openEHR

The *open*EHR Archetype Model

Archetype Object Model

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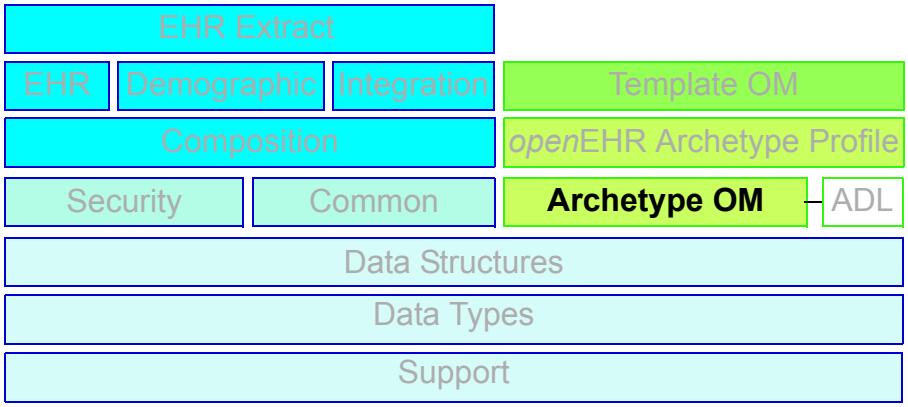

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Amendment Record

Issue	Details	Raiser	Completed
	RELEASE 1.1 candidate		
2.1	**SPEC-???**. Remove C_SINGLE_ATTRIBUTE and C_MULTIPLE_ATTRIBUTE classes. **SPEC-270**. Add specialisation semantics to ADL and AOM. Add various attributes and functions to ARCHETYPE_CONSTRAINT descendant classes. • move C_PRIMITIVE.*assumed_value* to attribute slot in UML • rename C_DEFINED_OBJECT.*default_value* function to *prototype_value* • correct *assumed_value* definition to be like ; remove its entry from all of the C_PRIMITIVE subtypes • convert BOOLEAN flag representation of patterns to functions and add a String data member for the pattern value, thus matching the XSDs and ADL • add ARCHETYPE.*is_template* attribute. • add ARCHETYPE.*is_component* attribute. • allow computed as well as stored attributes. • make ONTOLOGY.*terminologies_available* computed. **SPEC-263**. Change Date, Time etc classes in AOM to ISO8601_DATE, ISO8601_TIME etc from Support IM. **SPEC-296**. Convert Interval<Integer> to MULTIPLICITY_INTERVAL to simplify specification and implementation. **SPEC-300**. Archetype slot regular expressions should cover whole identifier. Added C_STRING.*is_pattern*. **SPEC-303**. Make *existence*, *occurrences* and *cardinality* optional in AOM. **SPEC-308**. Add validity rules to ARCHETYPE_ONTOLOGY. **SPEC-309**. ARCHETYPE_CONSTRAINT adjustments. **SPEC-178**. Add template object model to AM. • Add *is_exhaustive* attribute to ARCHETYPE_SLOT. • Add *is_template* attribute to ARCHETYPE. • Add *terminology_extracts* to ONTOLOGY.	T Beale, S Garde, S Kobayashi D Moner T Beale T Beale T Beale A Flinton S Heard T Beale T Beale T Beale	15 Apr 2013
	RELEASE 1.0.2		
2.0.2	**SPEC-257**. Correct minor typos and clarify text. Correct reversed definitions of *is_bag* and *is_set* in CARDINALITY class. **SPEC-251**. Allow both pattern and interval constraint on Duration in Archetypes. Add *pattern* attribute to C_DURATION class.	C Ma, R Chen, T Cook S Heard	20 Nov 2008
	RELEASE 1.0.1		

Issue	Details	Raiser	Completed
2.0.1	**CR-000200**. Correct Release 1.0 typographical errors. Table for missed class ASSERTION_VARIABLE added. Assumed_value assertions corrected; *standard_representation* function corrected. Added missed *adl_version*, *concept* rename from CR-000153. **CR-000216**: Allow mixture of W, D etc in ISO8601 Duration (deviation from standard). **CR-000219**: Use constants instead of literals to refer to terminology in RM. **CR-000232**. Relax validity invariant on CONSTRAINT_REF. **CR-000233**: Define semantics for *occurrences* on ARCHETYPE_INTERNAL_REF. **CR-000234**: Correct functional semantics of AOM constraint model package. **CR-000245**: Allow term bindings to paths in archetypes.	D Lloyd, P Pazos, R Chen, C Ma S Heard R Chen R Chen K Atalag T Beale S Heard	20 Mar 2007
RELEASE 1.0			
2.0	**CR-000153**. Synchronise ADL and AOM attribute naming. **CR-000178**. Add Template Object Model to AM. Text changes only. **CR-000167**. Add AUTHORED_RESOURCE class. Remove description package to resource package in Common IM.	T Beale T Beale T Beale	10 Nov 2005
RELEASE 0.96			
0.6	**CR-000134**. Correct numerous documentation errors in AOM. Including cut and paste error in TRANSLATION_DETAILS class in Archetype package. Corrected hyperlinks in Section 2.3. **CR-000142**. Update ADL grammar to support assumed values. Changed C_PRIMITIVE and C_DOMAIN_TYPE. **CR-000146**: Alterations to am.archetype.description from CEN MetaKnow **CR-000138**. Archetype-level assertions. **CR-000157**. Fix names of OPERATOR_KIND class attributes	D Lloyd S Heard, T Beale D Kalra T Beale T Beale	20 Jun 2005
RELEASE 0.95			
0.5.1	Corrected documentation error - return type of ARCHETYPE_CONSTRAINT.*has_path*; add optionality markers to Primitive types UML diagram. Removed erroneous aggregation marker from ARCHETYPE_ONTOLOGY.*parent_archetype* and ARCHETYPE_DESCRIPTION.*parent_archetype*.	D Lloyd	20 Jan 2005
0.5	**CR-000110**. Update ADL document and create AOM document. Includes detailed input and review from: - DSTC - CHIME, Uuniversity College London - Ocean Informatics Initial Writing. Taken from ADL document 1.2draft B.	T Beale A Goodchild Z Tun T Austin D Kalra N Lea D Lloyd S Heard T Beale	10 Nov 2004

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Table of Contents

1 Introduction

1.1 Purpose

This document contains the definitive formal 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)
- The *open*EHR Template Object Model (TOM)

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.

The most recent official release of this document is available at http://www.openehr.org/releases/latest.

The development version of this document can be found at http://www.openehr.org/releases/trunk/architecture/am/aom1.5.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 definition, 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 , 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 Background

2.1 Architectural 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.

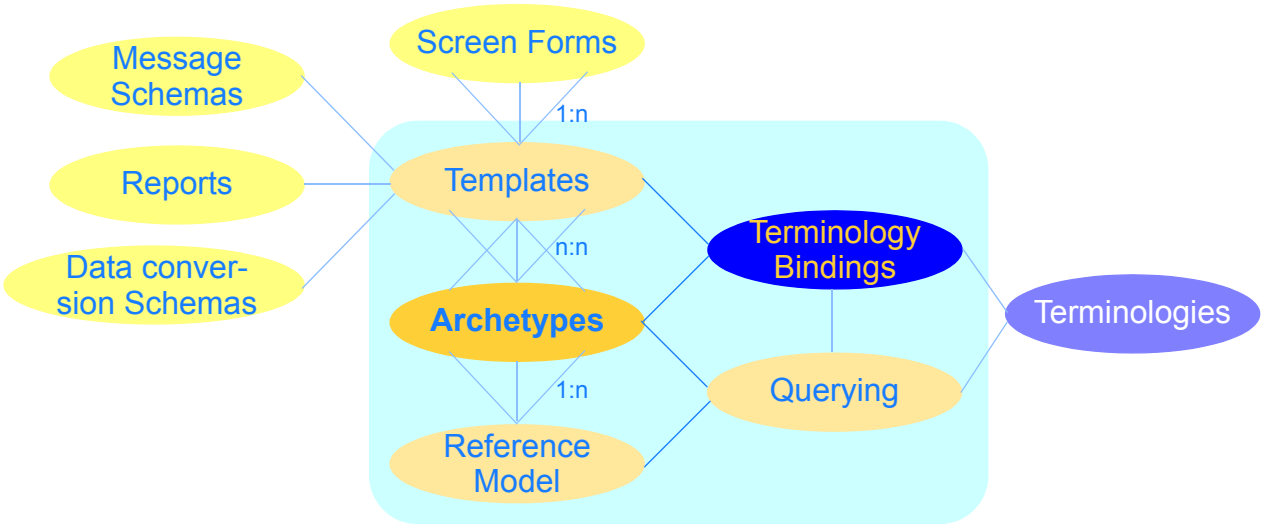


FIGURE 1 The *open*EHR Semantic Architecture

The semantics of archetypes are defined by the following specifications:

- the *open*EHR Archetype Object Model (AOM);
- the *open*EHR Archetype Profile (oAP);
- the Archetype Definition Language (ADL).

The AOM is the definitive formal expression of archetype semantics, and is independent of any particular syntax. **The main purpose of the AOM specification is to inform developers how to build software.**

The purpose of the *open*EHR Archetype Profile is to provide custom archetype classes for the *open*EHR reference model.

The *open*EHR archetype framework is described in terms of Archetype Definitions and Principles and *open*EHR Distributed Development Model documents..

The Archetype Definition Language (ADL) is a formal abstract syntax for archetypes, and can be used to provide a default serial expression of archetypes. It is the **primary document for *understanding* the semantics of archetypes**.

The semantics defined in the AOM and the Archetype Profile are used to express the object structures of source archetypes and flattened archetypes. With the addition of a small number of primitives defined in the Template Object Model (TOM), they also express the source and flattened form of *open*EHR templates. The two source forms are authored by users using tools, while the two flat forms are generated by tools. The rules for how to use the AOM for each of these forms is described in details in this specification.

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 measurement' archetype contains data points relevant to the result and measurement of blood pressure. Archetypes are assembled by templates to form structures used in computational systems, such as document definitions, message definitions and so on.

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. Apart from versioning, two kinds of relationship can exist 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

An archetype can be specialised in a descendant archetype in a similar way to a subclass in an object-oriented programming environment. Specialised archetypes are, like classes, expressed in a *differential* form with respect to the parent archetype. This 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 to the ultimate parent is known as an *archetype lineage*. For a non-specialised (i.e. top-level) archetype, the lineage is just itself.

In order for specialised archetypes to be used, the differential form used for authoring has to be *flattened* 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 slight differences in the semantics.

Any data created via the use of an archetype conforms to the flat form of the archetype, and to the flat form of every archetype up the lineage.

The semantics of specialisation are described in detail in the *open*EHR ADL specification.

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. There are two mechanisms for expressing composition: direct reference, and archetype *slots* which are defined in terms of constraints. The latter, unlike an object model, allows an archetype to have a composition relationship with any number of archetypes matching some constraint pattern. Depending on what archetypes are available within the system, the archetypes matched may vary.

2.2.2 Templates

In practical systems, archetypes are assembled into larger usable structures by the use of *open*EHR templates. A template is expressed in a source form similar to that of a specialised archetype, and

processed against an archetype library to product an operational template. The latter is like a large flat-form archetype, and is the form used for runtime validation, and also for the generation of all computational aretefacts derived from templates. Semantically, templates perform three functions: aggregating multiple archetypes, removing elements not needed for the use case of the template, and narrowing some existing constraints, in the same way as specialised archetypes. The effect is to re-use needed elements from the archetype library, arranged in a way that corresponds directly to the use case at hand.

2.3 The Development Environment

2.3.1 Model / Syntax Relationship

The AOM can be considered as the model of an in-memory archetype or a template, or equivalently, the syntax tree for any syntax form of the same. The abstract syntax form of an archetype is ADL, but an archetype may just as easily be parsed from and serialised to XML. The in-memory archetype representation may also be created by calls to a suitable AOM construction API, from an archetype or template editing tool. These relationships, and the relation between each form and its specification are shown in FIGURE 2.

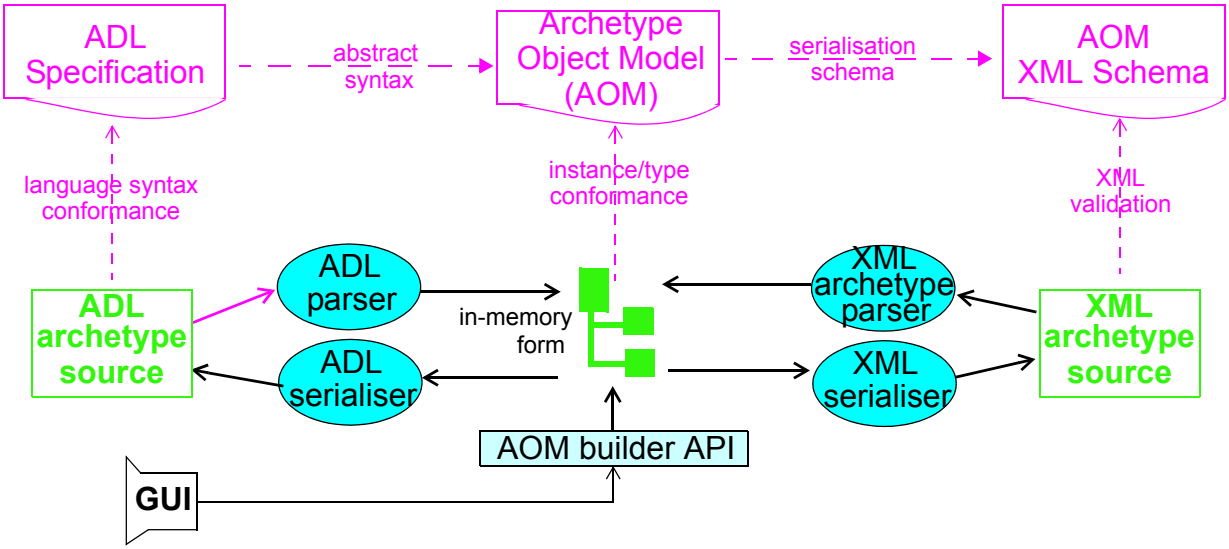


FIGURE 2 Relationship of archetype in-memory and syntax forms

The existence of source and flat form archetypes and templates, potentially in multiple serialised formats may initially appear confusing, although any given environment tends to use a single serialised form. FIGURE 3 illustrates all possible archetype and template artefact types, including file types, and shows which specifications they are defined by.

