REFERENCE MODEL

The *open*EHR Data Structures Information Model

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1. Ocean Informatics Australia

2. Centre for Health Informatics and Multi-professional Education, University College London

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Amendment Record

Issue	Details	Who	Completed
1.5.1	CR-000048. Pre-release review of documents. Fixed HISTORY UML diagram - remove superfluous T:XXX (no semantic change). Converted parameter types to UML box form.	D Lloyd	22 Feb 2005
1.5	CR-000101. Improve modelling of Structure classes. CR-000100. Correct inheritance error in ITEM_STRUCTURE package. CR-000024. Revert *meaning* to STRING and rename as *archetype_node_id*. CR-000118. Make package names lower case. CR-000123. EVENT should inherit from LOCATABLE. CR-000124. Fix path syntax in data structures IM document.	DSTC T Beale S Heard, T Beale T Beale Rong Chen T Beale	10 Dec 2004
1.4	CR-000019. Add HISTORY & STRUCTURE supertype. CR-000028. Change name of STRUCTURE class to avoid clashes. CR-000089. Remove ITEM.*displayed*. CR-000091. Correct anomalies in use of CODE_PHRASE and DV_CODED_TEXT. CR-000067. Change EVENT class to enable math function interval measurements. Renamed EVENT.*duration* and SINGLE_EVENT.*duration* to *width*. **Formally validated using ISE Eiffel 5.4.**	T Beale H Frankel DSTC T Beale S Heard	09 Mar 2004
1.3.3	CR-000041. Visually differentiate primitive types in openEHR documents.	D Lloyd	04 Sep 2003
1.3.2	CR-000013 Rename key classes - rename COMPOUND to CLUSTER to conform with CEN 13606.	D Kalra, T Beale	20 Jun 2003
1.3.1	Improved heading layout, package naming. Made HISTORY.*is_periodic* a function.	T Beale, Z Tun	18 Mar 2003
1.3	**Formally validated using ISE Eiffel 5.2.** No changes.	T Beale	20 Feb 2003
1.2.1	Minor corrections to terminology_id invariants.	Z Tun	08 Jan 2003
1.2	Defined packages properly and moved HISTORY classes from EHR RM. No change to semantics.	T Beale	18 Dec 2002
1.1.1	Minor corrections: SINGLE_S new function.	T Beale	10 Nov 2002
1.1	Minor adjustments due to change in DV_CODED_TEXT.	T Beale	1 Nov 2002
1.0	Taken from Common RM.	T Beale	11 Oct 2002

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1 Introduction

1.1 Purpose

This document describes the common data structures used in *open*EHR reference model, including lists, tables, trees, and history, along with one possible data representation (hierarchical) which is compatible with the CEN 13606 EHCR standard.

The intended audience includes:

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

1.2 Related Documents

Prerequisite documents for reading this document include:

- The *open*EHR Modelling Guide
- The *open*EHR Support Information Model
- The *open*EHR Data Types Information Model

1.3 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://www.openEHR.org/repositories/spec-dev/publishing/architecture/reference_model/data_structures/REV_HIST.html`. New versions are announced on `openehr-announce@openehr.org`.

1.4 Peer review

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.

1.5 Conformance

Conformance of a data or software artifact to an *open*EHR Reference Model specification is determined by a formal test of that artifact against the relevant *open*EHR Implementation Technology

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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.

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2 Background

2.1 Requirements

The requirements for structured data in the EHR and other systems are essentially that low-level data can be expressed in standard structures. The structures which are commonly required are as follows:

- single values, e.g. weight, height, blood sugar;
- lists of named/numbered elements, e.g. blood test results;
- tables of values with named columns and/or named rows, e.g. visual acuity results;
- trees of values, e.g. biochemistry, microbiology results;
- histories of values, each of which takes any of the above forms, e.g. a time series of blood pressures, glucose levels, or imaging data.

2.2 Design Principles

The design principle which particularly applies to the data structure models described here is the need to provide explicit specifications for logical structures using the same generic representation, such as hierarchy. The logical structures include tables, lists, trees, and the concept of history.

Regardless of whether such structures are treated as pure presentation or as having semantic significance, there are at various reasons for explicitly including the semantics of logical structures which are represented in a generic way such as hierarchy, including:

- it is essential for interoperability that a structure such as a logical table, list or linear history be encoded into the generic representation in the same way by all senders and receivers of information, otherwise there is no guarantee that any communicating party's software processes the structures in the intended fashion;
- software implementors can develop software which explicitly captures the logical structures as functional interfaces which are used as the only way of building such structures. Such interfaces (assuming they are bug-free) guarantee that all application software always creates correct structures - there is no need to rely on caller software each time making low level calls to create a table or list out of hierarchy elements;
- the use of a functional interface for such types means that application software at the receiver's end can always process incoming information in its intended form, enabling correct presentation of data on the screen.

One of the motivations for defining logical data structures explicitly is to remove the ambiguity in recording structure and time in previous EHR specifications and standards, such as CEN 13606, GEHR, GEHR Australia, and HL7 CDA specifications. The alternative in the past was to simply use generic hierarchical structures; there was no agreement in the standard about how a table might be represented, similarly, time had no standard representation. Where single values were recorded, an attribute meaning 'time of recording' was set appropriately; if a time series was required, there was no clear guideline as to how to model it. One way would have been to build a double list which is logically a two column table, whose first column was time-point data, but many other approaches are possible. The standardised approach removes all such ambiguity, and improves the quality of data and software.

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3 Overview

The rm.data_structures package contains two packages: the item_structure package and the history package. The first describes generic, path-addressable data structures, while the latter describes a generic notion of linear history, for recording events in past time. The data_structures package is illustrated in FIGURE 1.

