GLIF3: The Evolution of a Guideline Representation Format

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The Guideline Interchange Format (GLIF) is a language for structured representation of guidelines. It was developed to facilitate sharing clinical guidelines. GLIF version 2 enabled modeling a guideline as a flowchart of structured steps, representing clinical actions and decisions. However, the attributes of structured constructs were defined as text strings that could not be parsed, and such guidelines could not be used for computer-based execution that requires automatic inference. GLIF3 is a new version of GLIF designed to support computer-based execution. GLIF3 builds upon the framework set by GLIF2 but augments it by introducing several new constructs and extending GLIF2 constructs to allow a more formal definition of decision criteria, action specifications and patient data. GLIF3 enables guideline encoding at three levels: a conceptual flowchart, a computable specification that can be verified for logical consistency and completeness, and an implementable specification that can be incorporated into particular institutional information systems.

1 Introduction

Clinical guidelines are potential tools for standardizing patient care to improve its quality and cost effectiveness. Unfortunately, guidelines have not always been successful at affecting clinician behavior. Structured, computer-interpretable guidelines can be delivered to the point of care in a way that enables decision support.[1] Such guidelines might also provide workflow management support, quality assurance evaluation, and simulation for educational purposes.[2]

There are several approaches to creating computer-interpretable guidelines that enable decision support. The PRO*forma* model assists patient care through active decision support and workflow management.[3] PRODIGY structures a guideline as a set of choices for the clinician,[4] and models patient scenarios that drive decision-making. PRESTIGE[5] uses a declarative approach to representing knowledge about the healthcare enterprise, the patient health record, and the protocol. The Asbru language[6] represents guidelines in a manner that includes explicit intentions of the guideline authors. The EON guideline model uses a combination of modeling primitives, such as various decision-making mechanisms, flow of control constructs, actions and activities, and a distinction between the normal case and its exceptions.[7] Arden syntax[8] is a language for creating and sharing medical knowledge in the form of independent units called medical logic modules (MLMs). Each MLM contains sufficient logic to make a single medical decision.

Creating clinical guidelines in computer-interpretable form takes significant effort. Thus, sharing them among developers and across institutions is desirable. However, there are many logistical obstacles to this goal. GLIF is a structured representation language of guidelines that was developed by the InterMed Collaboratory.[9] Its goals are to (1) enable viewing of GLIF-formatted guidelines by different software tools and (2) enable adapting the guidelines to a variety of local uses. Its goal is not to be a medium for translation from one guideline formalism to another.*

The objective of the GLIF specification is to provide a representation for guidelines that is: (a) precise and unambiguous; (b) human-readable; (c) computable, in the sense that the logic and sequence in guidelines specified in GLIF can be interpreted by computer; and (d) adaptable to different clinical information standards, thus facilitating guideline sharing.

2 Background

Version 2.0 of GLIF (GLIF2) was published in 1998,[9] and consisted of the GLIF object model and the GLIF

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* In this sense, the word "interchange" in the expansion of the GLIF acronym is a misnomer.

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syntax. The GLIF model, published in Interface Definition Language (IDL),[10] allowed the specification of a guideline as a flowchart of temporally ordered steps. These steps represented clinical decision and action steps. Concurrency was modeled using branch and synchronization steps. GLIF's guideline class also specified maintenance information (author, status, modification date, and version), the intention of the guideline, eligibility criteria, and didactics. The GLIF guideline instance syntax, which was based on a separately developed language, specified the format of text files, which contained GLIF-encoded guidelines. These files were used for sharing and interchange.

