



The *openEHR* Archetype Model
Archetype Definition Language
Version 1 (ADL)

Editors: {T Beale, S Heard}¹

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0.9	Rewritten with sections on cADL and dDL.	T Beale	28 July 2003
0.8.1	Added basic type constraints, re-arranged sections.	T Beale	15 July 2003
0.8	Initial Writing	T Beale	10 July 2003

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1 Introduction

1.1 Purpose

This document describes the design basis and syntax of the Archetype Definition Language (ADL). It is intended for software developers, technically-oriented domain specialists and subject matter experts (SMEs). Although ADL is primarily intended to be read and written by tools, it is quite readable by humans and ADL archetypes can be hand-edited using a normal text editor.

The intended audience includes:

- Standards bodies producing health informatics standards;
- Software development organisations using *openEHR*;
- Academic groups using *openEHR*;
- The open source healthcare community;
- Medical informaticians and clinicians interested in health information;
- Health data managers.

1.2 Related Documents

Prerequisite documents for reading this document include:

- The *openEHR* Architecture Overview

Related documents include:

- The *openEHR* Archetype Object Model (AOM)
- 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/adl.pdf>. New versions are announced on openehr-announce@openehr.org.

1.5 Peer review

Known omissions or questions are indicated in the text with a “to be determined” paragraph, as follows:

TBD_1: (example To Be Determined paragraph)

Areas where more analysis or explanation is required are indicated with “to be continued” paragraphs like the following:

To Be Continued: more work required

Reviewers are encouraged to comment on and/or advise on these paragraphs as well as the main content. Please send requests for information to info@openEHR.org. Feedback should preferably be provided on the mailing list openehr-technical@openehr.org, or by private email.

1.6 Conformance

Conformance of a data or software artifact to an *openEHR* Reference Model specification is determined by a formal test of that artifact against the relevant *openEHR* Implementation Technology Specification(s) (ITSs), such as an IDL interface or an XML-schema. Since ITSs are formal, automated derivations from the Reference Model, ITS conformance indicates RM conformance.

2 Overview

2.1 What is ADL?

Archetype Definition Language (ADL) is a formal language for expressing archetypes, which are constraint-based models of domain entities, or what some might call “structured business rules”. The archetype concept is described by Beale [1], [2]. The *openEHR* Archetype Object Model [3] describes the definitive semantic model of archetypes, in the form of an object model. The ADL syntax is one possible serialisation of an archetype.

The *openEHR* archetype framework is described in terms of Archetype Definitions and Principles [6] and an Archetype System [7]. Other semantic formalisms which were considered in the course of archetype, and some which remain relevant are described in detailed in section 11 on page 109.

ADL uses three other syntaxes, cADL (constraint form of ADL), dADL (data definition form of ADL), and a version of first-order predicate logic (FOPL), to describe constraints on data which are instances of some information model (e.g. expressed in UML). It is most useful when very generic information models are used for describing the data in a system, for example, where the logical concepts `PATIENT`, `DOCTOR` and `HOSPITAL` might all be represented using a small number of classes such as `PARTY` and `ADDRESS`. In such cases, archetypes are used to constrain the *valid* structures of instances of these generic classes to represent the desired domain concepts. In this way future-proof information systems can be built - relatively simple information models and database schemas can be defined, and archetypes supply the semantic modelling, completely outside the software. ADL can thus be used to write archetypes for any domain where formal object model(s) exist which describe data instances.

When archetypes are used at runtime in particular contexts, they are *composed* into larger constraint structures, with local or specialist constraints added, via the use of *templates*. The formalism of templates is dADL. Archetypes can be *specialised* by creating an archetypes that reference existing archetypes as parents; such archetypes can only make certain changes while remaining compatible with the parent.

Another major function of archetypes is to connect information structures to formal terminologies. Archetypes are language-neutral, and can be authored in and translated into any language.

Finally, archetypes are completely path-addressable in a manner similar to XML data, using path expressions that are directly convertible to Xpath expressions.

2.1.1 Structure

Archetypes expressed in ADL resemble programming language files, and have a defined syntax. ADL itself is a very simple “glue” syntax, which uses two other syntaxes for expressing structured constraints and data, respectively. The cADL syntax is used to express the archetype definition, while the dADL syntax is used to express data which appears in the `language`, `description`, `ontology`, and `revision_history` sections of an ADL archetype. The top-level structure of an ADL archetype is shown in FIGURE 1.

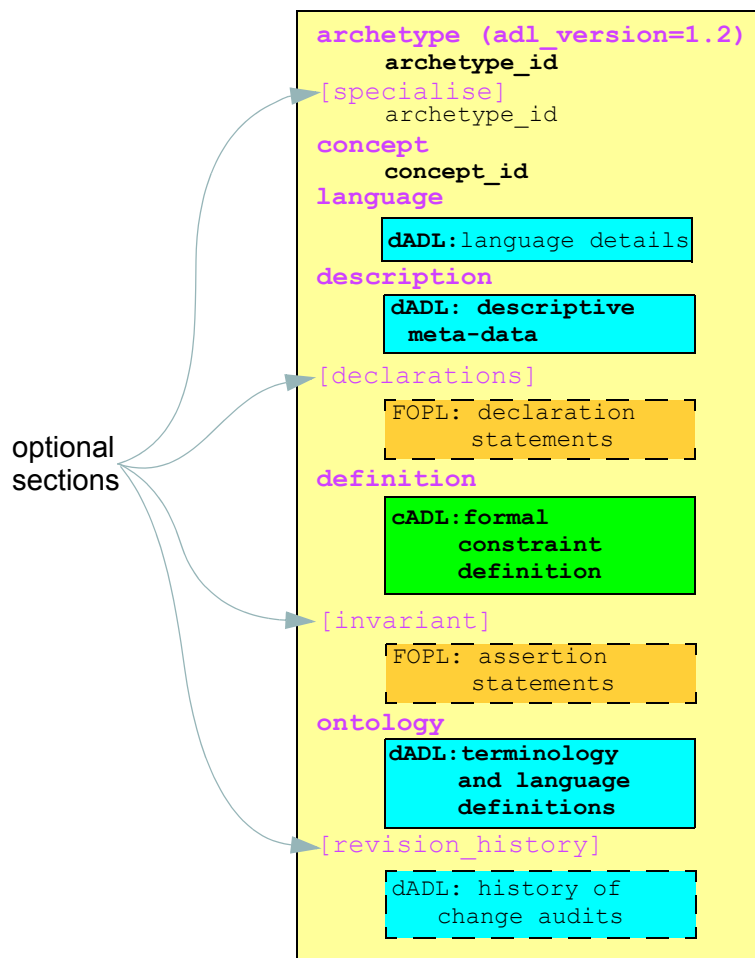


FIGURE 1 ADL Archetype Structure

This main part of this document describes dADL, cADL and ADL path syntax, before going on to describe the combined ADL syntax, archetypes and domain-specific type libraries.

2.1.2 An Example

The following is an example of a very simple archetype, giving a feel for the syntax. The main point to glean from the following is that the notion of ‘guitar’ is defined in terms of *constraints* on a *generic* model of the concept `INSTRUMENT`. The names mentioned down the left-hand side of the definition section (“INSTRUMENT”, “size” etc) are alternately class and attribute names from an object model. Each block of braces encloses a specification for some particular set of instances that conform to a specific concept, such as ‘guitar’ or ‘neck’, defined in terms of constraints on types from a generic class model. The leaf pairs of braces enclose constraints on primitive types such as Integer, String, Boolean and so on.

```

archetype (adl_version=1.2)
  adl-test-instrument.guitar.draft
  concept
    [at0000] -- guitar
  language
    original_language = <"en">
    translations = <"de", ...>
  definition
  
```

```

INSTRUMENT[at0000] matches {
  size matches {|60..120|}           -- size in cm
  date_of_manufacture matches {yyyy-mm-??} -- year & month ok
  parts cardinality matches {0..*} matches {
    PART[at0001] matches {           -- neck
      material matches {[local::at0003, -- timber
                                at0004]} -- timber or nickel alloy
    }
    PART[at0002] matches {           -- body
      material matches {[local::at0003} -- timber
    }
  }
}
}
ontology
term_definitions = <
  ["en"] = <
    items = <
      ["at0000"] = <
        text = <"guitar">;
        description = <"stringed instrument">
      >
      ["at0001"] = <
        text = <"neck">;
        description = <"neck of guitar">
      >
      ["at0002"] = <
        text = <"body">;
        description = <"body of guitar">
      >
      ["at0003"] = <
        text = <"timber">;
        description = <"straight, seasoned timber">
      >
      ["at0004"] = <
        text = <"nickel alloy">;
        description = <"frets">
      >
    >
  >
>

```

2.1.3 Semantics

As a parsable syntax, ADL has a formal relationship with structural models such as those expressed in UML, according to the scheme of FIGURE 2. Here we can see that ADL documents are parsed into a network of objects (often known as a ‘parse tree’) which are themselves defined by a formal, abstract object model (see [The openEHR Archetype Object Model \(AOM\)](#)). Such a model can in turn be re-expressed as any number of concrete models, such as in a programming language, XML-schema or OMG IDL.

While ADL syntax remains the primary abstract formalism for expressing archetypes, the AOM defines the semantics of an archetype, in particular relationships which must hold true between the parts of an archetype for it to be valid as a whole.

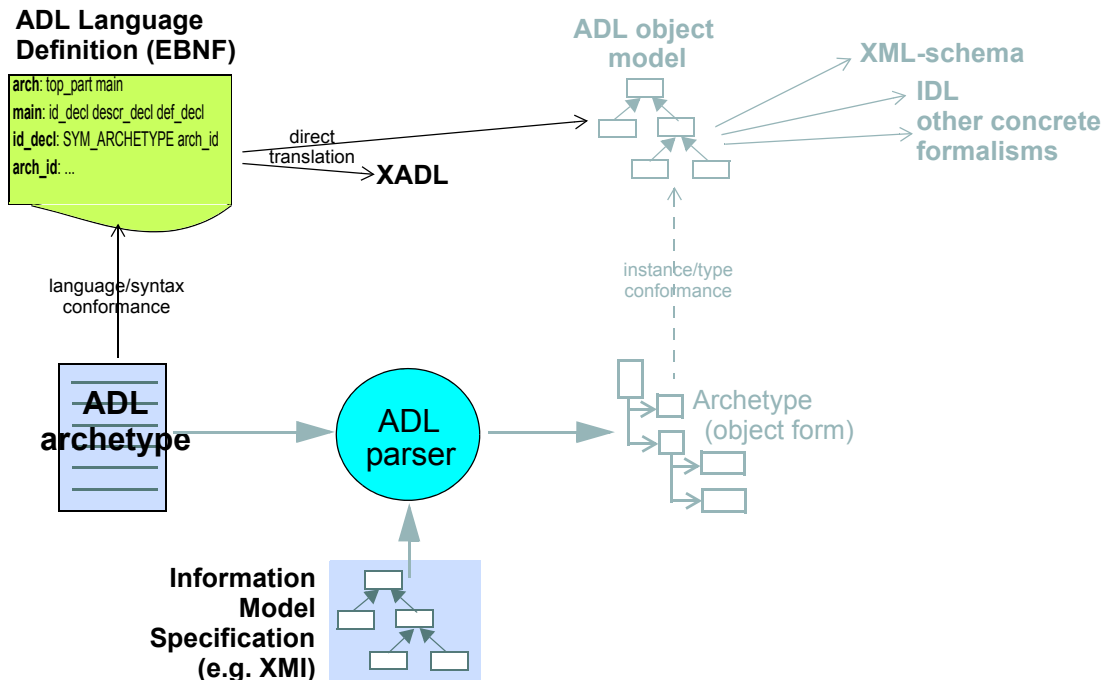


FIGURE 2 Relationship of ADL with Object Models

2.2 Computational Context

Archetypes are distinct, structured models of domain concepts, such as “blood pressure”. They sit between lower layers of knowledge resources in a computing environment, such as clinical terminologies and ontologies, and actual data in production systems. Their primary purpose is to provide a reusable, interoperable way of managing generic data so that it conforms to particular structures and semantic constraints. Consequently, they bind terminology and ontology concepts to information model semantics, in order to make statements about what valid data structures look like. ADL provides a solid formalism for expressing, building and using these entities computationally. Every ADL archetype is written with respect to a particular information model, often known as a “reference model”, if it is a shared, public specification.

Archetypes are applied to data via the use of templates, which are defined at a local level. Templates generally correspond closely to screen forms, and may be re-usable at a local or regional level. Templates do not introduce any new semantics to archetypes, they simply specify the use of particular archetypes, and default data values.

A third artifact which governs the functioning of archetypes and templates at runtime is a local *palette*, which specifies which natural language(s) and terminologies are in use in the locale. The use of a palette removes irrelevant languages and terminology bindings from archetypes, retaining only those relevant to actual use. FIGURE 3 illustrates the overall environment in which archetypes, templates, and a locale palette exist.

2.3 XML form of Archetypes

With ADL parsing tools it is possible to convert ADL to any number of forms, including various XML formats. XML instance can be generated from the object form of an archetype in memory. An XML-schema corresponding to the ADL Object Model is published at *openEHR.org*.

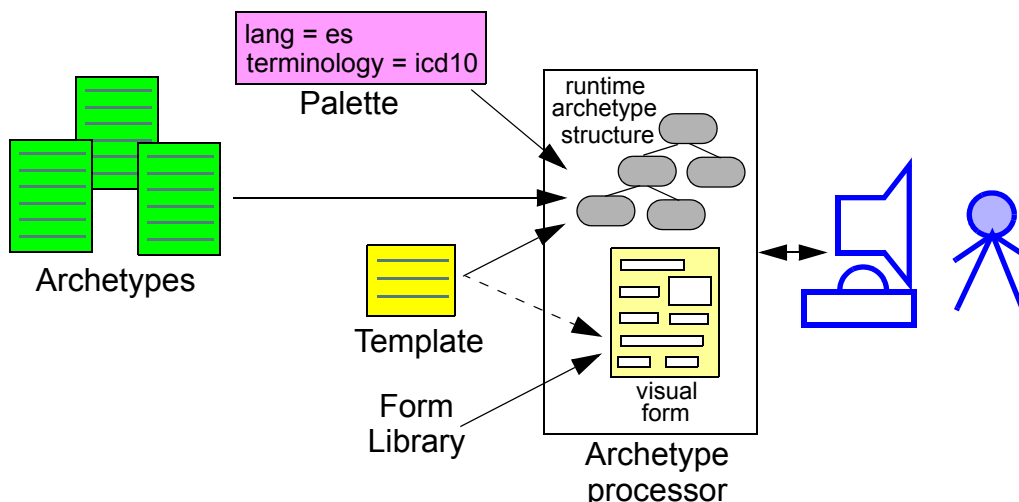


FIGURE 3 Archetypes, Templates, and Palettes

2.4 Changes From Previous Versions

For existing users of ADL or archetype development tools, the following provides a guide to the changes in the syntax.

2.4.1 Version 1.3 from Version 1.2

The specific changes made in version 1.3 of ADL are as follows.

Query syntax replaced by URI data type

In version 1.2 of ADL, it was possible to include an external query, using syntax of the form:

```
attr_name = <query("some_service", "some_query_string")>
```

This is now replaced by the use of URIs, which can express queries, for example:

```
attr_name = <http://some.service.org?some%20query%20etc>
```

No assumption is made about the URI; it need not be in the form of a query - it may be any kind of URI.

Top-level Invariant Section

In this version, invariants can only be defined in a top level block, in a way similar to object-oriented class definitions, rather than on every block in the definition section, as is the case in version 1.2 of ADL. This simplifies ADL and the Archetype Object Model, and makes an archetype more comprehensible as a “type” definition.

2.4.2 Version 1.2 from Version 1.1

ADL Version

The ADL version is now optionally (for the moment) included in the first line of the archetype, as follows.

```
archetype (adl_version=1.2)
```

It is strongly recommended that all tool implementors include this information when archetypes are saved, enabling archetypes to gradually become imprinted with their correct version, for more relia-

ble later processing. The `adl_version` indicator is likely to become mandatory in future versions of ADL.

dADL Syntax Changes

The dADL syntax for container attributes has been altered to allow paths and typing to be expressed more clearly, as part of enabling the use of Xpath-style paths. ADL 1.1 dADL had the following appearance:

```
school_schedule = <
  locations(1) = <...>
  locations(2) = <...>
  locations(3) = <...>
  subjects("philosophy:plato") = <...>
  subjects("philosophy:kant") = <...>
  subjects("art") = <...>
>
```

This has been changed to look like the following:

```
school_schedule = <
  locations = <
    [1] = <...>
    [2] = <...>
    [3] = <...>
  >
  subjects = <
    ["philosophy:plato"] = <...>
    ["philosophy:kant"] = <...>
    ["art"] = <...>
  >
```

The new appearance both corresponds more directly to the actual object structure of container types, and has the property that paths can be constructed by directly reading identifiers down the backbone of any subtree in the structure. It also allows the optional addition of typing information anywhere in the structure, as shown in the following example:

```
school_schedule = SCHEDULE <
  locations = LOCATION <
    [1] = <...>
    [2] = <...>
    [3] = ARTS_PAVILLION <...>
  >
  subjects = <
    ["philosophy:plato"] = ELECTIVE_SUBJECT <...>
    ["philosophy:kant"] = ELECTIVE_SUBJECT <...>
    ["art"] = MANDATORY_SUBJECT <...>
  >
```

These changes will affect the parsing of container structures and keys in the description and ontology parts of the archetype.

Revision History Section

Revision history is now recorded in a separate section of the archetype, both to logically separate it from the archetype descriptive details, and to facilitate automatic processing by version control systems in which archetypes may be stored. This section is included at the end of the archetype because it is in general a monotonically growing section.

Primary_language and Languages_available Sections

An attribute previously called 'primary_language' was required in the ontology section of an ADL 1.1 archetype. This is renamed to 'original_language' and is now moved to a new top level section in the archetype called 'language'. Its value is still expressed as a dADL String attribute. The 'languages_available' attribute previously required in the ontology section of the archetype is renamed to 'translations', no longer includes the original languages, and is also moved to this new top level section.

2.4.3 The Future: ADL Version 2.0

In version 2.0, the ADL syntax will be changed so that an archetype is close to being a regular dADL document. This has two consequences. Firstly, it means that special syntax such as "archetype (adl_version=1.2)" is converted to the standard object-oriented dADL tree form, and secondly, the structure of the archetype (i.e. naming of sections, design of dADL trees) is synchronised with the class definitions in the Archetype Object Model.

A full dADL form of an archetype will also be supported, in which an archetype is a faithful dADL serialisation of instances of the Archetype Object Model (AOM), allowing archetypes to be parsed as dADL documents.

Specific changes in version 2.0 will include the following.

Language section

What used to be the language section of an ADL 1.2 archetype will be adjusted to a form representing the two relevant AOM attributes, namely, `original_language` and `translations`, as per the following example:

```
original_language = <"en">
translations = <
  ["de"] = <
    author = <"edward.jones@translators.co.uk">
    accreditation = <"British Medical Translator id 00400595">
  >
  ["ru"] = <
    author = <"eva.sakharova@translators.co.ru">
    accreditation = <"Russion Translator id 892230A">
  >
>
```

2.5 Tools

A validating ADL parser is freely available from <http://www.openEHR.org>. It has been wrapped for use in Java and Microsoft .Net, and standard C/C++ environments. See the website for the latest status.

3 File Encoding and Character Quoting

Because ADL files are inherently likely to contain multiple languages, due to internationalised authoring and translation, they must be capable of accommodating characters from any language. ADL files do not explicitly indicate an encoding because they are assumed to be in UTF-8 encoding of unicode. For ideographic and script-oriented languages, this is a necessity. In actual fact, ADL files encoded in latin 1 (ISO-8859-1) or another variant of ISO-8859, and appear to work perfectly well, for various reasons:

- the contain nothing but ASCII, i.e. unicode code-points 0 - 127; this will be the case in English-language authored archetypes;
- some layer of the operating system is smart enough to do an on-the-fly conversion into UTF-8, even if the archetype tool being used is designed for UTF-8 only;
- the archetype tool (or the string-processing libraries it uses) might support UTF-8 and (most likely) ISO-8859 variants.

Thus, while **the only officially designated encoding for ADL and its constituent syntaxes is UTF-8**, real software systems may be more tolerant. This document therefore specifies that any tool designed to process ADL files need only support UTF-8; supporting other encodings is an optional extra.

There are three places in ADL files where non-ASCII characters can occur:

- in string values, demarcated by double quotes, e.g. "xxxx";
- in regular expression patterns, demarcated by either // or ^^;
- in character values, demarcated by single quotes, e.g. 'x';

Note that URIs (a data type in dADL) are not problematic, since all characters outside the 'unreserved set' defined by RFC 3986¹ are already percent-encoded. The unreserved set is:

```
unreserved = ALPHA / DIGIT / "-" / "." / "_" / "~"
```

In strings and characters, characters not in the lower ASCII (0-127) range should be UTF-8 encoded, with the exception of quoted single- and double quotes, and some non-printing characters, for which the following customary quoted forms are allowed (but not required):

- \r - carriage return
- \n - linefeed
- \t - tab
- \\ - backslash
- \" - literal double quote
- \' - literal single quote

Typically in a normal string, including multi-line paragraphs as used in dADL, only \\ and \" are likely to be necessary, since all of the others can be accommodated in their literal forms; the same goes for single characters - only \\ and \' are likely to commonly occur. However, some authors may prefer to use \n and \t to make intended formatting clearer, or to allow for text editors that do not react properly to such characters. Parsers should therefore support the above list.

1. Uniform Resource Identifier (URI): Generic Syntax, Internet proposed standard, January 2005; see <http://www.ietf.org/rfc/rfc3986.txt>

In regular expressions (only used in cADL string constraints), there will typically be backslash-escaped characters from the above list as well as other patterns like \s (whitespace) and \d (decimal digit), according to the PERL regular expression specification¹. These should not be treated as anything other than literal strings, since they are processed by a regular expression parser.

1. <http://www.perldoc.com/perl5.6/pod/perlre.html>

4 dADL - Data ADL

4.1 Overview

The dADL syntax provides a formal means of expressing *instance data* based on an underlying information model, which is readable both by humans and machines. The general appearance is exemplified by the following:

```

person = (List<PERSON>) <
  [01234] = <
    name = <                                     -- person's name
      forenames = <"Sherlock">
      family_name = <"Holmes">
      salutation = <"Mr">
    >
    address = <                                   -- person's address
      habitation_number = <"221B">
      street_name = <"Baker St">
      city = <"London">
      country = <"England">
    >
  >
  [01235] = <
    -- etc
  >
>

```

In the above the attribute names `person`, `name`, `address` etc, and the type `List<PERSON>` are all assumed to come from an information model. The `[01234]` and `[01235]` tags identify container items.

The basic design principle of dADL is to be able to represent data in a way that is both machine-processable and human readable, while making the fewest assumptions possible about the information model to which the data conforms. To this end, type names are optional; often, only attribute names and values are explicitly shown. No syntactical assumptions are made about whether the underlying model is relational, object-oriented or what it actually looks like. More than one information model can be compatible with the same dADL-expressed data. The UML semantics of composition/aggregation and association are expressible, as are shared objects. Literal leaf values are only of ‘standard’ widely recognised types, i.e. Integer, Real, Boolean, String, Character and a range of Date/time types. In standard dADL, all complex types are expressed structurally.

