

# Studies in Health Technology and Informatics

## Volume 192

Christoph Ulrich Lehmann, Elske Ammenwerth, Christian Nøhr

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# Studies in Health Technology and Informatics

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## Applying UML Connectors for Arranging Medical Archetypes into a Knowledge Base

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### Abstract

*To enable the efficient reuse of standard based medical data we propose to develop a higher level information model that will complement the archetype model of ISO 13606. This model will make use of the relationships that are specified in UML to connect medical archetypes into a knowledge base within a repository. UML connectors were analyzed for their ability to be applied in the implementation of a higher level model that will establish relationships between archetypes.*

*An information model was developed using XML Schema notation. The model allows linking different archetypes of one repository into a knowledge base. Presently it supports several relationships and will be advanced in future.*

**Keywords:** Archetypes, UML, knowledge base

### Introduction

Many of modern electronic health record (EHR) standards make use of the dual model architecture (i.e. ISO 13606). However, the impact of such standards is biased by the limited availability of tools that facilitate their usage and practical implementation. Clinical archetypes provide a means for health professionals to design what should be communicated as part of an electronic health record.

The semantic of archetype data fields can be defined by linking these fields to the registers through an “ontology section” [1,2]. However, a generally accepted method to semantically connect different data fields or archetypes is still missing and it cannot be resolved within the Archetype model of ISO 13606. Development of a higher level model that will enable semantic linking of archetypes and certain archetype data fields within a repository can advance the application of archetype based EHR systems and facilitate for example decision support [3] or medical data visualization [4] where the context of knowledge is very important. This can be further enhanced with semantics if the archetype is linked to knowledge representations, that might, for example, enable the system to act on the information directly e.g., by triggering an alert or notification if the value contained in the Blood test instance is above normal reference suggest some action or provide other existing information. The system that receives an instance of the Blood Test observation should be also able to deliver it to a specialist, who will proceed with its assessment. Archetypes connected to business process stages will allow semantic interoperability on the process level. Classification and categorization of archetypes will reduce the entropy of knowledge.

Archetypes are defined by Archetype Definition Language (ADL) [5] that currently supports neither inference nor rules to form a knowledge base. One approach to connect archetypes into a knowledge base is the semantic web [6,7]. Semantic web methods of domain description may be redundant and not specific for the limited applications that use archetyped medical data at the moment.

Transforming archetypes to widely accepted formats simplifies their processing by EHR systems. Several methods were developed to transform ADL archetypes to XML [8]. This allows processing of archetypes and archetyped medical data by electronic health records and facilitates the development of higher level models to organize archetypes into knowledge bases. To develop the infor-

mation model it is necessary to define the relationships between archetypes that the model will support.

## Motivation for the project

We advance the work that was performed within the ByMedConnect project [9]. The main goal of the project is to organize data exchange between heterogeneous EHR. Medical data is transferred in ISO 13606 archetype model conforming instances in form of XML files. The next step of the project will be aiming at the application of artificial intelligence tools for medical data structuring and decision support to make efficient secondary use of medical data. The information model that was developed for the visualization of archetyped medical data can provide a good basis for organizing the knowledge base. The goal of the research is to enrich the information model to enable definition of relationships between archetypes. This requires the definition of relationships between archetypes in the information model and methods for processing information model instances.

## Materials and Methods

To develop an information model and a method to connect archetypes we analyzed the existing connectors' types that are used to link domain concepts. Existing UML connectors' types were analyzed to find out which of them can be applied to connect different archetypes or archetype data fields and to set up semantically meaningful relations.

The ISO 13606 archetype model allows defining different relationships between archetypes connection. So the structure of the ISO 13606 archetype model was studied to find out which relationships are already implemented in the model and which are missing. The examples of weaknesses and advantages of ISO 13606 models were studied and presented in the paper.

Some of the UML connectors [10] were implemented in the model. An XML Schema [11] was used to specify the model.

