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KNOWLEDGE-ORIENTED ANALYSIS AND SUPPORT OF MEDICAL DOCUMENTATION

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ABSTRACT

The documentation of medical treatment is a knowledge-intensive task for structuring and organizing healthcare activities. Most of the approaches in computer-based patient records are, however, focusing on details of data management or user interaction. In this contribution, a method for a knowledge-based analysis of the healthcare process "medical documentation" is outlined, from which requirements to a knowledge- and process-oriented electronic medical documentation are derived. A prototypical architecture for an electronic documentation function which depends on an encyclopedic, disease-based representation of medical knowledge is proposed. In conclusion, potentials and open issues for the proposal of analysis and design of knowledge-oriented healthcare information systems are discussed.

Index Terms **-** knowledge process modeling, healthcare, electronic medical documentation, software architecture

1. MOTIVATION

The domain of medicine is characterized by its complexity, being subdivided into many specialized fields, and changing rapidly as well as growing exponentially. The treatment of patients is demanding up-to-date medical knowledge, and this demand is critical in terms of time. Healthcare can thus be defined as a knowledge-intensive field of work.

Knowledge necessary for patient treatment can roughly be divided into three types:

- General medical knowledge as a result of research.
- Patient-specific knowledge, being generated by obtaining patient information during examination and diagnostic measures by the clinician.
- Institutional knowledge, which is determined by the characteristics and objectives of the certain healthcare institution where a clinician is working.

Working in the field of patient treatment includes the task of subsuming information obtained about a specific patient under general medical knowledge, and of combining this with the institutional knowledge to determine optimal diagnostic or therapeutic procedures for the patient. Therefore, the utilization of these three types of knowledge structures healthcare activities around patients.

Modern software systems for healthcare institutions, e.g. medical practices or hospitals, however, basically focus on the management of patient data or on user interfaces for an efficient insertion or extraction of these data. Initial approaches to process management are noticeable today with the introduction of workflow engines in hospital information systems. Knowledge management in terms of stored formal medical knowledge is only applied in research projects for decision support systems.

Thus, the leading questions for this contribution are: Can the needs and uses of knowledge during patient treatment be analyzed and modeled? If so, is there a way to make use of the results of this analysis for deriving requirements and specifications of an adequate knowledge-oriented IT support? How could such an information system look like? We will consider these questions by the example of general medical documentation.

2. BACKGROUND

2.1. Knowledge in Healthcare

The problem of a time-critical need of medical knowledge in patient treatment has been expressed as knowledge dilemma in medicine: The impossibility for a clinician today even in subareas to gain all available scientific findings at the moment of a clinical decision in a special case [1]. Furthermore, the problems which originate in applying abstract knowledge to individuals [15]. Associated is the retroactive effect of an invention of new therapeutic measures on the differentiation of diseases, adding to the exponential growth of medicine [4].

Michael Polanyi established a classification of knowledge in general. He distinguished between formal, verbalized, expressible, explicit knowledge and human-bound, experiential, believed, sensed, tacit knowledge [11]. Both types of knowledge play an important role in healthcare: Explicit knowledge as textbook knowledge and tacit knowledge as clinical experience. Thus, both affect every clinical decision.

An approach for the use of this differentiation for knowledge management in companies, the well-known model of the dynamics of knowledge creation, has been developed by Nonaka and Takeuchi [9]. They

classify the conversion of knowledge in business processes in four types: internalization, creating tacit knowledge, externalization, producing explicit information objects, socialization, referring to a communication of tacit knowledge, and combination, where new information from the use of two or more information objects is derived.

2.2. Formalization of Medical Knowledge

Explicit medical knowledge has been subject to different kinds of formalization, with or without IT support. Medical terminologies, such as the ICD [18] or SNOMED [13] are used for coding, statistical analysis, accounting, or decision support. A representation of clinical information and medical semantics [3] has been developed through the creation of medical ontologies, e.g. UMLS [17] or OpenGALEN [10]. Finally, the application of medical knowledge bases for didactics, encyclopedia, as terminology server, or as decision support systems, has been established by medical knowledge engineering.

2.3. Modeling Languages for Knowledge-intensive Business Processes

The first step in management of business processes is their identification and documentation. Various process modeling languages have been developed for this task. In the last years, several approaches of extensions or additions to these languages have been introduced, allowing a knowledge-oriented process analysis [7]. approach of modeling lang processes for clinical practi eral medical

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For this c on of data or process modeling language KMDL (Knowledge Modeling and Description Language), for the following reasons: Classic business process modeling languages do not or statically show knowledge objects in business activities [6]. Clinical process modeling languages, on the other hand, represent medical knowledge directly, but they do not link it to objects or subjects and, in case of clinical practice guidelines, there is a lack of institutional knowledge [1].