A common question about dADL is why it is needed, when there is already XML? To start with, this question highlights the widespread misconception about XML, namely that because it can be read by a text editor, it is intended for humans. In fact, XML is designed for machine processing, and is textual to guarantee its interoperability. Realistic examples of XML (e.g. XML-schema instance, OWL-RDF ontologies) are generally unreadable for humans. dADL is on the other hand designed as a human-writable and readable formalism that is also machine processable; it may be thought of as an *abstract syntax for object-oriented data*. dADL also differs from XML by:

- providing a more comprehensive set of leaf data types, including intervals of numerics and date/time types, and lists of all primitive types;
- adhering to object-oriented semantics, particularly for container types, which XML schema languages generally do not;

- not using the confusing XML notion of ‘attributes’ and ‘elements’ to represent what are essentially object properties;
- requiring half the space of the equivalent XML.

Of course, this does not prevent XML exchange syntaxes being used for dADL, and indeed the conversion to XML instance is rather straightforward. Details on the XML expression of dADL and use of Xpath expressions is described in section 4.7 on page 36.

The dADL syntax as described above has a number of useful characteristics that enable the extensive use of paths to navigate it, and express references. These include:

- each $\langle \rangle$ block corresponds to an object (i.e. an instance of some type in an information model);
- the name before an ‘=’ is always an attribute name or else a container element key, which attaches to the attribute of the enclosing block;
- paths can be formed by navigating down a tree branch and concatenating attribute name, container keys (where they are encountered) and ‘/’ characters;
- every node is reachable by a path;
- shared objects can be referred to by path references.

4.2 Basics

4.2.1 Scope of a dADL Document

A dADL document may contain one or more objects from the same object model.

4.2.2 Keywords

dADL has no keywords of its own: all identifiers are assumed to come from an information model.

4.2.3 Reserved Characters

In dADL, a small number of characters are reserved and have the following meanings:

- ‘<’: open an object block;
- ‘>’: close an object block;
- ‘=’: indicate attribute value = object block;
- ‘(, ‘)’: type name or plug-in syntax type delimiters;
- ‘<#’: open an object block expressed in a plug-in syntax;
- ‘#>’: close an object block expressed in a plug-in syntax.

Within $\langle \rangle$ delimiters, various characters are used as follows to indicate primitive values:

- ‘”’: double quote characters are used to delimit string values;
- ‘’’: single quote characters are used to delimit single character values;
- ‘|’: bar characters are used to delimit intervals;
- []: brackets are used to delimit coded terms.

4.2.4 Comments

In a dADL text, comments satisfy the following rule:

comments are indicated by the characters "--". **Multi-line comments** are achieved using the "--" leader on each line where the comment continues. In this document, comments are shown in brown.

4.2.5 Information Model Identifiers

Two types of identifiers from information models are used in dADL: type names and attribute names.

A **type name** is any identifier with an initial upper case letter, followed by any combination of letters, digits and underscores. A **generic type name** (including nested forms) additionally may include commas and angle brackets, but no spaces, and must be syntactically correct as per the UML. An **attribute name** is any identifier with an initial lower case letter, followed by any combination of letters, digits and underscores. Any convention that obeys this rule is allowed.

At least two well-known conventions that are ubiquitous in information models obey the above rule. One of these is the following convention:

- type names are in all uppercase, e.g. PERSON, except for 'built-in' types, such as primitive types (Integer, String, Boolean, Real, Double) and assumed container types (List<T>, Set<T>, Hash<T, U>), which are in mixed case, in order to provide easy differentiation of built-in types from constructed types defined in the reference model. Built-in types are the same types assumed by UML, OCL, IDL and other similar object-oriented formalisms.
- attribute names are shown in all lowercase, e.g. home_address.
- in both type names and attribute names, underscores are used to represent word breaks. This convention is used to maximise the readability of this document.

Other conventions may be used, such as the common programmer's mixed-case or "camel case" convention exemplified by Person and homeAddress, as long as they obey the rule above. The convention chosen for any particular dADL document should be based on the convention used in the underlying information model. Identifiers are shown in green in this document.

4.2.6 Semi-colons

Semi-colons can be used to separate dADL blocks, for example when it is preferable to include multiple attribute/value pairs on one line. Semi-colons make no semantic difference at all, and are included only as a matter of taste. The following examples are equivalent:

```
term = <text = <"plan">; description = <"The clinician's advice">>

term = <text = <"plan"> description = <"The clinician's advice">>

term = <
  text = <"plan">
  description = <"The clinician's advice">
>
```

Semi-colons are completely optional in dADL.

4.3 Paths

Because dADL data is hierarchical, and all nodes are uniquely identified, a reliable path can be determined for every node in a dADL text. The syntax of paths in dADL is the standard ADL path syntax,

described in detail in section 7 on page 25. Paths are directly convertible to XPath expressions for use in XML-encoded data.

A typical ADL path used to refer to a node in a dADL text is as follows.

```
/term_definitions["en"]/items["at0001"]/text
```

In the following sections, paths are shown for all the dADL data examples.

4.4 Structure

4.4.1 General Form

A dADL document expresses serialised instances of one or more complex objects. Each such instance is a hierarchy of attribute names and object values. In its simplest form, a dADL text consists of repetitions of the following pattern:

```
attribute_name = <value>
```

In the most basic form of dADL, each attribute name is the name of an attribute in an implied or actual object or relational model. Each “value” is either a literal value of a primitive type (see Primitive Types on page 32) or a further nesting of attribute names and values, terminating in leaf nodes of primitive type values. Where sibling attribute nodes occur, the attribute identifiers must be unique, just as in a standard object or relational model.

Sibling attribute names must be unique.

The following shows a typical structure.

```
attr_1 = <
  attr_2 = <
    attr_3 = <leaf_value>
    attr_4 = <leaf_value>
  >
  attr_5 = <
    attr_3 = <
      attr_6 = <leaf_value>
    >
    attr_7 = <leaf_value>
  >
  attr_8 = <>
```

In the above structure, each “<>” encloses an instance of some type. The hierarchical structure corresponds to the part-of relationship between objects, otherwise known as *composition* and *aggregation* relationships in object-oriented formalisms such as UML (the difference between the two is usually described as being “sub-objects related by aggregation can exist on their own, whereas sub-objects related by composition are always destroyed with the parent”; dADL does not differentiate between the two, since it is the business of a model, not the data, to express such semantics). Associations between instances in dADL are also representable by references, and are described in section 4.4.6 on page 31.

4.4.1.1 Outer Delimiters

To be completely regular, an outer level of delimiters should be used, because the totality of a dADL text is an object, not a collection of disembodied attribute/object pairs. However, the outermost delim-

iters can be left out in order to improve readability, and without complicating the parsing process. The completely regular form would appear as follows:

```
<
  attr_1 = <
  >
  attr_8 = <>
>
```

Outer '<>' delimiters in a dADL text are optional.

4.4.1.2 Paths

The complete set of paths for the above example is as follows.

```
/attr_1
/attr_1/attr_2
/attr_1/attr_2/attr_3      -- path to a leaf value
/attr_1/attr_2/attr_4      -- path to a leaf value
/attr_1/attr_5
/attr_1/attr_5/attr_3
/attr_1/attr_5/attr_3/attr_6 -- path to a leaf value
/attr_1/attr_5/attr_7      -- path to a leaf value
/attr_8
```

4.4.2 Empty Sections

Empty sections are allowed at both internal and leaf node levels, enabling the author to express the fact that there is in some particular instance, no data for an attribute, while still showing that the attribute itself is expected to exist in the underlying information model. An empty section looks as follows:

```
address = <>      -- person's address
```

Nested empty sections can be used.

Note: within this document, empty sections are shown in many places to represent fully populated data, which would of course require much more space.

Empty sections can appear anywhere.

4.4.3 Container Objects

The syntax described so far allows an instance of an arbitrarily large object to be expressed, but does not yet allow for attributes of container types such as lists, sets and hash tables, i.e. items whose type in an underlying reference model is something like `attr:List<Type>`, `attr:Set<Type>` or `attr:Hash<ValueType, KeyType>`. There are two ways instance data of such container objects can be expressed in dADL. The first is to use a list style literal value, where the “list nature” of the data is expressed within the manifest value itself, as in the following examples.

```
fruits = <"pear", "cumquat", "peach">
some_primes = <1, 2, 3, 5>
```

See Lists of Built-in Types on page 35 for the complete description of list leaf types. This approach is fine for leaf data. However for containers holding non-primitive values, including more container objects, a different syntax is needed. Consider by way of example that an instance of the container `List<Person>` could be expressed as follows.

```
-- WARNING: THIS IS NOT VALID dADL
```

```
people = <
  <name = <> date_of_birth = <> sex = <> interests = <>>
  <name = <> date_of_birth = <> sex = <> interests = <>>
  -- etc
>
```

Here, “anonymous” blocks of data are repeated inside the outer block. However, this makes the data hard to read, and does not provide an easy way of constructing paths to the contained items. A better syntax becomes more obvious when we consider that members of container objects in their computable form are nearly always accessed by a method such as `member(i)`, `item[i]` or just plain `[i]`, in the case of array access in the C-based languages. dADL opts for the array-style syntax, known in dADL as container member *keys*. No attribute name is explicitly given (see Syntax Alternatives on page 45 for further discussion of this choice); any primitive comparable value is allowed as the key, rather than just integers used in C-style array access. Further, if integers are used, it is not assumed that they dictate ordinal indexing, i.e. it is possible to use a series of keys `[2]`, `[4]`, `[8]` etc. The following example shows one version of the above container in valid dADL:

```
people = <
  [1] = <name = <> birth_date = <> interests = <>>
  [2] = <name = <> birth_date = <> interests = <>>
  [3] = <name = <> birth_date = <> interests = <>>
>
```

Strings and dates may also be used. Keys are coloured blue in the this specification in order to distinguish the run-time status of key values from the design-time status of class and attribute names. The following example shows the use of string values as keys for the contained items.

```
people = <
  ["akmal:1975-04-22"] = <name = <> birth_date = <> interests = <>>
  ["akmal:1962-02-11"] = <name = <> birth_date = <> interests = <>>
  ["gianni:1978-11-30"] = <name = <> birth_date = <> interests = <>>
>
```

The syntax for primitive values used as keys follows exactly the same syntax described below for data of primitive types. It is convenient in some cases to construct key values from one or more of the values of the contained items, in the same way as relational database keys are constructed from sufficient field values to guarantee uniqueness. However, they need not be - they may be independent of the contained data, as in the case of hash tables, where the keys are part of the hash table structure, or equally, they may simply be integer index values, as in the ‘locations’ attribute in the ‘school_schedule’ structure shown below.

Container structures can appear anywhere in an overall instance structure, allowing complex data such as the following to be expressed in a readable way.

```
school_schedule = <
  lesson_times = <08:30:00, 09:30:00, 10:30:00, ...>

  locations = <
    [1] = <"under the big plane tree">
    [2] = <"under the north arch">
    [3] = <"in a garden">
  >

  subjects = <
    ["philosophy:plato"] = < -- note construction of key
      name = <"philosophy">
      teacher = <"plato">
      topics = <"meta-physics", "natural science">
    >
  >
```

```

    weighting = <76%>
  >
  ["philosophy:kant"] = <
    name = <"philosophy">
    teacher = <"kant">
    topics = <"meaning and reason", "meta-physics", "ethics">
    weighting = <80%>
  >
  ["art"] = <
    name = <"art">
    teacher = <"goya">
    topics = <"technique", "portraiture", "satire">
    weighting = <78%>
  >
>

```

Container instances are expressed using repetitions of a block introduced by a *key*, in the form of a primitive value in brackets i.e. '['].

The example above conforms directly to the object-oriented type specification (given in a pascal-like syntax):

```

class SCHEDULE
  lesson_times: List<Time>
  locations: List<String>
  subjects: List<SUBJECT> -- or it could be Hash<SUBJECT>
end

class SUBJECT
  name: String
  teacher: String
  topics: List<String>
  weighting: Real
end

```

Other class specifications corresponding to the same data are possible, but will all be isomorphic to the above.

How key values relate to a particular object structure depends on the class model of objects being created due to a dADL parsing process. It is possible to write a parser which makes reasonable inferences from a class model whose instances are represented as dADL text; it is also possible to include explicit typing information in the dADL itself (see Adding Type Information below).

4.4.3.1 Paths

Paths through container objects are formed in the same way as paths in other structured data, with the addition of the key, to ensure uniqueness. The key is included syntactically enclosed in brackets, in a similar way to how keys are included in Xpath expressions. Paths through containers in the above example include the following:

```

/school_schedule/locations[1]           -- path to "under the big..."
/school_schedule/subjects["philosophy:kant"] -- path to "kant"

```

4.4.4 Nested Container Objects

In some cases the data of interest are instances of nested container types, such as `List<List<Message>>` (a list of Message lists) or `Hash<List<Integer>, String>` (a hash of integer lists keyed by strings). The dADL syntax for such structures follows directly from the syntax for a single container

object. The following example shows an instance of the type `List<List<String>>` expressed in dADL syntax.

```
list_of_string_lists = <
  [1] = <
    [1] = <"first string in first list">
    [2] = <"second string in first list">
  >
  [2] = <
    [1] = <"first string in second list">
    [2] = <"second string in second list">
    [3] = <"third string in second list">
  >
  [3] = <
    [1] = <"only string in third list">
  >
>
```

4.4.4.1 Paths

The paths of the above example are as follows:

```
/list_of_string_lists[1]/[1]
/list_of_string_lists[1]/[2]
/list_of_string_lists[2]/[1]
etc
```

4.4.5 Adding Type Information

In many cases, dADL data is of a simple structure, very regular, and highly repetitive, such as the expression of simple demographic data. In such cases, it is preferable to express as little as possible about the implied reference model of the data (i.e. the object or relational model to which it conforms), since various software components want to use the data, and use it in different ways. However, there are also cases where the data is highly complex, and more model information is needed to help software parse it. Examples include large design databases such as for aircraft, and health records. Typing information is added to instance data using a syntactical addition inspired by the (type) casting operator of the C language, whose meaning is approximately: force the type of the result of the following expression to be `type`. In dADL typing is therefore done by including the type name in parentheses after the '=' sign, as in the following example.

```
destinations = <
  ["seville"] = (TOURIST_DESTINATION) <
    profile = (DESTINATION_PROFILE) <>
    hotels = <
      ["gran sevilla"] = (HISTORIC_HOTEL) <>
      ["sofitel"] = (LUXURY_HOTEL) <>
      ["hotel real"] = (PENSION) <>
    >
    attractions = <
      ["la corrida"] = (ATTRACTION) <>
      ["Alcázar"] = (HISTORIC_SITE) <>
    >
  >
>
```

Note that in the above, no type identifiers are included after the "hotels" and "attractions" attributes, and it is up to the processing software to infer the correct types (usually easy - it will be pre-determined by an information model). However, the complete typing information can be included, as follows.

```

hotels = (List<HOTEL>) <
  ["gran sevilla"] = (HISTORIC_HOTEL) <>
>

```

This illustrates the use of generic, or “template” type identifiers, expressed in the standard UML syntax, using angle brackets. Any number of template arguments and any level of nesting is allowed, as in the UML. There is a small risk of visual confusion between the template type delimiters and the standard dADL block delimiters, but technically there can never be any confusion, because only type names (first letter capitalised) may appear inside template delimiters, while only attribute names (first letter lower case) can appear after a dADL block delimiter.

Type identifiers can also include namespace information, which is necessary when same-named types appear in different packages of a model. Namespaces are included by prepending package names, separated by the ‘.’ character, in the same way as in most programming languages, as in the qualified type names `org.openehr.rm.ehr.content.ENTRY` and `Core.Abstractions.Relationships.Relationship`.

Type Information can be included optionally on any node immediately before the opening ‘<’ of any block, in the form of a UML-style type identifier in parentheses. Dot-separated namespace identifiers and template parameters may be used.

4.4.6 Associations and Shared Objects

All of the facilities described so far allow any object-oriented data to be faithfully expressed in a formal, systematic way which is both machine- and human-readable, and allow any node in the data to be addressed using an Xpath-style path. The availability of reliable paths allows not only the representation of single ‘business objects’, which are the equivalent of UML *aggregation* (and *composition*) hierarchies, but also the representation of *associations* between objects, and by extension, shared objects.

Consider that in the example above, ‘hotel’ objects may be shared objects, referred to by association. This can be expressed as follows.

```

destinations = <
  ["seville"] = <
    hotels = <
      ["gran sevilla"] = </hotels["gran sevilla"]>
      ["sofitel"] = </hotels["sofitel"]>
      ["hotel real"] = </hotels["hotel real"]>
    >
  >
>

bookings = <
  ["seville:0134"] = <
    customer_id = <"0134">
    period = <...>
    hotel = </hotels["sofitel"]>
  >
>

hotels = <
  ["gran sevilla"] = (HISTORIC_HOTEL) <>
  ["sofitel"] = (LUXURY_HOTEL) <>
  ["hotel real"] = (PENSION) <>
>

```

Associations are expressed via the use of fully qualified paths as the data for an attribute. In this example, there are references from a list of destinations, and from a booking list, to the same hotel object. If type information is included, it should go in the declarations of the relevant objects; type declarations can also be used before path references, which might be useful if the association type is an ancestor type (i.e. more general type) of the type of the actual object being referred to.

Data in other dADL documents can be referred to using the URI syntax to locate the document, with the internal path included as described above.

Shared objects are referenced using paths. Objects in other dADL documents can be referred to using normal URIs whose path section conforms to dADL path syntax.

4.4.6.1 Paths

The path set from the above example is as follows:

```
/destinations["seville"]/hotels["gran sevilla"]
/destinations["seville"]/hotels["sofitel"]
/destinations["seville"]/hotels["hotel real"]

/bookings["seville:0134"]/customer_id
/bookings["seville:0134"]/period
/bookings["seville:0134"]/hotel

/hotels["sofitel"]
/hotels["hotel real"]
/hotels["gran sevilla"]
```

4.5 Leaf Data - Built-in Types

All dADL data eventually devolve to instances of the primitive types `String`, `Integer`, `Real`, `Double`, `String`, `Character`, various date/time types, lists or intervals of these types, and a few special types. dADL does not use type or attribute names for instances of primitive types, only manifest values, making it possible to assume as little as possible about type names and structures of the primitive types. In all the following examples, the manifest data values are assumed to appear immediately inside a leaf pair of angle brackets, i.e.

```
some_attribute = <manifest value here>
```

4.5.1 Primitive Types

4.5.1.1 Character Data

Characters are shown in a number of ways. In the literal form, a character is shown in single quotes, as follows:

```
'a'
```

Characters outside the low ASCII (0-127) range must be UTF-8 encoded, with a small number of backslash-quoted ASCII characters allowed, as described in File Encoding and Character Quoting on page 20.

4.5.1.2 String Data

All strings are enclosed in double quotes, as follows:

```
"this is a string"
```

Quotes are encoded using ISO/IEC 10646 codes, e.g. :

```
"this is a much longer string, what one might call a &quot;phrase&quot;."
```


Line extension of strings is done simply by including returns in the string. The exact contents of the string are computed as being the characters between the double quote characters, with the removal of white space leaders up to the left-most character of the first line of the string. This has the effect of allowing the inclusion of multi-line strings in dADL texts, in their most natural human-readable form, e.g.:

```
text = <"And now the STORM-BLAST came, and he
        Was tyrannous and strong :
        He struck with his o'ertaking wings,
        And chased us south along.">
```

String data can be used to contain almost any other kind of data, which is intended to be parsed as some other formalism. Characters outside the low ASCII (0-127) range must be UTF-8 encoded, with a small number of backslash-quoted ASCII characters allowed, as described in File Encoding and Character Quoting on page 20.

4.5.1.3 Integer Data

Integers are represented simply as numbers, e.g.:

```
25
300000
29e6
```

Commas or periods for breaking long numbers are not allowed, since they confuse the use of commas used to denote list items (see section 4.5.4 below).

4.5.1.4 Real Data

Real numbers are assumed whenever a decimal is detected in a number, e.g.:

```
25.0
3.1415926
6.023e23
```

Commas or periods for breaking long numbers are not allowed. Only periods may be used to separate the decimal part of a number; unfortunately, the European use of the comma for this purpose conflicts with the use of the comma to distinguish list items (see section 4.5.4 below).

4.5.1.5 Boolean Data

Boolean values can be indicated by the following values (case-insensitive):

```
True
False
```

4.5.1.6 Dates and Times

Complete Date/Times

In dADL, full and partial dates, times and durations can be expressed. All full dates, times and durations are expressed using a subset of ISO8601. The Support IM provides a full explanation of the ISO8601 semantics supported in openEHR.

In dADL, the use of ISO 8601 allows extended form only (i.e. ‘.’ and ‘-’ must be used). The ISO 8601 method of representing partial dates consisting of a single year number, and partial times consisting of hours only are not supported, since they are ambiguous. See below for partial forms.

Patterns for complete dates and times in dADL include the following:

```
yyyy-MM-dd                -- a date
hh:mm:ss[,sss][Z|+/-hhmm] -- a time with optional seconds
yyyy-MM-ddThh:mm:ss[,sss][Z] -- a date/time
```

where:

```
yyyy    = four-digit year
MM       = month in year
dd       = day in month
hh       = hour in 24 hour clock
mm       = minutes
ss,sss  = seconds, including fractional part
Z        = the timezone in the form of a '+' or '-' followed by 4 digits
           indicating the hour offset, e.g. +0930, or else the literal 'Z'
           indicating +0000 (the Greenwich meridian).
```

Durations are expressed using a string which starts with 'P', and is followed by a list of periods, each appended by a single letter designator: 'Y' for years, 'M' for months, 'W' for weeks, 'D' for days, 'H' for hours, 'M' for minutes, and 'S' for seconds. The literal 'T' separates the YMWD part from the HMS part, ensuring that months and minutes can be distinguished. Examples of date/time data include:

```
1919-01-23      -- birthdate of Django Reinhardt
16:35:04,5      -- rise of Venus in Sydney on 24 Jul 2003
2001-05-12T07:35:20+1000 -- timestamp on an email received from Australia
P22D4TH15M0S    -- period of 22 days, 4 hours, 15 minutes
```

Partial Date/Times

Two ways of expressing partial (i.e. incomplete) date/times are supported in dADL. The ISO 8601 incomplete formats are supported in extended form only (i.e. with '-' and ':' separators) for all patterns that are unambiguous on their own. Dates consisting of only the year, and times consisting of only the hour are not supported, since both of these syntactically look like integers. The supported ISO 8601 patterns are as follows:

```
yyyy-MM          -- a date with no days
hh:mm            -- a time with no seconds
yyyy-MM-ddThh:mm -- a date/time with no seconds
yyyy-MM-ddThh    -- a date/time, no minutes or seconds
```

To deal with the limitations of ISO 8601 partial patterns in a context-free parsing environment, a second form of pattern is supported in dADL, based on ISO 8601. In this form, '?' characters are substituted for missing digits. Valid partial dates follow the patterns:

```
yyyy-MM-??      -- date with unknown day in month
yyyy-??-??      -- date with unknown month and day
```

Valid partial times follow the patterns:

```
hh:mm:??      -- time with unknown seconds
hh:?:?:??     -- time with unknown minutes and seconds
```

Valid date/times follow the patterns:

```
yyyy-MM-ddThh:mm:?? -- date/time with unknown seconds
yyyy-MM-ddThh:?:?:?? -- date/time with unknown minutes and seconds
yyyy-MM-ddT?:?:?:?? -- date/time with unknown time
yyyy-MM-??T?:?:?:?? -- date/time with unknown day and time
yyyy-??-??T?:?:?:?? -- date/time with unknown month, day and time
```

4.5.2 Intervals of Ordered Primitive Types

Intervals of any ordered primitive type, i.e., Integer, Real, Date, Time, Date_time and Duration, can be stated using the following uniform syntax, where N, M are instances of any of the ordered types:

|N..M| the inclusive range where N and M are integers, or the infinity indicator;

<N	less than N;
>N	greater than N;
>=N	greater than or equal to N;
<=N	less than or equal to N;
N +/-M	interval of N \pm M.
!= N	does not equal N;

The allowable values for N and M include any value in the range of the relevant type, as well as:

```
infinity
-infinity
*          equivalent to infinity
```

Examples of this syntax include:

```
|0..5|           -- integer interval
|0.0..1000.0|    -- real interval
|08:02..09:10|   -- interval of time
|>= 1939-02-01|  -- open-ended interval of dates
|5.0 +/-0.5|     -- 4.5 - 5.5
|>=0|           -- >= 0
|0..infinity|    -- 0 - infinity (i.e. >= 0)
```

4.5.3 Other Built-in Types

4.5.3.1 URIs

URI can be expressed as dADL data in the usual way found on the web, and follow the standard syntax from <http://www.ietf.org/rfc/rfc3986.txt>. Examples of URIs in dADL:

```
http://archetypes.are.us/home.html
ftp://get.this.file.com#section_5
http://www.mozilla.org/products/firefox/upgrade/?application=thunderbird
```

Encoding of special characters in URIs follows the IETF RFC 3986, as described under File Encoding and Character Quoting on page 20.