2.3.2 The Development Process

Archetypes and templates are authored and transformed according to a number of steps very similar to class definitions within an object-oriented programming environment. The activities in the process are as follows:

- *archetype authoring*: creates source-form archetypes, expressed in AOM objects;
- *archetype validation*: creates flattened archetypes;

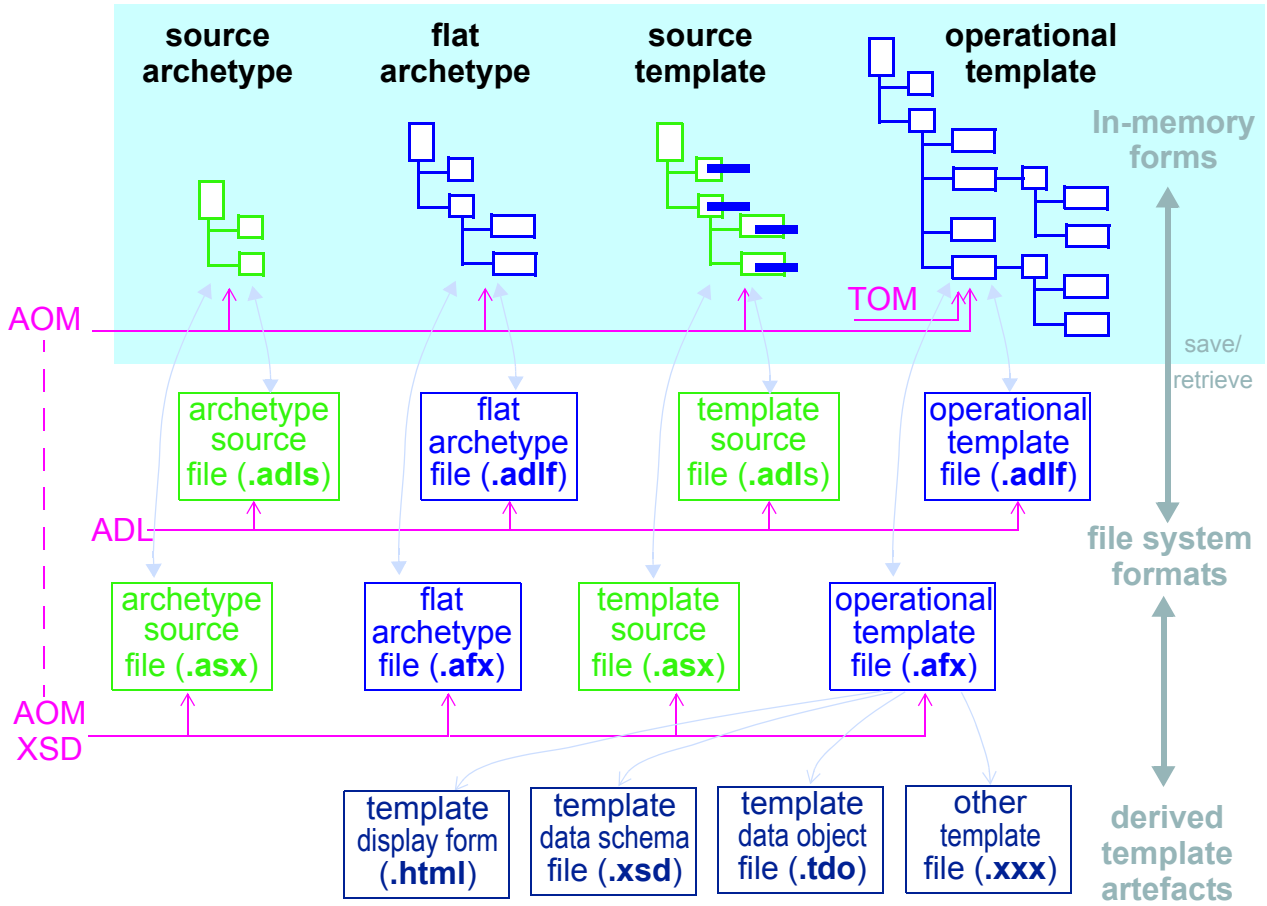


FIGURE 3 Relationship of computational artefacts and specifications

- *template authoring*: creates source-form templates that reference archetypes; also expressed as AOM / TOM objects;
- *operational template generation*: creates fully flattened archetype-based templates.

The tool chain for the process is illustrated in FIGURE 4. From a business point of view, template authoring is the starting point. A template references one or more archetypes, so its compilation (parsing, validation, flattening) involves both the template source and the validated, flattened forms of the referenced archetypes. With these as input, a template flattener can generate the final output, an operational template.

2.3.3 Compilation

A tool that parses, validates, flattens and serialises a library of archetypes is called a compiler. Due to archetype specialisation, *archetype lineages* rather than just single archetypes are processed - i.e. specialised archetypes can only be compiled in conjunction with their specialisation parents up to the top level. For any given lineage, compilation proceeds from the top-level archetype downward. Each archetype is validated, and if it passes, flattened with the parent in the chain. This continues until the archetype originally being compiled is reached. In the many cases of archetypes with no specialisations, compilation involves the one archetype only.

FIGURE 5 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.

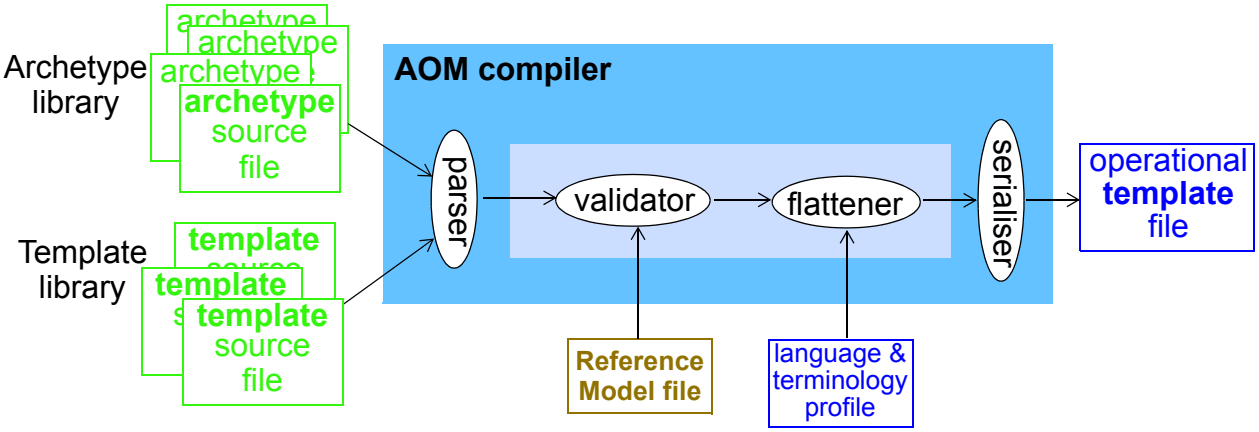


FIGURE 4 Archetype / template tool chain

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[1].

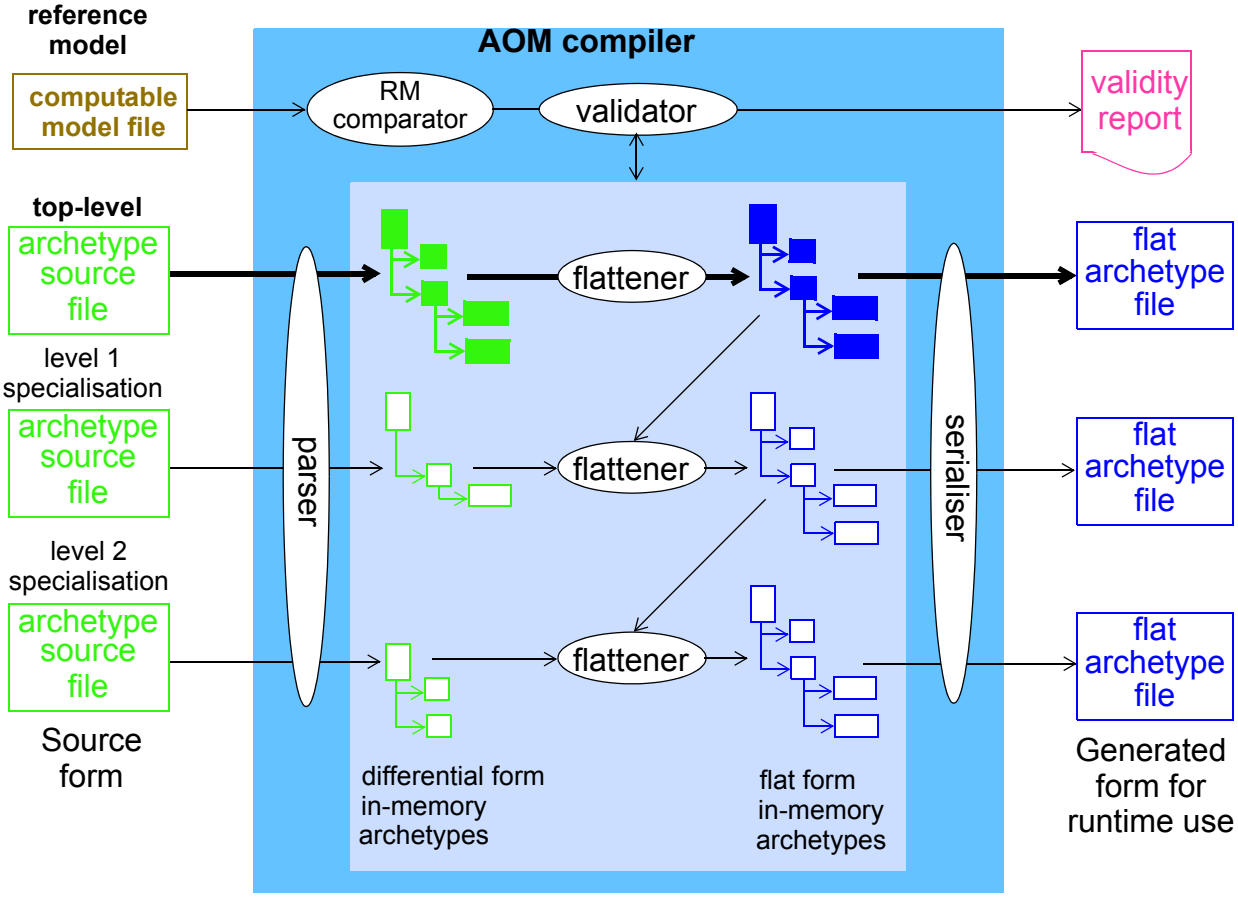


FIGURE 5 Computational model of archetype compilation

1. A dADL expression of the *open*EHR reference model is available for this purpose.

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

2.3.4 Optimisations

There is a subtlety in dealing with syntax and in-memory forms of archetypes and templates which becomes important in *open*EHR system design. Artefacts authored by whatever means, including by users with a tool (which may be as simple as a text editor), should always be considered 'suspect' until proven otherwise by reliable validation. This is true regardless of the original syntax - ADL, XML or something else. Once validated however, the flat form can be reserialised both in a format suitable for editor tools to use (ADL, XML, ...), and also in a format that can be regarded as a reliable pure object serialisation of the in-memory structure. The latter form is often XML-based, but can be any object representation form, such as JSON, the *open*EHR dADL syntax, a binary form, or a database structure. It will not be an abstract syntax form such as ADL, since there is an unavoidable semantic transformation required between the abstract syntax and object form.

The goal of this pure object serialisation is that it can be used as *persistence* of the validated artefact, to be converted to in-memory form using only generic object deserialisation, rather than the typical multi-pass compiler/validator that needs to be used for parsing an artefact of unreliable / unknown origin. This allows such validated artefacts to be used in both design environments and more importantly, runtime systems with no danger of compilation errors. It is the same principle used in creating .jar files from Java source code, and .Net assemblies from C# source code.

Within *open*EHR environments, managing the authoring and persisted forms of archetypes is achieved using various mechanisms including digital signing, which are described in the *open*EHR Distributed Development Model document.

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

3 Model Overview

The model described here is a pure object-oriented model that can be used with archetype parsers and software that manipulates archetypes and templates. It is independent of any particular serialised 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.

3.1 Package Structure

The *open*EHR Archetype Object Model is defined as the package `am.archetype`, as illustrated in FIGURE 6. It is shown in the context of the *open*EHR `am.archetype` packages.

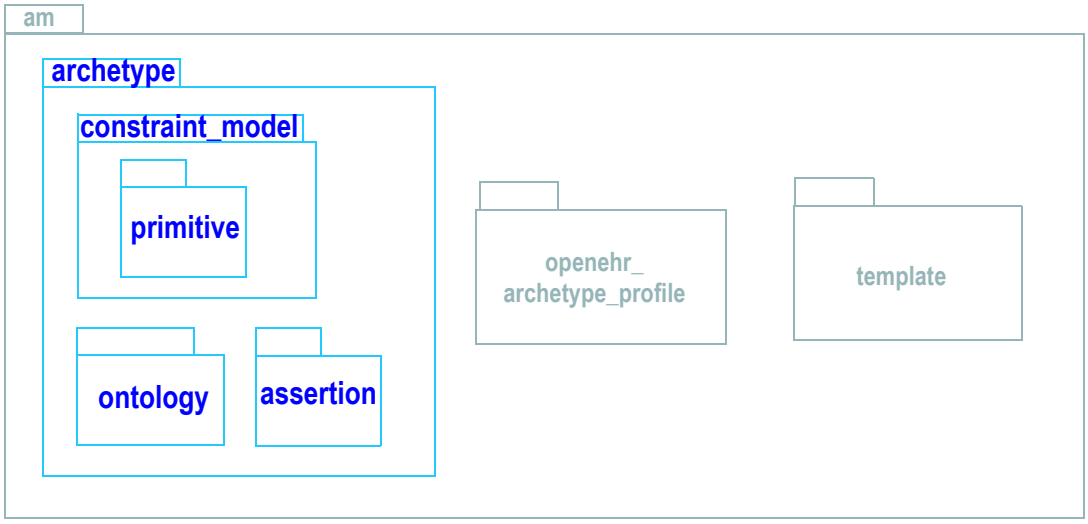


FIGURE 6 openehr.am.archetype Package

4 The Archetype Package

4.1 Overview

The model of archetypes and templates of all forms is illustrated in FIGURE 7. The structural representation is an object representation, deserialised from the *open*EHR ADL format, or one of its equivalent forms in another serialsation syntax. An ARCHETYPE instance is a modelled as a descendant of

