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Review Article

Modelling and comparing hospitals' information systems in Japan and Germany

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Abstract

Medicine and health care are developing to be and yet are driving economical factors worldwide and information and communication technology is one of their most important resources. Thus, there is a special need for effective and efficient information systems. These information systems have continually to be adjusted to changing demands stemming from innovation and trends in medicine (continuity of care, translational medicine), but also from trends in information technology and information management (e.g. SOA, "Green IT", ITIL). Teams worldwide meet the challenge and implement projects concerning information systems for hospitals, health care regions, or even nationwide health telematics like German teams do by introducing the electronic health card. Completing the IMIA "world-wide vision to improve the health of the world population" by application of information technology needs effective cooperation worldwide. As already stated in the bible (tower of babel) one common language is needed for cooperation. This requires a widely accepted terminology/ontology for describing information systems in health care, a common understanding of the domain and of the tasks to be supported by information systems, and shared methods for creating construction plans. As a small contribution we had proposed 3LGM^2 as an ontology to describe information systems, a reference model to describe the domain of health care information processing, and the 3LGM^2 tool to create models and plans for information systems in health care. In a joint project of the University of Leipzig (Germany) and Chiba University (Japan) we applied these concepts to systematically compare the information systems of the respective universities' medical centres. We regard this comparison as small but important step towards better cooperation between Asia and Europe in building health care information systems. The comparison unfolded e.g. differences concerning architectural styles, heterogeneity, redundancy, use of communication standards and organisation of information management between both hospitals. The confrontation of the information systems of both sites with each other using the same terminology provides new chances for sharing experiences and, thus, for cooperation. Despite of the differences, no reason could be found for rating one information system significantly better than the other. For doing this, a more thorough understanding of quality of information systems in health care and respective research is needed. ***(Journal of Korean Society of Medical Informatics 14-2, 87-96, 2008)***

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I. Introduction

Medicine and health care are developing to be and yet are driving economical factors worldwide[1)2)] and information and communication technology is one of their most important resources[3)]. Thus, there is a special need for effective and efficient information systems. But these information systems have to be adjusted continually to changing demands stemming from trends in medicine and health care like the following:

- Patient centered medicine and "continuity of care"[4)] demand for information systems not being designed for institutions but for patients[5)].
- Quality assurance as well as economic pressure call for access to and support by current medical knowledge. This demands for information systems offering guidance through evidence based clinical pathways[6)-8)].
- Evidence based medicine needs clinical research and, thus, information systems providing a "a two-way road" between bed (patient care) and bench (research) for making clinical data available e.g. in clinical trials [9)10)].
- Molecular diagnostics will enable individual design of therapeutic agents. This will demand for information systems being able to handle large amounts of molecular data. Since computer support in operating rooms will be used more widely[11)12)], this will demand for information systems being additionally able to process large amounts of image data in real time.

Complex, heterogeneous and even nation- or worldwide information systems are no unique issue in medicine and health care but can be found in other industries as well. Hence, we have to take into account related trends and issues discussed in that field. Let us consider especially SOA (service-oriented architectures)[13)] and "Green IT"[14)]. SOA is a promising approach to overcome information systems dominated by software of a single vendor and to support "best of breed" architectures[15)16)]. But there are still problems like defining services appropriately[17)18)] and managing complex service integration tools[19)]. "Green IT" is not only a commercial buzzword at current fairs[20)] but of considerable impact for health care providers. This is due to the fact that PCs and servers in a modern, large academic medical centre as e.g. the Leipzig University Medical Center, will have a power consumption of up to 1.7 megawatts. That is more than enough power to heat 170 detached houses even in coldest winter times and causes enormous costs and pollution as well.

Management of those information systems needs efficient IT departments and service providers within hospitals and other healthcare institutions. Well established approaches like CobiT (Control Objectives for Information and Related Technology)[21)] and ITIL (IT Infrastructure Library)[22)-26)] for delivering and controlling such services have been developed in other industries. Both approaches should now be used in medicine and health care as well.

Teams worldwide meet the challenge and implement projects concerning information systems for hospitals, health care regions, or even nationwide health telematics like German teams do by introducing the electronic health card.