4.5.3.2 Coded Terms

Coded terms are ubiquitous in medical and clinical information, and are likely to become so in most other industries, as ontologically-based information systems and the ‘semantic web’ emerge. The logical structure of a coded term is simple: it consists of an identifier of a terminology, and an identifier of a code within that terminology. The dADL string representation is as follows:

```
[terminology_id::code]
```

Typical examples from clinical data:

```
[icd10AM::F60.1]      -- from ICD10AM
[snomed-ct::2004950]   -- from snomed-ct
[snomed-ct(3.1)::2004950] -- from snomed-ct v 3.1
```

4.5.4 Lists of Built-in Types

Data of any primitive type can occur singly or in lists, which are shown as comma-separated lists of item, all of the same type, such as in the following examples:

```
"cyan", "magenta", "yellow", "black" -- printer's colours
1, 1, 2, 3, 5                          -- first 5 fibonacci numbers
08:02, 08:35, 09:10                    -- set of train times
```

No assumption is made in the syntax about whether a list represents a set, a list or some other kind of sequence - such semantics must be taken from an underlying information model.

Lists which happen to have only one datum are indicated by using a comma followed by a list continuation marker of three dots, i.e. "...", e.g.:

```
"en", ...      -- languages
"icd10", ...   -- terminologies
[at0200], ...
```

White space may be freely used or avoided in lists, i.e. the following two lists are identical:

```
1,1,2,3
1, 1, 2,3
```

4.6 Plug-in Syntaxes

Using the dADL syntax, any object structure can be serialised. In some cases, the requirement is to express some part of the structure in an abstract syntax, rather than in the more literal serialised object form of dADL. dADL provides for this possibility by allowing the value of any object (i.e. what appears between any matching pair of $\langle \rangle$ delimiters) to be expressed in some other syntax, known as a "plug-in" syntax. Plug-in syntaxes are indicated in dADL in a similar way as typed objects, i.e. by the use of the syntax type in parentheses preceding the $\langle \rangle$ block. For a plug-in section, the $\langle \rangle$ delimiters are modified to $\langle \# \# \rangle$, to allow for easier parser design, and easier recognition of such blocks by human readers. The general form is as follows:

```
attr_name = (syntax) <#
...
#>
```

The following example illustrates a cADL plug-in section in an archetype, which is itself a dADL document:

```
definition = (cadl) <#
  ENTRY[at0000] ∈ {          -- blood pressure measurement
    name ∈ {                -- any synonym of BP
      CODED_TEXT ∈ {
        code ∈ {
          CODE_PHRASE ∈ {[ac0001]}
        }
      }
    }
  }
#>
```

Clearly, many plug-in syntaxes might one day be used within dADL data; there is no guarantee that every dADL parser will support them. The general approach to parsing should be to use plug-in parsers, i.e. to obtain a parser for a plug-in syntax that can be built into the existing parser framework.

4.7 Expression of dADL in XML

The dADL syntax maps quite easily to XML instance. It is important to realise that people using XML often develop different mappings for object-oriented data, due to the fact that XML does not have systematic object-oriented semantics. This is particularly the case where containers such as lists and sets such as 'employees: List<Person>' are mapped to XML; many implementors have to invent additional tags such as 'employee' to make the mapping appear visually correct. The particular mapping chosen here is designed to be a faithful reflection of the semantics of the object-oriented data,

and does not try take into account visual aesthetics of the XML. The result is that Xpath expressions are the same for dADL and XML, and also correspond to what one would expect based on an underlying object model.

The main elements of the mapping are as follows.

Single Attributes

Single attribute nodes map to tagged nodes of the same name.

Container Attributes

Container attribute nodes map to a series of tagged nodes of the same name, each with the XML attribute 'id' set to the dADL key. For example, the dADL:

```
subjects = <
  ["philosophy:plato"] = <
    name = <"philosophy">
  >
  ["philosophy:kant"] = <
    name = <"philosophy">
  >
  >
```

maps to the XML:

```
<subjects id="philosophy:plato">
  <name>
    philosophy
  </name>
</subjects>
<subjects id="philosophy:kant">
  <name>
    philosophy
  </name>
</subjects>
```

This guarantees that the path `subjects[@id="philosophy:plato"]/name` navigates to the same element in both dADL and the XML.

Nested Container Attributes

Nested container attribute nodes map to a series of tagged nodes of the same name, each with the XML attribute 'id' set to the dADL key. For example, consider an object structure defined by the signature `countries:Hash<Hash<Hotel,String>,String>`. An instance of this in dADL looks as follows:

```
countries = <
  ["spain"] = <
    ["hotels"] = <...>
    ["attractions"] = <...>
  >
  ["egypt"] = <
    ["hotels"] = <...>
    ["attractions"] = <...>
  >
  >
```

can be mapped to the XML in which the synthesised element tag "_items" and the attribute "key" are used:

```
<countries key="spain">
```

```

    <_items key="hotels">
      ...
    </_items>
    <_items key="attractions">
      ...
    </_items>
  </countries>
</countries key="egypt">
  <_items id="hotels">
    ...
  </_items>
  <_items key="attractions">
    ...
  </_items>
</countries>

```

In this case, the dADL path `countries["spain"]/["hotels"]` will be transformed to the Xpath `countries[@key="spain"]/_items[@key="hotels"]` in order to navigate to the same element.

Type Names

Type names map to XML 'type' attributes e.g. the dADL:

```

destinations = <
  ["seville"] = (TOURIST_DESTINATION) <
    profile = (DESTINATION_PROFILE) <>
    hotels = <
      ["gran sevilla"] = (HISTORIC_HOTEL) <>
    >
  >
>

```

maps to:

```

<destinations id="seville" adl:type="TOURIST_DESTINATION">
  <profile adl:type="DESTINATION_PROFILE">
    ...
  </profile>
  <hotels id="gran sevilla" adl:type="HISTORIC_HOTEL">
    ...
  </hotels>
>

```

4.8 Syntax Specification

The grammar and lexical specification for the standard dADL syntax is shown below. This grammar is implemented using lex (.l file) and yacc (.y file) specifications for in the Eiffel programming environment. The current release of these files is available at http://svn.openehr.org/ref_impl_eiffel/TRUNK/libraries/common_libs/src/structures/syntax/dadl/parser/. The .l and .y files can easily be converted for use in another yacc/lex-based programming environment. The dADL production rules is available as an [HTML document](#).

4.8.1 Grammar

The following provides the dADL parser production rules (yacc specification) as of revision 36 of the Eiffel reference implementation repository (http://svn.openehr.org/ref_impl_eiffel).

```

input:
  attr_vals

```

```

| complex_object_block
| error

attr_vals:
  attr_val
| attr_vals attr_val
| attr_vals ; attr_val

attr_val:
  attr_id SYM_EQ object_block

attr_id:
  V_ATTRIBUTE_IDENTIFIER
| V_ATTRIBUTE_IDENTIFIER error

object_block:
  complex_object_block
| primitive_object_block
| plugin_object_block

plugin_object_block:
  V_PLUGIN_SYNTAX_TYPE V_PLUGIN_BLOCK

complex_object_block:
  single_attr_object_block
| multiple_attr_object_block

multiple_attr_object_block:
  untyped_multiple_attr_object_block
| type_identifier untyped_multiple_attr_object_block

untyped_multiple_attr_object_block:
  multiple_attr_object_block_head keyed_objects SYM_END_DBLOCK

multiple_attr_object_block_head:
  SYM_START_DBLOCK

keyed_objects:
  keyed_object
| keyed_objects keyed_object

keyed_object:
  object_key SYM_EQ object_block

object_key:
  [ simple_value ]

single_attr_object_block:
  untyped_single_attr_object_block
| type_identifier untyped_single_attr_object_block

untyped_single_attr_object_block:
  single_attr_object_complex_head SYM_END_DBLOCK
| single_attr_object_complex_head attr_vals SYM_END_DBLOCK

single_attr_object_complex_head:
  SYM_START_DBLOCK

```

```
primitive_object_block:
  untyped_primitive_object_block
| type_identifier untyped_primitive_object_block

untyped_primitive_object_block:
  SYM_START_DBLOCK primitive_object_value SYM_END_DBLOCK

primitive_object_value:
  simple_value
| simple_list_value
| simple_interval_value
| term_code
| term_code_list_value

simple_value:
  string_value
| integer_value
| real_value
| boolean_value
| character_value
| date_value
| time_value
| date_time_value
| duration_value
| uri_value

simple_list_value:
  string_list_value
| integer_list_value
| real_list_value
| boolean_list_value
| character_list_value
| date_list_value
| time_list_value
| date_time_list_value
| duration_list_value

simple_interval_value:
  integer_interval_value
| real_interval_value
| date_interval_value
| time_interval_value
| date_time_interval_value
| duration_interval_value

type_identifier:
  V_TYPE_IDENTIFIER
| V_GENERIC_TYPE_IDENTIFIER

string_value:
  V_STRING

string_list_value:
  V_STRING , V_STRING
| string_list_value , V_STRING
| V_STRING , SYM_LIST_CONTINUE
```


integer_value:

```

    V_INTEGER
| + V_INTEGER
| - V_INTEGER

```

integer_list_value:

```

    integer_value , integer_value
| integer_list_value , integer_value
| integer_value , SYM_LIST_CONTINUE

```

integer_interval_value:

```

    SYM_INTERVAL_DELIM integer_value SYM_ELLIPSIS integer_value
SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_LT integer_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_LE integer_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_GT integer_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_GE integer_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM integer_value SYM_INTERVAL_DELIM

```

real_value:

```

    V_REAL
| + V_REAL
| - V_REAL

```

real_list_value:

```

    real_value , real_value
| real_list_value , real_value
| real_value , SYM_LIST_CONTINUE

```

real_interval_value:

```

    SYM_INTERVAL_DELIM real_value SYM_ELLIPSIS real_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_LT real_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_LE real_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_GT real_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_GE real_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM real_value SYM_INTERVAL_DELIM

```

boolean_value:

```

    SYM_TRUE
| SYM_FALSE

```

boolean_list_value:

```

    boolean_value , boolean_value
| boolean_list_value , boolean_value
| boolean_value , SYM_LIST_CONTINUE

```

character_value:

```

    V_CHARACTER

```

character_list_value:

```

    character_value , character_value
| character_list_value , character_value
| character_value , SYM_LIST_CONTINUE

```

date_value:

```

    V_ISO8601_EXTENDED_DATE

```

date_list_value:

```
    date_value , date_value
| date_list_value , date_value
| date_value , SYM_LIST_CONTINUE
```

date_interval_value:

```
    SYM_INTERVAL_DELIM date_value SYM_ELLIPSIS date_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_LT date_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_LE date_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_GT date_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_GE date_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM date_value SYM_INTERVAL_DELIM
```

time_value:

```
    V_ISO8601_EXTENDED_TIME
```

time_list_value:

```
    time_value , time_value
| time_list_value , time_value
| time_value , SYM_LIST_CONTINUE
```

time_interval_value:

```
    SYM_INTERVAL_DELIM time_value SYM_ELLIPSIS time_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_LT time_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_LE time_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_GT time_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_GE time_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM time_value SYM_INTERVAL_DELIM
```

date_time_value:

```
    V_ISO8601_EXTENDED_DATE_TIME
```

date_time_list_value:

```
    date_time_value , date_time_value
| date_time_list_value , date_time_value
| date_time_value , SYM_LIST_CONTINUE
```

date_time_interval_value:

```
    SYM_INTERVAL_DELIM date_time_value SYM_ELLIPSIS date_time_value
SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_LT date_time_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_LE date_time_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_GT date_time_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_GE date_time_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM date_time_value SYM_INTERVAL_DELIM
```

duration_value:

```
    V_ISO8601_DURATION
```

duration_list_value:

```
    duration_value , duration_value
| duration_list_value , duration_value
| duration_value , SYM_LIST_CONTINUE
```

duration_interval_value:

```
    SYM_INTERVAL_DELIM duration_value SYM_ELLIPSIS duration_value
SYM_INTERVAL_DELIM
```

```
| SYM_INTERVAL_DELIM SYM_LT duration_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_LE duration_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_GT duration_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM SYM_GE duration_value SYM_INTERVAL_DELIM
| SYM_INTERVAL_DELIM duration_value SYM_INTERVAL_DELIM
```

term_code:

```
V_QUALIFIED_TERM_CODE_REF
```

term_code_list_value:

```
term_code , term_code
| term_code_list_value , term_code
| term_code , SYM_LIST_CONTINUE
```

uri_value:

```
V_URI
```

4.8.2 Symbols

The following provides the dADL lexical analyser production rules (lex specification) as of revision 36 of the Eiffel reference implementation repository (http://svn.openehr.org/ref_impl_eiffel):

```
-----/* definitions */-----
ALPHANUM [a-zA-Z0-9]
IDCHAR [a-zA-Z0-9_]
NAMECHAR [a-zA-Z0-9._\ -]
NAMECHAR_SPACE [a-zA-Z0-9._\ - ]
NAMECHAR_PAREN [a-zA-Z0-9._\ - ()]

UTF8CHAR (([\xC2-\xDF][\x80-\xBF]) | ([\xE0-\xEF][\x80-\xBF]) | ([\xF0-\xF7][\x80-\xBF]))

-----/** Separators */-----

[ \t\r]+          -- Ignore separators
\n+              -- (increment line count)

-----/** comments */-----

"--".*           -- Ignore comments
"--".*\n[ \t\r]* -- (increment line count)

-----/* symbols */-----
"-"             -- -> Minus_code
"+"             -- -> Plus_code
"*"             -- -> Star_code
"/"             -- -> Slash_code
"^"             -- -> Caret_code
"."             -- -> Dot_code
";"             -- -> Semicolon_code
","             -- -> Comma_code
":"             -- -> Colon_code
"!"             -- -> Exclamation_code
"("             -- -> Left_parenthesis_code
")"             -- -> Right_parenthesis_code
"$"             -- -> Dollar_code
```

```

"?"      -- -> SYM_DT_UNKNOWN
"?"      -- -> Question_mark_code

"|"      -- -> SYM_INTERVAL_DELIM

"["      -- -> Left_bracket_code
"]"      -- -> Right_bracket_code

"="      -- -> SYM_EQ

">="     -- -> SYM_GE
"<="     -- -> SYM_LE

"<"      -- -> SYM_LT or SYM_START_DBLOCK
">"      -- -> SYM_GT or SYM_END_DBLOCK

".."     -- -> SYM_ELLIPSIS
"... "   -- -> SYM_LIST_CONTINUE

-----/* keywords */ -----

[Tt][Rr][Uu][Ee]      -- -> SYM_TRUE

[Ff][Aa][Ll][Ss][Ee] -- -> SYM_FALSE

[Ii][Nn][Ff][Ii][Nn][Ii][Tt][Yy]      -- -> SYM_INFINITY

-----/* V_URI */ -----
[a-z]+:\/\|/^[<>|\{\}^~"\[\] ]*

-----/* V_QUALIFIED_TERM_CODE_REF form [ICD10AM(1998)::F23] */ -----
\[ {NAMECHAR_PAREN}+:: {NAMECHAR}+\]

-----/* ERR_V_QUALIFIED_TERM_CODE_REF */ -----
\[ {NAMECHAR_PAREN}+:: {NAMECHAR_SPACE}+\]

-----/* V_LOCAL_TERM_CODE_REF */ -----
\[ {ALPHANUM} {NAMECHAR}*\]

-----/* V_LOCAL_CODE */ -----
a[ct][0-9.]+

-----/* V_ISO8601_EXTENDED_DATE_TIME YYYY-MM-DDThh:mm:ss[,sss] [Z|+/-
nnnn] */ ---
[0-9]{4}-[0-1][0-9]-[0-3][0-9]T[0-2][0-9]:[0-6][0-9]:[0-6][0-9](,[0-9]+)?(Z|[+][0-9]{4})? |
[0-9]{4}-[0-1][0-9]-[0-3][0-9]T[0-2][0-9]:[0-6][0-9](Z|[+][0-9]{4})? |
[0-9]{4}-[0-1][0-9]-[0-3][0-9]T[0-2][0-9](Z|[+][0-9]{4})?

-----/* V_ISO8601_EXTENDED_TIME hh:mm:ss[,sss] [Z|+/-nnnn] */ -----
[0-2][0-9]:[0-6][0-9]:[0-6][0-9](,[0-9]+)?(Z|[+][0-9]{4})? |
[0-2][0-9]:[0-6][0-9](Z|[+][0-9]{4})?

-----/* V_ISO8601_EXTENDED_DATE YYYY-MM-DD */ -----
[0-9]{4}-[0-1][0-9]-[0-3][0-9] |
[0-9]{4}-[0-1][0-9]

-----/* V_ISO8601_DURATION PnYnMnWnDTnnHnnMnnS */ -----

```

```
-- here we allow a deviation from the standard to allow weeks to be
-- mixed in with the rest since this commonly occurs in medicine
```

```
P([0-9]+[yY])?([0-9]+[mM])?([0-9]+[wW])?([0-9]+[dD])?T([0-9]+[hH])?([0-9]+[mM])?([0-9]+[sS])? |
P([0-9]+[yY])?([0-9]+[mM])?([0-9]+[wW])?([0-9]+[dD])?
```

```
-----/* V_TYPE_IDENTIFIER */ -----
[A-Z]{IDCHAR}*
```

```
-----/* V_GENERIC_TYPE_IDENTIFIER */ -----
[A-Z]{IDCHAR}*<[a-zA-Z0-9,_<>]+>
```

```
-----/* V_ATTRIBUTE_IDENTIFIER */ -----
[a-z]{IDCHAR}*
```

```
-----/* CADL Blocks */ -----
\[ { [^{}]* } -- beginning of CADL block
<IN_CADL_BLOCK> \[ { [^{}]* } -- got an open brace
<IN_CADL_BLOCK> [^{}]* \] -- got a close brace
```

```
-----/* V_INTEGER */ -----
[0-9]+ |
[0-9]+[eE][+-]?[0-9]+
```

```
-----/* V_REAL */ -----
[0-9]+\.[0-9]+ |
[0-9]+\.[0-9]+[eE][+-]?[0-9]+
```

```
-----/* V_STRING */ -----
\" [^\\\"\\n]* \"
```

```
\" [^\\\"\\n]* { -- beginning of a multi-line string
<IN_STR> {
    \\\ -- match escaped backslash, i.e. \\ -> \
    \\\ -- match escaped double quote, i.e. \" -> "
    {UTF8CHAR}+ -- match UTF8 chars
    [^\\\"\\n]+ -- match any other characters
    \\\n[ \t\r]* -- match LF in line
    [^\\\"\\n]* \" -- match final end of string

    . | \n |
    <<EOF>> -- unclosed String -> ERR_STRING
}
```

```
-----/* V_CHARACTER */ -----
\' [^\\\'\\n']* -- normal character in 0-127
\' \\n -- \n
\' \\r -- \r
\' \\t -- \t
\' \\' -- \'
\' \\ -- \\
\' {UTF8CHAR} \' -- UTF8 char
\' .{1,2} |
\' \\ [0-9]+ (\\/)? -- invalid character -> ERR_CHARACTER
```

4.9 Syntax Alternatives

WARNING:the syntax in this section is not part of dADL

4.9.1 Container Attributes

A reasonable alternative to the syntax described above for nested container objects would have been to use an arbitrary member attribute name, such as “items”, or perhaps “_items” (in order to indicate to a parser that the attribute name cannot be assumed to correspond to a real property in an object model), as well as the key for each container member, giving syntax like the following:

```
people = <
  _items[1] = <name = <> birth_date = <> interests = <>>
  _items[2] = <name = <> birth_date = <> interests = <>>
  _items[3] = <name = <> birth_date = <> interests = <>>
>
```

Additionally, with this alternative, it becomes more obvious how to include the values of other properties of container types, such as ordering, maximum size and so on, e.g.:

```
people = <
  _items[1] = <name = <> birth_date = <> interests = <>>
  _items[2] = <name = <> birth_date = <> interests = <>>
  _items[3] = <name = <> birth_date = <> interests = <>>
  _is_ordered = <True>
  _upper = <200>
>
```

Again, since the names of such properties in any given object technology cannot be assumed, the special underscore form of attribute names is used.

However, we are now led to somewhat clumsy paths, where “_items” will occur very frequently, due to the ubiquity of containers in real data:

```
/people/_items[1]/
/people/_items[2]/
/people/_items[3]/
/people/_is_ordered/
/people/_upper/
```

A compromise which satisfies the need for correct representation of all attributes of container types and the need for brevity and comprehensibility of paths would be to make optional the “_items”, but retain other container pseudo-attributes (likely to be much more rarely used), thus:

```
people = <
  [1] = <name = <> birth_date = <> interests = <>>
  [2] = <name = <> birth_date = <> interests = <>>
  [3] = <name = <> birth_date = <> interests = <>>
  _is_ordered = <True>
  _upper = <200>
>
```

The above form leads to the following paths:

```
/people[1]/
/people[2]/
/people[3]/
/people/_is_ordered/
/people/_upper/
```

The alternative syntax in this subsection is not currently part of dADL, but could be included in the future, if there was a need to support more precise modelling of container types in dADL. If such support were to be added, it is recommended that the names of the pseudo-attributes (“_item”,

“_is_ordered” etc) be based on names of appropriate container types from a recognised standard such as OMG UML, OCL or IDL.

5 cADL - Constraint ADL

5.1 Overview

cADL is a syntax which enables constraints on data defined by object-oriented information models to be expressed in archetypes or other knowledge definition formalisms. It is most useful for defining the specific allowable constructions of data whose instances conform to very general object models. cADL is used both at “design time”, by authors and/or tools, and at runtime, by computational systems which validate data by comparing it to the appropriate sections of cADL in an archetype. The general appearance of cADL is illustrated by the following example:

```
PERSON[at0000] matches {                                -- constraint on PERSON instance
  name matches {                                         -- constraint on PERSON.name
    TEXT matches {/.+}/                                -- any non-empty string
  }
  addresses cardinality matches {0..*} matches { -- constraint on
    ADDRESS matches {                                   -- PERSON.addresses
      -- etc --
    }
  }
}
```

Some of the textual keywords in this example can be more efficiently rendered using common mathematical logic symbols. In the following example, the `matches`, `exists` and `implies` keywords have been replaced by appropriate symbols:

```
PERSON[at0000] ∈ {                                       -- constraint on PERSON instance
  name ∈ {                                               -- constraint on PERSON.name
    TEXT ∈ {/.+}/                                       -- any non-empty string
  }
  addresses cardinality ∈ {0..*} ∈ { -- constraint on
    ADDRESS ∈ {                                         -- PERSON.addresses
      -- etc --
    }
  }
}
```

The full set of equivalences appears below. Raw cADL is stored in the text-based form, to remove any difficulties with representation of symbols, to avoid difficulties of authoring cADL text in basic text editors which do not supply such symbols, and to aid reading in English. However, the symbolic form might be more widely used due to the use of tools, and formatting in HTML and other documentary formats, and may be more comfortable for non-English speakers and those with formal mathematical backgrounds. This document uses both conventions. The use of symbols or text is completely a matter of taste, and no meaning whatsoever is lost by completely ignoring one or other format according to one’s personal preference.