A web-application was developed to prove the concept and test the feasibility of the developed approach. The "Association" connector was implemented to bind [value]-[Normal interval] association for laboratory results archetypes. The application was implemented in Microsoft Visual Studio using asp.net and XSL templates that process XML visual medical concept files to present EHR content to users.

## Results

The following UML connectors' [12] were analyzed for the possibility to be applied to organize an archetype based knowledge base.

### Abstraction

An abstraction relationship is a dependency between model elements that represent the same concept at different levels of abstraction or from different viewpoints. You can add abstraction relationships to a model in several diagrams, including use case, class, and component diagrams. Archetypes of one type i.e. blood test may be attributed to a different level of abstraction depending on the requirements of a certain specialist. It can be focused i.e. to a diabetologist emphasizing the parameters special for diabetes or can be a general blood test. These different abstraction level archetypes must be distinguished within a repository.

## Aggregation

An aggregation relationship depicts a classifier as a part of, or as a subordinate to, another classifier. This is already implemented in the ISO 13606 archetype model. Archetypes are extensible formal constraint definitions of object structures. In common with object model classes, they can be *specialized*, as well as *composed* (i.e. aggregated). An archetype may have a container for another archetype. This can be used to define complex medical documents that consist of several concepts. However, the model implemented as including of one archetype into another while modeling and does not imply consistency if one of the archetypes is changed later.

## Composition

A composition relationship represents a whole-part relationship and is a type of aggregation. A composition relationship specifies that the lifetime of the part classifier is dependent on the lifetime of the whole classifier. In archetype model there exist a composition type of relationship. This is used to form whole Compositions in the EHR, e.g. for "discharge summary", "antenatal exam" and so on. However, this corresponds to the aggregation connector in UML [13].

## Association

An association relationship is a structural relationship between two model elements that shows that objects of one classifier (actor, use case, class, interface, node, or component) can connect and can navigate to objects of another classifier. This is a very important relationship for medical concepts. There exist several types of associations that are used on the daily basis by the doctors and cannot be implemented within the archetype model of ISO 13606. For example [value]-[Normal Interval] or [Secondary diagnosis]-[Primary diagnosis] especially when this relationship is one to many.

## Directed association

A directed association relationship is an association that is navigable in only one direction and in which the control flows from one classifier to another (for example, from an actor to a use case). Only one of the association ends specifies navigability. In Figure 1 we see an example, where a related primary diagnosis is specified using non-standard text field with a link to another archetype.

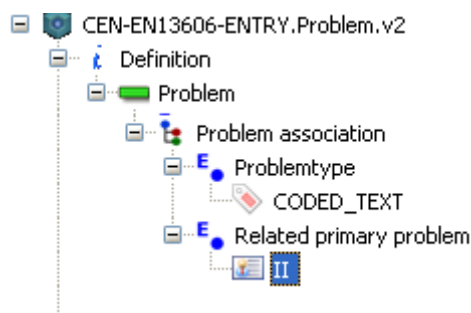


Figure 1- Association of archetypes

## Dependency

A dependency relationship indicates that changes to a one model element (the supplier or independent model element) can cause changes in another model element (the client or dependent model element). The supplier model element is independent because a change in the client does not affect it. The client model element depends on the supplier because a change to the supplier affects the client.

## Generalization



A generalization relationship indicates that a specialized (child) model element is based on a general (parent) model element. Although the parent model element can have one or more children, and any child model element can have one or more parents, typically a single parent has multiple children. Generalization is used in several archetype modeling tools e.g. LinkEHR [14]. One generic archetype can be specialized by adding specific names and values to the generic archetype. For example a generic laboratory test archetype becomes a basis for a Blood sugar archetype (Figure 2).