As Medical Informatics professionals we want to complete the IMIA "world-wide vision to improve the health of the world population"[27)] by application of information technology. Having the previous mentioned trends and innovations and the related complexity in mind, the need for effective and worldwide cooperation is evident. As already stated in the Christian bible (tower of Babel), cooperation needs one common language. This requires a widely accepted terminology/ontology for describing information systems in health care, a common understanding of the domain and of the tasks to be supported by information systems, and shared methods for creating construction plans.

The aim of this paper is to propose 3LGM² (three layer graph-based meta model) as a terminology/ontology for describing information systems in health care[28)] and to report on its application for comparing the information systems of Japanese and German academic medical centres. We therefore first explain 3LGM², a reference model providing a common understanding of the domain to be supported by information systems[29)], and the 3LGM² tool for creating models and plans for information systems [30]. Finally we report on a study of the University of Leipzig (Germany) and Chiba University (Japan) to compare the information systems of the respective universities' medical centres and discuss the results.

II. A language and method for describing and comparing information systems in health care

1. The three layer graph-based meta model 3LGM²

In[31] we proposed the three layer graph-based meta model (3LGM^2) as a meta model for modeling information systems in health care. 3LGM^2 has been designed to support the hospital information management in its enterprise architecture planning (EAP) (see e.g.[32) 33)]) activities.

(1) Basic Concepts

The *domain layer* of 3LGM^2 describes a hospital independently of the implementation of its information system by its enterprise functions. Enterprise functions can be considered to be a directive for human or machine action and may be understood as duty arising from an enterprise's mission and goals. For example, "clinical admission", "radiotherapy", or "care planning" may be enterprise functions. Enterprise functions need information of a certain type about physical or virtual things of the hospital. These types of information are represented as *entity types.* The access of an enterprise function to an entity type can be in a using or an updating manner (see Fig. 1).

The *logical tool layer* (see Fig. 2) concentrates on *application components* supporting enterprise functions. Application components are responsible for the processing, storage and transportation of data representing entity types. Application components may have a local *database* to store data. *Component interfaces* ensure the communication among application components. A component interface can receive or send messages of a certain message type. A message type transports (a) certain entity type(s). For the communication among application components, *communication links* can be defined as relations between two communication interfaces, one being the sender of a message, the other one being the receiver. Each communication link is described by the message types which in fact are communicated. Exchanged messages can use communication standards like HL7 or proprietary standards of certain vendors.

The *physical tool layer* (see Fig. 3) consists of physical data processing components (like personal computers, servers, switches, routers etc, but also non computer supported devices), which are physically connected via data transmission connections (e.g. data wires).

Between concepts of the different layers there exist so-called interlayer relationships, which enable to describe the dependencies between model elements belonging to different layers. Figure 4 illustrates, that the application component *Nursing Record System* supports three enterprise functions concerning nursing activities and is implemented on certain clusters and PCs.

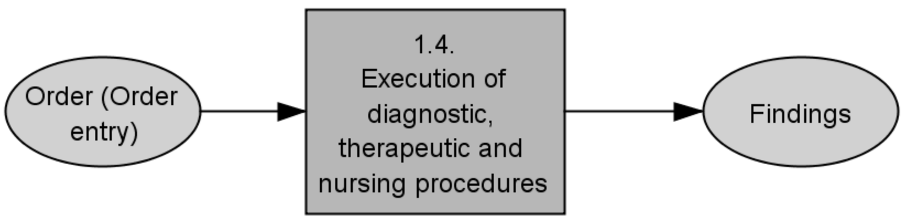

Figure 1. Example of a domain layer (detail): **The entity type *Execution of diagnostic···procedures* uses information about *orders* and updates information about *findings.***