GLIF2 has been the basis for several implementations of guideline-based applications, including one in Brigham and Women's Hospital's BICS information system,[11] and web-based applications for driving clinical consultations.[2] However, GLIF2 has certain deficiencies that limit its usability. As a result, non-standard extensions had been made to GLIF2 to implement the above applications. The deficiencies are:

1. GLIF2 does not specify how to structure important attributes of guideline steps, such as data and action names and logical condition expressions. Values of most attributes are specified simply as text strings. Thus, such guidelines cannot be used for automatic inference.
2. Integrating GLIF2 guidelines with heterogeneous clinical systems is difficult, as GLIF2 lacks features for mapping patient data references to entries in the electronic medical record.
3. GLIF2's decision model is limited. Decisions are either specified in a conditional step that models if-then-else semantics, or in a branch step for which no preference among the alternatives can be expressed.
4. GLIF2 provides only a limited set of low-level constructs. Important concepts such as those for describing iteration, patient-state, exception conditions, and events are lacking.
5. GLIF2 uses subguidelines to manage complexity in guideline flowcharts. These subguidelines can be used to expand action steps. However, because GLIF2's set of constructs is limited, GLIF2 guidelines tend to be cumbersome, even if they do use subguidelines.
6. The branch step can be used both for representing concurrent execution of multiple actions and for making selection among a set of alternatives. Thus, its semantics are a mixture of concurrency and decision-making.

This paper presents GLIF3, an evolving revision of GLIF that attempts to overcome several of GLIF2's limitations.**Overview of GLIF3**

GLIF3 enables guideline specification at three levels: a conceptual GLIF flowchart, a computable/parsable specification and an implementable specification. In addition, GLIF3 introduces substantive changes to GLIF2's object model and syntax. GLIF3 is intended to be sufficiently expressive to support specification of guidelines that differ in these ways: (1) their medical purposes (e.g., screening, disease management); (2) their intended uses (reference, patient management, and education); (3) the intended users (e.g., physician, patient); and (4) their utilization sites (e.g., ICU, out of hospital)[12]. We tried to avoid overlap in the functionality of different GLIF3 constructs, and not to enable a single GLIF construct to model two different guideline situations. For example, the branch step is no longer used to represent decision choices.).

3.1 Guideline Abstraction Levels

GLIF3 enables modeling of guidelines at three levels of abstraction:

A. Conceptual level. Guidelines at this level are represented as flowcharts that can be used for browsing, through guideline viewing programs. However, these guidelines cannot be used for computation in providing decision support.

B. Computable level. Guidelines at this level may be verified for logical consistency and completeness. Expression syntax, definitions of patient data items and clinical actions, and flow of the algorithm are specified at this level.

C. Implementable level. At this level, guidelines are appropriate for incorporation into particular institutional information system environments. Thus, these guidelines may incorporate non-sharable elements.

Figure 1 shows part of the conceptual specification of a guideline for management of stable angina.[13]**Changes in the object model**

The object model for GLIF3 defines new constructs and further structures GLIF2 constructs.

Representation in UML

The GLIF3 model is described using Unified Modeling Language (UML) class diagrams[14]. Additional constraints on represented concepts are being specified in the Object Constraint Language (OCL), a part of the UML standard.[14]