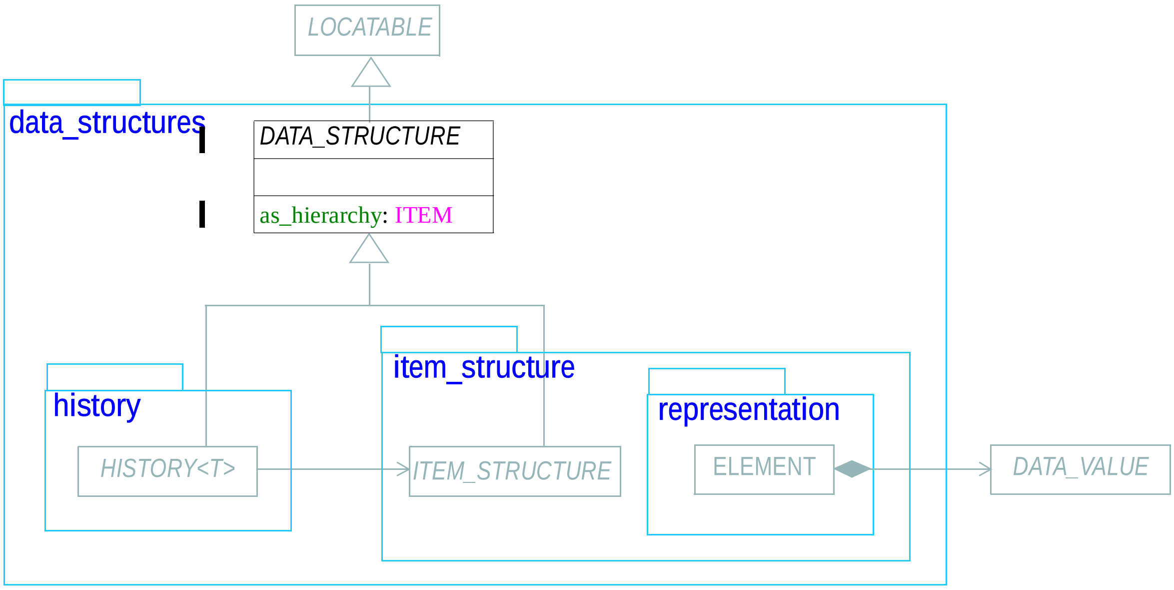

FIGURE 1 rm.data_structures Package

The data_structures package itself contains a single class, DATA_STRUCTURE, which is the ancestor of all *open*EHR data structures. Its only feature is the function *as_hierarchy*, which is implemented by each subtype of DATA_STRUCTURE, in order to generate a physical representation of the structure in CEN EN13606 form. The 13606 form is usually less optimal than the *open*EHR form, but is compatible with the less semantically rich standard, and is guaranteed (in theory) to be comprehensible to other systems which support CEN EN13606 as an interoperability standard.

3.1 Instance Structures

Diagrams of typical instances of the structures are included throughout this document. Each instance of shown in both physical and logical form. The physical form shows the instances which will occur in data if the structure is implemented using the representation package. The logical form shows the same instance in a logical form only - i.e. hiding the physical implementation. Only the latter form is used in other *open*EHR documents. In all instance diagrams, the following shorthand is used for well-known attribute names:

- “m = xxxx” - means “meaning = xxxx”, i.e. the meaning of the *archetype_node_id* attribute inherited from the LOCATABLE class.
- “n = xxxx” - means “name = xxxx”, i.e. the value of the *name* attribute inherited from the LOCATABLE class.
- “v = xxxx” - means “value = xxxx”, i.e. the value of the *value* attribute from the ELEMENT class.

3.2 Class Descriptions

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3.2.1 DATA_STRUCTURE Class

CLASS	***DATA_STRUCTURE (abstract)***	
Purpose	Abstract parent class of all data structure types. Includes the *as_hierarchy* function which can generate the equivalent CEN EN13606 single hierarchy for each subtype's physical representation. For example, the physical representation of an `ITEM_LIST` is `List<ELEMENT>`; its implementation of *as_hierarchy* will generate a `CLUSTER` containing the set of `ELEMENT` nodes from the list.	
Inherit	`LOCATABLE`	
Function	**Signature**	**Meaning**
	as_hierarchy: `ITEM`	Hierarchical equivalent of the physical representation of each subtype, compatible with CEN EN 13606 structures.
Invariants	***As_hierarchy_exists***: as_hierarchy /= Void	

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4 Item Structure Package

4.1 Overview

The Item_Structure classes presented here are a formalisation of the need for generic, archetypable data structures, and are used by all *open*EHR reference models.

The subtypes of the ITEM_STRUCTURE class explicitly model the logical data structure types which typically occur in health record data, and include ITEM_SINGLE (for single values such as a patient weight), ITEM_LIST (for lists such as parts of an address), ITEM_TREE (for hierarchically structured data such as a microbiology report) and ITEM_TABLE (for tabular data such as visual acuity or reflex test results). Each of these classes defines a functional interface, has an optimal physical representation using the basic types CLUSTER and ELEMENT from the representation package, and can generate a CEN EN13606-compliant hierarchical representation of its data. Any system implementing these types is guaranteed to create data which represents the logical structures of lists, tables and trees identically. The design principle RM-spatial [2] and preceding discussion describe the reasons behind this approach.

Data values are connected to spatial structures via the *value* attribute of the ELEMENT class of the Representation cluster. This class also carries an important attribute *null_flavor*, whose value indicates how to read the value. A small domain termlist containing values such as “unknown”, “not disclosed”, “undetermined”, etc, as described in the Flavours of Null vocabulary in the *open*EHR Support Information Model.

The *open*EHR class model for spatial structures is illustrated in FIGURE 2. It should be noted that these classes (ITEM_LIST etc) are not equivalents of similarly named classes (such as List<T>) in most data structure libraries - they also include per-node *name*, *archetype_node_id* and leaf node value and null flavour, and path capabilities.

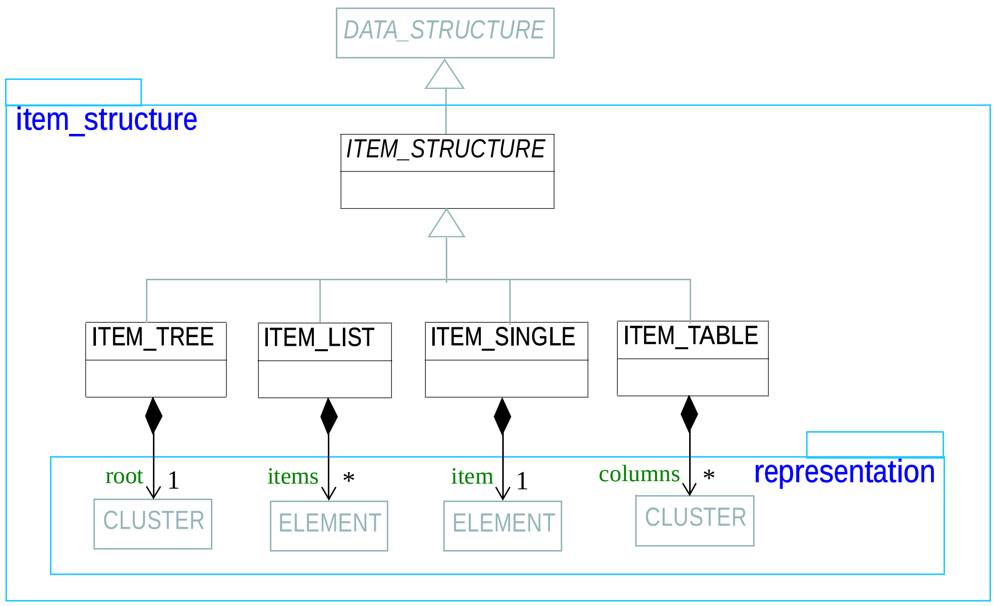

FIGURE 2 rm.data_structures.item_structure Package

4.2 Class Descriptions

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4.2.1 ITEM_STRUCTURE Class

CLASS	*ITEM_STRUCTURE (abstract)*	
Purpose	Abstract parent class of all spatial data types.	
GEHR	G1_HIERARCHICAL_PROPOSITION	
HL7	CDA `Structure` abstract type.	
Inherit	DATA_STRUCTURE	
Abstract	Signature	Meaning
Invariants		

