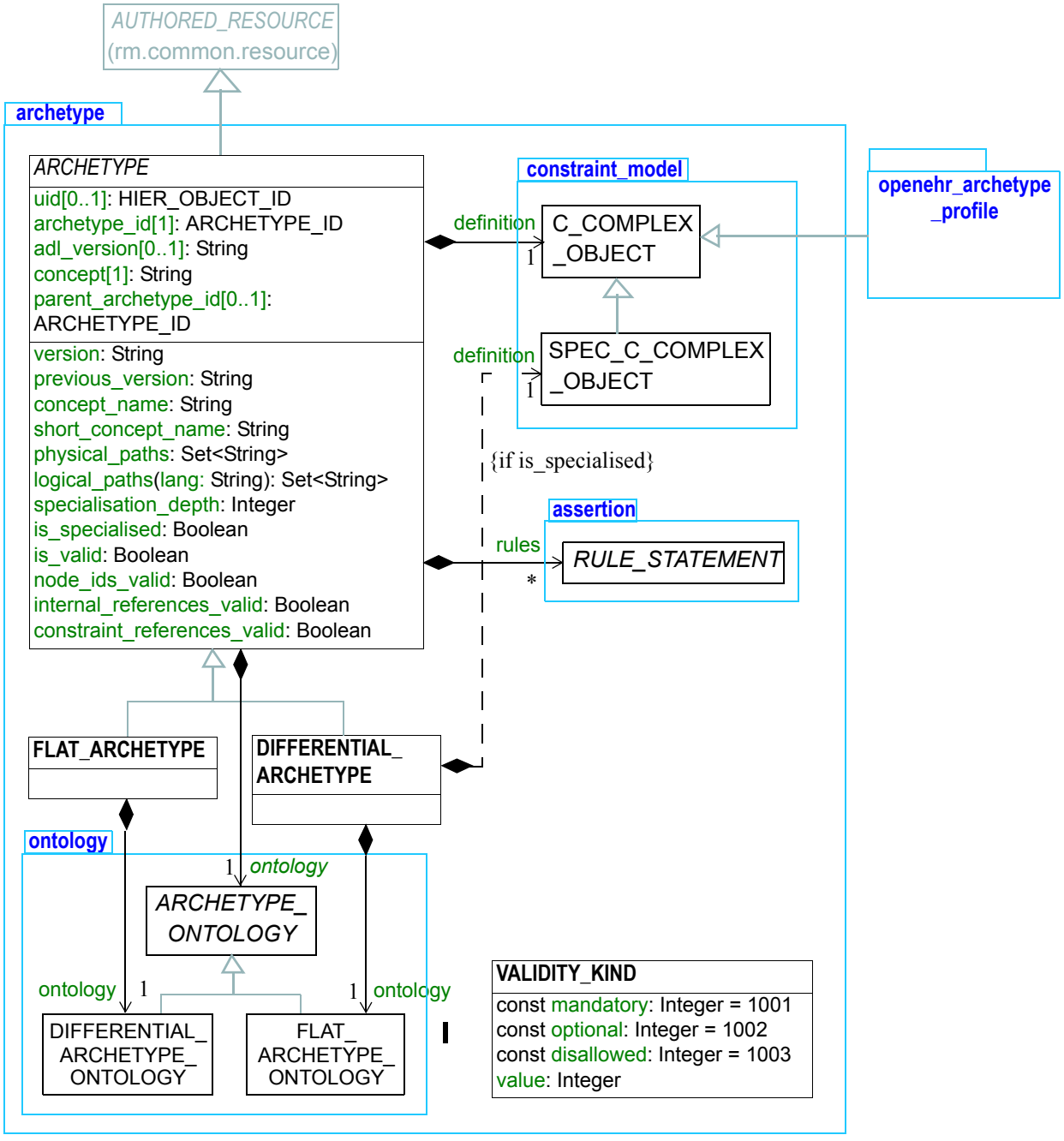


FIGURE 5 openehr.am.archetype Package

instance of a C_COMPLEX_OBJECT, which is to say, the root of the constraint structure of an archetype always takes the form of a constraint on a non-primitive object type. The last section of an archetype, the ontology, is represented by its own class, and is what allows the archetypes to be natural language- and terminology-neutral.

A utility class, VALIDITY_KIND is also included in the Archetype package. This class contains one integer attribute and three constant definitions, and is intended to be used as the type of any attribute in this constraint model whose value is logically 'mandatory', 'optional', or 'disallowed'. It is used in this model in the classes C_Date, C_Time and C_Date_Time.

The C_ATTRIBUTE type and subtypes of C_OBJECT enable the structural expression of constraints on single attributes of objects, in a recursive fashion. In addition to this, an archetype may include one or more rules. Rules are statements in a subset of predicate logic, which can be used to state constraints on parts of an object. They are not needed to constrain single attributes or objects (since this can be done with an appopriate C_ATTRIBUTE or C_OBJECT), but are necessary for constraints referring to more than one attribute, such as a constraint that 'systolic pressure should be >= diastolic pressure' in a blood pressure measurement archetype. They can also be used to declare variables, including external data query results, and make other constraints dependent on a variable value, e.g. the gender of the record subject.

FIGURE 6 illustrates a typical archetype object structure. Mandatory parts are shown with a bold association.

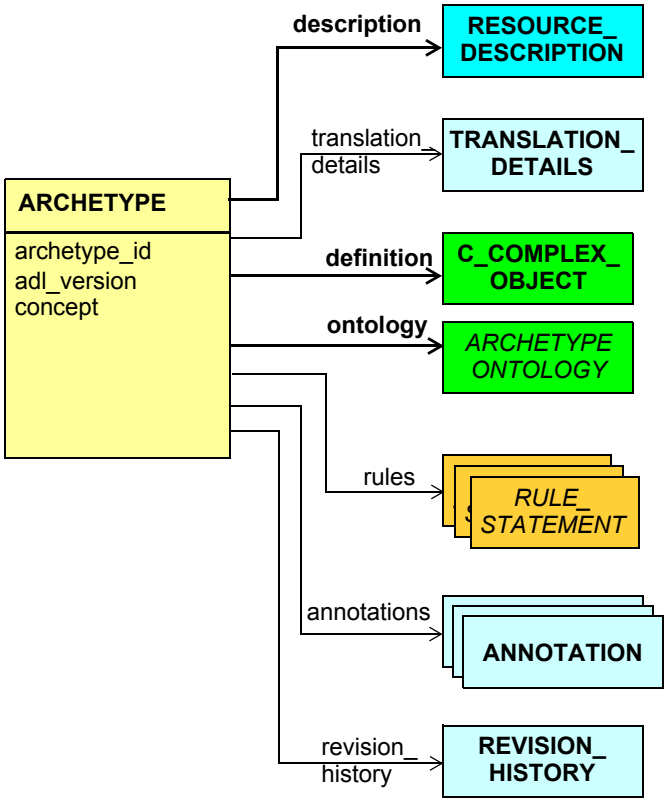


FIGURE 6 Archetype Object Structure

3.2 Class Descriptions

3.2.1 ARCHETYPE Class

CLASS	*ARCHETYPE (abstract)*	
Purpose	Root object of an archetype. Defines semantics of identfication, lifecycle, versioning, composition and specialisation.	
Inherit	`AUTHORED_RESOURCE`	
Attributes	**Signature**	**Meaning**
0..1	**adl_version**: `String`	ADL version if archteype was read in from an ADL sharable archetype.
1	**archetype_id**: `ARCHETYPE_ID`	Multi-axial identifier of this archetype in archetype space.
0..1	**uid**: `HIER_OBJECT_ID`	OID identifier of this archetype.
1	**concept**: `String`	The normative meaning of the archetype as a whole, expressed as a local archetype code, typically “at0000”.
0..1	**parent_archetype_id**: `ARCHETYPE_ID`	Identifier of the specialisation parent of this archetype.
1	**definition**: `C_COMPLEX_OBJECT`	Root node of this archetype
1	**ontology**: `ARCHETYPE_ONTOLOGY`	The ontology of the archetype.
0..1	**rules**: `List<RULE_STATEMENT>`	Rules relating to this archetype. Statements are expressed in first order predicate logic, and usually refer to at least two attributes.
Functions	**Signature**	**Meaning**
1	**version**: `String`	Version of this archetype, extracted from id.
0..1	**previous_version**: `String`	Version of predecessor archetype of this archetype, if any.
1	**short_concept_name**: `String`	The short concept name of the archetype extracted from the archetype_id.
	concept_name (a_lang**:** `String`): `String`	The concept name of the archetype in language *a_lang*; corresponds to the term definition of the *concept* attribute in the archetype ontology.

CLASS	ARCHETYPE (abstract)	
1	**physical_paths**: `Set<String>`	Set of language-independent paths extracted from archetype. Paths obey Xpath-like syntax and are formed from alternations of `C_OBJECT`.*node_id* and `C_ATTRIBUTE`.*rm_attribute_name* values.
	logical_paths (a_lang**:** `String`): `Set<String>`	Set of language-dependent paths extracted from archetype. Paths obey the same syntax as physical_paths, but with *node_ids* replaced by their meanings from the ontology.
1	**is_specialised**: `Boolean` ***ensure*** *Result* **implies** parent_archetype_id /= Void	True if this archetype is a specialisation of another.
1	**specialisation_depth**: `Integer` ***ensure*** *Result* = ontology. specialisation_depth	Specialisation depth of this archetype; larger than 0 if this archetype has a parent. Derived from *ontology.specialisation_depth*.
	node_ids_valid: `Boolean`	True if every *node_id* found on a `C_OBJECT` node is found in *ontology.term_codes*.
	internal_references_valid: `Boolean`	True if every `ARCHETYPE_INTERNAL_REF`. *target_path* refers to a legitimate node in the archetype *definition*.
	constraint_references_valid: `Boolean`	True if every `CONSTRAINT_REF`.*reference* found on a `C_OBJECT` node in the archetype *definition* is found in *ontology.constraint_codes*.
	is_valid: `Boolean` ***ensure*** ***not*** **(**node_ids_valid **and** internal_references_valid **and** constraint_references_valid) **implies not** *Result*	True if the archetype is valid overall; various tests should be used, including checks on node_ids, internal references, and constraint references.

CLASS	*ARCHETYPE (abstract)*
Invariant	***archetype_id_validity***: archetype_id /= Void ***concept_valid***: ontology.has_term_code(concept_code) ***uid_validity***: uid /= Void **implies not** uid.is_empty ***version_validity***: version /= Void **and then** version.is_equal(archetype_id.version_id) ***original_language_valid***: original_language /= void **and then** language /= Void ***and then*** code_set(Code_set_id_languages).has_code(original_language) ***description_exists***: description /= Void ***definition_exists***: definition /= Void ***ontology_exists***: ontology /= Void ***Specialisation_validity***: is_specialised **implies** specialisation_depth > 0 ***Rules_valid***: rules /= Void **implies not** rules.is_empty

The following validity rules apply to `ARCHETYPE` objects:

VASID: archetype specialisation parent identifier validity. the archetype identifier sated in the specialise clause must be the identifier of the immediate specialisation parent archetype.

VACSD: archetype concept specialisation depth. the specialisation depth of the concept code must match the specialisation depth of the archetype identifier.

VARDT: archetype definition typename validity. The topmost typename mentioned in the archetype definition section must match the type mentioned in the type-name slot of the first segment of the archetype id.

VATCD: archetype code specialisation level validity. Each archetype term ('at' code) and constraint code ('ac' code) used in the archetype definition part must have a specialisation level no greater than the specialisation level of the archetype.

VACCD: archetype definition code validity. The node identifier of the root node of the definition section must be the concept code mentioned earlier in the archetype.

The following validity rules apply across the `definition` and `ontology` parts of the archetype:

VATDF: archetype term validity. Each archetype term ('at' code) used as a node identifier the archetype definition must be defined in the term_definitions part of the ontology.

VACDF: constraint code validity. Each constraint code ('ac' code) used in the archetype definition part must be defined in the constraint_definitions part of the ontology.

VOTM: ontology translations missing. Translations must exist for term_definitions and constraint_definitions sections for all languages defined in the description / translations section.

VONSD: ontology code specialisation level validity. No archetype code (at-code or ac-code) defined in the ontology can be of a greater specialisation depth than the archetype.

3.2.2 DIFFERENTIAL_ARCHETYPE Class

CLASS	DIFFERENTIAL_ARCHETYPE	
Purpose	Differential form of an archetype. Also called the 'source' form, as this is the form of an archetype created by an editor. For non-specialised archetypes, this is the same as the flat form. For specialised archetypes, only the differences with respect to the parent are included.	
Inherit	ARCHETYPE	
Attributes	**Signature**	**Meaning**
1	**ontology**: DIFFERENTIAL_ARCHETYPE_ONTOLOGY	The differential form ontology of the archetype, which includes only codes and bindings defined in the current archetype.
Invariant		

3.2.3 FLAT_ARCHETYPE Class

CLASS	FLAT_ARCHETYPE	
Purpose	Inheritance-flattened form of an archetype.	
Inherit	ARCHETYPE	
Attributes	**Signature**	**Meaning**
1	**ontology**: FLAT_ARCHETYPE_ONTOLOGY	The flat form ontology of the archetype, which includes codes and bindings from all parents.
Invariant		

3.2.4 VALIDITY_KIND Class

CLASS	VALIDITY_KIND	
Purpose	An enumeration of three values which may commonly occur in constraint models.	
Use	Use as the type of any attribute within this model, which expresses constraint on some attribute in a class in a reference model. For example to indicate validity of Date/Time fields.	
Attributes	**Signature**	**Meaning**
1	***const* mandatory**: Integer = 1001	Constant to indicate mandatory presence of something

CLASS	VALIDITY_KIND	
1	***const* optional**: `Integer = 1002`	Constant to indicate optional presence of something
1	***const* disallowed**: `Integer = 1003`	Constant to indicate disallowed presence of something
1	**value**: `Integer`	Actual value
Functions	**Signature**	**Meaning**
	valid_validity (a_validity: `Integer): Boolean` ***ensure*** a_validity >= mandatory **and** a_validity <= disallowed	Function to test validity values.
Invariant	***Validity***: valid_validity(value)	

4 Constraint Model Package

4.1 Overview

FIGURE 7 illustrates the object model of constraints used in an archetype definition. This model is completely generic, and is designed to express the semantics of constraints on instances of classes which are themselves described in UML (or a similar object-oriented meta-model). Accordingly, the major abstractions in this model correspond to major abstractions in object-oriented formalisms, including several variations of the notion of 'object' and the notion of 'attribute'. The notion of 'object' rather than 'class' or 'type' is used because archetypes are about constraints on data (i.e. 'instances', or 'objects') rather than models, which are constructed from 'classes'. In this document, the word 'attribute' refers to any data property of a class, regardless of whether regarded as a 'relationship' (i.e. association, aggregation, or composition) or 'primitive' (i.e. value) attribute in an object model.

