



## The *openEHR* Archetype Model

# Archetype Object Model

*Editors:* T Beale<sup>a</sup>

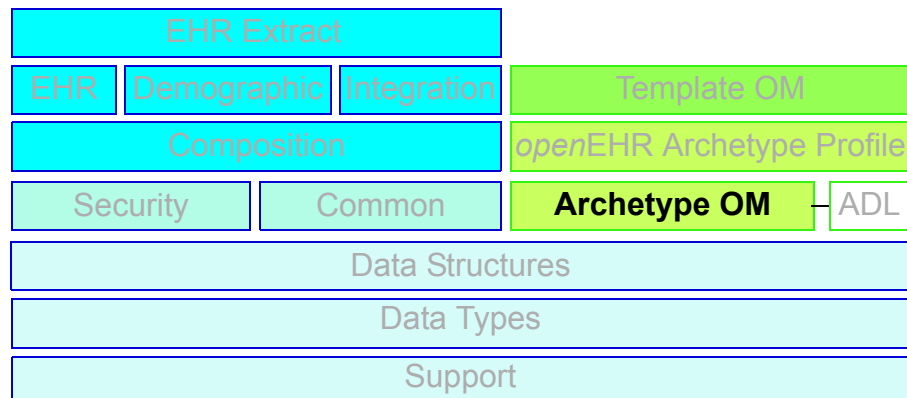
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# 1 Introduction

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## 1.1 Purpose

This document contains the definitive statement of archetype semantics, in the form of an object model for archetypes. The model presented here can be used as a basis for building software that processes archetypes, independent of their persistent representation; equally, it can be used to develop the output side of parsers that process archetypes in a linguistic format, such as the *openEHR* 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 *openEHR* 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 *openEHR* Architecture Overview

Related documents include:

- The *openEHR* Archetype Definition Language (ADL)
- The *openEHR* Archetype Profile (oAP)

## 1.3 Nomenclature

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

## 1.4 Status

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

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

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

Blue text indicates sections under active development.

## 1.5 Background

### 1.5.1 What is an Archetype?

Archetypes are constraint-based models of domain entities, or what some might call “structured business rules”. Each archetype describes configurations of data instances whose classes are described in a reference model; the instance configurations are considered to be valid exemplars of a particular

domain concept. Thus, in medicine, an archetype might be designed to constrain configurations of instances of a simple node/arc information model, that express a “microbiology test result” or a “physical examination”. Archetypes can be composed, specialised, and templated for local use. The archetype concept has been described in detail by Beale [1], [2]. Most of the detailed formal semantics are described in the *openEHR* Archetype Definition Language [4]. The *openEHR* archetype framework is described in terms of Archetype Definitions and Principles [4] and an Archetype System [5].

## 1.5.2 Context

The object model described in this document relates to linguistic forms of archetypes as shown in FIGURE 1. The model (upper right in the figure) is the object-oriented semantic equivalent of the ADL the Archetype Definition Language BNF language definition, and, by extension, any formal transformation of it. Instances of the model (lower right on the figure) are themselves archetypes, and correspond one-to-one with archetype documents expressed in ADL or a related language.

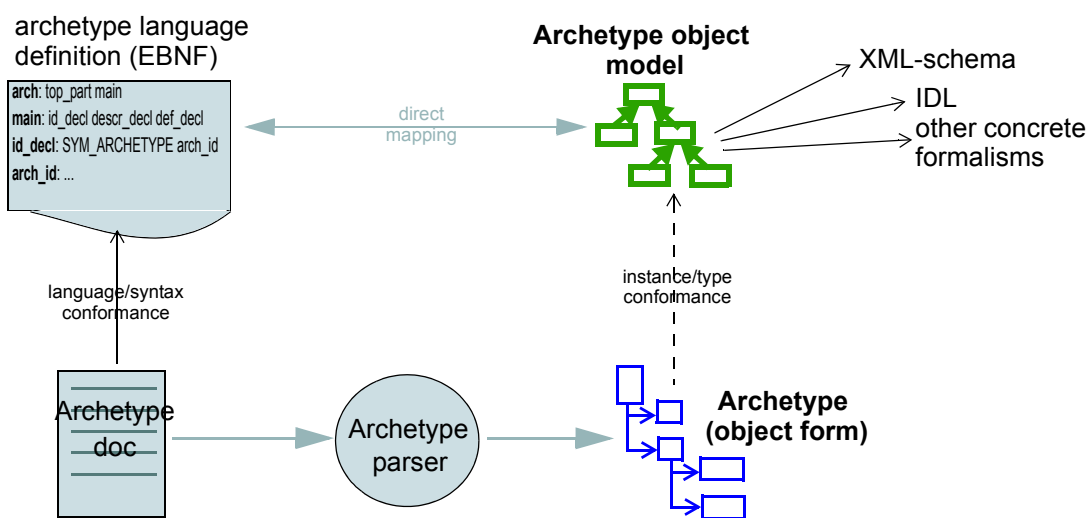


FIGURE 1 Relationship of Archetype Object Model to Archetype Languages

## 1.6 Tools

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

## 1.7 Changes from Previous Versions

### 1.7.1 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 The Archetype Object Model

### 2.1 Design Background

An underpinning principle of *openEHR* is the use of archetypes and templates, which are formal models of domain content, and are used to control data structure and content during creation, modification and querying. The elements of this architecture are twofold.

- The *openEHR* Reference Model (RM), defining the structure and semantics of information in terms of information models (IMs). The RM models correspond to the ISP RM/ODP information viewpoint, and define the data of *openEHR* EHR systems. The information model is designed to be invariant in the long term, to minimise the need for software and schema updates.
- The *openEHR* Archetype Model (AM), defining the structure and semantics of archetypes and templates. The AM consists of the archetype language definition language (ADL), the Archetype Object Model (AOM) and the *openEHR* Archetype profile (oAP).

The purpose of ADL is to provide an abstract syntax for textually expressing archetypes and templates. The AOM defines the object model equivalent, in terms of a UML model. It is a *generic* model, meaning that it can be used to express archetypes for any reference model in a standard way. ADL and the AOM are brought together in an ADL parser: a tool which can read ADL archetype texts, and whose parse-tree (resulting in-memory object representation) is instances of the AOM. The TOM defines the object model of templates, which are themselves used to put archetypes together into local information structures, usually corresponding to screen forms.

The purpose of the *openEHR* Archetype Profile is to define which classes and attributes of the *openEHR* RM can be sensibly archetyped, and to provide custom archetype classes.

### 2.2 Package Structure

The *openEHR* Archetype Object Model is defined as the package `am.archetype`, as illustrated in FIGURE 2. It is shown in the context of the *openEHR* `am.archetype` packages.

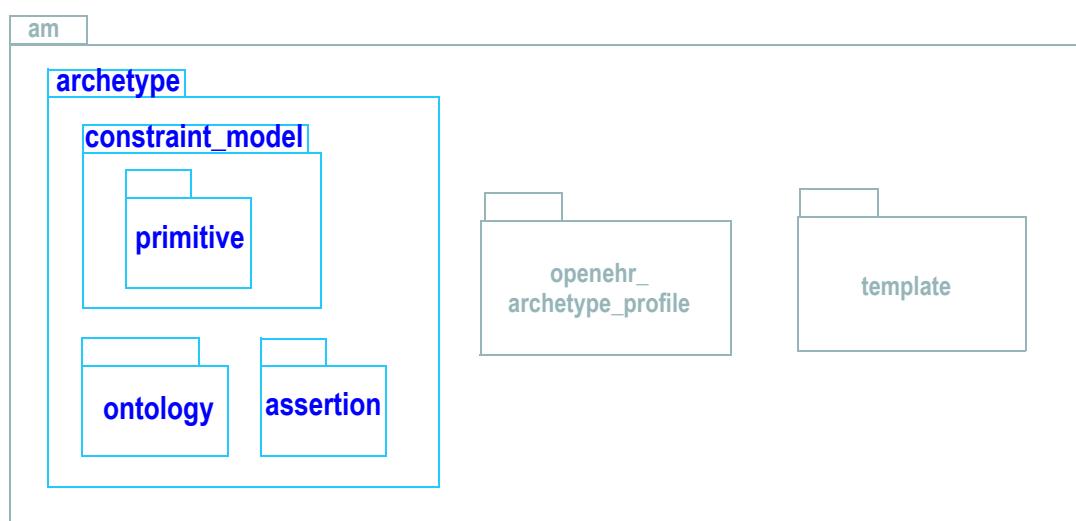


FIGURE 2 openehr.am.archetype Package

## 2.3 Model Overview

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

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

### 2.3.1 Archetypes as Objects

FIGURE 3 illustrates various processes that can be responsible for creating an archetype object structure, including parsing, database retrieval and GUI editing. A parsing process that would typically turn a syntax expression of an archetype (ADL, XML, OWL) into an object one. The input file is converted by a parser into an object parse tree, shown on the right of the figure, whose types are specified in this document. Database retrieval will cause the reconstruction of an archetype in memory from a structured data representation, such as relational data, object data or XML. Direct in-memory editing by a user with a GUI archetype editor application will cause on-the-fly creation and destruction of parts of an archetype during the editing session, which would eventually cause the archetype to be stored in some form when the user decides to commit it.