4.2.2 ITEM_SINGLE Class

CLASS	ITEM_SINGLE	
Purpose	Logical single value data structure.	
Use	Used to represent any data which is logically a single value, such as a person's height or weight.	
GEHR	G1_SIMPLE_PROPOSITION	
HL7	CDA `Item` type.	
Inherit	ITEM_STRUCTURE	
Attributes	Signature	Meaning
	item: ELEMENT	
Functions	Signature	Meaning
	as_hierarchy: ELEMENT	Generate a CEN EN13606-compatible hierarchy consisting of a single ELEMENT.
Invariants		

4.2.2.1 ITEM_SINGLE Paths

In the following path structure, the name of the `ITEM_SINGLE` object acts as the root-name.

- *the whole structure*: `"/[" <ITEM_SINGLE.name> "]"`
  e.g. `"/[weight]"`
  Xpath equivalent: `"/[meaning() = 'weight']"`

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- *the item*: “/[” <ITEM_SINGLE.name> “]/item”
  e.g. “/[weight]/item”
  Xpath equivalent: “/[meaning() = ‘weight’]/item”

4.2.2.2 ITEM_SINGLE Instance Structure

FIGURE 3 illustrates a ITEM_SINGLE instance, in both physical and logical forms.

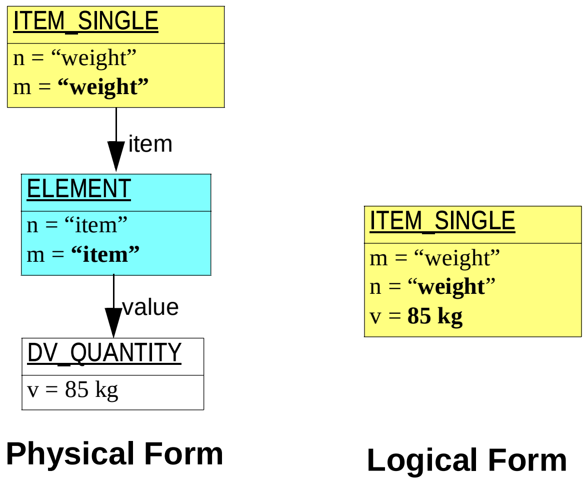

FIGURE 3 Instance Structure of ITEM_SINGLE

4.2.2.3 CEN EN13606 Hierarchy Encoding Rules

The ITEM_SINGLE encoding rules are as follows:

- The item is represented by a single ELEMENT.

4.2.3 ITEM_LIST Class

CLASS	**ITEM_LIST**	
Purpose	Logical list data structure, where each item has a value and can be referred to by a name and a positional index in the list.	
Use	Used to represent any data which is logically a list of values, such as blood pressure, most protocols, many blood tests etc.	
MisUse	Not to be used for time-based lists, which should be represented with the proper temporal class, i.e. HISTORY.	
GEHR	G1_LIST_PROPOSITION	
HL7	CDA 1.0 List Entry type.	
Inherit	ITEM_STRUCTURE	
Attributes	**Signature**	**Meaning**
	items: List<ELEMENT>	Physical representation of the list.
Functions	**Signature**	**Meaning**

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CLASS	ITEM_LIST	
	item_count: `Integer`	Count of all items
	names: `List<DV_TEXT>`	Retrieve the names of all items
	named_item(a_name:`String`**)**: `ELEMENT`	Retrieve the item with name ‘a_name’
	ith_item(i:`Integer`**)**: `ELEMENT`	Retrieve the i-th item with name
	as_hierarchy: `CLUSTER`	Generate a CEN EN13606-compatible hierarchy consisting of a single `CLUSTER` containing the `ELEMENT`s of this list.
Invariants	***Valid_structure***: items.forall({ITEM}.type = “ELEMENT”)	

4.2.3.1 ITEM_LIST Paths

In the following path structure for Lists, the *name* attribute of the `ITEM_LIST` object acts as the root-name.

- *whole list*: `“/[” <ITEM_LIST.name> “]”`
  e.g. `“/[BP protocol]”`
  Xpath equivalent: `“/[meaning() = ‘BP protocol’]”`
- *nth list item*: `“/[” <ITEM_LIST.name> “]/items[” <n> “]”`
  e.g. `“/[BP protocol]/items[2]”`
  Xpath equivalent: `“/[meaning() = ‘BP protocol’]/items[2]”`
- *named list item*: `“/[” <ITEM_LIST.name> “]/items[” <item_name> “]”`
  e.g. `“/[BP protocol]/items[cuff]”`
  Xpath equivalent: `“/[meaning() = ‘BP protocol’]/items[meaning() = ‘cuff’]”`

4.2.3.2 ITEM_LIST Instance Structure

FIGURE 4 illustrates a typical `ITEM_LIST` structure, in this case for a BP protocol.

4.2.3.3 CEN EN13606 Hierarchy Encoding Rules

The `ITEM_LIST` encoding rules are as follows:

- The list as a whole has a single `CLUSTER` object as the root.
- Each item is represented by an `ELEMENT` object, whose names is the name of the item.

4.2.4 ITEM_TABLE Class

CLASS	ITEM_TABLE
Purpose	Logical table data structure, in which columns are named and ordered. Some columns may be designated ‘key’ columns, containing key data for each row, in the manner of relational tables. This allows row-naming, where each row represents a body site, a blood antigen etc. All values in a column have the same data type.

