



The Archetype Object Model

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1 Introduction

1.1 Purpose

This document describes a generic object model for archetypes, based only upon the generally accepted semantics of object models (typified by the OMG UML meta-model). 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

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.

The latest version of this document can be found in PDF format at <http://svn.openehr.org/specification/TRUNK/publishing/architecture/am/aom.pdf>. New versions are announced on openehr-announce@openehr.org.

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.

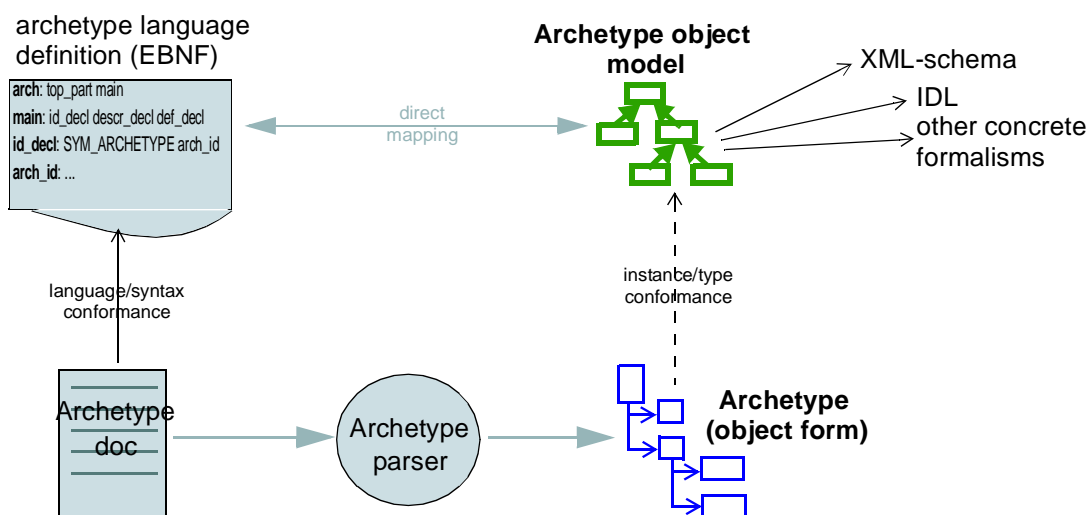


FIGURE 1 Relationship of Archetype Object Model to Archetype Languages

1.5.3 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>).

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 concepts controlling data structure and content of data. The elements of this architecture are twofold.

- The *openEHR* Reference Model (RM), defining the structure and semantics of information and service interfaces in terms of information models (IMs) and service models (SMs). These models correspond respectively to the ISP RM/ODP information and computational viewpoints. The information models define the data of *openEHR* EHR systems; meaning that every data instance in a system is an instance of a type defined in the Information Model (or to be completely correct, the corresponding type in the relevant ITS). 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 the 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 purpose of the *openEHR* Archetype Profile to define which classes and attributes of the *openEHR* RM can sensibly be archetyped, and to provide custom archetype classes.

2.2 Package Structure

The *openEHR* Archetype Profile model is defined as the package `am.openehr_rm_profile`, as illustrated in FIGURE 2. It is shown in the context of the *openEHR* `am` and `am.archetype` packages.

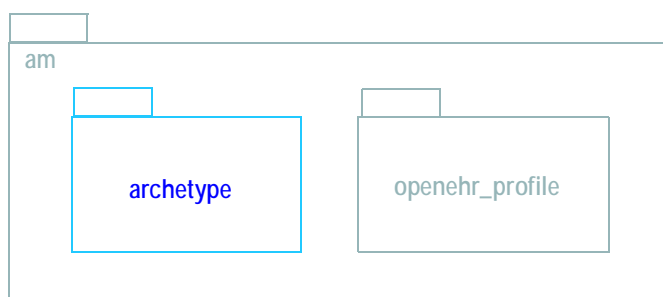


FIGURE 2 `openehr.am.archetype` Package

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

only on two groups of assumed types. The first group includes the following primitive inbuilt types, whose names and assumed semantics are described by ISO 11404 (the exact *openEHR* correspondences are described in the *openEHR* Support Information Model).

- Boolean
- Character
- Integer

The second are assumed library types:

- String
- Date
- Time
- Date_time
- Duration
- Hash <T, K:Comparable> (keyed list of items of any type)
- Interval <T:Comparable> (interval of instances of any ordered type)

To Be Determined: CEN WG I, Delft 7 Feb 2005 - T Nystadnes/D Kalra: rewrite with correct reference to ISO 11404 / ISO 8601 standards, remove "defacto standard"

Action: add State primitive type to list and to primitive package

These types are supported in most implementation technologies, including XML, Java and other programming languages. They are not defined in this specification, allowing them to be mapped to the most appropriate concrete types in each implementation technology.

The *openEHR* types used are:

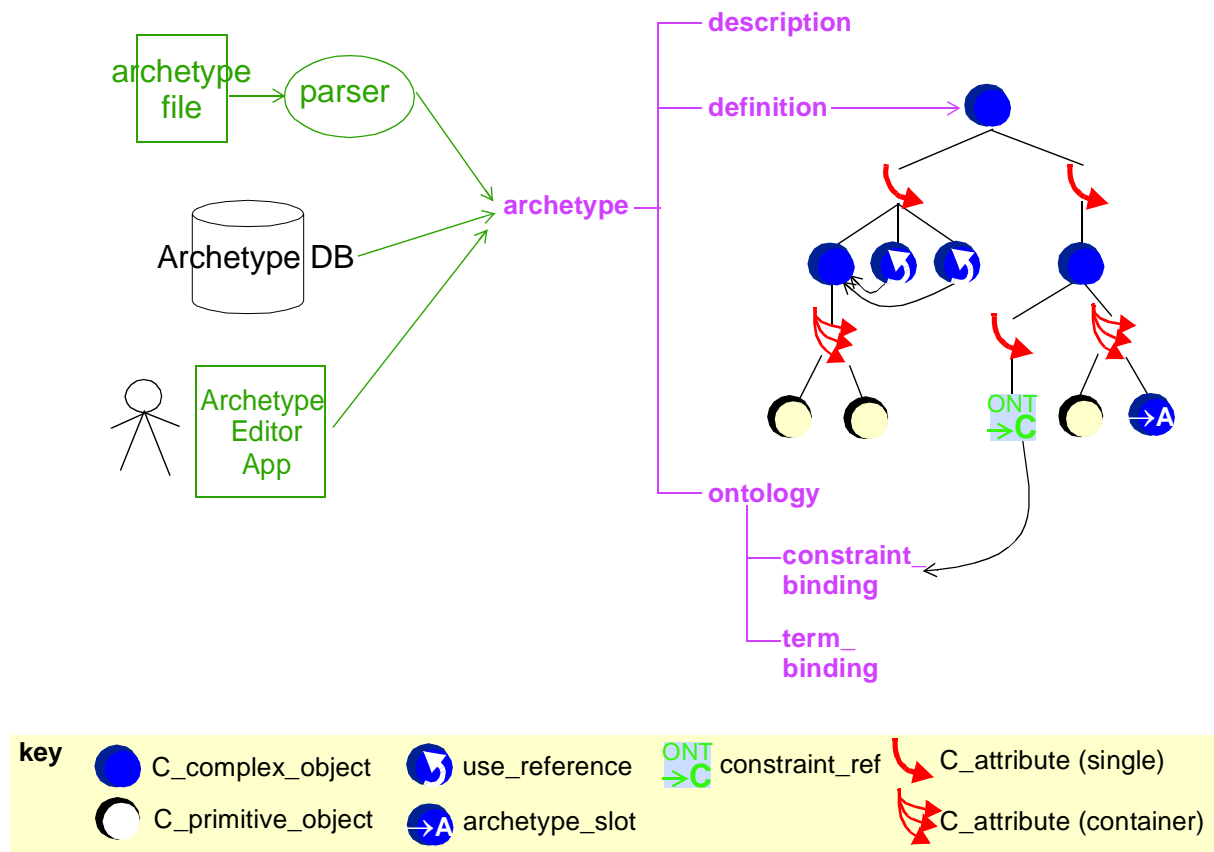
- ARCHETYPE_ID
- HIER_OBJECT_ID
- TERMINOLOGY_ID
- CODE_PHRASE
- DV_CODED_TEXT

The last of these can be found in the [openEHR RM.Data_types.Text](#) package, and is used only to represent coded term values in the model. The remaining *_ID types can be found in the [openEHR RM.Common.Identification](#) package.