The definition part of an archetype is an instance of a `C_COMPLEX_OBJECT` and consists of alternate layers of *object* and *attribute* constrainer nodes, each containing the next level of nodes. At the leaves are primitive object constrainer nodes constraining primitive types such as `String`, `Integer` etc. There are also nodes that represent internal references to other nodes, constraint reference nodes that refer to a text constraint in the constraint binding part of the archetype ontology, and archetype constraint nodes, which represent constraints on other archetypes allowed to appear at a given point. The full list of concrete node types is as follows:

C_COMPLEX_OBJECT: any interior node representing a constraint on instances of some non-primitive type, e.g. `OBSERVATION`, `SECTION`;

C_ATTRIBUTE: a node representing a constraint on an attribute (i.e. UML 'relationship' or 'primitive attribute') in an object type;

C_PRIMITIVE_OBJECT: an node representing a constraint on a primitive (built-in) object type;

ARCHETYPE_INTERNAL_REF: a node that refers to a previously defined object node in the same archetype. The reference is made using a path;

CONSTRAINT_REF: a node that refers to a constraint on (usually) a text or coded term entity, which appears in the ontology section of the archetype, and in ADL, is referred to with an "acNNNN" code. The constraint is expressed in terms of a query on an external entity, usually a terminology or ontology;

ARCHETYPE_SLOT: a node whose statements define a constraint that determines which other archetypes can appear at that point in the current archetype. It can be thought of like a keyhole, into which few or many keys might fit, depending on how specific its shape is. Logically it has the same semantics as a `C_COMPLEX_OBJECT`, except that the constraints are expressed in another archetype, not the current one.

The constraints define which configurations of reference model class instances are considered to conform to the archetype. For example, certain configurations of the classes `PARTY`, `ADDRESS`, `CLUSTER` and `ELEMENT` might be defined by a Person archetype as allowable structures for 'people with identity, contacts, and addresses'. Because the constraints allow optionality, cardinality and other choices, a given archetype usually corresponds to a set of similar configurations of objects.

The typename nomenclature `C_COMPLEX_OBJECT`, `C_PRIMITIVE_OBJECT`, `C_ATTRIBUTE` used here is intended to be read as "constraint on objects of type `XXXX`", i.e. a `C_COMPLEX_OBJECT` is a "constraint

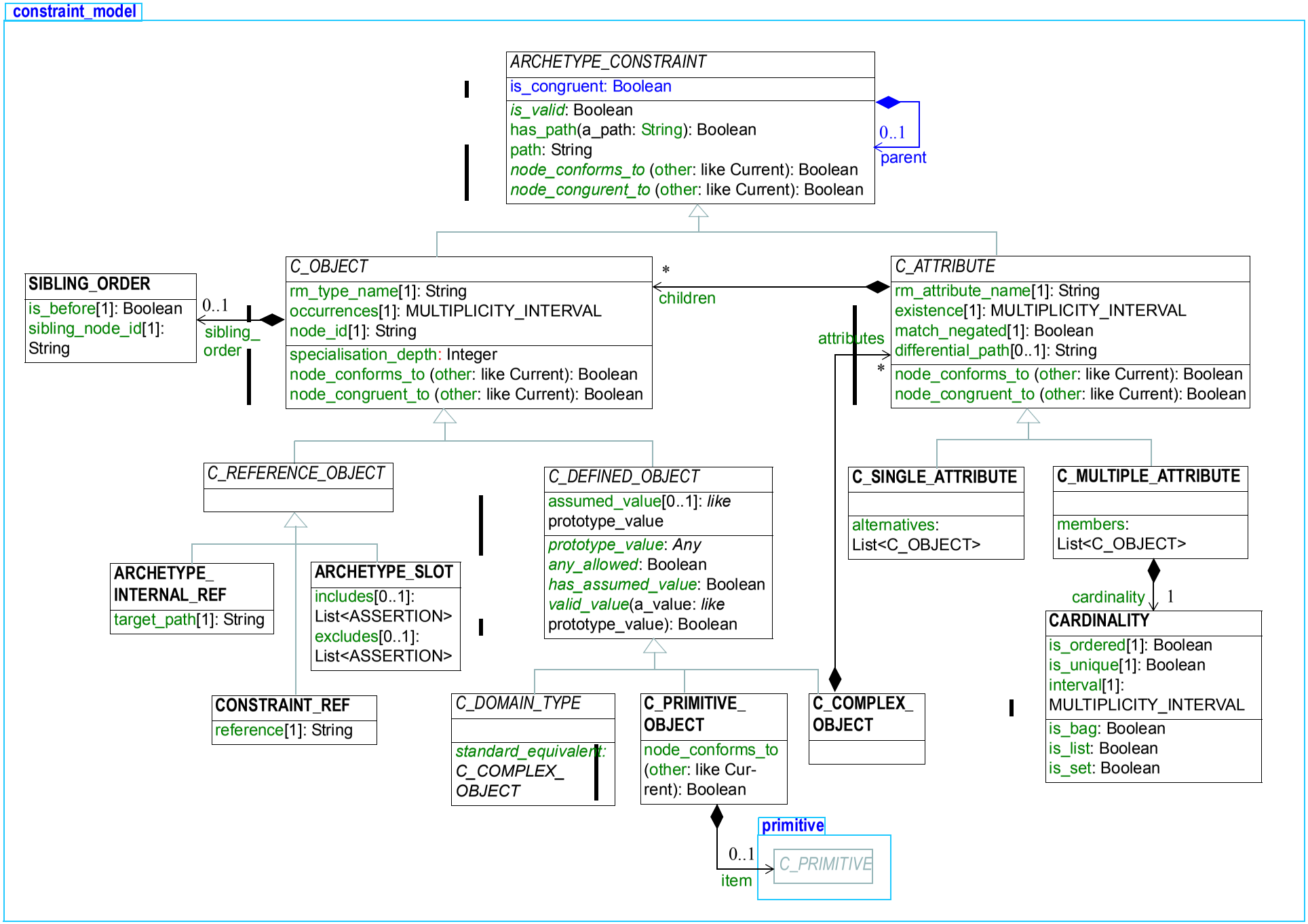


FIGURE 7 openehr.am.archetype.constraint_model Package

a complex object (defined by a complex reference model type)". These type names are used below in the formal model.

4.2 Semantics

The effect of the model is to create archetype description structures that are a hierarchical alternation of object and attribute constraints, as shown in FIGURE 3. This structure can be seen by inspecting an ADL archetype, or by viewing an archetype in the *open*EHR ADL workbench [9], and is a direct consequence of the object-oriented principle that classes consist of properties, which in turn have types that are classes. (To be completely correct, types do not always correspond to classes in an object model, but it does not make any difference here). The repeated object/attribute hierarchical structure of an archetype provides the basis for using paths to reference any node in an archetype. Archetype paths follow a syntax that is a subset of the W3C Xpath syntax.

4.2.1 All Node Types

A small number of properties are defined for all node types. The *path* feature computes the path to the current node from the root of the archetype, while the *has_path* function indicates whether a given path can be found in an archetype. The *is_valid* function indicates whether the current node and all subnodes are internally valid according to the semantics of this archetype model. The *node_conforms_to* function is used for comparison between corresponding nodes from different archetypes, in order to asert specialisation.

4.2.2 Attribute Node Types

Constraints on attributes are represented by instances of the two subtypes of `C_ATTRIBUTE`: `C_SINGLE_ATTRIBUTE` and `C_MULTIPLE_ATTRIBUTE`. For both subtypes, the common constraint is whether the corresponding instance (defined by the *rm_attribute_name* attribute) must exist. Both subtypes have a list of children, representing constraints on the object value(s) of the attribute.

Single-valued attributes (such as Person.date_of_birth: Date) are constrained by instances of the type `C_SINGLE_ATTRIBUTE`, which uses the children to represent multiple *alternative* object constraints for the attribute value.

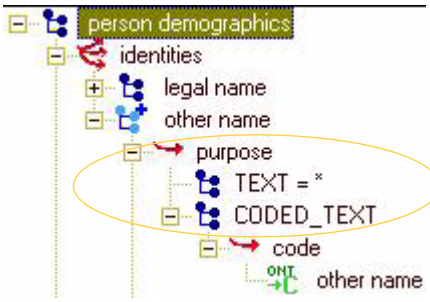
Multiply-valued attributes (such as `Person`.*contacts*: `List<Contact>`) are constrained by an instance of `C_MULTIPLE_ATTRIBUTE`, which allows multiple *co-existing* member objects of the container value of the attribute to be constrained, along with a cardinality constraint, describing ordering and uniqueness of the container. FIGURE 8 illustrates the two possibilities.

The need for both *existence* and *cardinality* constraints in the `C_MULTIPLE_ATTRIBUTE` class deserves some explanation, especially as the meanings of these notions are often confused in object-oriented literature. An existence constraint indicates whether an object will be found in a given attribute field, while a cardinality constraint indicates what the valid membership of a container object is. *Cardinality* is only required for container objects such as `List<T>`, `Set<T>` and so on, whereas *existence* is always required. If both are used, the meaning is as follows: the existence constraint says whether the container object will be there (at all), while the cardinality constraint says how many items must be in the container, and whether it acts logically as a list, set or bag.

4.2.3 Object Node Types

Node_id and Paths

The *node_id* attribute in the class `C_OBJECT`, inherited by all subtypes, is of great importance in the archetype constraint model. It has two functions:



C_SINGLE_ATTRIBUTE
with alternatives
(PERSON.address as structured
or free text form)

C_MULTIPLE_ATTRIBUTE
with collection (LIST.items)

FIGURE 8 Single and Multiple-valued C_ATTRIBUTEs

- it allows archetype object constraint nodes to be individually identified, and in particular, guarantees sibling node unique identification;
- it is the main link between the archetype definition (i.e. the constraints) and the archetype ontology, because each *node_id* is a 'term code' in the ontology.

The existence of *node_ids* in an archetype allows archetype paths to be created, which refer to each node. Not every node in the archetype needs a *node_id*, if it does not need to be addressed using a path; any leaf or near-leaf node which has no sibling nodes from the same attribute can safely have no *node_id*.

Sibling Ordering

Within a specialised archetype, redefined or added object nodes may be defined within a container attribute. Since specialised archetypes are in differential form, i.e. only redefined or added nodes are expressed, not nodes inherited unchanged, the relative ordering of siblings can't be stated simply by the ordering of such items within the relevant list within the differential form of the archetype. An explicit ordering indicator is required if indeed order is specific. The `C_OBJECT`.*sibling_order* attribute provides this possibility. It can only be set on a `C_OBJECT` descendant within a multiply-valued attribute, i.e. an instance of `C_MULTIPLE_ATTRIBUTE` for which the cardinality is ordered.

4.2.3.1 Defined Object Nodes (C_DEFINED_OBJECT)

The `C_DEFINED_OBJECT` subtype corresponds to the category of `C_OBJECT`s that are defined in an archetype by value, i.e. by inline definition. Four properties characterise `C_DEFINED_OBJECT`s as follows.

Any_allowed

The *any_allowed* function on a node indicates that any value permitted by the reference model for the attribute or type in question is allowed by the archetype; its use permits the logical idea of a completely "open" constraint to be simply expressed, avoiding the need for any further substructure. *Any_allowed* is effected in subtypes to indicate in concrete terms when it is True, usually related to Void attribute values.

Assumed_value

When archetypes are defined to have optional parts, an ability to define 'assumed' values is useful. For example, an archetype for the concept 'blood pressure measurement' might contain an optional

protocol section describing the patient position, with choices 'lying', 'sitting' and 'standing'. Since the section is optional, data could be created according to the archetype which does not contain the protocol section. However, a blood pressure cannot be taken without the patient in some position, so clearly there could be an implied value for patient position. Amongst clinicians, basic assumptions are nearly always made for such things: in general practice, the position could always safely be assumed to be "sitting" if not otherwise stated; in the hospital setting, "lying" would be the normal assumption. The assumed values feature of archetypes allows such assumptions to be explicitly stated so that all users/systems know what value to assume when optional items are not included in the data. Assumed values are definable at the leaf level only, which appears to be adequate for all purposes described to date; accordingly, they appear in descendants of C_PRIMITIVE and also C_DOMAIN_TYPE.

The notion of assumed values is distinct from that of 'default values'. The latter is a local requirement, and as such is stated in templates; default values *do* appear in data, while assumed values don't.

Valid_value

The *valid_value* function tests a reference model object for conformance to the archetype. It is designed for recursive implementation in which a call to the function at the top of the archetype definition would cause a cascade of calls down the tree. This function is the key function of an 'archetype-enabled kernel' component that can perform runtime data validation based on an archetype definition.

Default_value

This function is used to generate a reasonable default value of the reference object being constrained by a given node. This allows archteype-based software to build a 'prototype' object from an archetype which can serve as the initial version of the object being constrained, assuming it is being created new by user activity (e.g. via a GUI application). Implementation of this function will usually involve use of reflection libraries or similar.