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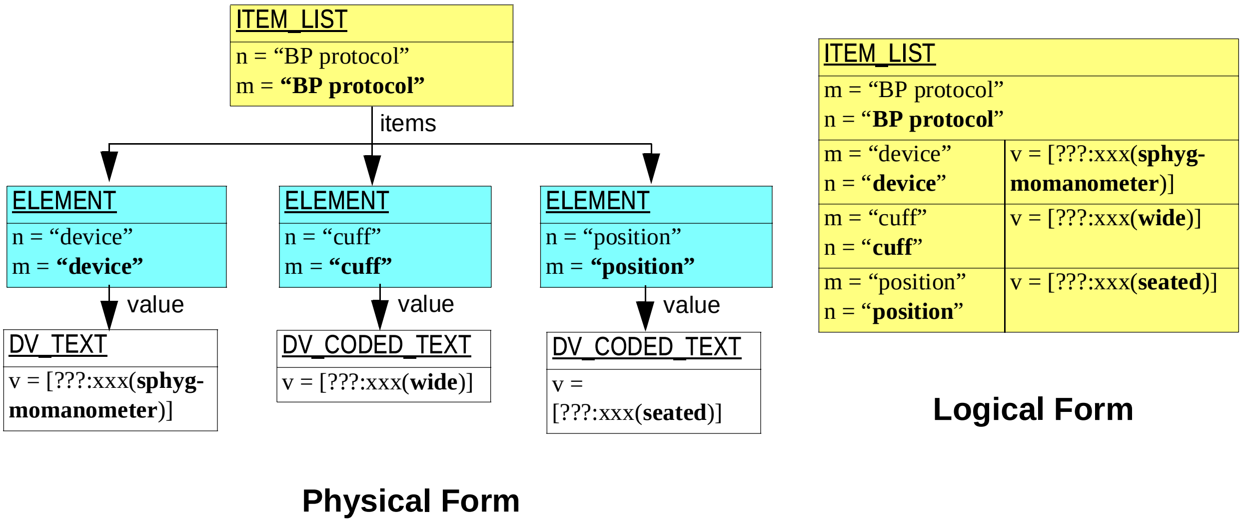

FIGURE 4 ITEM_LIST Instance Structure

CLASS	**ITEM_TABLE**	
Use	Used to represent any data which is logically a table of values, such as blood pressure, most protocols, many blood tests etc.	
MisUse	Not used for time-based data, which should be represented with the temporal class `HISTORY`.	
CEN	n/a	
GEHR	`G1_TABLE_PROPOSITION, G1_MATRIX_PROPOSITION`	
HL7	RIM structured types Table_structure, Table_cell, Table etc ; CDA 1.0 Table Entry type.	
Inherit	`ITEM_STRUCTURE`	
Attributes	**Signature**	**Meaning**
	columns: `List<CLUSTER>`	Physical representation of the table as a list of `CLUSTER`s, each containing the data of one column of the table.
Functions	**Signature**	**Meaning**
	row_count:`Integer`	Return the number of rows
	column_count:`Integer`	Return the number of columns
	row_names: `List<DV_TEXT>`	Return the row names
	column_names: `List<DV_TEXT>`	Return the column names

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CLASS	ITEM_TABLE	
	ith_row(i:`Integer`**)**: `List<ELEMENT>` ***require*** i >0 ***and*** i < row_count	Return the i-th row
	has_row_with_name(a_key:`String`**)**: `Boolean` ***require*** a_key /= Void ***and then not*** a_key.empty	True if there is a row whose first column has the name 'a_key'
	has_column_with_name(a_key:`String`): `Boolean` ***require*** a_key /= Void ***and then not*** a_key.empty	True if there is a column with name 'a_key'
	named_row(a_key:`String`): `List<ELEMENT>` ***require*** has_row_with_name(a_key)	Return the row whose first column has the name 'a_key'
	has_row_with_key(keys:`Set<String>`): `Boolean`	True if there is a row whose first n columns have the names in 'keys'
	row_with_key(key_vals:`Set<String>`): `List<ELEMENT>` ***require*** has_row_with_key(key_vals)	Return the row whose first n columns have names equal to the values in 'keys'
	element_at_cell_ij(i, j:`Integer`): `ELEMENT` ***require*** i >= 1 ***and*** i <= column_count j >= 1 ***and*** j <= row_count	Return the element at the column i, row j.
	element_at_named_cell (row_key, col_key:`String`): `ELEMENT` ***require*** has_row_with_name(row_key) has_column_with_name(column_key)	Return the element at the row whose first column has the name 'row_key' and column has the name 'col_key'
	hierarchy: `CLUSTER`	Generate a CEN EN13606-compatible hierarchy consisting of a single `CLUSTER` containing the `CLUSTER`s representing the columns of this table.
Invariants	***Valid_structure***: items.forall({ITEM}.type = "CLUSTER" ***and then*** {ITEM}.items.forall({ITEM}.type = "ELEMENT"))	

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4.2.4.1 ITEM_TABLE Paths

The following path patterns are legal for tables.

- *whole table*: "/[" <ITEM_TABLE.name> "]"
  e.g. "/[vision]"
  Xpath equivalent: "/[meaning() = 'vision']"
- *column*:"/" <ITEM_TABLE.name> "/columns[" <column-name> "]"
  e.g. "/[vision]/columns[left eye]"
  Xpath equivalent: "/[meaning() = 'vision']/columns[meaning() = 'left eye']"
- *row*: "/[" <ITEM_TABLE.name> "]/columns/items[" <row-name> "]"
  e.g. "/[vision]/columns/items[colour]"
  Xpath equivalent: "/[meaning() = 'vision']/columns/items[meaning() = 'colour']"
- *cell*: "/[" <ITEM_TABLE.name> "]/columns[" <column-name> "]/items[" <row-name> "]"
  e.g. "/[vision]/columns[left eye]/items[acuity w\/ glasses]"
  Xpath equivalent: "/[meaning() = 'vision']/columns[meaning() = 'left eye']/items[meaning() = 'acuity w/ glasses']"