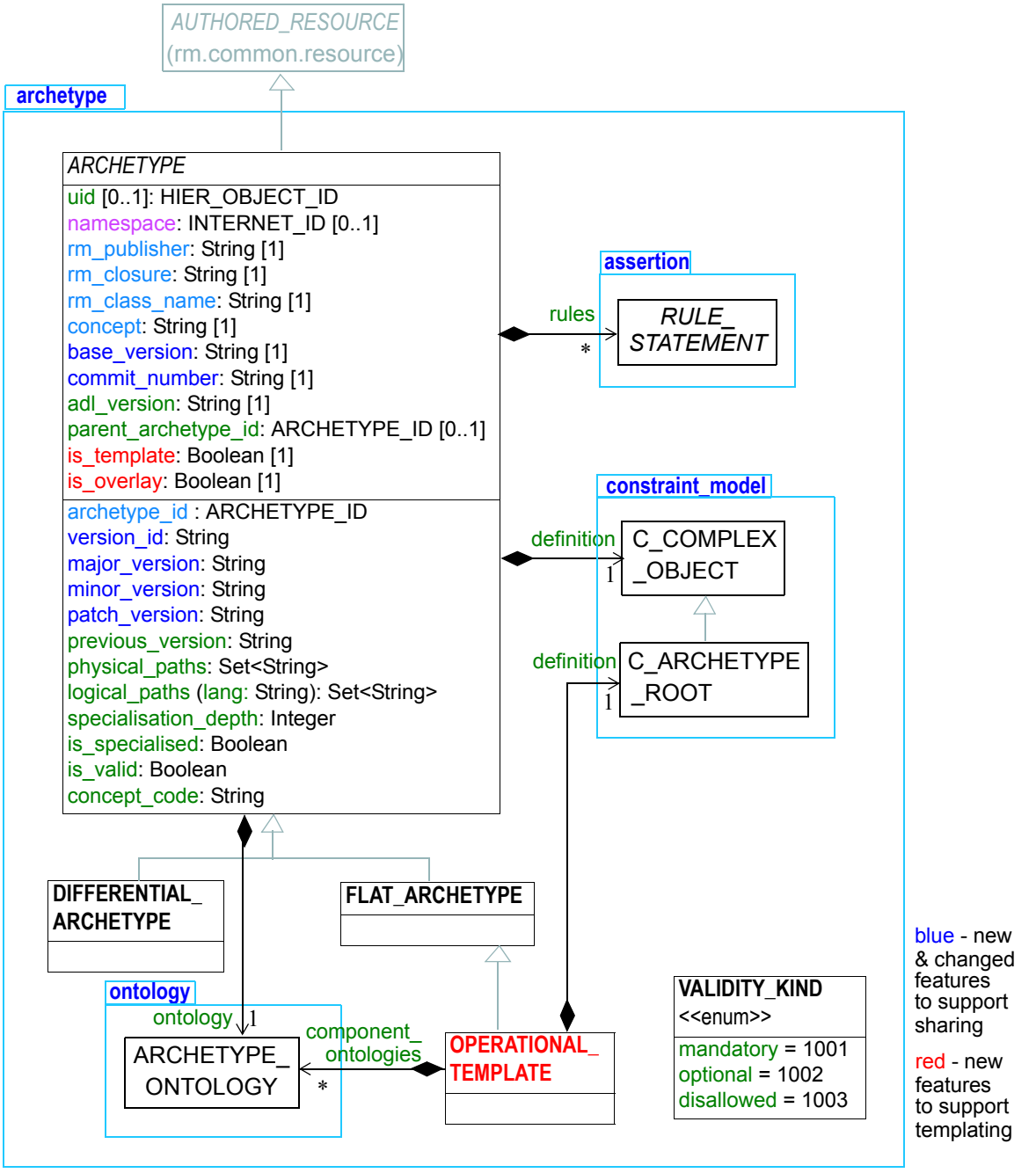


FIGURE 7 openehr.am.archetype Package

AUTHORED_RESOURCE, and accordingly includes descriptive meta-data, language information and revision history. The ARCHETYPE class adds a number of identifiying attributes and flags, a *definition*, optional *rules* part, and an *ontology*.

4.2 Design

4.2.1 Identification and other meta-data

In addition to the meta-data inherited from the AUTHORED_RESOURCE class, all archetype variants have a number of identifying and related meta-data properties defined by the ARCHETYPE class. The *archetype_id* attribute defines the mandatory multi-axial identifier of an archetype, while the optional *uid* attribute supports an ISO Oid or GUID style identifier. This will probably become mandatory in the future, in order to support lifecycle management properl.

The *adl_version* attribute in ADL 1.4 was used to indicate the ADL release used in the archetype-source file from which the AOM structure was created (the version number comes from the revision history of the *open*EHR ADL specification). In the current and future AOM and ADL specifications, the meaning of this attribute is generalised to mean 'the version of the archetype formalism' in which the current archetype is expressed. For reasons of convenience, the version number is still taken from the ADL specification, but now refers to all archetype-related specifications together, since they are always updated in a synchronised fashion.

4.2.2 Common Structural Parts

The archetype *definition* is the main definitional part of an archetype and is an instance of a C_COMPLEX_OBJECT or C_ARCHETYPE_ROOT. This means that the root of the constraint structure of an archetype always takes the form of a constraint on a non-primitive object type.

The *ontology* section of an archetype is represented by its own classes, and is what allows the archetypes to be natural language- and terminology-neutral.

In addition to this, an archetype may include one or more *rules*. Rules are statements expressed in a subset of predicate logic, which can be used to state constraints on multiple 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.

A utility class, VALIDITY_KIND is 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.

Lastly, *annotations* and *revision history* sections, inherited from the AUTHORED_RESOURCE class, can be included as required. The annotations section is of particular relevance to archetypes and templates, and is used to document individual nodes within an archetype or template, and/or nodes in reference model data, that may not be constrained in the archetype, but whose specific use in the archetyped data needs to be documented. In the former case, the annotations are keyed by an archetype path, while in the latter case, by a reference model path.

4.2.3 Structural Variants

The model in FIGURE 7 defines the structures of a number of variants of the 'archetype' idea. All concrete instances are instances of one of the concrete descendants of ARCHETYPE. FIGURE 8 illustrates the typical object structure of a *source archetype* - the form of archetype created by an authoring tool - represented by a DIFFERENTIAL_ARCHETYPE instance. Mandatory parts are shown in bold.

Source archetypes can be specialised, in which case their definition structure is a partial overlay on the flat parent, or 'top-level', in which case the definition structure is complete. C_ARCHETYPE_ROOT instances may only occur representing direct references to other archetypes - 'external references'.

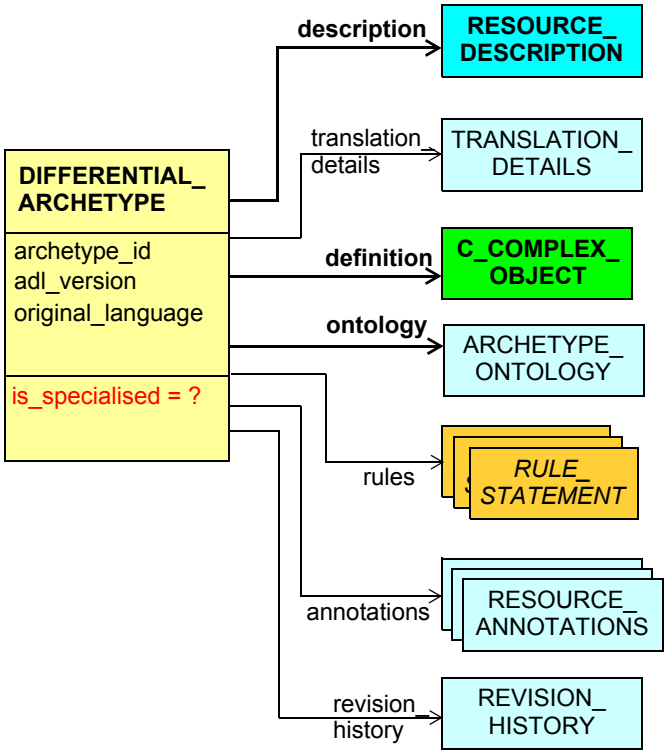


FIGURE 8 Source archetype instance structure

A *flat archetype* is generated from one or more source archetypes via the flattening process described in the next chapter of this specification, (also in the ADL specification). This generates a FLAT_ARCHETYPE from a DIFFERENTIAL_ARCHETYPE instance. The main two changes that occur in this operation are a) specialised archetype overlays are applied to the flat parent structure, resulting in a full archetype structure, and b) internal references (use_nodes) are replaced by their expanded form, i.e. a copy of the subtrees to which they point.

This form is used to represent the full 'operational' structure of a specialised archetype, and has two uses. The first is to generate backwards compatible ADL 1.4 legacy archetypes (always in flat form); the second is during the template flattening process, when the flat forms of all referenced archetypes and templates are ultimately combined into a single operational template.

For either immediate descendant of the ARCHETYPE class, if the property *is_template* = True, the structure is a template.

FIGURE 9 illustrates the structure of a *source template*, i.e instances of DIFFERENTIAL_ARCHETYPE class with *is_template* = True. A source template is an archetype containing C_ARCHETYPE_ROOT

objects representing slot fillers - each referring to an external archetype or template, or potentially an overlay archetype.

Another archetype variant, also shown in FIGURE 9 is the *template overlay*, i.e. DIFFERENTIAL_ARCHETYPE instances with *is_template, is_overlay* and *is_specialised* all set to True. These are purely local components of templates, and include only the *definition* and *ontology*. The definition structure is always a specialised overlay on something else, and may not contain any slot fillers or external references, i.e. no C_ARCHETYPE_ROOT objects. No identifier, *adl_version*, *languages* or *description* are required, as they are considered to be propagated from the owning root template. Accordingly, template overlays act like a simplified specialised archetype. Template overlays can be thought of as being similar to 'anonymous' or 'inner' classes in some object-oriented programming languages. (There is no technical reason why overlay *archetypes*, i.e. is_template = False, could not also exist, but as yet there seems no obvious practical use).

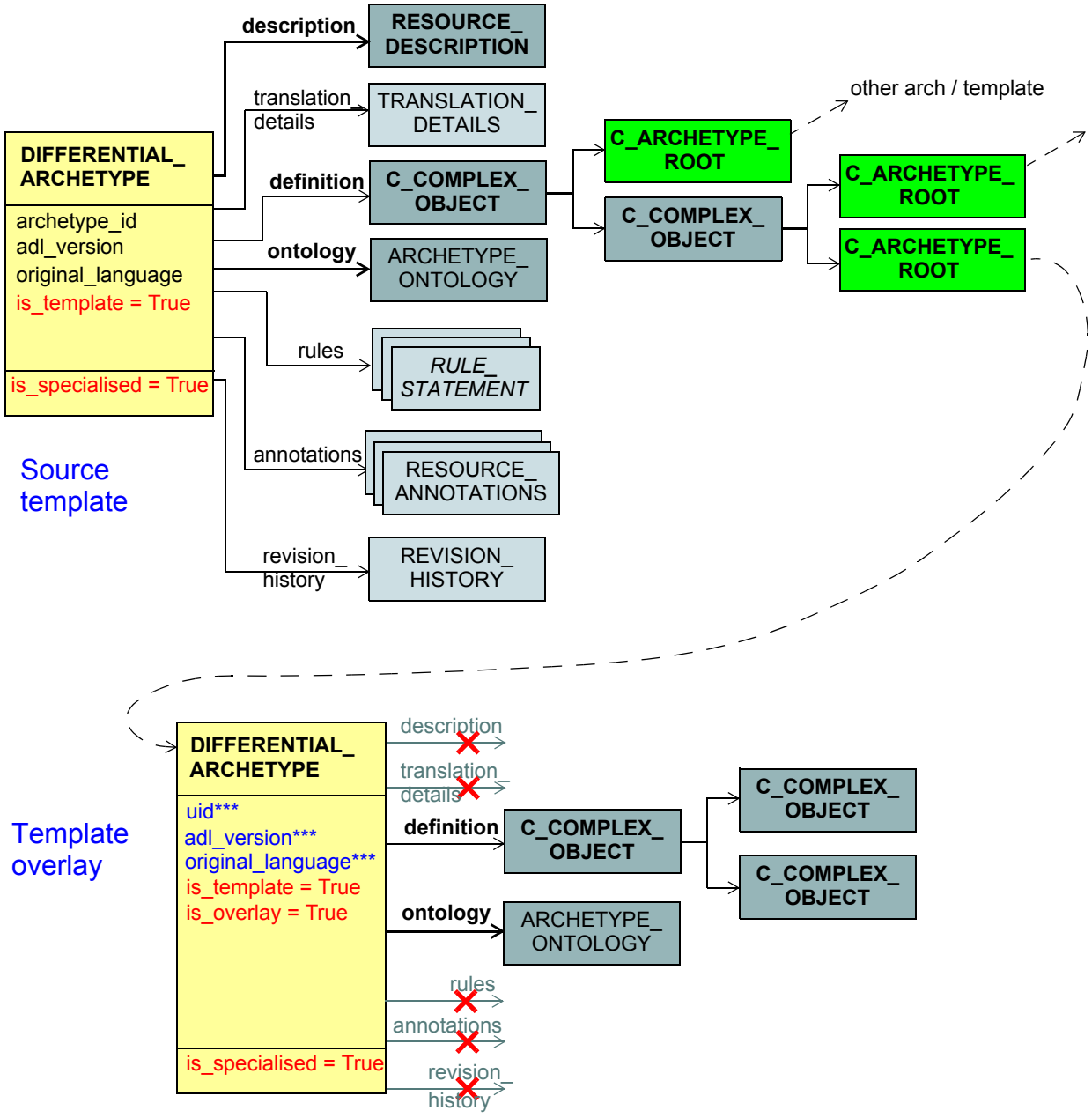


FIGURE 9 Source template instance structures

TBD_1: removal of the propagated parts has not been completely implemented yet

FIGURE 10 illustrates the resulting operational template, or compiled form of a template. This is created by building the composition of referenced archetypes and/or templates and/or template overlays, in their flattened form, to generate a single 'giant' archetype. The root node of this archetype, along