4.2.3.2 Complex Objects (C_COMPLEX_OBJECT)

Along with C_ATTRIBUTE, C_COMPLEX_OBJECT is the key structuring type of the constraint_model package, and consists of attributes of type C_ATTRIBUTE, which are constraints on the attributes (i.e. any property, including relationships) of the reference model type. Accordingly, each C_ATTRIBUTE records the name of the constrained attribute (in *rm_attr_name)*, the existence and cardinality expressed by the constraint (depending on whether the attribute it constrains is a multiple or single relationship), and the constraint on the object to which this C_ATTRIBUTE refers via its *children* attribute (according to its reference model) in the form of further C_OBJECTs.

4.2.3.3 Primitive Types

Constraints on primitive types are defined by the classes inheriting from C_PRIMITIVE, namely C_STRING, C_INTEGER and so on. These types do not inherit from ARCHETYPE_CONSTRAINT, but rather are related by association, in order to allow them to have the simplest possible definitions, independent even from the rest of ADL, in the hope of acceptance in heath standardisation organisations. Technically, avoiding inheritance from ARCHETYPE_CONSTRAINT / C_PRIMITIVE_OBJECT into these base types (in other words, coalescing the classes C_PRIMITIVE_OBJECT and C_PRIMITIVE) does not pose a problem, but could be effected at a later date if desired.

4.2.3.4 Domain-specific Extensions (C_DOMAIN_TYPE)

The main part of the archetype constraint model allows any type in a reference model to be archetyped - i.e. constrained - in a standard way, which is to say, by a regular cascade of C_COMPLEX_OBJECT / C_ATTRIBUTE / C_PRIMITIVE_OBJECT objects. This generally works well, especially for 'outer' container types in models. However, it occurs reasonably often that lower level log-

ical 'leaf' types need special constraint semantics that are not conveniently achieved with the standard aproach. To enable such classes to be integrated into the generic constraint model, the class C_DOMAIN_TYPE is included. This enables the creation of specific "C_" classes, inheriting from C_DOMAIN_TYPE, which represent custom semantics for particular reference model types. For example, a class called C_QUANTITY might be created which has different constraint semantics from the default effect of a C_COMPLEX_OBJECT / C_ATTRIBUTE cascade representing such constraints in the generic way (i.e. systematically based on the reference model). An example of domain-specific extension classes is shown in Domain-specific Extension Example on page 70.

4.2.3.5 Reference Objects (C_REFERENCE_OBJECT)

The subtypes of C_REFERENCE_OBJECT, namely, ARCHETYPE_SLOT, ARCHETYPE_INTERNAL_REF and CONSTRAINT_REF are used to express, respectively, a 'slot' where further archetypes can be used to continue describing constraints; a reference to a part of the current archetype that expresses exactly the same constraints needed at another point; and a reference to a constraint on a constraint defined in the archetype ontology, which in turn points to an external knowledge resource, such as a terminology.

A CONSTRAINT_REF is really a proxy for a set of constraints on an object that would normally occur at a particular point in the archetype as a C_COMPLEX_OBJECT, but where the actual definition of the constraints is outside the archetype definition proper, and is instead expressed in the binding of the constraint reference (e.g. 'ac0004') to a query or expression into an external service (e.g. a terminology service). The result of the query could be something like:

- a set of allowed CODED_TERMs e.g. the types of hepatitis
- an INTERVAL<QUANTITY> forming a reference range
- a set of units or properties or other numerical item

See the ADL specification for a fuller explanation, under the heading Placeholder constraints in the cADL section.

4.2.4 Assertions

Assertions are also used in ARCHETYPE_SLOTs, in order to express the 'included' and 'excluded' archetypes for the slot. In this case, each assertion is an expression that refers to parts of other archetypes, such as its identifier (e.g. 'include archetypes with short_concept_name matching xxxx'). Assertions are modelled here as a generic expression tree of unary prefix and binary infix operators. Examples of archetype slots in ADL syntax are given in the *open*EHR ADL document.

4.3 Class Definitions

4.3.1 ARCHETYPE_CONSTRAINT Class

CLASS	*ARCHETYPE_CONSTRAINT (abstract)*	
Purpose	Archetype equivalent to LOCATABLE class in *open*EHR Common reference model. Defines common constraints for any inheritor of LOCATABLE in any reference model.	
Abstract	**Signature**	**Meaning**

CLASS	*ARCHETYPE_CONSTRAINT (abstract)*	
	node_conforms_to (other: **like Current**): `Boolean` ***require*** other /= Void	True if constraints represented by this node are narrower or the same as *other*.
	node_congruent_to (other: **like Current**): `Boolean` ***require*** other /= Void	True if constraints represented by this node contain no redefnitions with respect to the node *other*, with the exception of *node_id* redefnition in `C_OBJECT` nodes.
	is_valid: `Boolean`	True if this node (and all its sub-nodes) is a valid archetype node for its type. This function should be implemented by each subtype to perform semantic validation of itself, and then call the is_valid function in any sub-parts, and generate the result appropriately.
Attributes	**Signature**	**Meaning**
0..1 (non-persistent)	**parent**: `ARCHETYPE_CONSTRAINT`	Parent node in hierarchy. Void if root node.
0..1 (non-persistent)	**is_congruent**: `Boolean`	True if this node is congruent to a corresponding node in a specialisation parent. Only applicable to nodes in specialised, differential archetypes.
Functions	**Signature**	**Meaning**
	path: `String`	Path of this node relative to root of archetype.
	has_path (a_path: `String`): `Boolean` ***require*** a_path /= Void	True if the relative path *a_path* exists at this node.
Invariant	***path_exists***: path /= Void	

4.3.2 C_ATTRIBUTE Class

CLASS	*C_ATTRIBUTE(abstract)*	
Purpose	Abstract model of constraint on any kind of attribute node.	
Attributes	**Signature**	**Meaning**
1	**rm_attribute_name**: `String`	Reference model attribute within the enclosing type represented by a `C_OBJECT`.

CLASS	C_ATTRIBUTE(abstract)	
0..1	**differential_path**: `String`	Path to the parent object of this attribute (i.e. doesn't include the name of this attribute). Used only for attributes in differential form, specialised archetypes. Enables only the redefined parts of a specialised archetype to be expressed, at the path where they occur.
1	**existence**: `MULTIPLICITY_INTERVAL`	Constraint on every attribute, regardless of whether it is singular or of a container type, which indicates whether its target object exists or not (i.e. is mandatory or not).
0..1	**children**: `List<C_OBJECT>`	Child `C_OBJECT` nodes. Each such node represents a constraint on the type of this attribute in its reference model. Multiples occur both for multiple items in the case of container attributes, and alternatives in the case of singular attributes.
1	**match_negated**: `Boolean`	True if the match operator on this attribute is negated, i.e. the constraint structure below this `C_ATTRIBUTE` is *not* to be matched by the data rather than to be matched.
Functions	**Signature**	**Meaning**
	rm_attribute_path: `String`	Path of this attribute with respect to owning `C_OBJECT`, including differential path where applicable.
(redefined)	**path**: `String`	If *has_differential_path*, returns *rm_attribute_path*, else returns *path* as defined in `ARCHETYPE_CONSTRAINT`.
(effected)	**node_conforms_to** (other: **like Current**): `Boolean` ***ensure*** Result = existence_conforms_to (other) **and** ((is_single **and** other.is_single) **or** cardinality_conforms_to (other))	True if this node on its own (ignoring any subparts) expresses the same or narrower constraints as *other*. Returns False if *cardinality* or *existence* is incompatible.
(effected)	**node_congruent_to** (other: **like Current**): `Boolean` ***ensure*** Result = node_conforms_to(other)	True if this node on its own (ignoring any subparts) expresses the same constraints as *other*.

CLASS	C_ATTRIBUTE(abstract)	
	existence_conforms_to (other: **like Current**): `Boolean` ***require*** other /= Void ***ensure*** existence.is_equal (other.existence) **or** other.existence.contains (existence)	True if the existence of this node conforms to existence of node *other*.
	cardinality_conforms_to (other: **like Current**): `Boolean` ***require*** other /= Void ***ensure*** cardinality.interval.is_equal (other.cardinality.interval) **or** other.cardinality.contains (cardinality)	True if the cardinality of this node conforms to cardinality of node *other*.
	has_differential_path: `Boolean`	True if differential_path is not Void..
	occurrences_total_range: `MULTIPLICITY_INTERVAL`	Minimal cardinality interval bounding occurrences of all child object nodes.
Invariant	***Rm_attribute_name_valid***: rm_attribute_name /= Void **and then not** rm_attribute_name.is_empty ***Existence_set***: existence /= Void **and then** (existence.lower >= 0 **and** existence.upper <= 1) ***Children_validity***: any_allowed **xor** children /= Void ***Children_occurrences_validity***: cardinality.interval.contains (occurrences_total_range) ***Differential_path_valid***: differential_path /= Void **implies not** differential_path.is_empty ***Has_differential_path_valid***: differential_path = Void **xor** has_differential_path	

The validity rules are as follows:

VCARM: attribute name reference model validity: an attribute name introducing an attribute constraint block must be defined in the underlying information model as an attribute of the type which introduces the enclosing object block.

VCAEX: archetype attribute reference model existence conformance: the existence of an attribute must conform, i.e. be the same or narrower, to the existence of the corresponding attribute in the underlying information model.

VCAM: archetype attribute reference model multiplicity conformance: the multiplicity, i.e. whether an attribute is multiply- or single-valued, of an attribute must conform to that of the corresponding attribute in the underlying information model.

The following validity rule applies to redefinition in a specialised archetype:

VSANCE: specialised archetype attribute node existence conformance: the existence of a redefined attribute node in a specialised archetype must conform to the existence of the corresponding node in the flat parent archetype by having an identical range, or a range wholly contained by the latter.

VSAM: specialised archetype attribute multiplicity conformance: the multiplicity, i.e. whether an attribute is multiply- or single-valued, of a redefined attribute must conform to that of the corresponding attribute in the parent archetype.

4.3.3 C_SINGLE_ATTRIBUTE Class

CLASS	C_SINGLE_ATTRIBUTE	
Purpose	Concrete model of constraint on a single-valued attribute node. The meaning of the inherited children attribute is that they are alternatives.	
Functions	**Signature**	**Meaning**
	alternatives: `List<C_OBJECT>`	List of alternative constraints for the single child of this attribute within the data.
Invariant	***Alternatives_valid***: alternatives /= Void **and then** alternatives.for_all(co: `C_OBJECT` | co.occurrences.upper <= 1)	

The following validity rules apply to single-valued attributes:

VACSO: single-valued attribute child object occurrences validity: the occurrences of a child object of a single-valued attribute cannot have an upper limit greater than 1.

VACSU: single-valued attribute child node uniqueness: any object node added as a child to a single-valued attribute must either have a node identifier or reference model type that is unique with respect to the node identifier or the reference model type of all other siblings.

VACSI: single-valued attribute child node identifier: any object node with a node identifier added as a child to a single-valued attribute must have a node identifier that is unique with respect to the node identifiers of all other siblings.

VACSIT: single-valued attribute child node reference model type: any object node without a node identifier added as a child to a single-valued attribute must have a reference model type that is unique with respect to the reference model types of all other siblings.

4.3.4 C_MULTIPLE_ATTRIBUTE Class

CLASS	C_MULTIPLE_ATTRIBUTE	
Purpose	Concrete model of constraint on multiply-valued (ie. container) attribute node.	
Attributes	**Signature**	**Meaning**

CLASS	C_MULTIPLE_ATTRIBUTE	
1	**cardinality**: CARDINALITY	Cardinality of this attribute constraint, if it constraints a container attribute.
Functions	**Signature**	**Meaning**
	members: List<C_OBJECT>	List of constraints representing members of the container value of this attribute within the data. Semantics of the uniqueness and ordering of items in the container are given by the *cardinality*.
	occurrences_total_range: MULTIPLICITY_INTERVAL	Total range generated from *occurrences* of all members as sum(all occurrences.lower) .. sum(all occurrences.upper)
Invariant	***Child_occurrences_validity***: cardinality /= Void **and then** cardinality.interval.contains(occurrences_total_range)	

The following validity rules apply to container attributes:

VACMI: child node identification: any object node added as a child to a container attribute must have a node identifier.

VACMM: child node identifier uniqueness: the node identifier of an object node added as a child to a container attribute must be unique with respect to the siblings in the container.

VACMC: cardinality/occurrences validity: the interval represented by:
(sum of all occurrences minimum values) .. (sum of all occurrences maximum values)
must be contained by the interval stated by the cardinality.

VCACA: archetype attribute reference model cardinality conformance: the cardinality of an attribute must conform, i.e. be the same or narrower, to the cardinality of the corresponding attribute in the underlying information model.

The following validity rule applies to cardinality redefinition in a specialised archetype:

VSANCC: specialised archetype attribute node cardinality conformance: the cardinality of a redefined (multiply-valued) attribute node in a specialised archetype must conform to the cardinality of the corresponding node in the flat parent archetype by either being identical, or being wholly contained by the latter.

4.3.5 CARDINALITY Class

CLASS	CARDINALITY
Purpose	Express constraints on the cardinality of container objects which are the values of multiply-valued attributes, including uniqueness and ordering, providing the means to state that a container acts like a logical list, set or bag. The cardinality cannot contradict the cardinality of the corresponding attribute within the relevant reference model.

