

The GLARE Approach to Clinical Guidelines: Main Features

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Abstract. In this paper, we present GLARE, a domain-independent prototypical system for acquiring, representing and executing clinical guidelines. GLARE has been built within a 7-year project with Azienda Ospedaliera San Giovanni Battista in Turin (one of the largest hospitals in Italy) and has been successfully tested on clinical guidelines in different domains, including bladder cancer, reflux esophagitis, and heart failure. GLARE is characterized by the adoption of advanced Artificial Intelligence (AI) techniques, to support medical decision making and to manage temporal knowledge.

Introduction

Clinical guidelines represent the current understanding of the best clinical practice, and are now one of the most central areas of research in Artificial Intelligence (AI) in medicine [1]. Clinical guidelines play different roles in the clinical process: e.g., they can be used to support physicians in the treatment of diseases, or for critiquing, for evaluation, and for education. Many different projects have been developed in recent years in order to realize computer-assisted management of clinical guidelines (see e.g., Asbru [2]), EON [3], GEM [4], GLIF [5], GUIDE [6], ONCOCIN [7], PROforma [8]).

In this paper we provide a brief and sketchy description of GLARE (GuideLine Acquisition, Representation and Execution), the prototypical system we have built (starting in 1997) in cooperation with Azienda Ospedaliera S. Giovanni Battista in Turin, one of the largest hospitals in Italy (see for more details [9,10,11]). GLARE is a domain independent manager of clinical guidelines, whose distinguishing feature is the introduction of advanced Artificial Intelligence techniques (i) to enhance the user-friendliness of the approach, (ii) to provide advanced decision making facilities, and (iii) to manage temporal data. Moreover, special attention has been devoted to the interaction of the system with DataBases (in particular with the hospital DB containing the patients' data).

1. GLARE in a glance

GLARE is based on the assumption that knowledge in the clinical guidelines is independent off its use (e.g., support, evaluation etc.), so that it is convenient (at least from the knowledge engineering point of view) to distinguish between the problem of acquiring and

representing clinical guidelines and the problem of “using” them (e.g., “executing” acquired guidelines on specific patients).

1.1 Representation formalism

In order to guarantee usability of GLARE to user-physicians not expert in Computer Science, we have defined a *limited set* of clear representation primitives [10] which are quite close to PROforma’s ones [8]. In particular, we have focused our attention on the concept of *action*, distinguishing between *atomic* and *composite actions*. Atomic actions can be regarded as elementary steps, in the sense that they do not need a further decomposition into sub-actions to be executed. Composite actions are composed by other actions (atomic or composite).

GLARE distinguishes between four different types of *atomic actions*: *work actions*, *query actions*, *decisions* and *conclusions*. *Work actions* are atomic actions which must be executed at a given point of the guideline, and can be described in terms of a set of attributes, such as name, (textual) description, cost, time, resources, goals. *Query actions* are requests of information, that can be obtained from the outside world (physicians, DataBases, knowledge bases). *Decision actions* are specific types of actions embodying the criteria which can be used to select among alternative paths in a guideline. In particular, *diagnostic decisions* are represented as an open set of triples <diagnosis, parameter, score> (where, in turn, a parameter is a triple <data, attribute, value>), plus a threshold to be compared with the different diagnoses’ scores. On the other hand, *therapeutic decisions* are based on a pre-defined set of parameters: effectiveness, cost, side-effects, compliance, duration. Finally, *conclusions* represent the explicit output of a decision process.

Composite actions are defined in terms of their components, via the *has-part* relation (this supports for top-down refinement in the description of guidelines). On the other hand, a set of *control relations* establish which actions might be executed next and in what order. We distinguish among four different control relations: *sequence*, *controlled* (*controlled* relations are used in order to represent synchronization as well as more general forms of temporally constrained actions, such as “A during B”, “start of A at least 1 hour after the beginning of B”, and so on), *alternative* and *repetition*. A distinguishing feature of GLARE is its capability of managing temporal constraints (see [11, 12] and section 2).