Knowledge process modeling languages like KMDL instead concentrate on knowledge types, on conversion of knowledge in business processes and thus provide a link between a utilization of domain-specific knowledge and the visualization of general business processes as well as healthcare-specific activities. KMDL is directly based on the knowledge management approach by Nonaka and Takeuchi [5][6]. The current KMDL version 2.2 provides three perspectives onto the sequence of actions, where the process view shows the business process as an execution of tasks, the activity view is used to consider knowledge conversions during a certain task, and the communication view focuses on the exchange of information in organizations. The modeling entities for process view as well as activity view can be found in fig. 1.

3. FROM KNOWLEDGE PROCESS ANALYSIS TO KNOWLEDGE-BASED DOCUMENTATION

3.1. Knowledge-Process Model

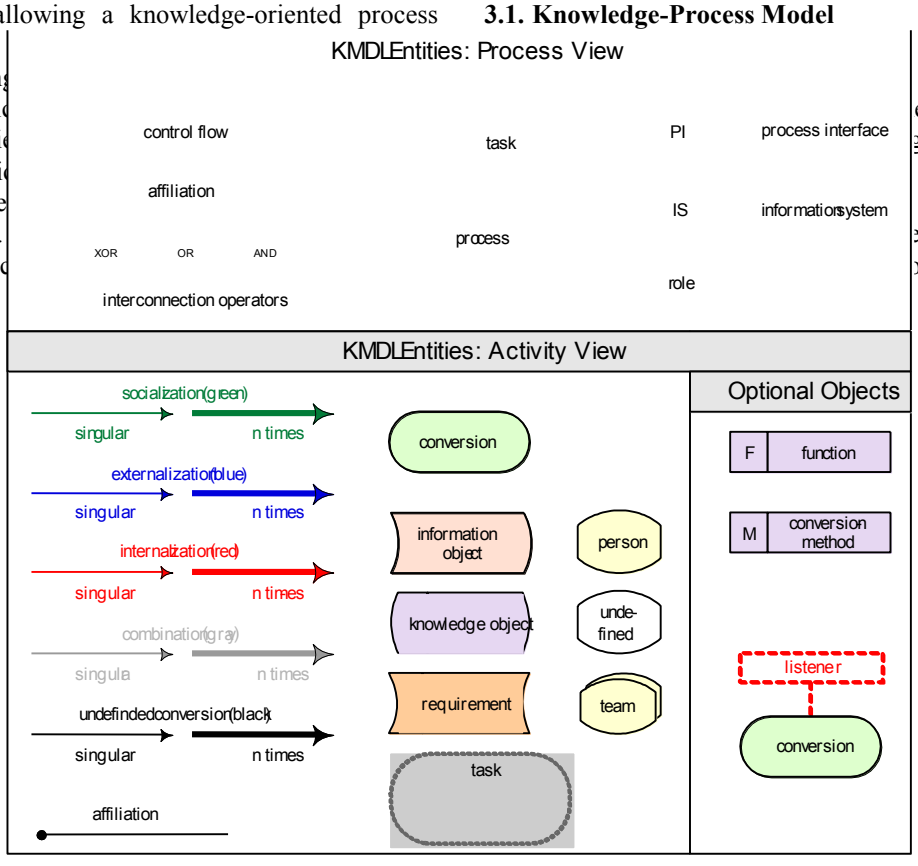

Figure 1: KMDL Entities for Activity View

information by a clinician or a treatment team. Thus, the fundament of the activity of documentation is clinical knowledge and its characteristics. This distinguishes documentation as one of the basic activities directly and completely referring to knowledge in healthcare as classified.
In fig. 2 a model of clinical documentation is presented as KMDL activity view. We introduce here the role or person of the clinician, dealing with the three different knowledge objects as we defined them, for the externalization of his or her tacit general medical knowledge, the institution he or she is working in, and about the special patient which is treated at the moment. Simultaneously, all of this knowledge is a requirement for correctly executing the documentation task: A person who does not have medical knowledge, is not aware of the characteristics of his or her institution, or does not know the patient, cannot document any correct finding, action or interpretation.