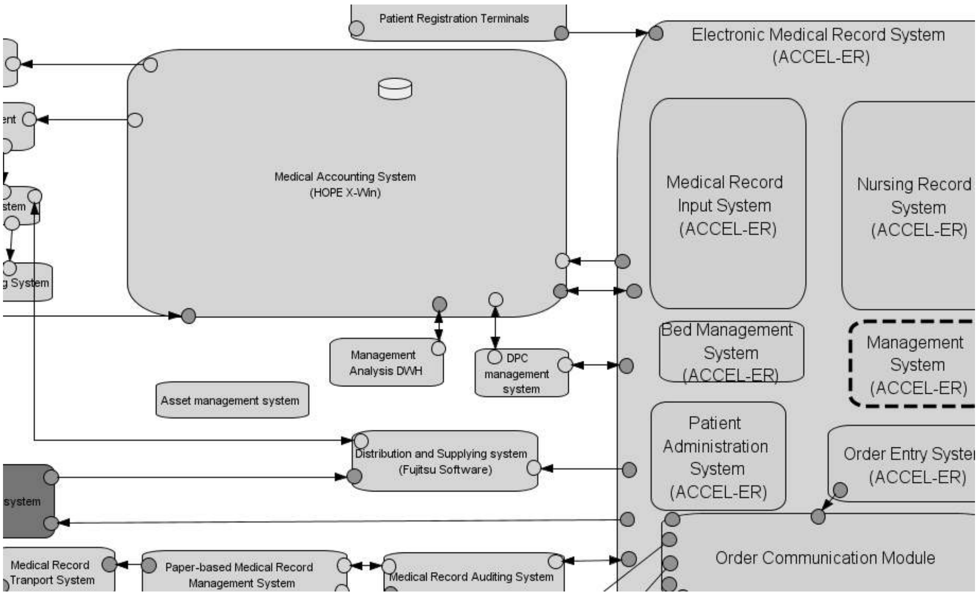

Figure 2. Example of a logical tool layer (detail of Chiba information system)**: application systems are depicted as rounded rectangles, databases as respective yellow symbol, component interfaces as filled circles, communication links as arrows.**

