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Representing Clinical Guidelines in UML: A Comparative Study

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Abstract. Clinical guidelines can be represented using models, such as GLIF, specifically designed for healthcare guidelines. This paper demonstrates that they can also be modelled using a mainstream business modelling language such as UML. The paper presents a guideline in GLIF and as UML activity diagrams, and then presents a mapping of GLIF primitives to UML. The potential benefits of using a mainstream modelling language are outlined. These include availability of advanced modelling tools, transfer between modelling tools, and automation via business workflow technology.

1. Introduction

The last five years has seen a significant rise in the development of evidence-based clinical guidelines and protocols encapsulating best practice for a range of medical conditions and treatments [7,9]. Many different specification techniques have been employed to capture both the control and data flow [6,8,11]. However capturing complex control and data flows within an organisation is a problem experienced across a range of problem domains and such clinical guidelines could be comparable with 'business processes' and 'workflows' both within and between organisations.

This paper explores the overlap and potential synergy between clinical guideline representation models and business process representation languages, with a view to automating clinical guidelines via mainstream business process automation (workflow) technology. More specifically, the paper compares one of the more significant clinical guideline representation models (GLIF3) with the representative power of a mainstream modelling language (UML). The paper presents a case study of the same clinical guideline in both UML and GLIF and explains how such a representational mapping can be achieved. This research work is being performed as part of the MediLink programme which is researching the development of a generic approach to advanced decision support in complex information- and knowledge-intensive domains, particularly the health domain, funded under the PRTLI programme.

2. Clinical Guideline Representation

Clinical practice guidelines are recommended strategies for patient care. The recent move towards evidence-based medicine has led to the development of evidence-based guidelines. Adoption of guidelines by healthcare professionals should improve the quality and cost-effectiveness of patient care. However the effect on clinician behaviour of textual (primarily paper-based) guideline dissemination has been disappointing. Guideline-based

computerised decision support at the point of care has the potential to deliver the true benefits of guidelines.

Approaches to guideline-based decision support vary from AI-based therapy planning systems, to more process-oriented approaches [11]. The former represent knowledge of the medical domain (e.g. the normal range of BP or glucose levels, the effect of a particular drug or treatment and its contra-indications, etc.) and then dynamically use this knowledge to plan what is the desired outcome for a particular patient and how to achieve it. By contrast, our emphasis is strongly process-oriented. We are investigating the use of business process automation technology to computerise guideline-based care.

Many guideline representation models have been proposed. The foremost requirements of a guideline representation model to support guideline automation are that it be precise, unambiguous and executable. In addition, guidelines encoded in the representation model should be readable by humans. If we are looking for a broadly applicable model, then it should support different kinds of guidelines (e.g. chronic disease management guidelines and intensive care guidelines) and different modes of use (e.g. education and patient management).

Clinical practice guidelines are time-consuming and expensive to develop; executable guidelines, from which all imprecision and ambiguity have been removed, are even more so. Ideally, therefore, once developed, such guidelines should be shareable amongst many institutions and/or practitioners [3]. Amongst other things, the sharability requirement implies that a guideline representation model should facilitate adaptation of guidelines to different settings and integration of guidelines with local computer systems.

3. A Guideline Representation Model: GLIF

3.1. An introduction to GLIF

GLIF (GuideLine Interchange Format), or more specifically GLIF3, the most recent version, was designed to facilitate guideline sharing and for representing a broad variety of guideline types [2]. GLIF favours the process-oriented view of guidelines and is thus well-suited to mapping to business process representation.

There are five main guideline flowchart step types (GLIF classes): action, decision, branch, synchronisation and patient state. *Action* steps specify work (a set of tasks) to be performed. *Decision* steps are used for conditional flowchart traversal. There are two kinds of decision steps: case steps, which represent decisions that can be automated by directly evaluating logical criteria based on data items from the EMR (e.g., if patient's level of glucose is lower than 7 mmol/l then ...) and choice steps, which represent choices that should be made by the user (physician, other health care provider, another program) since they are either safety-critical or require knowledge that is not specified by the guideline. *Branch* and *synchronisation* steps allow concurrency. Branch steps are used to model concurrent guideline steps. All of these guideline steps can occur in parallel. Synchronisation steps are used in conjunction with branch steps. When multiple guideline steps follow a branch step, the flow of control eventually converges in a single step - this is the synchronisation step. A continuation attribute specifies whether all, some or one of the preceding steps must have been completed before continuing. *Patient-state* steps characterise a patient's clinical state: a label that describes a patient state that is achieved by previous steps or an entry point to the guideline (e.g., patient, referred by GP with suspicion for Diabetes mellitus, type II, is coming to Diabetes Day Centre).

