3LGM:
Method and Tool to support the
Management of Heterogeneous Hospital Information Systems

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1 Introduction

Due to the increasing heterogeneity of diverse application systems and hardware platforms the complexity of hospital information systems steadily increases [1]. Nevertheless up to now there are only few methods and tools to support the management of large, heterogeneous hospital information systems. The three level graph-based model (3LGM) for design, evolution and assessment of hospital information systems gives the opportunity to model more than only technical aspects of a hospital information system (see below and [2]).

The use of 3LGM to model a specific hospital information system causes problems which are closely related to the complexity of the information system itself. On the one hand a computer-based tool is needed to manage the model. On the other hand the reduction of complexity within the levels of a 3LGM has to be supported. As in other modelling techniques, such as structured analysis (compare to [3]), there should be the possibility to build overviews or detailed views within each level of the 3LGM. Different views are important to support a top-down description of a hospital information system. Very detailed views are needed to expand the accessibility of a model for projects that deal with subsystems of a hospital information system. A rather rough view on the model is needed for the strategic management of a hospital information system.

We realized a computer-based tool (3LGM-tool) and broadened the methodology to provide mechanism for the refinement and coarsening of the levels. In the following we will give an overview of 3LGM and it's associated tool. With the help of an example we will furthermore explain the graph-based concepts of coarsening and refinenment of the levels. Finally we'll show how theses concepts were integrated into the tool.

2 The Three Level Graph-based Model (3LGM)

As thoroughly discussed in [2], we describe a hospital information system with the 3LGM on three levels: the procedure level, the logical and the physical tool level. In all levels the nodes and edges of the graph represent objects. The object's attributes and the graphs make possible a structured description of the hospital information system.

To describe the functionality of a hospital information system we draw a procedure level graph consisting of information procedures (compare to 'business functions' in [4]) as nodes and their information exchange as edges. Information procedures that can be directly used through users provide an access point. The realization of each information procedure is described through a projection of the procedures into the tools that are described on the logical and physical tool level. The logical tool level is made up of application-systems, their functions and communication-interfaces between different application-systems. Using communication-interfaces application-systems are for example able to exchange messages in HL7-format to realize data-integration. On the physical tool level physical subsystems like computer systems and their data transmission lines make up the graph. Between the objects of the three levels set-relations are defined. They enable a modelling of the *coherence* between the levels. Formally defined integrity constraints support the modelling process and help to test the *completeness* of a model. Figure 1 shows part of a very much simplified model. The realization of the information procedures 'clinical documentation' and 'patient- billing' are outlined.