CLASS	CARDINALITY	
Attributes	**Signature**	**Meaning**
1	**is_ordered**: `Boolean`	True if the members of the container attribute to which this cardinality refers are ordered.
1	**is_unique**: `Boolean`	True if the members of the container attribute to which this cardinality refers are unique.
1	**interval**: `MULTIPLICITY_INTERVAL`	The interval of this cardinality.
Functions	**Signature**	**Meaning**
	is_set: `Boolean` ***ensure*** *Result* = **not** is_ordered **and** is_unique	True if the semantics of this cardinality represent a set, i.e. unordered, unique membership.
	is_list: `Boolean` ***ensure*** *Result* = is_ordered **and not** is_unique	True if the semantics of this cardinality represent a list, i.e. ordered, non-unique membership.
	is_bag `Boolean` ***ensure*** *Result* = **not** is_ordered **and not** is_unique	True if the semantics of this cardinality represent a bag, i.e. unordered, non-unique membership.
Invariant	***Validity***: **not** interval.lower_unbounded	

4.3.6 C_OBJECT Class

CLASS	*C_OBJECT (abstract)*	
Purpose	Abstract model of constraint on any kind of object node.	
Attributes	**Signature**	**Meaning**
1	**rm_type_name**: `String`	Reference model type that this node corresponds to.
1	**occurrences**: `MULTIPLICITY_INTERVAL`	Occurrences of this object node in the data, under the owning attribute. Upper limit can only be greater than 1 if owning attribute has a cardinality of more than 1).

CLASS	C_OBJECT (abstract)	
1	**node_id**: `String`	Semantic id of this node, used to differentiate sibling nodes of the same type. [Previously called 'meaning']. Each *node_id* must be defined in the archetype ontology as a term code.
0..1	**parent**: `C_ATTRIBUTE`	`C_ATTRIBUTE` that owns this `C_OBJECT`.
0..1	**sibling_order**: `SIBLING_ORDER`	Optional indicator of order of this node with respect to another sibling. Only meaningful in a specialised archetype for a `C_OBJECT` within a `C_MULTIPLE_ATTRIBUTE`.
Functions	**Signature**	**Meaning**
(effected)	**node_conforms_to** (other: **like Current**): `Boolean` ***require*** other /= Void ***ensure*** *Result* = (is_addressable **and** other.is_addressable **and** ((node_id.is_equal (other.node_id) **and** rm_type_name.is_equal (other.rm_type_name) **and** occurrences.is_equal (other.occurrences)) **or** (rm_type_conforms_to(other) and occurrences_conforms_to (other) and node_id_conforms_to (other))) **or** (**not** is_addressable **and not** other.is_addressable **and** rm_type_conforms_to(other) **and** occurrences_conforms_to (other))	True if this node on its own (ignoring any subparts) expresses the same or narrower constraints as `other'. Returns False if any of rm_type_name, occurrences, node_id (& specialisation depth) is incompatible. *Note*: not easily evaluatable for `CONSTRAINT_REF` nodes.

CLASS	C_OBJECT (abstract)	
(effected)	**node_congruent_to** (other: **like Current**): `Boolean` ***require*** other /= Void ***ensure*** *Result* = rm_type_name.is_equal (other.rm_type_name) **and** occurrences.is_equal (other.occurrences) **and** node_id_conforms_to (other)	True if this node on its own (ignoring any subparts) expresses the same constraints as `other'. Returns False if any of rm_type_name, occurrences, sibling order is different:. The node_id may be redefined however.
	rm_type_conforms_to (other: **like Current**): `Boolean` ***require*** other /= Void ***ensure*** *Result* = rm_type_name.is_equal (other.rm_type_name) **or** rm_checker.is_sub_type_of (rm_type_name, other.rm_type_name)	True if this node rm_type_name conforms to other.rm_type_name by either being equal, or by being a subtype, according to the underlying reference model.
	occurrences_conforms_to (other: **like Current**): `Boolean` ***require*** other /= Void ***ensure*** occurrences.is_equal (other.occurrences) **or** other.occurrences.contains (occurrences)	True if this node occurrences conforms to other.occurrences.
	node_id_conforms_to (other: **like Current**): `Boolean` ***require*** other /= Void ***ensure*** *Result* = node_id.starts_with (other.node_id)	True if this node id conforms to other.node_id.

CLASS	C_OBJECT (abstract)	
	specialisation_depth: `Integer`	Level of specialisation of this archetype node, based on its *node_id*. The value 0 corresponds to non-specialised, 1 to first-level specialisation and so on. The level is the same as the number of '.' characters in the *node_id* code. If *node_id* is not set, the return value is -1, signifying that the specialisation level should be determined from the nearest parent `C_OBJECT` node having a *node_id*.
Invariant	***Rm_type_name_valid***: rm_type_name /= Void **and then not** rm_type_name.is_empty ***Node_id_valid***: node_id /= Void **and then not** node_id.is_empty ***Occurrences_validity***: occurrences /= Void **and then** (parent /= Void **implies** (**not** parent.is_multiple **implies** occurrences.upper <= 1)) ***Sibling_order_validity***: sibling_order /= Void **implies** specialisation_depth > 0 and parent.is_multiple	

The validity rules for all `C_OBJECTs` are as follows:

VCORM: object constraint type name existence: a type name introducing an object constraint block must be defined in the underlying information model.

VCORMT: object constraint type validity: a type name introducing an object constraint block must be the same as or conform to the type stated in the underlying information model of its owning attribute.

The following validity rules govern `C_OBJECTs` in specialised archetypes.

VSONCT: specialised archetype object node type conformance: the reference model type of a redefined object node in a specialised archetype must conform to the reference model type in the corresponding node in the flat parent archetype by either being identical, or conforming via an inheritance relationship in the relevant reference model.

VSONIR: specialised archetype object node redefinition: if defined, the node identifier of a redefined object node in a specialised archetype must be redefined into its specialised form if any other aspect of the immediate object constraint is redefined.

VSONCI: specialised archetype object node identifier conformance: if defined, the node identifier of a redefined object node in a specialised archetype must conform to the node identifier in the corresponding node in the flat parent archetype by either being identical, or being a derived identifier at the specialisation level of the child archeytpe.

VSONCO: specialised archetype object node occurrences conformance: the occurrences of a redefined object node in a specialised archetype must conform to the occurrences in the corresponding node in the flat parent archetype by either being identical, or being wholly contained by the latter.

VSSM: specialised archetype sibling marker validity: the sibling code used in a sibling marker in a specialised archetype must refer to a node found within the same container in the flat parent archetype.

4.3.7 SIBLING_ORDER Class

CLASS	SIBLING_ORDER	
Purpose	Defines the order indicator that can be used on an `C_OBJECT` within a container attribute in a specialised archetype to indicate its order with respect to a sibling defined in a higher specialisation level.	
Misuse	This type cannot be used on a `C_OBJECT` other than one within a container attribute in a specialised archetype.	
Attributes	**Signature**	**Meaning**
1	**is_before**: `Boolean`	True if the order relationship is 'before', if False, it is 'after'.
1	**sibling_node_id**: `String`	Node identifier of sibling before or after which this node should come.
Invariant	***sibling_node_id_validity***: sibling_node_id /= Void	

4.3.8 C_DEFINED_OBJECT Class

CLASS	*C_DEFINED_OBJECT (abstract)*	
Purpose	Abstract parent type of `C_OBJECT` subtypes that are defined by value, i.e. whose definitions are actually in the archetype rather than being by reference.	
Inherit	`C_OBJECT`	
Abstract	**Signature**	**Meaning**
	prototype_value: `Any`	Generate a prototype value from this constraint object
	valid_value `(a_value: like prototype_value): Boolean` ***require*** `a_value /= Void`	True if a_value is valid with respect to constraint expressed in concrete instance of this type.
	any_allowed: `Boolean`	True if any value (i.e. instance) of the reference model type would be allowed. Redefined in descedants.
Attributes	**Signature**	**Meaning**
0..1	**assumed_value: like** `prototype_value`	Value to be assumed if none sent in data
Functions	**Signature**	**Meaning**
	has_assumed_value: `Boolean`	True if there is an assumed value

CLASS	C_DEFINED_OBJECT (abstract)
Invariant	***Assumed_value_valid***: has_assumed_value **implies** assumed_value.conforms_to_type(rm_type_name) **and** valid_value(assumed_value)

The validity rules for `C_DEFINED_OBJECTs` are as follows:

VOBAV: object node assumed value validity: the value of an assumed value must fall within the value space defined by the constraint to which it is attached.

4.3.9 C_COMPLEX_OBJECT Class

CLASS	C_COMPLEX_OBJECT	
Purpose	Constraint on complex objects, i.e. any object that consists of other object constraints.	
Inherit	`C_DEFINED_OBJECT`	
Functions	**Signature**	**Meaning**
(effected)	**any_allowed**: `Boolean` ***ensure*** Result = attributes.is_empty	True if any value of the reference model type being constrained is allowed.
Attributes	**Signature**	**Meaning**
0..1	**attributes**: `Set<C_ATTRIBUTE>`	List of constraints on attributes of the reference model type represented by this object.
Invariant	***attributes_valid***: any_allowed **xor** (attributes /= Void **and not** attributes.is_empty)	

The validity rules for `C_COMPLEX_OBJECTs` are as follows:

VCATU: attribute uniqueness: sibling attributes occurring within an object node must be uniquely named with respect to each other, in the same way as for class definitions in an object reference model.

4.3.10 C_PRIMITIVE_OBJECT Class

CLASS	C_PRIMITIVE_OBJECT	
Purpose	Constraint on a primitive type.	
Inherit	`C_DEFINED_OBJECT`	
Functions	**Signature**	**Meaning**

CLASS	C_PRIMITIVE_OBJECT	
(effected)	**any_allowed**: `Boolean` ***ensure*** *Result* = (item = Void)	True if any value of the type being constrained in *item* is allowed.
(redefined)	**node_conforms_to** (other: **like Current**): `Boolean` ***ensure*** *Result* = precursor(other) **and** (other.any_allowed **or** (**not** any_allowed **and** item.node_conforms_to (other.item)	True if this node is a subset of, or the same as `other'.
Attributes	**Signature**	**Meaning**
0..1	**item**: `C_PRIMITIVE`	Object actually defining the constraint.
Invariant	***item_exists***: any_allowed **xor** item /= Void	

4.3.11 C_DOMAIN_TYPE Class

CLASS	*C_DOMAIN_TYPE (abstract)*	
Purpose	Abstract parent type of domain-specific constrainer types, to be defined in external packages.	
Inherit	`C_DEFINED_OBJECT`	
Abstract	**Signature**	**Meaning**
	standard_equivalent: `C_COMPLEX_OBJECT`	Standard (i.e. `C_OBJECT`) form of constraint.
Invariant		

4.3.12 C_REFERENCE_OBJECT Class

CLASS	*C_REFERENCE_OBJECT (abstract)*	
Purpose	Abstract parent type of `C_OBJECT` subtypes that are defined by reference.	
Inherit	`C_OBJECT`	
Abstract	**Signature**	**Meaning**
Invariant		

4.3.13 ARCHETYPE_SLOT Class

CLASS	ARCHETYPE_SLOT	
Purpose	Constraint describing a 'slot' where another archetype can occur.	
Inherit	C_REFERENCE_OBJECT	
Attributes	**Signature**	**Meaning**
0..1	**includes**: Set <ASSERTION>	List of constraints defining other archetypes that could be included at this point.
0..1	**excludes**: Set<ASSERTION>	List of constraints defining other archetypes that cannot be included at this point.
Invariant	***includes_valid***: includes /= Void **implies not** includes.is_empty ***excludes_valid***: excludes /= Void **implies not** excludes.is_empty ***validity***: any_allowed **xor** (includes /= Void **or** excludes /= Void)	

The validity rules for ARCHETYPE_SLOTs are as follows:

VDFAI: archetype identifier validity in definition. Any archetype identifier mentioned in an archetype slot in the definition section must conform to the published *open*EHR specification for archetype identifiers.

4.3.14 ARCHETYPE_INTERNAL_REF Class

CLASS	ARCHETYPE_INTERNAL_REF	
Purpose	A constraint defined by proxy, using a reference to an object constraint defined elsewhere in the same archetype. Note that since this object refers to another node, there are two objects with available occurrences values. The local *occurrences* value on an ARCHETYPE_INTERNAL_REF should always be used; when setting this from a serialised form, if no occurrences is mentioned, the target occurrences should be used (not the standard default of {1..1}); otherwise the locally specified occurrences should be used as normal. When serialising out, if the occurrences is the same as that of the target, it can be left out.	
Inherit	C_REFERENCE_OBJECT	
Attributes	**Signature**	**Meaning**
1	**target_path**: String	Reference to an object node using archetype path notation.
Invariant	***Consistency:*** **not** any_allowed ***target_path_valid***: target_path /= Void **and then not** target_path.is_empty -- **and then** ultimate_root.has_path(target_path)	

The following validity rules applies to internal references:

VUNT: use_node type validity: the type mentioned in a use_node statement must be the same as or a super-type (according to the reference model) of the reference model type of the node referred to.

VUNP: use_node path validity: the path mentioned in a use_node statement must refer to an object node defined elsewhere in the same archetype or any of its specialisation parent archetypes, that is not itself an internal reference node, and which carries a node identifier if one is needed at the reference point.

4.3.15 CONSTRAINT_REF Class

CLASS	CONSTRAINT_REF	
Purpose	Reference to a constraint described in the same archetype, but outside the main constraint structure. This is used to refer to constraints expressed in terms of external resources, such as constraints on terminology value sets.	
Inherit	`C_REFERENCE_OBJECT`	
Attributes	**Signature**	**Meaning**
1	**reference**: `String`	Reference to a constraint in the archetype local ontology.
Invariant	***Consistency:*** **not** any_allowed ***reference_valid***: reference /= Void	

The following validity rule applies to `CONSTRAINT_REF`s in a specialised archetype.

VSCNR: placeholder constraint node conformance: a placeholder node can only be defined into a reference model type conformant with the type of the original constraint in the parent archetype.

5 The Primitive Package

5.1 Overview

Ultimately any archetype definition will devolve down to leaf node constraints on instances of primitive types. The primitive package, illustrated in FIGURE 9, defines the semantics of constraint on such types.