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.

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

**FIGURE 3** Archetype Parsing Process

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 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.

2.4 The Archetype Package

2.4.1 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 consists of *identifying information*, a *description* - its meta-data, a *definition* - expressed in terms of constraints on instances of an object model, and an *ontology*. In the figure, identifying information and lifecycle state are part of the `ARCHETYPE` class. The archetype description is shown separated into revision history information and descriptive information about the archetype. Revision history information is concerned with the committal of the archetype to a repository, and takes the form of a list of audit trail items, while descriptive information describes the archetype itself (regardless of whether it has been committed to a repository of any kind). The archetype definition, the 'main' part of an archetype, is an 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.

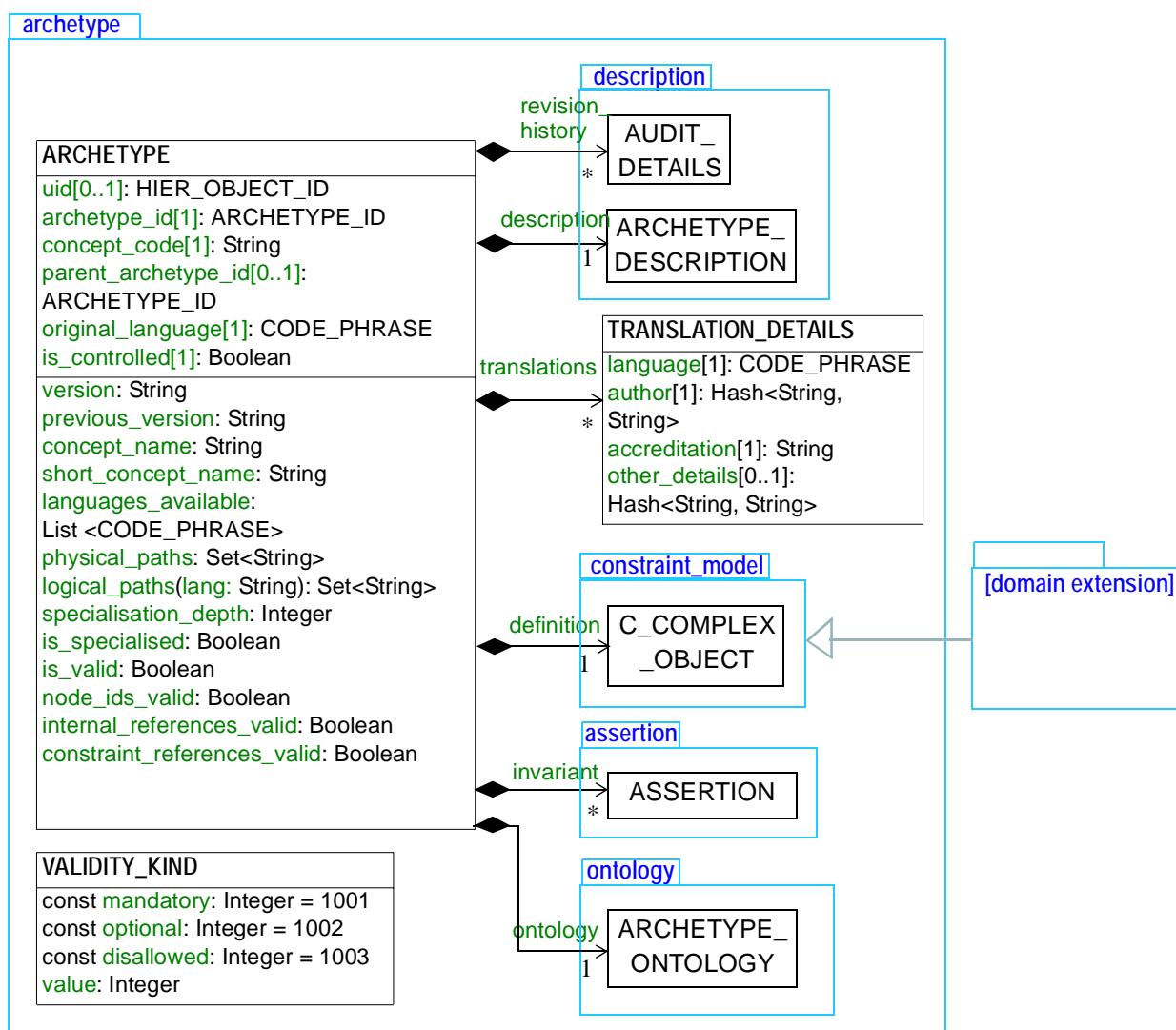


FIGURE 4 openehr.am.archetype Package

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`.

2.4.2 Natural Languages and Translation

Archetypes contain some natural language elements, including the description and ontology definitions. Every archetype is therefore created in some original language, which is recorded in the *original_language* attribute of the `ARCHETYPE` class. An archetype is translated by doing the following:

- translating every language-dependent element to the new language;
- adding a new `TRANSLATION_DETAILS` instance to `ARCHETYPE.translations`, containing details about the translator, organisation, quality assurance and so on.

The *languages_available* function provides a complete list of languages in the archetype.

2.4.3 ARCHETYPE Class

CLASS	ARCHETYPE	
Purpose	Archetype equivalent to <code>ARCHETYPED</code> class in Common reference model. Defines semantics of identification, lifecycle, versioning, composition and specialisation.	
Attributes	Signature	Meaning
	archetype_id: <code>ARCHETYPE_ID</code>	Multi-axial identifier of this archetype in archetype space.
	uid: <code>HIER_OBJECT_ID</code>	OID identifier of this archetype.
	concept_code: <code>String</code>	The normative meaning of the archetype as a whole, has the same value as the <i>concept_code</i> in the archetype ontology; corresponds to the <i>title</i> feature.
	original_language: <code>CODE_PHRASE</code>	Language in which this archetype was initially authored. Although there is no language primacy of archetypes overall, the language of original authoring is required to ensure natural language translations can preserve quality. Language is relevant in both the description and ontology sections.
	translations: <code>Hash</code> < <code>TRANSLATION_DETAILS</code> , <code>String</code> >	List of details for each natural translation made of this archetype. For each translation listed here, there must be corresponding sections in all language-dependent parts of the archetype.
	parent_archetype_id: <code>ARCHETYPE_ID</code>	Identifier of the specialisation parent of this archetype.

CLASS	ARCHETYPE	
	description: ARCHETYPE_DESCRIPTION	Description and lifecycle information of the archetype - all archetype information that is not required at runtime.
	definition: C_COMPLEX_OBJECT	Root node of this archetype
	ontology: ARCHETYPE_ONTOLOGY	The ontology of the archetype.
	revision_history: List<AUDIT_DETAILS>	The revision history of the archetype; only required if <i>is_controlled</i> = True (avoids large revision histories for informal or private editing situations).
	is_controlled: Boolean	True if this archetype is under any kind of change control (even file copying), in which case revision history is created.
Functions	Signature	Meaning
	version: String	Version of this archetype, extracted from id.
	previous_version: String	Version of predecessor archetype of this archetype, if any.
	short_concept_name: String	The short concept name of the archetype extracted from the <i>archetype_id</i> .
	concept_name (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_code</i> attribute in the archetype ontology.
	languages_available: Set<CODE_PHRASE>	Total list of languages available in this archetype, derived from <i>original_language</i> and <i>translations</i> .
	physical_paths: Set<String>	Set of language-independent paths extracted from archetype. Paths obey Xpath-like syntax and are formed from alternations of <i>C_OBJECT.node_id</i> and <i>C_ATTRIBUTE.rm_attribute_name</i> values.
	logical_paths (a_lang: String): Set<String>	Set of language-dependent paths extracted from archetype. Paths obey the same syntax as <i>physical_paths</i> , but with <i>node_ids</i> replaced by their meanings from the ontology.