After initial parsing, the in-memory representation is then validated by the semantic checker of the ADL parser, which can verify 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 information model (e.g. in XMI or some equivalent)

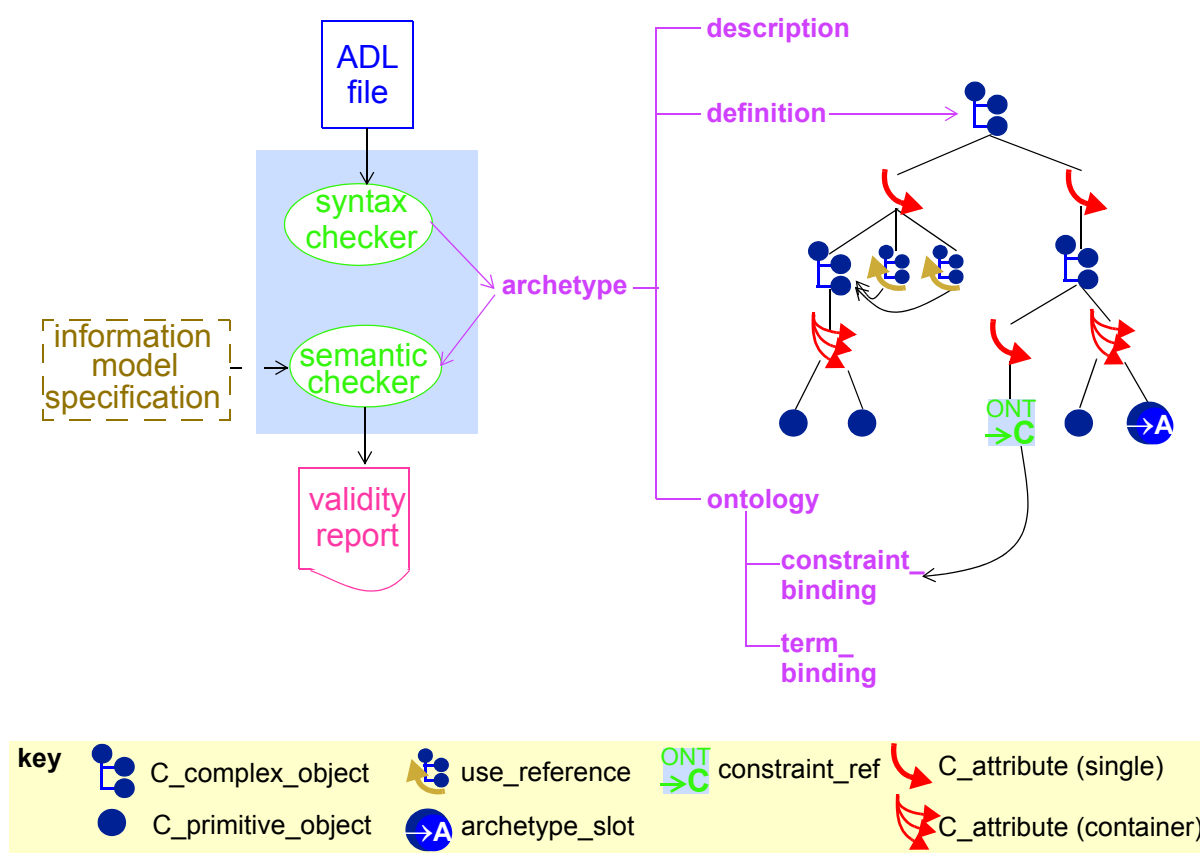


FIGURE 3 Archetype Parsing Process

As shown in the figure, the definition part of the in-memory archetype consists of alternate layers of *object* and *attribute* constrainer nodes, each containing the next level of nodes. 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. 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. *ENTRY*, *SECTION*;
- C\_attribute*: a node representing a constraint on an attribute (i.e. UML ‘relationship’ or ‘primitive attribute’) in an object type;
- C\_primitive\_object*: an node representing a constraint on a primitive (built-in) object type;
- Archetype\_internal\_ref*: a node that refers to a previously defined object node in the same archetype. The reference is made using a path;
- Constraint\_ref*: a node that refers to a constraint on (usually) a text or coded term entity, which appears in the ontology section of the archetype, and in ADL, is referred to with an “acNNNN” code. The constraint is expressed in terms of a query on an external entity, usually a terminology or ontology;
- Archetype\_slot*: a node whose statements define a constraint that determines which other archetypes can appear at that point in the current archetype. It can be thought of like a keyhole, into which few or many keys might fit, depending on how specific its shape is. Logically it has the same semantics as a *C\_COMPLEX\_OBJECT*, except that the constraints are expressed in another archetype, not the current one.

The typename nomenclature “*C\_complex\_object*”, “*C\_primitive\_object*”, “*C\_attribute*” used here is intended to be read as “constraint on xxxx”, i.e. a “*C\_complex\_object*” is a “constraint on a complex object (defined by a complex reference model type)”. These typenames are used below in the formal model.

## 2.3.2 The Archetype Ontology

There are no linguistic entities at all in the definition part of an archetype, with the possible exception of constraints on text items which might have been defined in terms of regular expression patterns or fixed strings. All linguistic entities are defined in the ontology part of the archetype, in such a way as to allow them to be translated into other languages in convenient blocks. As described in the *openEHR* ADL document, there are four major parts in an archetype ontology: term definitions, constraint definitions, term bindings and constraint bindings. The former two define the meanings of various terms and textual constraints which occur in the archetype; they are indexed with unique identifiers which are used within the archetype definition body. The latter two ontology sections describe the mappings of terms used internally to external terminologies. Due to the well-known problems with terminologies (described in some detail in the *openEHR* ADL document, and also by e.g. Rector [6] and others), mappings may be partial, incomplete, approximate, and occasionally, exact.

### 2.3.3 Archetype Specialisation

Archetypes can be specialised. The formal rules of specialisation are described in the *openEHR* Archetype Semantics document (forthcoming), but in essence are easy to understand. Briefly, an archetype is considered 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. Any data created via the use of the specialised archetype is thus conformant both to it and its parent. This notion of specialisation corresponds to the idea of ‘substitutability’, applied to data.

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

### 2.3.4 Archetype Composition

In 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 a multitude of others. Archetype slots are the means of composition, and are themselves defined in terms of constraints.

## 3 The Archetype Package

### 3.1 Overview

The model of an archetype, illustrated in FIGURE 4, is straightforward at an abstract level, mimicking the structure of an archetype document as defined in the *openEHR* Archetype Definition Language (ADL) document. An archetype is modelled as a particular kind of `AUTHORED_RESOURCE`, and as such, includes descriptive meta-data, language information and revision history. The `ARCHETYPE` class adds *identifying information*, a *definition* - expressed in terms of constraints on instances of an object model, and an *ontology*. The archetype definition, the ‘main’ part of an archetype, is an