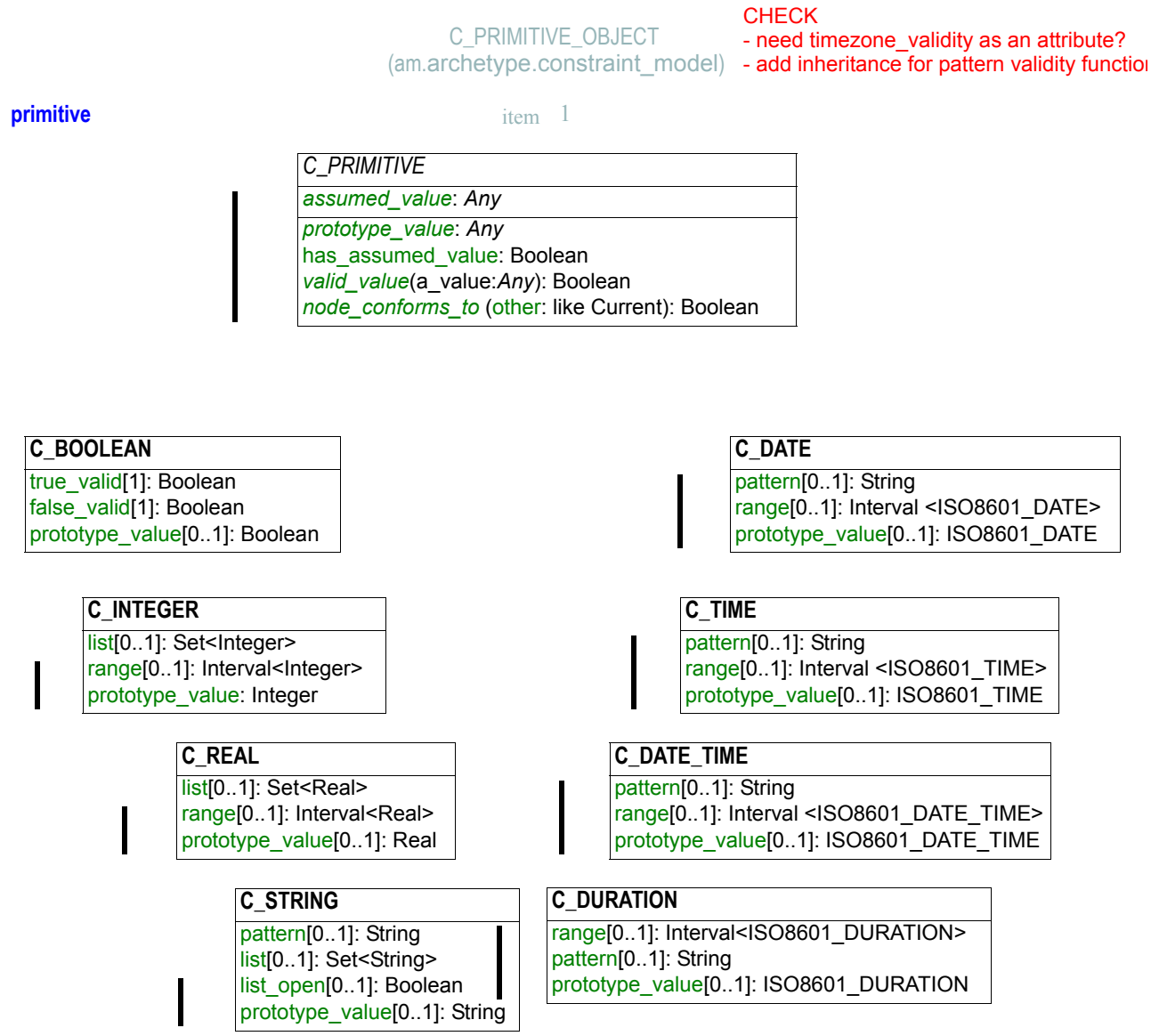


FIGURE 9 The openehr.am.archetype.primitive Package

Most of the types provide at least two alternative ways to represent the constraint; for example the `C_DATE` type allows the constraint to be expressed in the form of a pattern (defined in the ADL specification) or an `Interval<Date>`. Note that the interval form of dates is probably only useful for historical date checking (e.g. the date of an antique or a particular batch of vaccine), rather than constraints on future date/times.

5.2 Class Descriptions

5.2.1 C_PRIMITIVE Class

CLASS	*C_PRIMITIVE (abstract)*	
Purpose	Abstract supertype of all prmitive types.	
Abstract	**Signature**	**Meaning**
1	***prototype_value***: `Any`	A generated prototype value from this constraint object.
	has_assumed_value: `Boolean` ***ensure*** Result = assumed_value /= Void	True if there is an assumed value.
0..1	**assumed_value:** ***like*** prototype_value	Value to be assumed if none sent in data.
	valid_value `(a_value:` **like** prototype_value`):` `Boolean` ***require*** `a_value /= Void`	True if a_value is valid with respect to constraint expressed in concrete instance of this type.
	node_conforms_to (other: **like Current**): `Boolean` ***require*** other /= Void	True if this node is a subset of, or the same as `other'.
Invariant	***Assumed_value_valid***: has_assumed_value **implies** valid_value(assumed_value)	

5.2.2 C_BOOLEAN Class

CLASS	C_BOOLEAN	
Purpose	Constraint on instances of `Boolean`.	
Use	Both attributes cannot be set to False, since this would mean that the Boolean value being constrained cannot be True or False.	
Inherit	`C_PRIMITIVE`	
Attributes	**Signature**	**Meaning**
1	**true_valid**: `Boolean`	True if the value True is allowed
1	**false_valid**: `Boolean`	True if the value False is allowed
0..1 (redefined)	**prototype_value**: `Boolean`	A generated prototype value from this constraint object.

CLASS	C_BOOLEAN
Invariant	***Binary_consistency***: true_valid ***or*** false_valid ***Prototype_value_consistency***: prototype_value.value ***and*** true_valid ***or else not*** prototype_value.value ***and*** false_valid

5.2.3 C_STRING Class

CLASS	C_STRING	
Purpose	Constraint on instances of `STRING`.	
Inherit	`C_PRIMITIVE`	
Attributes	**Signature**	**Meaning**
0..1 (cond)	**pattern**: `String`	Regular expression pattern for proposed instances of `String` to match.
0..1 (cond)	**list**: `Set<String>`	Set of Strings specifying constraint
1	**list_open**: `Boolean`	True if the list is being used to specify the constraint but is not considered exhaustive.
0..1 (redefined)	**prototype_value**: `String`	A generated prototype value from this constraint object.
Functions	**Signature**	**Meaning**
	is_pattern: `Boolean`	True if *pattern* is not Void.
Invariant	***Consistency***: is_pattern **xor** list /= Void ***Pattern_validity***: is_pattern **implies not** pattern.is_empty ***List_open_validity***: list_open **implies not** is_pattern	

5.2.4 C_INTEGER Class

CLASS	C_INTEGER	
Purpose	Constraint on instances of `Integer`.	
Inherit	`C_PRIMITIVE`	
Attributes	**Signature**	**Meaning**
0..1 (cond)	**list**: `Set<Integer>`	Set of Integers specifying constraint

CLASS	C_INTEGER	
0..1 (cond)	**range**: `Interval<Integer>`	Range of Integers specifying constraint
0..1 (redefined)	**prototype_value**: `Integer`	A generated prototype value from this constraint object.
Invariant	***Consistency***: list /= Void ***xor*** range /= Void	

5.2.5 C_REAL Class

CLASS	C_REAL	
Purpose	Constraint on instances of `Real`.	
Inherit	`C_PRIMITIVE`	
Attributes	**Signature**	**Meaning**
0..1 (cond)	**list**: `Set<Real>`	Set of Reals specifying constraint
0..1 (cond)	**range**: `Interval<Real>`	Range of Real specifying constraint
0..1 (redefined)	**prototype_value**: `Real`	A generated prototype value from this constraint object.
Invariant	***Consistency***: list /= Void ***xor*** range /= Void	

5.2.6 C_DATE Class

CLASS	C_DATE	
Purpose	ISO 8601-compatible constraint on instances of `Date` in the form either of a set of validity values, or an actual date range. There is no validity flag for 'year', since it must always be by definition mandatory in order to have a sensible date at all. Syntax expressions of instances of this class include "YYYY-??-??" (date with optional month and day).	
Use	Date ranges are probably only useful for historical dates.	
Inherit	`C_PRIMITIVE`	
Attributes	**Signature**	**Meaning**
0..1 (cond)	**range**: `Interval <ISO8601_DATE>`	Interval of Dates specifying constraint

CLASS	C_DATE	
0..1 (cond)	**pattern**: `String`	ISO8601-based ADL pattern like "yyyy-??-xx"
0..1 (redefined)	**prototype_value**: `ISO8601_DATE`	A generated prototype value from this constraint object.
Functions	**Signature**	**Meaning**
	month_validity: `VALIDITY_KIND`	Validity of month in constrained date.
	day_validity: `VALIDITY_KIND`	Validity of day in constrained date.
	timezone_validity: `VALIDITY_KIND`	Validity of timezone in constrained date.
	validity_is_range: `Boolean` ***ensure*** Result = (range /= Void)	True if validity is in the form of a range; useful for developers to check which kind of constraint has been set.
Invariant	***Basic_validity***: range /= Void **xor** pattern /= Void ***Pattern_validity***: pattern /= Void **implies** valid_iso8601_date_constraint_pattern(pattern)	

5.2.7 C_TIME Class

CLASS	C_TIME	
Purpose	ISO 8601-compatible constraint on instances of `Time`. There is no validity flag for 'hour', since it must always be by definition mandatory in order to have a sensible time at all. Syntax expressions of instances of this class include "HH:??:xx" (time with optional minutes and seconds not allowed).	
Inherit	`C_PRIMITIVE`	
Attributes	**Signature**	**Meaning**
0..1 (cond)	**range**: `Interval <ISO8601_TIME>`	Interval of Times specifying constraint
0..1 (cond)	**pattern**: `String`	ISO8601-based ADL pattern like "hh:??:xx"
0..1 (redefined)	**prototype_value**: `ISO8601_TIME`	A generated prototype value from this constraint object.
Functions	**Signature**	**Meaning**
	minute_validity: `VALIDITY_KIND`	Validity of minute in constrained time.

CLASS	C_TIME	
	second_validity: VALIDITY_KIND	Validity of second in constrained time.
	millisecond_validity: VALIDITY_KIND	Validity of millisecond in constrained time.
	timezone_validity: VALIDITY_KIND	Validity of timezone in constrained date.
	validity_is_range: Boolean ***ensure*** Result = (range /= Void)	True if validity is in the form of a range; useful for developers to check which kind of constraint has been set.
Invariant	***Basic_validity***: range /= Void **xor** pattern /= Void ***Pattern_validity***: pattern /= Void **implies** valid_iso8601_time_constraint_pattern(pattern)	

5.2.8 C_DATE_TIME Class

CLASS	C_DATE_TIME	
Purpose	ISO 8601-compatible constraint on instances of Date_Time. There is no validity flag for 'year', since it must always be by definition mandatory in order to have a sensible date/time at all. Syntax expressions of instances of this class include "YYYY-MM-DDT??:??:??" (date/time with optional time) and "YYYY-MM-DDTHH:MM:xx" (date/time, seconds not allowed).	
Inherit	C_PRIMITIVE	
Attributes	**Signature**	**Meaning**
0..1 (cond)	**range**: Interval <ISO8601_DATE_TIME>	Range of Date_times specifying constraint
0..1 (cond)	**pattern**: String	ISO8601-based pattern like "yyyy-mm-ddT??:??:??"
0..1 (redefined)	**prototype_value**: ISO8601_DATE_TIME	A generated prototype value from this constraint object.
Functions	**Signature**	**Meaning**
	month_validity: VALIDITY_KIND	Validity of month in constrained date.
	day_validity: VALIDITY_KIND	Validity of day in constrained date.
	hour_validity: VALIDITY_KIND	Validity of hour in constrained time.

CLASS	C_DATE_TIME	
	minute_validity: VALIDITY_KIND	Validity of minute in constrained time.
	second_validity: VALIDITY_KIND	Validity of second in constrained time.
	millisecond_validity: VALIDITY_KIND	Validity of millisecond in constrained time.
	timezone_validity: VALIDITY_KIND	Validity of timezone in constrained date.
	validity_is_range: Boolean ***ensure*** Result = (range /= Void)	True if validity is in the form of a range; useful for developers to check which kind of constraint has been set.
Invariant	***Basic_validity***: range /= Void **xor** pattern /= Void ***Pattern_validity***: pattern /= Void **implies** valid_iso8601_date_time_constraint_pattern(pattern)	

5.2.9 C_DURATION Class

CLASS	C_DURATION	
Purpose	ISO 8601-compatible constraint on instances of `Duration`. In ISO 8601 terms, constraints might are of the form "PWD" (weeks and/or days), "PDTHMS" (days, hours, minutes, seconds) and so on. In official ISO 8601:2004, the 'W' (week) designator cannot be mixed in; allowing it is an *open*EHR-wide exception.	
Inherit	`C_PRIMITIVE`	
Attributes	**Signature**	**Meaning**
0..1	**range**: `Interval <ISO8601_DURATION>`	Constraint expressed as a range of durations.
0..1	**pattern**: `String`	ISO8601-based pattern. Allowed patterns: P[Y|y][M|m][D|d][T[H|h][M|m][S|s]] or P[W|w]
1 (redefined)	**prototype_value**: `ISO8601_DURATION`	The value to assume if this item is not included in data, due to being part of an optional structure.
Functions	**Signature**	**Meaning**
	years_allowed: `Boolean`	True if years are allowed in the constrained Duration.
	months_allowed: `Boolean`	True if months are allowed in the constrained Duration.
	weeks_allowed: `Boolean`	True if weeks are allowed in the constrained Duration.
	days_allowed: `Boolean`	True if days are allowed in the constrained Duration.
	hours_allowed: `Boolean`	True if hours are allowed in the constrained Duration.
	minutes_allowed: `Boolean`	True if minutes are allowed in the constrained Duration.
	seconds_allowed: `Boolean`	True if seconds are allowed in the constrained Duration.
	fractional_seconds_allowed: `Boolean`	True if fractional seconds are allowed in the constrained Duration.
	validity_is_range: `Boolean` ***ensure*** Result = (range /= Void)	True if validity is in the form of a range; useful for developers to check which kind of constraint has been set.