In the standard cADL documented in this section, literal leaf values (such as the regular expression `/..*/` in the above example) are always constraints on a set of ‘standard’ widely-accepted primitive types, as described in the dADL section. Other more sophisticated constraint syntax types are described in cADL - Constraint ADL on page 49.

5.2 Basics

5.2.1 Keywords

The following keywords are recognised in cADL:

- matches, ~matches, is_in, ~is_in
- occurrences, existence, cardinality
- ordered, unordered, unique
- infinity
- use_node, allow_archetype¹
- include, exclude

Symbol equivalents for some of the above are given in the following table.

Textual Rendering	Symbolic Rendering	Meaning
matches, is_in	∈	Set membership, “p is in P”
not, ~	~	Negation, “not p”

Keywords are shown in blue in this document.

The `matches` or `is_in` operator deserves special mention, since it is a key operator in cADL. This operator can be understood mathematically as set membership. When it occurs between a name and a block delimited by braces, the meaning is: the set of values allowed for the entity referred to by the name (either an object, or parts of an object - attributes) is specified between the braces. What appears between any matching pair of braces can be thought of as a *specification for a set of values*. Since blocks can be nested, this approach to specifying values can be understood in terms of nested sets, or in terms of a value space for objects of a set of defined types. Thus, in the following example, the `matches` operator links the name of an entity to a linear value space (i.e. a list), consisting of all words ending in “ion”.

```
aaa matches {/. *ion[^\s\n\t]/}-- the set of english words ending in 'ion'
```

The following example links the name of a type XXX with a complex multi-dimensional value space.

```
XXX matches {
  aaa matches {
    YYY matches {0..3}
  }
  bbb matches {
    ZZZ matches {>1992-12-01}
  }
}
```

The meaning of the constraint structure above is: in data matching the constraints, there is an instance of type XXX whose attribute values recursively match the inner constraints named after those attributes, and so on, to the leaf level.

Occasionally, the `matches` operator needs to be used in the negative, usually at a leaf block. Any of the following can be used to constrain the value space of the attribute `aaa` to any number except 5:

```
aaa ~matches {5}
```

¹. was ‘use_archetype’, which is now deprecated

```
aaa ~is_in {5}
aaa ∉ {5}
```

The choice of whether to use `matches` or `is_in` is a matter of taste and background; those with a mathematical background will probably prefer `is_in`, while those with a data processing background may prefer `matches`.

5.2.2 Comments

In a cADL text, comments satisfy the following rule:

comments are indicated by the characters “--”. **Multi-line comments** are achieved using the “--” leader on each line where the comment continues. In this document, comments are shown in brown.

5.2.3 Information Model Identifiers

As with dADL, identifiers from the underlying information model are used for all cADL nodes. Identifiers obey the same rules as in dADL: type names commence with an upper case letter, while attribute and function names commence with a lower case letter. In cADL, type names and any property (i.e. attribute or function) name can be used, whereas in dADL, only type names and attribute names appear.

A **type name** is any identifier with an initial upper case letter, followed by any combination of letters, digits and underscores. A **generic type name** (including nested forms) additionally may include commas and angle brackets, but no spaces, and must be syntactically correct as per the UML. An **attribute name** is any identifier with an initial lower case letter, followed by any combination of letters, digits and underscores. Any convention that obeys this rule is allowed.

Type identifiers are shown in this document in all uppercase, e.g. `PERSON`, while attribute identifiers are shown in all lowercase, e.g. `home_address`. In both cases, underscores are used to represent word breaks. This convention is used to improve the readability of this document, and other conventions may be used, such as the common programmer’s mixed-case convention exemplified by `Person` and `homeAddress`. The convention chosen for any particular cADL document should be based on that used in the underlying information model. Identifiers are shown in green in this document.

5.2.4 Node Identifiers

In cADL, an entity in brackets e.g. `[xxxx]` is used to identify “object nodes”, i.e. nodes expressing constraints on instances of some type. Object nodes always commence with a type name. Any string may appear within the brackets, depending on how it is used. However, in this document, all node identifiers are of the form of an archetype term identifier, i.e. `[atNNNN]`, e.g. `[at0042]`. Node identifiers are shown in magenta in this document.

5.2.5 Natural Language

cADL is completely independent of all natural languages. The only potential exception is where constraints include literal values from some language, and this is easily and routinely avoided by the use of separate language and terminology definitions, as used in ADL archetypes. However, for the purposes of readability, comments in English have been included in this document to aid the reader. In real cADL documents, comments are generated from the archetype ontology in the local language.

5.3 Structure

cADL constraints are written in a block-structured style, similar to block-structured programming languages like C. A typical block resembles the following (the recurring pattern `/./` is a regular expression meaning “non-empty string”):

```
PERSON[at0001] ∈ {
  name ∈ {
    PERSON_NAME[at0002] ∈ {
      forenames cardinality ∈ {1..*} ∈ {/./}
      family_name ∈ {/./}
      title ∈ {"Dr", "Miss", "Mrs", "Mr", ...}
    }
  }
  addresses cardinality ∈ {1..*} ∈ {
    LOCATION_ADDRESS[at0003] ∈ {
      street_number existence ∈ {0..1} ∈ {/./}
      street_name ∈ {/./}
      locality ∈ {/./}
      post_code ∈ {/./}
      state ∈ {/./}
      country ∈ {/./}
    }
  }
}
```

In the above, any identifier (shown in green) followed by the `∈` operator (equivalent text keyword: `matches` or `is_in`) followed by an open brace, is the start of a “block”, which continues until the closing matching brace (normally visually indented to come under the start of the line at the beginning of the block).

The example above expresses a constraint on an instance of the type `PERSON`; the constraint is expressed by everything inside the `PERSON` block. The two blocks at the next level define constraints on properties of `PERSON`, in this case `name` and `addresses`. Each of these constraints is expressed in turn by the next level containing constraints on further types, and so on. The general structure is therefore a recursive nesting of constraints on types, followed by constraints on properties (of that type), followed by types (being the types of the attribute under which it appears) until leaf nodes are reached.

We use the term “object” block or node to refer to any block introduced by a type name (in this document, in all upper case), while an “attribute” block or node is any block introduced by an attribute identifier (in all lower case in this document), as illustrated below.

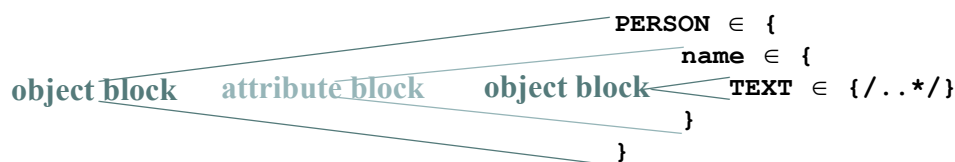
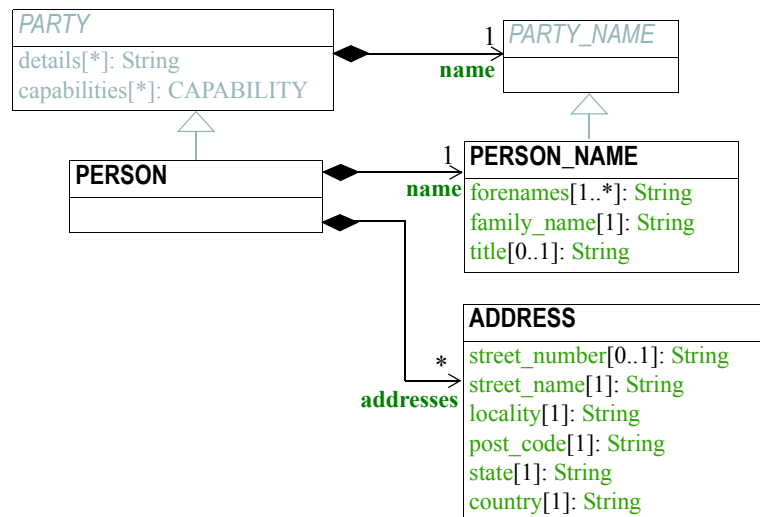


FIGURE 4 Object and Attribute Blocks in cADL

5.3.1 Complex Objects

It may now be clear that the identifiers in the above could correspond to entities in an object-oriented information model. A UML model compatible with the example above is shown in FIGURE 5. Note that there can easily be more than one model compatible with a given fragment of cADL syntax,

**FIGURE 5 UML Model of PERSON**

and in particular, there may be more properties and classes in the reference model than are mentioned in the cADL constraints. In other words, a cADL text includes constraints *only for those parts of a model which are useful or meaningful to constrain*.

Constraints expressed in cADL cannot be stronger than those from the information model. For example, the `PERSON.family_name` attribute is mandatory in the model in FIGURE 5, so it is not valid to express a constraint allowing the attribute to be optional. In general, a cADL archetype can only further constrain an existing information model. However, it must be remembered that for very generic models consisting of only a few classes and a lot of optionality, this rule is not so much a limitation as a way of adding meaning to information. Thus, for a demographic information model which has only the types `PARTY` and `PERSON`, one can write cADL which defines the concepts of entities such as `COMPANY`, `EMPLOYEE`, `PROFESSIONAL`, and so on, in terms of constraints on the types available in the information model.

This general approach can be used to express constraints for instances of any information model. An example showing how to express a constraint on the *value* property of an `ELEMENT` class to be a `QUANTITY` with a suitable range for expressing blood pressure is as follows:

```

ELEMENT[at0010] matches {    -- diastolic blood pressure
    value matches {
        QUANTITY matches {
            magnitude matches { |0..1000| }
            property matches { "pressure" }
            units matches { "mm[Hg]" }
        }
    }
}

```

5.3.2 Attribute Constraints

In any information model, attributes are either single-valued or multiply-valued, i.e. of a generic container type such as `List<Contact>`.

5.3.2.1 Existence

The only constraint that applies to all attributes is to do with existence. Existence constraints say whether an attribute value must exist, and are indicated by “0..1” or “1” markers at line ends in UML diagrams (and often mistakenly referred to as a “cardinality of 1..1”). It is the absence or presence of

the cardinality constraint in cADL which indicates that the attribute being constrained is single-valued or a container attribute respectively. Existence constraints are expressed in cADL as follows:

```
QUANTITY matches {
  units existence matches {0..1} matches {"mm[Hg]"}
}
```

The meaning of an existence constraint is to indicate whether a value - i.e. an object - is mandatory or optional (i.e. obligatory or not) in runtime data for the attribute in question. The above example indicates that a value for the 'units' attribute is optional. The same logic applies whether the attribute is of single or multiple cardinality, i.e. whether it is a container or not. For container attributes, the existence constraint indicates whether the whole container (usually a list or set) is mandatory or not; a further *cardinality* constraint (described below) indicates how many members in the container are allowed.

An existence constraint may be used directly after any attribute identifier, and indicates whether the object to which the attribute refers is mandatory or optional in the data.

Existence is shown using the same constraint language as the rest of the archetype definition. Existence constraints can take the values {0}, {0..0}, {0..1}, {1}, or {1..1}. The first two of these constraints may not seem initially obvious, but may be reasonable in some cases: they say that an attribute must not be present in the particular situation modelled by the archetype. The default existence constraint, if none is shown, is {1..1}.

5.3.3 Single-valued Attributes

Repeated blocks of object constraints of the same class (or its subtypes) can have two possible meanings in cADL, depending on whether the cardinality is present or not in the containing attribute block. With no cardinality, the meaning is that each child object constraint of the attribute in question is a possible alternative for the value of the attribute in the data, as shown in the following example:

```
ELEMENT[at0004] matches {                                -- speed limit
  value matches {
    QUANTITY matches {
      magnitude matches {|0..55|}
      property matches {"velocity"}
      units matches {"mph"}          -- miles per hour
    }
    QUANTITY matches {
      magnitude matches {|0..100|}
      property matches {"velocity"}
      units matches {"km/h"}         -- km per hour
    }
  }
}
```

Here, the cardinality of the *value* attribute is 1..1 (the default), while the occurrences of both *QUANTITY* constraints is optional, leading to the result that only one *QUANTITY* instance can appear in runtime data, and it can match either of the constraints.

Two or more object blocks introduced by type names appearing after an attribute which is not a container (i.e. for which there is no cardinality constraint) are taken to be alternative constraints, only one of which needs to be matched by the data.

Note that there is a more efficient way to express the above example, using domain type extensions. See Customising ADL on page 105 for examples.

5.3.4 Container Attributes

5.3.4.1 Cardinality

Container attributes are indicated in cADL with the *cardinality* constraint. Cardinalities indicate limits on the number of members of instances of container types such as lists and sets. Consider the following example:

```
HISTORY occurrences ∈ {1} ∈ {
  periodic ∈ {False}
  events cardinality ∈ {*} ∈ {
    EVENT[at0002] occurrences ∈ {0..1} ∈ {} -- 1 min sample
    EVENT[at0003] occurrences ∈ {0..1} ∈ {} -- 2 min sample
    EVENT[at0004] occurrences ∈ {0..1} ∈ {} -- 3 min sample
  }
}
```

The keyword *cardinality* indicates firstly that the property events must be of a container type, such as *List<T>*, *Set<T>*, *Bag<T>*. The integer range indicates the valid membership of the container; a single ‘*’ means the range 0..*, i.e. ‘0 to many’. The type of the container is not explicitly indicated, since it is usually defined by the information model. However, the semantics of a logical set (unique membership, ordering not significant), a logical list (ordered, non-unique membership) or a bag (unordered, non-unique membership) can be constrained using the additional keywords *ordered*, *unordered*, *unique* and *non-unique* within the cardinality constraint, as per the following examples:

```
events cardinality ∈ {*; ordered} ∈ { -- logical list
events cardinality ∈ {*; unordered; unique} ∈ { -- logical set
events cardinality ∈ {*; unordered} ∈ { -- logical bag
```

In theory, none of these constraints can be stronger than the semantics of the corresponding container in the relevant part of the reference model. However, in practice, developers often use lists to facilitate integration, when the actual semantics are intended to be of a set; in such cases, they typically ensure set-like semantics in their own code rather than by using an *Set<T>* type. How such constraints are evaluated in practice may depend somewhat on knowledge of the software system.

A cardinality constraint may be used after any attribute name (or after its existence constraint, if there is one) in order to indicate that the attribute refers to a container type, what number of member items it must have in the data, and optionally, whether it has “list”, “set”, or “bag” semantics, via the use of the keywords *ordered*, *unordered*, *unique* and *non-unique*.

The numeric part of the cardinality constraint can take the values {0}, {0..0}, {0..n}, {m..n}, {0..*}, or {*}. The first two of these constraints are unlikely to be useful, but there is no reason to prevent them. There is no default cardinality, since if none is shown, the relevant attribute is assumed to be single-valued (in the interests of uniformity in archetypes, this holds even for smarter parsers that can access the reference model and determine that the attribute is in fact a container_).

Cardinality and existence constraints can co-occur, in order to indicate various combinations on a container type property, e.g. that it is optional, but if present, is a container that may be empty, as in the following:

```
events existence ∈ {0..1} cardinality ∈ {0..*} ∈ {-- etc --}
```

5.3.4.2 Occurrences

A constraint on occurrences is used only with cADL object nodes (not attribute nodes), to indicate how many times in runtime data an instance of a given class conforming to a particular constraint can occur. It only has significance for objects which are children of a container attribute, since by definition, the occurrences of an object which is the value of a single-valued attribute can only be 0..1 or

1..1, and this is already defined by the attribute existence. However, it is not illegal. In the example below, three `EVENT` constraints are shown; the first one (“1 minute sample”) is shown as mandatory, while the other two are optional.

```
events cardinality ∈ {*} ∈ {
  EVENT[at0002] occurrences ∈ {1..1} ∈ {}    -- 1 min sample
  EVENT[at0003] occurrences ∈ {0..1} ∈ {}    -- 2 min sample
  EVENT[at0004] occurrences ∈ {0..1} ∈ {}    -- 3 min sample
}
```

Another contrived example below expresses a constraint on instances of `GROUP` such that for `GROUP`s representing tribes, clubs and families, there can only be one “head”, but there may be many members.

```
GROUP[at0103] ∈ {
  kind ∈ {/tribe|family|club/}
  members cardinality ∈ {*} ∈ {
    PERSON[at0104] occurrences ∈ {1} ∈ {
      title ∈ {"head"}
      -- etc --
    }
    PERSON[at0105] occurrences ∈ {0..*} ∈ {
      title ∈ {"member"}
      -- etc --
    }
  }
}
```

The first `occurrences` constraint indicates that a `PERSON` with the title “head” is mandatory in the `GROUP`, while the second indicates that at runtime, instances of `PERSON` with the title “member” can number from none to many. Occurrences may take the value of any range including `{0..*}`, meaning that any number of instances of the given class may appear in data, each conforming to the one constraint block in the archetype. A single positive integer, or the infinity indicator, may also be used on its own, thus: `{2}`, `{*}`. A range of `{0..0}` or `{0}` indicates that no occurrences of this object are allowed in this archetype. The default `occurrences`, if none is mentioned, is `{1..1}`.

An occurrences constraint may appear directly after any type name, in order to indicate how many times data objects conforming to the block introduced by the type name may occur in the data.

Where cardinality constraints are used (remembering that occurrences is always there by default, if not explicitly specified), cardinality and occurrences must always be compatible. The validity rule is:

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

5.3.5 “Any” Constraints

There are two cases where it is useful to state a completely open, or “any”, constraint. The “any” constraint is shown by a single asterisk (*) in braces. The first is when it is desired to show explicitly that some property can have any value, such as in the following:

```
PERSON[at0001] matches {
  name existence matches {0..1} matches {*}
  -- etc --
}
```


The “any” constraint on *name* means that any value permitted by the underlying information model is also permitted by the archetype; however, it also provides an opportunity to specify an existence constraint which might be narrower than that in the information model. If the existence constraint is the same, an “any” constraint on a property is equivalent to no constraint being stated at all for that property in the cADL.

The second use of “any” as a constraint value is for types, such as in the following:

```

ELEMENT[at0004] matches {                                -- speed limit
  value matches {
    QUANTITY matches { * }
  }
}

```

The meaning of this constraint is that in the data at runtime, the value property of `ELEMENT` must be of type `QUANTITY`, but can have any value internally. This is most useful for constraining objects to be of a certain type, without further constraining value, and is especially useful where the information model contains subtyping, and there is a need to restrict data to be of certain subtypes in certain contexts.

5.3.6 Object Node Identification and Paths

In many of the examples above, some of the object node typenames are followed by a node identifier, shown in brackets.

Node identifiers are required for any object node which is intended to be addressable elsewhere in the cADL text, or in the runtime system and which would otherwise be ambiguous i.e. has sibling nodes.

In the following example, the `PERSON` type does not require an identifier, since no sibling node exists at the same level, and unambiguous paths can be formed:

```

members cardinality ∈ { * } ∈ {
  PERSON ∈ {
    title ∈ { "head" }
  }
}

```

The path to the *title* attribute is

```
members/title
```

However, where there are more than one sibling node, node identifiers must be used to ensure distinct paths:

```

members cardinality ∈ { * } ∈ {
  PERSON[at0104] ∈ {
    title ∈ { "head" }
  }
  PERSON[at0105] matches {
    title ∈ { "member" }
  }
}

```

The paths to the respective *title* attributes are now:

```

members[at0104]/title
members[at0105]/title

```

Logically, all non-unique parent nodes of an identified node must also be identified back to the root node. The primary function of node identifiers is in forming paths, enabling cADL nodes to be unambiguously referred to. The node identifier can also perform a second function, that of giving a design-

time *meaning* to the node, by equating the node identifier to some description. Thus, in the example shown in section 5.3.1, the `ELEMENT` node is identified by the code `[at0010]`, which can be designated elsewhere in an archetype as meaning “diastolic blood pressure”.

Node ids are required only where it is necessary to create paths, for example in “use” statements. However, the underlying reference model might have stronger requirements. The *openEHR* EHR information models [17] for example require that all node types which inherit from the class `LOCATABLE` have both a *archetype_node_id* and a runtime *name* attribute. Only data types (such as `QUANTITY`, `CODED_TEXT`) and their constituent types are exempt.

Paths are used in cADL to refer to cADL nodes, and are expressed in the ADL path syntax, described in detail in section 7 on page 25. ADL paths have the same alternating object/attribute structure implied in the general hierarchical structure of cADL, obeying the pattern `TYPE/attribute/TYPE/attribute/...`.

Paths in cADL always refer to object nodes, and can only be constructed through nodes having node ids, or nodes which are the only child object of a single-cardinality attribute.

Unusually for a path syntax, a trailing object identifier can be required, even if the attribute corresponds to a single relationship (as might be expected with the “name” property of an object) because in cADL, it is legal to define multiple alternative object constraints - each identified by a unique node id - for a relationship node which has single cardinality.

Consider the following cADL example:

```
HISTORY occurrences ∈ {1} ∈ {  
  periodic ∈ {False}  
  events cardinality ∈ {*} ∈ {  
    EVENT[at0002] occurrences ∈ {0..1} ∈ {} -- 1 min sample  
    EVENT[at0003] occurrences ∈ {0..1} ∈ {} -- 2 min sample  
    EVENT[at0004] occurrences ∈ {0..1} ∈ {} -- 3 min sample  
  }  
}
```

The following paths can be constructed:

```
/ -- the HISTORY object  
/periodic -- the HISTORY.periodic attribute  
/events[at0002] -- the 1 minute event object  
/events[at0003] -- the 2 minute event object  
/events[at0004] -- the 3 minute event object
```

It is valid to add attribute references to the end of a path, if the underlying information model permits it, as in the following example.

```
/events/count -- count attribute of the items property
```

These examples are *physical* paths because they refer to object nodes using codes. Physical paths can be converted to *logical* paths using descriptive meanings for node identifiers, if defined. Thus, the following two paths might be equivalent:

```
/events[at0004] -- the 3 minute event object  
/events[3 minute event] -- the 3 minute event object
```

None of the paths shown here have any validity outside the cADL block in which they occur, since they do not include an identifier of the enclosing document, normally an archetype. To reference a cADL node in a document from elsewhere (e.g. another archetype of a template) requires that the identifier of the document itself be prefixed to the path, as in the following archetype example:

```
[openehr-ehr-entry.apgar-result.v1]/events[at0002]
```

This kind of path expression is necessary to form the larger paths which occur when archetypes are composed to form larger structures.

5.3.7 Internal References

It occurs reasonably often that one needs to include a constraint which is a repeat of an earlier complex constraint, but within a different block. This is achieved using an archetype internal reference, according to the following rule:

An archetype internal reference is introduced with the `use_node` keyword, in a line of the following form:

```
use_node TYPE object_path
```

This statement says: use the node of type `TYPE`, found at (the existing) path `object_path`. The following example shows the definitions of the `ADDRESS` nodes for phone, fax and email for a home `CONTACT` being reused for a work `CONTACT`.

```
PERSON ∈ {
  identities ∈ {
    -- etc --
  }
  contacts cardinality ∈ {0..*} ∈ {
    CONTACT [at0002] ∈ {                                -- home address
      purpose ∈ {-- etc --}
      addresses ∈ {-- etc --}
    }
    CONTACT [at0003] ∈ {                                -- postal address
      purpose ∈ {-- etc --}
      addresses ∈ {-- etc --}
    }
    CONTACT [at0004] ∈ {                                -- home contact
      purpose ∈ {-- etc --}
      addresses cardinality ∈ {0..*} ∈ {
        ADDRESS [at0005] ∈ {                            -- phone
          type ∈ {-- etc --}
          details ∈ {-- etc --}
        }
        ADDRESS [at0006] ∈ {                            -- fax
          type ∈ {-- etc --}
          details ∈ {-- etc --}
        }
        ADDRESS [at0007] ∈ {                            -- email
          type ∈ {-- etc --}
          details ∈ {-- etc --}
        }
      }
    }
  }
  CONTACT [at0008] ∈ {                                -- work contact
    purpose ∈ {-- etc --}
    addresses cardinality ∈ {0..*} ∈ {
      use_node ADDRESS /contacts[at0004]/addresses[at0005] -- phone
      use_node ADDRESS /contacts[at0004]/addresses[at0006] -- fax
      use_node ADDRESS /contacts[at0004]/addresses[at0007] -- email
    }
  }
}
```

The type mentioned in the `use_node` reference must always be the same type as, or a super-type of the referenced type. In most cases, it will be the same. In some cases, an archetype section might use a

subtype of the type required by the reference model (e.g. in the above example, a type such as `POSTAL_ADDRESS`); a `use_node` reference to such a node can legally mention the parent type (`ADDRESS`, in the example). Whether this possibility has practical utility remains to be seen.