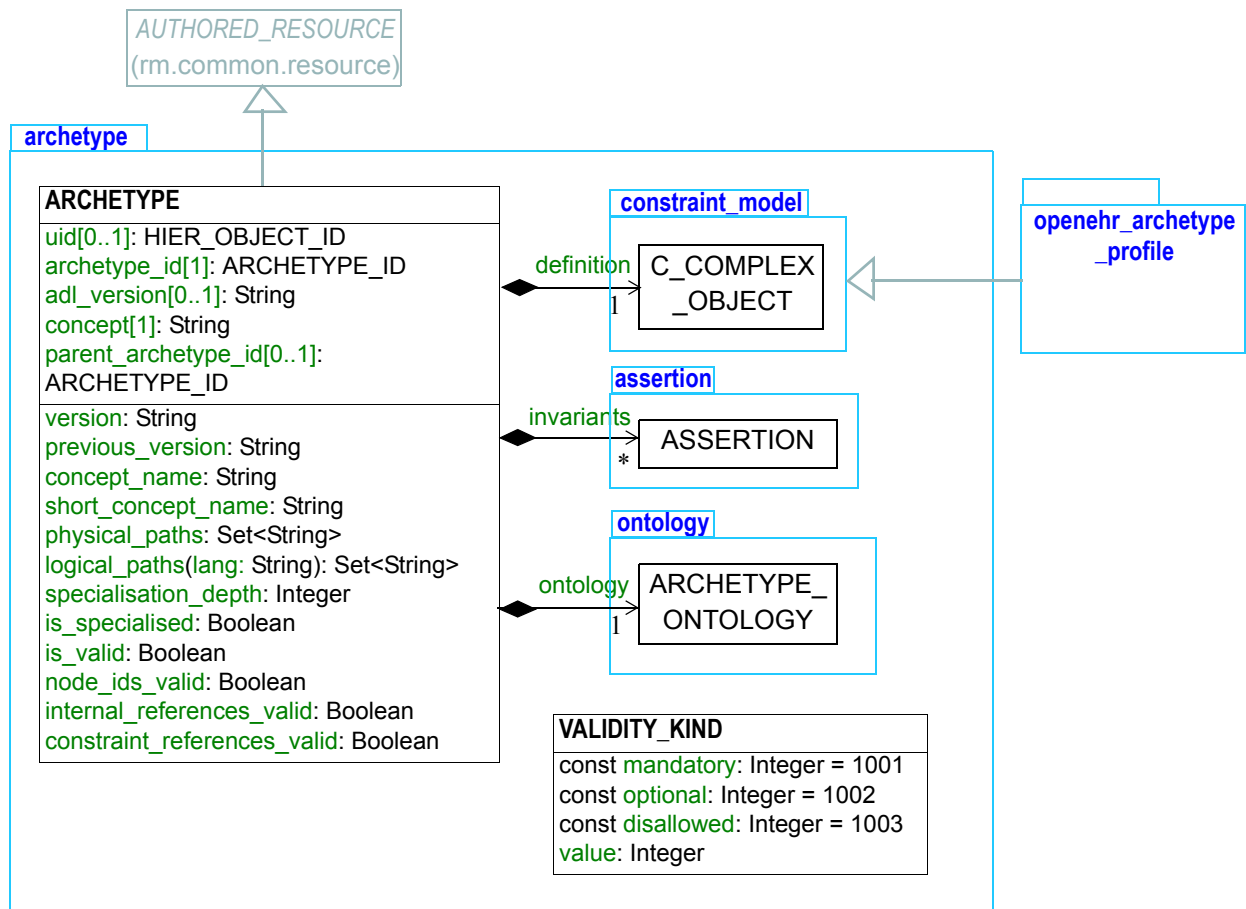


FIGURE 4 openehr.am.archetype Package

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

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

## 3.2 Class Descriptions

### 3.2.1 ARCHETYPE Class

CLASS	ARCHETYPE	
<b>Purpose</b>	Archetype equivalent to ARCHETYPED class in Common reference model. Defines semantics of identification, lifecycle, versioning, composition and specialisation.	
<b>Inherit</b>	AUTHORED_RESOURCE	
Attributes	Signature	Meaning
0..1	<b>adl_version</b> : String	ADL version if archetype was read in from an ADL sharable archetype.
1..1	<b>archetype_id</b> : ARCHETYPE_ID	Multi-axial identifier of this archetype in archetype space.
0..1	<b>uid</b> : HIER_OBJECT_ID	OID identifier of this archetype.
1..1	<b>concept</b> : String	The normative meaning of the archetype as a whole, expressed as a local archetype code, typically “at0000”.
0..1	<b>parent_archetype_id</b> : ARCHETYPE_ID	Identifier of the specialisation parent of this archetype.
1..1	<b>definition</b> : C_COMPLEX_OBJECT	Root node of this archetype
1..1	<b>ontology</b> : ARCHETYPE_ONTOLOGY	The ontology of the archetype.
0..1	<b>invariants</b> : Set<ASSERTION>	Invariant statements about this object. Statements are expressed in first order predicate logic, and usually refer to at least two attributes.
Functions	Signature	Meaning
1..1	<b>version</b> : String	Version of this archetype, extracted from id.
0..1	<b>previous_version</b> : String	Version of predecessor archetype of this archetype, if any.
1..1	<b>short_concept_name</b> : String	The short concept name of the archetype extracted from the archetype_id.
	<b>concept_name</b> (a_lang: String): String	The concept name of the archetype in language <i>a_lang</i> ; corresponds to the term definition of the <i>concept</i> attribute in the archetype ontology.

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

CLASS	ARCHETYPE
Invariant	<p><i>archetype_id_validity</i>: archetype_id /= Void</p> <p><i>concept_valid</i>: ontology.has_term_code(concept_code)</p> <p><i>uid_validity</i>: uid /= Void <b>implies not</b> uid.is_empty</p> <p><i>version_validity</i>: version /= Void <b>and then</b> version.is_equal(archetype_id.version_id)</p> <p><i>original_language_valid</i>: original_language /= void <b>and then</b> language /= Void <b>and then</b> code_set(Code_set_id_languages).has_code(original_language)</p> <p><i>description_exists</i>: description /= Void</p> <p><i>definition_exists</i>: definition /= Void</p> <p><i>ontology_exists</i>: ontology /= Void</p> <p><i>Specialisation_validity</i>: is_specialised <b>implies</b> specialisation_depth &gt; 0</p> <p><i>Invariants_valid</i>: invariants /= Void <b>implies not</b> invariants.is_empty</p>

### 3.2.2 VALIDITY\_KIND Class

CLASS	VALIDITY_KIND	
Purpose	An enumeration of three values which may commonly occur in constraint models.	
Use	Use as the type of any attribute within this model, which expresses constraint on some attribute in a class in a reference model. For example to indicate validity of Date/Time fields.	
Attributes	Signature	Meaning
1..1	<i>const mandatory</i> : Integer = 1001	Constant to indicate mandatory presence of something
1..1	<i>const optional</i> : Integer = 1002	Constant to indicate optional presence of something
1..1	<i>const disallowed</i> : Integer = 1003	Constant to indicate disallowed presence of something
1..1	<i>value</i> : Integer	Actual value
Functions	Signature	Meaning
	<p><i>valid_validity</i> (a_validity: Integer) : Boolean</p> <p><i>ensure</i> a_validity &gt;= mandatory <b>and</b> a_validity &lt;= disallowed</p>	Function to test validity values.
Invariant	<i>Validity</i> : valid_validity(value)	



## 4 Constraint Model Package

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### 4.1 Overview

FIGURE 5 illustrates the class model of 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’.

An informal way of understanding the model is as follows. An archetype definition is an instance of a `C_COMPLEX_OBJECT`, which can be thought of as expressing constraints on a object that is of some particular reference model type (recorded in the attribute `rm_type_name`), and which is larger than a simple instance of a primitive type such as String or Integer. The constraints define what 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. At the leaf nodes of an archetype definition are `C_PRIMITIVE_OBJECT` nodes, defining the constraints on leaf values of objects, i.e. Integers, Strings etc.

### 4.2 Semantics

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

#### 4.2.1 All Node Types

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

#### 4.2.2 Attribute Node Types

Constraints on attributes are represented by instances of the two subtypes of `C_ATTRIBUTE`: `C_SINGLE_ATTRIBUTE` and `C_MULTIPLE_ATTRIBUTE`. For both subtypes, the common constraint is

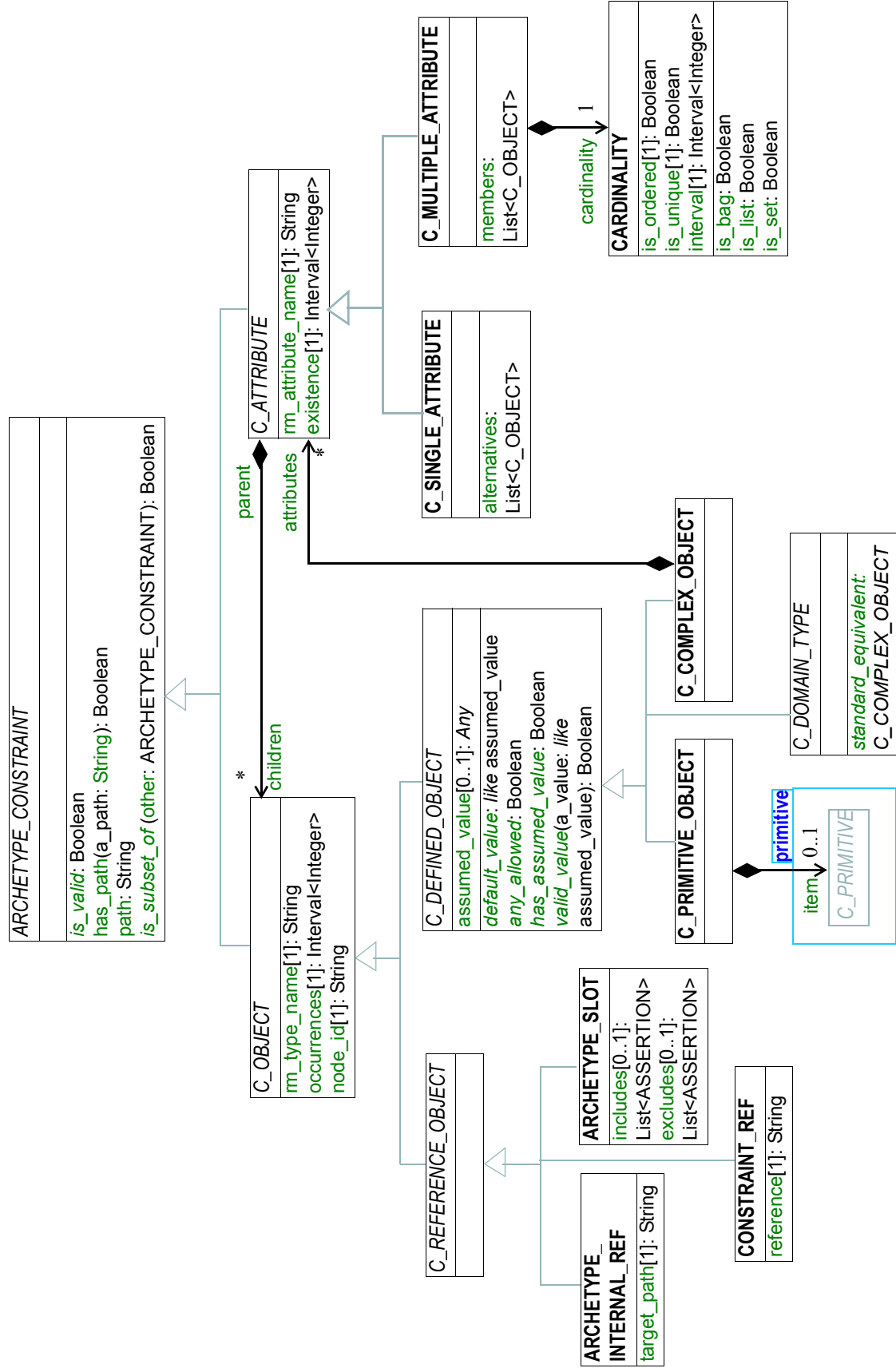


FIGURE 5 openehr.am.archetype.constraint\_model Package

whether the corresponding instance (defined by the *rm\_attribute\_name* attribute) must exist. Both subtypes have a list of children, representing constraints on the object value(s) of the attribute.

Single-valued attributes (such as *Person.date\_of\_birth*: Date) are constrained by instances of the type *C\_SINGLE\_ATTRIBUTE*, which uses the children to represent multiple *alternative* object constraints for the attribute value.

Multiply-valued attributes (such as *Person.contacts*: List<Contact>) are constrained by an instance of *C\_MULTIPLE\_ATTRIBUTE*, which allows multiple *co-existing* member objects of the container value of the attribute to be constrained, along with a cardinality constraint, describing ordering and uniqueness of the container. FIGURE 6 illustrates the two possibilities.

