Medical Informatics Europe '96
J. Brender et al. (Eds.)
IOS Press, 1996

Resource Management Constraints in Guideline-Based Care

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Abstract. Despite the increased interest they raise, it has been difficult to introduce guidelines in clinical practice, namely due to the dificulty in adapting guidelines into patient care plans, and the management of the latter taking into account specificity of patients and policies for the management of scarce resources. This paper presents a *Constraint Store* as an extension to the representation and handling of guidelines that provide decision support facilities in guideline-based care.

1. Introduction

Guidelines have raised increased interest recently as they a) reduce the variation in medical care given in different areas by different doctors; b) improve the quality of medical care by providing best practice knowledge; c) improve the coordination of the care agents (including the patient) during the execution of a care plan; d) reduce the cost of medical care; and e) decrease the risk of legal action resulting from poor medical care [1,2,3,4,5]. However, there are difficulties in introducing them in medical practice ranging from the fear that they are too rigid [6], to the lack of electronic support [7] to assist their use in real practice.

Such support for guideline-based care is a main goal of project PRESTIGE, which is addressing the problems of handling terminologies and modelling clinical acts and guidelines, capitalising on the results of previous projects such as GALEN[8], NUCLEUS[9] and DILEMMA[10].

A major problem in the introduction of guidelines arises from the conflicts raised by the fact that while guidelines must be flexible (e.g. enumerating possible alternatives, their costs and benefits together with the relevant sources of information), actual care plans must be precise and specific to their patients and clinical settings. The problems in supporting guideline-based care can thus be eased if a distinction is made between generic guidelines and specific care plans. Guidelines can be viewed as imposing relatively loose constraints, that have to be checked against tighter constraints imposed by local conditions, namely the management of scarce resources, the focus of this paper.

Support of guidelines thus requires that, their representation is powerful enough to include the specification of these resource constraints, and their checking, in the process of adapting guidelines into care plans. Decision support is demand in this process aimed at adequately allocate resources to patients, and to monitor the need of further resources [11].

This paper focus on the problems of supporting guideline-based care, from a resource management perspective, and is structured as follows. Section 2 addreses problems arising from the adaptation of general guidelines into patient care plans. The Constraint Store is presented in section 3 as an extension for guideline representation, that manages guideline constraints. Its characteristics are addressed in section 4. Section 5 presents some examples that illustrate the use of this extension. Section 6 finally presents work still to be done.

2. From Guidelines to Care Plans

To provide electronic support to guideline based care, it is necessary to support the process of instantiation of a generic guideline into a care plan for a specific patient. Whereas guidelines must be quite general and abstract many of the existing conditions, a care plan for a specific patient must take into account a number of local factors playing an important role in the plan.

The instantiation of a guideline into a patient care plan usually comprises several steps to include rules adopted by a specific country, region or local health centre, and patient specific data. Given its generality, the design of the guideline will usually overlook many real life constraints, but these will have to be considered eventually in the process of instantiation.

For example, although a guideline might recommend one of two alternative actions (e.g. complementary tests), local health conditions might impose that one of them is not feasible or, less strongly, inadequate (e.g. it requires resources not available locally thus forcing the patient to be moved, with increase in cost, time and patient inconvenience). The local guideline instances should therefore recommend the (only) feasible action. Another guideline might specifiy that two actions are done concurrently (and independently form each other), and national policies, to decrease resources, time and patient inconvenience, might impose the additional restriction that both actions are done during the same visit to a health care centre.

These examples illustrate the usual situation where scarce resources are in conflict with ideal care plans: the locally imposed test might be unsuitable for some patients due to its invasiveness; some centres might have insufficient resources to do both actions in one visit.

Decision support is thus needed in the adaptation of guidelines, to consider and check the constraints imposed at the various steps of instantiation. These contraints are often "soft", their violation being acceptable if penalized (overriding the locally available test increases cost, and not performing the two actions in the same visit increases time spent in the health centre). Such support has a twofold perspective: a) to prevent or minimise the violation of constraints, and b) to monitor the use of available resources and detect bottlenecks of the health care system, as explicitely specified constraints express medical knowledge or health care policies.

3. Managing Guideline Constraints

A guideline can be viewed as a network of actions, each action including a number of attributes such as its goals and objectives, the agents that perform it, the recipient of the action and the location where it is performed. The Generic Protocol Model [12] includes an extensive compilation of all these entities and includes for each action a set of states (e.g. started, scheduled) to allow a protocol manager, to actually manage a care plan, by staging the different phases of the actions and the overall care plan.