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

5.3.8 Archetype Slots

At any point in a cADL definition, a constraint can be defined which allows other archetypes to be used, rather than defining the desired constraints inline. This is known as an archetype “slot”, or “chaining point”, i.e. a connection point whose allowable fillers are constrained by a set of statements, written in the ADL assertion language (defined in section 5 on page 23).

An archetype slot is defined in terms of two lists of assertions statements defining which archetypes are allowed and/or which are excluded from filling that slot. Since archetype slots are typed, the (possibly abstract) type of the allowed archetypes is already constrained. Otherwise, any assertion about a filler archetype can be made. The assertions do not constrain data in the way that other archetype statements do, instead they constrain archetypes. Two kinds of reference may be used in a slot assertion. The first is a reference to an object-oriented property of the filler archetype itself, where the property names are defined by the `ARCHETYPE` class in the Archetype Object Model. Examples include:

```
archetype_id
parent_archetype_id
short_concept_name
```

This kind of reference is usually used to constrain the *archetype_id* of the filler candidates. The second kind of reference is to absolute paths in the definition of the filler archetype, and these take the same form as archetype paths elsewhere in the archetype.

The slot might be “wide”, meaning it allows numerous other archetypes, or “narrow”, where it allows only a few or just one archetype. All references to attributes of an archetype take the form of absolute paths starting from the root of the archetype. The paths are defined with respect to the archetype object model (AOM). Typical paths include:

A basic kind of assertion is on the identifier of archetypes allowed in the slot, and it is possible to limit this to a single archetype, meaning that the choice of archetype in that slot is fixed. In general, however, the intention of archetypes is to provide highly re-usable models of real world content with local constraining left to templates. The full semantics of archetype chaining are described in the “Archetype Object Model” document.

An **archetype slot** is introduced with the keyword `allow_archetype`, and is expressed using two lists of assertions, each introduced with the keywords `include` and `exclude`, respectively.

The following example shows how the “Objective” `SECTION` in a problem/SOAP headings archetype defines two slots, indicating which `OBSERVATION` and `SECTION` archetypes are allowed and excluded under the *items* property.

```
SECTION [at2000] occurrences ∈ {0..1} ∈ {          -- objective
  items ∈ {
    allow_archetype OBSERVATION occurrences ∈ {0..1} ∈ {
      include
        short_concept_name ∈ {/.+//}
    }
  }
}
```

```

allow_archetype SECTION occurrences ∈ {0..*} ∈ {
  include
    archetype_id ∈ {/.*\..iso-ehr\.section\..*\..*/}
  exclude
    archetype_id ∈ {/.*\..iso-ehr\.section\.patient_details\..*/}
}
}
}

```

Here, every constraint inside the block starting on an `allow_archetype` line contains constraints that must be met by archetypes in order to fill the slot. In the examples above, the constraints are in the form of regular expression syntax. In cADL, the PERL version of this is assumed. Other constraints are possible as well, including that the allowed archetype must contain a certain keyword, or a certain path. The latter is quite powerful – it allows archetypes to be linked together on the basis of context. For example, under a “genetic relatives” heading in a Family History Organiser archetype, the following logical constraint might be used:

```

allow_archetype EVALUATION occurrences ∈ {0..*} matches {
  include
    short_concept_name ∈ {"family_history_subject"}
    ^ ∃ /subject/relation
      → /subject/relation ∈ {
        CODED_TEXT ∈ {
          defining_code ∈ {[ac0003]} -- "parent" or "sibling"
        }
      }
}
}

```

5.3.9 Placeholder Constraints

Not all constraints can be defined easily within an archetype. One very common category of constraint that should be defined externally, and referenced from the archetype is the ‘value set’ for a coded attribute. The need within the archetype in this case is to limit an attribute value to a particular set of codes, i.e. value set, from a terminology.

The value set could be simply enumerated within the archetype, for example using the `C_CODE_PHRASE` type defined in the *openEHR* Archetype Profile; this will work perfectly well, but has at least two limitations. Firstly, the intended set of values allowed for the attribute may change over time (e.g. as has happened with ‘types of hepatitis’ since 1980), requiring the archetype to be updated. With a large repository of archetypes, each containing coded term constraints, this approach is likely to be unsustainable and error-prone. Secondly, the best means of defining the value set is in general not likely to be via enumeration of the individual terms, but in the form of a semantic expression that can be evaluated against the terminology. This is because the value set is typically logically specified in terms of inclusions, exclusions, conjunctions and disjunctions of general categories.

Consider for example the value set logically defined as “any bacterial infection of the lung”. The possible values would be codes from a target terminology, corresponding to numerous strains of pneumococcus, staphylococcus and so on, but not including species that are never found in the lung. Rather than enumerate the list of codes corresponding to this value set (which is likely to be quite large), the archetype author is more likely to rely on semantic links within the terminology to express the set; a query such as ‘is-a bacteria and has-site lung’ might be definable against the terminology (such as SNOMED-CT or the WHO ICD10 terminology).

In a similar way, other value sets, including for quantitative values, are likely to be specified by queries or formal expressions, and evaluated by an external knowledge service. Examples include “any unit of pressure” and “normal range values for serum sodium”.

In all such cases, expressing the constraint could be done by including the query or other formal expression within the archetype itself. However, experience shows that this is problematic in various ways. Firstly, there is little if any standardisation in such formal value set expressions or queries for use with knowledge services; two archetype authors could easily create competing syntactical expressions for the same logical constraint. A second problem is that errors might be made in the query expression itself, or the expression may be correct at the time of authoring, but need subsequent adjustment as the relevant knowledge resource grows and changes. The consequence of this is the same as for a value set enumerated inline - it is unlikely to be sustainable for large numbers of archetypes. These problems are not accidental: a query with respect to a terminological, ontological or other knowledge resource is most likely to be authored correctly by maintainers or experts of the knowledge resource, rather than archetype authors; it may well be altered over time due to improvements in the query formalism itself.

The solution adopted in ADL is to store only *identifiers* of query expressions which when evaluated return a required value set, while query expressions are assumed to be stored in a query repository, or some part of the relevant knowledge service. Rather than store external identifiers inline in a cADL text, the ADL approach is to store a ‘placeholder’ internal code of the form [acNNNN], e.g. [ac0012]. Codes of this form are defined in the archetype ontology section, and can be mapped to query identifiers for one or more knowledge resources. This approach would allow a single ‘ac’ code to be defined for the value set.

5.3.10 Mixed Structures

Three types of structure which represent constraints on complex objects have been presented so far:

- *complex object structures*: any node introduced by a type name and followed by {} containing constraints on attributes;
- *internal references*: any node introduced by the keyword `use_node`, followed by a type name; such nodes indicate re-use of a complex object constraint that has already been expressed elsewhere in the archetype;
- *archetype slots*: any node introduced by the keyword `allow_archetype`, followed by a type name; such nodes indicate a complex object constraint which is expressed in some other archetype.

At any given node, all three types can co-exist, as in the following example:

```
SECTION[at2000] ∈ {
  items cardinality ∈ {0..*; ordered} ∈ {
    ENTRY[at2001] ∈ {-- etc --}
    allow_archetype ENTRY ∈ {-- etc --}
    use_node ENTRY [at0001]/some_path[at0004]/
    ENTRY[at2002] ∈ {-- etc --}
    use_node ENTRY /[at1002]/some_path[at1012]/
    use_node ENTRY /[at1005]/some_path[at1052]/
    ENTRY[at2003] ∈ {-- etc --}
  }
}
```

Here, we have a constraint on an attribute called *items* (of cardinality 0..*), expressed as a series of possible constraints on objects of type `ENTRY`. The 1st, 4th and 7th are described “in place” (the details are removed here, for brevity); the 3rd, 5th and 6th are expressed in terms of internal references to other nodes earlier in the archetype, while the 2nd is an archetype slot, whose constraints are expressed in other archetypes matching the include/exclude constraints appearing between the braces

of this node (again, avoided for the sake of brevity). Note also that the `ordered` keyword has been used to indicate that the list order is intended to be significant.

5.4 Constraints on Primitive Types

While constraints on complex types follow the rules described so far, constraints on attributes of primitive types in cADL are expressed without type names, and omitting one level of braces, as follows:

```
some_attr matches {some_pattern}
```

rather than:

```
some_attr matches {
  PRIMITIVE_TYPE matches {
    some_pattern
  }
}
```

This is made possible because the syntax patterns of all primitive type constraints are mutually distinguishable, i.e. the type can always be inferred from the syntax alone. Since all leaf attributes of all object models are of primitive types, or lists or sets of them, cADL archetypes using the brief form for primitive types are significantly less verbose overall, as well as being more directly comprehensible to human readers. Currently the cADL grammar **only supports the brief form** used in this specification since no practical reason has been identified for supporting the more verbose version. Theoretically however, there is nothing to prevent it being used in the future, or in some specialist application.

5.4.1 Constraints on String

Strings can be constrained in two ways: using a list of fixed strings, and using using a regular expression. All constraints on strings are case-sensitive.

5.4.1.1 List of Strings

A String-valued attribute can be constrained by a list of strings (using the dADL syntax for string lists), including the simple case of a single string. Examples are as follows:

```
species ∈ {"platypus"}
species ∈ {"platypus", "kangaroo"}
species ∈ {"platypus", "kangaroo", "wombat"}
```

The first example constraints the runtime value of the *species* attribute of some object to take the value "platypus"; the second constrains it be either "platypus" or "kangaroo", and so on. **In almost all cases, this kind of string constraint should be avoided**, since it usually renders the body of the archetype language-dependent. Exceptions are proper names (e.g. "NHS", "Apgar"), product trade-names (but note even these are typically different in different language locales, even if the different names are not literally translations of each other). The preferred way of constraining string attributes in a language independent way is with local [ac] codes. See Local Constraint Codes on page 28.

5.4.1.2 Regular Expression

The second way of constraining strings is with regular expressions, a widely used syntax for expressing patterns for matching strings. The regular expression syntax used in cADL is a proper subset of that used in the Perl language (see [18] for a full specification of the regular expression language of Perl). Three uses of it are accepted in cADL:

```
string_attr matches {/regular expression/}
string_attr matches {=~ /regular expression/}
string_attr matches {!~ /regular expression/}
```

The first two are identical, indicating that the attribute value must match the supplied regular expression. The last indicates that the value must *not* match the expression. If the delimiter character is required in the pattern, it must be quoted with the backslash ('\') character, or else alternative delimiters can be used, enabling more comprehensible patterns. A typical example is regular expressions including units. The following two patterns are equivalent:

```
units ∈ {/km\|h|mi\|h/}  
units ∈ {^km/h|mi/h^}
```

The rules for including special characters within strings are described in File Encoding and Character Quoting on page 20.

The regular expression patterns supported in cADL are as follows.

Atomic Items

- match any single character. E.g. / . . . / matches any 3 characters which occur with a space before and after;
- [xyz] match any of the characters in the set xyz (case sensitive). E.g. /[0-9]/ matches any string containing a single decimal digit;
- [a-m] match any of the characters in the set of characters formed by the continuous range from a to m (case sensitive). E.g. /[0-9]/ matches any single character string containing a single decimal digit, /[S-Z]/ matches any single character in the range s - z;
- [^a-m] match any character except those in the set of characters formed by the continuous range from a to m. E.g. /^[^0-9]/ matches any single character string as long as it does not contain a single decimal digit;

Grouping

(pattern) parentheses are used to group items; any pattern appearing within parentheses is treated as an atomic item for the purposes of the occurrences operators. E.g. /([0-9][0-9])/ matches any 2-digit number.

Occurrences

- * match 0 or more of the preceding atomic item. E.g. /.*/ matches any string; /[a-z]*/ matches any non-empty lower-case alphabetic string;
- + match 1 or more occurrences of the preceding atomic item. E.g. /a.+/ matches any string starting with 'a', followed by at least one further character;
- ? match 0 or 1 occurrences of the preceding atomic item. E.g. /ab?/ matches the strings "a" and "ab";
- {m,n} match m to n occurrences of the preceding atomic item. E.g. /ab{1,3}/ matches the strings "ab" and "abb" and "abbb"; /[a-z]{1,3}/ matches all lower-case alphabetic strings of one to three characters in length;
- {m,} match at least m occurrences of the preceding atomic item;
- {,n} match at most n occurrences of the preceding atomic item;
- {m} match exactly m occurrences of the preceding atomic item;

Special Character Classes

- \d, \D match a decimal digit character; match a non-digit character;
- \s, \S match a whitespace character; match a non-whitespace character;

Alternatives

`pattern1|pattern2` match either `pattern1` or `pattern2`. E.g. `/lying|sitting|standing/` matches any of the words "lying", "sitting" and "standing".

A similar warning should be noted for the use of regular expressions to constrain strings: they should be limited to non-linguistically dependent patterns, such as proper and scientific names. The use of regular expressions for constraints on normal words will render an archetype linguistically dependent, and potentially unusable by others.

5.4.2 Constraints on Integer

Integers can be constrained using a list of integer values, and using an integer interval.

5.4.2.1 List of Integers

Lists of integers expressed in the syntax from dADL (described in Lists of Built-in Types on page 35) can be used as a constraint, e.g.:

```
length matches {1000}           -- fixed value of 1000
magnitude matches {0, 5, 8}     -- any of 0, 5 or 8
```

The first constraint requires the attribute `length` to be 1000, while the second limits the value of `magnitude` to be 0, 5, or 8 only.

5.4.2.2 Interval of Integer

Integer intervals are expressed using the interval syntax from dADL (described in Intervals of Ordered Primitive Types on page 34). Examples include

```
length matches {|1000|}         -- point interval of 1000 (=fixed value)
length matches {|950..1050|}    -- allow 950 - 1050
length matches {|0..1000|}      -- allow 0 - 1000
length matches {|<10|}          -- allow up to 9
length matches {|>10|}          -- allow 11 or more
length matches {|<=10|}         -- allow up to 10
length matches {|>=10|}         -- allow 10 or more
length matches {|100+/-5|}       -- allow 100 +/- 5, i.e. 95 - 105
rate matches {|0..infinity|}    -- allow 0 - infinity, i.e. same as >= 0
```

Intervals may be combined in integer constraints, using the semicolon character (';') as follows:

```
critical_range matches {|5..9; 101..110|}
```

5.4.3 Constraints on Real

Constraints on Real values follow exactly the same syntax as for Integers, in both list and interval forms. The only difference is that the real number values used in the constraints are indicated by the use of the decimal point and at least one succeeding digit, which may be 0. Typical examples are:

```
magnitude ∈ {5.5}              -- fixed value
magnitude ∈ {|5.5|}            -- point interval (=fixed value)
magnitude ∈ {|5.5..6.0|}       -- interval
magnitude ∈ {5.5, 6.0, 6.5}    -- list
magnitude ∈ {|<10.0|}          -- allow anything less than 10.0
magnitude ∈ {|>10.0|}          -- allow greater than 10.0
magnitude ∈ {|<=10.0|}         -- allow up to 10.0
magnitude ∈ {|>=10.0|}         -- allow 10.0 or more
magnitude ∈ {|80.0+/-12.0|}     -- allow 80 +/- 12
```

5.4.4 Constraints on Boolean

Boolean runtime values can be constrained to be True, False, or either, as follows:

```
some_flag matches {True}  
some_flag matches {False}  
some_flag matches {True, False}
```

5.4.5 Constraints on Character

Characters can be constrained in two ways: using a list of characters, and using a regular expression.

5.4.5.1 List of Characters

The following examples show how a character value may be constrained using a list of fixed character values. Each character is enclosed in single quotes.

```
color_name matches {'r'}  
color_name matches {'r', 'g', 'b'}
```

5.4.5.2 Regular Expression

Character values can also be constrained using single-character regular expression elements, also enclosed in single quotes, as per the following examples:

```
color_name matches {'[rgbcmky]'}  
color_name matches {'^[s\t\n]'}
```

The only allowed elements of the regular expression syntax in character expressions are the following:

- any item from the Atomic Items list above;
- any item from the Special Character Classes list above;
- the '.' character, standing for "any character";
- an alternative expression whose parts are any item types, e.g. 'a' | 'b' | [m-z]

5.4.6 Constraints on Dates, Times and Durations

Dates, times, date/times and durations may all be constrained in three ways: using a list of values, using intervals, and using patterns. The first two ways allow values to be constrained to actual date, time etc values, while the last allows values to be constrained on the basis of which parts of the date, time etc are present or missing, regardless of value. The pattern method is described first, since patterns can also be used in lists and intervals.

NB: for the date/time constraint type, parser writers should consider allowing the 'T' character to be optional on read but mandatory on save for some time. This is because previous versions of ADL did not include it, with the result that existing tools have created archetypes without the 'T' in date/time constraint patterns.

5.4.6.1 Date, Time and Date/Time

Patterns

Dates, times, and date/times (i.e. timestamps), can be constrained using patterns based on the ISO 8601 date/time syntax, which indicate which parts of the date or time must be supplied. A constraint pattern is formed from the abstract pattern `yyyy-mm-ddThh:mm:ss` (itself formed by translating each field of an ISO 8601 date/time into a letter representing its type), with either '?' (meaning optional) or 'x' (not allowed) characters substituted in appropriate places. A simplified grammar of the pattern is as follows (EBNF; all tokens shown are literals):

```
date_constraint:      yyyy - mm|??|XX - dd|??|XX  
time_constraint:      hh : mm|??|XX : ss|??|XX  
time_in_date_constraint: T hh|??|XX : mm|??|XX : ss|??|XX  
date_time_constraint: date_constraint time_in_date_constraint
```

All expressions generated by this grammar must also satisfy the validity rules:

- where '??' appears in a field, only '??' or 'XX' can appear in fields to the right
- where 'XX' appears in a field, only 'XX' can appear in fields to the right

A fuller grammar can be defined to implement both the simplified grammar and validity rules.

The following table shows the valid patterns that can be used, and the types implied by each pattern.

Implied Type	Pattern	Explanation
Date	yyyy-mm-dd	full date must be specified
Date	yyyy-mm-??	optional day; e.g. day in month forgotten
Date	yyyy-??-??	optional month, day; i.e. any date allowed; e.g. mental health questionnaires which include well known historical dates
Date	yyyy-mm-XX	mandatory month, no day
Date	yyyy-??-XX	optional month, no day
Time	hh:mm:ss	full time must be specified
Time	hh:mm:XX	no seconds; e.g. appointment time
Time	hh:?:XX	optional minutes, no seconds; e.g. normal clock times
Time	hh:?:?:	optional minutes, seconds; i.e. any time allowed
Date/Time	yyyy-mm-ddThh:mm:ss	full date/time must be specified
Date/Time	yyyy-mm-ddThh:mm:??	optional seconds; e.g. appointment date/time
Date/Time	yyyy-mm-ddThh:mm:XX	no seconds; e.g. appointment date/time
Date/Time	yyyy-mm-ddThh:?:?:XX	no seconds, minutes optional; e.g. in patient-recollected date/times
Date/Time	yyyy-??-??T?:?:?:	minimum valid date/time constraint

Intervals

Dates, times and date/times can also be constrained using intervals. Each date, time etc in an interval may be a literal date, time etc value, or a value based on a pattern. In the latter case, the limit values are specified using the patterns from the above table, but with numbers in the positions where 'x' and '?' do not appear. For example, the pattern yyyy-??-xx could be transformed into 1995-??-xx to mean any partial date in 1995. Examples of such constraints:

1995-??-xx	-- any partial date in 1995
09:30:00	-- exactly 9:30 am
< 09:30:00	-- any time before 9:30 am
<= 09:30:00	-- any time at or before 9:30 am
> 09:30:00	-- any time after 9:30 am
>= 09:30:00	-- any time at or after 9:30 am
2004-05-20..2004-06-02	-- a date range
2004-05-20T00:00:00..2005-05-19T23:59:59	-- a date/time range

5.4.6.2 Duration Constraints

Patterns

Patterns based on ISO 8601 can be used to constraint durations in the same way as for Date/time types. The general form of a pattern is (EBNF; all tokens are literals):

```
P[Y|y][M|m][W|w][D|d][T[H|h][M|m][S|s]]
```

Note that allowing the ‘W’ designator to be used with the other designators corresponds to a deviation from the published ISO 8601 standard used in *openEHR*, namely:

- durations are supposed to take the form of PnnW or PnnYnnMnnDTnnHnnMnnS, but in *openEHR*, the W (week) designator can be used with the other designators, since it is very common to state durations of pregnancy as some combination of weeks and days.

The use of this pattern indicates which “slots” in an ISO duration string may be filled. Where multiple letters are supplied in a given pattern, the meaning is “or”, i.e. any one or more of the slots may be supplied in the data. This syntax allows specifications like the following to be made:

```
Pd      -- a duration containing days only, e.g. P5d
Pm      -- a duration containing months only, e.g. P5m
PTm     -- a duration containing minutes only, e.g. PT5m
Pwd     -- a duration containing weeks and/or days only, e.g. P4w
PThm    -- a duration containing hours and/or minutes only, e.g. PT2h30m
```

List and Intervals

Durations can also be constrained by using absolute ISO 8601 duration values, or ranges of the same, e.g.:

```
PT1m      -- 1 minute
P1dT8h    -- 1 day 8 hrs
|PT0m..PT1m30s| -- Reasonable time offset of first apgar sample
```

5.4.7 Constraints on Lists of Primitive types

In many cases, the type in the information model of an attribute to be constrained is a list or set of primitive types, e.g. List<Integer>, Set<String> etc. As for complex types, this is indicated in cADL using the `cardinality` keyword (as for complex types), as follows:

```
some_attr cardinality ∈ {0..*} ∈ {some_constraint}
```

The pattern to match in the final braces will then have the meaning of a list or set of value constraints, rather than a single value constraint. Any constraint described above for single-valued attributes, which is commensurate with the type of the attribute in question, may be used. However, as with complex objects, the meaning is now that every item in the list is constrained to be any one of the values implied by the constraint expression. For example,

```
speed_limits cardinality ∈ {0..*; ordered} ∈ {50, 60, 70, 80, 100, 130}
```

constrains each value in the list corresponding to the value of the attribute *speed_limits* (of type List<Integer>), to be any one of the values 50, 60, 70 etc.

5.4.8 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 optionally definable on primitive types only, and are expressed after the constraint expression, by a semi-colon (;) followed by a value of the same type as that implied by the preceding part of the constraint. The use of assumed values is illustrated here for a number of primitive types:

```
length matches {|0..1000|; 200}           -- allow 0 - 1000, assume 200
some_flag matches {True, False; True}     -- allow T or F, assume T
some_date matches {yyyy-mm-dd hh:mm:XX; 1800-01-01T00:00:00}
```

If no assumed value is stated, no reliable assumption can be made by the receiver of the archetyped data about what the values of removed optional parts might be, from inspecting the archetype. However, this usually corresponds to a situation where the assumed value does not even need to be stated - the same value will be assumed by all users of this data, if its value is not transmitted. In other cases, it may be that it doesn't matter what the assumed value is. For example, an archetype used to capture physical measurements might include a "protocol" section, which in turn can be used to record the "instrument" used to make a given measurement. In a blood pressure specialisation of this archetype it is fairly likely that physicians recording or receiving the data will not care about what instrument was used.