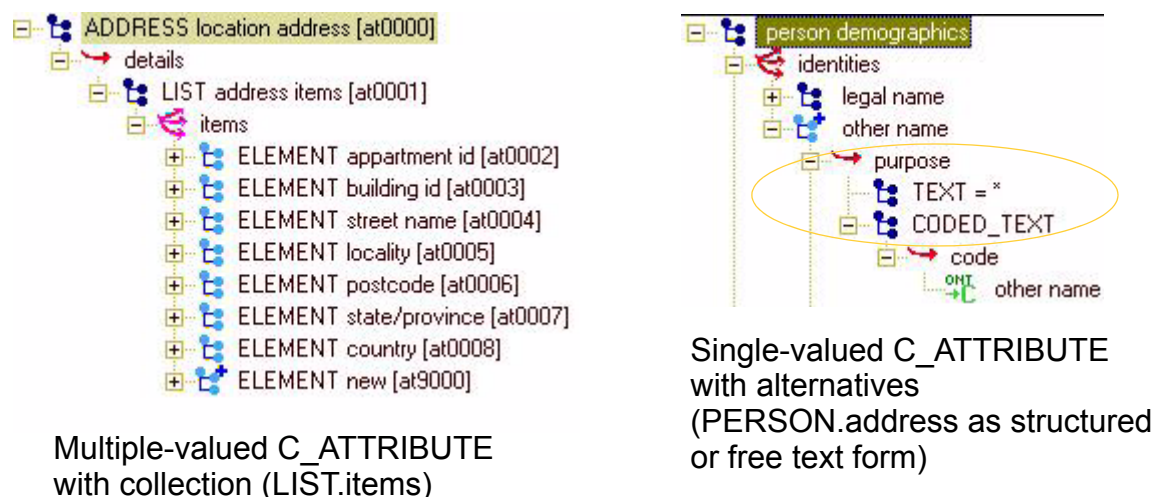


FIGURE 6 Single and Multiple-valued C\_ATTRIBUTES

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

## 4.2.3 Object Node Types

### Node\_id and Paths

The *node\_id* attribute in the class *C\_OBJECT*, inherited by all subtypes, is of great importance in the archetype constraint model. It has two functions:

- 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*.

#### 4.2.3.1 Defined Object Nodes (C\_DEFINED\_OBJECT)

The C\_DEFINED\_OBJECT subtype corresponds to the category of C\_OBJECTs that are defined in an archetype by value, i.e. by inline definition. Four properties characterise C\_DEFINED\_OBJECTs as follows.

##### Any\_allowed

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

##### Assumed\_value

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

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

##### Valid\_value

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

##### Default\_value

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

#### 4.2.3.2 Complex Objects (C\_COMPLEX\_OBJECT)

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

### 4.2.3.3 Primitive Types

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

### 4.2.3.4 Domain-specific Extensions (C\_DOMAIN\_TYPE)

The main part of the archetype constraint model allows any type in a reference model to be archetyped - i.e. constrained - in a standard way, which is to say, by a regular cascade of `C_COMPLEX_OBJECT / C_ATTRIBUTE / C_PRIMITIVE_OBJECT` objects. This generally works well, especially for 'outer' container types in models. However, it occurs reasonably often that lower level logical 'leaf' types need special constraint semantics that are not conveniently achieved with the standard approach. 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 53.

### 4.2.3.5 Reference Objects (C\_REFERENCE\_OBJECT)

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

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

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

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

## 4.2.4 Assertions

The `C_ATTRIBUTE` and subtypes of `C_OBJECT` enable constraints to be expressed in a structural fashion such that any constraint concerning a single attribute may be expressed, including recursively. In addition to this, any instance of a `C_COMPLEX_OBJECT` may include one or more *invariants*. Invariants are statements in a form of predicate logic, which can also be used to state constraints on parts of an object. They are not needed to constrain single attributes (since this can be done with an appropriate `C_ATTRIBUTE`), but are necessary for constraints referring to more than one attribute, such as a con-

straint that ‘systolic pressure should be  $\geq$  diastolic pressure’ in a blood pressure measurement archetype. Invariants are expressed using a syntax derived from the OMG’s OCL syntax (adapted for use with objects rather than classes).

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

## 4.3 Class Definitions

### 4.3.1 ARCHETYPE\_CONSTRAINT Class

CLASS	<b>ARCHETYPE_CONSTRAINT (abstract)</b>	
<b>Purpose</b>	Archetype equivalent to <code>LOCATABLE</code> class in <i>openEHR</i> Common reference model. Defines common constraints for any inheritor of <code>LOCATABLE</code> in any reference model.	
<b>Abstract</b>	<b>Signature</b>	<b>Meaning</b>
	<i>is_subset_of</i> (other: <code>ARCHETYPE_CONSTRAINT</code> ): Boolean <i>require</i> other $\neq$ Void	True if constraints represented by <i>other</i> are narrower than this node. Note: not easily evaluable for <code>CONSTRAINT_REF</code> nodes.
	<i>is_valid</i> : Boolean	True if this node (and all its sub-nodes) is a valid archetype node for its type. This function should be implemented by each subtype to perform semantic validation of itself, and then call the <i>is_valid</i> function in any sub-parts, and generate the result appropriately.
<b>Functions</b>	<b>Signature</b>	<b>Meaning</b>
	<i>path</i> : String	Path of this node relative to root of archetype.
	<i>has_path</i> (a_path: String): Boolean <i>require</i> a_path $\neq$ Void	True if the relative path <i>a_path</i> exists at this node.
<b>Invariant</b>	<i>path_exists</i> : path $\neq$ Void	

### 4.3.2 C\_ATTRIBUTE Class

CLASS	<b>C_ATTRIBUTE(<i>abstract</i>)</b>	
<b>Purpose</b>	Abstract model of constraint on any kind of attribute node.	
Attributes	Signature	Meaning
1..1	<b>rm_attribute_name</b> : String	Reference model attribute within the enclosing type represented by a C_OBJECT.
1..1	<b>existence</b> : Interval<Integer>	Constraint on every attribute, regardless of whether it is singular or of a container type, which indicates whether its target object exists or not (i.e. is mandatory or not).
0..1	<b>children</b> : 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.
<b>Invariant</b>	<b>Rm_attribute_name_valid</b> : rm_attribute_name != Void <b>and then not</b> rm_attribute_name.is_empty <b>Existence_set</b> : existence != Void <b>and then</b> (existence.lower >= 0 <b>and</b> existence.upper <= 1) <b>Children_validity</b> : any_allowed <b>xor</b> children != Void	

### 4.3.3 C\_SINGLE\_ATTRIBUTE Class

CLASS	<b>C_SINGLE_ATTRIBUTE</b>	
<b>Purpose</b>	Concrete model of constraint on a single-valued attribute node. The meaning of the inherited children attribute is that they are alternatives.	
Functions	Signature	Meaning
	<b>alternatives</b> : List<C_OBJECT>	List of alternative constraints for the single child of this attribute within the data.
<b>Invariant</b>	<b>Alternatives_exists</b> : alternatives != Void	

### 4.3.4 C\_MULTIPLE\_ATTRIBUTE Class

CLASS	<b>C_MULTIPLE_ATTRIBUTE</b>	
<b>Purpose</b>	Abstract model of constraint on any kind of attribute node.	
Attributes	Signature	Meaning

CLASS	C_MULTIPLE_ATTRIBUTE	
1..1	<b>cardinality:</b> CARDINALITY	Cardinality of this attribute constraint, if it constraints a container attribute.
Functions	Signature	Meaning
	<b>members:</b> List<C_OBJECT>	List of constraints representing members of the container value of this attribute within the data. Semantics of the uniqueness and ordering of items in the container are given by the <i>cardinality</i> .
<b>Invariant</b>	<b>Cardinality_validity:</b> cardinality != Void <b>Members_valid:</b> members != Void <b>and then</b> members.for_all(co: C_OBJECT   co.occurrences.upper <= 1)	

### 4.3.5 CARDINALITY Class

CLASS	CARDINALITY	
<b>Purpose</b>	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.	
Attributes	Signature	Meaning
1..1	<b>is_ordered:</b> Boolean	True if the members of the container attribute to which this cardinality refers are ordered.
1..1	<b>is_unique:</b> Boolean	True if the members of the container attribute to which this cardinality refers are unique.
1..1	<b>interval:</b> Interval<Integer>	The interval of this cardinality.
Functions	Signature	Meaning
	<b>is_bag:</b> Boolean <i>ensure</i> <i>Result</i> = <b>not</b> is_ordered <b>and not</b> is_unique	True if the semantics of this cardinality represent a set, i.e. unordered, unique membership.
	<b>is_list:</b> Boolean <i>ensure</i> <i>Result</i> = is_ordered <b>and not</b> is_unique	True if the semantics of this cardinality represent a list, i.e. ordered, non-unique membership.