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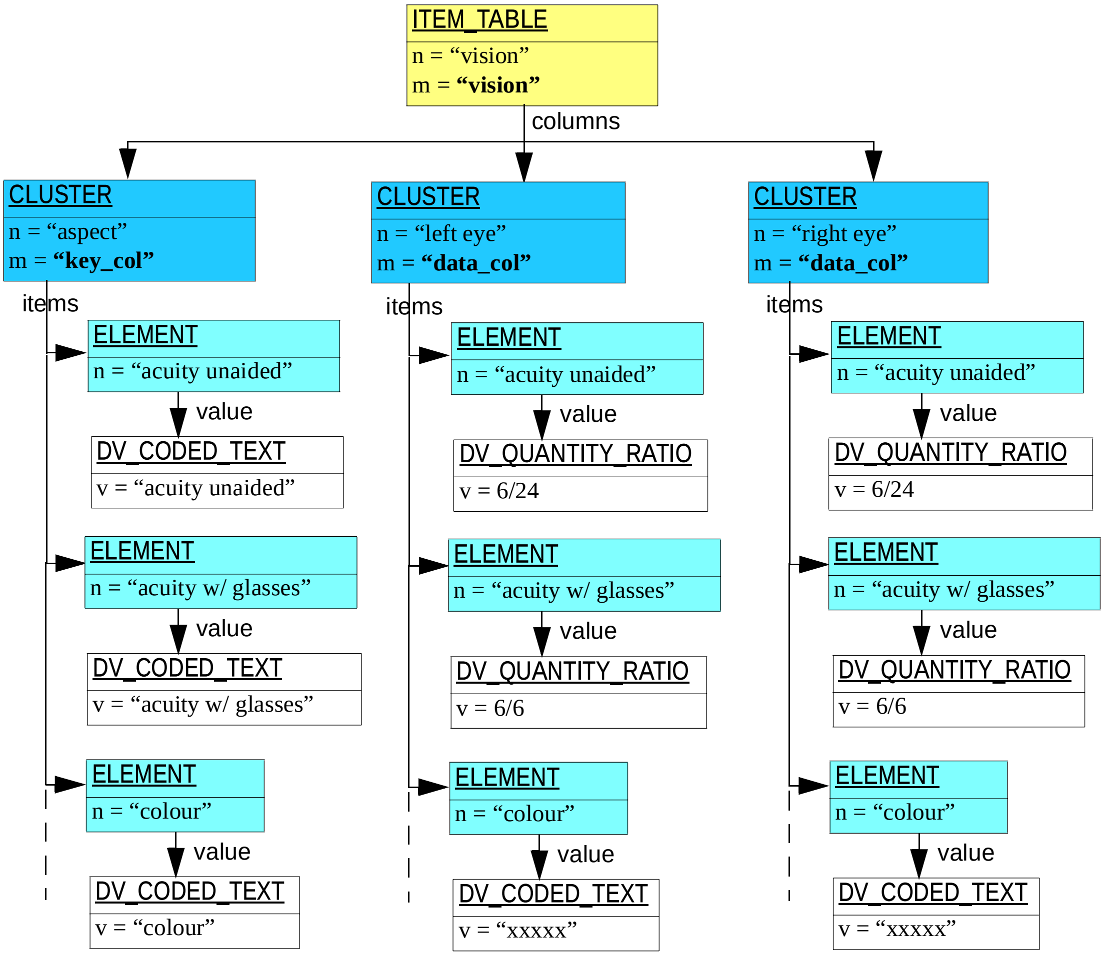
4.2.4.2 ITEM_TABLE Instance Structure

FIGURE 5 illustrates a table of visual acuity test results.



Physical Form

ITEM_TABLE m = “vision” n = “**vision**”		
m = “key_col” n = “**aspect**”	m = “data_col” n = [???:xxx(**left eye**)]	m = “data_col” n = [???:xxx(**right eye**)]
m = “acuity unaided” n = “**acuity unaided**”	6/24	6/24
m = “acuity with glasses” n = “**acuity with glasses**”	6/6	6/6
m = “colour” n = “**colour**”	normal	normal

Logical Form

FIGURE 5 ITEM_TABLE Instance Structure

4.2.4.3 CEN EN13606 Hierarchy Encoding Rules

The `ITEM_TABLE` encoding rules are as follows:

- A `CLUSTER` is required as the parent of all columns.

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- Each column is represented by a CLUSTER, whose name value is the name of the column.
- Each row item in a given column is represented by an ELEMENT under the relevant column CLUSTER.
- The name of each ELEMENT object is the name of its row.

4.2.5 ITEM_TREE Class

CLASS	ITEM_TREE	
Purpose	Logical tree data structure.	
Use	Used to represent data which are logically a tree such as audiology results, microbiology results, biochemistry results.	
MisUse		
CEN	The CEN cluster is effectively the only data structure available in CEN, and is equivalent to the ITEM_TREE type.	
GEHR	G1_TREE_PROPOSITION	
HL7	This can be constructed with CDA 1.0 Lists. Act and Act_relationship are the closest correspondents in the HL7 RIM.	
Inherit	ITEM_STRUCTURE	
Attributes	**Signature**	**Meaning**
	root: CLUSTER	Physical representation of the tree.
Functions	**Signature**	**Meaning**
	has_element_path(a_path:String): Boolean	True if path 'a_path' is a valid leaf path
	element_at_path(a_path:String**)**: ELEMENT ***require*** has_element_path(a_path)	Return the leaf element at the path 'a_path'
	as_hierarchy: CLUSTER	Generate a CEN EN13606-compatible hierarchy, which is the same as the tree's physical representation.
Invariants		

4.2.5.1 ITEM_TREE Paths

Tree paths are of the following form.

- *whole tree*: "/[" <ITEM_TREE.name> "]"
  e.g. "/[biochemistry]"

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- *node*: `“/[” <ITEM_TREE.name> “]/items[” <node-name>...<node-name>`,
  e.g. `“/[biochemistry]/items[lipid studies]”`
- *leaf value*: `“/[” <ITEM_TREE.name> “]/items[” <node-name>...<node-name> “/items[” <leaf-name> “]”`
  e.g. `“/[biochemistry]/items[lipid studies]/items[LDL cholesterol]”`

4.2.5.2 ITEM_TREE Instance Structure

FIGURE 6 illustrates te logical and physical form of an example `ITEM_TREE` instance, representing a biochemistry result.

4.2.5.3 CEN EN13606 Hierarchy Encoding Rules

Data of an `ITEM_TREE` instance are simply replicated as is to produce the correct EN13606 hierarchical form.

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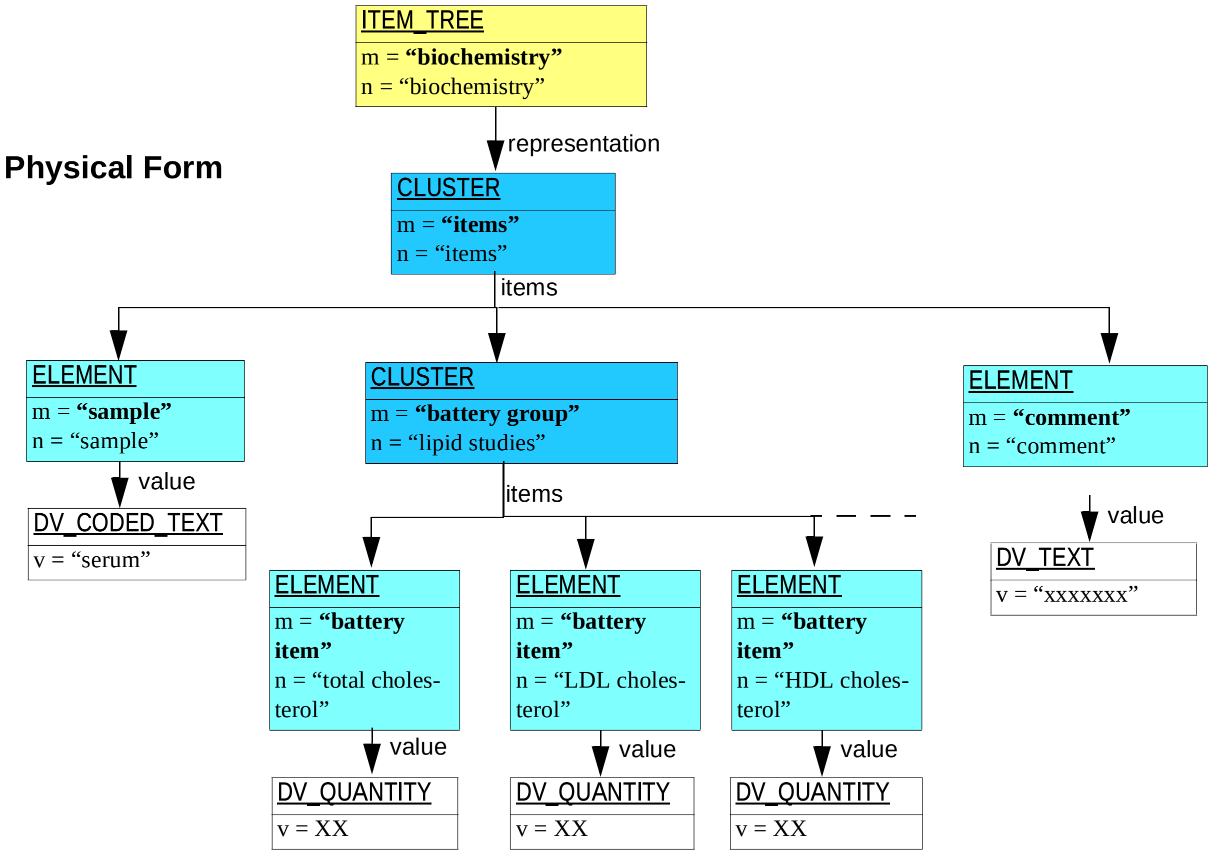

