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Specifying Hospital Information Systems Using Business Process Modeling

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Abstract. One important step in the development of a comprehensive hospital information system (HIS) is the analysis phase. In this phase information modeling is commonly used but it lacks in some important aspects. In this paper a two-level analysis procedure is proposed suitable for the development of enterprise-wide and computerized HIS. The first level uses business process modeling for initial analysis and a WFMS based simulation for validation. The second level uses information modeling to specify data models. This approach allows the specification of models for HIS covering structural as well as behavioral aspects of a hospital more accurately.

1. Introduction

Information and knowledge are critical resources that have come to be recognized as complements to labor and capital resources. *Hospital information systems (HIS)* are the artifacts (the combination of technology, data and people) that produce and maintain the information resource for the medical care in hospitals.

Using computers to perform specialized medical treatments (for instance computer tomography) or routine personal tasks (such as word processing, spreadsheet analysis or electronic communication) is well underway. But there is a vital need for hospital information systems that go significantly beyond computerized routine and stand-alone support. They have to be enterprise-wide and have to permanently support the core business processes by providing the appropriate information in the right time and place. This would help to visibly enhance the business value of an HIS.

Preparing an HIS for the University Hospital of Saarland [1] a data model applying the Entity Relationship Model [2] was developed first. Data and information modeling (we use both terms as synonyms in this paper) are commonly used to specify local and enterprise-wide information systems. But they are rather static and restricted to the data view. Such models do not provide hints on the lifetime as well as on the value and importance of the data. Thus, information modeling tends to cement once defined data structures and the types of information that might be used. Furthermore, data models alone are incapable to focus on the hospital services. It is difficult to transfer changes in the hospital behavior and in the information needs (for example caused by the use of public networks and chip card systems) into a data model. The affected areas of the data model are not easily identified.

For the development of a comprehensive hospital information system [3] the approach of business process modeling may provide the solid understanding of the hospital services that determine the information needs. Therefore, we propose a *two-level procedure* during analysis. First, a business process model is specified to capture the main hospital behavior. Afterwards, one or more data models are specified for the identified hospital processes. This approach allows the specification of models covering structural as well as behavioral aspects of a hospital more accurately.

In this paper we focus on the first level using *business process modeling* to analyze the hospital processes and derive the relevant behavioral specifications for an HIS. For evaluating the business process model we used the simulation capacities of a workflow management system.

2. The business process view on hospitals

From a business process point of view a hospital consists of a high number of cooperating business processes linked together by client/server relationships. Each process provides a specific set of services. The processes can be differentiated in main and service processes for a given field of investigation (here a hospital). Main processes contribute directly to the hospital's goals. Service processes provide their outcome to their clients. In this context the clients are main processes and other service processes.

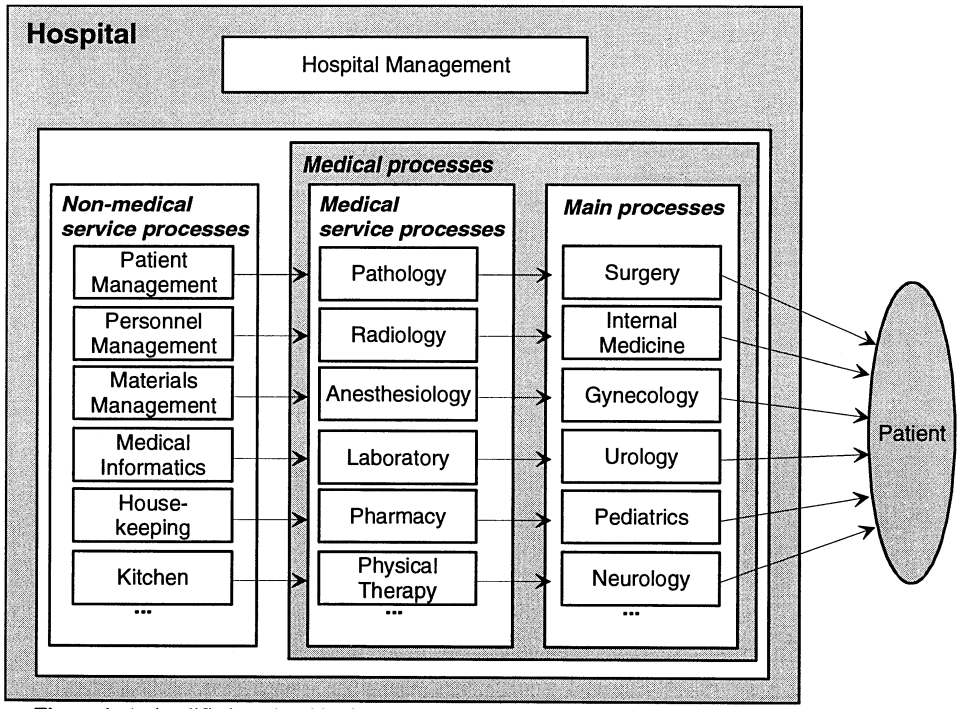

Figure 1: A simplified top-level business process architecture of a hospital

Figure 1 shows a top-level *business process architecture* of a hospital concentrating on patient treatment. The overall service provided by the main processes may be summarized as "medical treatment of patients in hospital". Typical main processes are surgery, internal medicine, gynecology, urology, pediatrics and so on. Such main processes supply particular

services to treat patients (the clients of a hospital). In order to provide these services a hospital needs a number of medical service processes such as radiology, anesthesiology, laboratory and pharmacy. There are also a number of non-medical processes needed such as patient management, personnel management and housekeeping.

On this level of abstraction you can already see differences between hospitals. They differ in the number of services they provide and in their assignment of services to business processes.

