MEDICAL DECISION SUPPORT IN CLINICAL RECORD MANAGEMENT SYSTEMS

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Abstract - The clinical record is a primary support for the diagnostic process performed by physicians. The development of a Clinical Record Management System can significantly improve the quality of patient care by properly supporting the physicians' tasks and, in particular, the diagnostic process. In this paper we address some key issues in designing a medical decision support system. Acquisition of medical knowledge is supported by a knowledge editor based on a conceptual model of diseases, aetiologies, evidence and their relationships. Diagnostic support is carried out by an algorithm which, according to the production rules generated by the knowledge editor and to the patient's clinical data, formulates a set of diagnostic hypotheses and suggests tests and examinations for their validation. The definition of an internal model for the clinical record allows for clinical data from different departments to be integrated. On the other hand, the definition of external models allows for custom presentations of clinical data to be created.

1. Introduction

The continuous scientific and technological progress in Medicine calls for new and more effective information systems for medical organization support, on both the administrative and patient care sides [1]. The spread of projects aimed at designing or upgrading *Hospital Information Systems* confirms these needs. In order to ensure resource optimization and support in medical practice, the Hospital Information System must be present in all departments of the hospital, allow communication and interconnection and provide suitable applications to support the physicians in their work.

Physicians' activity is aimed at patient care and largely involves the management of clinical data, which is accomplished by means of the *clinical record* (CR). A *Clinical Record Management System* (CRMS) can

largely improve the quality of patient care by emphasizing the relationships between data, actions and events and by providing support for the classification of clinical data [2] [4]. The CRMS should also support the physician's decisions in the fields of diagnosis and therapy with advice, suggestions and recommendations. The key issues in designing a medical decision support system that emerged from the analysis carried out in hospital departments, are listed below:

- representation and acquisition of medical knowledge (long-term memory);
- integration of clinical data from different departments (short-term memory);
- development of diagnostic algorithms which operate on inexact and incomplete data (inferential engine);
- definition of custom models of the CR (user interface).

In this paper we address these issues by presenting the solutions we adopted within the CRMS prototype we are currently developing within the ESPRIT EDITH project (European Distributed Information Technology for Healthcare) with the sponsorship of Olivetti Ricerca. The global architecture of the prototype, sketched in Figure 1, is fully described in [3].

2. Representation of medical knowledge

The first requirement outlined concerns medical knowledge. The conceptual model we developed for medical knowledge is represented in Figure 2 by means of an object-based formalism. This model acts as a guideline for knowledge acquisition inside a

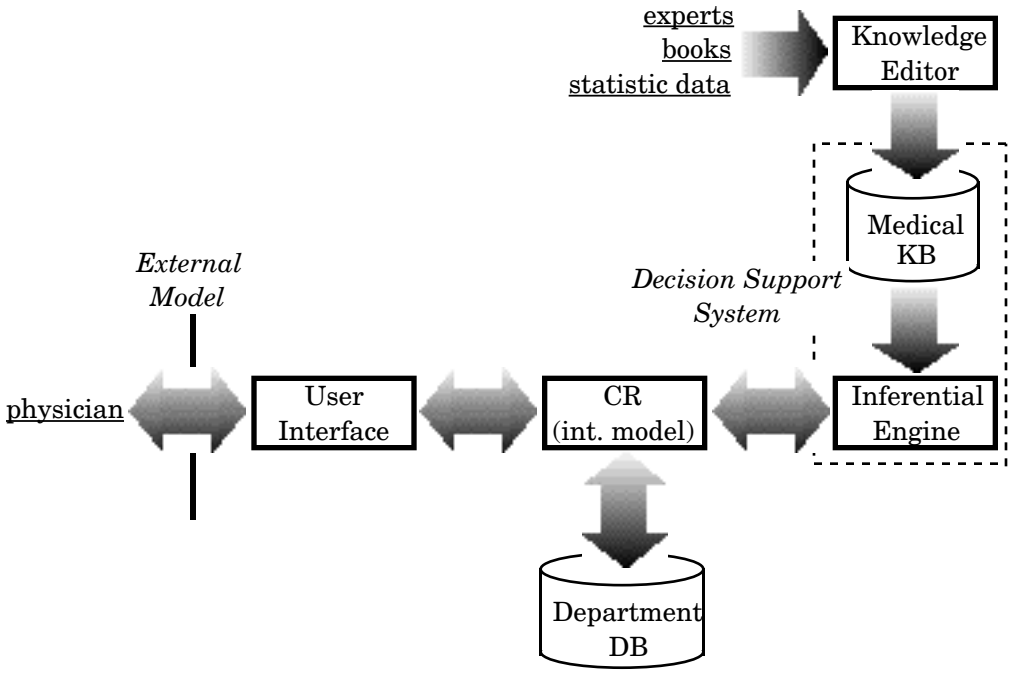

Figure 1. Global architecture of the CRMS.