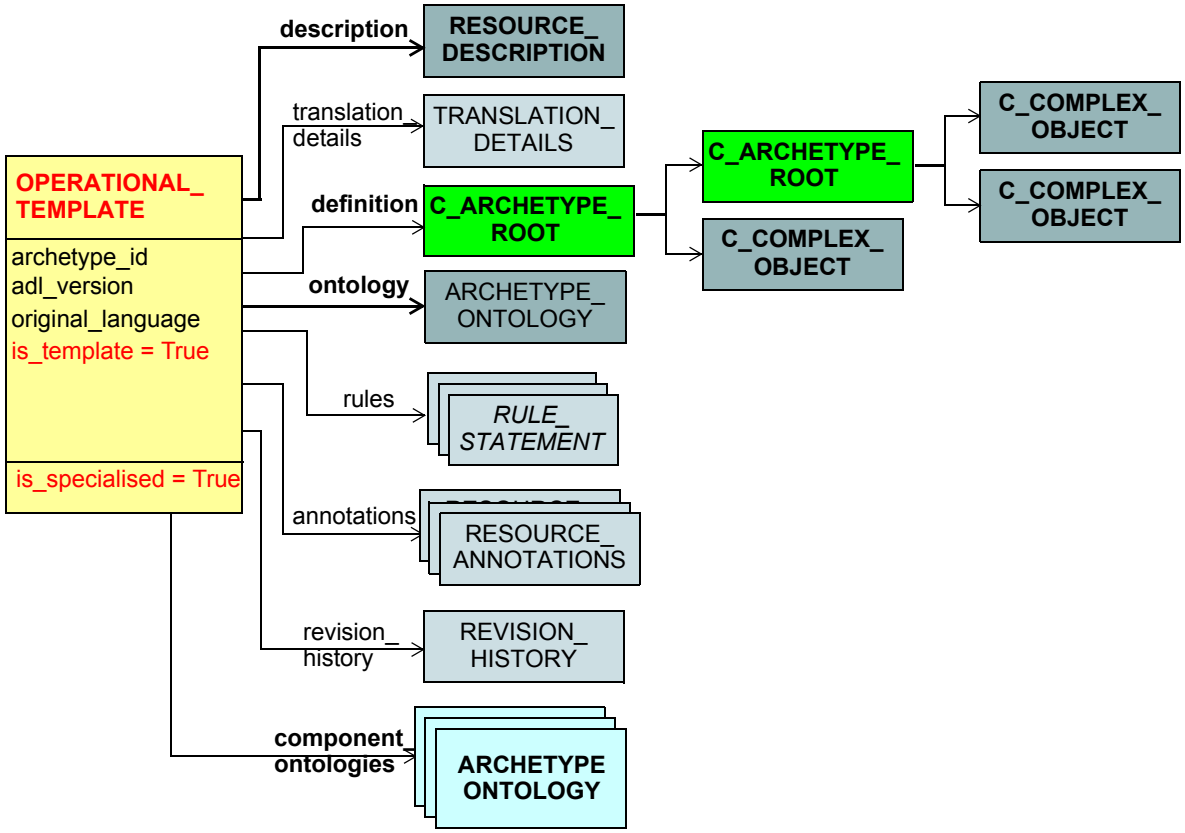


FIGURE 10 Operational template instance structure

with every archetype/template root node within, is represented using a `C_ARCHETYPE_ROOT` object. An operational template also has a *component_ontologies* property containing the ontologies from every constituent archetype, template and overlay.

More details of template development, representation and semantics are described in the next section.

4.3 Class Descriptions

4.3.1 ARCHETYPE Class

CLASS	*ARCHETYPE (abstract)*
Purpose	Root object of an archetype. Defines semantics of identfication, lifecycle, versioning, composition and specialisation.
Inherit	`AUTHORED_RESOURCE`

CLASS	*ARCHETYPE (abstract)*	
Attributes	**Signature**	**Meaning**
0..1	**adl_version**: `String`	ADL version if archteype was read in from an ADL shareable archetype.
0..1	**uid**: `HIER_OBJECT_ID`	OID identifier of this archetype.
0..1	**namespace**: `INTERNET_ID`	Reverse domain name namespace identifier.
1	**rm_publisher**: `String`	Name of the Reference Model publisher.
1	**rm_closure**: `String`	Name of the package in whose closure the *rm_class_name* class is found (there can be more than one possibility in a reference model).
1	**rm_class_name**: `String`	Name of the root class of this archetype.
1	**concept**: `String`	The short concept name of the archetype as used in the multi-axial *archetype_id*.
1	**base_version**: `String`	The full numeric version of this archetype consisting of 3 parts, e.g. 1.8.2. The *archetype_id* feature includes only the major version.
1	**commit_number**: `String`	Commit version of this archetype, extracted from *version*.
1	**is_template**: `Boolean`	Indicates the type of artefact, i.e. archetype, or template. If not present (e.g. in serialised forms), assumed to be False.
1	**is_overlay**: `Boolean`	Indicates the artefact to be an overlay of an archetype or template; if True, *is_specialised* must also be True.
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.
1	**is_valid**: `Boolean`	True if the archetype is valid overall.

CLASS	*ARCHETYPE (abstract)*	
Functions	**Signature**	**Meaning**
1	**archetype_id**: `ARCHETYPE_ID`	Multi-axial identifier of this archetype in archetype space, generated from *namespace_id*, *rm_class_id*, *concept_id* and *version_id*.
1	**concept_code**: `String` ***ensure*** Result.is_equal (definition.node_id)	The concept code of the root object of the archetype, also standing for the concept of the archetype as a whole.
1	**version_id**: `String`	Full version identifier string, based on *base_version* and *lifecycle*, e.g. 1.8.2-rc4.
1	**major_version**: `String`	Major version of this archetype, extracted from *base_version*.
1	**minor_version**: `String`	Minor version of this archetype, extracted from *base_version*.
1	**patch_version**: `String`	Patch version of this archetype, extracted from *base_version*. Equivalent to patch version in patch version in semver.org sytem.
0..1	**previous_version**: `String`	Version of predecessor archetype of this archetype, if any.
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.
1	**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.
	is_specialised: `Boolean` ***ensure*** *Result* **implies** parent_archetype_id /= Void	True if this archetype is a specialisation of another.
	specialisation_depth: `Integer` ***ensure*** *Result* = ontology.specialisation_depth	Specialisation depth of this archetype; larger than 0 if this archetype has a parent. Derived from the specialisation depth of *concept_code*.

CLASS	*ARCHETYPE (abstract)*
Invariant	-- invariants for all archetypes ***Uid_validity***: uid /= Void **implies not** uid.is_empty ***Version_validity***: major_version /= Void **and then** major_version.is_equal (archetype_id.version_id) ***Template_validity***: is_template **implies** is_specialised ***Overlay_validity***: is_overlay **implies** (is_specialised **and** is_template) ***Original_language_valid***: original_language /= void **and** language /= Void **and then** code_set (Code_set_id_languages).has_code (original_language) ***Concept_valid***: ontology.has_term_code (concept_code) ***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 -- template / overlay invariants ***Archetype_id_validity***: is_overlay **xor** archetype_id /= Void ***Template_uid_validity***: is_overlay **implies** uid /= Void ***Description_existence***: is_overlay **implies** description = Void ***Annotations_existence***: is_overlay **implies** annotations = Void ***Rules_existence***: is_overlay **implies** rules = Void

4.3.2 DIFFERENTIAL_ARCHETYPE Class

CLASS	DIFFERENTIAL_ARCHETYPE	
Purpose	Root object of the differential form of an archetype or template. Also called the 'source' form, as this is the form of an archetype created by an editor tool. For non-specialised archetypes, this is the almost same as the flat form (apart from the expansion of internal references in the flat form). For specialised archetypes, only the differences with respect to the parent are represented.	
Inherit	ARCHETYPE	
Attributes	**Signature**	**Meaning**
Invariant		

4.3.3 FLAT_ARCHETYPE Class

CLASS	FLAT_ARCHETYPE	
Purpose	Root object of the inheritance-flattened form of an archetype or template.	
Inherit	ARCHETYPE	
Attributes	**Signature**	**Meaning**

CLASS	FLAT_ARCHETYPE
Invariant	

4.3.4 OPERATIONAL_TEMPLATE Class

CLASS	OPERATIONAL_TEMPLATE	
Purpose	Root object of an operational template. An operational template is derived from a template definition and the archetypes mentioned by that template by a process of flattening, and potentially removal of unneeded languages and terminologies.	
Use	An operational template is used for generating and validating canonical openEHR data, and also as a source artefact for generating other downstream technical artefacts, including XML schemas, APIs and UI form definitions.	
Inherit	`FLAT_ARCHETYPE`	
Attributes	**Signature**	**Meaning**
1 (redefined)	**definition**: `C_ARCHETYPE_ROOT`	Root node is replaced with a `C_ARCHETYPE_ROOT`. This has the effect that every interior node inn the entire structure has a `C_ARCHETYPE_ROOT` above it.
1	**component_ontologies**: `Hash <FLAT_ARCHETYPE_ONTOLOGY, String>`	Compendium of flattened ontologies of any archetypes externally referenced from this archetype, keyed by archetype identifier. This will almost always be present in a template.
Functions	**Signature**	**Meaning**
	component_ontology (an_id: `String`): `FLAT_ARCHETYPE_ONTOLOGY`	Ontology for archetype or template component with identifier *an_id*.
Invariant	***Is_specialised***: is_specialised ***Is_template***: is_template ***Definition_existence***: definition /= Void ***Component_ontologies_existence***: component_ontologies /= Void	

4.3.5 VALIDITY_KIND Class

CLASS	VALIDITY_KIND
Purpose	An enumeration of three values which may commonly occur in constraint models.

CLASS	VALIDITY_KIND	
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	**mandatory**: `Integer = 1001`	Constant to indicate mandatory presence of something
1	**optional**: `Integer = 1002`	Constant to indicate optional presence of something
1	**disallowed**: `Integer = 1003`	Constant to indicate disallowed presence of something
Functions	**Signature**	**Meaning**
	valid_validity (n: `Integer`) : `Boolean` ***ensure*** n >= mandatory **and** n <= disallowed	Function to test validity values.
Invariant		

4.4 Validity Rules

The following validity rules apply to all varieties of `ARCHETYPE` object:

VARCN: archetype concept validity. The node_id of the root object of the archetype must be of the form at0000{.1}*, where the number of '.1' components equals the specalisation depth, and must be defined in the ontology.

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

VACDF: constraint code validity. Each constraint code ('ac' code) of a given specialisation level used in the archetype definition part must be defined in the constraint_definitions part of the ontology of the current archetype or of a specialisation parent, according to specialisation level.

VETDF: external term validity. Each external term used within the archetype definition must exist in the relevant terminology (subject to tool accesibility; codes for inaccessible terminologies should be flagged with a warning indicating that no verification was possible).

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

VOKU: object key unique. Within any keyed list in an archetype, including the desription, ontology, and annotations sections, each item must have a unique key with respect to its siblings.

VARDT: archetype definition typename validity. The typename mentioned in the outer block of the archetype definition section must match the type mentioned in the first segment of the archetype id.

VRANP: annotation path valid. Each path mentioned in an annotation within the annotations section must either be a valid archetype path, or a 'reference model' path, i.e. a path that is valid for the root class of the archetype.

VRRLP: rule path valid. Each path mentioned in a rule in the rules section must be found within the archetype, or be an RM-valid extension of a path found within the archetype.

The following validity rules apply to ARCHETYPE objects for which *is_overlay* = False:

VARID: archetype identifier validity. The archetype must have an identifier that conforms to the *open*EHR specification for archetype identifiers.

VDEOL: original language specified. An original_language section containing the meta-data of the original authoring language must exist.

VARD: description specified. A description section containing the main meta-data of the archetype must exist.

The following rules apply to specialised archetypes.

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

VALC: archetype language conformance. The languages defined in a specialised archetype must be the same as or a subset of those defined in the flat parent.

VACSD: archetype concept specialisation depth. The specialisation depth of the concept code must be one greater than the specialisation depth of the parent archetype.

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.

5 Constraint Model Package

5.1 Overview

FIGURE 11 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.
- `C_ARCHETYPE_ROOT`: stands for the root node of an archetype; enables another archetype to be referenced from the present one. Used in both archetypes and templates.

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.

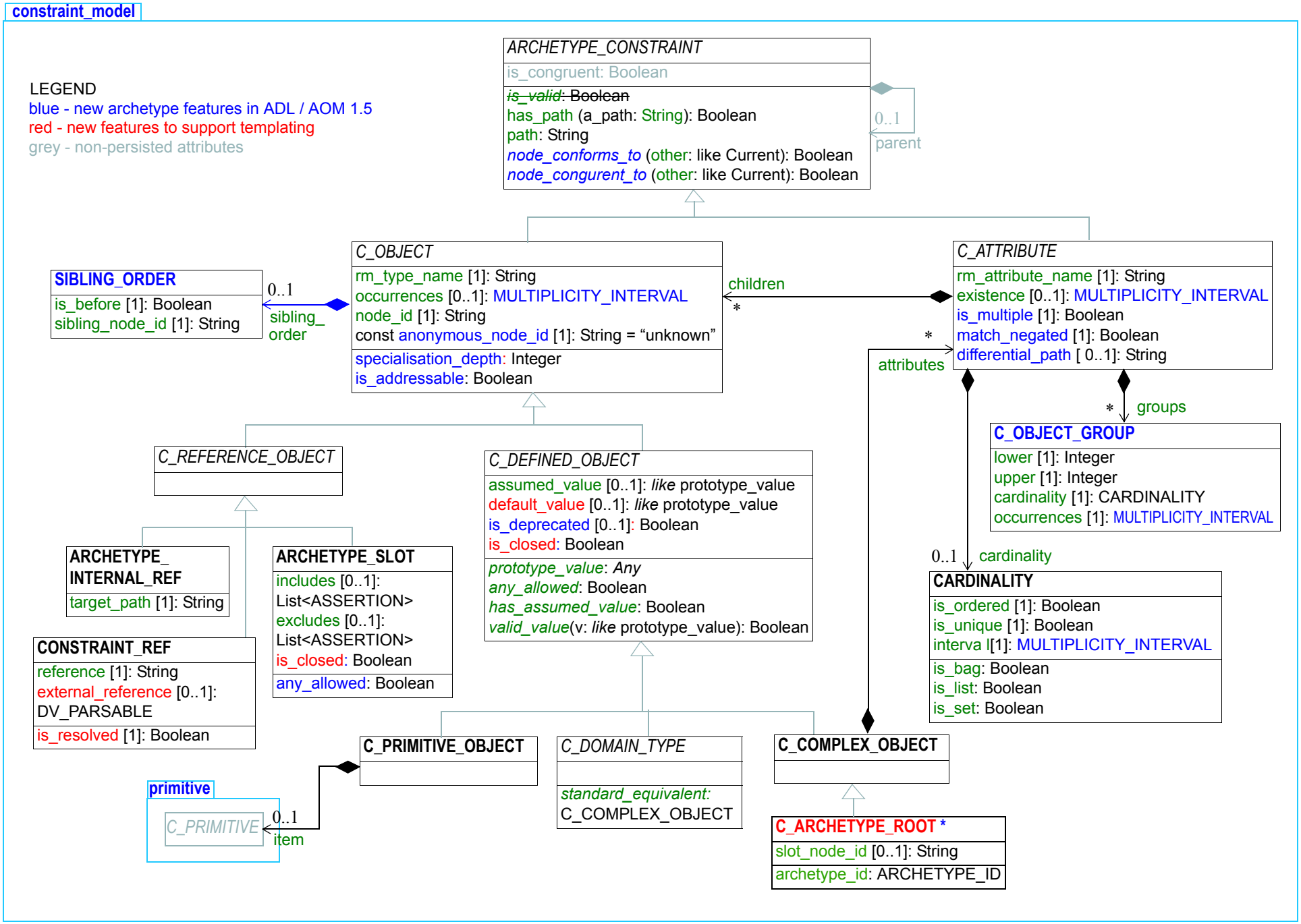


FIGURE 11 openehr.am.archetype.constraint_model Package

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

5.2 Semantics

The effect of the model is to create archetype description structures that are a hierarchical alternation of object and attribute constraints. 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 directly convertible in and out of the W3C Xpath syntax.