We can thus derive from the activity model, that three classes of knowledge are required for clinical documentation. Furthermore, medical data, measures and interpretations are externalized with these classes in background. Finally, the knowledge to store a patient record is individually bound to the treating clinician(s). The KMDL model of clinical documentation can therefore provide additional insight to the actual activity, based here only on a generic approach, containing no enhancement by institutional details.

3.2. Requirements for Knowledge-Supporting IT

We will continue the short example of analysis and IT support of a generic healthcare process by transforming the resulting findings of the KMDL modeling into requirements to a software component supporting the process. Since we chose medical documentation, the information system in general is an electronic patient record, where the knowledge a clinician externalizes is structured case-specifically.

Another necessary structure in the component has to be the certain date of a consultation (called interaction), based on the sequential or time-specific tasks the process model is built of. Moreover, looking at the treatment process as a whole, this long-term process describes what clinicians call an episode of care—"a series of temporally contiguous health care services related to treatment of a given spell of illness or provided in response to a specific request by the patient or other relevant entity" [8]. A medical documentation function basing on the knowledge-oriented model we presented, must therefore structure the inserted data patient-, episode- and interaction-based.

The supporting system furthermore has to allow the classification of certain diagnostic and therapeutic measures and findings. Personal interpretations of a user need to be marked as such, including a diagnosis.
Specifically, the potential of a knowledge-oriented documentation support lies in providing general, patient-independent knowledge that is relevant to clinical documentation. General knowledge need not be individual-bound and can thus be stored as explicit knowledge in a software system. This change in knowledge-utilizing in the process of documentation can avoid errors prevailing whenever single persons rely on their own mind for externalization of actually already explicit, general knowledge.
In the following section, we propose a prototype for general medical documentation that directly derives from the requirements of the knowledge process.

3.3. Knowledge-based Medical Documentation

The requirements from the preceding section can become the basis for specifications of an electronic documentation function, concerning the above-developed assumptions and requirements to the process of clinical documentation in general.

Beginning with the proposed potential of a system which provides knowledge support, the electronic medical documentation we suggest is knowledge-

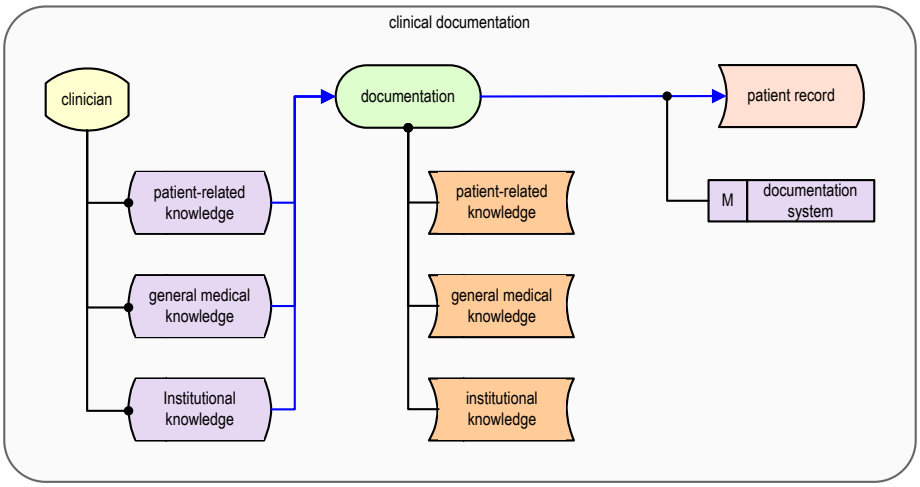

Figure 2: KDML Activity View of Medical Documentation

based. Two potential types of knowledge can be stored in the software, one being general knowledge about diseases, and one, referring to this knowledge, as institution-specific knowledge.

Four structuring concepts can serve as components of the software:

- The patient, forming the upper classification of data, because medical documentation is patient-specific.
- The episode which is described by the process of treatment of a certain (acute) disease.
- The interaction as time-specific structuring criterion which keeps the option of a chronological view at the record.
- The treatment situation / the executed measures. While the treatment situation is an aggregation of a clinician's interpretation on the information about a patient, executed measures represent explicit knowledge about the actions performed, including diagnostic and therapeutic means.

From these specifications we can conclude possible details of a reference implementation, a documentation system based on a medical knowledge representation. For this contribution, we chose the OpenGALEN medical ontology [10] (see fig. 3), but every terminology containing and linking pathological knowledge in this way can be utilized.