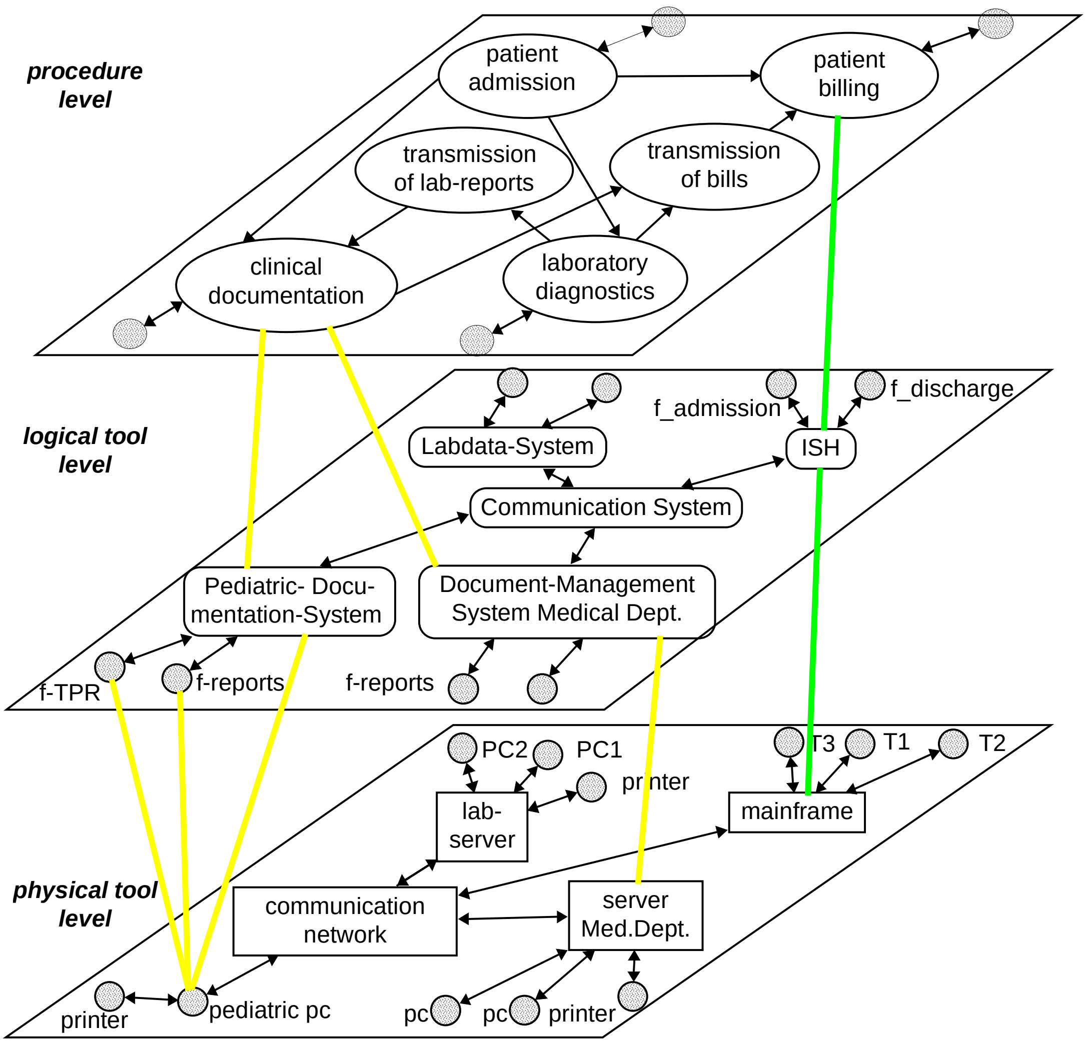

Figure 1: Example of a 3lgm.

3 The 3LGM-Tool

The 3LGM-tool makes available special graph-editors to build a graphical user-interface for the recording, managing and visualisation of all objects belonging to a 3LGM of a specific hospital information system. The recording of objects and their attributes is supported through all kinds of input-aids such as default values, listboxes,... . An important feature is the possibility to catalogue instances of attributes and whole objects. Thus a definite vocabulary is used when describing objects and objects can be reused in different (sub-)models. The first is important for example when messagetypes, that are communicated over a communication-interface, are described. Moreover the 3lgm-tool offers possibilities to present the relationship of objects between the levels graphically. Through the implementation of integrity constraints it is for example possible to collect information about an intended delete operation prior to the deletion. Once a model of a hospital information system is put into the 3LGM-tool, major parts of the documentation that is required for information systems (e.g. annual reports) can be generated automatically. With the help of a protocol function reports about insertions and deletions can be drafted. They might be useful for planning the evolution of a hospital information system.

The 3LGM-tool is still a prototype which was developed during two diploma thesis' ([5],[6]). Nevertheless it is used within the management of the hospital information system of Heidelberg University Hospitals and Leipzig University Hospitals. At Leipzig University Hospitals it was used when devising a strategic plan for the management of the hospital information system [4]. The 3LGM-Tool is available as freeware on the internet (http:/ix.urz.uni-heidelberg.de/~hc7/3lgm).

4 Methods

4.1 Coarsening of levels

Although the level-graphs of 3lgm consist of different kind of nodes and have to fullfill special integrity constraints (compare to [2]), graph-theoretic concepts can be used and modified to generate overviews by coarsening the level-graphs. The coarsening of a level-graph can be defined as a surjective projection of the nodes of the level-graph which is to be coarsed, into the nodes of the resulting coarsed level-graph. For the transmission of the edges formal rules can be defined.