1.2 Acquisition tool

GLARE’s acquisition module provides expert-physicians with a user-friendly and easy-to-use tool for acquiring clinical guidelines. In order to achieve these goals, we have implemented:

- (i) a graphical interface, which supports primitives for drawing the control information in the guideline, and ad hoc windows to acquire the internal properties of the objects;
- (ii) facilities for browsing the guideline;
- (iii) automatic consistency checking of temporal constraints.

As regards issues (i) and (ii), figure 1 shows part of the guideline for gallbladder stones treatment. The left part of the figure displays the window representing the general structure of the guideline: it shows in form of a tree the hierarchy of actions introduced by the expert physician. Each node represents an action, and each action has as sons the sub-actions composing it. The right part of the figure shows the window used to acquire the control relations between the components of composite actions. Each sub-action is represented as a node in the graph (different forms and colours are used to distinguish

among different types of actions), while control relations are represented as arcs. By clicking on the nodes in the graph, the user can trigger other windows in order to acquire the internal descriptions (attributes and parameters) of nodes. Issue (iii) is sketched in section 2.

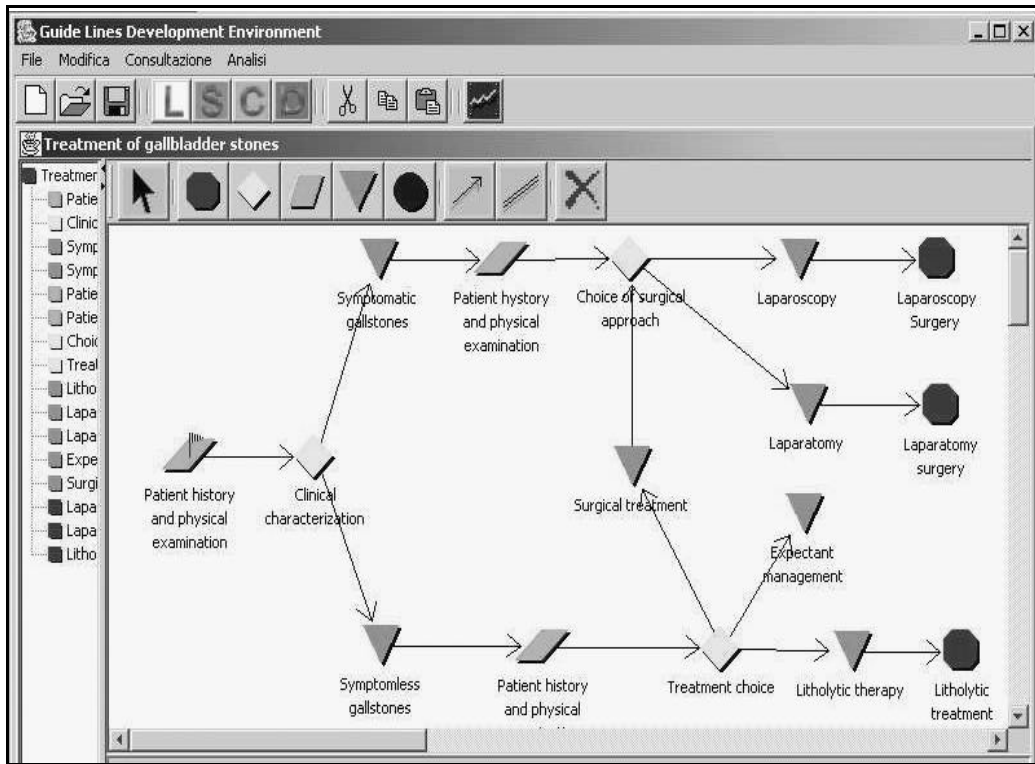


Figure 1: Part of the gallbladder stones treatment guideline, represented through the GLARE acquisition module graphical interface.