CLASS	ARCHETYPE	
	is_specialised: Boolean <i>ensure</i> <i>Result implies</i> parent_archetype_id /= Void	True if this archetype is a specialisation of another.
	specialisation_depth: 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> .
	node_ids_valid: Boolean	True if every <i>node_id</i> found on a C_OBJECT node is found in <i>ontology.term_codes</i> .
	internal_references_valid: Boolean	True if every ARCHETYPE_INTERNAL_REF. <i>target_path</i> refers to a legitimate node in the archetype <i>definition</i> .
	constraint_references_valid: 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> .
	is_valid: Boolean <i>ensure</i> <i>not</i> (node_ids_valid and internal_references_valid and constraint_references_valid) implies not <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.
Invariant	<i>archetype_id_validity:</i> archetype_id /= Void <i>uid_validity:</i> uid /= Void implies not uid.is_empty <i>version_validity:</i> version /= Void and then version.is_equal(archetype_id.version_id) <i>original_language_valid:</i> original_language /= void and then language /= Void and then code_set("languages").has(original_language) <i>description_exists:</i> description /= Void <i>definition_exists:</i> definition /= Void <i>ontology_exists:</i> ontology /= Void <i>revision_history_validity:</i> is_controlled implies (revision_history /= Void and then revision_history.is_empty) <i>Specialisation_validity:</i> is_specialised implies specialisation_depth > 0	

2.4.4 TRANSLATION_DETAILS Class

CLASS	TRANSLATION_DETAILS
Purpose	Class providing details of a natural language translation.

CLASS	TRANSLATION_DETAILS	
Attributes	Signature	Meaning
	language: CODE_PHRASE	Language of translation
	author: Hash<String, String>	Translator name and other demographic details
	accreditation: String	Accreditation of translator, usually a national translator's association id
	other_details: Hash<String, String>	Any other meta-data
Invariant	<i>Validity:</i> valid_validity(value)	

2.4.5 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
	const mandatory: Integer = 1001	Constant to indicate mandatory presence of something
	const optional: Integer = 1002	Constant to indicate optional presence of something
	const disallowed: Integer = 1003	Constant to indicate disallowed presence of something
	value: Integer	Actual value
Functions	Signature	Meaning
	valid_validity (a_validity: Integer): Boolean <i>ensure</i> a_validity >= mandatory and a_validity <= disallowed	Function to test validity values.
Invariant	<i>Validity:</i> valid_validity(value)	

2.5 Archetype Description Package

To Be Determined: indicate ISO 11179 correspondence

To Be Determined: indicate CEN WG II Medical Knowledge meta-data correspondence/conformance

The archetype.description package is illustrated in FIGURE 5. What is normally considered the ‘meta-data’ of an archetype, i.e. its author, date of creation, purpose, and other descriptive items, is described by the ARCHETYPE_DESCRIPTION and ARCHETYPE_DESCRIPTION_ITEM classes. The parts of this that are in natural language, and therefore may require translated versions, are represented in instances of the ARCHETYPE_DESCRIPTION_ITEM class. Thus, if an ARCHETYPE_DESCRIPTION has more than one ARCHETYPE_DESCRIPTION_ITEM, each of these should carry exactly the same information in a different natural language.

The AUDIT_DETAILS class is concerned with the creation and modification of the archetype in a repository. Each instance of this class in an actual archetype represents one act of committal to the repository, with the attributes documenting who, when and why. Where archetypes are managed in a controlled document repository with versioning, audit information will be stored somewhere in the repository (e.g. in version control files); the revision_history within the archetype is intended to act simply as a documentary copy, or trace of the revision history information so far, for the benefit of the reader of the archetype. Given that archetypes in different places may well be managed in different kinds of repositories, having a copy of the revision history in a standardised form within the archetype enables it to be used interoperably by archetype tools.

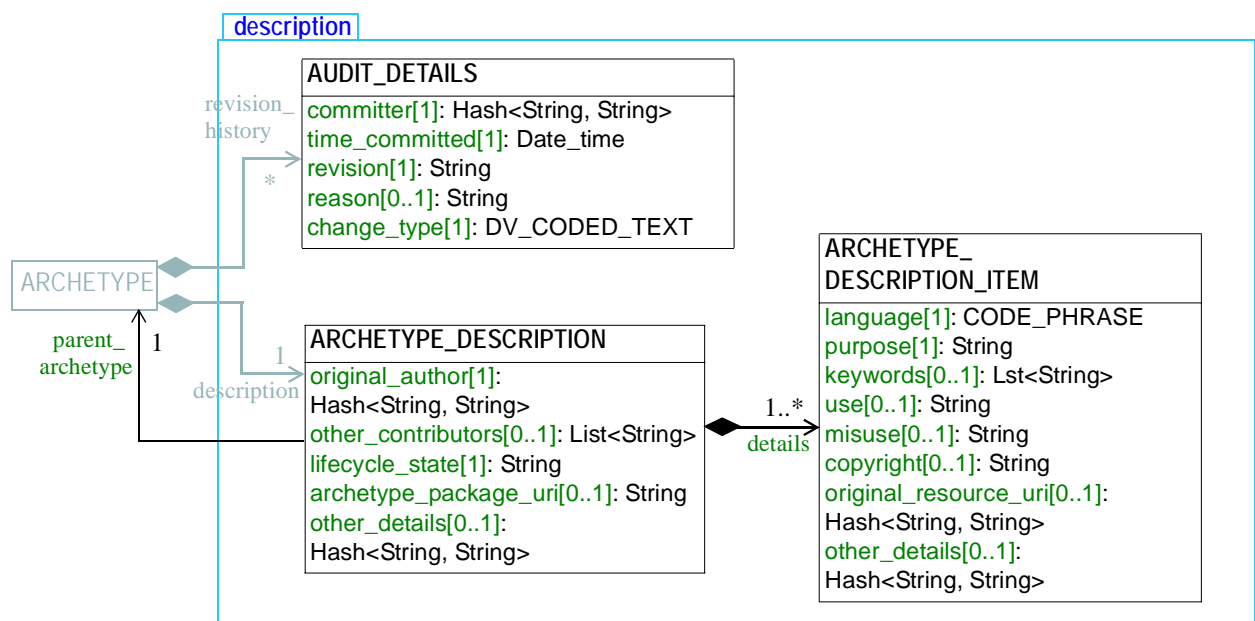


FIGURE 5 openehr.am.archetype.description Package

2.5.1 Making Changes to Archetypes

Any change to an archetype which is committed to the archetype repository causes a new addition to the *revision_history*. Some changes cause new revisions only, if they do not change the formal semantics of the archetype, for example, the addition of a new language translation. Changes to the definition section of the archetype will usually cause a new version of the archetype, i.e. a ‘new’ archetype, since version is part of the archetype identifier. The rules for which changes cause a new version and which do not are described in the *openEHR* Archetype Semantics document.