CLASS	CARDINALITY	
	<b>is_set</b> Boolean <i>ensure</i> <i>Result</i> = <b>not</b> is_ordered <b>and</b> is_unique	True if the semantics of this cardinality represent a bag, i.e. unordered, non-unique membership.
<b>Invariant</b>	<i>Validity</i> : <b>not</b> interval.lower_unbounded	

#### 4.3.6 C\_OBJECT Class

CLASS	<b>C_OBJECT (abstract)</b>	
<b>Purpose</b>	Abstract model of constraint on any kind of object node.	
Attributes	Signature	Meaning
1..1	<b>rm_type_name</b> : String	Reference model type that this node corresponds to.
1..1	<b>occurrences</b> : Interval<Integer>	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).
1..1	<b>node_id</b> : String	Semantic id of this node, used to differentiate sibling nodes of the same type. [Previously called ‘meaning’]. Each <i>node_id</i> must be defined in the archetype ontology as a term code.
0..1	<b>parent</b> : C_ATTRIBUTE	C_ATTRIBUTE that owns this C_OBJECT.
<b>Invariant</b>	<i>rm_type_name_valid</i> : rm_type_name != Void <b>and then not</b> rm_type_name.is_empty <i>node_id_valid</i> : node_id != Void <b>and then not</b> node_id.is_empty <i>Occurrences_validity</i> : occurrences != Void <b>and then</b> (parent != Void <b>implies</b> (not parent.is_multiple <b>implies</b> occurrences.upper <= 1))	

#### 4.3.7 C\_DEFINED\_OBJECT Class

CLASS	<b>C_DEFINED_OBJECT (abstract)</b>	
<b>Purpose</b>	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.	
<b>Inherit</b>	C_OBJECT	
Abstract	Signature	Meaning

CLASS	<b>C_DEFINED_OBJECT (abstract)</b>	
	<b>default_value:</b> like assumed_value	Generate a default value from this constraint object
	<b>valid_value</b> (a_value: like assumed_value) : Boolean <b>require</b> a_value /= Void	True if a_value is valid with respect to constraint expressed in concrete instance of this type.
	<b>any_allowed:</b> Boolean	True if any value (i.e. instance) of the reference model type would be allowed. Redefined in descendants.
Attributes	Signature	Meaning
0..1	<b>assumed_value:</b> Any	Value to be assumed if none sent in data
Functions	Signature	Meaning
	<b>has_assumed_value:</b> Boolean	True if there is an assumed value
<b>Invariant</b>	<i>Assumed_value_valid:</i> has_assumed_value <b>implies</b> valid_value(assumed_value)	

#### 4.3.8 C\_COMPLEX\_OBJECT Class

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

### 4.3.9 C\_PRIMITIVE\_OBJECT Class

CLASS	C_PRIMITIVE_OBJECT	
Purpose	Constraint on a primitive type.	
Inherit	C_DEFINED_OBJECT	
Functions	Signature	Meaning
(effected)	<b>any_allowed:</b> Boolean <i>ensure</i> Result = (item = Void)	True if any value of the type being constrained in <i>item</i> is allowed.
Attributes	Signature	Meaning
0..1	<b>item:</b> C_PRIMITIVE	Object actually defining the constraint.
Invariant	<i>item_exists</i> : any_allowed <b>xor</b> item /= Void	

### 4.3.10 C\_DOMAIN\_TYPE Class

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

### 4.3.11 C\_REFERENCE\_OBJECT Class

CLASS	C_REFERENCE_OBJECT ( <i>abstract</i> )	
Purpose	Abstract parent type of C_OBJECT subtypes that are defined by reference.	
Inherit	C_OBJECT	
Abstract	Signature	Meaning
Invariant		

### 4.3.12 ARCHETYPE\_SLOT Class

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

### 4.3.13 ARCHETYPE\_INTERNAL\_REF Class

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

**4.3.14 CONSTRAINT\_REF Class**

CLASS	CONSTRAINT_REF	
<b>Purpose</b>	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.	
<b>Inherit</b>	C_REFERENCE_OBJECT	
<b>Attributes</b>	<b>Signature</b>	<b>Meaning</b>
<b>1..1</b>	<b>reference:</b> String	Reference to a constraint in the archetype local ontology.
<b>Invariant</b>	<i>Consistency:</i> not any_allowed <i>reference_valid:</i> reference != Void	



## 5 The Assertion Package

### 5.1 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 invariants in complex object constraints. In both of these places, their role is to constrain something *inside* the archetype. Constraints on external resources such as terminologies are expressed in the constraint binding part of the archetype ontology, described in section 7 on page 49. The assertion package is illustrated below in FIGURE 7.

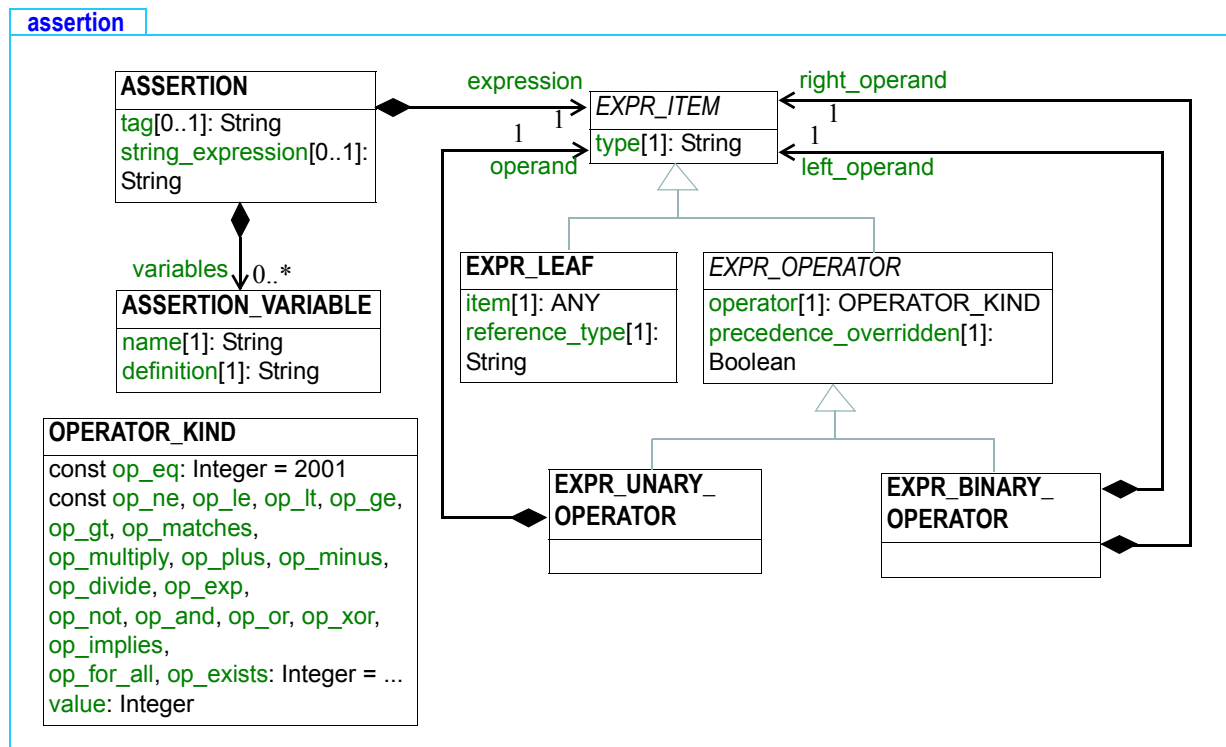


FIGURE 7 The openehr.am.archetype.assertion package

### 5.2 Semantics

The concrete syntax of assertion statements in archetypes is designed to be compatible with the OMG Object Constraint Language (OCL) [10]. Archetype assertions are essentially statements which contain the following elements:

- *variables*, which are attribute names, or ADL paths terminating in attribute names (i.e. equivalent of referencing class feature in a programming language);
- *manifest constants* of any primitive type, plus 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**

The written syntax of assertions is defined in the *openEHR* ADL document. The package described here is currently designed to allow the representation of a general-purpose binary expression tree, as would be generated by a parser. This may be replaced in the future by a more specific model, if needed.

This relatively simple model of expressions is sufficiently powerful for representing FOL expressions on archetype structures, although it could clearly be more heavily subtyped.

## 5.3 Class Descriptions

### 5.3.1 ASSERTION Class

CLASS	ASSERTION	
<b>Purpose</b>	Structural model of a typed first order predicate logic assertion, in the form of an expression tree, including optional variable definitions.	
<b>Attributes</b>	<b>Signature</b>	<b>Meaning</b>
<b>0..1</b>	<b>tag:</b> String	Expression tag, used for differentiating multiple assertions.
<b>1..1</b>	<b>expression:</b> <code>EXPR_ITEM</code>	Root of expression tree.
<b>0..1</b>	<b>string_expression:</b> String	String form of expression, in case an expression evaluator taking String expressions is used for evaluation.
<b>0..1</b>	<b>variables:</b> <code>List&lt;ASSERTION_VARIABLE&gt;</code>	Definitions of variables used in the assertion expression.
<b>Invariant</b>	<i>Tag_valid:</i> tag $\neq$ Void <b>implies not</b> tag.is_empty <i>Expression_valid:</i> expression $\neq$ Void and then expression.type.is_equal("BOOLEAN")	

### 5.3.2 EXPR\_ITEM Class

CLASS	<i>EXPR_ITEM (abstract)</i>	
<b>Purpose</b>	Abstract parent of all expression tree items.	
<b>Attributes</b>	<b>Signature</b>	<b>Meaning</b>
<b>1..1</b>	<b>type:</b> 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".