Logical Form

ITEM_TREE	
m = “biochemistry” n = “**biochemistry**”	
m = **“sample”** n = “sample” v = “serum”	
m = **“battery group”** n = “lipid studies”	
	m = **“battery item”** n = “total cholesterol” v = XXX
	m = **“battery item”** n = “total cholesterol” v = XXX
	m = **“battery item”** n = “total cholesterol” v = XXX
m = **“comment”** n = “comment” v = “xxxx”	

FIGURE 6 ITEM_TREE Instance Structure

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5 Representation Package

5.1 Overview

This package contains classes for a simple hierarchical representation of any data structure, as shown in FIGURE 7. These classes are compatible with the CEN EN13606 classes of the same names, and instances can be losslessly generated to and from EN13606 instances structures.

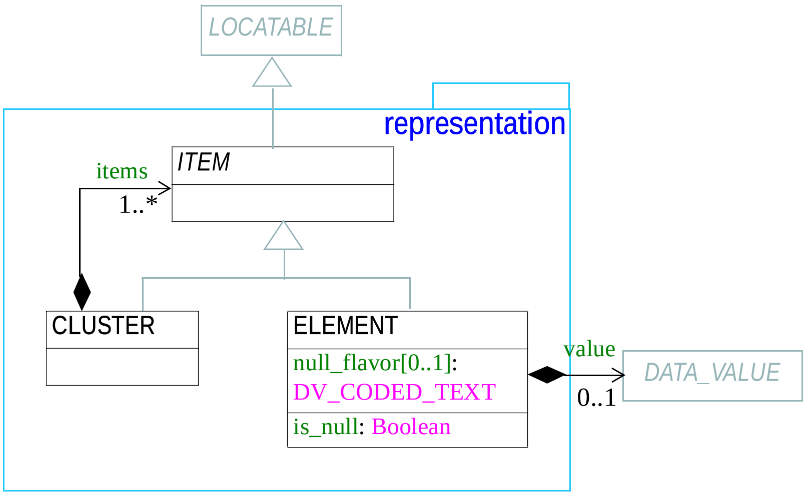

FIGURE 7 rm.data_structures.representation Package

5.2 Class Descriptions

5.2.1 ITEM Class

CLASS	***ITEM (abstract)***	
Purpose	The abstract parent of `CLUSTER` and `ELEMENT` representation classes.	
CEN	`ITEM` class	
OMG HDTF	COAS::Observation	
Synapses	Item class	
GEHR	`G1_HIERARCHICAL_ITEM`	
HL7	n/a	
Inherit	`LOCATABLE`	
Attributes	**Signature**	**Meaning**

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5.2.2 CLUSTER Class

CLASS	CLUSTER	
Purpose	The grouping variant of ITEM, which may contain further instances of ITEM, in an ordered list.	
CEN	ClusterOCC class	
OMG HDTF	COAS::CompositeObservation	
Synapses	Compound class	
GEHR	G1_HIERARCHICAL_GROUP	
HL7	Act_context	
Inherit	ITEM	
Attributes	**Signature**	**Meaning**
	items: List<ITEM>	Ordered list of items - CLUSTER or ELEMENT objects - under this CLUSTER.
Invariants	***Items_non_empty***: items /= Void ***and then not*** items.empty	

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5.2.3 ELEMENT Class

CLASS	ELEMENT	
Purpose	The leaf variant of `ITEM`, to which a `DATA_VALUE` instance is attached.	
CEN	DataItem class	
OMG HDTF	COAS::AtomicObservation	
Synapses	Element class	
GEHR	`G1_HIERARCHICAL_VALUE`	
HL7	Act	
Inherit	`ITEM`	
Attributes	**Signature**	**Meaning**
	value: `DATA_VALUE`	data value of this leaf
	null_flavor: `DV_CODED_TEXT`	flavour of null value, e.g. indeterminate, not asked etc
Functions	**Signature**	**Meaning**
	is_null: `Boolean`	True if value logically not known, e.g. if indeterminate, not asked etc.
Invariants	***Null_flavor_indicated***: is_null ***xor*** null_flavour /= Void ***Null_flavour_valid***: is_null ***implies*** terminology(“openehr”).codes_for_group_name(“null flavour”, “en”).has(null_flavor.defining_code)	

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6 History Package

6.1 Overview

The `history` package defines classes which formalise the concept of past, linear time, at which data of any complexity can be recorded. It allows both discrete (instantaneous) and continuous events (i.e. states) within periodic or aperiodic series.

The approach taken is that single samples, which are the most common in most circumstances, are represented in the same way as multiple samples, i.e. time series, allowing all software to access all data in a uniform way, regardless of whether it is a single measurement of weight, a long series of three- or four-dimensional images, or even a series of encapsulated multimedia items. This is clearly a better situation than past models, since there is no logical difference between one sample of any datum and many.