2.5.2 ARCHETYPE_DESCRIPTION Class

CLASS	ARCHETYPE_DESCRIPTION	
Purpose	Defines the descriptive meta-data of an archetype.	
Attributes	Signature	Meaning
	original_author: Hash<String, String>	Original author of this archetype, with all relevant details, including organisation.
	other_contributors: List<String>	Other contributors to the archetype, probably listed in “name <email>” form.
	lifecycle_state: String	Lifecycle state of the archetype, typically including states such as: <i>initial</i> , <i>submitted</i> , <i>experimental</i> , <i>awaiting_approval</i> , <i>approved</i> , <i>super-seded</i> , <i>obsolete</i> .
	details: List<ARCHETYPE_DESCRIPTION_ITEM>	Details of all parts of archetype description that are natural language-dependent.
	archetype_package_uri: String	URI of package to which this archetype belongs.
	other_details: Hash<String, String>	Additional non language-sensitive archetype meta-data, as a list of name/value pairs.
	parent_archetype: ARCHETYPE	Reference to owning archetype
Invariant	original_author_validity: original_author /= Void and then not original_author.is_empty details_exists: details /= Void and then not details.is_empty language_validity: details.for_all (d parent_archetype.languages_available.has(d.language)) Parent_archetype_valid: parent_archetype /= Void and then parent_archetype.description = Current	

2.5.3 ARCHETYPE_DESCRIPTION_ITEM Class

CLASS	ARCHETYPE_DESCRIPTION_ITEM	
Purpose	Language-specific detail of archetype description. When an archetype is translated for use in another language environment, each ARCHETYPE_DESCRIPTION_ITEM needs to be copied and translated into the new language.	
Attributes	Signature	Meaning

CLASS	ARCHETYPE_DESCRIPTION_ITEM	
	language: CODE_PHRASE	The localised language in which the items in this description item are written. Coded from <i>openEHR</i> Code Set “languages”.
	purpose: String	Purpose of the archetype.
	keywords: List<String>	Keywords which characterise this archetype, used e.g. for indexing and searching.
	use: String	Description of the uses of the archetype, i.e. contexts in which it could be used.
	misuse: String	Description of any misuses of the archetype, i.e. contexts in which it should not be used.
	copyright: String	Optional copyright statement for the archetype as a knowledge resource.
	original_resource_uri: Hash<String, String>	URIs of original clinical document(s) or description of which archetype is a formalisation, in the language of this description item; keyed by meaning.
	other_details: Hash<String, String>	Additional language-sensitive archetype meta-data, as a list of name/value pairs.
Invariant	<i>Language_valid:</i> language /= Void and then code_set(“languages”).has(language) <i>purpose_exists:</i> purpose /= Void and then not purpose.is_empty <i>use_valid:</i> use /= Void implies not use.is_empty <i>misuse_valid:</i> misuse /= Void implies not misuse.is_empty <i>copyright_valid:</i> copyright /= Void implies not copyright.is_empty	

2.5.4 AUDIT_DETAILS Class

CLASS	AUDIT_DETAILS	
Purpose	Revision history information for one committal of the archetype to a repository.	
Attributes	Signature	Meaning
	committer: Hash<String, String>	Identification of the author of the main content of this archetype, along with all relevant details.
	time_committed: DATE_TIME	Date/time of this change
	revision: String	Revision corresponding to this change. Various kinds of change cause only a new revision, not a version change, for example, adding a new translation of the ontology, changing meta-data, and certain changes to the archetype definition itself.
	reason: String	Natural language reason for change.
	change_type: DV_CODED_TEXT	Type of change. Coded using the <i>openEHR</i> Terminology “audit change type” group.
Invariant	committer_validity: committer /= Void and then not committer.is_empty time_committed_exists: time_committed /= Void reason_valid: reason /= Void implies not reason.is_empty revision_valid: revision /= Void and then not revision.is_empty Change_type_exists: change_type /= Void and then terminology(“openehr”).codes_for_group_name(“audit change type”, “en”).has(change_type.defining_code)	

2.6 Constraint Model Package

2.6.1 Overview

FIGURE 6 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’.

One way to comprehend the model is via the following statements that can be made about it.

- Any 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 type (recorded in the attribute *rm_type_name*) in a reference model, and which is larger than a simple instance of a primitive type such as String or Integer.
- A `C_COMPLEX_OBJECT` 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`.
- The key subtypes of `C_OBJECT`, are `C_COMPLEX_OBJECT` (described above) `C_PRIMITIVE_OBJECT` (constraints on instances of primitive types such as String, Integer, Boolean and Date).
- The other subtypes of `C_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.
- All nodes in an archetype constraint structure are instances of the supertype `ARCHETYPE_CONSTRAINT`, which provides a number of important common features to all nodes.

2.6.2 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.

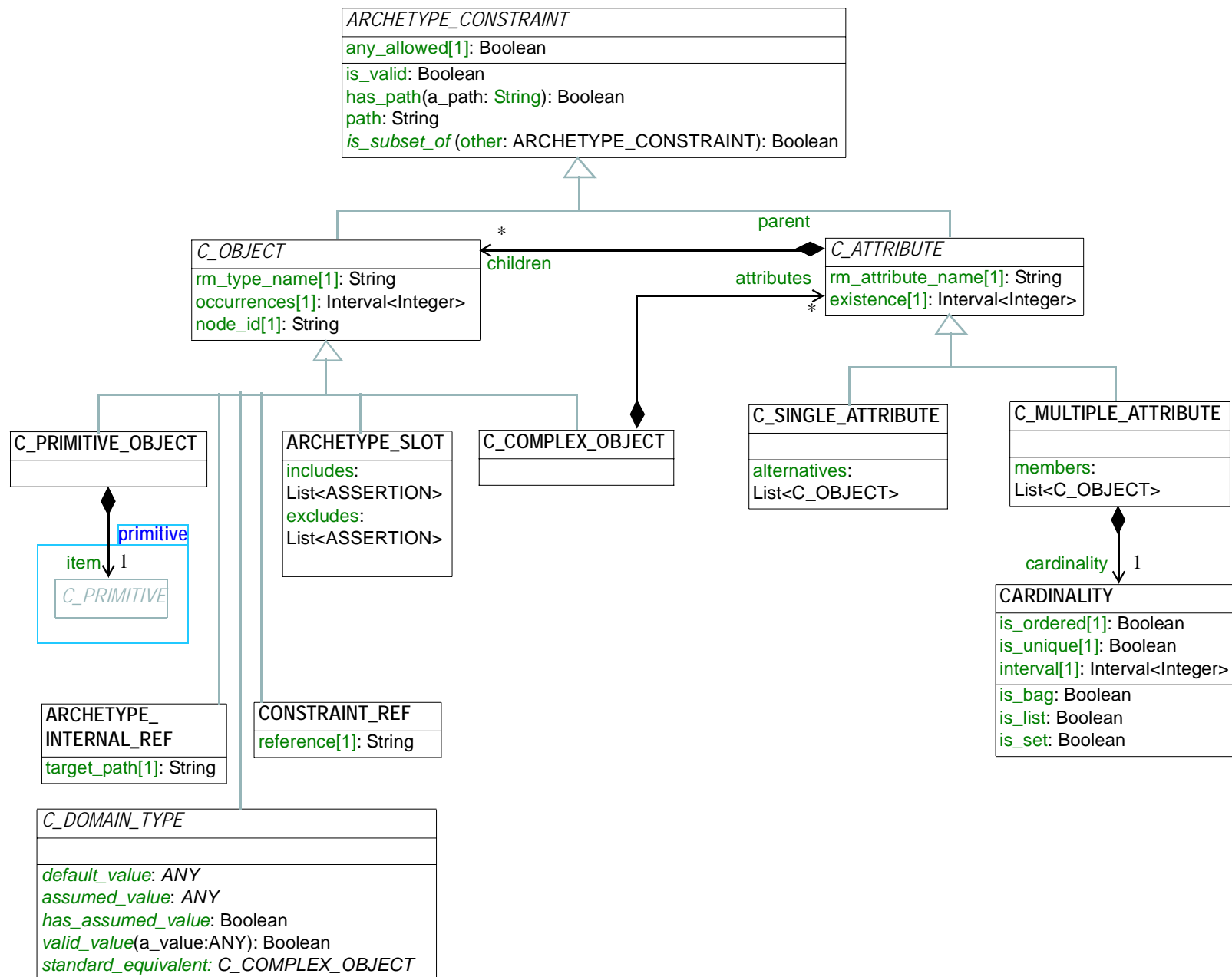


FIGURE 6 openehr.am.archetype.constraint_model Package

All Node Types

A small number of properties is defined for all node types. The *any_allowed* flag set 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. 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.

Attribute Nodes

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

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

Multiply-valued attributes (such as `Person.contacts: List<Contact>`) are constrained by an instance of `C_MULTIPLE_ATTRIBUTE`, which allows multiple *co-existing* member objects of the container value of the attribute to be constrained, along with a cardinality constraint, describing ordering and uniqueness of the container. FIGURE 7 illustrates the two possibilities.