CLASS	<b>EXPR_ITEM (abstract)</b>
Invariant	<i>Type_valid</i> : type != Void and then not type.is_empty

### 5.3.3 EXPR\_LEAF Class

CLASS	<b>EXPR_LEAF</b>	
Purpose	<p>Expression tree leaf item. This can represent one of:</p> <ul style="list-style-type: none"> <li>a manifest constant of any primitive type (Integer, Real, Boolean, String, Character, Date, Time, Date_time, Duration), or (in future) of any complex reference model type, e.g. a DV_CODED_TEXT;</li> <li>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 <i>archetype_id</i> attribute of the enclosing archetype;</li> <li>a constraint, expressed in the form of concrete subtype of C_OBJECT; most often this will be a C_PRIMITIVE_OBJECT.</li> </ul>	
Inherit	EXPR_ITEM	
Attributes	Signature	Meaning
1..1	<b>item</b> : ANY	The value referred to; a manifest constant, an attribute path (in the form of a String), or for the right-hand side of a 'matches' node, a constraint, often a C_PRIMITIVE_OBJECT. [Future: paths including function names as well, even if not constrained in the archetype - as long as they are in the reference model].
1..1	<b>reference_type</b> : 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	<i>Item_valid</i> : item != Void <i>Reference_type_valid</i> : reference_type != Void	

### 5.3.4 EXPR\_OPERATOR Class

CLASS	<b>EXPR_OPERATOR (abstract)</b>
Purpose	Abstract parent of operator types.

CLASS	<b>EXPR_OPERATOR (abstract)</b>	
Inherit	EXPR_ITEM	
Attributes	Signature	Meaning
1..1	<b>operator:</b> OPERATOR_KIND	Code of operator.
1..1	<b>precedence_overridden:</b> 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		

### 5.3.5 EXPR\_UNARY\_OPERATOR Class

CLASS	<b>EXPR_UNARY_OPERATOR</b>	
Purpose	Unary operator expression node.	
Inherit	EXPR_OPERATOR	
Attributes	Signature	Meaning
1..1	<b>operand:</b> EXPR_ITEM	Operand node.
Invariant	<i>operand_valid:</i> operand != Void	

### 5.3.6 EXPR\_BINARY\_OPERATOR Class

CLASS	<b>EXPR_BINARY_OPERATOR</b>	
Purpose	Binary operator expression node.	
Inherit	EXPR_OPERATOR	
Attributes	Signature	Meaning
1..1	<b>left_operand:</b> EXPR_ITEM	Left operand node.
1..1	<b>right_operand:</b> EXPR_ITEM	Right operand node.
Invariant	<i>left_operand_valid:</i> operand != Void <i>right_operand_valid:</i> operand != Void	

**5.3.7 ASSERTION\_VARIABLE Class**

CLASS	ASSERTION_VARIABLE	
<b>Purpose</b>	Definition of a named variable used in an assertion expression. Note: the definition of named variables may change; still under development in ADL2.	
<b>Attributes</b>	<b>Signature</b>	<b>Meaning</b>
<b>1..1</b>	<b>name:</b> String	Name of variable.
<b>1..1</b>	<b>definition:</b> String	Formal definition of the variable. (see ADL2 specification; still under development).
<b>Invariant</b>	<i>Name_valid:</i> name != Void <b>and then not</b> name.is_empty <i>Definition_valid:</i> definition != Void <b>and then not</b> definition.is_empty	

### 5.3.8 OPERATOR\_KIND Class

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

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



## 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 8, defines the semantics of constraint on such types.

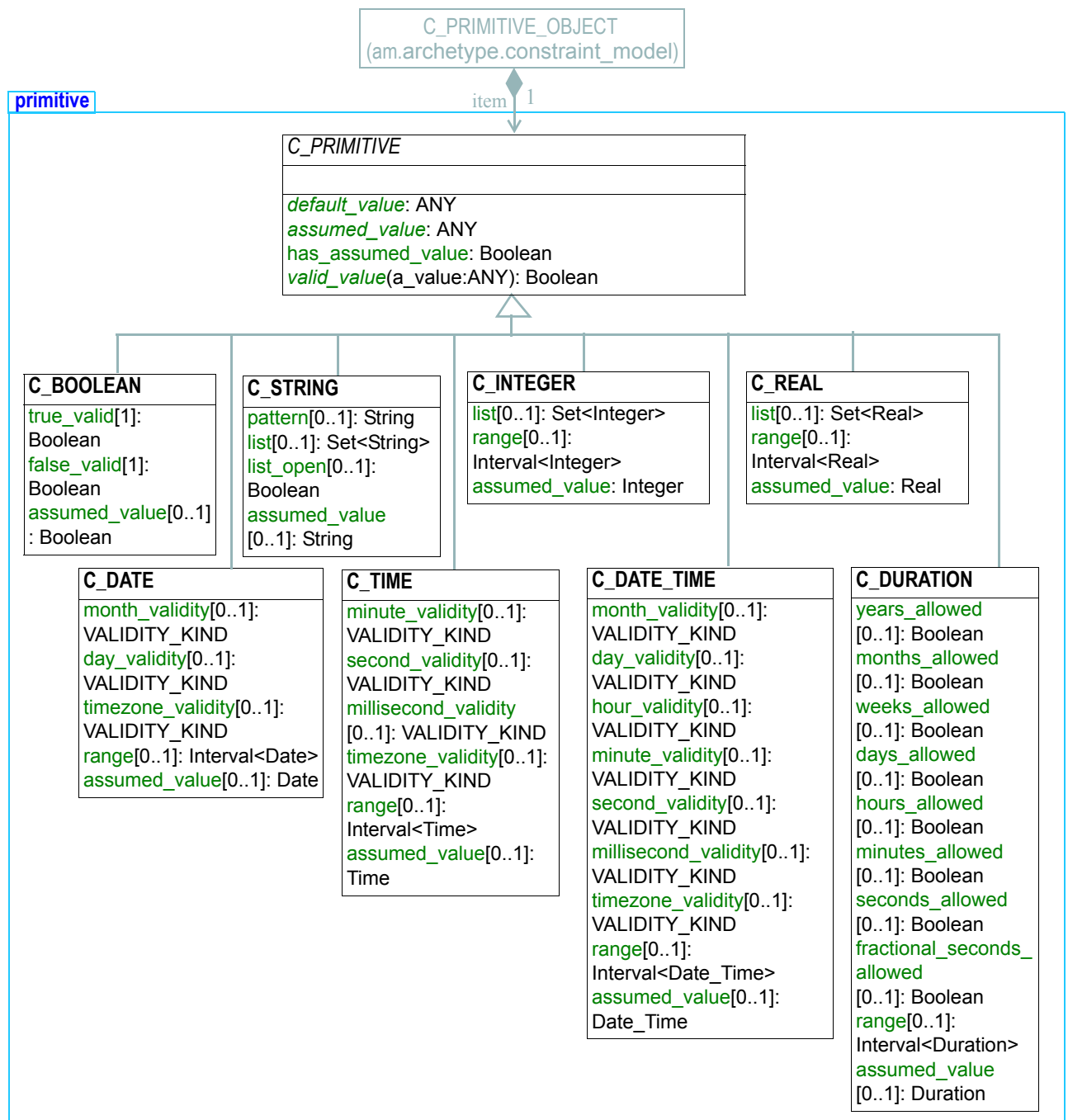


FIGURE 8 The openehr.am.archetype.primitive Package

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 speci-

fication) 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	<b>C_PRIMITIVE (abstract)</b>	
<b>Purpose</b>	Abstract supertype of all primitive types.	
<b>Abstract</b>	<b>Signature</b>	<b>Meaning</b>
1..1	<b>default_value</b> : ANY	Generate a default value from this constraint object
1..1	<b>has_assumed_value</b> : Boolean	True if there is an assumed value
1..1	<b>assumed_value</b> : <i>like</i> default_value	Value to be assumed if none sent in data
	<b>valid_value</b> (a_value: <i>like</i> default_value): Boolean <i>require</i> a_value /= Void	True if a_value is valid with respect to constraint expressed in concrete instance of this type.
<b>Invariant</b>	<i>Assumed_value_valid</i> : has_assumed_value <b>implies</b> valid_value(assumed_value)	

### 6.2.2 C\_BOOLEAN Class

CLASS	<b>C_BOOLEAN</b>	
<b>Purpose</b>	Constraint on instances of Boolean.	
<b>Use</b>	Both attributes cannot be set to False, since this would mean that the Boolean value being constrained cannot be True or False.	
<b>Inherit</b>	C_PRIMITIVE	
<b>Attributes</b>	<b>Signature</b>	<b>Meaning</b>
1..1	<b>true_valid</b> : Boolean	True if the value True is allowed
1..1	<b>false_valid</b> : Boolean	True if the value False is allowed
1..1 (redefined)	<b>assumed_value</b> : Boolean	The value to assume if this item is not included in data, due to being part of an optional structure.



CLASS	C_BOOLEAN
Invariant	<i>Binary_consistency</i> : true_valid <b>or</b> false_valid <i>Default_value_consistency</i> : default_value.value <b>and</b> true_valid <b>or else not</b> default_value.value <b>and</b> 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)	<b>pattern</b> : String	Regular expression pattern for proposed instances of String to match.
0..1 (cond)	<b>list</b> : Set<String>	Set of Strings specifying constraint
1..1	<b>list_open</b> : Boolean	True if the list is being used to specify the constraint but is not considered exhaustive.
1..1 (redefined)	<b>assumed_value</b> : String	The value to assume if this item is not included in data, due to being part of an optional structure.
Invariant	<i>Consistency</i> : pattern != Void <b>xor</b> list != Void <i>pattern_exists</i> : pattern != Void <b>implies not</b> pattern.is_empty	

### 6.2.4 C\_INTEGER Class

CLASS	C_INTEGER	
Purpose	Constraint on instances of Integer.	
Inherit	C_PRIMITIVE	
Attributes	Signature	Meaning
0..1 (cond)	<b>list</b> : Set<Integer>	Set of Integers specifying constraint
0..1 (cond)	<b>range</b> : Interval<Integer>	Range of Integers specifying constraint

CLASS	C_INTEGER	
<b>1..1 (redefined)</b>	<b>assumed_value:</b> Integer	The value to assume if this item is not included in data, due to being part of an optional structure.
<b>Invariant</b>	<i>Consistency:</i> list != Void <i>xor</i> range != Void	

### 6.2.5 C\_REAL Class

CLASS	C_REAL	
<b>Purpose</b>	Constraint on instances of Real.	
<b>Inherit</b>	C_PRIMITIVE	
Attributes	Signature	Meaning
<b>0..1 (cond)</b>	<b>list:</b> Set<Real>	Set of Reals specifying constraint
<b>0..1 (cond)</b>	<b>range:</b> Interval<Real>	Range of Real specifying constraint
<b>1..1 (redefined)</b>	<b>assumed_value:</b> Real	The value to assume if this item is not included in data, due to being part of an optional structure.
<b>Invariant</b>	<i>Consistency:</i> list != Void <i>xor</i> range != Void	

### 6.2.6 C\_DATE Class

CLASS	C_DATE	
<b>Purpose</b>	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).	
<b>Use</b>	Date ranges are probably only useful for historical dates.	
<b>Inherit</b>	C_PRIMITIVE	
Attributes	Signature	Meaning
<b>0..1 (cond)</b>	<b>month_validity:</b> VALIDITY_KIND	Validity of month in constrained date.