To define the surjective function on the nodes of a level-graph, these nodes should be divided into disjunct classes considering the integrity constraints of the level-graph. The coarsed level-graph obtaines one node for each class of the 'old' graph. The formal rule for the transmission of the edges defines, that only edges, that connect nodes which belong to different classes, are transferred into the coarsed level-graph (for details see [5]). Figure 2 shows the coarsening of the the procedure level of figure 1.

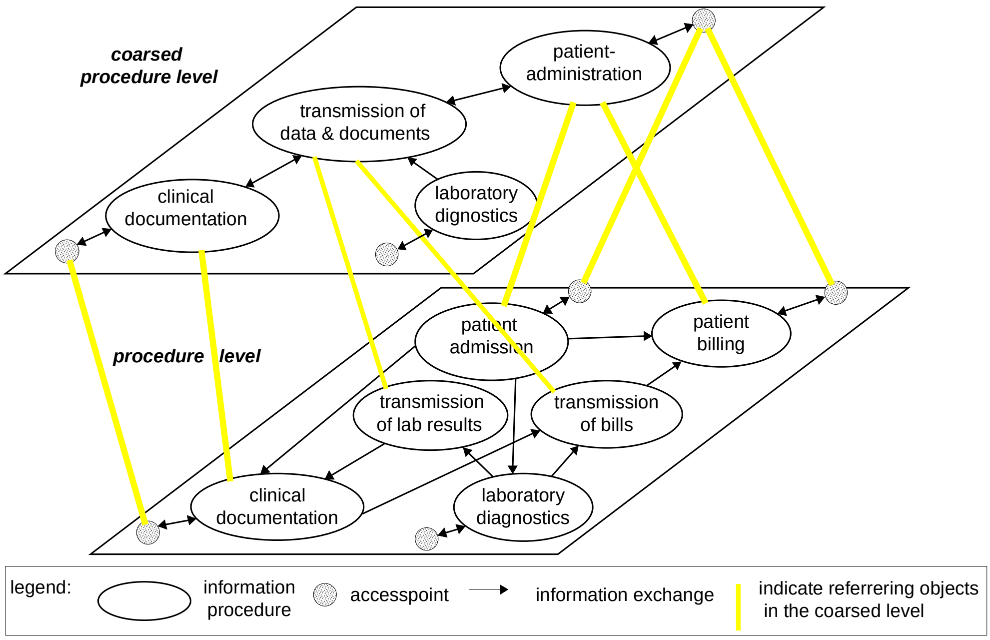

Figure 2: Coarsening of the procedure level of figure 1.

4.2 Refinement of levels

When a level-graph is refined, new nodes and edges have to be introduced. Thus only a formal rule can be given that guarantees that the original level-graph is a coarsening of the refined level-graph. A detailed formal description of the rule can be found in [5]. Here only a rough outline of the rule demonstrating the refinement of the procedure level-graph in figure 1 will be given. The four steps are illustrated in figure 3.

Let us denote that the information procedure 'clinical documentation' is to be refined.

(1) Specify the graph that will substitute the information procedure 'clinical documentation'.

(2) Transfer the information procedures that exchange information with 'clinical documentation'.

(3) Specify the new information exchange between the graph specified in (1) and the information procedures transferred in (2).

(4) Copy all other information procedures and information exchange edges into the refined graph.