5.2.1 All Node Types

Path Functions

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.

Conformance Functions

All node types include two functions that formalise the notion of *conformance* of a specialised archetype to a parent archetype. Both functions take an argument which must be a corresponding node in a parent archetype, not necessarily the immediate parent. A 'corresponding' node is one found at the same or a *congruent* path. A congruent path is one in which one or more at-codes have been redefined in the specialised archetype. FIGURE 12 illustrates the classes implementing these functions.

The *node_conforms_to* function returns True if the node on which it is called is a valid specialisation of the 'other' node. The *node_congruent_to* function returns True if the node on which it is called is the same as the other node, with the possible exception of a redefined at-code. The latter may happen due to the need to restrict the domain meaning of node to a meaning narrower than that of the same node in the parent. The formal semantics of both functions are given in the section Class Definitions on page 37.

5.2.2 Attribute Node Types

Constraints on reference model *attributes*, including computed attributes (represented by functions with no aguments in most programming languages), are represented by instances of C_ATTRIBUTE. The expressible constraints include:

- *is_multiple*: a flag that indicates whether the C_ATTRIBUTE is constraining a multiply-valued (i.e. container) RM attribute or a single-valued one;
- *existence*: whether the corresponding instance (defined by the *rm_attribute_name* attribute) must exist;
- *child objects*: representing allowable values of the object value(s) of the attribute.

In the case of single-valued attributes (such as Person.*date_of_birth*) the children represent one or more *alternative* object constraints for the attribute value.

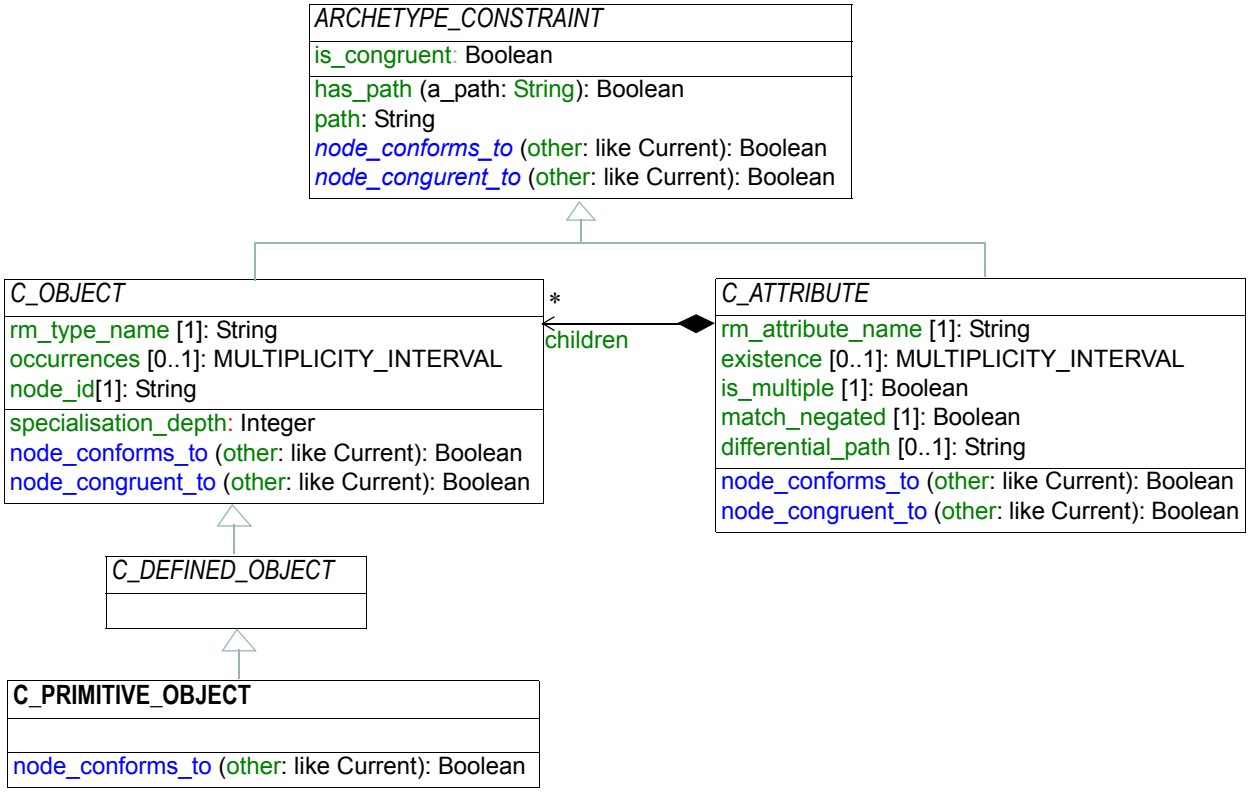
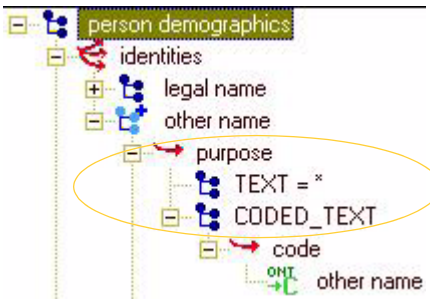


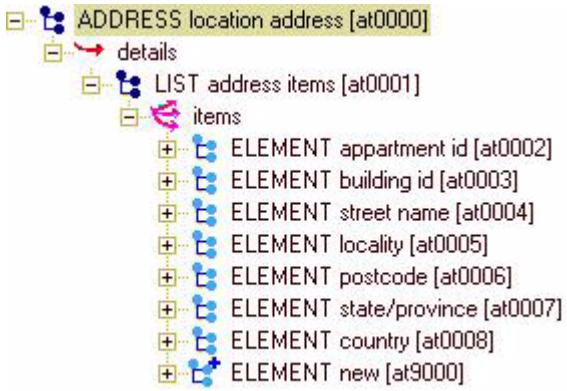
FIGURE 12 Node conformance/congruence functions

For multiply-valued attributes (such as `Person`.*contacts*: `List<Contact>`), a *cardinality* constraint on the container can be defined. The constraint on child objects is essentially the same except that more than one of the alternatives can co-exist in the data. FIGURE 13 illustrates the two possibilities.

The appearance of both *existence* and *cardinality* constraints in `C_ATTRIBUTE` deserves some explanation, especially as the meanings of these notions are often confused in object-oriented literature. An



C_ATTRIBUTE - is_multiple = False showing *alternative* child objects (PERSON.address as structured or free text form)



C_ATTRIBUTE - is_multiple = True showing a collection of possible child objects

FIGURE 13 Single and Multiple-valued C_ATTRIBUTEs

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 possible. 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. Both existence and cardinality are optional in the model, since they are only needed to override the settings from the reference model.

5.2.3 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:

- 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_ATTRIBUTE` for which the cardinality is ordered.

5.2.3.1 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 containing a data point for 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 is 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_value* 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 formally definable at any hierarchical level, but are expected to be practically useful at leaf and near-leaf level only. Accordingly, the features *assumed_value* and *has_assumed_value* appear in C_DEFINED_OBJECT. In most cases, it would be expected that assumed values are stated only in C_COMPLEX_OBJECTs corresponding to low-level reference model concepts (such as the *open*EHR DV_ types), descendants of C_PRIMITIVE and descendants of C_DOMAIN_TYPE.

Note that the notion of assumed values is distinct from that of 'default values'. The latter notion is that of a default 'pre-filled' value that is provided (normally in a local context by a template) for a data item that is to be filled in by the user, but which is typically the same in many cases. Default values are thus simply an efficiency mechanism for users. As a result, 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.

Prototype_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.

Default_value

This attribute allows a user-specified default value to be defined within an archetype. The *default_value* object must be of the same type as defined by the *prototype_value* function, pass the *valid_value* test. Where defined, the *prototype_value* function would return this value instead of a synthesised value.

Node Deprecation

It is possible to mark an instance of any defined node type as deprecated, meaning that by preference it should not be used, and that there is an alternative solution for recording the same information. Rules or recommendations for how deprecation should be handled are outside the scope of the archetype proper, and should be provided by the governance framework under which the archetype is managed.

Node Closing

A node may be redefined into multiple child nodes in a specialised archetype. If the children are considered to exhaustively define the value space corresponding to the original node, the latter may be 'closed', meaning no further children can be defined. This also has a runtime implication: a closed node cannot have any instances, only its children can.

5.2.3.2 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.

5.2.3.3 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.

5.2.3.4 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 logical '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 86.

5.2.3.5 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.

5.2.4 Grouping constructs

Within a container attribute, it is not uncommon to need to define and constrain sub-groups within the overall list of objects in the container. Two types of constraint are needed:

- to control the total number of elements allowed in the group at runtime, from the total defined;
- to control the number of times the group repeats.

The first constraint is achieved by defining a cardinality of the group. A cardinality of '*' means that in the data, the group may contain any number of objects, each conforming to one of the object types defined within that group in the archetype. A cardinality of '1' specifies a 'choice' of 1 of N items in the group.

Control of repetition of the group as a whole is achieved with an occurrences constraint on the group, indicating the number of times the group can repeat within the data.

FIGURE 14 illustrates the group constraint part of the `constraint_model` package. A grouping constraint is represented as a `C_OBJECT_GROUP` instance attached to a `C_ATTRIBUTE`. The primary representation of the group is as two integer indices into the `C_ATTRIBUTE`.*children* list. The children actually referenced are computed by the functions *lower_child* and *upper_child*.

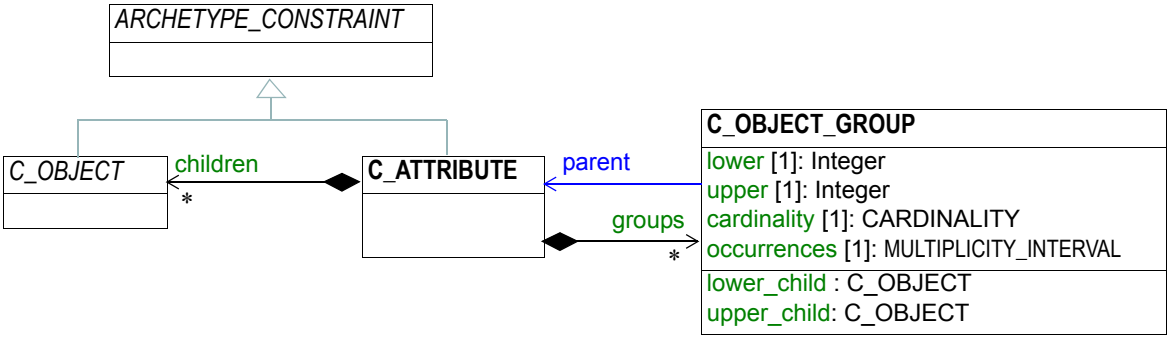


FIGURE 14 Group constraint

The integer range representation is used because it allows the validity conditions on `C_ATTRIBUTE` for groups to be easily stated. If there are multiple groups for a given container, all have to obey invariants that state either mutual exclusion or proper containment, i.e. overlapping is not possible.

5.2.5 Assertions

Assertions are also used in `ARCHETYPE_SLOT`s, 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.

5.3 Class Definitions

5.3.1 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**
	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.
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	

5.3.2 C_ATTRIBUTE Class

CLASS	C_ATTRIBUTE	
Purpose	The model of a constraint on a reference model attribute (including computed attributes).	
Inherit	ARCHETYPE_CONSTRAINT	
Attributes	**Signature**	**Meaning**
1	**rm_attribute_name**: String	Reference model attribute within the enclosing type represented by a C_OBJECT.
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.
0..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). Only set if it overrides the underlying reference model or parent archetype in the case of specialised archteypes.
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.
0..1	**cardinality**: CARDINALITY	Cardinality of this attribute constraint, if it constraints a container attribute.
0..1	**groups**: List<C_OBJECT_GROUP>	Group constraints applying to the children of this attribute.
Functions	**Signature**	**Meaning**
	rm_attribute_path: String	Path of this attribute with respect to owning C_OBJECT, including differential path where applicable.

CLASS	C_ATTRIBUTE	
(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` ***require*** other /= Void	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` ***require*** other /= Void	True if this node on its own (ignoring any subparts) expresses the same constraints as *other*.
	existence_conforms_to (other: **like Current**): `Boolean` ***require*** other /= Void	True if the existence of this node conforms to existence of node *other*; returns True if the existence of this attribute is Void.
	cardinality_conforms_to (other: **like Current**): `Boolean` ***require*** other /= Void	True if the cardinality of this node conforms to cardinality of node *other*, returns True if the cardinality of this attribute is Void.
	has_differential_path: `Boolean`	True if differential_path is not Void..
	occurrences_lower_sum: `INTEGER`	Sum of lower bounds of occurrences of all child objects.
	minimum_child_count: `INTEGER`	Notional minimum number of possible children, counting 1 for each mandatory child and 1 further child to cover all optional children.
	groups_valid: `Boolean`	True if *groups* is valid.