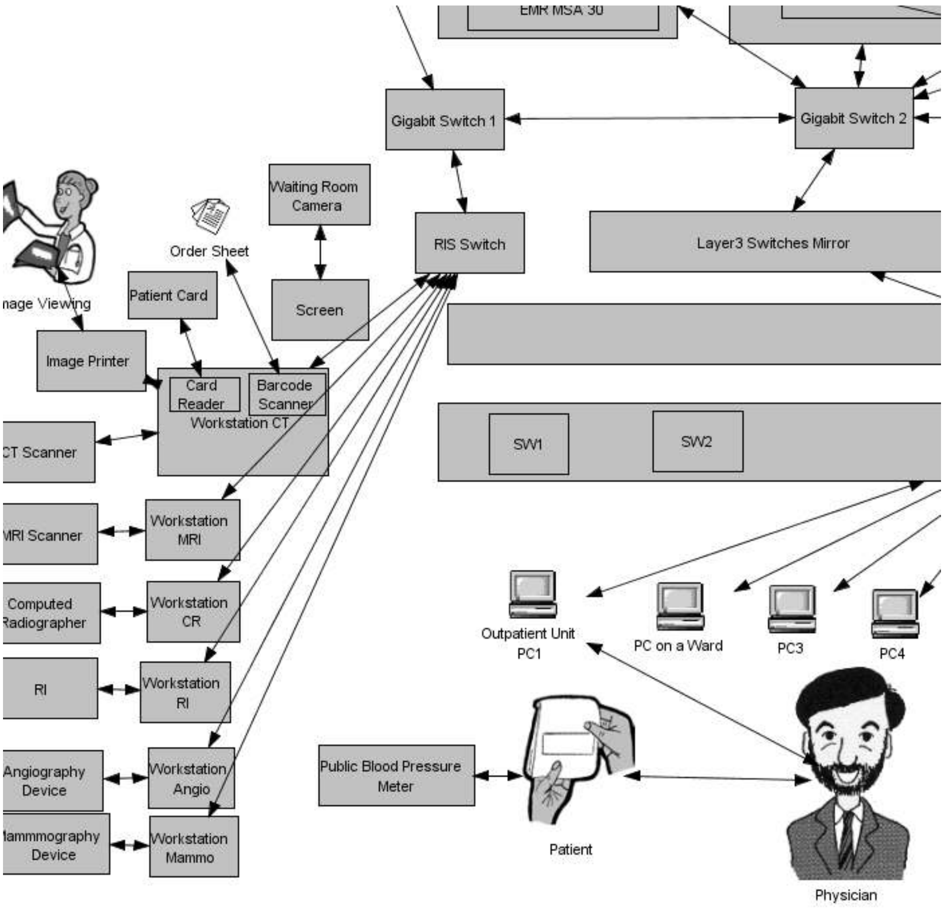

Figure 3. Example of a physical tool layer (detail of Chiba information system)

A comprehensive UML-based description of the 3LGM² can be found in[31].

(2) A reference model for the domain layer of hospital information systems

The domain layer of an information system in health care can be described by enterprise functions and entity types. As the identification and modeling of adequate enterprise functions and entity types for a hospital is rather time- and consequently cost-intensive, a functional reference model for the domain layer of hospital information systems has been developed[29]. It consists of hierarchically structured sets of hospital functions and entity types. The designated enterprise functions base on the Heidelberg requirements index for information processing in hospitals[34], thus the main enterprise function of a hospital is patient treatment, together with maintenance functions like supply management, scheduling and resource allocation, hospital administration, hospital management and research and teaching. The mentioned enterprise functions are in turn refined by sub-functions. Moreover, the enterprise functions bear a relation to each other by entity types which they can update or use.

For defining entity types within the reference model of the domain layer the Health Level 7 Reference Information Model (HL7-RIM) was used.

The Reference Model for the Domain Layer of Hospital Information Systems is available as a 3LGM² model and can for this reason be immediately used for modeling hospital information systems.

Following the definition of reference models in[35] the Reference Model of the Domain Layer can be used as a model pattern for the domain layer of hospital information systems and, additionally, can help to compare hospital information systems by means of a uniform terminology used for the domain layer. I.e. it is possible to see how the same enterprise functions are supported by application components in different information systems.

(3) The 3LGM² tool for modelling information systems

The Meta model has been supplemented by the 3LGM² tool[30] (see Fig. 5). Using 3LGM² as the ontological basis,

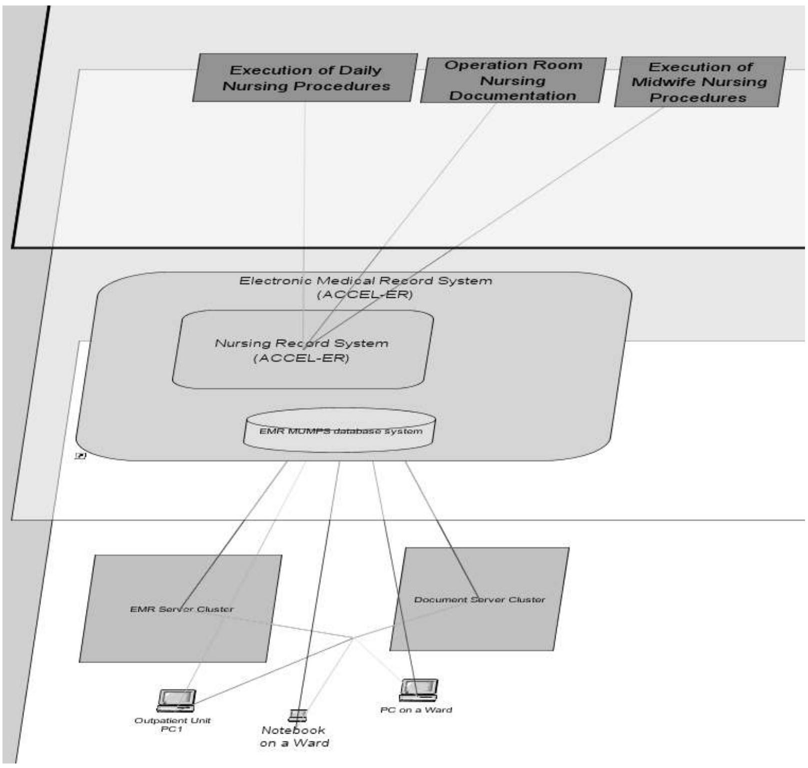

Figure 4. Example of interlayer relationships (detail of Chiba information system)

