3LGM²-Modeling to support management of health information systems

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ABSTRACT

Objective: Both regional health information systems (rHIS) and hospital information systems (HIS) need systematic information management. Due to their complexity information management needs a thorough description or model of the managed information system.
Methods: The three layer graph-based meta-model (3LGM²) and the 3LGM² tool provide means for effectively describing and modeling HIS by hospital functions, application systems and physical data processing components. The 3LGM² tool has been used to model parts of the information system of the health care system of the German federal state Saxony and of the Leipzig University Medical Centre.
Results: Experiences showed, that 3LGM² is suitable for supporting information management even in rHIS. We explain some benefits for information management in regional as well as local settings.
Conclusions: Acceptance of the 3LGM² depends strictly on its integration in management structures on the institutional, regional, and even national or European level.

1. Introduction

The driving force for health care has recently been the trend towards a better coordination of care. The focus has been changed from isolated procedures in a single health care institution (e.g. a hospital or a general practice) to the patient-oriented care process spreading over institutional boundaries. Health care providers and health care professionals in a region – and in many cases even worldwide – have to cooperate in order to achieve better health for the patient [1–4].

An institution's system for communicating and processing information, i.e. its information system (IS), is that socio-technical subsystem of the institution which presents infor-mation at the right time, in the right place to the right people [5,6]. Consequently, the heterogeneity of the institution is reflected by its information system. This holds especially for a hospital's information system (HIS). It has to be actively designed and constructed like (a complex of) building(s) out of different and usually heterogeneous bricks and components.

Widening the scope to the health care region and the necessity for regional cooperation of health care professionals and institutions, we have to claim for the respective cooperation of institutional information systems, e.g. hospital information systems or practitioner's information systems. They shall form again an information system, i.e. the regional health information system (rHIS). Since the complexity of an rHIS is

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something like the product of the complexity of the information systems included, there is an even stronger demand for systematic information management in the region [1].

Like an architect, each information manager needs a blueprint or model for the information system architecture respectively the enterprise architecture [7–9] she or he is responsible for. In Ref. [10], we proposed the three layer graph-based meta-model (3LGM^2) as a meta-model for modeling HIS. 3LGM^2 had been designed to support information management in its enterprise architecture planning (EAP) (see e.g. [9,11]) activities.

This paper deals with the following questions:

- Is 3LGM^2 suitable for supporting information management even in rHIS?
- What benefit can be expected using 3LGM^2?
- Are there organizational prerequisites for a useful application of 3LGM^2 in regional settings?

We, therefore, will shortly introduce the meta-model 3LGM^2 and the 3LGM^2 tool for modeling information systems, present a 3LGM^2 model of parts of the rHIS of the German federal state Saxony, and illustrate some benefits of the model for further development of digital image communication in Saxony and for strategic information management planning at the Leipzig University Medical Center. Finally, we will discuss the questions mentioned above.

2. Method: the three layer graph-based meta-model 3LGM^2 and the 3LGM^2 tool

3LGM^2 distinguishes three layers of information systems, which especially provide a framework for describing both information processes at the domain layer and communication paths between application components and their interdependencies.

The *domain layer* of 3LGM^2 describes a hospital independently of its implementation by its enterprise functions. Enterprise functions have to be performed by a hospital within its business processes in order to reach its aims. To perform these enterprise functions, information of a certain type about physical or virtual things of the hospital is needed. These types of information are represented as *entity types*. Enterprise functions may interpret or update information about entities of certain entity types. The *logical tool layer* focuses on *application components* supporting enterprise functions. Application components are responsible for the processing, storage and transportation of data representing entity types. *Component interfaces* ensure the communication among application components. The *physical tool layer* consists of physical data processing components (like personal computers, servers, switches, routers, etc.), which are physically connected via data transmission connections (e.g. data wires). They carry the application components.