CLASS	C_ATTRIBUTE
Invariant	***Rm_attribute_name_valid***: rm_attribute_name /= Void **and then not** rm_attribute_name.is_empty ***Existence_valid***: existence /= Void **implies** (existence.lower >= 0 **and** existence.upper <= 1) ***Children_validity***: any_allowed **xor** children /= Void ***Cardinality_valid***: cardinality /= Void **implies** is_multiple ***Children_occurrences_lower_sum_validity***: (cardinality /= Void **and then not** cardinality.interval.upper_unbounded) **implies** occurrences_lower_sum <= cardinality.interval.upper ***Children_orphans_validity***: (cardinality /= Void **and then not** cardinality.interval.upper_unbounded) **implies** minimum_child_count <= cardinality.interval.upper ***Differential_path_valid***: differential_path /= Void **implies not** differential_path.is_empty ***Has_differential_path_valid***: differential_path = Void **xor** has_differential_path ***Alternatives_valid***: not is_multiple **implies** children.for_all (co: C_OBJECT | co.occurrences.upper <= 1) ***Groups_valid***: groups /= Void **implies** is_multiple ***Child_occurrences_validity***: cardinality /= Void **implies** cardinality.interval.intersects (occurrences_total_range)

5.3.2.1 Conformance Semantics

The following functions formally define the conformance of an attribute node in a specialised archetype to the corresponding node in a parent archetype, where 'corresponding' means a node found at the same or a congruent path.

```
node_conforms_to (other: like Current): Boolean
    require
       other /= Void
    do
       Result := existence_conforms_to (other) and
          ((is_single and other.is_single) or
          (is_multiple and cardinality_conforms_to (other)))
    end

node_congruent_to (other: like Current): Boolean
    require
       other /= Void
    do
       Result := node_conforms_to(other)
    end

existence_conforms_to (other: like Current): Boolean
    require
       other_exists: other /= Void
       other_is_flat: other.existence /= Void
    do
       Result := existence = Void or
                existence.is_equal (other.existence) or
                other.existence.contains (existence)
    end
```

```
cardinality_conforms_to (other: like Current): Boolean
    require
       other_exists: other /= Void
    do
       Result := cardinality = Void or else -- Current is flat
             other.cardinality = Void or else -- other is flat
             other.cardinality.contains (cardinality)
    end
```

5.3.2.2 Validity Rules

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 (stored or computed) of the type which introduces the enclosing object block.

VCAEX: archetype attribute reference model existence conformance: the existence of an attribute, if set, 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.

VDIFV: archetype attribute differential path validity: an archetype may only have a differential path if it is specialised..

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

VDIFP: specialised archetype attribute differential path validity: if an attribute constraint has a differential path, the path must exist in the flat parent, and also be valid with respect to the reference model, i.e. in the sense that it corresponds to a legal potential construction of objects.

VSANCE: specialised archetype attribute node existence conformance: the existence of a redefined attribute node in a specialised archetype, if stated, 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.

The following validity rules apply to single-valued attributes, i.e when `C_ATTRIBUTE`.*is_multiple* is False:

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.

The following validity rules apply to container attributes, i.e when C_ATTRIBUTE.*is_multiple* is True:

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.

VACMCU: cardinality/occurrences upper bound validity: where a cardinality with a finite upper bound is stated on an attribute, for all immediate child objects for which an occurrences constraint is stated, the occurrences must either have an open upper bound (i.e. n..*) which is interpreted as the maximum value allowed within the cardinality, or else a finite upper bound which is <= the cardinality upper bound.

VACMCL: cardinality/occurrences lower bound validity: where a cardinality with a finite upper bound is stated on an attribute, for all immediate child objects for which an occurrences constraint is stated, the sum of occurrences lower bounds must be lower than the cardinality upper limit.

VACMCO: cardinality/occurrences orphans: it must be possible for at least one instance of one optional child object (i.e. an object for which the occurrences lower bound is 0) and one instance of every mandatory child object (i.e. object constraints for which the occurrences lower bound is >= 1) to be included within the cardinality range.

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, if stated, 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.

5.3.2.3 Groups validity algorithm

The following pseudo-code expresses the validity of the *groups* attribute, where it is non-Void:

```
    groups.for_all ( TBC )
To Be Determined:
```

5.3.3 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 on which this cardinality is defined are ordered.
1	**is_unique**: `Boolean`	True if the members of the container attribute on which this cardinality is defined 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	

5.3.4 C_OBJECT Class

CLASS	*C_OBJECT (abstract)*	
Purpose	Abstract model of constraint on any kind of object node.	
Inherit	`ARCHETYPE_CONSTRAINT`	
Attributes	**Signature**	**Meaning**
1	**rm_type_name**: `String`	Reference model type that this node corresponds to.

CLASS	C_OBJECT (abstract)	
0..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). Only set if it overrides the parent archetype in the case of specialised archteypes, or else the occurrences inferred from the underlying reference model existence and/or cardinality of the containing attribute.
1	**node_id**: String	Semantic identifier of this node, used to distinguish sibling nodes of the same type. [Previously called 'meaning']. Each *node_id* must be defined in the archetype ontology as a term code, or else have the special Anonymous_node_id value.
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_ATTRIBUTE with *is_multiple* = True.
Functions	**Signature**	**Meaning**
	is_addressable: Boolean ***ensure*** Result = not node_id.starts_with (Anonymous_node_id)	True if this node is addressable via an at-code. Non-addressable nodes have *node_id* set to the Anonymous_node_id.
(effected)	**node_conforms_to** (other: ***like* Current**): Boolean ***require*** other /= Void	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.
(effected)	**node_congruent_to** (other: ***like* Current**): Boolean ***require*** other /= Void	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.

CLASS	C_OBJECT (abstract)	
	rm_type_conforms_to (other: ***like* Current**): `Boolean` ***require*** other /= Void	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	True if this node occurrences conforms to other.occurrences. returns True if occurrences of this object is Void.
	node_id_conforms_to (other: ***like* Current**): `Boolean` ***require*** other /= Void	True if this node id conforms to other.node_id.
	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** parent /= Void **and** parent.is_single) **implies** occurrences.upper <= 1 ***Sibling_order_validity***: sibling_order /= Void **implies** specialisation_depth > 0 and parent.is_multiple	

5.3.4.1 Occurrences inferencing rules

The notion of 'occurrences' does not exist in an object model that might be used as the reference model on which archteypes are based, because it is a class model. However, archetypes make statements about how many objects conforming to a specific object constraint node might exist, within a container attribute. In an operational template, an occurrences constraint is required on all children of container attributes. Most such constraints come from the source template(s) and archetypes, but in some cases, there will be nodes with no occurrences. In these cases, the occurrences constraint is inferred from the reference model according to the following algorithm, where `c_object` represents any object node in an archetype.

```
if not c_object.is_root and
    c_object.occurrences = Void and
    is_container_attribute(c_object.parent)
then
    if parent_attr.cardinality.upper_unbounded then
       c_object.set_occurrences ({0..*})
```

```
        else
            c_object.set_occurrences ({0, parent_attr.cardinality.upper})
        end
    end
```

Occurrences is not required on children of single-valued attributes, because the notional occurrences is always the same as the existence constraint of the owning attribute in the flat parent structure, or else the reference model.

5.3.4.2 Conformance and congruence semantics

The following functions formally define the conformance of an object node in a specialised archetype to the corresponding node in a parent archetype, where 'corresponding' means a node found at the same or a congruent path.

```
node_conforms_to (other: like Current): Boolean
    require
        other /= Void
    do
        if is_addressable and other.is_addressable then
            if node_id.is_equal (other.node_id) then
                Result := rm_type_name.is_equal (other.rm_type_name) and
                        occurrences.is_equal(other.occurrences) -- maybe just
conforms
            else
                Result := (rm_type_conforms_to(other) and
                        occurrences_conforms_to (other) and
                        node_id_conforms_to (other))
            end
        elseif not is_addressable and not other.is_addressable then
            Result := rm_type_conforms_to(other) and
                    occurrences_conforms_to (other)
        end
    end

node_congruent_to (other: like Current): Boolean
        -- True if this node makes no changes to 'other' (from a
        -- specialisation parent archetype) apart from possible
        -- change of node-id
    require
        other /= Void
    do
        Result := rm_type_name.is_equal (other.rm_type_name) and
                occurrences.is_equal (other.occurrences) and
                node_id_conforms_to (other)
    end

rm_type_conforms_to (other: like Current): Boolean
    require
        other /= Void
    do
        Result := rm_type_name.is_equal (other.rm_type_name) or
              rm_checker.is_sub_type_of (rm_type_name, other.rm_type_name)
    end

occurrences_conforms_to (other: like Current): Boolean
    require
        other_exists: other /= Void
        other_is_flat: other.occurrences /= Void
```

```
        do
            Result := occurrences = Void or
                  occurrences.is_equal (other.occurrences) or
                  other.occurrences.contains (occurrences)
        end

    node_id_conforms_to (other: like Current): Boolean
        require
            other_exists: other /= Void
        do
            Result := node_id.starts_with (other.node_id)
        end
```

5.3.4.3 Validity Rules

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.

VCOCD: object constraint definition validity: an object constraint block consists of one of the following (depending on subtype): an 'any' constraint; a reference; an inline definition of sub-constraints, or nothing, in the case where occurrences is set to {0}.

The following validity rules govern C_OBJECTs in specialised archetypes.

VSONT: specialised archetype object node meta-type conformance: the meta-type of a redefined object node (i.e. the AOM node type such as C_COMPLEX_OBJECT etc) in a specialised archetype must be the same as that of the corresponding node in the flat parent, with the exceptions of the ARCHETYPE_INTERNAL_REF, CONSTRAINT_REF and C_ARCHETYPE_ROOT meta-types (see validity rules VSUNT and VSCNR).

VSONCT: specialised archetype object node reference 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.

VSONI: specialised archetype object node correspondence: if an object node in a specialised archetype is a specialisation of a node in the flat parent, it must carry a node identifier specalised at the level of the child archetype if the corresponding node in the parent carries an identifier, and may not, if the corresponding node in the parent does not.

VSONIN: specialised archetype new object node identifier: if an object node in a specialised archetype is a new node with respect to the flat parent, and it carries a node identifier, the identifier must be a 'new' node identifier, specalised at the level of the child archetype.

VSONIR: specialised archetype object node redefinition: if it exists, the node identifier of an object node in a specialised archetype that is a redefinition of a node in the flat parent must be redefined into its specialised form if either reference model type or occurrences of the immediate object constraint is redefined, with the exception of occurrences being redefined to {0}, i.e. exclusion.

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.

: specialised archetype object node occurrences conformance: the occurrences of a redefined object node in a specialised archetype, if stated, 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 order validity: the sibling order node id 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.

5.3.5 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	

5.3.6 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

CLASS	C_DEFINED_OBJECT (abstract)	
	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 descendants.
Attributes	**Signature**	**Meaning**
0..1	**assumed_value:** ***like*** prototype_value	Value to be assumed if none sent in data
0..1	**default_value**: ***like*** prototype_value	Default value set in a template, and present in an operational template. Generally limited to leaf and near-leaf nodes.
0..1	**is_deprecated**: Boolean	True if this node and by implication all sub-nodes are deprecated for use. .
0..1	**is_closed**: Boolean	True if this node is closed for further redefinition. Any child nodes defined as siblings are considered to exhaustively represent the possible value space of this original parent node.
Functions	**Signature**	**Meaning**
	has_assumed_value: Boolean	True if there is an assumed value
	has_default_value: Boolean	True if there is a default value
Invariant	***Assumed_value_valid***: has_assumed_value **implies** assumed_value.conforms_to_type (rm_type_name) **and** valid_value (assumed_value) ***Default_value_valid***: has_default_value **implies** default_value.conforms_to_type (rm_type_name) **and** valid_value (default_value)	

5.3.6.1 Validity Rules

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.

5.3.7 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***: attributes /= Void	

5.3.7.1 Validity Rules

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.

5.3.8 C_ARCHETYPE_ROOT Class

CLASS	C_ARCHETYPE_ROOT
Purpose	A specialisation of C_COMPLEX_OBJECT whose *node_id* attribute is an archetype identifier rather than the normal internal node code (i.e. at-code).

CLASS	C_ARCHETYPE_ROOT	
Use	Used in two situations. The first is to represent an 'external reference' to an archetype from within another archetype or template. This supports re-use. The second use is within a template, where it is used as a slot-filler. In this situation, the *node_id* is set to the id of the slot being filled from the parent archetype or template (i.e. an at-code), allowing node matching to occur during flattening. In both uses within source archetypes and templates, the *children* attribute is Void. During flattening, the *node_id* is set to the *archetype_id*, via a call to *convert_to_flat*. This call also sets the *slot_node_id* attribute to remember the *node_id* of the slot being filled. When used in a source archetype the *children* attribute is Void; when used in a source template, any attribute sub-structure is an 'overlay' of the same form as a specialised archetype. In an operational template, the structure contains the result of flattening any template overlay structure and the underlying flat archetype. The only formal difference from a normal `C_COMPLEX_OBJECT` is that the *node_id* attribute is an archetype or template identifier rather than an archetype-internal node code.	
Inherit	`C_COMPLEX_OBJECT`	
Attributes	**Signature**	**Meaning**
0..1	**slot_node_id**: `String`	Node identifier of slot, if this archetype is being used to fill a slot.
1	**archetype_id**: `String`	Identifier of the archetype which this `C_ARCHETYPE_ROOT` specifies as a filler.
Functions	**Signature**	**Meaning**
	is_flat_form: `Boolean`	True if *convert_to_flat* has been called.
Procedures	**Signature**	**Meaning**
	convert_to_flat ***ensure*** is_flat_form	Convert this node to flat form, by replacing its *node_id* with the archetype id, and recording the *node_id* (which is the id of the slot in the parent archetype) in *slot_node_id*.
Invariant	***Node_id_validity***: is_flat_form **implies** archetype_ref.valid_id(node_id) ***Slot_node_id_validity***: slot_node_id /= Void **implies not** slot_node_id.is_empty	

5.3.8.1 Validity Rules

The following validity rules apply to `C_ARCHETYPE_ROOT` objects:

VARXS: external reference conforms to slot: the archetype identifier of the reference object must conform to the archetype slot constraint of the flat parent and be of a reference model type from the same reference model as the current archetype.

VARXNC: external reference node identifier validity: if the reference object corresponds to a slot in the parent archetype, the slot_node_id must carry the node_id of the corresponding ARCHETYPE_SLOT; if there is no slot, the path of the node must exist in the flat parent.

VARXTV: external reference type validity: the reference model type of the reference object archetype identifier must be identical, or conform to the type of the slot, if there is one, in the parent archetype, or else to the reference model type of the attribute in the flat parent under which the reference object appears in the child archetype.

VARXR: external reference refers to resolvable artefact: the archetype identifier of the reference object must refer to an artefact that can be found in the current repository.

5.3.9 C_PRIMITIVE_OBJECT Class

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

5.3.10 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`

CLASS	*C_DOMAIN_TYPE (abstract)*	
Abstract	**Signature**	**Meaning**
	standard_equivalent: C_COMPLEX_OBJECT	Standard (i.e. C_OBJECT) form of constraint.
Invariant		

5.3.10.1 Validity Rules

The validity rules for C_DOMAIN_TYPEs are as follows:

VSDTV: domain type conformance. In a specialised archetype, an object constraint that is a descendant of C_DOMAIN_TYPE and redefines an object node in the parent must conform to that object node, which must also be a descendant of C_DOMAIN_TYPE.