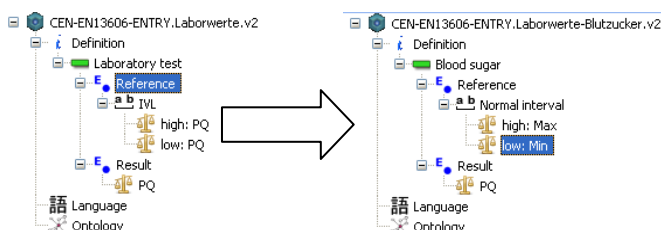


Figure 2- Serialization of archetypes

## Realization

A realization relationship exists between two model elements when one of them must realize, or implement, the behavior that the other specifies. This relationship is implemented by the openEHR Template model where a user can specify localization properties of an archetype. For example reference interval, data fields names, language properties and so on. However, there exist no mechanism to maintain consistency of the [archetype]-[template] relationship when the archetype is changed. A possible archetype repository is presented in Figure 3. Archetypes are connected by the proposed UML connectors.

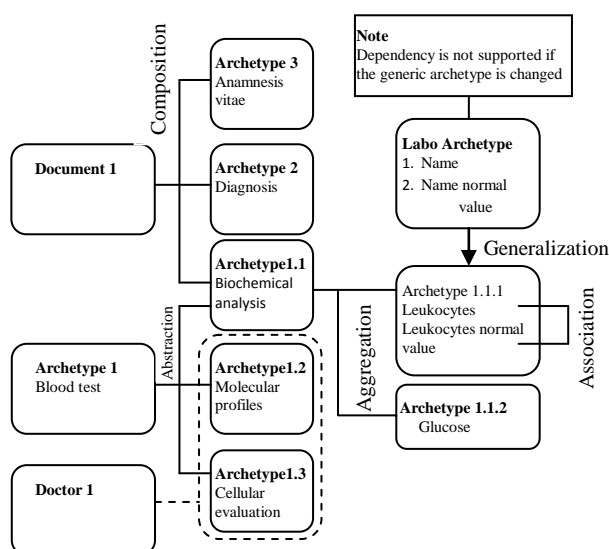


Figure 3- Application of UML connectors in an archetype repository

To demonstrate the example of how the archetypes can be connected within a repository we can have a look at a group of archetypes for Blood tests (figure 3). There can exist several abstractions for a blood test:

1. Cellular test
2. Molecular profiles

```
<items>
  <ITEM xsi:type="ELEMENT">
    <name>
      <originalText>Leukocytes</originalText>
    </name>
  </ITEM>
  <ITEM xsi:type="ELEMENT">
    <name>
      <originalText>Reference-Leukocytes</originalText>
    </name>
    <value xsi:type="IVL_PQ">
      <high>
        <value>50</value>
        <units>...</units>
      </high>
      <low>
        <value>10</value>
      </low>
    </value>
  </ITEM>
</items>
```

Figure 5- XML definition of an archetype

3. Biochemical analysis

Archetypes can be combined to fulfill different needs. For example each doctor can use his/her own set of archetypes, or archetypes with different level of abstraction, e.g. blood test can be more or less detailed for different specialists.

## Model Implementation

Archetypes are hierarchical structures and support an XPath-like definition to access substructures. An information model that allows building a knowledge base was developed considering the archetype model of ISO 13606 in form of XML schema to ensure a full compatibility with archetypes. Each information model entity (ME) is stored as XML file, which can be generated manually or partially automatically (Figure 4).