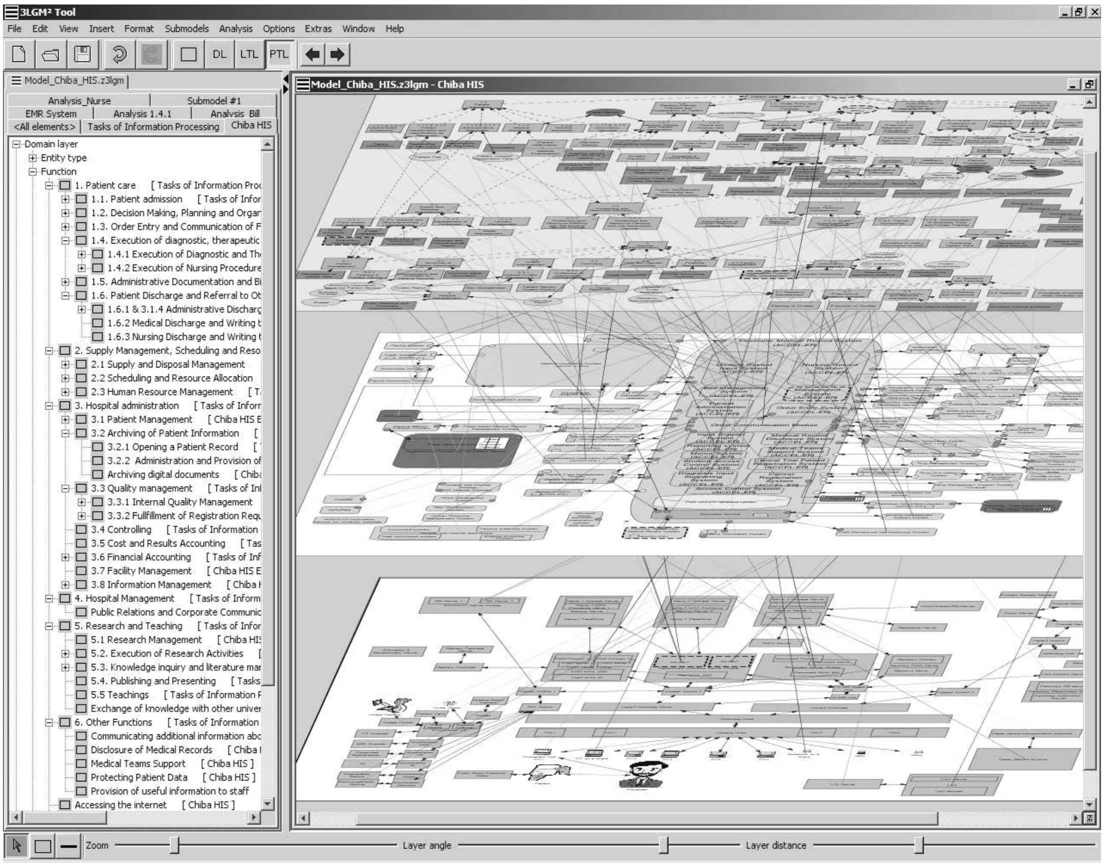

Figure 5. The 3LGM² tool (modeling details of Chiba information system)

this tool enables information managers to graphically design even complex HIS. It assists information managers similarly to computer aided design tools (CAD) supporting architects. The tool provides means for analyzing a HIS or an rHIS model and thus for assessing the rHIS's quality.

Ⅲ. Comparison of a Japanese and a German Hospital Information System on the Basis of 3LGM² models

In a joint study of the University of Leipzig (Germany) and Chiba University (Japan) we applied 3LGM² and the reference model for the domain layer of hospital information systems to systematically compare the information systems of the respective universities' medical centres. Using 3LGM² and the 3LGM² tool, several architectural criteria of an information system (IS) can be assessed. Four of them are explained in the following:

a. A DB^1 style of the logical tool layer is characterized by all application components using the data stored in a single database, while multiple databases for different purposes denote a DB^n style[35)]. By extracting application components together with associated databases it can be determined if an IS has DB^1 or DB^n style.

b. Vertical fragmentation of an IS means according to[36)] that different organizational units use different application systems to fulfill different or equal enterprise functions. On the basis of application component configurations 3LGM² models can be examined according to vertical fragmentation.