5.3.11 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		

5.3.12 ARCHETYPE_SLOT Class

CLASS	ARCHETYPE_SLOT	
Purpose	Constraint describing a ‘slot’ point at which one or more other archetypes matching the slot constraint can be included.	
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.

CLASS	ARCHETYPE_SLOT	
1	**is_closed**: Boolean	True if this slot specification in this artefact is closed to further filling either in further specialisations or at runtime. Default value False, i.e. unless explicitly set, a slot remains open.
Functions	**Signature**	**Meaning**
	any_allowed: Boolean ***ensure*** **Result = not** (has_includes **or has_excludes) and not** is_closed	True if no constraints stated, and slot is not closed.
Invariant	***includes_valid***: includes /= Void **implies not** includes.is_empty ***excludes_valid***: excludes /= Void **implies not** excludes.is_empty	

5.3.12.1 Validity Rules

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.

VDSIV: archetype slot 'include' constraint validity. The 'include' constraint in an archetype slot must conform to the slot constraint validity rules.

VDSEV: archetype slot 'exclude' constraint validity. The 'exclude' constraint in an archetype slot must conform to the slot constraint validity rules.

The slot constraint validity rules are as follows:

```
if includes not empty and = 'any' then
    not (excludes empty or /= 'any') ==> VDSEV Error
elseif includes not empty and /= 'any' then
    not (excludes empty or = 'any') ==> VDSEV Error
elseif excludes not empty and = 'any' then
    not (includes empty or /= 'any') ==> VDSIV Error
elseif excludes not empty and /= 'any' then
    not (includes empty or = 'any') ==> VDSIV Error
end
```

The following validity rules apply to ARCHETYPE_SLOTs defined as the specialisation of a slot in a parent archetype:

VDSSM: specialised archetype slot definition match validity. The set of archetypes matched from a library of archetypes by a specialised archetype slot definition must be a proper subset of the set matched from the same library by the parent slot definition.

VDSSP: specialised archetype slot definition parent validity. The flat parent of the specialisation of an archetype slot must be open (is_closed = False).

VDSSC: specialised archetype slot definition closed validity. In the specialisation of an archetype slot, either the slot can be specified to be closed (is_closed = True) or the slot can be narrowed, but not both.

5.3.13 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 if set. When setting this from a serialised form, if no occurrences is mentioned, the target occurrences should be used; otherwise the locally specified occurrences should be used as normal.	
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)	

5.3.13.1 Validity Rules

The following validity rules applies to internal references:

VUNT: use_node reference model type validity: the reference model type mentioned in an ARCHETYPE_INTERNAL_REF node must be the same as or a supertype (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.

The following validity rule applies to the redefinition of an internal reference in a specialised archetype:

VSUNT: use_node meta-type validity: a ARCHETYPE_INTERNAL_REF node may be redefined in a specialised archetype by another ARCHETYPE_INTERNAL_REF (e.g. in order to redefine occurrences), or by a node structure that legally redefines the node referred to by the reference, according to other validity rules.

5.3.14 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.
0..1	**external_reference**: DV_PARSABLE	Direct reference to external resource, usually arrived at by resolution of *reference* and an associated constraint binding.
Functions	**Signature**	**Meaning**
	is_resolved: Boolean **ensure** Result = external_reference /= Void	True if external_reference has been assigned.
Invariant	***Consistency:*** **not** any_allowed ***reference_valid***: reference /= Void	

5.3.14.1 Validity Rules

The following validity rule applies to CONSTRAINT_REFs 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.

5.3.15 C_OBJECT_GROUP Class

CLASS	C_OBJECT_GROUP	
Purpose	Type that represents a group constraint within the overall list of children under a C_ATTRIBUTE.	
Attributes	**Signature**	**Meaning**
1	**lower**: Integer	Index of lower member of this group, within parent attribute's children.
1	**upper**: Integer	Index of upper member of this group, within parent attribute's children.
1	**cardinality**: CARDINALITY	Cardinality of this group, treated as a list.

CLASS	C_OBJECT_GROUP	
1	**occurrences**: MULTIPLICITY_INTERVAL	Occurrences of this group within the data.
1	**parent**: C_ATTRIBUTE	Owning C_ATTRIBUTE.
Functions	**Signature**	**Meaning**
	lower_child: C_OBJECT ensure Result = parent.children.i_th (lower)	Lower child corresponding to *lower*.
	upper_child: C_OBJECT ensure Result = parent.children.i_th (upper)	Upper child corresponding to *lower*.
Invariant	***Lower_validity***: lower >= 0 **and** lower <= parent.children.count ***Upper_validity***: upper >= lower **and** upper <= parent.children.count ***Cardinality_validity***: cardinality /= Void ***Occurrences_validity***: occurrences /= Void	

6 The Primitive Package

6.1 Overview

Ultimately any archetype definition will devolve down to leaf node constraints on instances of primitive types. The primitive package, illustrated in FIGURE 15, defines the semantics of constraint on such types.

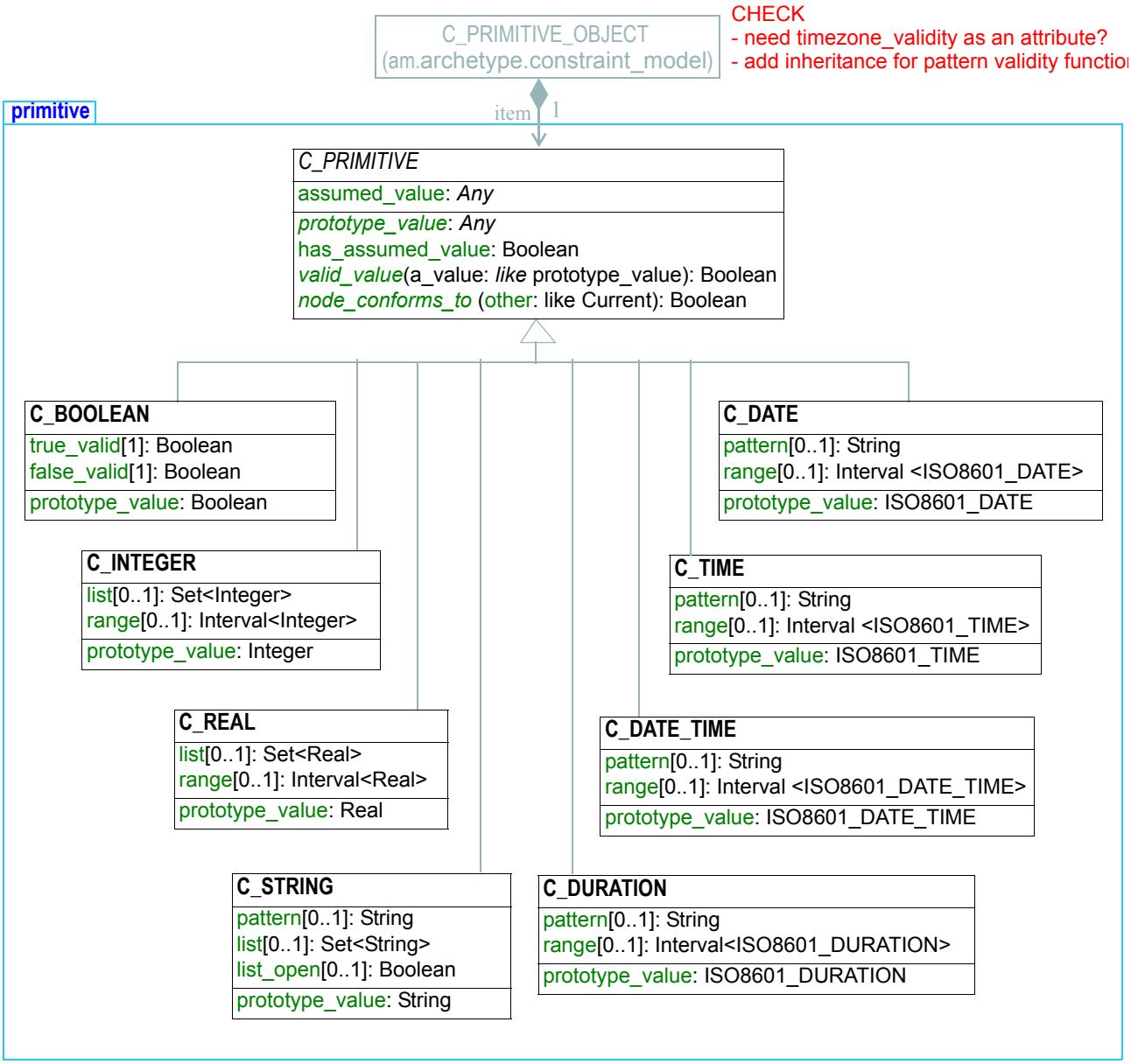


FIGURE 15 The openehr.am.archetype.primitive Package

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.

6.2 Class Descriptions

6.2.1 C_PRIMITIVE Class

CLASS	*C_PRIMITIVE (abstract)*	
Purpose	Abstract supertype of all prmitive types.	
Attributes	**Signature**	**Meaning**
0..1	**assumed_value**: ***like*** prototype_value	Value to be assumed if none sent in data.
Functions	**Signature**	**Meaning**
	prototype_value**:** `Any`	A generated prototype value from this constraint object. Redefined in all descendants.
	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'.
	has_assumed_value: `Boolean` ***ensure*** Result = assumed_value /= Void	True if there is an assumed value.
Invariant	***Assumed_value_valid***: has_assumed_value **implies** valid_value(assumed_value)	

6.2.2 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

CLASS	C_BOOLEAN	
Functions	**Signature**	**Meaning**
(redefined)	**prototype_value**: `Boolean`	A generated prototype value from this constraint object.
Invariant	***Binary_consistency***: true_valid ***or*** false_valid ***Prototype_value_consistency***: .value ***and*** true_valid ***or else not*** .value ***and*** false_valid	

6.2.3 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.
Functions	**Signature**	**Meaning**
(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	

6.2.4 C_INTEGER Class

CLASS	C_INTEGER
Purpose	Constraint on instances of `Integer`.
Inherit	`C_PRIMITIVE`

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

6.2.5 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
Functions	**Signature**	**Meaning**
(redefined)	**prototype_value**: `Real`	A generated prototype value from this constraint object.
Invariant	***Consistency***: list /= Void ***xor*** range /= Void	

6.2.6 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).

CLASS	C_DATE	
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
0..1 (cond)	**pattern**: String	ISO8601-based ADL pattern like "yyyy-??-xx"
Functions	**Signature**	**Meaning**
(redefined)	**prototype_value**: ISO8601_DATE	A generated prototype value from this constraint object.
	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)	

6.2.7 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

CLASS	C_TIME	
0..1 (cond)	**pattern**: `String`	ISO8601-based ADL pattern like "hh:??:xx"
Functions	**Signature**	**Meaning**
(redefined)	**prototype_value**: `ISO8601_TIME`	A generated prototype value from this constraint object.
	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_time_constraint_pattern(pattern)	

6.2.8 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??:??:??"
Functions	**Signature**	**Meaning**

CLASS	C_DATE_TIME	
(redefined)	**prototype_value**: `ISO8601_DATE_TIME`	A generated prototype value from this constraint object.
	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.
	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)	

6.2.9 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]
Functions	**Signature**	**Meaning**
(redefined)	**prototype_value**: `ISO8601_DURATION`	A generated prototype value from this constraint object.
	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)

7 The Assertion Package

7.1 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 8 on page 78. The assertion package is illustrated below in FIGURE 16.

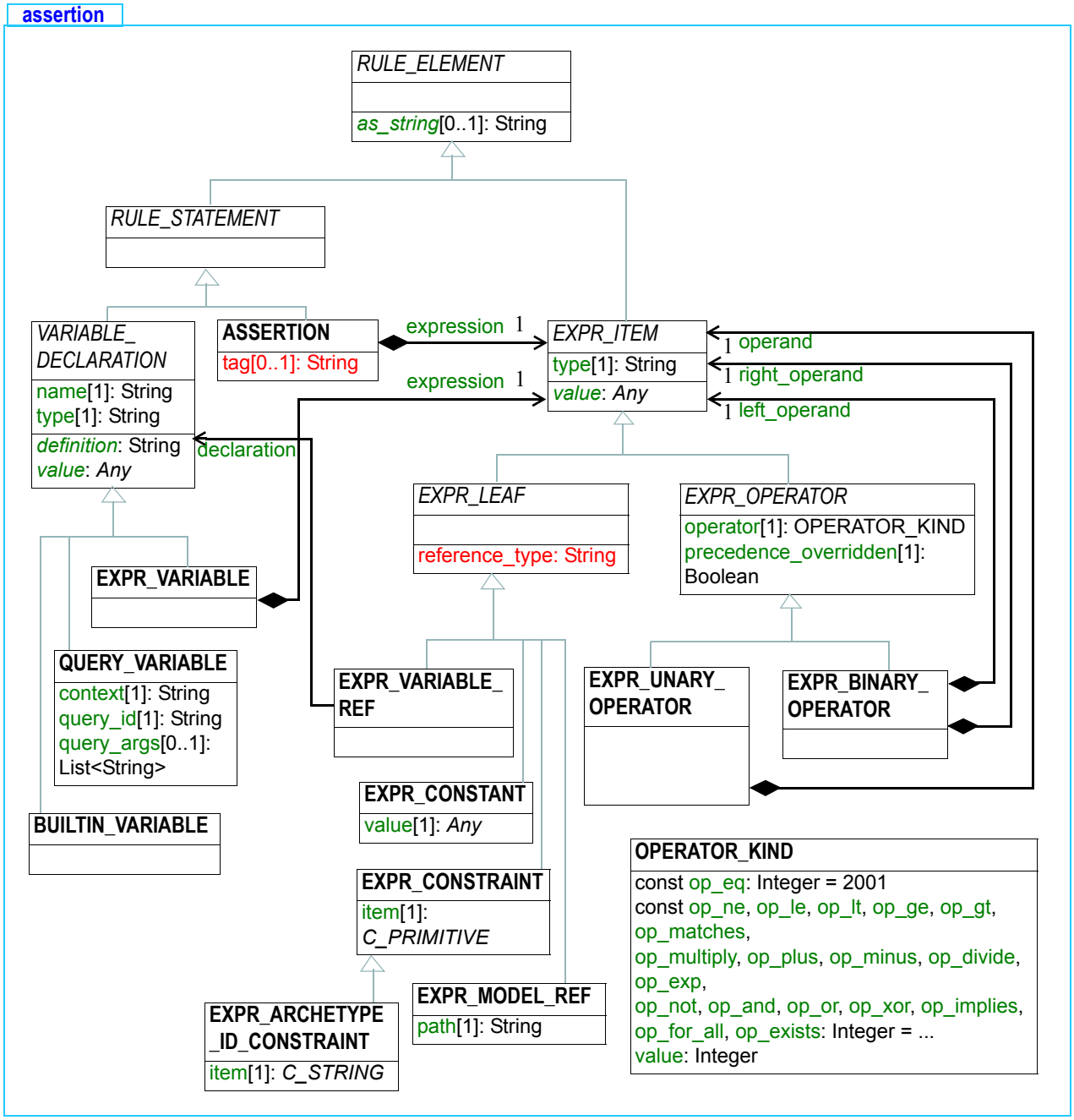


FIGURE 16 The openehr.am.archetype.assertion package

7.2 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.