The meta-model has been supplemented by the 3LGM^2 tool [12]. Using 3LGM^2 as the ontological basis this tool enables information managers to graphically design even complex HIS (Fig. 1). It assists information managers similarly to computer aided design tools (CAD) supporting architects. The tool provides means for analyzing models of information systems and thus for assessing its quality. On the modeling canvas, which dominates the main window of the tool, an information system can be modeled and displayed on three layers as explained before. The three different layers can be viewed and edited separately but also in a multi-layer view. Models especially of rHIS tend to be rather complex. Depending on the complexity
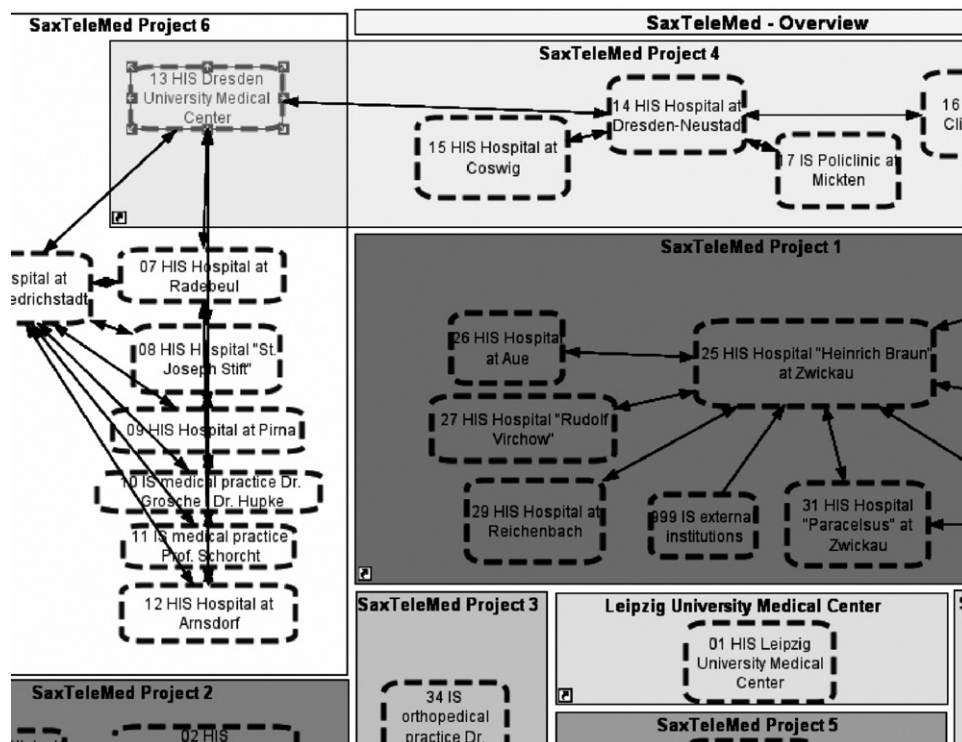

Fig. 1 – 3LGM^2 model of the Saxonian-rHIS: cutout of the overview at the logical tool layer.

and the required level of detail the model diagram may easily get unclear and confusing. The 3LGM^2 tool includes functionality to extract subsets of models into submodels. It provides a set of predefined analysis functions, which are designed to answer specific questions arising in information management business.

3. Results

3.1. A 3LGM^2 model of the rHIS of the German federal state of Saxony

Applying the 3LGM^2 tool we constructed a 3LGM^2 model comprising a detailed description of the current state of the Leipzig University Medical Center's HIS (UKL-KIS) ("KIS Universitätsklinikum Leipzig") and important elements of the rHIS of Saxony. The rHIS of Saxony has been further developed by the SAXTELEMED project, funded by the Saxonian Ministry of Social Affairs [13]. The project focused mainly on the exchange of radiological images and intended to improve integration of ambulatory and inpatient care.

Fig. 1 gives an overview of the model (SAX-rHIS model) at the logical tool layer. At a low level of granularity, it shows the hospital information systems and the information systems of practitioners involved as application components. Frames and respective headers indicate subprojects of SAXTELEMED. Subprojects had been defined at seven medical centers to realize an infrastructure for exchanging radiological images between these centers and healthcare institutions in the neighborhood. Now the ministry's focus is on connecting these 'islands'. One of the frames contains the UKL-KIS. Each frame is linked to the related, more detailed sub-model of the respective information system and their components. The 3LGM^2 tool thereby provides comfortable means for switching between different levels of granularity.

3.2. Supporting further development of the Saxonian-rHIS

Investments in Saxonian hospitals – especially, those for information technology – are funded by the Ministry of Social Affairs. Respective proposals are reviewed by experts in this field.