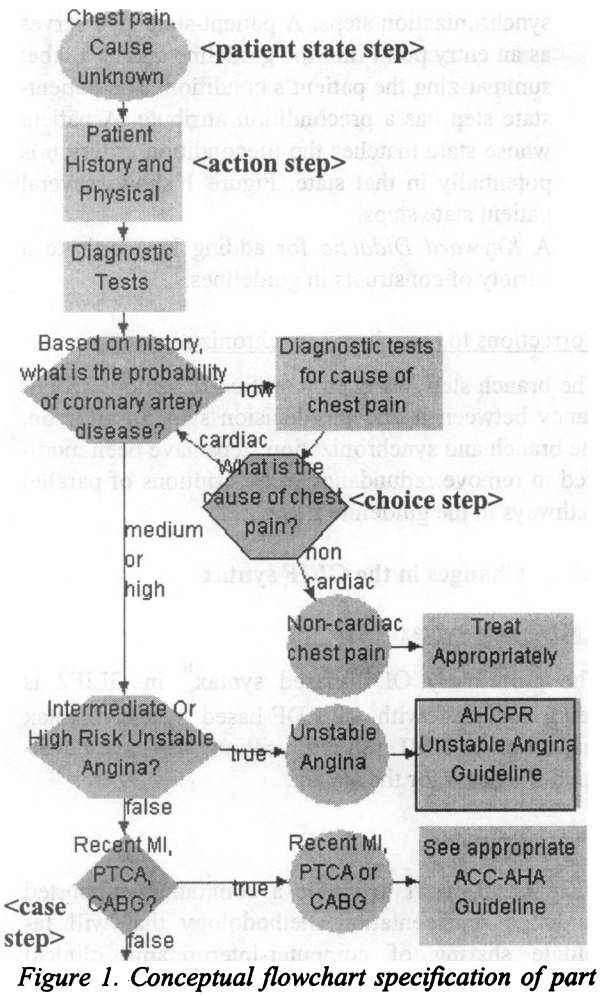

Figure 1. Conceptual flowchart specification of part of a stable angina guideline.

Support for managing complexity of guidelines

In comparison with GLIF2, GLIF3 more fully defines a mechanism for specifying guideline steps recursively through the nesting of subguidelines in action and decision steps. For example, *AHCPR Unstable Angina Guideline*, shown in Figure 1 as an action step, can be expanded by zooming, through the nesting mechanism, to show its details in the form of another flowchart diagram. Because nesting allows grouping of parts of a guideline into modular units (subguidelines), it is a mechanism that allows guideline parts to be reused. Furthermore, the modularity resulting from nesting permits adaptation of a guideline to a specific institution by replacing or elaborating upon specific sections of the guideline. For example, an action specified at a high-level may be replaced with a detailed procedure.

A new feature in GLIF3 is the *macro step*. Like Visual Basic, Object Linking and Embedding Custom Control (OCX), and Java Beans, a macro step is a special class with attributes that define information needed to instantiate a set of underlying GLIF steps. For example, as shown in Figure 2a, an MLM can be described using a pattern of GLIF components: a decision step that contains a *criterion* (logic slot) and is triggered by *events* (evoke slot), followed by an action step that include *action specifications* (action slot). Macro steps benefit authoring, visual understanding, and execution of guidelines. They also enable declarative specification of a procedural pattern that is realized by a flowchart of guideline steps.

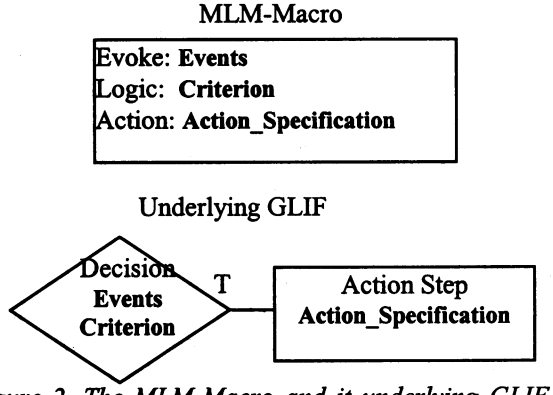

Figure 2. The MLM-Macro and it underlying GLIF pattern. (a) MLM-Macro; (b) underlying GLIF

In GLIF3, we added a capability that provides multiple views of the same guideline. Since different users may be interested in different parts of a large, complex guideline, differential display capability is supported. This capability is provided through the use of filters that collapse segments of the guideline into a default view of the guideline customized to a given user, situation, etc.

Expression specification

We added to GLIF3 a structured grammar for specifying expressions and criteria. The grammar can specify logical criteria, numerical expressions, temporal expressions, and text string operations. It is a superset of the Arden Syntax logic grammar,[15] and adds new operators such as "is a", "overlaps", "xor", "from now", "is unknown" and "at least k of …".

Domain ontology support

In GLIF2, an Action Specification contained a Patient Data class that textually defined patient data items.

GLIF3 facilitates using of standard medical vocabularies and integrating shared guidelines into clinical information systems environments via a layered approach for referencing clinical terms. The *core GLIF* layer provides a standard interface to all medical data and concepts that may be represented and referenced by GLIF. The interface views all data items as being literals (constants) or variables. Each data item may

refer to a concept that is defined by the two other domain ontology layers. This approach enables each data item to contain specific relevant attributes. The *Reference Information Model* (RIM) *layer* provides a semantic hierarchy for medical concepts, and allows attribute specification for each class of medical data. Different RIMs, such as the HL7 RIM, may be used in different guidelines.