The model defines a structure which enables 'histories' consisting of a number of events situated along a timeline to be expressed. Histories may consist of discrete periodic events or states, i.e. values which are maintained for longer than an instant. Each state interval or event instant is associated with a spatial data structure. The effect is that repeated instances of spatially complex data can recur in

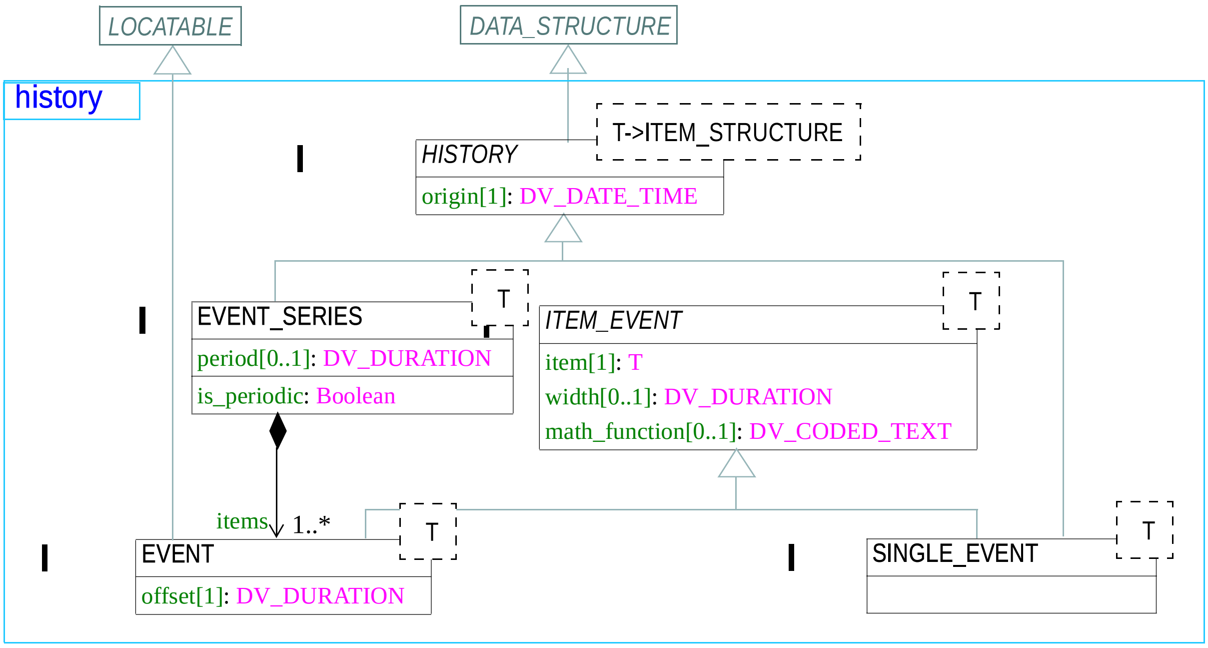

FIGURE 8 rm.data_structures.history Package

time, corresponding to the way data are actually measured. A special type, `SINGLE_EVENT<T>` is provided to cater for the many cases where a history is only one event long. A periodic discrete series would be used to represent most vital signs monitor output, but also manual measurements repeated in time, as long as the measurer and the protocol remain the same. The `history` package is shown in FIGURE 8.

6.1.1 Scope

It should be noted that the intention of this model is to represent single sample and time-based data for which measurement protocol is the same. It is not intended for measurements in "coarse" time taken by different people, different instruments, or with any other difference in data-gathering tech-

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nique. In these cases, separate, usually single-sample histories are used, usually occurring in distinct container objects (e.g. Compositions, in the EHR). Accordingly, in the general practice setting, the use of `HISTORY<T>` will correspond to measurement series which occur *during* the clinical session (i.e. during a patient contact). In a hospital setting, nurses' observations might occur in 4-hourly intervals, and there is no well-defined clinical session - simply a series of `ENTRYs` during the time of the episode. Two approaches are possible here.

- If each observation is to be committed to the EHR as soon as it is made, the result should be distinct Compositions in time, each with its Event_context corresponding to the period of the nurse's presence. Each Composition will contain the Single_event subtype of History (unless the nurse actually performed a series of measurements on the spot).
- If observations are not committed to the EHR immediately, but are stored elsewhere and only committed (say) at the end of each day, then the result will be a single Composition whose Event_context corrsponds to the data gathering period, and which contains an instance of the Event_series subtype of History, itself containing the multiple measurements made over the day.

Whether time-based data remain outside the record until a series of desired length is gathered, or entered as it occurs is completely up to the design of applications and systems; the approach taken should be based on the desired availability of the data in the system in question. If for example, it must be visible in the EHR as soon as the appropriate Compositions are written, then it should be represented as Histories in each relevant Composition; if it need only be available at some much later point in time (e.g. because it is known that no-one but the treating clinician is interested in it), then it can be stored in another system until sufficient items have been gathered for entry into the EHR.

6.1.2 Instantaneous and Interval Events

The model describes two kinds of "events": instantaneous or "point in time" events, and "interval events". The first kind have a width of zero, while interval events have non-zero width, meaning that their values effectively summarise the actual instantaneous values that must have occurred during the period of the event interval. For all interval events, it is essential to know the mathematical function of the value (which itself is in general a complex structure, such as a blood pressure) with respect to the actual instantaneous values which existed in the real world, and may have been sampled at a fine rate to generate the interval event. These functions include "minimum", "maximum", "mean", "mode" and so on (the full set of possibilities is coded by the *open*EHR Terminology group "event math functions"), and describe the mathematical meaning of all values in the Event data. The function indicator is provided as an attribute on `EVENT<T>` and `SINGLE_EVENT<T>`; in the case of event series, this allows for interval events of more than one mathematical function type to occur in the same history, for example a history of maxima and minima. Such data can be conveniently used for generating sophisticated graphs of the underlying datum over time.

6.2 Class Descriptions

6.2.1 HISTORY<T: ITEM_STRUCTURE> Class

CLASS	*HISTORY<T: ITEM_STRUCTURE> (abstract)*
Purpose	The abstract parent class of various concrete historical structures, currently including discrete series and series of states, either of which may be periodic.