Guideline nesting is supported, to hide complexity and enhance comprehensibility. Action and decision steps can be represented by subguidelines (e.g. DM diagnosed subguideline in our example).

3.2. Sample guideline: Diagnosis of Diabetes mellitus

For the purposes of this study we chose to encode the process of diagnosis of diabetes mellitus, based on the official guideline, refined to suit the needs of the Diabetes Day Centre in St. James's Hospital, Dublin. This medical domain was carefully selected as there is already a significant body of knowledge and experience, it represents an information-rich domain in which clinicians have to make complex decisions based on many different factors and it is a domain in which there are relatively large numbers of patients [1]. The localised version of the guideline represents the diabetes mellitus diagnostic process in daily practice, integrating such services as scheduling, report authoring, and querying databases. It was also adjusted to highlight representational issues for the purposes of this paper and is not a consensus-based clinical guideline.

The top-level flowchart for the diagnostic guideline is shown graphically in Figure 1 while Figure 2 shows a subguideline for the "DM diagnosed Guideline" action. In these diagrams, action steps are represented by rectangles, case decision steps by diamonds, choice decisions by hexagons, branch and synchronisation steps by upright and inverted triangles, respectively, and patient state steps by ovals. These diagrams were prepared using the Protégé 2000 knowledge representation tool, and a prepared domain ontology for GLIF [10].

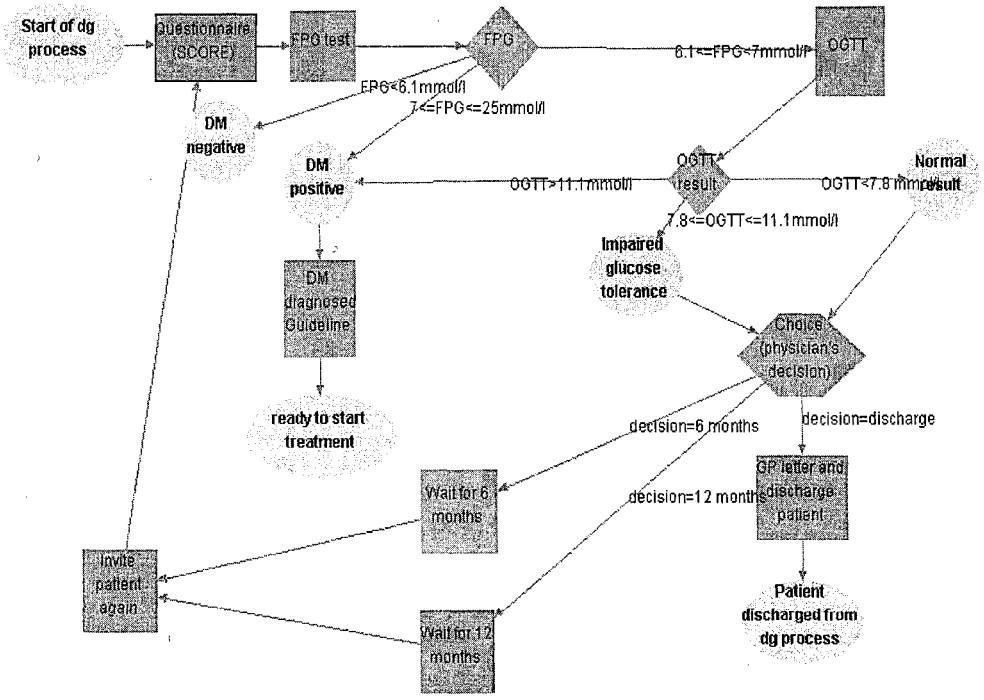

Figure 1: Diabetes Diagnosis guideline in GLIF

In Figure 1 note they use of patient state steps at entry and exit points from the guideline as well as to mark significant states in the guideline process (e.g. DM diagnosed). Recall that case steps (diamonds) represent automatable decision points, whereas choice steps (hexagons) require user decision or confirmation. Note that the "DM diagnosed Guideline" action step (rectangle) is encoded by a nested guideline (see Figure 2).