5.5 Syntax Specification

The grammar for the standard cADL syntax is shown below. The form used in *openEHR* is the same as this, but with custom additions, described in the *openEHR* Archetype Profile. The resulting grammar and lexical analysis specification used in the *openEHR* reference ADL parser is implemented using lex (.l file) and yacc (.y file) specifications for the Eiffel programming environment. The current release of these files is available at http://my.openehr.org/wsvn/ref_impl_eiffel/TRUNK/components/adl_parser/src/syntax/cadl/parser/?rev=0&sc=0. The .l and .y files can be converted for use in other yacc/lex-based programming environments. The production rules of the .y file are available as an [HTML document](#).

5.5.1 Grammar

The following is an extract of the cADL parser production rules (yacc specification), minus custom additions, as of revision 158 of the Eiffel reference implementation repository (http://svn.openehr.org/ref_impl_eiffel). Note that because of interdependencies with path and assertion production rules, practical implementations may have to include all production rules in one parser.

```
input:
    c_complex_object
| error

c_complex_object:
    c_complex_object_head SYM_MATCHES SYM_START_CBLOCK c_complex_object_body
    SYM_END_CBLOCK

c_complex_object_head:
    c_complex_object_id c_occurrences

c_complex_object_id:
    type_identifier
| type_identifier V_LOCAL_TERM_CODE_REF

c_complex_object_body:
```

```
    c_any
  | c_attributes

c_object:
  c_complex_object
  | archetype_internal_ref
  | archetype_slot
  | constraint_ref
  | c_primitive_object
  | V_C_DOMAIN_TYPE
  | ERR_C_DOMAIN_TYPE
  | error

archetype_internal_ref:
  SYM_USE_NODE type_identifier object_path
  | SYM_USE_NODE type_identifier error

archetype_slot:
  c_archetype_slot_head SYM_MATCHES SYM_START_CBLOCK c_includes c_excludes
  SYM_END_CBLOCK

c_archetype_slot_head:
  c_archetype_slot_id c_occurrences

c_archetype_slot_id:
  SYM_ALLOW_ARCHETYPE type_identifier
  | SYM_ALLOW_ARCHETYPE type_identifier V_LOCAL_TERM_CODE_REF
  | SYM_ALLOW_ARCHETYPE error

c_primitive_object:
  c_primitive

c_primitive:
  c_integer
  | c_real
  | c_date
  | c_time
  | c_date_time
  | c_duration
  | c_string
  | c_boolean
  | error

c_any:
  *

c_attributes:
  c_attribute
  | c_attributes c_attribute

c_attribute:
  c_attr_head SYM_MATCHES SYM_START_CBLOCK c_attr_values SYM_END_CBLOCK

c_attr_head:
  V_ATTRIBUTE_IDENTIFIER c_existence
  | V_ATTRIBUTE_IDENTIFIER c_existence c_cardinality
```

```

c_attr_values:
  c_object
| c_attr_values c_object
| c_any
| error

c_includes:
  -/-
| SYM_INCLUDE assertions

c_excludes:
  -/-
| SYM_EXCLUDE assertions

c_existence:
  -/-
| SYM_EXISTENCE SYM_MATCHES SYM_START_CBLOCK existence_spec SYM_END_CBLOCK

existence_spec:
  V_INTEGER
| V_INTEGER SYM_ELLIPSIS V_INTEGER

c_cardinality:
  SYM_CARDINALITY SYM_MATCHES SYM_START_CBLOCK cardinality_spec
SYM_END_CBLOCK

cardinality_spec:
  occurrence_spec
| occurrence_spec ; SYM_ORDERED
| occurrence_spec ; SYM_UNORDERED
| occurrence_spec ; SYM_UNIQUE
| occurrence_spec ; SYM_ORDERED ; SYM_UNIQUE
| occurrence_spec ; SYM_UNORDERED ; SYM_UNIQUE
| occurrence_spec ; SYM_UNIQUE ; SYM_ORDERED
| occurrence_spec ; SYM_UNIQUE ; SYM_UNORDERED

cardinality_limit_value:
  integer_value
| *

c_occurrences:
  -/-
| SYM_OCCURRENCES SYM_MATCHES SYM_START_CBLOCK occurrence_spec
SYM_END_CBLOCK
| SYM_OCCURRENCES error

occurrence_spec:
  cardinality_limit_value
| V_INTEGER SYM_ELLIPSIS cardinality_limit_value

c_integer_spec:
  integer_value
| integer_list_value
| integer_interval_value
| occurrence_spec

c_integer:
  c_integer_spec

```

```
| c_integer_spec ; integer_value  
| c_integer_spec ; error
```

c_real_spec:

```
    real_value  
| real_list_value  
| real_interval_value
```

c_real:

```
    c_real_spec  
| c_real_spec ; real_value  
| c_real_spec ; error
```

c_date_spec:

```
    V_ISO8601_DATE_CONSTRAINT_PATTERN  
| date_value  
| date_interval_value
```

c_date:

```
    c_date_spec  
| c_date_spec ; date_value  
| c_date_spec ; error
```

c_time_spec:

```
    V_ISO8601_TIME_CONSTRAINT_PATTERN  
| time_value  
| time_interval_value
```

c_time:

```
    c_time_spec  
| c_time_spec ; time_value  
| c_time_spec ; error
```

c_date_time_spec:

```
    V_ISO8601_DATE_TIME_CONSTRAINT_PATTERN  
| date_time_value  
| date_time_interval_value
```

c_date_time:

```
    c_date_time_spec  
| c_date_time_spec ; date_time_value  
| c_date_time_spec ; error
```

c_duration_spec:

```
    V_ISO8601_DURATION_CONSTRAINT_PATTERN  
| duration_value  
| duration_interval_value
```

c_duration:

```
    c_duration_spec  
| c_duration_spec ; duration_value  
| c_duration_spec ; error
```

c_string_spec:

```
    V_STRING  
| string_list_value  
| string_list_value , SYM_LIST_CONTINUE
```



```

| V_REGEXPP

c_string:
  c_string_spec
| c_string_spec ; string_value
| c_string_spec ; error

c_boolean_spec:
  SYM_TRUE
| SYM_FALSE
| SYM_TRUE , SYM_FALSE
| SYM_FALSE , SYM_TRUE

c_boolean:
  c_boolean_spec
| c_boolean_spec ; boolean_value
| c_boolean_spec ; error

constraint_ref:
  V_LOCAL_TERM_CODE_REF

any_identifier:
  type_identifier
| V_ATTRIBUTE_IDENTIFIER

-- for string_value etc, see dADL spec

-- for attribute_path, object_path, call_path, etc, see Path spec

-- for assertions, assertion, see Assertion spec

```

5.5.2 Symbols

The following shows the lexical specification for the cADL grammar.

```

-----/* definitions */ -----
ALPHANUM [a-zA-Z0-9]
IDCHAR [a-zA-Z0-9_]
NAMECHAR [a-zA-Z0-9._\ -]
NAMECHAR_SPACE [a-zA-Z0-9._\ - ]
NAMECHAR_PAREN [a-zA-Z0-9._\ - () ]

UTF8CHAR (([\xC2-\xDF][\x80-\xBF])|(\xE0[\xA0-\xBF][\x80-\xBF])|([\xE1-\xE7][\x80-\xBF][\x80-\xBF])|(\xF0[\x90-\xBF][\x80-\xBF][\x80-\xBF])|([\xF1-\xF7][\x80-\xBF][\x80-\xBF][\x80-\xBF]))

-----/* comments */ -----
"--".*                                -- Ignore comments
"--".*\n[ \t\r]*

-----/* symbols */ -----
"--"      -- -> Minus_code
"+"       -- -> Plus_code
"*"       -- -> Star_code
"/"       -- -> Slash_code
"^"       -- -> Caret_code
"="       -- -> Equal_code
"."       -- -> Dot_code
";"       -- -> Semicolon_code

```

```

", "      -- -> Comma_code
": "      -- -> Colon_code
"! "      -- -> Exclamation_code
"("      -- -> Left_parenthesis_code
") "      -- -> Right_parenthesis_code
"$ "      -- -> Dollar_code

"?? "     -- -> SYM_DT_UNKNOWN
"? "     -- -> Question_mark_code

"| "      -- -> SYM_INTERVAL_DELIM

"[ "      -- -> Left_bracket_code
"] "      -- -> Right_bracket_code

"{ "      -- -> SYM_START_CBLOCK
"} "      -- -> SYM_END_CBLOCK

".. "     -- -> SYM_ELLIPSIS
"... "    -- -> SYM_LIST_CONTINUE

-----/* common keywords */ -----

[Mm] [Aa] [Tt] [Cc] [Hh] [Ee] [Ss] -- -> SYM_MATCHES

[Ii] [Ss]_[Ii] [Nn]                -- -> SYM_MATCHES

-----/* assertion keywords */ -----

[Tt] [Hh] [Ee] [Nn]                -- -> SYM_THEN

[Ee] [Ll] [Ss] [Ee]                -- -> SYM_ELSE

[Aa] [Nn] [Dd]                     -- -> SYM_AND

[Oo] [Rr]                          -- -> SYM_OR

[Xx] [Oo] [Rr]                     -- -> SYM_XOR

[Nn] [Oo] [Tt]                     -- -> SYM_NOT

[Ii] [Mm] [Pp] [Ll] [Ii] [Ee] [Ss] -- -> SYM_IMPLIES

[Tt] [Rr] [Uu] [Ee]                -- -> SYM_TRUE

[Ff] [Aa] [Ll] [Ss] [Ee]           -- -> SYM_FALSE

[Ff] [Oo] [Rr] [_] [Aa] [Ll] [Ll]  -- -> SYM_FORALL

[Ee] [Xx] [Ii] [Ss] [Tt] [Ss]      -- -> SYM_EXISTS

-----/* cADL keywords */ -----

[Ee] [Xx] [Ii] [Ss] [Tt] [Ee] [Nn] [Cc] [Ee] -- -> SYM_EXISTENCE

[Oo] [Cc] [Cc] [Uu] [Rr] [Rr] [Ee] [Nn] [Cc] [Ee] [Ss] -- -> SYM_OCCURRENCES

```

```

[Cc][Aa][Rr][Dd][Ii][Nn][Aa][Ll][Ii][Tt][Yy]      -- -> SYM_CARDINALITY

[Oo][Rr][Dd][Ee][Rr][Ee][Dd]                        -- -> SYM_ORDERED

[Uu][Nn][Oo][Rr][Dd][Ee][Rr][Ee][Dd]                -- -> SYM_UNORDERED

[Uu][Nn][Ii][Qq][Uu][Ee]                            -- -> SYM_UNIQUE

[Ii][Nn][Ff][Ii][Nn][Ii][Tt][Yy]                    -- -> SYM_INFINITY

[Uu][Ss][Ee][_][Nn][Oo][Dd][Ee]                      -- -> SYM_USE_NODE

[Uu][Ss][Ee][_][Aa][Rr][Cc][Hh][Ee][Tt][Yy][Pp][Ee] -- ->
SYM_ALLOW_ARCHETYPE

[Aa][Ll][Ll][Oo][Ww][_][Aa][Rr][Cc][Hh][Ee][Tt][Yy][Pp][Ee]
SYM_ALLOW_ARCHETYPE

[Ii][Nn][Cc][Ll][Uu][Dd][Ee]                        -- -> SYM_INCLUDE

[Ee][Xx][Cc][Ll][Uu][Dd][Ee]                        -- -> SYM_EXCLUDE

-----/* V_URI */ -----
[a-z]+:\./\.[^>_]*

-----/* V_QUALIFIED_TERM_CODE_REF */ -----
-- any qualified code, e.g. [local::at0001], [local::ac0001], [loinc::700-0]
--

\[ [a-zA-Z0-9() . _ \- ]+ :: [a-zA-Z0-9 . _ \- ]+ \]

-----/* V_LOCAL_TERM_CODE_REF */ -----
-- any unqualified code, e.g. [at0001], [ac0001], [700-0]
--

\[ [a-zA-Z0-9] [a-zA-Z0-9 . _ \- ]* \]

-----/* V_LOCAL_CODE */ -----
a[ct][0-9.]+

-----/* V_QUALIFIED_TERM_CODE_REF */ -----
-- any qualified code, e.g. [local::at0001], [local::ac0001], [loinc::700-0]
--

\[ [a-zA-Z0-9() . _ \- ]+ :: [a-zA-Z0-9 . _ \- ]+ \]

-----/* V_ISO8601_DURATION */ -----
P([0-9]+[yY])?([0-9]+[mM])?([0-9]+[wW])?([0-9]+[dD])?T([0-9]+[hH])?([0-9]+[mM])?([0-9]+[sS])? |
P([0-9]+[yY])?([0-9]+[mM])?([0-9]+[wW])?([0-9]+[dD])?

-----/* V_ISO8601_DATE_CONSTRAINT_PATTERN */ -----
[yY][yY][yY][yY]-[mM?X][mM?X]-[dD?X][dD?X]

-----/* V_ISO8601_TIME_CONSTRAINT_PATTERN */ -----
[hH][hH]:[mM?X][mM?X]:[sS?X][sS?X]

-----/* V_ISO8601_DATE_TIME_CONSTRAINT_PATTERN */ -----
[yY][yY][yY][yY]-[mM?][mM?]-[dD?X][dD?X][ T][hH?X][hH?X]:[mM?X][mM?X]:[sS?X][sS?X]

-----/* V_ISO8601_DURATION_CONSTRAINT_PATTERN */ -----

```

```

P[yY]?[mM]?[wW]?[dD]?T[hH]?[mM]?[sS]? |
P[yY]?[mM]?[wW]?[dD]?

-----/* V_TYPE_IDENTIFIER */ -----
[A-Z]{IDCHAR}*

-----/* V_GENERIC_TYPE_IDENTIFIER */ -----
[A-Z]{IDCHAR}*<[a-zA-Z0-9,_<>]+>

-----/* V_ATTRIBUTE_IDENTIFIER */ -----
[a-z]{IDCHAR}*

-----/* V_C_DOMAIN_TYPE - sections of dADL syntax */ -----
{mini-parser specification}

-- this is an attempt to match a dADL section inside cADL. It will
-- probably never work 100% properly since there can be '>' inside "||"
-- ranges, and also strings containing any character, e.g. units string
-- containing "{}" chars. The real solution is to use the dADL parser on
-- the buffer from the current point on and be able to fast-forward the
-- cursor to the last character matched by the dADL scanner

[A-Z]{IDCHAR}*[ \n]*<                                -- match a pattern like
                                                         -- 'Type_Identifier whitespace <'

<IN_C_DOMAIN_TYPE> {
    [^>]*>[ \n]*[^>]A-Z                                -- match up to next > not
                                                         -- followed by a '}' or '>'

    [^>]*>+[ \n]*[]A-Z                                -- final section - '...>
                                                         -- whitespace } or beginning of
                                                         -- a type identifier'

    [^>]*[ \n]*                                        -- match up to next '}' not
                                                         -- preceded by a '>'
}

-----/* V_REGEXP */ -----
{mini-parser specification}
"/"                                                    -- start of regexp
<IN_REGEXP1>[^/]*\\\/                                  -- match any segments with quoted slashes
<IN_REGEXP1>[^/]}*\\\/                                  -- match final segment

\^[^^\n]*\^{                                           -- regexp formed using '^' delimiters

-----/* V_INTEGER */ -----
[0-9]+

-----/* V_REAL */ -----
[0-9]+\.[0-9]+
[0-9]+\.[0-9]+[eE][+-]?[0-9]+

-----/* V_STRING */ -----
\"[^\\"\\n"]*\"

\"[^\\"\\n"]*{                                          -- beginning of a multi-line string
<IN_STR> {
    \\\"\\\"                                           -- match escaped backslash, i.e. \\ -> \

```

```
\\\ "          -- match escaped double quote, i.e. \" -> "  
{UTF8CHAR}+   -- match UTF8 chars  
[^\\"\\n"]+    -- match any other characters  
\\\n[ \t\r]*   -- match LF in line  
[^\\"\\n"]*\\ " -- match final end of string  
  
.|\\n        |  
<<EOF>>      -- unclosed String -> ERR_STRING  
}
```


6 Assertions

6.1 Overview

This section describes the assertion sub-language of archetypes. Assertions are used in archetype “slot” clauses in the `cADL definition` section, and in the `invariant` section. The following simple assertion in an invariant clause says that the speed in kilometres of some node is related to the speed-in-miles by a factor of 1.6:

```
validity: /speed[at0002]/kilometres/magnitude =
          /speed[at0004]/miles/magnitude * 1.6
```

The archetype assertion language is a small language of its own. Formally it is a first-order predicate logic with equality and comparison operators ($=$, $>$, etc). It is very nearly a subset of the OMG’s emerging OCL (Object Constraint Language) syntax, and is very similar to the assertion syntax which has been used in the Object-Z [14] and Eiffel [12] languages and tools for over a decade. (See Sowa [15], Hein [8], Kilov & Ross [9] for an explanation of predicate logic in information modelling.)

6.2 Keywords

The syntax of the invariant section is a subset of first-order predicate logic. In it, the following keywords can be used:

- `exists`, `for_all`,
- `and`, `or`, `xor`, `not`, `implies`
- `true`, `false`

Symbol equivalents for some of the above are given in the following table.

Textual Rendering	Symbolic Rendering	Meaning
<code>matches</code> , <code>is_in</code>	\in	Set membership, “p is in P”
<code>exists</code>	\exists	Existential quantifier, “there exists ...”
<code>for_all</code>	\forall	Universal quantifier, “for all x...”
<code>implies</code>	\supset , \rightarrow	Material implication, “p implies q”, or “if p then q”
<code>and</code>	\wedge	Logical conjunction, “p and q”
<code>or</code>	\vee	Logical disjunction, “p or q”
<code>xor</code>	$\underline{\vee}$	Exclusive or, “only one of p or q”
<code>not</code> , \sim	\sim , \neg	Negation, “not p”

The not operator can be applied as a prefix operator to all other operators except `for_all`; either textual rendering “not” or “ \sim ” can be used.

6.3 Operators

Assertion expressions can include arithmetic, relational and boolean operators, plus the existential and universal quantifiers.

6.3.1 Arithmetic Operators

The supported arithmetic operators are as follows:

addition: +
subtraction: -
multiplication: *
division: /
exponent: ^
modulo division: % - remainder after integer division

6.3.2 Equality Operators

The supported equality operators are as follows:

equality: =
inequality: <>

The semantics of these operators are of value comparison.

6.3.3 Relational Operators

The supported relational operators are as follows:

less than: <
less than or equal: <=
greater than: >
greater than or equal: >=

The semantics of these operators are of value comparison. Their domain is limited to values of comparable types.

6.3.4 Boolean Operators

The supported boolean operators are as follows:

not: **not**
and: **and**
xor: **xor**
implies: **implies**
set membership: **matches**, **is_in**

The boolean operators also have symbolic equivalents shown earlier.

6.3.5 Quantifiers

The two standard logical quantifier operators are supported:

existential quantifier: **exists**
universal quantifier: **for_all**

These operators also have the usual symbolic equivalents shown earlier.

6.4 Operands

Operands in an assertion expression can be any of the following:

manifest constant: any constant of any primitive type, expressed according to the dADL syntax for values

variable reference: any name starting with '\$', e.g. \$body_weight;

object reference: a path referring to an object node, i.e. any path ending in a node identifier

property reference: a path referring to a property, i.e. any path ending in ".property_name"

If an assertion is used in an archetype slot definition, its paths refer to the archetype filling the slot, not the one containing the slot.

6.5 Precedence and Parentheses

To Be Continued:

6.6 Future

6.6.1 Variables

To Be Determined: main problem of variables is that they must have names, which are language-dependent; imagine if there were a mixture of variables added by authors in different languages. The only solution is to name them with terms.

To Be Determined: Variables have to be treated as term coordinations, and should be coded e.g. using ccNNNN codes ("cc" = coordinated code). Then they can be given meanings in any language.

Predefined Variables

A number of predefined variables can be referenced in ADL assertion expressions, without prior definition, including:

- \$current_date: Date; returns the date whenever the archetype is evaluated
- \$current_time: Time; returns time whenever the archetype is evaluated
- \$current_date_time: Date_Time; returns date/time whenever the archetype is evaluated

To Be Continued: these should be coded as well, using openEHR codes

Archetype-defined Variables

Variables can also be defined inside an archetype, as part of the assertion statements in an invariant. The syntax of variable definition is as follows:

```
let $var_name = reference
```

Here, a reference can be any of the operand types listed above. 'Let' statements can come anywhere in an invariant block, but for readability, should generally come first.

The following example illustrates the use of variables in an invariant block:

```
invariant
  let $sys_bp =
    /data[at9001]/events[at9002]/data[at1000]/items[at1100]
  let $dia_bp =
    /data[at9001]/events[at9002]/data[at1000]/items[at1200]
  $sys_bp >= $dia_bp
```

To Be Continued:

6.7 Syntax Specification

The assertion grammar is part of the cADL grammar, which is available as an [HTML document](http://my.openehr.org/wsvn/ref_impl_eiffel/TRUNK/components/adl_parser/src/syntax/cadl/parser/?rev=0&sc=0). This grammar is implemented and tested using lex (.l file) and yacc (.y file) specifications for in the Eiffel programming environment. The current release of these files is available at http://my.openehr.org/wsvn/ref_impl_eiffel/TRUNK/components/adl_parser/src/syntax/cadl/parser/?rev=0&sc=0. The .l and .y files can easily be converted for use in another yacc/lex-based programming environment.

6.7.1 Grammar

The following provides the cADL parser production rules (yacc specification) as of revision 46 of the Eiffel reference implementation repository (http://svn.openehr.org/ref_impl_eiffel). Note that because of interdependencies with path and assertion production rules, practical implementations may have to include all production rules in one parser.

```
assertions:
    assertion
| assertions assertion

assertion:
    any_identifier : boolean_expression
| boolean_expression
| any_identifier : error

boolean_expression:
    boolean_leaf
| boolean_node

boolean_node:
    SYM_EXISTS absolute_path
| SYM_EXISTS error
| V ATTRIBUTE IDENTIFIER SYM_MATCHES SYM_START_CBLOCK c_primitive
SYM_END_CBLOCK
| SYM_NOT boolean_leaf
| arithmetic_expression = arithmetic_expression
| arithmetic_expression SYM_NE arithmetic_expression
| arithmetic_expression SYM_LT arithmetic_expression
| arithmetic_expression SYM_GT arithmetic_expression
| arithmetic_expression SYM_LE arithmetic_expression
| arithmetic_expression SYM_GE arithmetic_expression
| boolean_expression SYM_AND boolean_expression
| boolean_expression SYM_OR boolean_expression
| boolean_expression SYM_XOR boolean_expression
| boolean_expression SYM_IMPLIES boolean_expression

boolean_leaf:
    ( boolean_expression )
| SYM_TRUE
| SYM_FALSE

arithmetic_expression:
    arithmetic_leaf
| arithmetic_node

arithmetic_node:
    arithmetic_expression + arithmetic_leaf
```

```
| arithmetic_expression - arithmetic_leaf  
| arithmetic_expression * arithmetic_leaf  
| arithmetic_expression / arithmetic_leaf  
| arithmetic_expression ^ arithmetic_leaf
```

arithmetic_leaf:

```
( arithmetic_expression )  
| integer_value  
| real_value  
| absolute_path
```


7 ADL Paths

7.1 Overview

The notion of paths is integral to ADL, and a common path syntax is used to reference nodes in both dADL and cADL sections of an archetype. The same path syntax works for both, because both dADL and cADL have an alternating object/attribute structure. However, the interpretation of path expressions in dADL and cADL differs slightly; the differences are explained in the dADL and cADL sections of this document. This section describes only the common syntax and semantics.