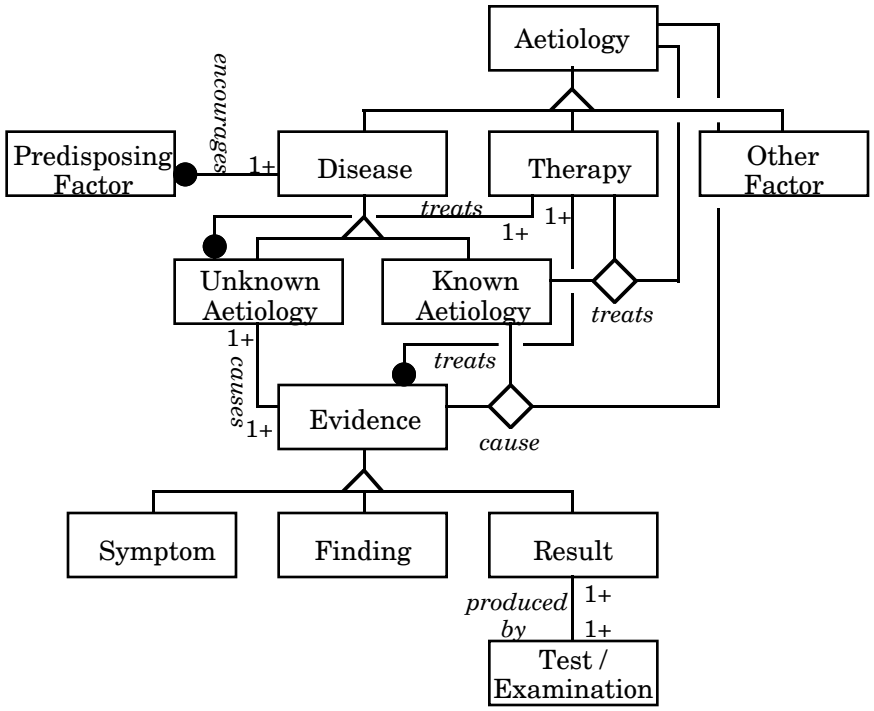

Figure 2. Object-based conceptual model of medical knowledge. Triangles represent disjoint generalization, rhombuses ternary associations; dark circles and the symbol *1+* describe zero-or-more and one-or-more association multiplicity, respectively.

knowledge editor where physicians describe diseases, their aetiologies and therapies, and the related evidence. The links defined between the different entities allow for a set of production rules for diagnosis and therapy prescription to be automatically generated. Rules are associated with *confidence factors* which express to what extent our belief in a hypothesis is modified by the evidence.

In more detail, the rules generated have the following structure:

$$antecedent \underset{CF'}{\overset{CF}{\rightleftarrows}} consequent$$

where CF expresses to what extent our belief in the consequent is encouraged when the antecedent is true, and CF' to what extent it is discouraged when the antecedent is false. For instance, if we consider the association *causes* between diseases and evidence, rules will have the form:

$$evid_1 \wedge ... \wedge evid_n \underset{CF'}{\overset{CF}{\rightleftarrows}} disease$$

If evidence $evid_1$ to $evid_n$ are found to be true, our confidence in the presence of the disease will be increased by CF; if one or more of them are found to be false, our confidence will be decreased by CF'.

3. Internal model of the clinical record

The entire diagnostic process is based on the patient's clinical data. We enforce inter-department integration and consistency of clinical data by adopting a unique *internal model* of the CR throughout the whole hospital information system [5]. In this model, the CR