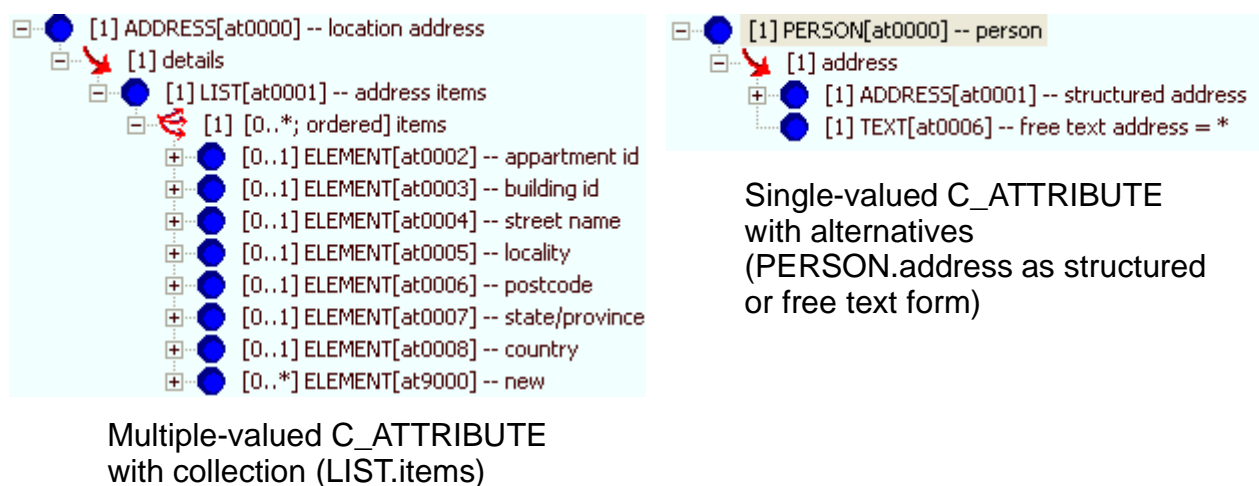


FIGURE 7 Single and Multiple-valued C_ATTRIBUTES

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. Quite simply, 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.

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.

Constraint References

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 (such as an ontology or 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

To Be Determined: whether this approach should be used instead:

To Be Determined: The other problem is that the `CONSTRAINT_REF` could probably stand for a `C_PRIMITIVE_OBJECT`, such as a plain `C_string` or `C_integer` (which can still be a little bit complex - e.g. a `Interval<Integer>`).

To Be Determined: Following on logically from this, a more correct modelling possibility might be to introduce a common parent for `C_COMPLEX_OBJECT` and `C_PRIMITIVE_OBJECT` which corresponds to the idea of `C_OBJECTS` 'defined by value in the archetype' (as opposed to defined elsewhere, like in binding query to a terminology, or else in an entirely different archetype, which is what the slot gives you). If I introduced such a type, then `CONSTRAINT_REF` should have a property called something like 'proxy_for' or 'equivalent', which points to this new type, allowing it to stand for either a primitive or complex constraint structure. Now that you have driven me to think of that, I see it as being quite a good improvement - maybe Andrew will have feedback on it.

To Be Determined: Another parent is probably needed for `C_DOMAIN_TYPE` and `C_PRIMITIVE`, to coalesce their leaf attributes `assumed_value` etc. This would probably require merging `C_PRIMITIVE_OBJECT` and `C_PRIMITIVE`.

Assertions

The `C_ATTRIBUTE` and subtypes of `C_OBJECT` enable constraints to be expressed in a structural fashion. 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 be used to state constraints on parts of an object. They are not needed to state constraints on a single attribute (since this can be done with an appropriate `C_ATTRIBUTE`), but are necessary to state constraints on more than one attribute, such as a constraint 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).

To Be Continued: give decent example

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.

Node_id and Paths

The *node_id* attribute in the class `C_OBJECT`, inherited to 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 is what 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*.

Domain-specific Extensions

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.

Assumed Values

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 or ‘assumed’ value. The archetype allows this 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.

2.6.3 ARCHETYPE_CONSTRAINT Class

CLASS	ARCHETYPE_CONSTRAINT (<i>abstract</i>)	
Purpose	Archetype equivalent to LOCATABLE class in <i>openEHR</i> Common reference model. Defines common constraints for any inheritor of LOCATABLE in any reference model.	
Attributes	Signature	Meaning
	any_allowed: Boolean	True if any instance value of this type is considered valid in this archetype. Allows completely 'open' constraints to be expressed without requiring any further structure.
Functions	Signature	Meaning
	is_valid: Boolean	True if this node (and all its sub-nodes) is a valid archetype node for its type. This function should be implemented by each subtype to perform semantic validation of itself, and then call the is_valid function in any sub-parts, and generate the result appropriately.
	path: String	Path of this node relative to root of archetype.
	has_path (a_path: String): Boolean <i>require</i> a_path /= Void	True if the relative path <i>a_path</i> exists at this node.
	is_subset_of (other: ARCHETYPE_CONSTRAINT): Boolean <i>require</i> other /= Void	True if constraints represented by <i>other</i> are narrower than this node.
Invariant	<i>path_exists</i> : path /= Void	

To Be Continued: Note: *is_subset_of* is relatively easy to evaluate for structures, but acNNNN constraints and assertions will be harder, and will most likely require evaluation in a subsumptive environment like OWL.

2.6.4 C_ATTRIBUTE Class

CLASS	C_ATTRIBUTE(<i>abstract</i>)	
Purpose	Abstract model of constraint on any kind of attribute node.	
Attributes	Signature	Meaning

CLASS	C_ATTRIBUTE(<i>abstract</i>)	
	rm_attribute_name: String	Reference model attribute within the enclosing type represented by a C_OBJECT.
	existence: 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).
	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.
Invariant	<i>Rm_attribute_name_valid:</i> rm_attribute_name /= Void and then not rm_attribute_name.is_empty <i>Existence_set:</i> existence /= Void and then (existence.lower >= 0 and existence.upper <= 1) <i>Children_validity:</i> any_allowed xor children /= Void	

2.6.5 C_SINGLE_ATTRIBUTE Class

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

2.6.6 C_MULTIPLE_ATTRIBUTE Class

CLASS	C_MULTIPLE_ATTRIBUTE	
Purpose	Abstract model of constraint on any kind of attribute node.	
Attributes	Signature	Meaning
	cardinality: CARDINALITY	Cardinality of this attribute constraint, if it constraints a container attribute.
Functions	Signature	Meaning

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

2.6.7 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.	
Attributes	Signature	Meaning
	is_ordered: Boolean	True if the members of the container attribute to which this cardinality refers are ordered.
	is_unique: Boolean	True if the members of the container attribute to which this cardinality refers are unique.
	interval: Interval<Integer>	The interval of this cardinality.
Attributes	Signature	Meaning
	is_bag: Boolean <i>ensure</i> <i>Result</i> = not is_ordered and not is_unique	True if the semantics of this cardinality represent a set, i.e. unordered, unique membership.
	is_list: Boolean <i>ensure</i> <i>Result</i> = is_ordered and not is_unique	True if the semantics of this cardinality represent a list, i.e. ordered, non-unique membership.
	is_set: Boolean <i>ensure</i> <i>Result</i> = not is_ordered and is_unique	True if the semantics of this cardinality represent a bag, i.e. unordered, non-unique membership.
Invariant	Validity: not interval.lower_unbounded	

2.6.8 C_OBJECT Class

CLASS	C_OBJECT (abstract)	
Purpose	Abstract model of constraint on any kind of object node.	
Attributes	Signature	Meaning
	rm_type_name: String	Reference model type that this node corresponds to.
	occurrences: 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).
	node_id: 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.
	parent: C_ATTRIBUTE	C_ATTRIBUTE that owns this C_OBJECT.
Invariant	<i>rm_type_name_valid</i> : rm_type_name /= Void and then not rm_type_name.is_empty <i>node_id_valid</i> : node_id /= Void and then not node_id.is_empty	