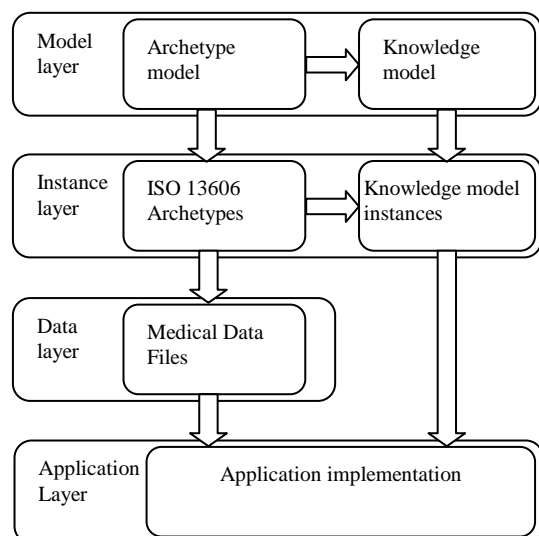


Figure 4- Archetype relationships definition scheme

An instance is logically divided into two main sections: metadata and medical content. The metadata section specifies the properties of the ME. The data fields are derived from different archetypes and combined into groups. The groups allow specifying the user context for each element. This allows not only connecting different archetype and archetype data fields but enables more specified description of each medical document.

The developed information model is based on the archetype model of ISO 13606. The archetypes and information model instances that contain relationships between archetypes and archetype data fields are placed on the instance level. On the data level ME files with specified content and properties are associated with corresponding XML medical data files.

### Archetype set

In the ByMedConnect dataset an archetype of laboratory results is represented as a set of archetypes of a similar structure. Each archetype contains one ELEMENT of type Physical Quantity (PQ) consisting of a value (the measurement result) and a unit, marked with a name (i.e. “Leukocytes”), one ELEMENT of type PQ interval that contains the reference interval for the measured parameter and one ELEMENT of type DATE for the date of measurement.

The content of the blood test report is specified in the content section of a ME and consists of a set of elements; each referring to the corresponding archetype.

A Web application was built using XML, XSL and C#. This Web application can display archetyped medical data collected from different sources and generate reports conforming to various archetypes based on the approach described above. Medical data are offered to the system as XML structures.

The application aimed at presenting complex medical documents that consist of more than one archetype to a user. The example below describes the components and the process that lead to the display of the medical data on a user’s desktop. When the application calls medical data, a template generates the interface for the medical document. It analyzes the archetypes and the relationships between them. Then it looks for the referenced archetypes in the specified archetype repository. Then it analyses the data repository to find matching data. The process is based on the targeted user

context. All elements are combined to display the medical data on the user's device. XML notation is used to structure the data. Paths are expressed in XPath notation.

## Discussion

Connecting archetypes within a domain model will expand the application of archetype based electronic health records. The methods to connect archetypes that are available in the ISO 13606 archetype model are not sufficient and consistent. This can be advanced by implementing a higher level information model. The model must support at least the relationships that are defined in UML.

The information model complementing the archetype layer must be able to provide different semantic for connectors. For example "Association" connector may have different meanings such as [value]-[normal interval], [primary diagnosis-secondary diagnosis].

Modification of existing UML connectors in order to apply different logical mechanisms, e.g. fuzzy logic [15], modal logic [16] will enable expressing knowledge more explicitly and closed to the reality.

Figure 3 shows the hierarchy of concepts, however there can exist relationships between concepts of one level (figure 5). These relationships can be even more complex. For example the directed association that means Results of the Blood test 1 lead to the Diagnosis 1 that leads to Medication 1. In logic this directed association can be expressed by implication.

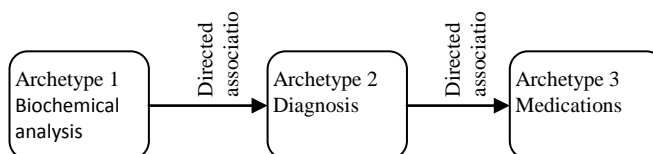


Figure 6- Directed association (implication)

The future research will be focused on automated methods for the definition and processing of relationships between archetypes.

## Conclusion

The UML connectors were analyzed for their ability to be applied in the implementation of a higher level model that will establish relationships between archetypes.

An information model was developed using XML Schema notation. The model allows linking different archetypes of one repository into a knowledge base. Presently it supports several relationships and will be advanced in future.

The introduced information model allows semantic connection of different archetypes or archetype data fields. The implemented web-application shows a high potential of the developed models and specifications. The relationships are at the moment static. Further research will advance the model to enable dynamic definition of the relationships and inference rules.

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