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CLASS	*HISTORY<T: ITEM_STRUCTURE> (abstract)*	
CEN	Time was encoded as part of the `Item` structure.	
GEHR	Time was encoded as part of the `G1_HIERARCHICAL_PROPOSITION` structure.	
HL7	The data type History `HIST<T>` is equivalent in intention to `HISTORY<T>`.	
Inherit	`DATA_STRUCTURE`	
Attributes	Signature	Meaning
	origin: `DV_DATE_TIME`	Time origin of this event history. The first event is not necessarily at the origin point.
Invariants	***origin_exists***: origin /= Void	

6.2.2 EVENT_SERIES <T: ITEM_STRUCTURE> Class

CLASS	EVENT_SERIES<T: ITEM_STRUCTURE>	
Purpose	Defines the semantics of a time segment which consists of events which occur at known instants of time, and which may be periodically spaced. This class is generic, allowing types to be generated which are locked to particular structure types, such as `EVENT_SERIES<ITEM_LIST>`	
Inherit	`HISTORY<T>`	
Attributes	Signature	Meaning
	items: `List <EVENT<T>>`	The items in the series.
	period: `DV_DURATION`	period between samples in this segment if periodic
Functions	Signature	Meaning
	is_periodic: `Boolean`	Indicates whether history is periodic.
	as_hierarchy: `CLUSTER`	Generate a CEN EN13606-compatible hierarchy of the physical representation.
Invariants	***items_exists***: items /= Void **and then not** items.empty ***periodic_validity***: is_periodic ***xor*** period = Void	

6.2.2.1 CEN EN13606 Hierarchy Encoding Rules

To Be Continued:

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6.2.3 ITEM_EVENT <T: ITEM_STRUCTURE> Class

CLASS	*ITEM_EVENT <T: ITEM_STRUCTURE> (abstract)*	
Purpose	Abstract generic class modelling an event not anchored in time.	
Attributes	Signature	Meaning
	item: `T`	The data of this event.
	width: `DV_DURATION`	Length of the interval during which the state was true. Void if an instantaneous event.
	math_function: `DV_CODED_TEXT`	Mathematical function for non-instantaneous events - e.g. “maximum”, “mean” etc. Coded using *open*EHR Terminology group “event math function”.
Functions	Signature	Meaning
	is_instantaneous: `Boolean` ***ensure*** width = Void ***implies*** Result	True if this event is instantaneous
Invariants	***item_exists***: item /= Void ***math_function_validity***: width /= Void ***implies*** (math_function /= Void ***and then*** terminology(“openehr”).codes_for_group_name(“event math function”, “en”).has(math_function.defining_code))	

6.2.4 EVENT <T: ITEM_STRUCTURE> Class

CLASS	**EVENT<T: ITEM_STRUCTURE>**	
Purpose	Defines a single event in a series. This class is generic, allowing types to be generated which are locked to particular spatial types, such as `EVENT<ITEM_LIST>`. In cases where samples are missing, there will correspondingly be missing `EVENT` instances. Every `EVENT` instance that is supplied must have an item.	
HL7	The data type HistoryItem `HXIT<T>` is close to `EVENT<T>` in its intent.	
Inherit	`ITEM_EVENT<T>, LOCATABLE`	
Attributes	Signature	Meaning
	offset: `DV_DURATION`	Offset of this sample from the origin of the history
Invariants	***offset_exists***: offset /= Void	

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6.2.5 SINGLE_EVENT<T: ITEM_STRUCTURE> Class

CLASS	SINGLE_EVENT<T: ITEM_STRUCTURE>	
Purpose	A subtype of `HISTORY<T>` catering for the very common case of single events. The motivation for this class is to reduce the number of temporal objects associated with a datum to one.	
Inherit	`HISTORY<T>, ITEM_EVENT<T>`	
Functions	**Signature**	**Meaning**
	as_hierarchy: `CLUSTER`	Generate a CEN EN13606-compatible hierarchy of the physical representation.
Invariants		

6.2.5.1 CEN EN13606 Hierarchy Encoding Rules

To Be Continued:

6.3 History Paths

History paths include the following possibilities:

- *whole history by name*: `"/" HISTORY.name`
  e.g. `"/history"`
- *whole history by time*: `"/origin=<dt>"`
  e.g. `"/origin=2001-05-10 16:45:00"`
- *event*: `"/" HISTORY.name "/" EVENT.name`
  e.g. `"/history/event_3"`

Typical paths which refer to a particular item within the spatial data of an event series:

- 16th sample on lead 3 of an ECG (represented as a `ITEM_LIST` structure): `"/history/event_16/ECG_result/lead_3"`
- 3rd sample of apgar breathing datum of a newborn (apgar represented as a `ITEM_LIST` structure): `"/history/event_3/apgar_result/breathing"`
- 2min sample of apgar breathing datum of a newborn (apgar represented as a `ITEM_LIST` structure): `"/history/offset=2min/apgar_result/breathing"`

6.4 History Instance Structures

All data corresponding to events in historical time are represented as histories which ultimately contain one or more instances of a spatial data structure representing a particular instance of clinical data. A history consists of segments of time. Each segment is either a periodic discrete series - a series of time points - or a continuous time section of a certain duration. For each timepoint in a discrete series, there is an instance of the data structure, which might be a list, table, tree or other structure; for each continuous segment, there is one instance, representing the state of something which was true during the duration of the segment.

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6.4.1 Single Sample

FIGURE 9 illustrates a single weight measurement in instance form. The event history objects contain the timing information, which in this case is simply the time of measurement (the origin).

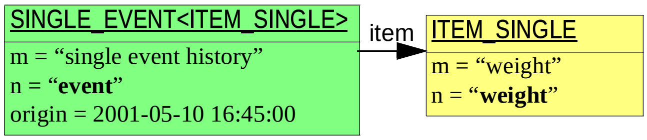

FIGURE 9 Single sample Instance Structure

6.4.2 State History

FIGURE 10 illustrates two time segments representing episodes of chest pain, the first at 5 minutes' offset from an initial event and lasting 5 minutes, the second 15 minutes later, and lasting 15 minutes.

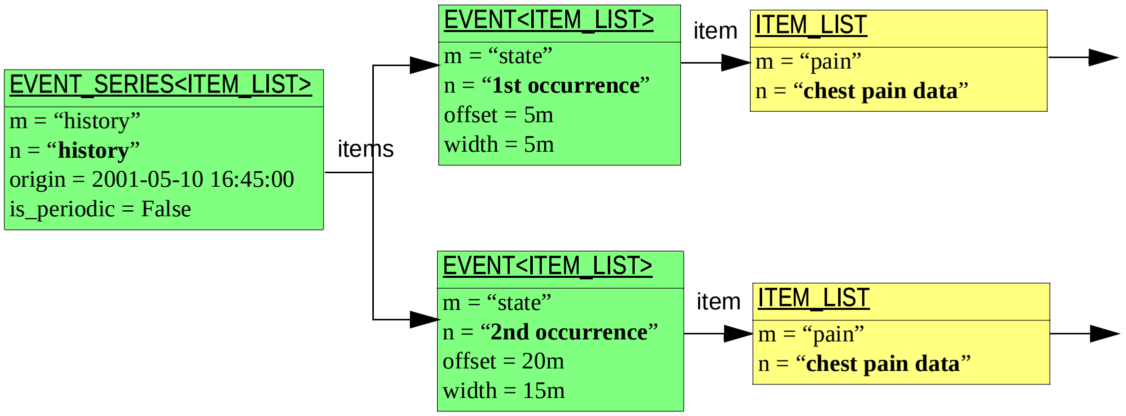

FIGURE 10 State History Instance Structure

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A.6 Resources

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