2.6.9 C_COMPLEX_OBJECT Class

CLASS	C_COMPLEX_OBJECT	
Purpose	Constraint on complex objects, i.e. any object that consists of other object constraints.	
Inherit	C_OBJECT	
Attributes	Signature	Meaning
	attributes: Set<C_ATTRIBUTE>	List of constraints on attributes of the reference model type represented by this object.
	invariants: Set<ASSERTION>	Invariant statements about this object. Statements are expressed in first order predicate logic, and usually refer to at least two attributes.
Invariant	<i>attributes_valid</i> : any_allowed xor (attributes /= Void and not attributes.is_empty) <i>invariant_consistency</i> : any_allowed implies invariants = Void <i>invariants_valid</i> : invariants /= Void implies not invariants.is_empty	

2.6.10 ARCHETYPE_SLOT Class

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

2.6.11 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.	
Inherit	C_OBJECT	
Attributes	Signature	Meaning
	target_path: String	Reference to an object node using archetype path notation.
Invariant	<i>Consistency:</i> not any_allowed <i>target_path_valid:</i> target_path /= Void and then not target_path.is_empty -- and then ultimate_root.has_path(target_path)	

2.6.12 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_OBJECT	
Attributes	Signature	Meaning

CLASS	CONSTRAINT_REF	
	reference: String	Reference to a constraint in the archetype local ontology.
Invariant	<i>Consistency:</i> not any_allowed <i>reference_valid:</i> reference /= Void and then not reference.is_empty and then archetype.ontology.has_constraint(reference)	

2.6.13 C_PRIMITIVE_OBJECT Class

CLASS	C_PRIMITIVE_OBJECT	
Purpose	Constraint on a primitive type.	
Inherit	C_OBJECT	
Attributes	Signature	Meaning
	item: C_PRIMITIVE	Object actually defining the constraint.
Invariant	<i>item_exists:</i> any_allowed xor item /= Void	

2.6.14 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_OBJECT	
Abstract	Signature	Meaning
	default_value: ANY	Generate a default value from this constraint object
	has_assumed_value: Boolean	True if there is an assumed value
	assumed_value: <i>like</i> default_value	Value to be assumed if none sent in data
	valid_value (a_value: like 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.
	standard_representation: C_COMPLEX_OBJECT	Standard form of constraint
Invariant	<i>Assumed_value_valid:</i> valid_value(assumed_value)	

2.7 The Assertion Package

2.7.1 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 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 2.9 on page 49.

2.7.2 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. The assertion package is illustrated below in FIGURE 8.

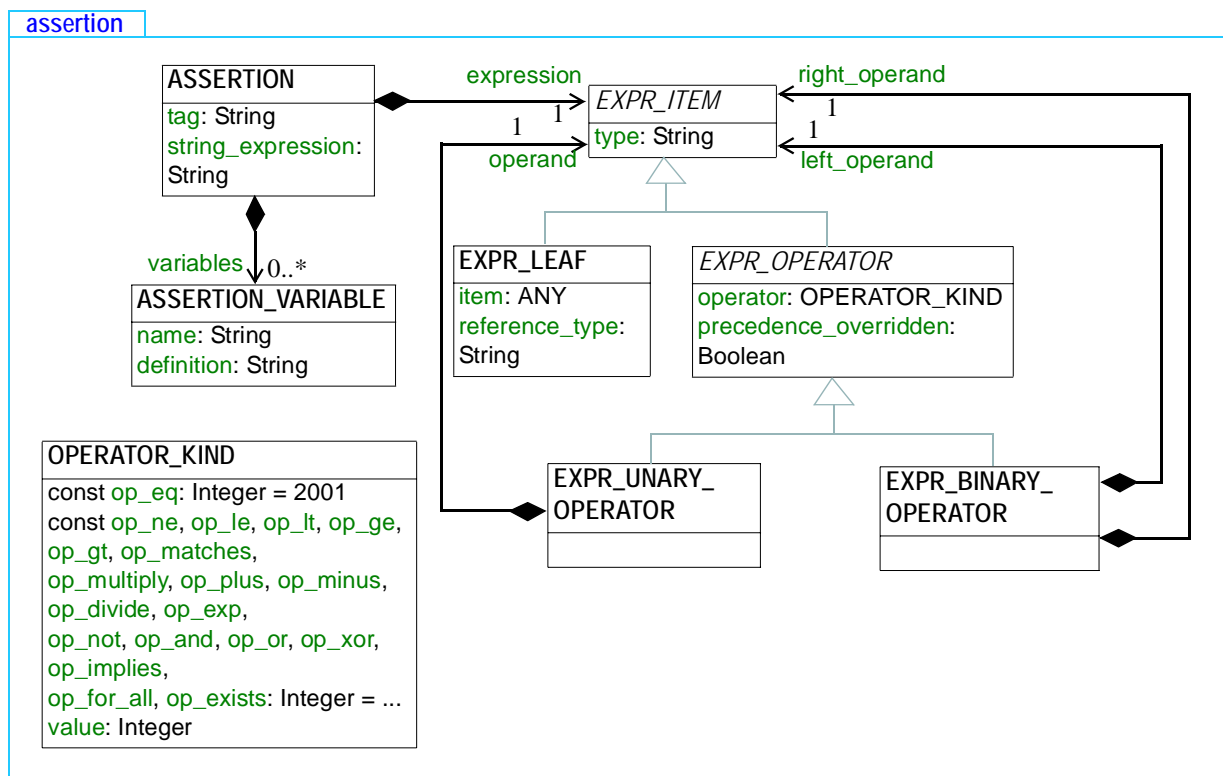


FIGURE 8 The openehr.am.archetype.assertion package

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

2.7.3 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.	
Attributes	Signature	Meaning
	tag: String	Expression tag, used for differentiating multiple assertions.
	expression: EXPR_ITEM	Root of expression tree.
	string_expression: String	String form of expression, in case an expression evaluator taking String expressions is used for evaluation.
	variables: List<ASSERTION_VARIABLE>	Definitions of variables used in the assertion expression.
Invariant	<i>Tag_valid:</i> tag /= Void implies not tag.is_empty <i>Expression_valid:</i> expression /= Void and then expression.type.is_equal("BOOLEAN")	

2.7.4 EXPR_ITEM Class

CLASS	EXPR_ITEM (abstract)	
Purpose	Abstract parent of all expression tree items.	
Attributes	Signature	Meaning
	type: String	Type name of this item. 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	<i>Type_valid:</i> type /= Void and then not type.is_empty	

2.7.5 EXPR_LEAF Class

CLASS	EXPR_LEAF	
Purpose	Expression tree leaf item	
Inherit	EXPR_ITEM	
Attributes	Signature	Meaning
	item: ANY	The value referred to; a manifest constant, an attribute path, or a C_PRIMITIVE. [Future: possibly function names as well, even if not constrained in the archetype - as long as they are in the reference model].
	reference_type: String	Type of reference: “constant”, “attribute”, “function”
Invariant	<i>Item_valid:</i> item /= Void	

2.7.6 EXPR_OPERATOR Class

CLASS	EXPR_OPERATOR (<i>abstract</i>)	
Purpose	Abstract parent of operator types.	
Inherit	EXPR_ITEM	
Attributes	Signature	Meaning
	operator: OPERATOR_KIND	Code of operator.
	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		

2.7.7 EXPR_UNARY_OPERATOR Class

CLASS	EXPR_UNARY_OPERATOR	
Purpose	Unary operator expression node.	
Inherit	EXPR_OPERATOR	

CLASS	EXPR_UNARY_OPERATOR	
Attributes	Signature	Meaning
	operand: EXPR_ITEM	Operand node.
Invariant	<i>operand_valid</i> : operand /= Void	

2.7.8 EXPR_BINARY_OPERATOR Class

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

2.7.9 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 '<>')
	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 <i>ensure</i> an_op >= op_eq and an_op <= op_exp	Function to test operator values.
Invariant	Validity : valid_operator(value)	