The general form of the path syntax is as follows (see syntax section below for full specification):

```
path: ['/' path_segment { '/' path_segment }+
path_segment: attr_name [ '[' object_id ']' ]
```

Essentially ADL paths consist of segments separated by slashes ('/'), where each segment is an attribute name with optional object identifier predicate, indicated by brackets ('[]').

ADL Paths are formed from an alternation of segments made up of an attribute name and optional object node identifier predicate, separated by slash ('/') characters. Node identifiers are delimited by brackets (i.e. []).

Similarly to paths used in file systems, ADL paths are either absolute or relative, with the former being indicated by a leading slash.

Paths are **absolute** or **relative** with respect to the document in which they are mentioned. Absolute paths commence with an initial slash ('/') character.

The ADL path syntax also supports the concept of “movable” path patterns, i.e. paths that can be used to find a section anywhere in a hierarchy that matches the path pattern. Path patterns are indicated with a leading double slash (“//”) as in Xpath.

Path **patterns** are absolute or relative with respect to the document in which they are mentioned. Absolute paths commence with an initial slash ('/') character.

7.2 Relationship with W3C Xpath

The ADL path syntax is semantically a subset of the Xpath query language, with a few syntactic shortcuts to reduce the verbosity of the most common cases. Xpath differentiates between “children” and “attributes” sub-items of an object due to the difference in XML between Elements (true sub-objects) and Attributes (tag-embedded primitive values). In ADL, as with any pure object formalism, there is no such distinction, and all subparts of any object are referenced in the manner of Xpath children; in particular, in the Xpath abbreviated syntax, the key `child::` does not need to be used.

ADL does not distinguish attributes from children, and also assumes the `node_id` attribute. Thus, the following expressions are legal for cADL structures:

```
items[1]           -- the first member of 'items'
items[systolic]    -- the member of 'items' with meaning 'systolic'
items[at0001]      -- the member of 'items' with node id 'at0001'
```

The Xpath equivalents are:

```
items[1]           -- the first member of 'items'
items[meaning() = 'systolic'] -- the member of 'items' for which the meaning()
function evaluates to "systolic"
items[@node_id = 'at0001'] -- the member of 'items' with key 'at0001'
```

In the above, `meaning()` is a notional function is defined for Xpath in *openEHR*, which returns the rubric for the `node_id` of the current node. Such paths are only for display purposes, and paths used for computing always use the 'at' codes, e.g. `items[at0001]`, for which the Xpath equivalent is `items[@node_id = 'at0001']`.

The ADL movable path pattern is a direct analogue of the Xpath syntax abbreviation for the 'descendant' axis.

7.3 Path Syntax

The ADL path grammar is available as an [HTML document](http://my.openehr.org/wsvn/ref_impl_eiffel/libraries/common_libs/src/structures/object_graph/path/?rev=0&sc=0). This grammar is implemented and tested using lex (.l file) and yacc (.y file) specifications for in the Eiffel programming environment. The current release of these files is available at http://my.openehr.org/wsvn/ref_impl_eiffel/libraries/common_libs/src/structures/object_graph/path/?rev=0&sc=0. The .l and .y files can easily be converted for use in another yacc/lex-based programming environment.

7.3.1 Grammar

The following provides the ADL path parser production rules (yacc specification) as of revision 46 of the Eiffel reference implementation repository (http://svn.openehr.org/ref_impl_eiffel).

```
input:
    movable_path
  | absolute_path
  | relative_path
  | error

movable_path:
    SYM_MOVABLE_LEADER relative_path

absolute_path:
    / relative_path
  | absolute_path / relative_path

relative_path:
    path_segment
  | relative_path / path_segment

path_segment:
    V_ATTRIBUTE_IDENTIFIER V_LOCAL_TERM_CODE_REF
  | V_ATTRIBUTE_IDENTIFIER
```

7.3.2 Symbols

The following specifies the symbols and lexical patterns used in the path grammar.

```
-----/* symbols */-----
"."      Dot_code
"/"      Slash_code

 "["     Left_bracket_code
 "]"     Right_bracket_code
```

"//"
SYM_MOVABLE_LEADER

-----/* term code reference */ -----
\[[a-zA-Z0-9] [a-zA-Z0-9._\-\]* \] V_LOCAL_TERM_CODE_REF

-----/* identifiers */ -----
[a-z] [a-zA-Z0-9_]* V_ATTRIBUTE_IDENTIFIER

8 ADL - Archetype Definition Language

8.1 Introduction

This section describes ADL archetypes as a whole, adding a small amount of detail to the descriptions of dADL and cADL already given. The important topic of the relationship of the cADL-encoded definition section and the dADL-encoded ontology section is discussed in detail. In this section, only standard ADL (i.e. the cADL and dADL constructs and types described so far) is assumed. Archetypes for use in particular domains can also be built with more efficient syntax and domain-specific types, as described in Customising ADL on page 105, and the succeeding sections.

An ADL archetype follows the structure shown below:

```

archetype
    archetype_id
    [specialize
        parent_archetype_id]
    concept
        coded_concept_name
    language
        dADL language description section
    description
        dADL meta-data section
    definition
        cADL structural section
    invariant
        assertions
    ontology
        dADL definitions section
    [revision_history
        dADL section]
  
```

8.2 Basics

8.2.1 Keywords

ADL has a small number of keywords which are reserved for use in archetype declarations, as follows:

- archetype, specialise/specialize, concept,
- language,
- description, definition, invariant, ontology

All of these words can safely appear as identifiers in the definition and ontology sections.

8.2.2 Node Identification

In the definition section of an ADL archetype, a particular scheme of codes is used for node identifiers as well as for denoting constraints on textual (i.e. language dependent) items. Codes are either local to the archetype, or from an external lexicon. This means that the archetype description is the same in all languages, and is available in any language that the codes have been translated to. All term codes are shown in brackets ([]). Codes used as node identifiers and defined within the same archetype are prefixed with “at” and by convention have 4 digits, e.g. [at0010]. Codes of any length are acceptable in ADL archetypes. Specialisations of locally coded concepts have the same root, fol-

lowed by “dot” extensions, e.g. [at0010.2]. From a terminology point of view, these codes have no implied semantics - the “dot” structuring is used as an optimisation on node identification.

8.2.3 Local Constraint Codes

A second kind of local code is used to stand for constraints on textual items in the body of the archetype. Although these could be included in the main archetype body, because they are language- and/or terminology-sensitive, they are defined in the ontology section, and referenced by codes prefixed by “ac”, e.g. [ac0009]. As for “at” codes, the convention used in this document is to use 4-digit “ac” codes, even though any number of digits is acceptable. The use of these codes is described in section 8.6.4

8.3 Header Sections

8.3.1 Archetype Section

This section introduces the archetype and must include an identifier. A typical `archetype` section is as follows:

```
archetype (adl_version=1.4)
  mayo.openehr-ehr-entry.haematology.v1
```

The multi-axial identifier identifies archetypes in a global space. The syntax of the identifier is described under Archetype Identification on page 9 in The openEHR Archetype System.

8.3.2 Controlled Indicator

A flag indicating whether the archetype is change-controlled or not can be included after the version, as follows:

```
archetype (adl_version=1.4; controlled)
  mayo.openehr-ehr-entry.haematology.v1
```

This flag may have the two values “controlled” and “uncontrolled” only, and is an aid to software. Archetypes that include the “controlled” flag should have the revision history section included, while those with the “uncontrolled” flag, or no flag at all, may omit the revision history. This enables archetypes to be privately edited in an early development phase without generating large revision histories of little or no value.

8.3.3 Specialise Section

This optional section indicates that the archetype is a specialisation of some other archetype, whose identity must be given. Only one specialisation parent is allowed, i.e. an archetype cannot ‘multiply-inherit’ from other archetypes. An example of declaring specialisation is as follows:

```
archetype (adl_version=1.4)
  mayo.openehr-ehr-entry.haematology-cbc.v1
specialise
  mayo.openehr-ehr-entry.haematology.v1
```

Here the identifier of the new archetype is derived from that of the parent by adding a new section to its domain concept section. See Archetype Identification on page 9 in The openEHR Archetype System.

Note that both the US and British English versions of the word “specialise” are valid in ADL.

8.3.4 Concept Section

All archetypes represent some real world concept, such as a “patient”, a “blood pressure”, or an “ante-natal examination”. The concept is always coded, ensuring that it can be displayed in any language the archetype has been translated to. A typical `concept` section is as follows:

```
concept
[at0010]      -- haematology result
```

In this concept definition, the term definition of `[at0010]` is the proper description corresponding to the “haematology-cbc” section of the archetype id above.

8.3.5 Language Section and Language Translation

The `language` section includes data describing the original language in which the archetype was authored (essential for evaluating natural language quality), and the total list of languages available in the archetype. There can be only one `original_language`. The `translations` list must be updated every time a translation of the archetype is undertaken. The following shows a typical example.

```
language
  original_language = <"en">
  translations = <
    ["de"] = <
      author = <"freddy@something.somewhere.co.uk">
      accreditation = <"British Medical Translator id 00400595">
    >
    ["ru"] = <
      author = <"vladimir@something.somewhere.ru">
      accreditation = <"Russian Translator id 892230A">
    >
  >
```

Archetypes must always be translated completely, or not at all, to be valid. This means that when a new translation is made, every language dependent section of the `description` and `ontology` sections has to be translated into the new language, and an appropriate addition made to the `translations` list in the `language` section.

8.3.6 Description Section

The `description` section of an archetype contains descriptive information, or what some people think of as document “meta-data”, i.e. items that can be used in repository indexes and for searching. The dADL syntax is used for the description, as in the following example.

```
description
  original_author = <
    ["name"] = <"Dr J Joyce">
    ["organisation"] = <"NT Health Service">
    ["date"] = <2003-08-03>
  >
  lifecycle_state = <"initial">
  archetype_package_uri =
    <"www.aihw.org.au/data_sets/diabetic_archetypes.html">

  details = <
    ["en"] = <
      purpose = <"archetype for diabetic patient review">
      use = <"used for all hospital or clinic-based diabetic reviews,
        including first time. Optional sections are removed according
        to the particular review">
```

```

misuse = <"not appropriate for pre-diagnosis use">
original_resource_uri =
    <"www.healthdata.org.au/data_sets/
        diabetic_review_data_set_1.html">
other_details = <...>
>
["de"] = <
    purpose = <"Archetyp für die Untersuchung von Patienten
        mit Diabetes">
    use = <"wird benutzt für alle Diabetes-Untersuchungen im
        Krankenhaus, inklusive der ersten Vorstellung. Optionale
        Abschnitte werden in Abhängigkeit von der speziellen
        Vorstellung entfernt.">
    >
    misuse = <"nicht geeignet für Benutzung vor Diagnosestellung">
    original_resource_uri =
        <"www.healthdata.org.au/data_sets/
            diabetic_review_data_set_1.html">
    other_details = <...>
    >
    >
    >

```

A number of details are worth noting here. Firstly, the free hierarchical structuring capability of dADL is exploited for expressing the “deep” structure of the details section and its subsections. Secondly, the dADL qualified list form is used to allow multiple translations of the purpose and use to be shown. Lastly, empty items such as misuse (structured if there is data) are shown with just one level of empty brackets. The above example shows meta-data based on the HL7 Templates Proposal [17] and the meta-data of the SynEx and GeHR archetypes.

Which descriptive items are required will depend on the semantic standards imposed on archetypes by health standards organisations and/or the design of archetype repositories and is not specified by ADL.

8.4 Definition Section

The definition section contains the main formal definition of the archetype, and is written in the Constraint Definition Language (cADL). A typical definition section is as follows:

```

definition
ENTRY[at0000] ∈ {
    name ∈ {
        CODED_TEXT ∈ {
            code ∈ {
                CODE_PHRASE ∈ {[ac0001]}
            }
        }
    }
}
data ∈ {
    HISTORY[at9001] ∈ {
        events cardinality ∈ {1..*} ∈ {
            EVENT[at9002] occurrences ∈ {0..1} ∈ {-- baseline
                name ∈ {
                    CODED_TEXT ∈ {
                        code ∈ {
                            CODE_PHRASE ∈ {[ac0002]}
                        }
                    }
                }
            }
        }
    }
}

```

```

    }
    data ∈ {
      LIST_S[at1000] ∈ {          -- systemic arterial BP
        items cardinality ∈ {2..*} ∈ {
          ELEMENT[at1100] ∈ {          -- systolic BP
            name ∈ {          -- any synonym of 'systolic'
              CODED_TEXT ∈ {
                code ∈ {
                  CODE_PHRASE ∈ {[ac0002]}
                }
              }
            }
          }
        value ∈ {
          QUANTITY ∈ {
            magnitude ∈ {0..1000}
            property ∈ {[properties::0944]}
            units ∈ {[units::387]} -- "mm[Hg]"
          }
        }
      }
      ELEMENT[at1200] ∈ {          -- diastolic BP
        name ∈ {          -- any synonym of 'diastolic'
          CODED_TEXT ∈ {
            code ∈ {
              CODE_PHRASE ∈ {[ac0003]}
            }
          }
        }
        value ∈ {
          QUANTITY ∈ {
            magnitude ∈ {0..1000}
            property ∈ {[properties::0944]}
            units ∈ {[units::387]} -- "mm[Hg]"
          }
        }
      }
      ELEMENT[at9000] occurrences ∈ {0..*} ∈ {*}
                                     -- unknown new item
    }
    ...

```

This definition expresses constraints on instances of the types ENTRY, HISTORY, EVENT, LIST_S, ELEMENT, QUANTITY, and CODED_TEXT so as to allow them to represent a blood pressure measurement, consisting of a history of measurement events, each consisting of at least systolic and diastolic pressures, as well as any number of other items (expressed by the [at9000] “any” node near the bottom).

8.5 Invariant Section

The `invariant` section in an ADL archetype introduces assertions which relate to the entire archetype, and can be used to make statements which are not possible within the block structure of the `definition` section. Any constraint which relates more than one property to another is in this category, as are most constraints containing mathematical or logical formulae. Invariants are expressed in the archetype assertion language, described in section 6 on page 79.

An invariant statement is a first order predicate logic statement which can be evaluated to a boolean result at runtime. Objects and properties are referred to using paths.

The following simple example says that the speed in kilometres of some node is related to the speed-in-miles by a factor of 1.6:

```
invariant
  validity: /speed[at0002]/kilometres/magnitude =
            /speed[at0004]/miles/magnitude * 1.6
```

8.6 Ontology Section

8.6.1 Overview

The `ontology` section of an archetype is expressed in dADL, and is where codes representing node IDs, constraints on text or terms, and bindings to terminologies are defined. Linguistic language translations are added in the form of extra blocks keyed by the relevant language. The following example shows the layout of this section.

```
ontology
  terminologies_available = <"snomed_ct", ...>

  term_definitions = <
    ["en"] = <
      items = <...>
    >
    ["de"] = <
      items = <...>
    >
  >

  term_binding = <
    ["snomed_ct"] = <
      items = <...>
    >
    ...
  >

  constraint_definitions = <
    ["en"] = <...>
    ["de"] = <
      items = <...>
    >
    ...
  >

  constraint_binding = <
    ["snomed_ct"] = <...>
    ...
  >
```

The `term_definitions` section is mandatory, and must be defined for each translation carried out.

Each of these sections can have its own meta-data, which appears within description sub-sections, such as the one shown above providing translation details.

In some cases, term definitions may have been lifted from existing terminologies (only a safe thing to do if the definitions *exactly* match the need in the archetype). To indicate where definitions come from, a “provenance” tag can be used, as follows:

```
[“at4000”] = <
  text = <“plan”>;
  description = <“The clinician's professional advice”>;
  provenance = <“ACME_terminology(v3.9a)”>
>
```

Note that this does not indicate a *binding* to any term, only its origin. Bindings are described in section 8.6.5 and section 8.6.6.

8.6.4 Constraint_definition Section

The `constraint_definition` section is of exactly the same form as the `term_definition` section, and provides the definitions - i.e. the meanings - of the local constraint codes, which are of the form [acNNNN]. Each such code refers to some constraint such as “any term which is a subtype of ‘hepatitis’ in the ICD9AM terminology”; the constraint definitions do not provide the constraints themselves, but define the *meanings* of such constraints, in a manner comprehensible to human beings, and usable in GUI applications. This may seem a superfluous thing to do, but in fact it is quite important. Firstly, term constraints can only be expressed with respect to particular terminologies - a constraint for “kind of hepatitis” would be expressed in different ways for each terminology which the archetype is bound to. For this reason, the actual constraints are defined in the `constraint_binding` section. An example of a constraint term definition for the hepatitis constraint is as follows:

```
items = <
  [“ac1015”] = <
    text = <“type of hepatitis”>
    description = <“any term which means a kind of viral hepatitis”>
  >
>
```

Note that while it often seems tempting to use classification codes, e.g. from the ICD vocabularies, these will rarely be much use in terminology or constraint definitions, because it is nearly always *descriptive*, not classificatory terms which are needed.

8.6.5 Term_binding Section

This section is used to describe the equivalences between archetype local terms and terms found in external terminologies. The purpose is solely for allowing query engine software which wants to search for an instance of some external term to determine what equivalent to use in the archetype. Note that this is distinct from the process of embedding mapped terms in runtime data, which is also possible with the data models of HL7v3, openEHR, and CEN 13606.

A typical term binding section resembles the following:

```
term_binding(“umls”) = <
  [“umls”] = <
    items =<
      [“at0000”] = <[umls::C124305]> -- apgar result
      [“at0002”] = <[umls::00000000]> -- 1-minute event
      [“at0004”] = <[umls::C234305]> -- cardiac score
      [“at0005”] = <[umls::C232405]> -- respiratory score
      [“at0006”] = <[umls::C254305]> -- muscle tone score
      [“at0007”] = <[umls::C987305]> -- reflex response score
      [“at0008”] = <[umls::C189305]> -- color score
      [“at0009”] = <[umls::C187305]> -- apgar score
    >
  >
>
```



```

["at0010"] = <[umls::C325305]> -- 2-minute apgar
["at0011"] = <[umls::C725354]> -- 5-minute apgar
["at0012"] = <[umls::C224305]> -- 10-minute apgar
>
>
>

```

Each entry simply indicates which term in an external terminology is equivalent to the archetype internal codes. Note that not all internal codes necessarily have equivalents: for this reason, a terminology binding is assumed to be valid even if it does not contain all of the internal codes.

To Be Determined: future possibility: more than one binding to the same terminology for different purposes, or by different authors?

To Be Determined: need to handle numerous small vocabularies defined by one authority e.g. HL7.

8.6.6 Constraint_binding Section

The last of the ontology sections formally describes text constraints from the main archetype body. They are described separately because they are terminology dependent, and because there may be more than one for a given logical constraint. A typical example follows:

```

constraint_binding = <
  ["snomed_ct"]
  items = <
    ["ac0001"] = <http://terminology.org?terminology_id=snomed_ct&&
      has_relation=[102002];with_target=[128004]>
    ["ac0002"] = <http://terminology.org?terminology_id=snomed_ct&&
      synonym_of=[128025]>
  >
>
>

```

In this example, each local constraint code is formally defined to refer to the result of a query to a service, in this case, a terminology service which can interrogate the Snomed-CT terminology.

8.7 Revision History Section

The revision history section of an archetype shows the audit history of changes to the archetype, and is expressed in dADL syntax. It is optional, and is included at the end of the archetype, since it does not contain content of direct interest to archetype authors, and will monotonically grow in size. Where archetypes are stored in a version-controlled repository such as CVS or some commercial product, the revision history section would normally be regenerated each time by the authoring software, e.g. via processing of the output of the 'prs' command used with SCCS files, or 'rlog' for RCS files. The following shows a typical example, with entries in most-recent-first order (although technically speaking, the order is irrelevant to ADL).

```

revision_history
  revision_history = <
    ["1.57"] = <
      committer = <"Miriam Hanoosh">
      committer_organisation = <"AIHW.org.au">
      time_committed = <2004-11-02 09:31:04+1000>
      revision = <"1.2">
      reason = <"Added social history section">
      change_type = <"Modification">
    >
  >

```

```
-- etc
["1.1"] = <
  committer = <"Enrico Barrios">
  committer_organisation = <"AIHW.org.au">
  time_committed = <"2004-09-24 11:57:00+1000">
  revision = <"1.1">
  reason = <"Updated HbA1C test result reference">
  change_type = <"Modification">
>
["1.0"] = <
  committer = <"Enrico Barrios">
  committer_organisation = <"AIHW.org.au">
  time_committed = <"2004-09-14 16:05:00+1000">
  revision = <"1.0">
  reason = <"Initial Writing">
  change_type = <"Creation">
>
>
```

8.8 Validity Rules

This section describes the formal (i.e. checkable) semantics of ADL archetypes. It is recommended that parsing tools use the identifiers published here in their error messages, as an aid to archetype designers.

8.8.1 Global Archetype Validity

The following validity constraints apply to an archetype as a whole. Note that the term “section” means the same as “attribute” in the following, i.e. a section called “definition” in a dADL text is a serialisation of the value for the attribute of the same name.

VARID: archetype identifier validity. The archetype must have an identifier value for the [archetype_id](#) section. The identifier must conform to the published *openEHR* specification for archetype identifiers.

VARCN: archetype concept validity. The archetype must have an archetype term value in the [concept](#) section. The term must exist in the archetype ontology.

VARDF: archetype definition validity. The archetype must have a [definition](#) section, expressed as a cADL syntax string, or in an equivalent plug-in syntax.

VARON: archetype ontology validity. The archetype must have an [ontology](#) section, expressed as a cADL syntax string, or in an equivalent plug-in syntax.

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

8.8.2 Coded Term Validity

All node identifiers (‘at’ codes) used in the `definition` part of the archetype must be defined in the `term_definitions` part of the ontology.

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

All constraint identifiers ('ac' codes) used in the `definition` part of the archetype must be defined in the `constraint_definitions` part of the ontology.

VACDF: node identifier validity. Each constraint code used in the archetype definition part must be defined in the `constraint_definitions` part of the ontology.

8.8.3 Definition Section

The following constraints apply to the `definition` section of the archetype.

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

VDFPT: path validity in definition. Any path mentioned in the definition section must be valid syntactically, and a valid path with respect to the hierarchical structure of the definition section.