CLASS	C_DURATION
Invariant	***Basic_validity***: pattern /= Void **or** range /= Void ***Pattern_valid***: pattern /= Void **implies** valid_iso8601_duration_constraint_pattern (pattern)

6 The Assertion Package

6.1 Overview

Assertions are expressed in archetypes in typed first-order predicate logic (FOL). They are used in two places: to express archetype slot constraints, and to express rules in complex object constraints. In both of these places, their role is to constrain something *inside* the archetype. Constraints on external resources such as terminologies are expressed in the constraint binding part of the archetype ontology, described in section 7 on page 63. The assertion package is illustrated below in FIGURE 10.

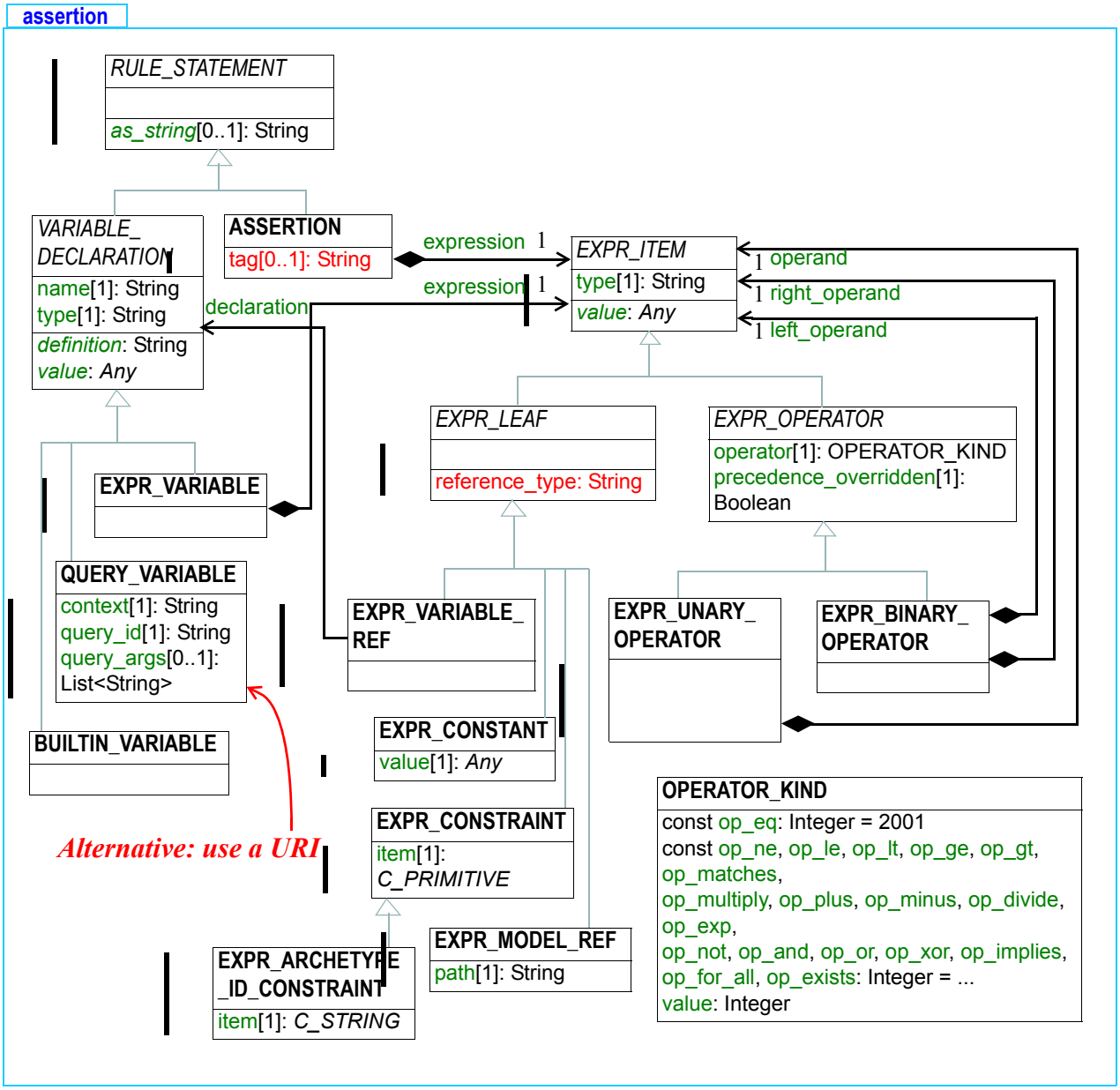


FIGURE 10 The openehr.am.archetype.assertion package

6.2 Semantics

Archetype assertions are statements which contain the following elements:

- *variables*, which are inbuilt, archetype path-based, or external query results;
- *manifest constants* of any primitive type, including the date/time types
- *arithmetic operators*: +, *, -, /, ^ (exponent), % (modulo division)
- *relational operators*: >, <, >=, <=, =, !=, **matches**
- *boolean operators*: **not**, **and**, **or**, **xor**
- *quantifiers* applied to container variables: **for_all**, **exists**

A syntax of assertions is defined in the *open*EHR ADL specification. The package described here is designed to allow the representation of a general-purpose expression tree, as generated by a parser. This relatively simple model of expressions is sufficiently powerful for representing the subset of FOL expressions required in archetypes and templates.

6.3 Class Descriptions

6.3.1 RULE_STATEMENT Class

CLASS	*RULE_STATEMENT (abstract)*	
Purpose	Abstract concept of any statement in a block of rule statements.	
Abstract	**Signature**	**Meaning**
	as_string: `String`	Serialised to ADL string form.
Invariant		

6.3.2 ASSERTION Class

CLASS	ASSERTION	
Purpose	Structural model of a typed first order predicate logic assertion, in the form of an expression tree, including optional variable definitions.	
Inherit	`RULE_STATEMENT`	
Attributes	**Signature**	**Meaning**
0..1	**tag**: `String`	Expression tag, used for differentiating multiple assertions.
1	**expression**: `EXPR_ITEM`	Root of expression tree.
Invariant	***Tag_valid***: tag /= Void **implies not** tag.is_empty ***Expression_valid***: expression /= Void and then expression.type.is_equal(“BOOLEAN”)	

6.3.3 VARIABLE_DECLARATION Class

CLASS	*VARIABLE_DECLARATION (abstract)*	
Purpose	Definition of a named variable used in an assertion expression.	
Inherit	`RULE_STATEMENT`	
Abstract	**Signature**	**Meaning**
	definition: `String`	Formal definition of the variable.
	value: `Any`	Value of the variable once evaluated.
Attributes	**Signature**	**Meaning**
1	**name**: `String`	Name of variable.
1	**type**: `String`	Type of variable, from the *open*EHR assumed types or the *open*EHR reference model.
Invariant	***Name_valid***: name /= Void **and then not** name.is_empty ***Type_valid***: type /= Void **and then not** type.is_empty	

6.3.4 EXPR_VARIABLE Class

CLASS	EXPR_VARIABLE	
Purpose	A variable whose definition is an expression, including atomic expressions such as constants and model references (i.e. path references).	
Inherit	`VARIABLE_DECLARATION`	
Attributes	**Signature**	**Meaning**
1	**expression**: `EXPR_ITEM`	Expression tree of expression.
Invariant	***Expression_valid***: expression /= Void	

6.3.5 BUILTIN_VARIABLE Class

CLASS	BUILTIN_VARIABLE	
Purpose	A variable with a name and definition from a small set of assumed environmental variables. It is assumed that the implementation will correctly generate the appropriate values and types for these variables. The current set of built-in variables is as follows: • current_date: `ISO8601_DATE` • current_time: `ISO8601_TIME` • current_date_time: `ISO8601_DATE_TIME`	
Inherit	`VARIABLE_DECLARATION`	
Attributes	**Signature**	**Meaning**
Invariant		

6.3.6 QUERY_VARIABLE Class

CLASS	QUERY_VARIABLE	
Purpose	Definition of a variable whose value is derived from a query run on a data context in the operational environment. Typical uses of this kind of variable are to obtain values like the patient date of birth, sex, weight, and so on. It could also be used to obtain items from a knowledge context, such as a drug database.	
Inherit	`VARIABLE_DECLARATION`	
Attributes	**Signature**	**Meaning**
0..1	**context**: `String`	Optional name of context. This allows a basic separation of query types to be done in more sophisticated environments. Possible values might be “patient”, “medications” and so on. **Not yet standardised.**
1	**query_id**: `String`	Identifier of query in the external context, e.g. “date_of_birth”. **Not yet standardised.**
1	**query_args**: List<`String`>	Optional arguments to query. **Not yet standardised.**
Invariant	***Context_valid***: context /= Void **implies not** context.is_empty ***Query_id_valid***: query_id /= Void **and then not** query_id.is_empty	

6.3.7 EXPR_ITEM Class

CLASS	*EXPR_ITEM (abstract)*	
Purpose	Abstract parent of all expression tree items.	
Attributes	**Signature**	**Meaning**
1	**type**: `String`	Type name of this item in the mathematical sense. For leaf nodes, must be the name of a primitive type, or else a reference model type. The type for any relational or boolean operator will be “Boolean”, while the type for any arithmetic operator, will be “Real” or “Integer”.
Invariant	***Type_valid***: type /= Void **and then not** type.is_empty	

6.3.8 EXPR_ITEM Class

CLASS	*EXPR_ITEM (abstract)*	
Purpose	Expression tree leaf item representing one of: • a manifest constant of any primitive type; • a path referring to a value in the archetype; • a constraint; • a variable reference.	
Inherit	`EXPR_ITEM`	
Functions	**Signature**	**Meaning**
	reference_type: `String`	Type of reference: “constant”, “attribute”, “function”, “constraint”. The first three are used to indicate the referencing mechanism for an operand. The last is used to indicate a constraint operand, as happens in the case of the right-hand operand of the ‘matches’ operator.
Invariant		

6.3.9 EXPR_CONSTANT Class

CLASS	EXPR_CONSTANT	
Purpose	Constant expression tree leaf item. This can represent a manifest constant of any primitive type, i.e.: • Integer, • Real, • Boolean, • String, • Character, • Date, • Time, • Date_time, • Duration • an Interval of any of the above types that are Ordered (see Support IM) • a list of any of the above types.	
Inherit	EXPR_LEAF	
Attributes	Signature	Meaning
1	**value**: Any	The constant value.
Invariant	***Value_valid***: value /= Void	

6.3.10 EXPR_CONSTRAINT Class

CLASS	EXPR_CONSTRAINT	
Purpose	Expression tree leaf item representing a constraint on a primitive type, expressed in the form of concrete subtype of C_PRIMITIVE.	
Inherit	EXPR_LEAF	
Attributes	Signature	Meaning
1	**item**: C_PRIMITIVE	The constraint.
Invariant	***Item_valid***: item /= Void	

6.3.11 EXPR_ARCHETYPE_ID_CONSTRAINT Class

CLASS	EXPR_ARCHETYPE_ID_CONSTRAINT
Purpose	Expression tree leaf item representing a constraint on an archetype identifier.

CLASS	EXPR_ARCHETYPE_ID_CONSTRAINT	
Inherit	EXPR_LEAF	
Attributes	Signature	Meaning
1	**item**: C_STRING	A constraint on ARCHETYPE_ID objects for use within ARCHETYPE_SLOTs.
Invariant	***Constraint_validity***: item.is_pattern -- **and** item.pattern matches ARCHETYPE_ID.template	

6.3.12 EXPR_MODEL_REF Class

CLASS	EXPR_MODEL_REF	
Purpose	Expression tree leaf item representing a reference to a value found in data at a location specified by a path in the archetype definition. • A path referring to a value in the archetype (paths with a leading '/' are in the definition section. • Paths with no leading '/' are in the outer part of the archetype, e.g. "archetype_id/value" refers to the String value of the *archetype_id* attribute of the enclosing archetype.	
Inherit	EXPR_ITEM	
Attributes	Signature	Meaning
1	**path**: String	The path.
Invariant	***Path_valid***: path /= Void	

6.3.13 EXPR_VARIABLE_REF Class

CLASS	EXPR_VARIABLE_REF	
Purpose	Expression tree leaf item representing a reference to a defined variable.	
Inherit	EXPR_LEAF	
Attributes	Signature	Meaning
1	**declaration**: *VARIABLE_DECLARATION*	The variable referred to.
Invariant	***Declaration_valid***: declaration /= Void	

6.3.14 EXPR_OPERATOR Class

CLASS	*EXPR_OPERATOR (abstract)*	
Purpose	Abstract parent of operator types.	
Inherit	EXPR_ITEM	
Attributes	**Signature**	**Meaning**
1	**operator**: OPERATOR_KIND	Code of operator.
1	**precedence_overridden**: Boolean	True if the natural precedence of operators is overridden in the expression represented by this node of the expression tree. If True, parentheses should be introduced around the totality of the syntax expression corresponding to this operator node and its operands.
Invariant		

6.3.15 EXPR_UNARY_OPERATOR Class

CLASS	EXPR_UNARY_OPERATOR	
Purpose	Unary operator expression node.	
Inherit	EXPR_OPERATOR	
Attributes	**Signature**	**Meaning**
1	**operand**: EXPR_ITEM	Operand node.
Invariant	***operand_valid***: operand /= Void	

6.3.16 EXPR_BINARY_OPERATOR Class

CLASS	EXPR_BINARY_OPERATOR	
Purpose	Binary operator expression node.	
Inherit	EXPR_OPERATOR	
Attributes	**Signature**	**Meaning**
1	**left_operand**: EXPR_ITEM	Left operand node.
1	**right_operand**: EXPR_ITEM	Right operand node.