The subguideline in Figure 2 depicts the actions to be taken when a patient has been diagnosed with DM. Many of the tasks are administrative - arranging appointments and printing referral letters for clinical nutritionist, eye examination, chiropodist and diabetician. The first three of these appointments can be arranged in parallel – hence the branch and subsequent synchronisation steps - but the diabetician appointment must follow the others and therefore cannot be arranged till the dates of the other referrals have been decided. As well as these flowcharts, a computable GLIF guideline specification would include detailed decision criteria, definitions of patient data items and how to find them in the electronic patient record, iteration information, details of how to invoke services and applications such as appointment scheduling and report generation, etc.

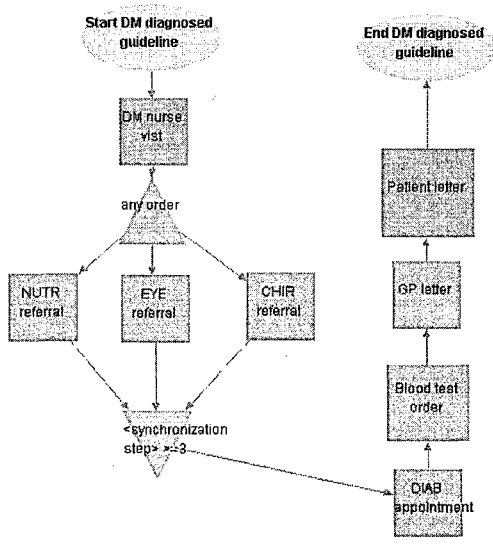

Figure 2: Diabetes Mellitus action subguideline

4. Clinical Guidelines in UML

The representation of clinical guidelines using mainstream IT representational techniques has been attempted previously using flowcharts, sequence diagrams or high-level petri nets [4,]. However, the software industry has adopted a set of modelling notations, called the Unified Modelling Language (UML). In more recent versions of (v1.4 and the emergent v2.0), considerable extensions have been made to the UML Activity Graph Modelling language so that it is capable of representing more complex, and process-oriented problems. UML is supported by all major software modelling tool vendors and its modelling elements are underpinned by a semi formal language which facilitates rigorous specification. The Object Management Group (OMG) which is the standards body

responsible for UML, is advocating the Model Driven Architectural approach to systems automation, where the models created in UML can generate executable specifications as well as facilitating sharing of designs. By using such technology for clinical guideline representation, guideline developers may avail of a wide choice of modelling tools, automated generation of documentation, generation of executable code, traceability of the development/local customisation, and in certain circumstance implementation automation.

4.1. Mapping sample GLIF guideline to UML

In order to investigate the appropriateness of UML for clinical guideline representation (and ultimately automation), the MediLink programme is performing a series of case studies. In this paper we outline how the GLIF3 representation of a guideline can be represented as UML activity graphs and workflows. Figure 3 is a UML activity diagram representing the overall guideline for diagnosing diabetes mellitus. It corresponds with the GLIF flowchart of Figure 1. Note the graphically subtle distinction between states (e.g. Diabetes mellitus state) and activities (e.g. FPG test). Figure 4 depicts the nested activity "DM diagnosed guideline", which corresponds with the GLIF sub-guideline in Figure 2.

This case study illustrates the mapping of GLIF process-oriented clinical guidelines into UML activity diagrams. Table 1 summarises the correspondence between elements of the two representation languages. GLIF action steps are mapped to UML activities. GLIF case steps map to UML decision points, while choice steps can be represented by a series of activity (in which clinician interaction takes place resulting in a value for the decision to be made) followed by a decision point.