To enhance standardization, the acquisition tool interacts with the Clinical DB, which provides a “standard” terminology (in the form of a hierarchy) to be used when building a new guideline, and stores the descriptions and the set of possible values of clinical findings.

1.3 Execution tool

GLARE’s execution module executes an acquired guideline for a specific patient, taking into account the patient’s data, automatically retrieved from the Patient DB, which is used to store patients’ data. The execution tool stores the status of the execution in another DataBase (Instance DB) and interacts with the user-physician via a user-friendly graphical interface.

The typical use of our execution tool is “on-line”: a user physician executes a guideline applied to a specific patient (i.e., s/he instantiates a general guideline considering the data of a given patient). However, we also envision the possibility of adopting our execution tool for “off-line” execution (this might be useful in different tasks, including education, critiquing and evaluation). In the on-line execution, the delays between actions in the guideline must be forced at execution time, while in off-line execution, the execution engine must jump directly from an action to the next one (without waiting for the given delay). To support both modalities, we adopt the “agenda technique” [9].

The advanced temporal reasoning and decision support facilities of the execution module are sketched in section 2 (see also [12]).

1.4 Implementation and testing

A prototypical version of the GLARE system has been implemented in Java. In the first implementation, we used Access to store DataBases (i.e. Patient DB, Instance DB, Clinical DB and the Guidelines DB). We are currently switching to the Cache' DBMS, which has been recently adopted by the Azienda. In the meanwhile, we are trying to make GLARE as independent of the DBMS as possible, by inserting an intermediate XML layer.

We have already tested our prototype acquisition and representation system considering different domains, including bladder cancer, reflux esophagitis and heart failure. In the case of bladder cancer, the expert physicians started to design the guideline algorithm from scratch, using directly our acquisition tool (after a short training). In the cases of reflux esophagitis, and heart failure, the physicians started with guidelines algorithms previously described on paper (using drawings and text), and used our acquisition tool to introduce them into a computer format. In both cases, they were assisted by a knowledge engineer. The acquisition of an already built clinical guideline using our system was reasonably fast (e.g., the acquisition of the guideline on heart failure required 3 days), and the facilities of GLARE proved to be useful to check several syntactic and semantic correctness criteria (e.g., temporal consistency of constraints). Moreover, our representation formalism proved to be expressive enough to cover the clinical algorithms (i.e., actions and control relations between them). On the other hand, the formalism for describing the internal description (in terms of a set of attributes) of actions could only be partially tested, since we couldn't have such data from physicians.

2. Advanced features in GLARE

Two of the distinguishing (and advanced) features of GLARE are sketched below.

- (1) GLARE supports an advanced treatment of temporal constraints in the guidelines. Temporal constraints (e.g., on the order and/or delay between actions, on their duration, and so on) are an intrinsic part of clinical guidelines. GLARE provides an expressive high-level language to manage such constraints, with specific extensions (wrt "standard" AI languages [13]) to cope with repeated/periodic actions. A temporal reasoning algorithm has been devised in order to check (during the acquisition phase) the consistency of the temporal constraints in a guideline. The representation language has been designed in such a way that our algorithm is both correct and complete, and operates in polynomial time. Constraint propagation algorithms have also been devised in order to support temporal reasoning during the execution phase (see [12] for a comprehensive description)
- (2) GLARE's execution tool also incorporates a decision support facility (called *hypothetical reasoning*), able to assist physicians in choosing among different therapeutic or diagnostic alternatives and thus enhancing the user-friendliness of our approach. Through the adoption of the hypothetical reasoning facility, it is possible to compare different paths in the guideline, by simulating what could happen if a certain choice was made. In particular, users are helped in gathering various types of information, needed to discriminate among alternatives. Again,

specific attention has been paid to the problem of gathering temporal information (we devised advanced correct, complete and tractable temporal reasoning algorithms to achieve such a task).

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