2.8 The Primitive Package

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

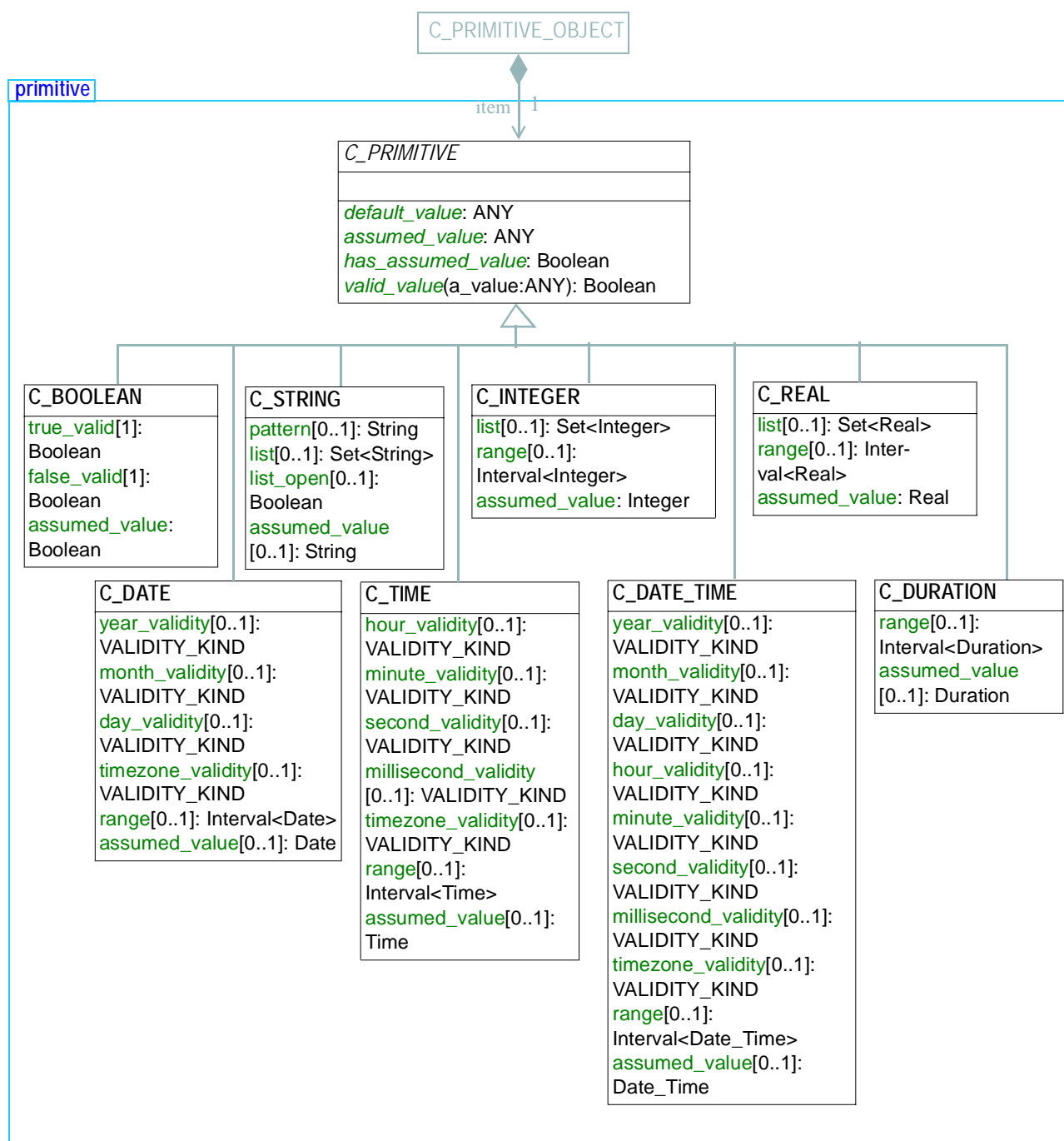


FIGURE 9 The openehr.am.archetype.primitive Package

Action: add State primitive type

2.8.1 C_PRIMITIVE Class

CLASS	C_PRIMITIVE (abstract)	
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.	
Abstract	Signature	Meaning
	default_value: ANY	Generate a default value from this constraint object
	has_assumed_value: Boolean	True if there is an assumed value
	assumed_value: <i>like</i> default_value	Value to be assumed if none sent in data
	valid_value (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.
	standard_representation: C_COMPLEX_OBJECT	Standard form of constraint
Invariant	<i>Assumed_value_valid:</i> valid_value(assumed_value)	

2.8.2 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
	true_valid: Boolean	True if the value True is allowed
	false_valid: Boolean	True if the value False is allowed
	assumed_value: 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 <i>or</i> false_valid <i>Default_value_consistency</i> : default_value.value <i>and</i> true_valid <i>or else not</i> default_value.value <i>and</i> false_valid

2.8.3 C_STRING Class

CLASS	C_STRING	
Purpose	Constraint on instances of STRING.	
Inherit	C_PRIMITIVE	
Attributes	Signature	Meaning
	pattern : String	Regular expression pattern for proposed instances of String to match.
	list : Set<String>	Set of Strings specifying constraint
	list_open : Boolean	True if the list is being used to specify the constraint but is not considered exhaustive.
	assumed_value : 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 xor list /= Void <i>pattern_exists</i> : pattern /= Void implies not pattern.is_empty	

To Be Continued: TB: is list_open really useful? If the list is open, then what's the difference from 'any_allowed'

2.8.4 C_INTEGER Class

CLASS	C_INTEGER	
Purpose	Constraint on instances of Integer.	
Inherit	C_PRIMITIVE	
Attributes	Signature	Meaning
	list : Set<Integer>	Set of Integers specifying constraint
	range : Interval<Integer>	Range of Integers specifying constraint
	assumed_value : Integer	The value to assume if this item is not included in data, due to being part of an optional structure.

CLASS	C_INTEGER
Invariant	<i>Consistency:</i> list /= Void <i>xor</i> range /= Void

2.8.5 C_REAL Class

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

2.8.6 C_DATE Class

CLASS	C_DATE	
Purpose	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.	
Use	Date ranges are probably only useful for historical dates.	
Inherit	C_PRIMITIVE	
Attributes	Signature	Meaning
	month_validity: VALIDITY_KIND	Validity of month in constrained date.
	day_validity: VALIDITY_KIND	Validity of day in constrained date.
	timezone_validity: VALIDITY_KIND	Validity of timezone in constrained date.
	range: Interval<Date>	Interval of Dates specifying constraint
	assumed_value: Date	The value to assume if this item is not included in data, due to being part of an optional structure.

CLASS	C_DATE	
Functions	Signature	Meaning
	validity_is_range: 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>Month_validity_optional: month_validity = {VALIDITY_KIND}.optional implies (day_validity = {VALIDITY_KIND}.optional or day_validity = {VALIDITY_KIND}.disallowed)</p> <p>Month_validity_disallowed: month_validity = {VALIDITY_KIND}.disallowed implies day_validity = {VALIDITY_KIND}.disallowed</p> <p>Validity_is_range: validity_is_range = (range /= Void)</p>	

2.8.7 C_TIME Class

CLASS	C_TIME	
Purpose	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.	
Inherit	C_PRIMITIVE	
Attributes	Signature	Meaning
	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.
	range: Interval<Time>	Interval of Times specifying constraint
	assumed_value: Time	The value to assume if this item is not included in data, due to being part of an optional structure.
Functions	Signature	Meaning
	validity_is_range: 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_TIME
Invariant	<p>Minute_validity_optional: minute_validity = {VALIDITY_KIND}.optional implies (second_validity = {VALIDITY_KIND}.optional or second_validity = {VALIDITY_KIND}.disallowed)</p> <p>Minute_validity_disallowed: minute_validity = {VALIDITY_KIND}.disallowed implies second_validity = {VALIDITY_KIND}.disallowed</p> <p>Second_validity_optional: second_validity = {VALIDITY_KIND}.optional implies (millisecond_validity = {VALIDITY_KIND}.optional or millisecond_validity = {VALIDITY_KIND}.disallowed)</p> <p>Second_validity_disallowed: second_validity = {VALIDITY_KIND}.disallowed implies millisecond_validity = {VALIDITY_KIND}.disallowed</p> <p>Validity_is_range: validity_is_range = (range /= Void)</p>

2.8.8 C_DATE_TIME Class

CLASS	C_DATE_TIME	
Purpose	Constraint on instances of Date_Time. re is no validity flag for 'year', since it must always be by definition mandatory in order to have a sensible date/time at all.	
Inherit	C_PRIMITIVE	
Attributes	Signature	Meaning
	month_validity: VALIDITY_KIND	Validity of month in constrained date.
	day_validity: VALIDITY_KIND	Validity of day in constrained date.
	hour_validity: VALIDITY_KIND	Validity of hour in constrained time.
	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.
	range: Interval<Date_Time>	Range of Date_times specifying constraint
	assumed_value: Date_Time	The value to assume if this item is not included in data, due to being part of an optional structure.