CLASS	C_DATE	
0..1 (cond)	<b>day_validity:</b> VALIDITY_KIND	Validity of day in constrained date.
0..1 (cond)	<b>timezone_validity:</b> VALIDITY_KIND	Validity of timezone in constrained date.
0..1 (cond)	<b>range:</b> Interval<Date>	Interval of Dates specifying constraint
1..1 (redefined)	<b>assumed_value:</b> Date	The value to assume if this item is not included in data, due to being part of an optional structure.
Functions	Signature	Meaning
1..1	<b>validity_is_range:</b> Boolean	True if validity is in the form of a range; useful for developers to check which kind of constraint has been set.
Invariant	<b>Month_validity_optional:</b> month_validity = {VALIDITY_KIND}.optional <b>implies</b> (day_validity = {VALIDITY_KIND}.optional <b>or</b> day_validity = {VALIDITY_KIND}.disallowed) <b>Month_validity_disallowed:</b> month_validity = {VALIDITY_KIND}.disallowed <b>implies</b> day_validity = {VALIDITY_KIND}.disallowed <b>Validity_is_range:</b> validity_is_range = (range /= Void)	

## 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)	<b>minute_validity:</b> VALIDITY_KIND	Validity of minute in constrained time.
0..1 (cond)	<b>second_validity:</b> VALIDITY_KIND	Validity of second in constrained time.
0..1 (cond)	<b>millisecond_validity:</b> VALIDITY_KIND	Validity of millisecond in constrained time.

CLASS	C_TIME	
0..1 (cond)	<b>timezone_validity:</b> VALIDITY_KIND	Validity of timezone in constrained date.
0..1 (cond)	<b>range:</b> Interval<Time>	Interval of Times specifying constraint
1..1 (redefined)	<b>assumed_value:</b> Time	The value to assume if this item is not included in data, due to being part of an optional structure.
Functions	Signature	Meaning
1..1	<b>validity_is_range:</b> Boolean	True if validity is in the form of a range; useful for developers to check which kind of constraint has been set.
Invariant	<p><i>Minute_validity_optional:</i> minute_validity = {VALIDITY_KIND}.optional <b>implies</b> (second_validity = {VALIDITY_KIND}.optional <b>or</b> second_validity = {VALIDITY_KIND}.disallowed)</p> <p><i>Minute_validity_disallowed:</i> minute_validity = {VALIDITY_KIND}.disallowed <b>implies</b> second_validity = {VALIDITY_KIND}.disallowed</p> <p><i>Second_validity_optional:</i> second_validity = {VALIDITY_KIND}.optional <b>implies</b> (millisecond_validity = {VALIDITY_KIND}.optional <b>or</b> millisecond_validity = {VALIDITY_KIND}.disallowed)</p> <p><i>Second_validity_disallowed:</i> second_validity = {VALIDITY_KIND}.disallowed <b>implies</b> millisecond_validity = {VALIDITY_KIND}.disallowed</p> <p><i>Validity_is_range:</i> validity_is_range = (range /= Void)</p>	

## 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)	<b>month_validity:</b> VALIDITY_KIND	Validity of month in constrained date.
0..1 (cond)	<b>day_validity:</b> VALIDITY_KIND	Validity of day in constrained date.

CLASS	C_DATE_TIME	
0..1 (cond)	<b>hour_validity:</b> VALIDITY_KIND	Validity of hour in constrained time.
0..1 (cond)	<b>minute_validity:</b> VALIDITY_KIND	Validity of minute in constrained time.
0..1 (cond)	<b>second_validity:</b> VALIDITY_KIND	Validity of second in constrained time.
0..1 (cond)	<b>millisecond_validity:</b> VALIDITY_KIND	Validity of millisecond in constrained time.
0..1 (cond)	<b>timezone_validity:</b> VALIDITY_KIND	Validity of timezone in constrained date.
0..1 (cond)	<b>range:</b> Interval<Date_Time>	Range of Date_times specifying constraint
1..1 (redefined)	<b>assumed_value:</b> Date_Time	The value to assume if this item is not included in data, due to being part of an optional structure.
Functions	Signature	Meaning
1..1	<b>validity_is_range:</b> Boolean	True if validity is in the form of a range; useful for developers to check which kind of constraint has been set.

CLASS	C_DATE_TIME
Invariant	<p><b><i>Month_validity_optional:</i></b> month_validity = {VALIDITY_KIND}.optional <b>implies</b> (day_validity = {VALIDITY_KIND}.optional <b>or</b> day_validity = {VALIDITY_KIND}.disallowed)</p> <p><b><i>Month_validity_disallowed:</i></b> month_validity = {VALIDITY_KIND}.disallowed <b>implies</b> day_validity = {VALIDITY_KIND}.disallowed</p> <p><b><i>Day_validity_optional:</i></b> day_validity = {VALIDITY_KIND}.optional <b>implies</b> (hour_validity = {VALIDITY_KIND}.optional <b>or</b> hour_validity = {VALIDITY_KIND}.disallowed)</p> <p><b><i>Day_validity_disallowed:</i></b> day_validity = {VALIDITY_KIND}.disallowed <b>implies</b> hour_validity = {VALIDITY_KIND}.disallowed</p> <p><b><i>Hour_validity_optional:</i></b> hour_validity = {VALIDITY_KIND}.optional <b>implies</b> (minute_validity = {VALIDITY_KIND}.optional <b>or</b> minute_validity = {VALIDITY_KIND}.disallowed)</p> <p><b><i>Hour_validity_disallowed:</i></b> hour_validity = {VALIDITY_KIND}.disallowed <b>implies</b> minute_validity = {VALIDITY_KIND}.disallowed</p> <p><b><i>Minute_validity_optional:</i></b> minute_validity = {VALIDITY_KIND}.optional <b>implies</b> (second_validity = {VALIDITY_KIND}.optional <b>or</b> second_validity = {VALIDITY_KIND}.disallowed)</p> <p><b><i>Minute_validity_disallowed:</i></b> minute_validity = {VALIDITY_KIND}.disallowed <b>implies</b> second_validity = {VALIDITY_KIND}.disallowed</p> <p><b><i>Second_validity_optional:</i></b> second_validity = {VALIDITY_KIND}.optional <b>implies</b> (millisecond_validity = {VALIDITY_KIND}.optional <b>or</b> millisecond_validity = {VALIDITY_KIND}.disallowed)</p> <p><b><i>Second_validity_disallowed:</i></b> second_validity = {VALIDITY_KIND}.disallowed <b>implies</b> millisecond_validity = {VALIDITY_KIND}.disallowed</p> <p><b><i>Validity_is_range:</i></b> validity_is_range = (range /= Void)</p>

## 6.2.9 C\_DURATION Class

CLASS	C_DURATION	
<b>Purpose</b>	ISO 8601-compatible constraint on instances of <i>Duration</i> . In ISO 8601 terms, constraints might be 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 <i>openEHR</i> -wide exception.	
<b>Inherit</b>	C_PRIMITIVE	
Attributes	Signature	Meaning
0..1	<b>years_allowed</b> : Boolean	True if years are allowed in the constrained Duration.
0..1	<b>months_allowed</b> : Boolean	True if months are allowed in the constrained Duration.
0..1	<b>weeks_allowed</b> : Boolean	True if weeks are allowed in the constrained Duration.
0..1	<b>days_allowed</b> : Boolean	True if days are allowed in the constrained Duration.
0..1	<b>hours_allowed</b> : Boolean	True if hours are allowed in the constrained Duration.
0..1	<b>minutes_allowed</b> : Boolean	True if minutes are allowed in the constrained Duration.
0..1	<b>seconds_allowed</b> : Boolean	True if seconds are allowed in the constrained Duration.
0..1	<b>fractional_seconds_allowed</b> : Boolean	True if fractional seconds are allowed in the constrained Duration.
1..1	<b>range</b> : Interval<Duration>	Range of Durations specifying constraint
1..1 (redefined)	<b>assumed_value</b> : Duration	The value to assume if this item is not included in data, due to being part of an optional structure.
<b>Invariant</b>	<b><i>Range_valid</i></b> : range != Void <b>or else</b> (years_allowed <b>or</b> months_allowed <b>or</b> weeks_allowed <b>or</b> days_allowed <b>or</b> hours_allowed <b>or</b> minutes_allowed <b>or</b> seconds_allowed <b>or</b> fractional_seconds_allowed)	