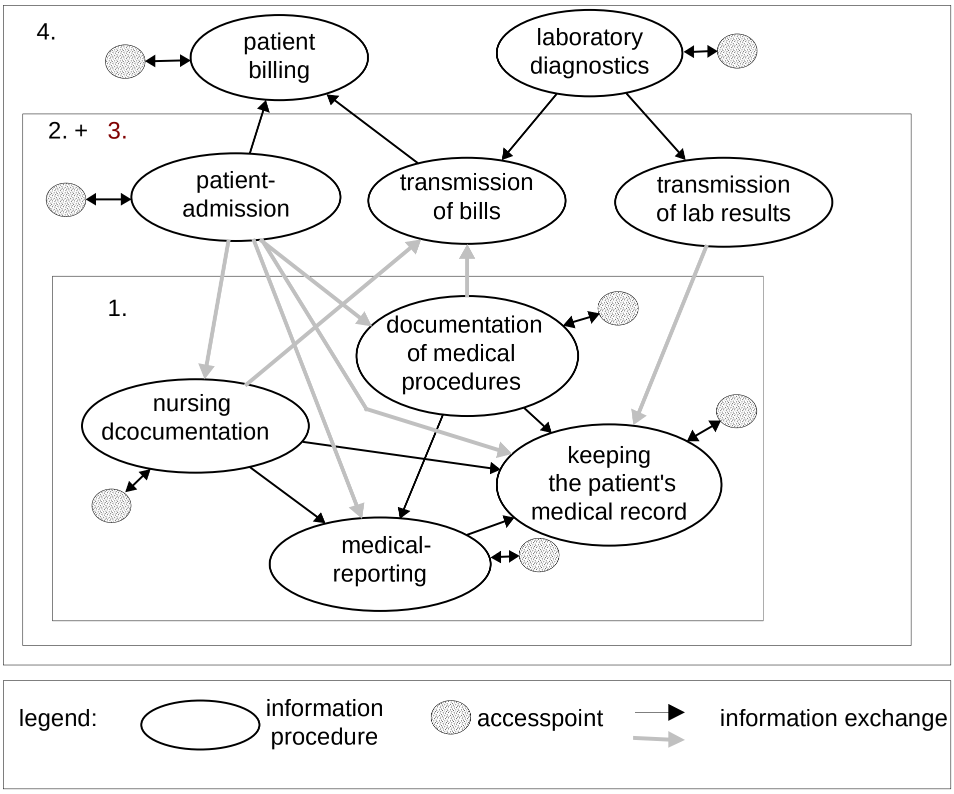

Figure 3: Refinement of the procedure level in figure 1.

If multiple nodes of a level-graph shall be refined, we have to distinguish whether they exchange information or not. In the latter steps (1) - (3) can be repeated on the same level-graph. If the nodes exchange information, steps (1) -(4) have to be completed for the first node. To refine another node the rule has to be used on the refined level-graph. Thus you construct refinements until all nodes that have to be refined are replaced.

5 Discussion

5.1 Extended Applicability of 3LGM vs. Complexity of a Model

With the refinement and coarsening of levels overviews and detailed views can be integrated into the 3LGM by using concepts of the graph-theory. With these definitions it is possible to create an overview based on the tasks of a hospital information system (as described in [8]) in the procedure level. In that case you have to summarize information procedures of similar functionality for the coarsening. Refinements in the tool-levels enable you to construct detailed views for diffrent departements of a hospital for example.

Another advantage of the definitions of coarsening and refinement is, that also relationships between nodes can be described as whole-part relations. The relationship can be shown in an aggregation graph (compare to figure 4 for example). Thus an important view for nodes of different granularity is also integrated into the 3LGM.