Business processes in a hospital have some characteristic properties when comparing them to processes of other business branches:

- A high number of cooperating organizational units
- Limited resources (e.g. beds, personnel, devices)
- A high ratio of manual activities
- Most medical processes can be blueprinted only roughly in advance
- Details of medical processes are frequently changed

Business processes in hospitals are very complex and variable. The daily work requires frequent reactions on interim results of diagnostic processes and on unexpected medical indications. The services are therefore only roughly scheduled and are often changed in detail. The specialized organizational units frequently interact with each other and with partners in their environment (e.g. patients, practitioners, insurances).

The amount of communication and coordination caused by decentralization and the restrictions of limited resources impair the quality of patient treatment essentially. With an enterprise-wide and computerized HIS the information deficiencies caused by decentralization get reduced. A fast information access gives employees more time for value adding activities. Limited resources like beds and devices may easier be managed. By this, an HIS will result in a quality improvement of the medical services and in an increase of efficiency and reduction of costs in the non-medical area.

3. Modeling the hospital processes

We used the *Semantic Object Model* SOM for modeling the hospital processes. SOM [4,5] is an object-oriented approach for the analysis and design of business processes and business application systems. One of the most important features of SOM is a stepwise and hierarchical procedure of modeling. The result is a hierarchical process model comprising multiple levels of abstraction. This makes SOM very suitable to capture the hospital-specific properties and requirements. For more details about using SOM for modeling hospital processes see [6,7].

We restricted the business process modeling to the domain *treatment of in-patients*. The initial top-level process model consists of patients (specified as an *external business object*) receiving the service "Treatment of in-patients" (by a *business transaction*) from the hospital (an *internal business object*). Next, we refined the hospital into the *business objects* "patient management", "ward" and "service provider" (on this level of abstraction summarizing all the service providers) and unveiled further transactions.

The ward is the primary place of contact and the coordination center for the treatment of in-patients. The patient management fulfills administrational tasks such as collecting and processing the patients data for accounting and billing. The ward supervises the complete treatment of an in-patient even if some medical services are provided in other places by (ward-)external providers.

In SOM the behavioral view is modeled using a task-event schema. Such a diagram depicts the tasks of the business objects linked together by transactions and events. The

tasks are identified out of the need that objects have to provide, send or receive services. Tasks are triggered by internal events (for instance when another task of the object is finished) or external events (for instance an input arrived). For the sake of simplicity only a small part of the process model is described here. A structural view on business processes in SOM would look like figure 1.

4. Simulating business process models

Before any further efforts in specifying information systems are made process models should be validated by simulation, thus guaranteeing high quality. In the context described here the use of the simulation capacities of a workflow management system (WFMS) eases this task. Workflow management systems that support the execution of business processes help to match the process model with the reality. We used the WFMS *FlowMark* of IBM [8] which allows a discrete, dynamic and stochastic simulation.

Workflow specifications for the WFMS are directly derived from the process model. Each workflow is considered "flat" existing on one level of abstraction only. Corresponding to different levels of refinement in SOM you can get multiple workflow specifications. By this, you can simulate and validate the different levels.

Before the simulation of a given workflow specification can start, some simulation-relevant data have to be added: the variation in start intervals for each process and sub-process; the variation in the duration time for each task; the probability of a transition between tasks; the available capacities of resources and the required capacity of the resources for each task.

The WFMS based simulation outlined here makes an animation of process models as well as the calculation of capacities and performance possible. Considering such calculations the processes can be rated and an optimization (business process reengineering) may ensue.

5. Conclusions

The benefits of a hospital information system are sufficiently known and well accepted. Still an open issue is the development of an HIS in such a way that the benefits take effect. One important step in the development is the analysis phase. In this phase information modeling is commonly used but it lacks in some important aspects as mentioned above.

In this paper we propose a two-level analysis procedure for an enterprise-wide and computerized HIS. The first level uses business process modeling for analysis and a WFMS based simulation for validation. The second level uses information modeling to specify data models.

Business process modeling allows a systematic system engineering procedure to identify the required communication and information resources of a comprehensive HIS. The applied SOM approach supports a stepwise and hierarchical modeling (top down procedure). Starting with the main processes of a hospital each level of abstraction unveils some more details and correspondingly more information that are required for performing the business processes. The result is an easy handling of complexity and the possibility to check the completeness and consistency of the information.

The described two-level modeling approach has several benefits:

- While an information model only unveils *which* information an HIS has to provide, a business process model clarifies *where* and *when* information is produced and consumed.

Therefore, the combination of this techniques is much more capable of dealing with change and evolution.

- Due to the increasing need for information processing in hospitals and due to economic restrictions it is necessary to integrate legacy systems as well as standard software products [9]. Enterprise-wide business process models help to classify application systems, to expose the need of interfaces between different application systems and to discover the areas in a hospital which are not sufficiently covered by any application system.
- It is very complex, time-consuming and susceptible for mistakes to develop and maintain an enterprise-wide data model. An alternative is to use the business process model to combine a set of local data models. Each local data model could describe the information resources for one or more business processes. Additionally, the different data models could represent various levels of abstraction.
- Flat data models are not very apt to act as reference models and the attempts to systematically manage hierarchical data models have not yet succeeded. A hierarchical process model as described here is much more promising. The reusability and the efforts for extensions and adaptations depend strongly on the level of abstraction. At least the more abstract levels of such a process model can be considered as extendible and reusable reference models [1,10] for an HIS.

To summarize, a two-level analysis procedure helps to overcome the limitations of using information modeling alone and has the above mentioned benefits. The analytical results are better in quality, more reproducible and reusable. This advantage is paid with additional costs and time.

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