From Pure Information Handling to Knowledge Management in Medicine

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1. Information Handling in Medicine

Taken from a somehow extreme point of view, clinical medicine is dominated by the handling of information. A physician performing a diagnostic or therapeutic task extracts data from the current patient comparing it with information on similar cases and referring it to his clinical experience. In this process, he uses medical knowledge: terminological knowledge, causal knowledge, strategic knowledge, etc. This knowledge stems from his own experience, from the communication with his clinical colleagues and the scientific community in general.

Due to the increasing international collaboration (e.g. via international networks) the amount of information on the one hand and the available knowledge on the other hand is exploding. Consequently, the task of information handling gets more and more cumbersome. In the seventies, the first medical expert systems were mainly built to support diagnostic problem solving. Using production rules for knowledge representation was very popular and supposed to deliver adequate means towards a rapid construction of automatic problem solvers. Nevertheless, these systems didn’t satisfy the most urgent requirement: the increasing need for intelligent information providers. The missing acceptance of medical expert systems by clinicians confirms this historically.

Problem specific information retrieval is not only complicated by the amount of information but additionally by a lack of structure, both causing informational overhead and disorientation. In order to succeed in performing rapid and selective information retrieval, it is indispensable to develop information providers on the basis of conceptually structured knowledge. Different clinical tasks and situations are leading to different system specifications based on a kernel of shared medical knowledge.

There are several approaches to develop application independent representation systems and to define suitable application programming interfaces to enable the sharing of medical knowledge. Approaches as the Unified Medical Language System (UMLS [HUMPHREYS & LINDBERG 1993]) or the Generalized Architecture for Languages, Encyclopaedias and Nomenclatures in Medicine (GALEN [RECTOR et al. 1994]) simplify information handling for example by realizing a unified access to international online databases. Although they don’t cover considerably more than terminological medical knowledge, they mark the transition from pure information handling to
knowledge-based approaches. For instance, a unified access to international online databases employs knowledge about medical concepts and the terms denoting them in different languages. Even this example demonstrates the necessity of an international, cooperative exchange of knowledge requiring the application of knowledge management methods. In general, the increasing need for intelligent information providers demands knowledge management in medicine.

In the following, we first summarize obstacles on the way of developing methods and tools for a situation specific and flexible knowledge management environment. Then, we focus on a method for conceptual structuring as a basis for a comprehensive kernel of medical knowledge. Formalizing and operationalizing conceptual structures, we take care of compatibility with the representation mechanisms used in standardization efforts as the GALEN project. This guarantees the possibility to couple standardized access to international online database with our knowledge management tools, at least in the two medical domains, we are working in (neurology and human genetics).

2. Obstacles

Developing knowledge based system components for constructing and maintaining a kernel of medical knowledge as basis for computer based knowledge management, one has to be aware of some general characteristics of medical domains:

- Different medical schools complicate the process of interviewing medical experts and require means for explicit representation of competing knowledge contents.
- The lack of standardized terminology arises problems with finding generally accepted medical terms to be used in knowledge representation.
- One has to be aware of a high innovation rate making dynamical revision mechanisms for non-monotonic, but nevertheless consistent update of the knowledge base necessary.

Besides these general characteristics of medical knowledge, there are some irreducible difficulties which make the realization of knowledge management tools a hard endeavor:

- The high variability of medical facts enforces a high degree of flexibility concerning representation, retrieval, and presentation of knowledge.
- The specific uncertainty of medical knowledge requires means for representing and dealing with different forms of uncertainty.

There is a strong demand for dealing with contextuality. Especially because flexible reaction on different clinical contexts assigns dramatically different degrees of relevance to medical knowledge.

3. Assisting Devices for Modeling and Managing Distributed Medical Knowledge - a Profile

In the center of knowledge management there is the human-machine-ensemble. Exclusively dealing with computer systems is not sufficient. Instead, methods and
concepts are needed which cover the interaction of the human-machine-ensemble and thus consider the needs and aims of the physician. The machine should give orientation to the physician and assist him during the process of solving diagnostic or therapeutic problems. Such assisting devices can only be achieved by means for user and context specific interaction with the machine. What is presented by the system must include or at least partly correspond with still not resolved aspects of a clinical problem and contribute to a better understanding of real world phenomena.