CLASS	EXPR_BINARY_OPERATOR
Invariant	***left_operand_valid***: operand /= Void ***right_operand_valid***: operand /= Void

6.3.17 OPERATOR_KIND Class

CLASS	OPERATOR_KIND	
Purpose	Enumeration type for operator types in assertion expressions	
Use	Use as the type of operators in the Assertion package, or for related uses.	
Constants	**Signature**	**Meaning**
	op_eq: `Integer = 2001`	Equals operator (‘=’ or ‘==’)
	op_ne: `Integer = 2002`	Not equals operator (‘!=’ or ‘/=’ or ‘<>’)
	op_le: `Integer = 2003`	Less-than or equals operator (‘<=’)
	op_lt: `Integer = 2004`	Less-than operator (‘<’)
	op_ge: `Integer = 2005`	Greater-than or equals operator (‘>=’)
	op_gt: `Integer = 2006`	Greater-than operator (‘>’)
	op_matches: `Integer = 2007`	Matches operator (‘matches’ or ‘is_in’)
	op_not: `Integer = 2010`	Not logical operator
	op_and: `Integer = 2011`	And logical operator
	op_or: `Integer = 2012`	Or logical operator
	op_xor: `Integer = 2013`	Xor logical operator
	op_implies: `Integer = 2014`	Implies logical operator
	op_for_all: `Integer = 2015`	For-all quantifier operator
	op_exists: `Integer = 2016`	Exists quantifier operator
	op_plus: `Integer = 2020`	Plus operator (‘+’)
	op_minus: `Integer = 2021`	Minus operator (‘-’)
	op_multiply: `Integer = 2022`	Multiply operator (‘*’)
	op_divide: `Integer = 2023`	Divide operator (‘/’)

CLASS	OPERATOR_KIND	
	op_exp: `Integer = 2024`	Exponent operator (‘^’)
Attributes	**Signature**	**Meaning**
	value: `Integer`	Actual value of this instance
Functions	**Signature**	**Meaning**
	valid_operator (an_op: `Integer): Boolean` ***ensure*** an_op >= op_eq **and** an_op <= op_exp	Function to test operator values.
Invariant	***Validity***: valid_operator(value)	

7 Ontology Package

7.1 Overview

All linguistic and terminological entities in an archetype are represented in the ontology part of an archetype, whose semantics are given in the Ontology package, shown below.

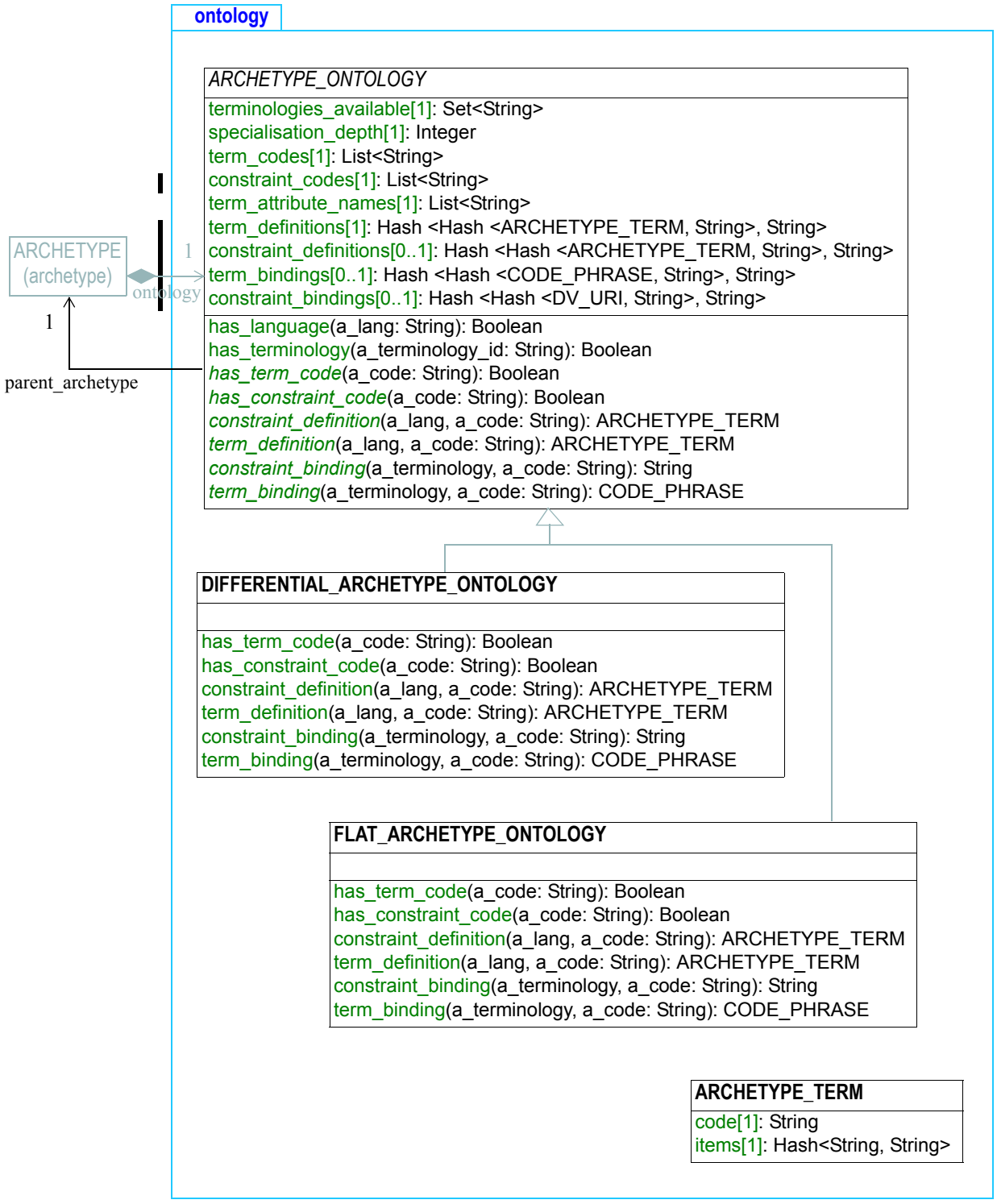


FIGURE 11 openehr.am.archetype.ontology Package

An archetype ontology consists of the following elements.

- A list of terms defined local to the archetype. These are identified by ‘atNNNN’ codes, and perform the function of archetype node identifiers from which paths are created. There is one such list for each natural language in the archetype. A term ‘at0001’ defined in English as ‘blood group’ is an example.
- A list of external constraint definitions, identified by ‘acNNNN’ codes, for constraints defined external to the archetype, and referenced using an instance of a CONSTRAINT_REF. There is one such list for each natural language in the archetype. A term ‘ac0001’ corresponding to ‘any term which is-a blood group’, which can be evaluated against some external terminology service.
- Optionally, a set of one or more bindings of term definitions to term codes from external terminologies.
- Optionally, a set of one or more bindings of the external constraint definitions to external resources such as terminlogies.

The differential variant of the ARCHETYPE_ONTOLOGY class defines an archetype ontology that only contains terms, constraints and bindings that were introduced in the owning archetype, whereas the flat variant contains all codes and bindings obtained by compressing an archetype lineage through inheritance.

7.2 Semantics

7.2.1 Specialisation Depth

Any given archetype occurs at some point in a lineage of archetypes related by specialisation, where the depth is indicated by the *specialisation_depth* attribute. An archetype which is not a specialisation of another has a specialisation_depth of 0. Term and constraint codes *introduced* in the ontology of specialised archetypes (i.e. which did not exist in the ontology of the parent archetype) are defined in a strict way, using ‘.’ (period) markers. For example, an archetype of specialisation depth 2 will use term definition codes like the following:

- ‘at0.0.1’ - a new term introduced in this archetype, which is not a specialisation of any previous term in any of the parent archetypes;
- ‘at0001.0.1’ - a term which specialises the ‘at0001’ term from the top parent. An intervening ‘.0’ is required to show that the new term is at depth 2, not depth 1;
- ‘at0001.1.1’ - a term which specialises the term ‘at0001.1’ from the immediate parent, which itself specialises the term ‘at0001’ from the top parent.

This systematic definition of codes enables software to use the structure of the codes to more quickly and accurately make inferences about term definitions up and down specialisation hierarchies. Constraint codes on the other hand do not follow these rules, and exist in a flat code space instead.

7.2.2 Term and Constraint Definitions

Local term and constraint definitions are modelled as instances of the class ARCHETYPE_TERM, which is a code associated with a list of name/value pairs. For any term or constraint definition, this list must at least include the name/value pairs for the names “text” and “description”. It might also include such things as “provenance”, which would be used to indicate that a term was sourced from an external terminology. The attribute *term_attribute_names* in ARCHETYPE_ONTOLOGY provides a list of

attribute names used in term and constraint definitions in the archetype, including “text” and “description”, as well as any others which are used in various places.

7.3 Class Descriptions

7.3.1 ARCHETYPE_ONTOLOGY Class

CLASS	ARCHETYPE_ONTOLOGY (abstract)	
Purpose	Local ontology of an archetype. This abstract class defines nearly all the semantics of the ontology of an archetype. It is specialised into differential and flat subtypes which implement some routines and supply various different validation semantics.	
Attributes	**Signature**	**Meaning**
1	**terminologies_available**: `Set<String>`	List of terminologies to which term or constraint bindings exist in this terminology.
1	**specialisation_depth**: `Integer`	Specialisation depth of this archetype. Unspecialised archetypes have depth 0, with each additional level of specialisation adding 1 to the specialisation_depth.
1	**term_codes**: `List<String>`	List of all term codes in the ontology. Most of these correspond to “at” codes in an ADL archetype, which are the *node_ids* on `C_OBJECT` descendants. There may be an extra one, if a different term is used as the overall archetype *concept* from that used as the node_id of the outermost `C_OBJECT` in the definition part.
1	**constraint_codes**: `List<String>`	List of all term codes in the ontology. These correspond to the “ac” codes in an ADL archetype, or equivalently, the `CONSTRAINT_REF`.*reference* values in the archetype definition.
1	**term_attribute_names**: `List<String>`	List of ‘attribute’ names in ontology terms, typically includes ‘text’, ‘description’, ‘provenance’ etc.
1	**parent_archetype**: `ARCHETYPE`	Archetype which owns this ontology.
1	**term_definitions**: `Hash <Hash <ARCHETYPE_TERM, String>, String>`	Directory of term definitions as a two-level table. The outer hash keys are language codes, e.g. `"en"`, `"de"`, while the inner hash keys are term codes, e.g. `"at0004"`.

CLASS	ARCHETYPE_ONTOLOGY (abstract)	
0..1	**constraint_definitions**: `Hash <Hash <ARCHETYPE_TERM, String>, String>`	Directory of constraint definitions as a two-level table. The outer hash keys are language codes, e.g. "en", "de", while the inner hash keys are term codes, e.g. "at0004".
0..1	**term_bindings**: `Hash <Hash <CODE_PHRASE, String>, String>`	Directory of term bindings as a two-level table. The outer hash keys are terminology ids, e.g. "SNOMED_CT", and the inner hash keys are term codes, e.g. "at0004" etc. The indexed `CODE_PHRASE` objects represent the bound external codes, e.g. Snomed or ICD codes in string form, e.g. "SNOMED_CT::10094842".
0..1	**constraint_bindings**: `Hash <Hash <DV_URI, String>, String>`	Directory of constraint bindings as a two-level table. The outer hash keys are terminology ids, e.g. "SNOMED_CT", and the inner hash keys are constraint codes, e.g. "ac0004" etc. The indexed `DV_URI` objects represent references to externally defined resources, usually a terminology subset.
Abstract	**Signature**	**Meaning**
	has_term_code(a_code: `String`): `Boolean`	True if *term_codes* has *a_code*.
	has_constraint_code(a_code: `String`): `Boolean`	True if *constraint_codes* has *a_code*.
	term_definition(a_lang, a_code: `String`): `ARCHETYPE_TERM` ***require*** has_language(a_lang) has_term_code(a_code)	Term definition for a code, in a specified language.
	constraint_definition(a_lang, a_code: `String`): `ARCHETYPE_TERM` ***require*** has_language(a_lang) has_constraint_code(a_code)	Constraint definition for a code, in a specified language.

