Implementing Ontology-Driven Care Pathways Using UML Activity Diagrams

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Abstract. Care pathways provide a formal representation of clinical guidelines, evidence-based best practice or care provider protocols. Executable care pathways can be used in an Electronic Health Record system to drive the process of care in a similar way to a standard business workflow. Care pathways are generally more complex than business workflows and this has led to the development of various domain-specific languages for pathway modeling, including GLIF and PROforma, as well as the application of visual approaches using BPMN, UML and BPM+ Health. The open source cityEHR health record system represents care pathways as HL7 CDA document templates which are generated from ontology models of the underlying clinical domain, built using an ontology architecture based on the ISO 13606 Reference Model. This paper describes how clinicians can specify pathways as UML Activity Diagrams that are then transformed into the ontology models and HL7 CDA representations that drive the executable pathways in cityEHR. It is shown that the simple application of UML Activity Diagrams is sufficient to support executable care pathways, specified as ontology models and represented as HL7 CDA in the patient record.

Keywords. Care Pathways, HL7 CDA, ISO 13606, UML Activity Diagram, Ontology, OWL/XML.

1. Introduction

Care pathways can be useful tools in guiding patient care, often incorporating evidence based best practice. A good definition of the care pathway is provided by Kinsman et al [1] who assert that it is an intervention – that is, an active instrument in the care of a patient – which can provide:

- a structured plan of care, for use by the multidisciplinary care team
- the formalism of evidence-based best practice, at local level
- a definition of the actions to be taken in patient care
- the criteria (sequence, timing and conditions to be met) for each action
- a way to standardize care for the local care provider

Several Domain Specific Languages have been developed for the specification of clinical guidelines and care pathways, such as the Guideline Interchange Format (GLIF) [2], and the guideline modeling language PROforma [3]. The most recent addition to these efforts has been as part of the Workflow Module of HL7 Fast

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Healthcare Interoperability Resources (FHIR) [4] which covers a range of plan and activity-based standardization efforts.

Since care pathways can be visualized in a similar way to other other business workflows, there have also been various graphical approaches to their specification, using both general business modeling such as the Business Process and Model Notation (BPMN) [5] or Unified Modeling Language (UML)/Systems Modeling Language (SysML) Activity Diagrams [6, 7] and healthcare-specific approaches such as BPM+ Health [8], which has now transitioned to the HL7 BPM Community [9]. A good summary of these approaches for patient-centric care pathways is provided by Cassidy et al [10].

When care pathways are incorporated into the day-to-day record keeping and patient management provided by an Electronic Health Record (EHR) they become 'executable', in the sense that their formal specification can be used to control the process of care through the EHR, not merely just to describe or record it. We have previously described the implementation of executable care pathways in cityEHR, an open source EHR that represents all clinical information, including the care pathways, as XML, using the HL7 Clinical Document Architecture (CDA) [11]. In cityEHR the specification of the HL7 CDA documents for the pathways is made as an ontology, from which the CDA documents are generated. These ontology specifications are created using a spreadsheet, configured to make a familiar tool for the use of clinicians and clinical analysts.

This paper describes a new process and tooling by which the care pathways for cityEHR can be specified as UML [12] (or SysML [13]) Activity Diagrams and then transformed first to the ontology specification and then to the HL7 CDA templates required for their execution in the EHR.

2. Method

The base requirements for modeling the process of a care pathway are to support:

- a set of actions executed in sequence or in parallel
- branches in the sequence of execution
- conditions on the execution of actions or sequences of actions
- (repeatable) loops in the sequence of actions

These base requirements are inherently supported by UML Activity diagrams and are translated into the document-centric model of HL7 CDA by representing a pathway as a Clinical Document, actions as CDA Acts, and sequences of Acts as CDA Sections. The CDA Subject of an Act to associate the action performed with another CDA document in the EHR – recording clinical information in a Form, writing a Letter, Booking an appointment, placing an Order, making a Prescription or launching another Pathway, where Form, Letter, Booking, Order, Prescription and Pathway are defined as types of CDA documents with associated behaviour and functionality in the EHR [10].