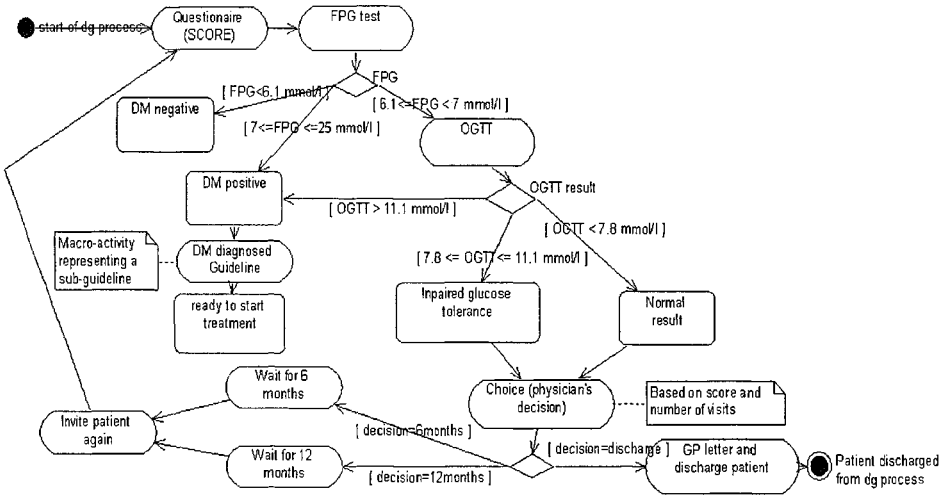

Figure 3: UML Activity Diagram for the diagnosis of diabetes guideline

Branch and synchronisation steps have their counterparts in UML (though these do not provide equivalent options). GLIF patient state steps are mapped to UML in several ways. When used to indicate the start and end of a process, they are represented by start and stop states (solid small circles). Patient states internal to the flowchart may be represented by state elements in the activity diagrams (rounded rectangles), or by translating them into pre- and post-conditions on activities in the activity diagrams (an option we have not demonstrated here).

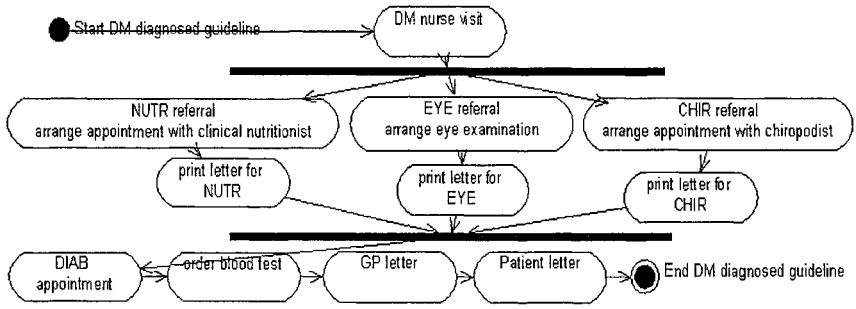

Figure 4: Diabetes Mellitus Sub Activity Diagram

Table 1: Mapping GLIF elements to UML

GLIF3	UML
Action step	Activity
Case step	Decision point
Choice step	Activity *followed by* Decision point
Patient state	State Start- and stop state Pre- and post conditions
Branch point	Synchronisation bar
Synchronisation point	Synchronisation bar

4.2. Analysis

The mapping has illustrated that the modelling elements of GLIF3 are representable in UML. However, the advantages of using UML are not simply the visual representation. The GLIF3 specification also involves details, such as decision criteria, relevant patient data, and iteration information that must be provided to make the specification computable. Work is on-going in the MediLink project to attempt to capture such semantics using a combination of representational aspects of UML, UML's OCL and UML's XML model description interchange format (XMI). For example, information flows within a guideline can be modelled in UML and be tied (for consistency assurance) to existing information models, criteria and constraints can be expressed as conditional statements in OCL.

Encoding guidelines with a comprehensive modelling tool allows the customisation, which is needed to apply the guideline within a particular hospital or healthcare centre, to be performed within the modelling tool. This would provide traceability of the customisation effort. It would also ease the automation effort of the guideline, including the integration of the clinical guideline system with other healthcare systems. Another potential advantage of representing the Guideline in UML is that the actual guideline models and specification can be delivered (exported and shared) between differing UML based modelling tools via UML's XMI interface.

5. Conclusions and Future Work

This paper has outlined the requirements for modelling and representing process oriented clinical guidelines. The paper has taken a significant existing clinical guideline representation approach (GLIF3), developed within and explicitly for, the health

informatics industry and demonstrated how such guidelines can also be modelled within existing mainstream information technology using UML. Mapping of the representational primitives of GLIF3 to UML modelling elements has been presented and the potential benefits of using such mainstream technologies have been outlined. Work is currently on-going in the MediLink programme to provide a correspondence of GLIF3 "computable level" specifications to UML style formal specifications. More broadly the project is seeking to provide full UML representation of clinical guidelines as well as automating their execution within a UML based workflow environment.

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