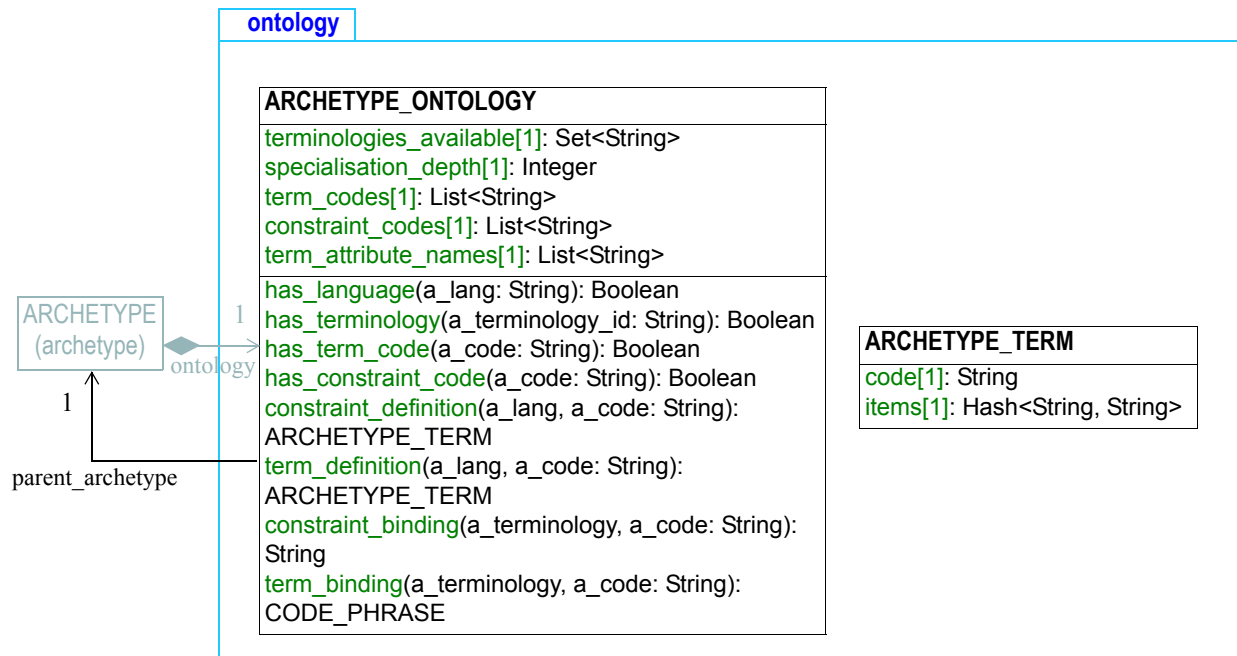




## 7 Ontology Package

### 7.1 Overview

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



**FIGURE 9** openehr.am.archetype.ontology Package

An archetype ontology consists of the following things.

- 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 terminologies.

### 7.2 Semantics

#### Specialisation Depth

Any given archetype occurs at some point in a hierarchy of archetypes related by specialisation, where the depth is indicated by the *specialisation\_depth* attribute. An archetype which is not a spe-

cialisation 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.

## Term and Constraint Definitions

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

## 7.3 Class Descriptions

### 7.3.1 ARCHETYPE\_ONTOLOGY Class

CLASS	ARCHETYPE_ONTOLOGY	
Purpose	Local ontology of an archetype.	
Attributes	Signature	Meaning
1..1	<b>terminologies_available:</b> Set<String>	List of terminologies to which term or constraint bindings exist in this terminology.
1..1	<b>specialisation_depth:</b> Integer	Specialisation depth of this archetype. Unspecialised archetypes have depth 0, with each additional level of specialisation adding 1 to the <code>specialisation_depth</code> .

CLASS	ARCHETYPE_ONTOLOGY	
1..1	<b>term_codes:</b> List<String>	List of all term codes in the ontology. Most of these correspond to “at” codes in an ADL archetype, which are the <i>node_ids</i> on C_OBJECT descendants. There may be an extra one, if a different term is used as the overall archetype <i>concept</i> from that used as the <i>node_id</i> of the outermost C_OBJECT in the definition part.
1..1	<b>constraint_codes:</b> 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. <i>reference</i> values in the archetype definition.
1..1	<b>term_attribute_names:</b> List<String>	List of ‘attribute’ names in ontology terms, typically includes ‘text’, ‘description’, ‘provenance’ etc.
1..1	<b>parent_archetype:</b> ARCHETYPE	Archetype which owns this ontology.
Functions	Signature	Meaning
	<b>has_language</b> (a_lang: String): Boolean	True if language ‘a_lang’ is present in archetype ontology.
	<b>has_terminology</b> (a_terminology_id: String): Boolean <i>require</i> has_terminology(a_terminology_id)	True if terminology ‘a_terminology’ is present in archetype ontology.
	<b>has_term_code</b> (a_code: String): Boolean	True if <i>term_codes</i> has <i>a_code</i> .
	<b>has_constraint_code</b> (a_code: String): Boolean	True if <i>constraint_codes</i> has <i>a_code</i> .
	<b>constraint_definition</b> (a_lang, a_code: String): ARCHETYPE_TERM <i>require</i> has_language(a_lang) has_constraint_code(a_code)	Constraint definition for a code, in a specified language.

CLASS	ARCHETYPE_ONTOLOGY	
	<b>term_binding</b> (a_terminology_id, a_code: String): CODE_PHRASE <i>require</i> has_terminology(a_terminology_id) has_term_code(a_code)	Binding of term corresponding to <i>a_code</i> in target external terminology <i>a_terminology_id</i> as a CODE_PHRASE.
	<b>constraint_binding</b> (a_terminology_id, a_code: String): String <i>require</i> has_terminology(a_terminology_id) has_constraint_code(a_code)	Binding of constraint corresponding to <i>a_code</i> in target external terminology <i>a_terminology_id</i> , as a string, which is usually a formal query expression.
<b>Invariant</b>	<i>terminologies_available_exists</i> : terminologies_available != void <i>term_codes_exists</i> : term_codes != void <i>constraint_codes_exists</i> : constraint_codes != void <i>term_bindings_exists</i> : term_bindings != void <i>constraint_bindings_exists</i> : constraint_bindings != void <i>term_attribute_names_valid</i> : term_attribute_names != void <b>and then</b> term_attribute_names.has("text") <b>and</b> term_attribute_names.has("description") <i>Parent_archetype_valid</i> : parent_archetype != Void and then parent_archetype.description = Current	

### 7.3.2 ARCHETYPE\_TERM Class

CLASS	ARCHETYPE_TERM	
<b>Purpose</b>	Representation of any coded entity (term or constraint) in the archetype ontology.	
<b>Attributes</b>	<b>Signature</b>	<b>Meaning</b>
<b>1..1</b>	<b>code</b> : String	Code of this term.
<b>0..1</b>	<b>items</b> : Hash <String, String>	Hash of keys ("text", "description" etc) and corresponding values.
<b>Functions</b>	<b>Signature</b>	<b>Meaning</b>
<b>1..1</b>	<b>keys</b> : Set<String>	List of all keys used in this term.
<b>Invariant</b>	<i>code_valid</i> : code != void <b>and then not</b> code.is_empty <i>keys_valid</i> : keys != Void	

## 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 *openEHR* are documented in the *openEHR* Archetype Profile (oAP) specification.

### A.2 Scientific/Clinical Computing Types

FIGURE 10 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 measurement 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.

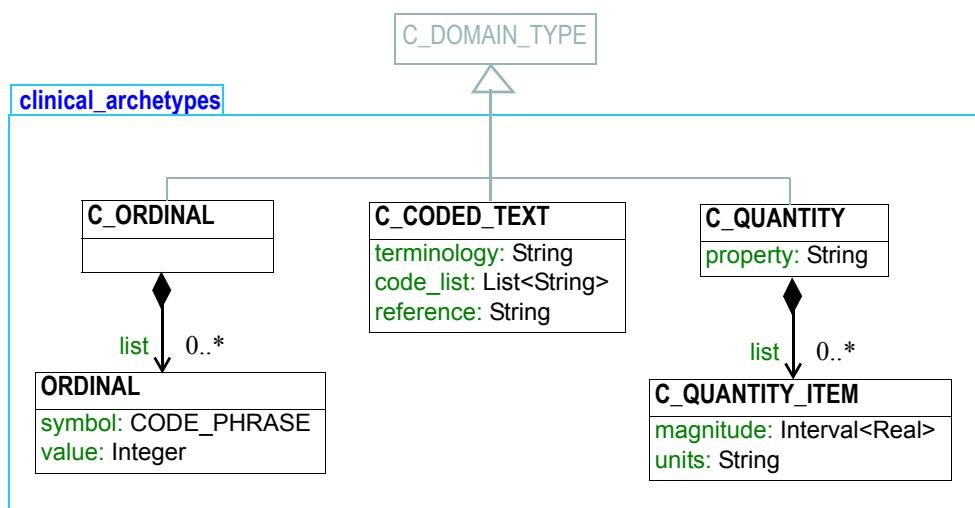


FIGURE 10 Example Domain-specific Package



## **B Using Archetypes with Diverse Reference Models**

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### **B.1 Overview**

The archetype model described in this document can be used with any reference model which is expressed in UML or a similar object-oriented formalism. It can also be used with E/R models. The following section describes its use a number of reference models used in clinical computing.

### **B.2 Clinical Computing Use**

To Be Continued:

- data types
- class naming
- domain archetype semantics versus LCD semantics of exchange models
- mapping from C\_DOMAIN\_TYPE subtypes into various RMs

#### **B.2.1 *openEHR***

#### **B.2.2 CEN ENV13606**

#### **B.2.3 HL7 Clinical Document Architecture (CDA)**





## C References

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### Publications

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### Resources

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