The correspondence between a UML Activity diagram and an HL7 CDA Clinical Document is shown in Figure 1, using the simple example of a care pathway to undertake a Lifestyle Assessment [14], formulate a diet and exercise plan, then communicate both the assessment results and the plan in a letter of advice to the patient.

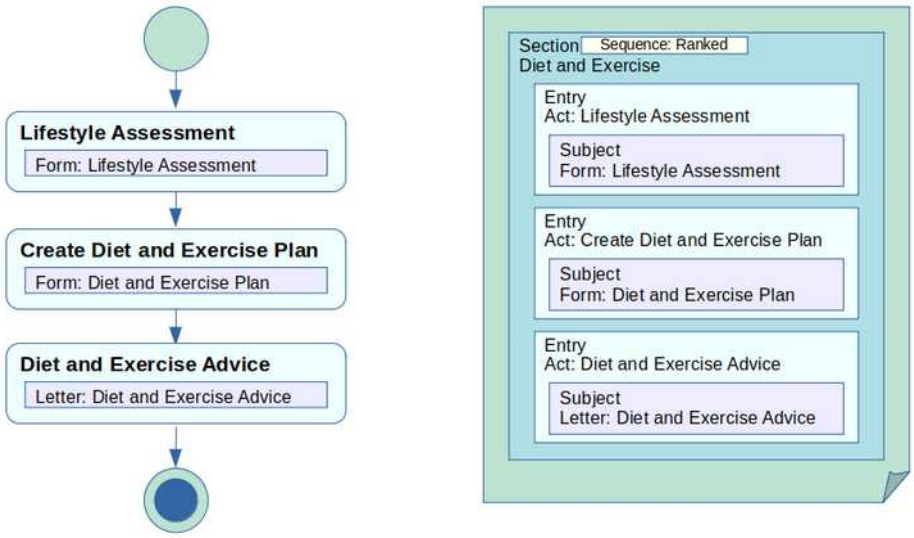

Figure 1. Correspondence between UML Activity Diagram and HL7 CDA Document

Our first objective for implementation was to find an open source UML modeling environment that could be used to specify care pathways as Activity Diagrams and could be saved in an XML representation suitable for transformation to the required ontology specification represented as OWL/XML. A good survey of open source UML environment is provided by Freire et al [15] and this was used as the starting point for evaluation and selection of a suitable environment, with the primary selection criteria being ease of use, the ability to save Activity Diagrams as XML and the suitability of that XML representation for transformation to OWL/XML.

Detailed evaluation was undertaken with the UML tools ArgoUML [16], BOUML [17], Dia [18] and Modelio [19], with the latter being chosen as the modeling environment primarily because it saves Activity Diagrams using a profile of the XML Metadata Interchange (XMI) standard [20] which is most easily processed using standard XSLT transformations [21]. Figure 2 shows the stages of XSLT processing for transformation from the UML Activity diagram to an executable care pathway.

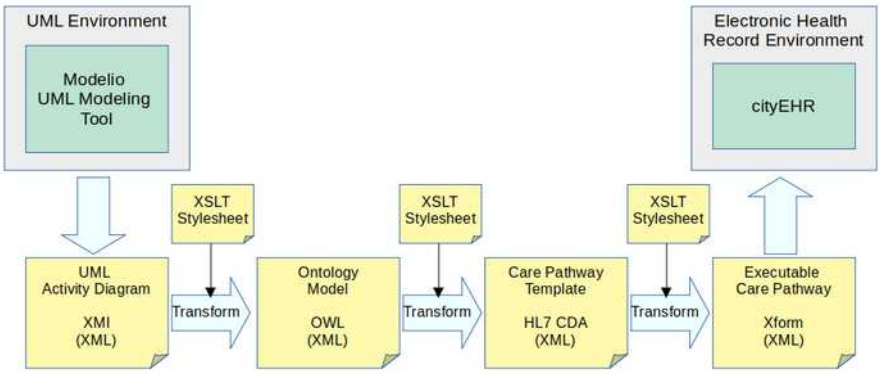

Figure 2. Transformation from UML Activity Diagram to Executable Care Pathway

3. Results

The Modelio UML environment was used to create a full care pathway for Lifestyle Assessment that includes branches conditional on the Body Mass Index (BMI) of the patient and loops for repetition of the entire pathway for patients assessed to be underweight or obese. A simpler care pathway was also implemented for assessment and monitoring of patients in a Fracture Liaison Service (FLS) following diagnosis of a fragility fracture.