CLASS	ARCHETYPE_ONTOLOGY (abstract)	
	term_binding (a_terminology_id, a_code: `String`): `CODE_PHRASE` ***require*** has_terminology (a_terminology_id) **and** has_term_code (a_code)	Binding of term corresponding to *a_code* in target external terminology *a_terminology_id* as a `CODE_PHRASE`.
	constraint_binding (a_terminology_id, a_code: `String`): `String` ***require*** has_terminology (a_terminology_id) **and** has_constraint_code (a_code)	Binding of constraint corresponding to *a_code* in target external terminology *a_terminology_id*, as a string, which is usually a formal query expression.
Functions	**Signature**	**Meaning**
	has_language (a_lang: `String`): `Boolean`	True if language 'a_lang' is present in archetype ontology.
	has_terminology (a_terminology_id: `String`): `Boolean` ***require*** has_terminology (a_terminology_id)	True if terminology 'a_terminology' is present in archetype ontology.
Invariant	***terminologies_available_exists***: terminologies_available /= void ***term_codes_validity***: term_codes /= void ***constraint_codes_validity*** constraint_codes /= void ***term_definitions_validity***: term_definitions /= void ***constraint_definitions_validity*** constraint_definitions /= void **implies not** constraint_definitions.is_empty ***term_bindings_validity***: term_bindings /= void **implies not** term_bindings.is_empty ***constraint_bindings_validity***: constraint_bindings /= void **implies not** constraint_bindings.is_empty ***term_attribute_names_valid***: term_attribute_names /= void **and then** term_attribute_names.has("text") **and** term_attribute_names.has("description") ***Parent_archetype_valid***: parent_archetype /= Void and then parent_archetype.description = Current	

7.3.2 DIFFERENTIAL_ARCHETYPE_ONTOLOGY Class

CLASS	DIFFERENTIAL_ARCHETYPE_ONTOLOGY	
Purpose	Differential form of an archetype ontology, containing only codes and bindings introduced in the current archetype.	
Functions	**Signature**	**Meaning**
(effected)	**has_term_code**(a_code: `String`): `Boolean`	
(effected)	**has_constraint_code**(a_code: `String`): `Boolean`	
(effected)	**term_definition**(a_lang, a_code: `String`): `ARCHETYPE_TERM`	
(effected)	**constraint_definition**(a_lang, a_code: `String`): `ARCHETYPE_TERM`	
(effected)	**term_binding** (a_terminology_id, a_code: `String`): `CODE_PHRASE`	
(effected)	**constraint_binding** (a_terminology_id, a_code: `String`): `String`	
Invariant		

7.3.3 FLAT_ARCHETYPE_ONTOLOGY Class

CLASS	FLAT_ARCHETYPE_ONTOLOGY	
Purpose	Flat form of an archetype ontology, containing codes and bindings from all archetypes in the inheritance lineage of the current archetype.	
Functions	**Signature**	**Meaning**
(effected)	**has_term_code**(a_code: `String`): `Boolean`	
(effected)	**has_constraint_code**(a_code: `String`): `Boolean`	
(effected)	**term_definition**(a_lang, a_code: `String`): `ARCHETYPE_TERM`	

CLASS	FLAT_ARCHETYPE_ONTOLOGY	
(effected)	**constraint_definition**(a_lang, a_code: `String`): `ARCHETYPE_TERM`	
(effected)	**term_binding** (a_terminology_id, a_code: `String`): `CODE_PHRASE`	
(effected)	**constraint_binding** (a_terminology_id, a_code: `String`): `String`	
Invariant		

7.3.4 ARCHETYPE_TERM Class

CLASS	ARCHETYPE_TERM	
Purpose	Representation of any coded entity (term or constraint) in the archetype ontology.	
Attributes	Signature	Meaning
1	**code**: `String`	Code of this term.
1	**items**: `Hash <String, String>`	Hash of keys (`"text"`, `"description"` etc) and corresponding values.
Functions	Signature	Meaning
	keys: `Set<String>` ***ensure*** Result /= Void	List of all keys used in this term.
Invariant	***code_valid***: code /= void **and then not** code.is_empty ***items_valid***: items /= Void	

Appendix A Domain-specific Extension Example

A.1 Overview

Domain-specific classes can be added to the archetype constraint model by inheriting from the class C_DOMAIN_TYPE. This section provides an example of how domain-specific constraint classes are added to the archetype model. Actual additions to the AOM for *open*EHR are documented in the *open*EHR Archetype Profile (oAP) specification.

A.2 Scientific/Clinical Computing Types

FIGURE 12 shows the general approach, used to add constraint classes for commonly used concepts in scientific and clinical computing, such as 'ordinal' (used heavily in medicine, particularly in pathology testing), 'coded term' (also heavily used in clinical computing) and 'quantity', a general scientific meansurement concept. The constraint types shown are C_ORDINAL, C_CODED_TEXT and C_QUANTITY which can optionally be used in archetypes to replace the default constraint semantics represented by the use of instances of C_OBJECT / C_ATTRIBUTE to constrain ordinals, coded terms and quantities. The following model is intended only as an example, and does not try to define any normative semantics of the particular constraint types shown.

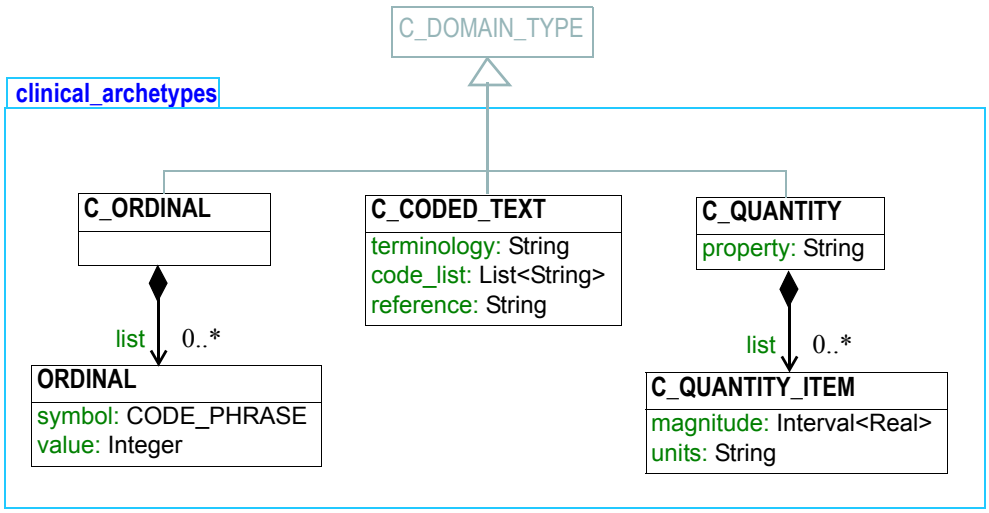


FIGURE 12 Example Domain-specific Package

Appendix B Algorithms

B.1 Validation of Specialised Archetype

The following class provides an indicative algorithm that can be used to validate a specialised archetype against the flat form of its specialisation parent. It is expressed in a Pascal-style notation dervived from the Eiffel reference implementation of the ADL compiler developed for the *open*EHR Foundation. The code and keywords should be self-explanatory, except possibly in the case of the 'agent' keyword. This is used in Eiffel to pass a routine as an object to another routine. The C# equivalent is the 'delegate'; in Java there are various workarounds. The original code can be found at THIS URL.

The design approach of the following class is quite simple: traverse the tree structure of the differential form of a specialised archetype with an agent (delegate) that finds the equivalent node in the flat parent, and determines whether the child node conforms or not.

```
class ARCHETYPE_VALIDATOR

    target: DIFFERENTIAL_ARCHETYPE
            -- differential archetype being validated

    flat_parent: FLAT_ARCHETYPE
            -- flat version of parent archetype, if target is specialised

    validate_specialised_definition is
            -- validate definition of specialised archetype against flat parent
        require
            Target_specialised: target.is_specialised
        local
            def_it: C_ITERATOR
        do
            create def_it.make(target.definition)
            def_it.do_while(agent specialised_node_validate, agent node_test)
        end

    node_test (a_c_node: ARCHETYPE_CONSTRAINT): BOOLEAN  is
            -- return True if a conformant path of a_c_node within the differential archetype is
            -- found within the flat parent archetype - i.e. a_c_node is inherited or redefined from
            -- parent (but not new) and no previous errors encountered
        local
            apa: ARCHETYPE_PATH_ANALYSER
        do
            create apa.make_from_string(a_c_node.path)
            Result := passed and flat_parent.has_path (apa.path_at_level (flat_parent.specialisation_depth))
        end

    specialised_node_validate (a_c_node: ARCHETYPE_CONSTRAINT; depth: INTEGER)
            -- perform grafts of node from differential archetype on corresponding node in flat parent
            -- only interested in C_COMPLEX_OBJECTs
        local
```

```
    co_parent_flat, co_child_diff: C_OBJECT
    apa: ARCHETYPE_PATH_ANALYSER
    child_attr_name: STRING
    ca_parent, ca_child, ca_child_diff: C_ATTRIBUTE
do
    create apa.make_from_string (a_c_node.path)

    if a_c_node instance_of C_ATTRIBUTE then
        ca_child_diff := (C_ATTRIBUTE) a_c_node
        ca_parent_flat ?= flat_parent.definition.c_attribute_at_path (apa.path_at_level (flat_parent.specialisation_depth))
        if not ca_child_diff.node_conforms_to(ca_parent_flat) then
            passed := False
            if ca_child_diff.is_single /= ca_parent_flat.is_single then
                add_error("VSAM", <<ca_child_diff.path>>)
            elseif not ca_child_diff.existence_conforms_to (ca_parent_flat) then
                add_error("VSANCE", <<ca_child_diff.path, ca_child_diff.existence.as_string,
                            ca_parent_flat.path, ca_parent_flat.existence.as_string>>)
            elseif not ca_child_diff.cardinality_conforms_to (ca_parent_flat) then
                add_error("VSANCC", <<ca_child_diff.path, ca_child_diff.cardinality.as_string,
                            ca_parent_flat.path, ca_parent_flat.cardinality.as_string>>)
            end
        elseif ca_child_diff.node_congruent_to (ca_parent_flat) and ca_child_diff.parent.is_congruent then
            ca_child_diff.set_is_congruent
        end

    elseif a_c_node instance_of C_OBJECT then
        co_child_diff := (C_OBJECT) a_c_node

        -- find corresponding node in parent by using child node path, 'de-specialised' by one level
        co_parent_flat := flat_parent.c_object_at_path (apa.path_at_level (flat_parent.specialisation_depth))

        -- C_CODE_PHRASE conforms to CONSTRAINT_REF, but is not testable in any way;
        -- sole exception in ADL/AOM; just warn
        if co_parent_flat instance_of CONSTRAINT_REF and co_child_diff instance_of C_CODE_PHRASE then
            if co_child_diff instance_of C_CODE_PHRASE then
                add_warning("WCRC", <<co_child_diff.path>>)
            else
                add_error("VSCNR", <<co_parent_flat.generating_type, co_parent_flat.path, co_child_diff.generating_type,
                                                                co_child_diff.path>>)
                passed := False
            end
        else
            -- if the child is a redefine of a parent use_node, then have to do the comparison to the
            -- use_node target, unless they both are use_nodes, in which case leave them as is
            if co_parent_flat instance_of ARCHETYPE_INTERNAL_REF and
                                            not co_child_diff instance_of ARCHETYPE_INTERNAL_REF then
                co_parent_flat := flat_parent.c_object_at_path ((ARCHETYPE_INTERNAL_REF) co_parent_flat.path)
            end
```

```
                -- now determine if child object is same as or a specialisation of flat object
                if dynamic_type (co_child_diff) /= dynamic_type (co_parent_flat) then
                    add_error("VSONT", <<co_child_diff.path, co_child_diff.type, co_parent_flat.path, co_parent_flat.type>>)
                    passed := False
                elseif not co_child_diff.node_conforms_to(co_parent_flat) then
                    passed := False
                    if not co_child_diff.rm_type_conforms_to (co_parent_flat) then
                        add_error("VSONCT", <<co_child_diff.path, co_child_diff.rm_type_name,
                                                co_parent_flat.path, co_parent_flat.rm_type_name>>)
                    elseif not co_child_diff.occurrences_conforms_to (co_parent_flat) then
                        add_error("VSONCO", <<co_child_diff.path, co_child_diff.occurrences.as_string,
                                                co_parent_flat.path, co_parent_flat.occurrences.as_string>>)
                    elseif co_child_diff.is_addressable then
                        if not co_child_diff.node_id_conforms_to (co_parent_flat) then
                            add_error("VSONCI", <<co_child_diff.path, co_child_diff.node_id, co_parent_flat.path,
                                                    co_parent_flat.node_id>>))
                        elseif co_child_diff.node_id.is_equal(co_parent_flat.node_id) then
                            add_error("VSONIR", <<co_child_diff.path, co_parent_flat.path, co_child_diff.node_id>>))
                        end
                    else
                        add_error("VSONNC", <<co_child_diff.rm_type_name, co_child_diff.path,
                                                co_parent_flat.rm_type_name, co_parent_flat.path>>))
                    end
                else
                    -- nodes are at least conformant; check for congruence for specalisation path replacement
                    if co_child_diff instance_of C_COMPLEX_OBJECT then
                        if co_child_diff.node_congruent_to (co_parent_flat) and
                                                (co_child_diff.is_root or else co_child_diff.parent.is_congruent) then
                            co_child_diff.set_is_congruent
                        end
                    end

                    if co_child_diff.sibling_order /= Void and then not
                        co_parent_flat.parent.has_child_with_id (co_child_diff.sibling_order.sibling_node_id) then
                        passed := False
                        add_error("VSSM", <<co_child_diff.path, co_child_diff.sibling_order.sibling_node_id>>))
                    end
                end
            end
        end
    end
end
```

B.2 Inheritance-flattening

cxx

7.3.5 What is a Redefined Node?

7.3.5.1 Correspondence of Redefined Nodes

Formally speaking, the correspondence of redefined nodes to the parent archetype nodes from which they are derived can be determined according to the following rules.

1. For an identified node in the parent archetype (i.e. at least any child of a container attribute and multiple same-typed children of single-valued attributes), the specialised archetype includes one or more nodes carrying a specialised node identifier, at a congruent path position.
2. For a non-identified node in the parent archetype (i.e. an unidentified child node of a single-valued attribute), the following conditions apply.
   a) Where the node in the parent is the only child node of the attribute, the specialised archetype can include one or more nodes at the corresponding location, whose types *conform* (in the sense of the reference model) to that of the parent node,

To Be Determined: provided that for any type for which there is more than one such node, each node of that type carries a specialised node identifier. [Extension node code maybe?]

   b) Where more than one such child node exists in the parent (each of which must be of different reference model types, by the identification rules described under Summary of Object Node Identification Rules on page 61), a specialised node in the child is matched to the parent node of the same or most immediate parent type from the reference model.
   c) Where there are multiple nodes in the parent under the single-valued attribute, and multiple nodes in the child at the same location, matching of specialised nodes to parent nodes may become ambiguous, if reference model subtypes are used.

The above rules are used to determine the lineage of a given node in a specialised archetype, which is required both for archetype validation and for archetype flattening. In case 2c, archetype authoring tools should indicate ambiguities to the authoring user, and potentially offer to add node identifiers in order to remove the ambiguity. For most archetypes and reference models, the use of non-identified nodes is likely to be limited, and such ambiguities will not arise. However for models and archetypes where single-valued attribute alternatives are heavily used and redefined, it is advisable that node identifiers be used both in the parent and specialised child archetypes.

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