The specification of guideline constraints and the detection of their satisfaction or violation still requires work to be done. In the guideline presented in figure 1 for illustration, action A migth represent a visit to a physician followed by one of investigations B or C. A final diagnosis is established in action D, that proposes one of treatments E or F to conclude.

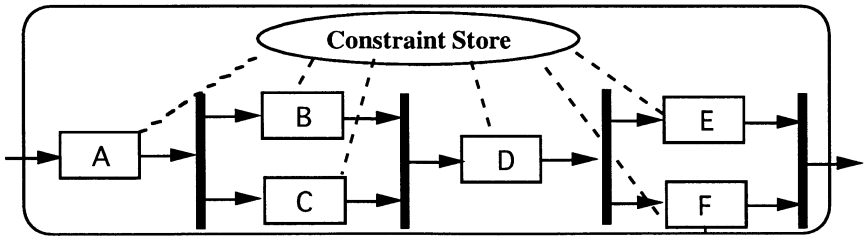

Figure 1. The Constraint Store Component of a Guideline Instance

In this guideline relatively few constraints are specified (e.g. only the sequence and type of actions) and all by inheriting its properties instances of the guideline avoid violation of (semantic) constraints (e.g. all start by a diagnostic task). Resource management constraints though require different handling. At the most general level, ideal medical practice might impose that the guideline does not exceed a given time. At a local level, resource management policies might impose that care plans do not exceed a given cost (e.g. that claimed to health authorities). Scarce resource might impose long delays for investigations B and C, unless done externally at an extra cost. Hence either the cost or duration of a care plan is exceeded.

To manage this type of constraints, we propose the introduction in the guideline manager of a **Constraint Store**. For example, if the whole guideline is to be executed in less than 100 days, at the guideline level the constraint store should include (and check) the constraint

$$Ta+max(Tb, Tc)+Td+max(Te, Tf) \leq 100$$

This constraint is inherited by all guideline local instances, which will further include locally desirable constraints, such as the overall cost should not exceed 1000 units:

$$Ca+max(Cb, Cc)+Cd+max(Ce, Cf) \leq 1000$$

Finally, patient related data is added to the constraint store as a care plan is executed, as is the following case when a patient has already executed steps A and B:

$$Ca = 50 \qquad Cb = 200 \qquad Ta = 1 \qquad Tb = 14$$

4. Constraint Solving Capabilities

The Constraint Store should exhibit a number of (decision support) capabilities to handle the conflicting constraints that can be raised during guideline instantiation.

Constraint solving power. Constraint Stores should detect unsatisfiability of constraints as early as possible, even from incomplete data. If investigations B and C cost at least 300 and 400 respectively, and treatments E and F both cost no less than 750, the Constraint Store should detect the violation of the cost limit of 1000, even before their actual selection. Moreover, as constraint violation is detected at the local level, not at patient level (i.e. without patient specific data) health administrators may identify a problem as being local and take appropriate measures (e.g claim higher reimbursements, or restructure the health services).

Soft constraints handling. Some constraints are "hard", in that there is no way to avoid them (e.g. action D costs no less than 100), or it is not acceptable to relax them (e.g. the delay between investigations B or C and treatments E or F should never exceed some, otherwise the treatments are no longer adequate). Other constraints are "soft" and may be relaxed: if existing resources and sound medical knowledge enforce the cost of a specific patient care plan to exceed the limit of 1000 then such cost constraint ought to be relaxed. Since constraints might be soft, the Constraint Store should not only detect constraint violation, but also relax soft constraints and find acceptable solutions (e.g. relaxing the least important constraints).

Interactivity and Explananations. Unsatisfiable constraints must be identified and explained to the user. If a local Health administrator is entering the cost of the actions of a guideline and a constraint violation is found, then the relevant actions and constraints should be identified (e.g.the Constraint Store should explain that the costs of B, C, E and F alone violate the overall cost constraint). This is particularly useful when a large number of constraints makes it difficult to identify the real causes of the problems.