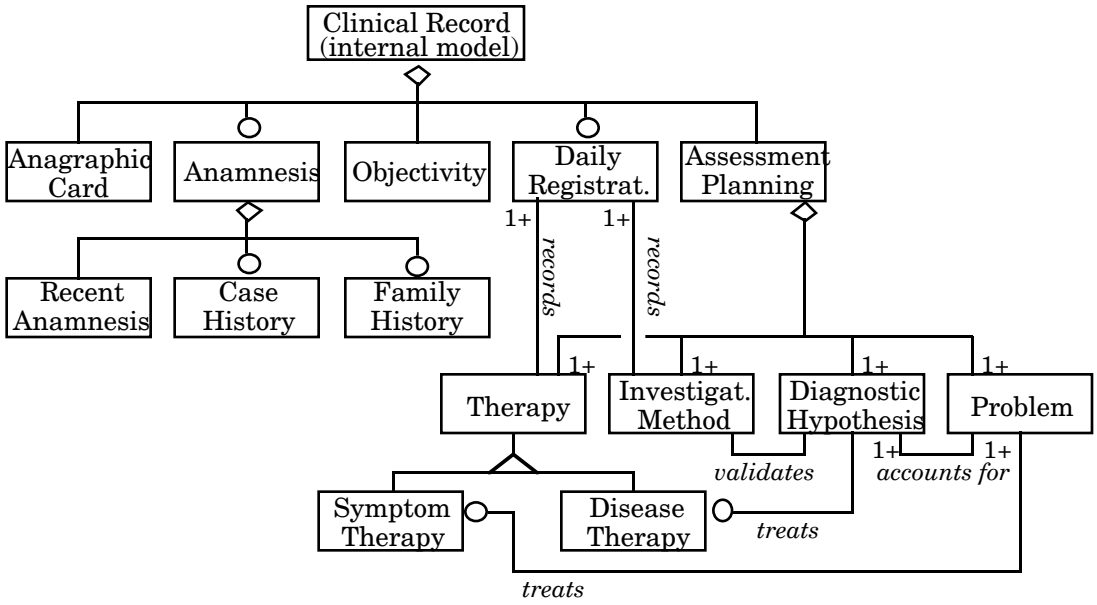

Figure 3. Object-based conceptual model of the internal model of the CR. The graphic formalism used is the same as that described in Figure 2; small rhombuses represent *part-of* associations.

includes the following components (see Figure 3):

- anagraphic card;
- anamnesis;
- objectivity;
- assessment and planning;
- daily registration.

Knowledge of a patient as modelled from the schema in Figure 3 is involved in the inference process with different roles. Some of the entities act as sources of facts for guiding inference, others as repositories of inferred facts. The correspondence between the entities in the CR and those on which inference is based (see Figure 2) can be summarized as follows:

- Recent Anamnesis → Symptoms
- Case History and Family History → Predisposing Factors or Other Aetiologic Factors
- Objectivity → Findings
- Daily Registration → Results of tests or examinations
- Diagnostic Hypothesis ← Diseases and Aetiologies
- Investigation Method ← required Tests/Examinations
- Problem → driving Symptoms
- Therapy prescription ← Therapy

4. Diagnosis and therapy prescription

The diagnostic algorithm we are currently developing consists of three distinct phases:

1. *formulation of diagnostic hypotheses*;
2. *validation of diagnostic hypotheses*;
3. *therapy prescription*.

Phase 1 is aimed at determining, based on the available evidence, a set of diagnostic hypotheses to be further investigated. Given a set of *driving symptoms* (those recorded in the CR as the problem reported by the patient)

and a set of *preliminary findings*, the algorithm selects all the rules of type

$evid_1 \wedge ... \wedge evid_n \rightleftarrows$ disease(+aetiology)

whose antecedent includes at least one driving symptom or one preliminary finding. Each of the selected rules is associated with a score depending on its confidence factor and on the number of driving symptoms and preliminary findings contained in its antecedent. The diseases appearing in the consequents of the selected rules are the *diagnostic hypotheses*; since the number of hypotheses is in general relatively large, only the most likely are initially pursued. The likelihood of a diagnostic hypothesis d is evaluated by considering the scores of the rules having d as the consequent.

During phase 2, the tests and examinations which most significantly concur in proving the diagnostic hypotheses are proposed and their confidence factors are updated according to the results of the tests and examinations actually performed. For each hypothesis d pursued, the working rules are selected among all those having d as the consequent, according to the values of the related confidence factors and to the costs and complexities of the clinical tests/examinations in the antecedent. For each working rule, the evidences appearing in the antecedent and not yet assessed are submitted to the physician for investigation. After the physician has investigated all or part of the evidence, a resulting confidence factor is calculated for each diagnostic hypothesis. If no hypothesis has a confidence factor sufficiently high, both absolutely and relatively to the other hypotheses, phase 2 may be repeated with an extended set of working rules. If the degree of reliability in the diagnosis is still insufficient, it may be necessary to repeat phases 1 and 2 with different hypotheses.

Once a hypothesis has been validated, in phase 3 a therapy is proposed. As shown in Figure 2, therapies may be aimed at treating either diseases or evidence. In both cases, therapy prescription is driven by rules produced by the knowledge editor.

5. External model of the clinical record

A *user interface* for the CRMS must be conceived and designed considering the interactions between physicians, patients, and the system. Users perceive the CR according to custom *external models* which fit the individual needs and methodologies of their department and reflect their mental model of the tasks to be carried out.

An external model consists of a set of *documents* which support the insertion of clinical data from different sources and their presentation to the user; the document layout may be free (*sheet*) or constrained (*form*). Each piece of clinical data in a document is characterized by an *interaction method* which determines the rules for data input and presentation to the user. Interaction methods are associated with the *data types* defined in the internal model. For

instance, the simple data type "number" can be presented according to three interaction methods: "plain text", "slider" and "knob"; the complex data type "array of number" can be presented according to two interaction methods: "table" and "chart".

The link between the external and the internal models is established by the user specifying for each piece of data appearing in the external model its *role* within the internal model.

6. Conclusion

In this paper we have presented a model of a Clinical Record Management System capable of supporting the physician's decisions in the fields of diagnosis and therapy prescription. A prototype of this model is currently being tested within a real hospital. Our future work will consist mainly in investigating the possible extensions of the internal and external models of the clinical record aimed at achieving a higher degree of generality, and in studying hybrid formalisms for closer modelling of medical knowledge.

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