Conveying a better understanding of real world phenomena excludes any prothetical substitution of a physicians competence or deficiencies. Instead, the main task of knowledge management tools consists of an adaptive situation and problem specific assistance. In most cases, such a cognitive assistance can already be achieved by a flexible access to relevant medical knowledge. An enhanced form of cognitive assistance enables a physician to delegate subtasks to problem solving modules [Spreckelsen & Bürsner 1996]. Hereby, the physician controls the whole process and the automation of subtasks is embedded in the physicians doing: „The human’s role is primarily to achieve total system performance objectives as a manager of knowledge resources that can vary in kind and amount of ‘intelligence’ or ‘power’. ([Woods & Roth 1988], pp. 23). In medicine, there are ethical reasons that demand for human control on every step of performing diagnostic or therapeutic tasks.

Enabling a physician to practice control in the postulated form, transparency of the assisting (computer based) devices is a prerequisite: On the highest level, transparency can be achieved by presenting knowledge to a human problem solver determined by specific situations of his work and his intention, i.e. determined by specific views [Bürsner & Schmidt 1995]. The views represent a global frame for understanding system structures and behaviour. They are indexing knowledge units according to the current clinical context. They guide the physician to the relevant structures and contents down to the lowest structural level of the knowledge base.

4. Conceptual Structuring as a Basis for Knowledge Management

The building blocks of the views are the concepts: entity of disease, syndrome, symptom, clinical examination, etc. There are also primitive concepts: a CT image, a video demonstrating a clinical sign, etc. Both categories of concepts pre-structure (the description and representation of) medical concepts. This conceptual layer is built up during knowledge acquisition by medical experts and knowledge engineers together. Above the conceptual layer there is a further pre-structuring layer: the layer of schemes. The schemes provide knowledge representation structures for the representation of both, the medical concepts on the second layer and the entities describing concrete medical knowledge contents on the third layer. Type consistence is given by a homomorphic mapping between the structural layer and the conceptual layer and also between the conceptual layer and the entity layer (cf. figure 1).

For the formal description of all the three layers, we use an enhancement of the nested graph model [Poulavassilis & Levene 1994] as a homogeneous formal language. The formal language is based on labelled, directed graphs. It is possible to embed a typed derivate of the frame-slot-model by providing an enhanced scope of modelling constructs, as for example the representation of cycles upon typed frames. The graphs can be nested, i.e. again their nodes can be graphs. By the means of the labels the elements of a layer can be indexed and they can mutually reference each
other. The combination of labelling and nesting allows to express a lot of semantics just through the way of nesting structures. Referring to the representation of medical knowledge, this kind of structuring enables the flexible construction of context specific views on entities of medical knowledge and their relations. Furthermore, creating views as nested labelled graphs guarantees transparency from highest constructs to the primitives.

![Diagram](image.png)

**Fig. 1:** 3-layered approach of conceptual structuring

### 5. Benefits

The formal description leads to the definition of criteria preserving consistency (structural and semantic integrity) of the knowledge base. For instance, it is guaranteed that each piece or structure of medical knowledge is represented exactly by a single entry and can be referenced by its label.

Our approach of formal representation of application specific views enables context or situation specific indexing of structures and objects of medical knowledge. Based upon the views, different clinical contexts can explicitly be represented. These contexts can be used both for domain specific support of knowledge acquisition by physicians and for an intelligent retrieval in medical knowledge management. Thus, a physician is able to acquire and distribute his knowledge and additionally he gets support in managing the knowledge distributed by others.

In analogy to the nested construction of structures for representing views, it is possible to create visual constructs as a basis for the realization of a graphical user interface. Thus, visualization methods can be coupled with the formal representation of the knowledge.
6. Outlook

On the basis of conceptual structuring we are aiming at the development of a workbench for flexible knowledge management in medicine comprising several knowledge based system components. In a hypothetical shell-model of such a workbench, the knowledge base as the kernel of the whole is surrounded by tools for knowledge elicitation, knowledge retrieval, knowledge visualization and knowledge processing. These allow the configuration of different kinds of authoring (structural, visual and content-based), tutoring and assisting systems.

![Shell architecture for medical knowledge management workbench](image)

**Fig. 2:** shell architecture for medical knowledge management workbench

References