The variety of constraints in guidelines, and its relatively small number, demand constraint solving systems as general purpose as possible, rather than being very specialised to handle specific constraints (e.g. linear programming packages).This is the case, with a number of constraint systems such as CHIP [13] and Eclipse [14], developed as extensions of logic programming which in some cases have originated packages in more conventional languages

(e.g. C++), more easily embedded in information systems. The handling of soft constraints with interactive and explaning capabilities can be built on top of these basic constraint systems. In particular, we have been developing and incremental constraint solver which can efficiently handle hundreds to thousands of both hard and soft constraints [15], and a recent extension handles linear constraints on real numbers, as those illustrated above [16].

5. Decision Support Examples in the Management of Resource Constraints

Gathering Statistics. Prior to evaluate resource constraints, resources needs have to be identified and modelled into instances of a guideline. By explicitely introducing resource constraints, health care administrators and planners will get measurements of the resources being used and to collect statistics from these. For example, constraints regarding guideline costs not only provide a means to check, *during* its execution, whether a particular care plan satisfies cost limits, but they also provide, *after* execution, its cost. Statistics from many care plans enable health administrators to obtain their average cost and compare them with other settings (e.g. other hospitals, health regions or countries).

Improving Local Policies. Analysis of constraints violation, allow health providers to identify bottlenecks and critical points in health care, and to devise resource management policies that either avoid these problems, or justify more resources from funding sources.

5.1Managing the Resources of a Patient Care Plan

Since a patient specific care plan is managed by several care agents (e.g physicians, nurses, administrative staff that book certain acts), all taking decisions regarding the patient, they would benefit from a system that monitors the execution of the plan, checks the satisfiability of its constraints, and warn, *in advance*, that actions proposed may violate guideline constraints. If warnings are given *prior* to committement to such actions, they might be revised, possibly with the support from the justifications provided by the system.

Cost constraints. In the guideline above, assume that investigation B is more inconvenient to the patient (e.g. more painful) but C is abnormally expensive (e.g. local premises where C is usually made are fully booked and C has to be done externally at an extra cost). If the physician choses investigation C, then (s)he might be warned about the unusually high cost of the care plan, due to the abnormal situation in C. From this explanation and, if upon agreement of physician and patient, the alternative B might be selected.

Time constraints. Assume that treatments E and F should be done within a certain time with respect to investigations B or C, and that it might be impossible to book treatment E in time, due to resource shortages. If the decision support system allerts for a violation of the time limit, then alternative treatment F might be selected instead. These time violations might even occur earlier in the guideline. For example, if prior to booking investigation B, the system warns about the unavailibility of treatments E and F, investigation B might deliberately be delayed to comply with the small delay required between the investigation and treatment actions (and it may possible antecipate the reservation for the resources required by E or F).

Trading time and cost constraints. Tme and cost can often be traded. In the guideline above, time limit might be exceeded with treatment E but not with F, that is more expensive and exceeds the cost limit. Given this justification, a physician might select the adequate treatment based on the relevance of these constraints. A constraint store able to deal with soft constraints with relevance weigths may provide not only the reason but also the importance of the violation, thus helping physicians (or administrative staff) to take the right decision.

Real time allocation of resources. Availibility of resources, and constraints that such availibility poses to a care plan, often change in time. The booking of a certain examination

within a certain time frame might be impossible, unless existing bookings are rescheduling. In such situations, and possibly helped by a scheduling server, such rescheduling might be negotiated and the care plan completed without violations, namely if the scheduling server is developed with the same constraint technology of the guideline resource manager [17].

6. Conclusion

This paper discussed, from a resource management pesrpective, the problems of adapting a general guideline into a specific patient care plan, and the management of the latter. To ease these problems we propose the introduction of Constraint Store as an extension to guideline and care plan representations, and illustrate its use with some examples.

The actual implementation of such scheme has now started in project PRESTIGE. An important aspect is its integration with clinical information systems (developed by other members of the project) since the information about resources (their availability and cost) is ususally maintained in such systems. Implementation will therefore identify a set of services related to resource management that will be demanded to the clinical information system.

Another important aspect is that resource management decisions are taken by several agents, possibly in different sites, demanding a telematics view of clinical information systems.The guideline approach helps coordinating the work of the different agents in a shared care setting, and the introduction of resource management constraints will further help these agents to comply with the resource management policies embedded in these constraints.

Acknowledgments. This work was supported by Project PRESTIGE of the EU (HC 1040) and by JNICT under grant PBIC/C/TIT/1242/92.

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