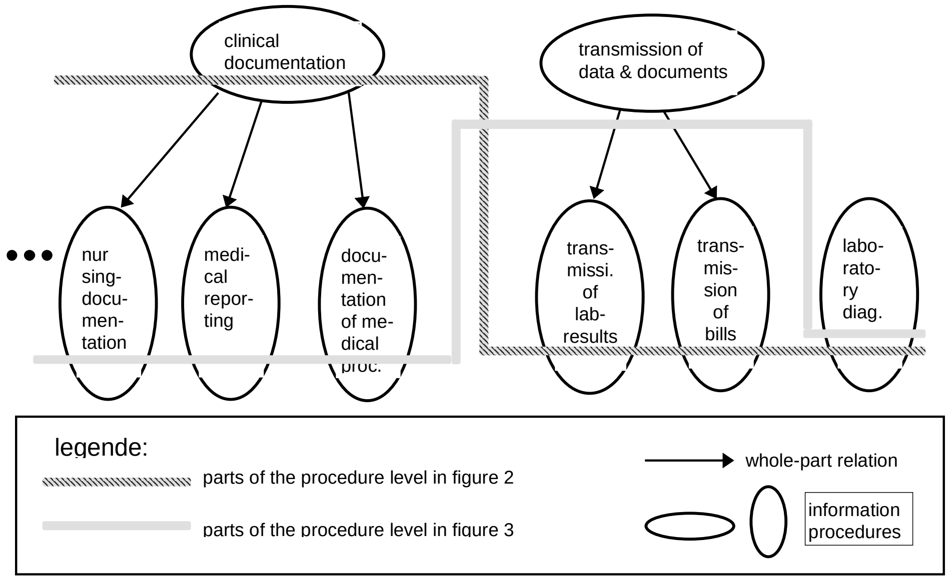

Figure 4: Part of the aggregation graph of the procedures used in figures 1 to 3.

In a refined and coarsed model difficulties may arise simply because more than three levels have to be handled. Instead there might exist many different layers of the procedure level, of the logical and of the physical tool level, each called a level-complex. A hierarchy between layers within a level-complex does not exist. Difficulties in handling these level-complexes arise mainly when projections between the level-complexes have to be specified. Also the insertion and deletion of nodes or edges into a level-complex cannot be handled without a computer-based tool.

5.2 Integration of coarsening and refinement into a computer-based tool

As described above a computer-based tool assists in using 3LGM by providing special graph-editors that help to record, manage and visualize all objects of a 3LGM. The refinement and coarsening of already existing level-graphs can be integrated in a tool easily, since their defintions and rules are very clear-cut. For the coarsening the user-interface of the graph-editors has to be extended in a manner that the user can subdivide nodes into disjunct classes. The transfer of the edges and the construction of the coarsed level could then be fully automated. For the refinement the user-interface of the graph-editors also have to be extended. The user should be guided through the steps of the given rule mentionened above to refine a graph. Steps (2) and (4) should thereby be triggered by the user and execute automatically.

To visualize the aggreation-graph a new component has to be introduced into the tool. Existing insert- and delete operations have to be expanded. In coarsed and refined levels they apply to all layers of a level-complex. Moreover a model-manager should be introduced. It should support the user in managing and navigating through the different layers of a level-complex.

Meanwhile the 3LGM-Tool supports the coarsening of procedure levels. When implementing this part of the tool, we learned how much effort is involved in accomplishing consistncy between the different layers of the procedure level-complex (compare to [6]). Currently we are still working on the implementation of the refinement and aggregation-graph. Tests have to prove the applicability of coarsening and refinement in the procedure level before the functionality for the tool-levels will also be extended.

6 References:

[1] BAKKER AR, EHLERS CT, BRYANT JR, HAMMOND WE (HRSG.) (1992): *Hospital Information Systems: Scope - Design - Architecture*. Amsterdam: North-Holland.

[2] WINTER A , HAUX R (1995): A Three Level graph-based Model for the Management of Computer-Supported Hospital Information Systems. *Methods of Information in Medicine*, **34**(4), 378-396.

[3] DEMARCO T (1979): *Structured Analyses and System Specification*. New York: Yourdon.

[4] MARTIN J: *Information Engineering, Book II: Planning & Analysis.* Prentice Hall: Englewood Cliffs1989.

[5] BUCHAUER A (1995): *Methoden und Werkzeuge zur Anwendung des graphenbasierten Drei-Ebenen Modells zum Beschreiben, Bewerten und Planen von Krankenhausinformations-systemen.* Bericht 2/95 der Abteilung Medizinische Informatik, Universität Heidelberg.

[6] AMMENWERTH E (1996): *Evaluation eines Werkzeuges und von Methoden zur Anwendung des 3LGM für das Management von Krankenhausinformationssystemen*. Diplomarbeit im Studiengang Medizinische Informatik, Universität Heidelberg / Fachhochschule Heilbronn.

[7] WINTER A (1996): *Rahmenkonzept für die Weiterentwicklung des Klinikuminformationssystems des Universitätsklinikum Leipzig 1996 - 2000.* Universitätsklinikum Leipzig.

[8] SHORTLIFFE P, WIEDERHOLD F (1990): *Medical Informatics - Computer Applications in Health Care*. New York, Amsterdam: Addison Wesley.