The *medical knowledge layer* contains a term dictionary (e.g., UMLS) and can provide access to medical knowledge bases. It can provide more specific information about medical concepts and their interrelationships. With such knowledge, we can examine the correctness of criteria and action specifications by performing range checks and semantic checks (e.g., a body-part has no "timestamp" attribute).

Flexible decision model

GLIF3 provides a flexible decision model through a hierarchy of decision step classes. This decision hierarchy distinguishes between decision steps that can be automated (*case steps*) and ones that have to be made by a physician or other health worker and cannot be automated (*choice steps*). Examples of case and choice steps are shown in Figure 1. The decision hierarchy can be extended in the future to model decisions that consider uncertainty or patient preferences. The hierarchy might be extended to support different decision models.

Extended action specification model

The action specification model has been extended to include two types of actions: (1) guideline-flow-relevant actions, such as calling of a sub-guideline, or computing values for data; and (2) clinically relevant actions, such as making recommendations. Clinically relevant actions reference the domain ontology for representations of clinical concepts such as prescriptions, laboratory test orders, or referrals.

Other new concepts

Representations for several new concepts were added to GLIF3. They include specifications for the following:

- Describing *Iterations* and conditions that control the iteration flow.
- Describing *Events* and triggering of guideline steps by events.
- Describing *Exceptions* in guideline flow and associated exception-handling mechanisms.
- Representing *Patient-State* as another kind of guideline step (a node in the flowchart), in addition to the existing action, decision, branch, and synchronization steps. A patient-state step serves as an entry point into the guideline and as a label summarizing the patient's condition. The patient-state step has a precondition attribute. A patient whose state matches the precondition criterion is potentially in that state. Figure 1 shows several patient state steps.
- A *Keyword Didactic* for adding keywords to a variety of constructs in guidelines.

Corrections to branch and synchronization step

The branch step has been modified to remove redundancy between it and the decision step. In addition, the branch and synchronization steps have been modified to remove redundancy in descriptions of parallel pathways in the guideline flowchart.

3.3 Changes in the GLIF syntax

XML-based syntax

The proprietary ODIF-based syntax[16] in GLIF2 is being replaced with an RDF-based syntax[17] syntax that relies on XML for serialization. We have developed a schema for the syntax.

4 Discussion

GLIF is an effort to create a community-supported guideline representation methodology that will facilitate sharing of computer-interpretable clinical guidelines. It was developed through a collaboration of a number of institutions, including Stanford Medical Informatics; the Decision Systems Group of Brigham & Women's Hospital, Harvard Medical School; the Department of Medical Informatics at Columbia University; and the Center for Medical Education at McGill University. The Laboratory for Computer Science at Massachusetts General Hospital, participated in the development of GLIF2. GLIF3 tries to leverage the years of effort that have gone into the development of other existing methodologies. Like EON[7], GLIF models a clinical guideline as a flowchart. GLIF3 includes the patient-state step that is similar in functionality to scenarios, which are used in PRODIGY[4]. GLIF3 also uses a superset of Arden Syntax[8] for expressing decision criteria and supports the MLM-macro that can be used to map GLIF-encoded guidelines into MLMs.

GLIF3 is evolving very rapidly. More work still needs to be done on the specification of its domain ontology. We are currently specifying several clinical guidelines, at the three abstraction levels, in order to evaluate GLIF3. To solicit comments from the com-

munity, the current GLIF3 specification is published on the Internet at http://www.glif.org/glif3_info.html.

Future versions of GLIF will explore structured representations for (1) specifying goals of guideline steps,[6] (2) probabilistic models for decision-making,[18] and (3) incorporation of patient preferences in decision steps.[19]

We are developing software tools for authoring, verifying, viewing, distributing, and executing guidelines. These tools are being implemented in Java to provide portability and use over the Internet.

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