8.9 Syntax Specification

8.9.1 Grammar

This section describes the ADL grammar, as implemented and tested in the *openEHR* implementation project.

```
--
-- From revision 63 of http://svn.openehr.org/ref_impl_eiffel/TRUNK
--

input:
    archetype
| error

archetype:
    arch_identification arch_specialisation arch_concept arch_description
    arch_definition arch_invariant arch_ontology

arch_identification:
    arch_head V_ARCHETYPE_ID
| SYM_ARCHETYPE error

arch_head:
    SYM_ARCHETYPE
| SYM_ARCHETYPE arch_meta_data

arch_meta_data:
    ( arch_meta_data_items )

arch_meta_data_items:
    arch_meta_data_item
| arch_meta_data_items ; arch_meta_data_item

arch_meta_data_item:
    SYM_ADL_VERSION = V_VERSION_STRING
| SYM_IS_CONTROLLED

arch_specialisation:
    -/-
```

```
| SYM_SPECIALIZE V_ARCHETYPE_ID
| SYM_SPECIALIZE error

arch_concept:
  SYM_CONCEPT V_LOCAL_TERM_CODE_REF
| SYM_CONCEPT error

arch_description:
  -/-
| SYM_DESCRIPTION V_DADL_TEXT
| SYM_DESCRIPTION error

arch_definition:
  SYM_DEFINITION V_CADL_TEXT
| SYM_DEFINITION error

arch_invariant:
  -/-
| SYM_INVARIANT V_ASSERTION_TEXT
| SYM_INVARIANT error

arch_ontology:
  SYM_ONTOLOGY V_DADL_TEXT
| SYM_ONTOLOGY error
```

8.9.2 Symbols

The following shows the ADL lexical specification.

```
-----/* symbols */ -----
"--"      Minus_code
"+"      Plus_code
"*"      Star_code
"/"      Slash_code
"^"      Caret_code
"="      Equal_code
"."      Dot_code
";"      Semicolon_code
","      Comma_code
":"      Colon_code
"!"      Exclamation_code
"("      Left_parenthesis_code
")"      Right_parenthesis_code
"$"      Dollar_code
"?"      Question_mark_code

 "["      Left_bracket_code
 "]"      Right_bracket_code

-----/* keywords */ -----
^[Aa][Rr][Cc][Hh][Ee][Tt][Yy][Pp][Ee][ \t\r]*\n      SYM_ARCHETYPE
^[Ss][Pp][Ee][Cc][Ii][Aa][Ll][Ii][SsZz][Ee][ \t\r]*\n  SYM_SPECIALIZE
^[Cc][Oo][Nn][Cc][Ee][Pp][Tt][ \t\r]*\n              SYM_CONCEPT
^[Dd][Ee][Ff][Ii][Nn][Ii][Tt][Ii][Oo][Nn][ \t\r]*\n  SYM_DEFINITION
  -- mini-parser to generate V_DADL_TEXT

^[Dd][Ee][Ss][Cc][Rr][Ii][Pp][Tt][Ii][Oo][Nn][ \t\r]*\n  SYM_DESCRIPTION
  -- mini-parser to generate V_CADL_TEXT
```

```

^[Ii][Nn][Vv][Aa][Rr][Ii][Aa][Nn][Tt][ \t\r]*\n          SYM_INVARIANT
  -- mini-parser to generate V_ASSERTION_TEXT

^[Oo][Nn][Tt][Oo][Ll][Oo][Gg][Yy][ \t\r]*\n          SYM_ONTOLOGY
  -- mini-parser to generate V_DADL_TEXT

-----/* term code reference */ -----
\[ [a-zA-Z0-9] [a-zA-Z0-9.-]* \]          V_LOCAL_TERM_CODE_REF

-----/* archetype id */ -----
[a-zA-Z] [a-zA-Z0-9_-]+ \. [a-zA-Z] [a-zA-Z0-9_-]+ \. [a-zA-Z0-9]+
                                          V_ARCHETYPE_ID

-----/* identifiers */ -----
[a-zA-Z] [a-zA-Z0-9_-]*          V_IDENTIFIER

```

9 The ADL Parsing Process

9.1 Overview

FIGURE 6 illustrates the ADL parsing process. An ADL file is converted by the ADL parser into an ADL parse tree. This tree is an in-memory object structure representation of the semantics of the archetype, in a form corresponding to the *openEHR* Archetype Object Model. This model 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).

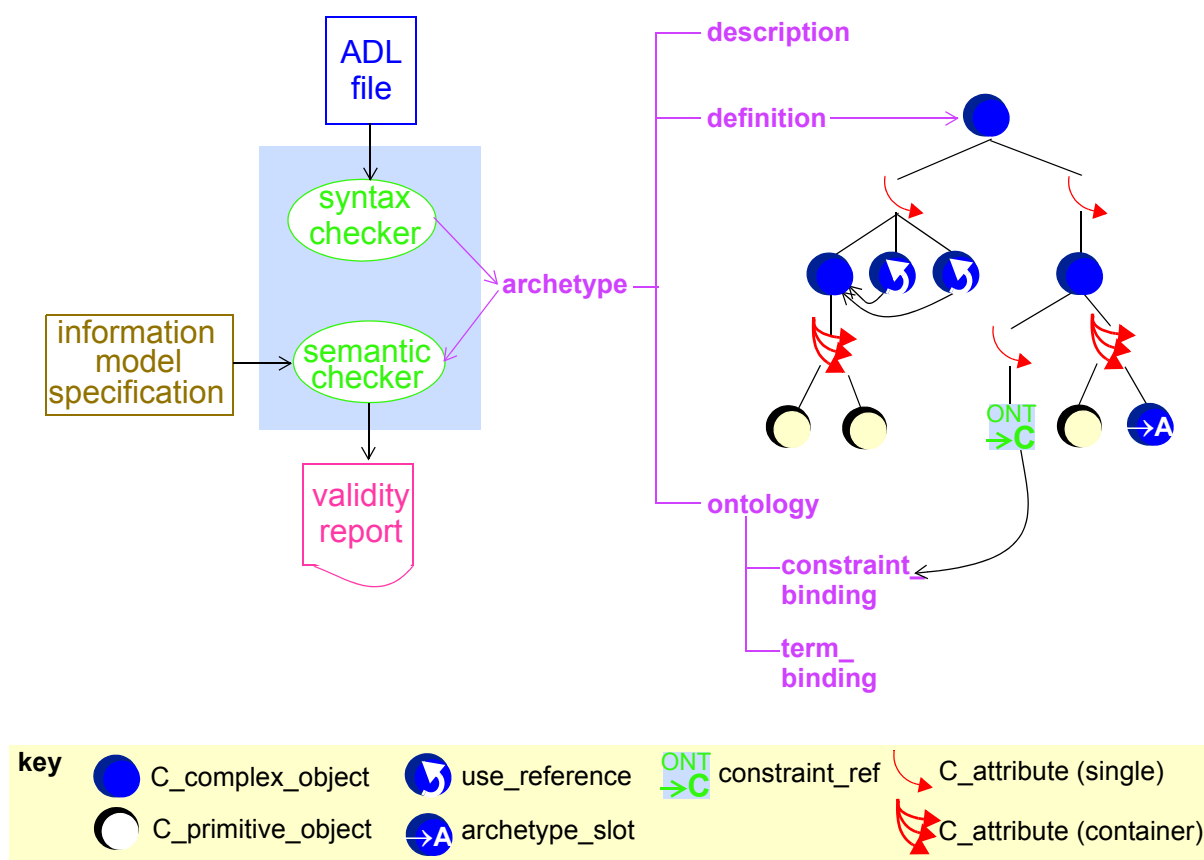


FIGURE 6 Parsed ADL Structure

The object equivalent of an ADL file is shown on the right. It consists of alternate layers of object and relationship nodes, each containing the next level of nodes. At the extremities are leaf nodes - object nodes constraining primitive types such as *String*, *Integer* etc. There are also “use” nodes which represent internal references to other nodes, text constraint nodes which refer to a text constraint in the constraint binding part of the archetype, 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: a 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 conceptualised as 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.

See the *openEHR* Archetype Object Model (AOM) for details.

10 Customising ADL

10.1 Introduction

Standard ADL has a completely regular way of representing constraints. Type names and attribute names from a reference model are mentioned in an alternating, hierarchical structure that is isomorphic to the aggregation structure of the corresponding classes in the reference model. Constraints at the leaf nodes are represented in a syntactic way that avoids committing to particular modelling details. The overall result enables constraints on most reference model types to be expressed. This section describes how to handle exceptions from the standard semantics. *openEHR* uses a small number of such exceptions, which are documented in the *openEHR* Archetype Profile (oAP) document.

A situation in which standard ADL falls short is when the required semantics of constraint are different from those available naturally from the standard approach. Consider the reference model type `DV_QUANTITY`, shown at the top of FIGURE 7, which could be used to represent a person's age in an archetype.

QTY
property: String
magnitude: Real
units: String

FIGURE 7 Example reference model type

A typical ADL constraint to enable `QTY` to be used to represent age in clinical data can be expressed in natural language as follows:

```
property matches "time"
units matches "years" or "months"
if units is "years" then magnitude matches 0..200 (for adults)
if units is "months" then magnitude matches 3..36 (for infants)
```

The standard ADL expression for this requires the use of multiple alternatives, as follows:

```
age matches {
  QTY matches {
    property matches {"time"}
    units matches {"yr"}
    magnitude matches {|0.0..200.0|}
  }
  QTY matches {
    property matches {"time"}
    units matches {"mth"}
    magnitude matches {|3.0..12.0|}
  }
}
```

While this is a perfectly legal approach, it is not the most natural expression of the required constraint, since it repeats the constraint of *property* matching "time". It also makes processing by software slightly more difficult than necessary.

A more convenient possibility is to introduce a new class into the archetype model, representing the concept "constraint on `QTY`", which we will call `C_QTY`. Such a class fits into the class model of arche-

types (see the *openEHR AOM*) by inheriting from the class `C_DOMAIN_TYPE`. The `C_QTY` class is illustrated in FIGURE 8, and corresponds to the way constraints on `QTY` objects are often expressed in user applications, which is to say, a property constraint, and a separate list of units/magnitude pairs.

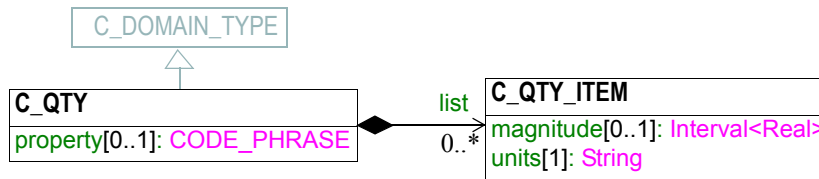


FIGURE 8 Example C_XX Type

The question now is how to express a constraint corresponding to this class in an ADL archetype. The solution is logical, and uses standard ADL. Consider that a particular constraint on a `QTY` must be an *instance* of the `C_QTY` type. An instance of any class can be expressed in ADL using the dADL syntax (ADL's object serialisation syntax) at the appropriate point in the archetype, as follows:

```

value matches {
  C_QTY <
    property = <[openehr::128]>
    list = <
      items = <
        [1] = <
          units = <"yr">
          magnitude = <|0.0..200.0|>
        >
        [2] = <
          units = <"mth">
          magnitude = <|1.0..36.0|>
        >
      >
    >
  >
}
  
```

This approach can be used for any custom type which represents a constraint on a reference model type. Since the syntax is generic, only one change is needed to an ADL parser to support dADL sections within the cADL (definition) part of an archetype. The syntax rules are as follows:

- the dADL section occurs inside the `{}` block where its standard ADL equivalent would have occurred (i.e. no other delimiters or special marks are needed);
- the dADL section must be 'typed', i.e. it must start with a type name, which should correspond directly to a reference model type;
- the dADL instance must obey the semantics of the custom type of which it is an instance, i.e. include the correct attribute names and relationships.

It should be understood of course, that just because a custom constraint type has been defined, it does not need to be used to express constraints on the reference model type it targets. Indeed, any mixture of standard ADL and dADL-expressed custom constraints may be used within the one archetype.

10.1.1 Custom Syntax

A dADL section is not the only possibility for expressing a custom constraint type. A useful alternative is a custom addition to the ADL syntax. Custom syntax can be smaller, more intuitive to read, and easier to parse than embedded dADL sections. A typical example of the use of custom syntax is

to express constraints on the type `CODE_PHRASE` in the *openEHR* reference model (`rm.data_types` package). This type models the notion of a ‘coded term’, which is ubiquitous in clinical computing. The standard ADL for a constraint on the *defining_code* attribute of a class `CODE_PHRASE` is as follows:

```
defining_code matches {
  CODE_PHRASE matches {
    terminology_id matches {"local"}
    code_string matches {"at0039"} -- lying
  }
  CODE_PHRASE matches {
    terminology_id matches {"local"}
    code_string matches {"at0040"} -- sitting
  }
}
```

However, as with `QUANTITY`, the most typical constraint required on a `CODE_PHRASE` is factored differently from the standard ADL - the need is almost always to specify the terminology, and then a set of *code_strings*. A type `C_CODE_PHRASE` type can be defined as shown in FIGURE 9.

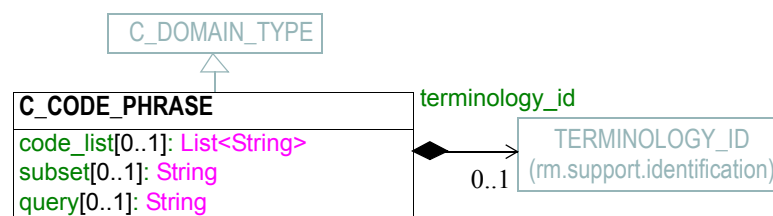


FIGURE 9 `C_CODE_PHRASE`

Using the dADL section method, including a `C_CODE_PHRASE` constraint would require the following section:

```
defining_code matches {
  C_CODE_PHRASE <
    terminology_id = <
      value = <"local">
    >
    code_list = <
      ["1"] = <"at0039">
      ["2"] = <"at0040">
    >
  >
}
```

Although this is perfectly legal, a more compact and readable rendition of this same constraint is provided by a custom syntax addition to ADL, which enables the above example to be written as follows:

```
defining_code matches {
  [local::
    at0039,
    at0040]
}
```

The above syntax should be understood as an extension to the ADL grammar, and an archetype tool supporting the extension needs to have a modified parser. While these two ADL fragments express exactly the same constraint, the second is shorter and clearer.

11 Relationship of ADL to Other Formalisms

11.1 Overview

Whenever a new formalism is defined, it is reasonable to ask the question: are there not existing formalisms which would do the same job? Research to date has shown that in fact, no other formalism has been designed for the same use, and none easily express ADL's semantics. During ADL's initial development, it was felt that there was great value in analysing the problem space very carefully, and constructing an abstract syntax exactly matched to the solution, rather than attempting to use some other formalism - undoubtedly designed for a different purpose - to try and express the semantics of archetypes, or worse, to start with an XML-based exchange format, which often leads to the conflation of abstract and concrete representational semantics. Instead, the approach used has paid off, in that the resulting syntax is very simple and powerful, and in fact has allowed mappings to other formalisms to be more correctly defined and understood. The following sections compare ADL to other formalisms and show how it is different.

11.2 Constraint Syntaxes

11.2.1 OCL (Object Constraint Language)

The OMG's Object Constraint Language (OCL) appears at first glance to be an obvious contender for writing archetypes. However, its designed use is to write constraints on *object models*, rather than on *data*, which is what archetypes are about. As a concrete example, OCL can be used to make statements about the *actors* attribute of a class *Company* - e.g. that *actors* must exist and contain the *Actor* who is the *lead* of *Company*. However, if used in the normal way to write constraints on a class model, it cannot describe the notion that for a particular kind of (acting) company, such as 'itinerant jugglers', there must be at least four actors, each of whom have among their *capabilities* 'advanced juggling', plus an *Actor* who has *skill* 'musician'. This is because doing so would constrain all instances of the class *Company* to conform to the specific configuration of instances corresponding to actors and jugglers, when what is intended is to allow a myriad of possibilities. ADL provides the ability to create numerous archetypes, each describing in detail a concrete configuration of instances of type *Company*.

OCL's constraint types include function pre- and post-conditions, and class invariants. There is no structural character to the syntax - all statements are essentially first-order predicate logic statements about elements in models expressed in UML, and are related to parts of a model by 'context' statements. This makes it impossible to use OCL to express an archetype in a structural way which is natural to domain experts. OCL also has some flaws, described by Beale [4].

However, OCL is in fact relevant to ADL. ADL archetypes include invariants (and one day, might include pre- and post-conditions). Currently these are expressed in a syntax very similar to OCL, with minor differences. The exact definition of the ADL invariant syntax in the future will depend somewhat on the progress of OCL through the OMG standards process.

11.3 Ontology Formalisms

11.3.1 OWL (Web Ontology Language)

The Web Ontology Language (OWL) [20] is a W3C initiative for defining Web-enabled ontologies which aim to allow the building of the "Semantic Web". OWL has an abstract syntax [13], developed

at the University of Manchester, UK, and an exchange syntax, which is an extension of the XML-based syntax known as RDF (Resource Description Framework). We discuss OWL only in terms of its abstract syntax, since this is a semantic representation of the language unencumbered by XML or RDF details (there are tools which convert between abstract OWL and various exchange syntaxes).

OWL is a general purpose description logic (DL), and is primarily used to describe “classes” of things in such a way as to support *subsumptive* inferencing within the ontology, and by extension, on data which are instances of ontology classes. There is no general assumption that the data itself were built based on any particular class model - they might be audio-visual objects in an archive, technical documentation for an aircraft or the Web pages of a company. OWL’s class definitions are therefore usually constraint statements on an *implied* model on which data *appears* to be based. However, the semantics of an information model can themselves be represented in OWL. Restrictions are the primary way of defining subclasses.

In intention, OWL is aimed at representing some ‘reality’ and then making inferences about it; for example in a medical ontology, it can infer that a particular patient is at risk of ischemic heart disease due to smoking and high cholesterol, if the knowledge that ‘ischemic heart disease has-risk-factor smoking’ and ‘ischemic heart disease has-risk-factor high cholesterol’ are in the ontology, along with a representation of the patient details themselves. OWL’s inferencing works by subsumption, which is to say, asserting either that an ‘individual’ (OWL’s equivalent of an object-oriented instance or a type) conforms to a ‘class’, or that a particular ‘class’ ‘is-a’ (subtype of another) ‘class’; this approach can also be understood as category-based reasoning or set-containment.

ADL can also be thought of as being aimed at describing a ‘reality’, and allowing inferences to be made. However, the reality it describes is in terms of constraints on information structures (based on an underlying information model), and the inferencing is between data and the constraints. Some of the differences between ADL and OWL are as follows.

- ADL syntax is predicated on the existence of existing object-oriented reference models, expressed in UML or some similar formalism, and the constraints in an ADL archetype are in relation to types and attributes from such a model. In contrast, OWL is far more general, and requires the explicit expression of a reference model in OWL, before archetype-like constraints can be expressed.
- Because information structures are in general hierarchical compositions of nodes and elements, and may be quite deep, ADL enables constraints to be expressed in a structural, nested way, mimicking the tree-like nature of the data it constrains. OWL does not provide a native way to do this, and although it is possible to express approximately the same constraints in OWL, it is fairly inconvenient, and would probably only be made easy by machine conversion from a visual format more or less like ADL.
- As a natural consequence of dealing with heavily nested structures in a natural way, ADL also provides a path syntax, based on Xpath [21], enabling any node in an archetype to be referenced by a path or path pattern. OWL does not provide an inbuilt path mechanism; Xpath can presumably be used with the RDF representation, although it is not yet clear how meaningful the paths would be with respect to the named categories within an OWL ontology.
- ADL also natively takes care of disengaging natural language and terminology issues from constraint statements by having a separate ontology per archetype, which contains ‘bindings’ and language-specific translations. OWL has no inbuilt syntax for this, requiring such semantics to be represented from first principles.

- Lastly, OWL (as of mid 2004) is still under development, and has only a very limited set of primitive constraint types (it is not possible for example to state a constraint on an Integer attribute of the form ‘any value between 80 and 110’), although this is being addressed; by contrast, ADL provides a rich set of constraints on primitive types, including dates and times.

Research to date shows that the semantics of an archetype are likely to be representable inside OWL, assuming expected changes to improve its primitive constraint types occur. To do so would require the following steps:

- express the relevant reference models in OWL (this has been shown to be possible);
- express the relevant terminologies in OWL (research on this is ongoing);
- be able to represent concepts (i.e. constraints) independently of natural language (status unknown);
- convert the cADL part of an archetype to OWL; assuming the problem of primitive type constraints is solved, research to date shows that this should in principle be possible.

To *use* the archetype on data, the data themselves would have to be converted to OWL, i.e. be expressed as ‘individuals’. In conclusion, we can say that mathematical equivalence between OWL and ADL is probably provable. However, it is clear that OWL is far from a convenient formalism to express archetypes, or to use them for modelling or reasoning against data. The ADL approach makes use of existing UML semantics and existing terminologies, and adds a convenient syntax for expressing the required constraints. It also appears fairly clear that even if all of the above conversions were achieved, using OWL-expressed archetypes to validate data (which would require massive amounts of data to be converted to OWL statements) is unlikely to be anywhere near as efficient as doing it with archetypes expressed in ADL or one of its concrete expressions.

Nevertheless, OWL provides a very powerful generic reasoning framework, and offers a great deal of inferencing power of far wider scope than the specific kind of ‘reasoning’ provided by archetypes. It appears that it could be useful for the following archetype-related purposes:

- providing access to ontological resources while authoring archetypes, including terminologies, pure domain-specific ontologies, etc;
- providing a semantic ‘indexing’ mechanism allowing archetype authors to find archetypes relating to specific subjects (which might not be mentioned literally within the archetypes);
- providing inferencing on archetypes in order to determine if a given archetype is subsumed within another archetype which it does not specialise (in the ADL sense);
- providing access to archetypes from within a semantic Web environment, such as an ebXML server or similar.

Research on these areas is active in the US, UK, Australia, Spain, Denmark and Turkey (mid 2004).

11.3.2 KIF (Knowledge Interchange Format)

The Knowledge Interchange Format (KIF) is a knowledge representation language whose goal is to be able to describe formal semantics which would be sharable among software entities, such as information systems in an airline and a travel agency. An example of KIF (taken from [10]) used to describe the simple concept of “units” in a `QUANTITY` class is as follows:

```
(defrelation BASIC-UNIT
  (=> (BASIC-UNIT ?u) ; basic units are distinguished
      (unit-of-measure ?u))) ; units of measure
```

```
(deffunction UNIT*
  ; Unit* maps all pairs of units to units
  (=> (and (unit-of-measure ?u1)
           (unit-of-measure ?u2))
       (and (defined (UNIT* ?u1 ?u2))
            (unit-of-measure (UNIT* ?u1 ?u2)))))
; It is commutative
(= (UNIT* ?u1 ?u2) (UNIT* ?u2 ?u1))
; It is associative
(= (UNIT* ?u1 (UNIT* ?u2 ?u3))
   (UNIT* (UNIT* ?u1 ?u2) ?u3))

(deffunction UNIT^
  ; Unit^ maps all units and reals to units
  (=> (and (unit-of-measure ?u)
           (real-number ?r))
       (and (defined (UNIT^ ?u ?r))
            (unit-of-measure (UNIT^ ?u ?r)))))
; It has the algebraic properties of exponentiation
(= (UNIT^ ?u 1) ?u)
(= (unit* (UNIT^ ?u ?r1) (UNIT^ ?u ?r2))
   (UNIT^ ?u (+ ?r1 ?r2)))
(= (UNIT^ (unit* ?u1 ?u2) ?r)
   (unit* (UNIT^ ?u1 ?r) (UNIT^ ?u2 ?r)))
```

It should be clear from the above that KIF is a definitional language - it defines all the concepts it mentions. However, the most common situation in which we find ourselves is that information models already exist, and may even have been deployed as software. Thus, to use KIF for expressing archetypes, the existing information model and relevant terminologies would have to be converted to KIF statements, before archetypes themselves could be expressed. This is essentially the same process as for expressing archetypes in OWL.

It should also be realised that KIF is intended as a knowledge exchange format, rather than a knowledge representation format, which is to say that it can (in theory) represent the semantics of any other knowledge representation language, such as OWL. This distinction today seems fine, since Web-enabled languages like OWL probably don't need an exchange format other than their XML equivalents to be shared. The relationship and relative strengths and deficiencies is explored by e.g. Martin [11].

11.4 XML-based Formalisms

11.4.1 XML-schema

Previously, archetypes have been expressed as XML instance documents conforming to W3C XML schemas, for example in the Good Electronic Health Record (GeHR; see <http://www.gehr.org>) and *openEHR* projects. The schemas used in those projects correspond technically to the XML expressions of information model-dependent object models shown in FIGURE 2. XML archetypes are accordingly equivalent to serialised instances of the parse tree, i.e. particular ADL archetypes serialised from objects into XML instance.

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