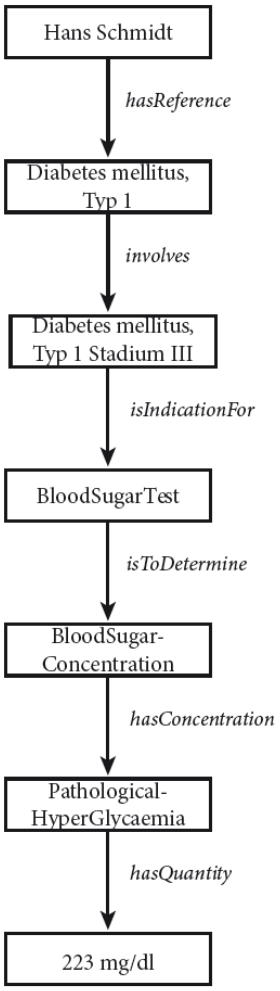

Figure 3: Concepts and Sanctions of OpenGALEN

The documentation function derived from this knowledge base has been designed and implemented after the CommonKADS methodology for knowledge-based applications [12], which is also usable for capturing knowledge-intensive business processes [16]. The resulting web-based application consists of three components: a patient table, an episode and interaction table, and the file view showing the treatment situation and measures for a special patient at a certain point of time. Further details on the architecture of this type of software are provided in [2].

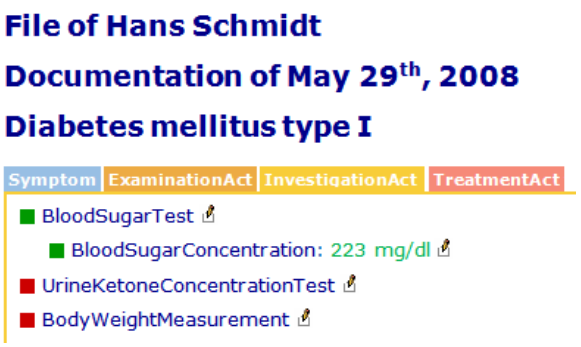

Figure 4: User Interface of a Knowledge-Based Medical Documentation Function

As a visual example, the knowledge-based documentation of a treatment situation is shown in the tree-type view in fig. 4. The general medical knowledge of diabetes is adopted from OpenGALEN, suggesting a superset of possible treatment situations, from which a clinician has to specify the patient's actual condition (patient-related knowledge) by activating the red square before the items that then switches to green. Moreover, free text fields after the active items can serve as additions, resulting in a set of patient-specific information independent from but linked to the knowledge representation. In the screenshot, the clinician can specify diagnostic measures executed at an interaction, e.g. the surveillance of blood sugar, and the result of this action.

A third way of documentation are additional files or documents belonging to the treatment situation or to diagnostic or therapeutic measures, which can also be uploaded instead of adding free text. Here this could be a finding where the result of a diagnostic measure is stored.

The resulting documentation function is therefore designed as a proposal for an episode-oriented, knowledge-based type of medical documentation and implemented according to the specifications derived above.

In the following last section, we summarize the results of our consideration, raise open questions and discuss future tasks in this field of work.

4. DISCUSSION

In the present contribution, we have shown the possibility of a healthcare knowledge management approach trough a generic medical process as simple example. We have modeled a KMDL activity view of medical documentation and derived several deductions from its analysis. A transformation of these statements into requirements to a knowledge-oriented optimization of medical documentation was possible, and these requirements can be used for a specification

of a documentation-supporting software component. Finally, we have presented a documentation function based on OpenGALEN as an exemplary implementation of the established specifications.

The example process is of course short and abstract, not referring to an institution-specific business process including personnel, activities, or localizations. Institutional knowledge has therefore been omitted from the technical considerations. Moreover, general medical documentation itself is only a part of the real documentation process, which also includes additional administrative processes like patient transport or drug order, and in some cases features very detailed documentation types like an operation summary, which itself bases on a new quality of medical knowledge.

A good start for future work would thus be an application of the suggested method to more practical process examples. Additionally, the knowledge process analysis must be expanded from general medical documentation alone to many other clinical processes, especially administrative and care activities.

An implemented form of a knowledge-based documentation function as it is proposed here has yet to be practically used. This could lead to an examination of the effect of knowledge support to the documenting person(s).

The unified approach presented here, leading from a capture of knowledge-intensive processes in healthcare over requirements to optimized variants of these processes to a transformation into details of knowledge-based information systems could be well-suited for the support of clinicians in their time-critical, knowledge-intensive duties of everyday clinical work.

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