7.3 Class Descriptions

7.3.1 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		

7.3.2 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 distinguishing 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")	

7.3.3 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	

7.3.4 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	

7.3.5 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		

7.3.6 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	

7.3.7 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	

7.3.8 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		

7.3.9 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	

7.3.10 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	

7.3.11 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.pattern_template	

7.3.12 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	

7.3.13 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	

7.3.14 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		

7.3.15 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	

7.3.16 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

7.3.17 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)	

8 Ontology Package

8.1 Overview

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

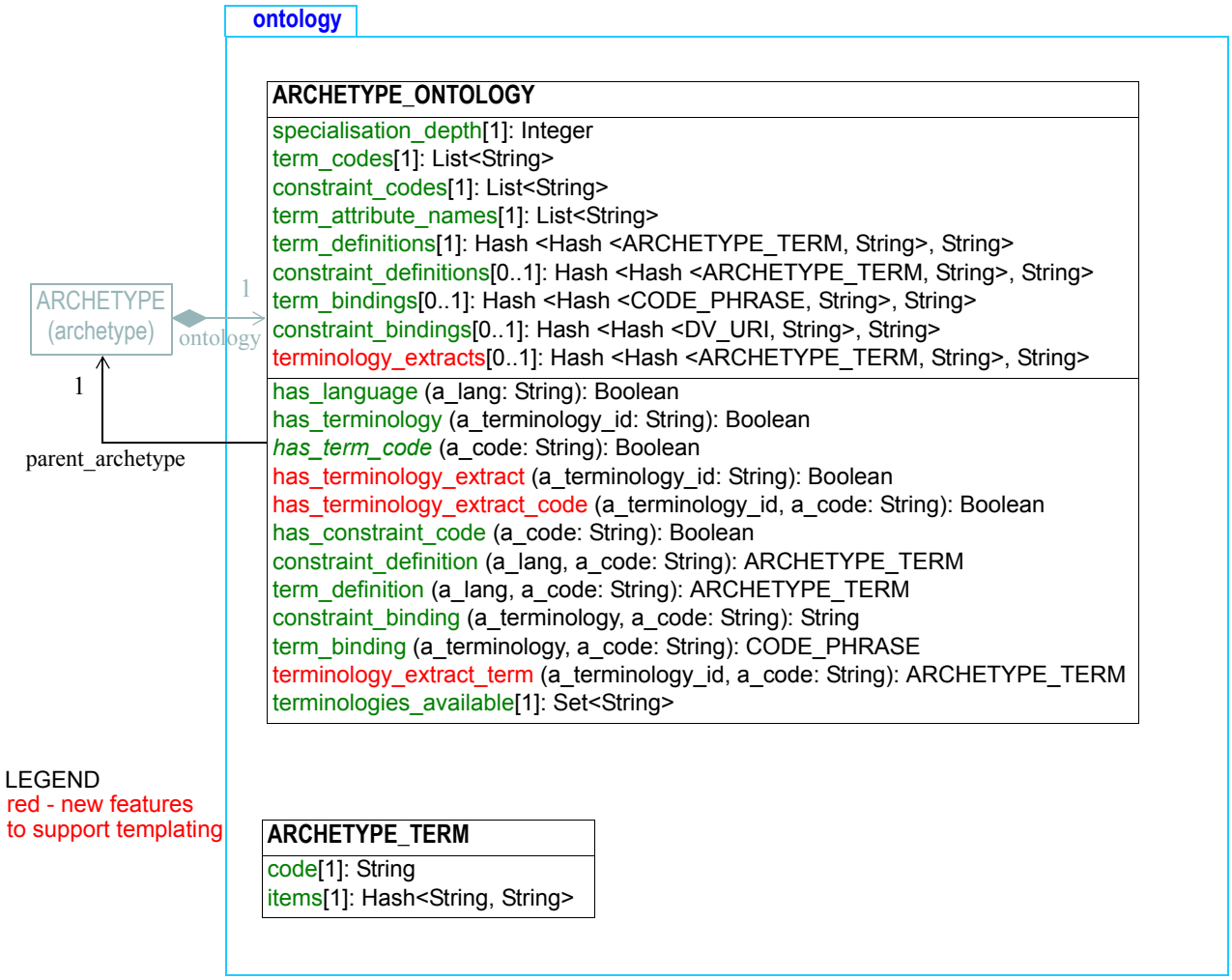


FIGURE 17 openehr.am.archetype.ontology Package

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.
- Optionally, extracts from external terminologies such as SNOMED CT, ICDx, or any local terminology. These extracts include the codes and preferred term rubrics, enabling the terms to be used for both display purposes. Such extracts are nearly always added due to localised templating, and correspond to small value sets for which no external reference set or subset is defined.

Depending on whether the archetype is in differential or flat form, an instance of the ARCHETYPE_ONTOLOGY class contains terms, constraints, bindings and terminology extracts that were respecitvely either introduced in the owning archetype, or all codes and bindings obtained by compressing an archetype lineage through inheritance. A typical instance structure of ARCHETYPE_ONTOLOGY is illustrated in FIGURE 18.

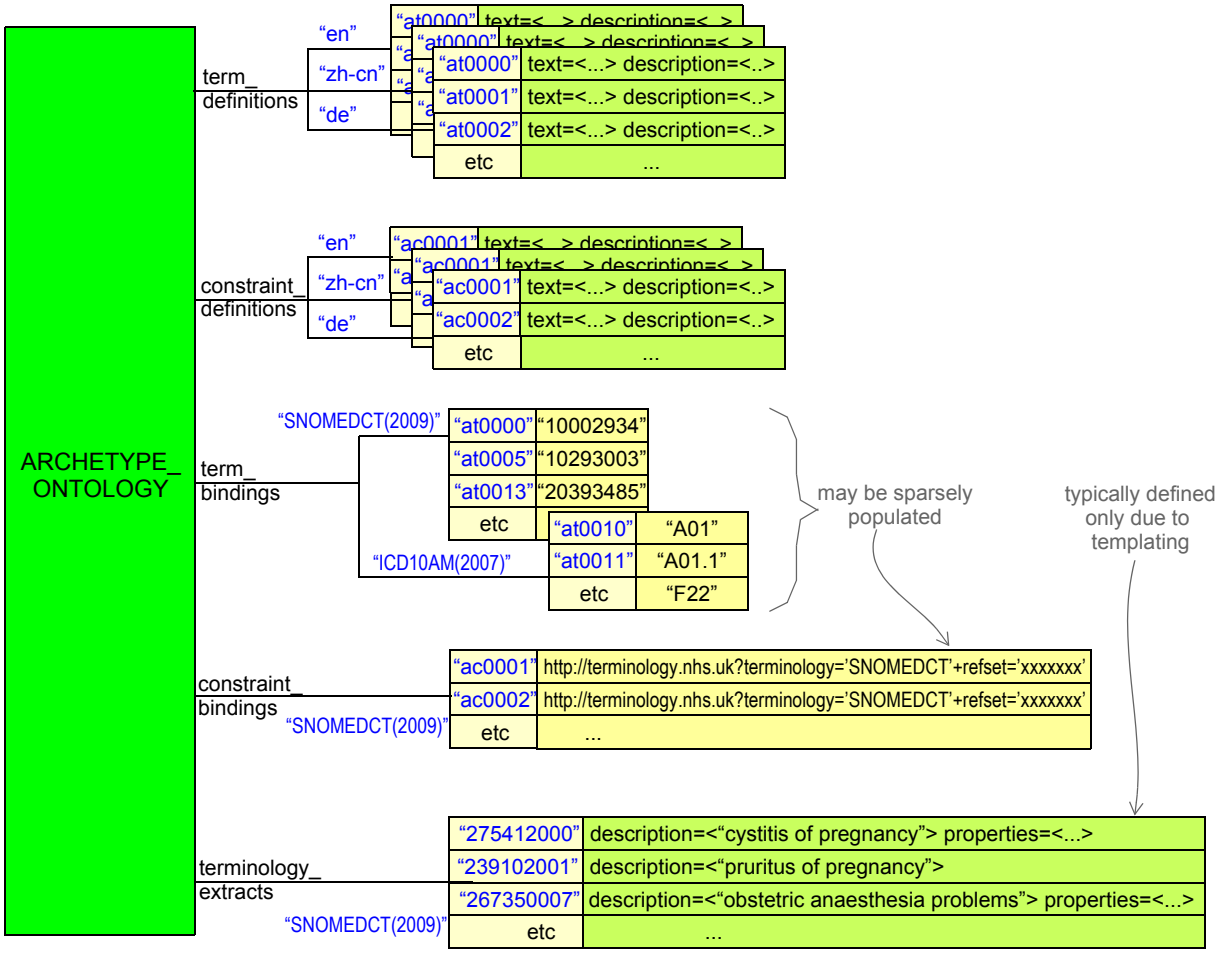


FIGURE 18 Archetype ontology structure.

8.2 Semantics

8.2.1 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.

8.2.2 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.

8.3 Class Descriptions

8.3.1 ARCHETYPE_ONTOLOGY Class

CLASS	ARCHETYPE_ONTOLOGY	
Purpose	Local ontology of an archetype. This class defines the semantics of the ontology of an archetype.	
Attributes	**Signature**	**Meaning**
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.

CLASS	ARCHETYPE_ONTOLOGY	
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"`.
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.

CLASS	ARCHETYPE_ONTOLOGY	
0..1	**terminology_extracts**: `Hash <Hash <ARCHETYPE_TERM, String>, String>`	Directory of extracts of external terminologies, as a two-level table. The outer hash keys are terminology ids, e.g. “SNOMED_CT”, while the inner hash keys are term codes or code-phrases from the relevant terminology, e.g. `“10094842”`.
Functions	**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*.
	has_terminology_extract_code (a_terminology_id, a_code: `String`): `Boolean` ***require*** has_terminology_extract (a_terminology_id)	True if *terminology_extracts* has for *a_terminology* 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.
	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`.

CLASS	ARCHETYPE_ONTOLOGY	
	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.
	terminology_extract_term (a_terminology_id, a_code: `String`): `ARCHETYPE_TERM` ***require*** has_terminology_extract (a_terminology_id) **and** has_terminology_extract_code (a_code)	Return an `ARCHETYPE_TERM` from specified terminology extract, for specified term code.
	has_language (a_lang: `String`): `Boolean` ***require*** a_lang /= Void	True if language 'a_lang' is present in archetype ontology.
	has_terminology (a_terminology_id: `String`): `Boolean` ***require*** a_terminology_id /= Void	True if terminology *a_terminology* is present in archetype ontology.
	has_terminology_extract (a_terminology_id: `String`): `Boolean` ***require*** a_terminology_id /= Void	True if there is a terminology extract for *a_terminology* is present in archetype ontology.
	terminologies_available: `Set<String>` ***ensure*** Result /= Void	List of terminologies to which term or constraint bindings exist in this terminology, computed from *terminology_bindings* and *constraint_bindings*.

CLASS	ARCHETYPE_ONTOLOGY
Invariant	***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

8.3.1.1 Validity Rules

The following validity rules apply to instances of this class in an archetype:

VONSD: specialisation level of codes. Term or constraint code defined in archetype ontology must be of the same specialisation level as the archetype (differential archetypes), or the same or a less specialised level (flat archetypes).

VONLC: language consistency. Languages consistent: all term codes and constraint codes exist in all languages.

VOTBK: ontology term binding key valid. Every term binding must be to either a defined archetype term ('at-code') or to a path that is valid in the flat archetype.

VOCBK: ontology constraint binding key valid. Every constraint binding must be to a defined archetype constraint code ('ac-code').

8.3.2 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.

CLASS	ARCHETYPE_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 19 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.

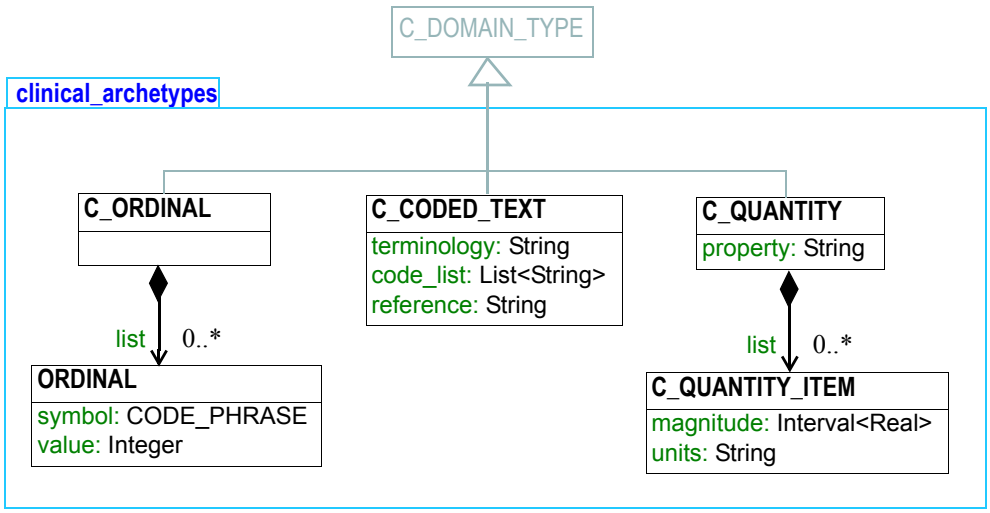


FIGURE 19 Example Domain-specific Package

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
            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 not co_child_diff instance_of CONSTRAINT_REF 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>>)
            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)
                if dynamic_type (co_child_diff) /= dynamic_type (co_parent_flat) then
                    add_error("VSUNT", <<co_child_diff.path, co_child_diff.generating_type,
                                        co_parent_flat.path, co_parent_flat.generating_type>>)
                end
```

```
                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>>)
                elseif not co_child_diff.node_conforms_to(co_parent_flat) then
                    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("", <<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("VSONI", <<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
                        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

8.3.3 What is a Redefined Node?

8.3.3.1 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 in the ADL specification Summary of Object Node Identification Rules), 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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