The SAX-rHIS model is the only central repository for information concerning the rHIS infrastructure in Saxony. Using this repository providing information about the SAX-rHIS and applying the analysis tools of the 3LGM^2 tool, officers in the ministry, reviewers, and applicants among others gain the following advantages:

- Funding proposals had been prepared at the different sites supported by different consultants. They used various approaches for describing the information system architectures planned. The proposals differed, e.g. in description of functionality (i.e. the enterprise functions to be supported), naming of already installed application components at the related hospitals and institutions, ways of illustrating interoperability between application components or hardware components respectively. Thus, especially reviewers could hardly compare the solutions proposed. Within the SAX-rHIS model application components at different sites supporting the same enterprise function (e.g. report writing), are linked to the same function. In general the same real world entities (e.g. communication standards, message types, software products and brands, etc.) are represented by the same modeling concepts and elements. So the different information systems' architectures are described in a coherent way, which overcomes the individual methods used in different proposals before. Thus, the model supports the stakeholders mentioned above in understanding and comparing different solutions.

- Given, hospital A wants to introduce an application component for radiological imaging, i.e. a radiological modality. In order to avoid unnecessary investments it should be questioned, whether there is already a similar modality in another hospital B and whether it would be possible to transport images from hospital B to A. Appropriate modalities can be found by selecting the function "radiological imaging" at the domain layer; the analysis tool will then highlight the components used for imaging at their different sites. Communication paths on which images could be transported can be found by using a shortest path algorithm implemented in the 3LGM^2 tool [14]. Fig. 2 shows a calculated communication path, if for B the hospital at Rabenstein City and for A the hospital "Bethanien" at Plauen City is taken. The algorithm finds that images from the modalities in Rabenstein can be sent to the diagnosing system in Plauen.

3.3. Preparing a strategic information management plan (SIM plan) for the Leipzig University Medical Center

We have completed the third issue of the SIM-plan for the Leipzig University Medical Center, which is valid for 2005–2007. Its structure is close to the recommendations in [6]. So, description and analysis of the current state of the UKL-KIS form an important part of the plan.

Within the SAX-rHIS model there are a lot of submodels describing not only the information systems of SAX-TELEMED subprojects but also submodels describing different aspects of the UKL-KIS. They are the central repository for information about the UKL-KIS. For example, it delivers detailed information concerning interfaces between application systems and the communication server as well as descriptions about redundant storage and communication of patient data. Similar as illustrated in Fig. 2 it can be derived, what communication links might be used to transport pathological findings to the application systems used at the ward.

For preparing the strategic plan rather simple features of the 3LGM^2 turned out to be very helpful. Besides features for exporting graphical illustrations like Fig. 2 we used the reporting facilities of the 3LGM^2 tool to generate tables describing what application systems are used for particular enterprise functions in different organizational units. As an example Table 1 shows, that for admission of outpatients four different software products are used and that
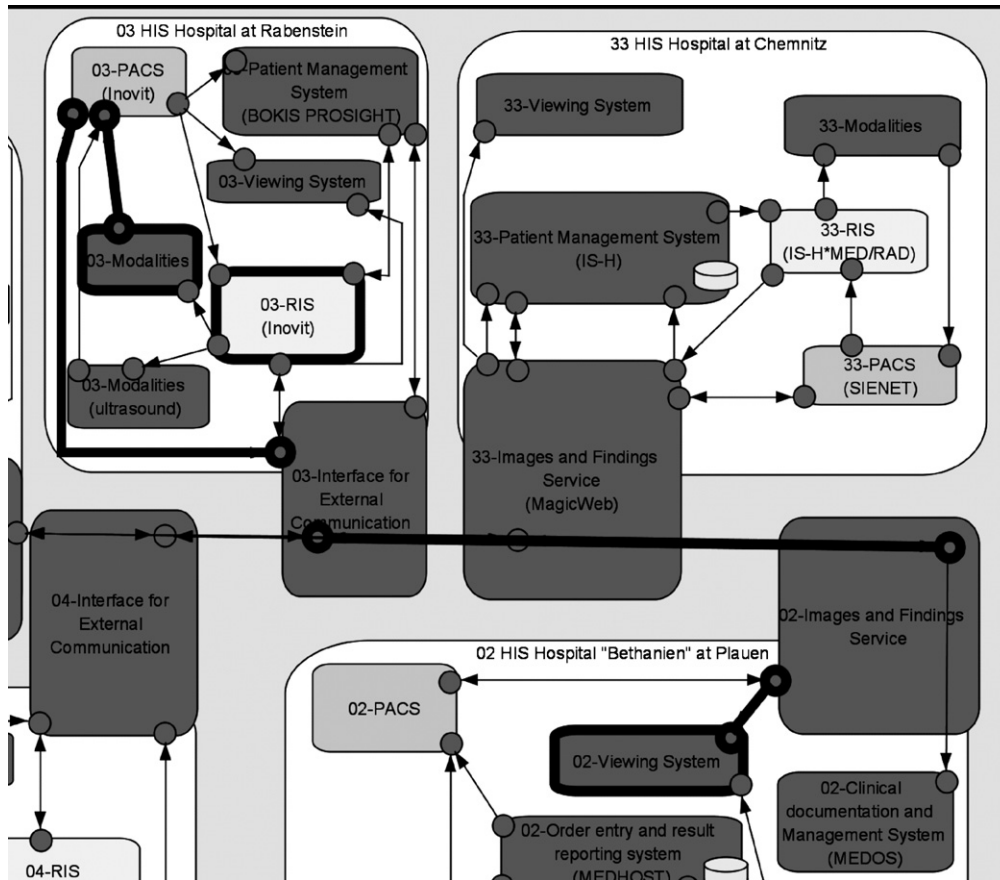
Fig. 2 – Calculated communication path in the Saxonian-rHIS: images can be sent from the application component "03-Modalities" (a modality in the hospital of Rabenstein City) to the component "02-Viewing System" (component for supporting writing of radiological findings in the hospital of Bethanien City).