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

2.8.9 C_DURATION Class

CLASS	C_DURATION	
Purpose	Constraint on instances of Duration.	
Inherit	C_PRIMITIVE	
Attributes	Signature	Meaning
	range: Interval<Duration>	Range of Durations specifying constraint
	assumed_value: Duration	The value to assume if this item is not included in data, due to being part of an optional structure.
Invariant	<i>Range_valid:</i> range /= Void	

2.9 Ontology Package

2.9.1 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.

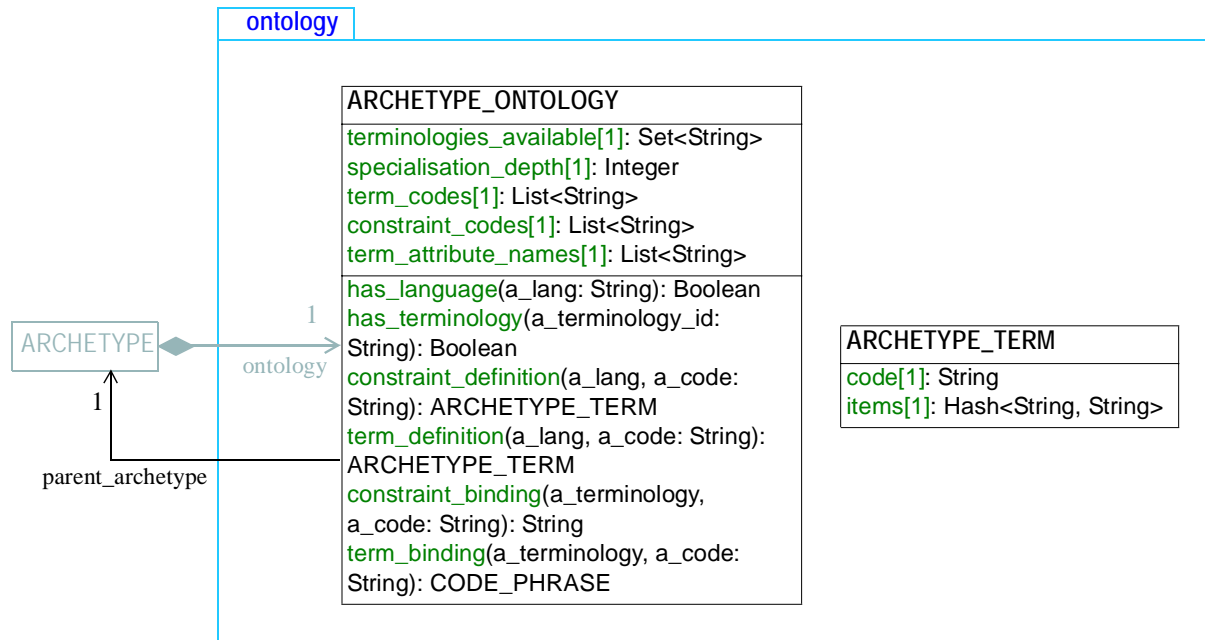


FIGURE 10 openehr.am.archetype.ontology Package

An archetype ontology consists essentially 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.

2.9.2 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 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.

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.

2.9.3 ARCHETYPE_ONTOLOGY Class

CLASS	ARCHETYPE_ONTOLOGY	
Purpose	Local ontology of an archetype.	
Attributes	Signature	Meaning
	terminologies_available: Set<String>	List of terminologies to which term or constraint bindings exist in this terminology.
	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.
	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 <i>node_ids</i> on <code>C_OBJECT</code> descendants. There may be an extra one, if a different term is used as the overall archetype concept_code from that used as the node_id of the outermost <code>C_OBJECT</code> in the definition part.

CLASS	ARCHETYPE_ONTOLOGY	
	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 <i>CONSTRAINT_REF.reference</i> values in the archetype definition.
	term_attribute_names: List<String>	List of ‘attribute’ names in ontology terms, typically includes ‘text’, ‘description’, ‘provenance’ etc.
	parent_archetype: ARCHETYPE	Archetype which owns this ontology.
Functions	Signature	Meaning
	has_language (a_lang: String): Boolean	True if language ‘a_lang’ is present in archetype ontology.
	has_terminology (a_terminology_id: String): Boolean <i>require</i> has_terminology(a_terminology_id)	True if terminology ‘a_terminology’ is present in archetype ontology.
	term_definition (a_lang, a_code: String): ARCHETYPE_TERM <i>require</i> has_language(a_lang) term_codes.has(a_code)	Term definition for a code, in a specified language.
	constraint_definition (a_lang, a_code: String): ARCHETYPE_TERM <i>require</i> has_language(a_lang) constraint_codes.has(a_code)	Constraint definition for a code, in a specified language.
	term_binding (a_terminology_id, a_code: String): CODE_PHRASE <i>require</i> has_terminology(a_terminology_id) term_codes.has(a_code)	Binding of term corresponding to <i>a_code</i> in target external terminology <i>a_terminology_id</i> as a CODE_PHRASE.

CLASS	ARCHETYPE_ONTOLOGY	
	constraint_binding (a_terminology_id, a_code: String): String <i>require</i> has_terminology(a_terminology_id) constraint_codes.has(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.
Invariant	<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 and then term_attribute_names.has("text") and term_attribute_names.has("description") <i>concept_code_valid</i> : term_codes.has (concept_code) <i>Parent_archetype_valid</i> : parent_archetype /= Void and then parent_archetype.description = Current	

2.9.4 ARCHETYPE_TERM Class

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

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.

A.2 Scientific/Clinical Computing Types

FIGURE 11 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.

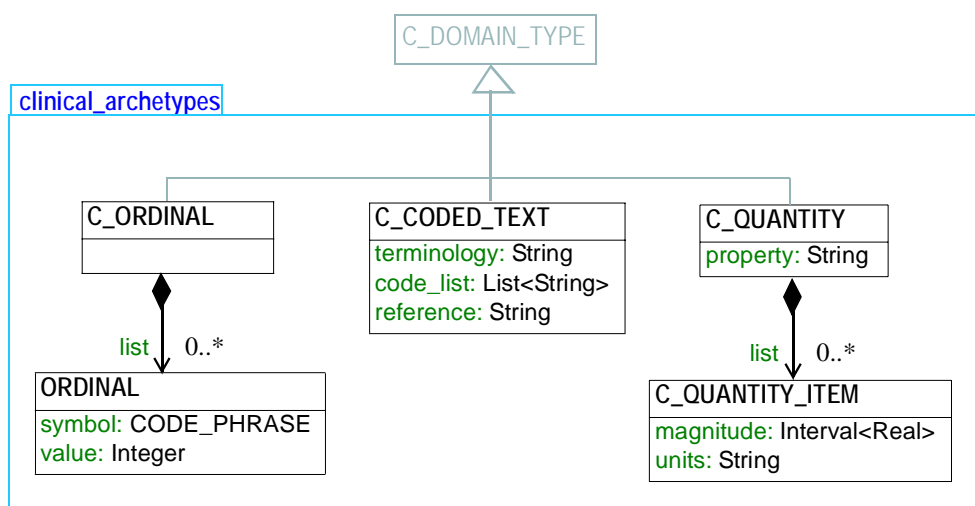


FIGURE 11 Example Domain-specific Package

B Using Archetypes with Diverse Reference Models

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)

B.2.4 HL7v3 RIM

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END OF DOCUMENT