It was found that although the Activity Diagrams are sufficient to specify the pathways and create the ontology models required to drive the executable care pathways in the EHR, there are additional details required in the specific care settings in which the pathways are used. In particular, it is necessary to assign the role of the clinical user designated to perform each action and to specify the time period between triggering an action in the pathway and the time at which it is to be performed. For example, in the FLS pathway two patient monitoring actions are triggered after the patient has been assessed and a treatment recommended; these actions are scheduled at 12 weeks and 12 months after being triggered.

To accommodate these requirements, the cityEHR system was enhanced to allow users to modify the templates in the library of care pathways to add the additional information not included in the UML Activity diagram specification. Previously it had only been possible to modify each single instance of a pathway as it was executed for an individual user. Allowing such tailoring of the template pathways was preferred over adding information (as notes) in the UML Activity Diagrams, since the details are specific to the particular care settings in which the pathways are used, rather than being fundamental properties of the underlying clinical model. Figure 3 shows the execution of a pathway. The template is instantiated with data from the patient record and each act, when triggered, creates a new CDA document (Form, Letter, Booking, Order or Prescription) that is completed by the assigned user and stored in the patient record.

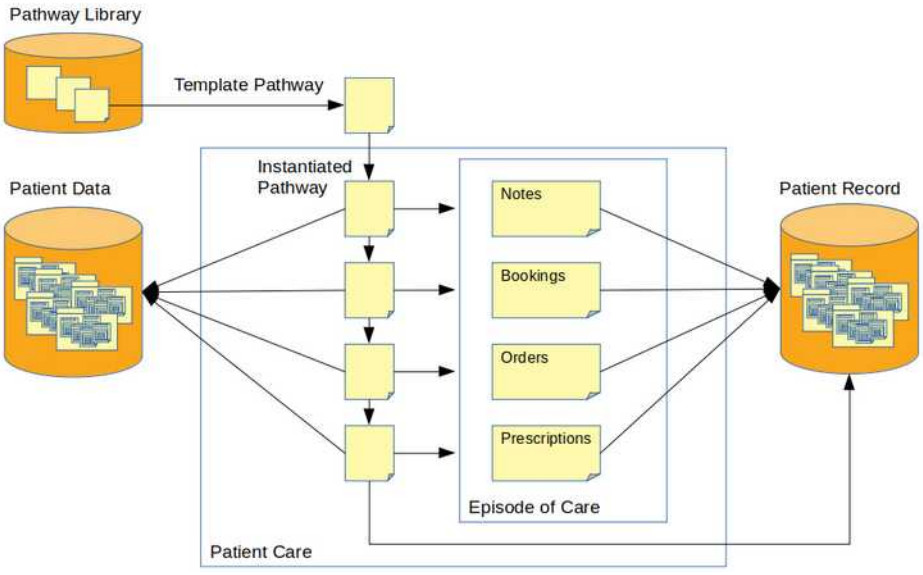

Figure 3. Instantiation of Executable Care Pathways from the Template Library.

4. Conclusions

UML Activity diagrams provide an easy and familiar way to design and specify care pathways, supported by a wide range of modeling tools. Using the standard XMI representation, the Activity diagrams can be transformed into templates of HL7 CDA clinical documents which can be used to drive interaction with the executable care pathway through a user interface generated as a standard XForm used by the cityEHR health records system. It has been demonstrated that this approach is sufficient to support care pathways for Lifestyle Assessment and for patient management in a Fracture Liaison clinic.

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