one product (MCS IKA) has been installed as two different and separated application systems. Additionally it can be seen, that in department STRA1 (radiation therapy and radiation oncology) two different application systems are in duty for the same function. So the table clearly shows a heterogeneity, which is worth to be discussed very seriously.

Even those things, which cannot be found in the model turned out to be of major importance for the strategic plan: the lack of powerful interfaces to other health care institutions in the region lead to the clear statement, to concentrate on better integration into the rHIS of Saxony within the next 3 years.

4. Discussion

In the previous sections, we shortly introduced the $3LGM^2$ and the corresponding $3LGM^2$ tool for modeling information systems and demonstrated possible opportunities for information management of an rHIS on the case of the SAXTELEMED project. On the basis of this case study, we now can answer our research questions as follows:

Table 1 – Excerpt from the table of enterprise functions, organizational units and application components, generated automatically by the $3LGM^2$ tool		
Enterprise function	Organizational unit	Application system (software product)
Admission (outpatient)	KCHA1, GYNA4, IN4A4, HUG, IN1A2, IN1A3, HNOA1, GYNA8, IN1A5, GYNA5, CHZA, AUG, NCHA1, …	Patient management system (SAP IS-H)
	NET	Outpatient management system NET (MediTec)
	PSYA1	Outpatient management system PSY (MCS IKA)
	RADA1	RIS Radiology information system RAD (MEDOS)
	STRA1	Patient management system (SAP IS-H)
		Outpatient management system STR (MCS IKA)

Although 3LGM^2 had been developed to model information systems of hospitals it could be used successfully to model the information system of a regional health care setting as well.

The possible benefits for information management using 3LGM^2 are obvious. Only the consistent use of a common modeling instrument – here the 3LGM^2 – mandatory for all involved partner institutions of a rHIS makes it possible to compare the information systems which shall be integrated, to identify redundancies and weaknesses, to illustrate their capabilities, and to formulate integration requirements on a common basis. This is especially important for a super-ordinate institution, in our case the Saxonian Ministry of Social Affairs, which has to coordinate the different information system architectures of the involved partner institutions to grow together to a rHIS. But it can also support consultants, which in many cases accomplish tele-medical projects like those described above, because they can easily get a consistent survey of the rHIS and its components. Ideally, the information management of the partner institutions is already working with that common modeling instrument for their in-house purposes. This would on the one hand decrease the modeling efforts for the rHIS considerably. On the other hand the partner institutions could easily discover deficiencies of their information system concerning the integration to the rHIS.

The case of SAXTELEMED additionally shows that there are some organizational prerequisites for a useful application of 3LGM^2 in regional settings. Especially for a rHIS, there must be a super-ordinate institution responsible for information management from a regional perspective. This might become an important challenge because healthcare regions, at least in Germany, are not institutional bodies with their own administration, but a rather loose coupling of autonomous institutions. Nevertheless, the super-ordinate institution could be a ministry for health, another health care body or even a health care enterprise. Experiences at the Leipzig University Medical Center additionally show, that a rHIS model is merely useful, if it is up-to-date and, that the model can just be maintained if (and only if) tactical and strategic information management [15] are closely connected. As a consequence the UKL-KIS model has been implemented as the central repository for the information systems components at the Leipzig University Medical Center. To ensure that the model remains up-to-date, project managers are obliged to document changes of information system components concerned by their projects within the UKL-KIS model.

So we can finally conclude that 3LGM^2 as modeling instrument for information systems can support information management for rHIS considerably if the organizational prerequisites are fulfilled. This may even hold for a nationwide or European perspective.

Acknowledgments

Account of what the research has learned

Before the case study reported on in this paper we knew that

1. 3LGM^2 is a meta-model providing modeling concepts for a hospital information system which seems to be adequate for information management;
2. The 3LGM^2 tool enables modelers to create models of information systems of hospitals;
3. The 3LGM^2 tool provides various means for analyzing models of hospital information systems, which seem to be valuable support for information managers in hospitals.

By this case study we found that

1. The modeling concepts of 3LGM^2 are also sufficient to model regional Health Information systems;
2. The 3LGM^2 tool enables modelers to model even regional Health Information systems in practice. Its concepts of sub-models and coarsening help managing the complexity of rHIS models;
3. 3LGM^2 tool's means for analyzing models provide benefits for information managers in local as well as in regional settings;
4. Application of 3LGM^2 and the 3LGM^2 tool requires an institution for information management and its successful use depends strictly on its integration in management structures on the institutional, regional, and even national or European level.

REFERENCES

[1] A. Winter, Health Information Systems, in: Yearbook of Medical Informatics, Schattauer, Stuttgart, 2004, pp. 359–368.

[2] P. Doupi, J.V.D. Lei, Towards personalized Internet health information: the STEPPS architecture, Med. Inform. Internet Med. 27 (3) (2002) 139–151.

[3] R. Lazarus, K. Kleinman, I. Dashevsky, C. Adams, P. Kludt, A. DeMaria Jr., R. Platt, Use of automated ambulatory-care encounter records for detection of acute illness clusters, including potential bioterrorism events, Emerg. Infect. Dis. 8 (8) (2002) 753–760.

[4] N. Maglaveras, I. Iakovidis, P.C. de Groen, Regional health information networks and telematics applications in a user friendly information society, Meth. Inform. Med. 41 (2002) 357–450.

[5] M. Berg, Medical work and the computer-based patient record: a sociological perspective, Meth. Inform. Med. 37 (1998) 294–301.

[6] B. Brigl, E. Ammenwerth, C. Dujat, S. Graber, A. Gro[ss]e, A. Haber, C. Jostes, A. Winter, Preparing strategic information management plans for hospitals: a practical guideline. SIM plans for hospitals: a guideline, Int. J. Med. Inform. 74 (1) (2005) 51–65.

[7] Chief Information Officer Council. A Practical Guide to Federal Enterprise Architecture, Boston. Chief Information Officer Council c/o Rob C. Thomas, U.S. Customs Service

7681 Boston Boulevard Springfield, VA 22153, 2001 February 2001. Report No.: http://www.cio.gov.

[8] J. Martin, Information engineering, in: Book II: Planning & Analysis, Prentice Hall, Englewood Cliffs, 1990.

[9] S.H. Spewak, S.C. Hill, Enterprise architecture planning: developing a blueprint for data, in: Applications and Technology, John Wiley & Sons, New York, 1992.

[10] A. Winter, B. Brigl, T. Wendt, Modeling hospital information systems (Part 1): the revised three-layer graph-based meta model 3LGM^2, Meth. Inform. Med. 43 (5) (2003) 544–551.

[11] J.A. Zachman, A framework for information systems architecture, IBM Sys. J. 26 (3) (1987).

[12] T. Wendt, A. Häber, B. Brigl, A. Winter, Modeling hospital information systems (Part 2): using the 3LGM2 tool for modeling patient record management, Meth. Inform. Med. 43 (3) (2004) 256–267.

[13] Saxonian Ministry for Social Affairs. Saxtelemed [Website]. http://www.saxtelemed.de, 2003.

[14] B. Brigl, S. Strübing, T. Wendt, A. Winter, Modeling interdependencies between information processes and communication paths in hospitals, Meth. Inform. Med. 45 (2) (2003) 216–224.

[15] A.F. Winter, E. Ammenwerth, O.J. Bott, B. Brigl, A. Buchauer, S. Gräber, A. Grant, A. Häber, W. Hasselbring, R. Haux, A. Heinrich, H. Janssen, I. Kock, O.-S. Penger, H.-U. Prokosch, A. Terstappen, A. Winter, Strategic information management plans: the basis for systematic information management in hospitals, in: Yearbook of Medical Informatics, Schattauer, Stuttgart, 2003, pp. 431–441.