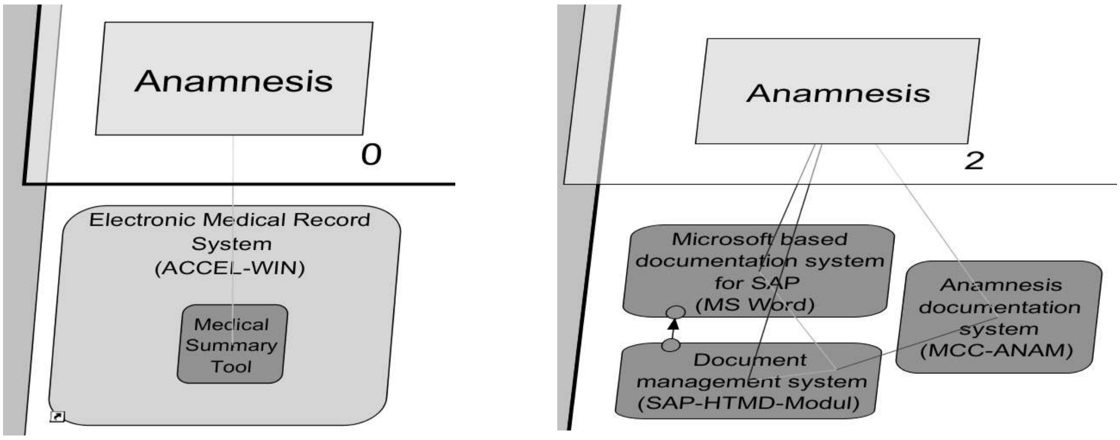

Figure 6. Functional leanness (extract from Chiba information system model, left) and functional redundancy(extract from Leipzig information system model, right) of the function 'Anamnesis'.

c. The functional redundancy factor of an IS (FRED(is))[5] measures by how many application components each enterprise function is supported. An information system is is functionally lean if FRED(is) = 0. FRED is calculated by an analysis function of the 3LGM^2 tool (see Fig. 6).

d. Communication links can use communication standards like HL7. The 3LGM^2 tools allows for assessing the usage of communication standards like HL7.

The reference model for the domain layer of hospital information systems (c.f. 2.2) was used to model identical domain layers for the information systems of both medical centers. Thus, a common understanding of information processing in hospitals became basis for both models and comparability was achieved.

During the study, a 3LGM^2 model of Chiba university hospital's (CUH) information system has been created which now contains over 2700 model elements including the reference model of the domain layer. For Leipzig University Hospital's (LUH) information system, a 3LGM^2 model built upon the reference model had already existed.

Comparing application architectures according to the criteria a. – d we gained the following results:

a. Starting from the logical tool layers of the Japanese and the German model different architecture styles of both HIS become apparent. In LUH's HIS, there is a variety of application components from different vendors. Many of these applications have database systems where patient-related data is stored redundantly. To exchange data and keeping data consistent between different application components a communication server is used. Thus, LUH's HIS is a typical example of the DB^n style. On the contrary, the center of CUH's HIS is an EMR system which accesses a MUMPS database storing all patient-related data. There are many application systems which use the database of the EMR system and therefore have no or only a small database. As a result, although CUH's HIS does not only contain one database there are many indications of a DB^1 architecture style.

b. The central EMR system of CUH emphasizes horizontal integration of patient care related application components within all clinics. In LUH, on the contrary, different clinics often use different applications for the documentation of patient-related data. Thus, the LUH HIS model reveals some vertical fragmentation artifacts.

c. Both HIS of CUH and LUH are functionally redundant. For the CUH IS a functional redundancy factor of 0.1 was calculated which is lower than that of Leipzig's HIS (0.55).

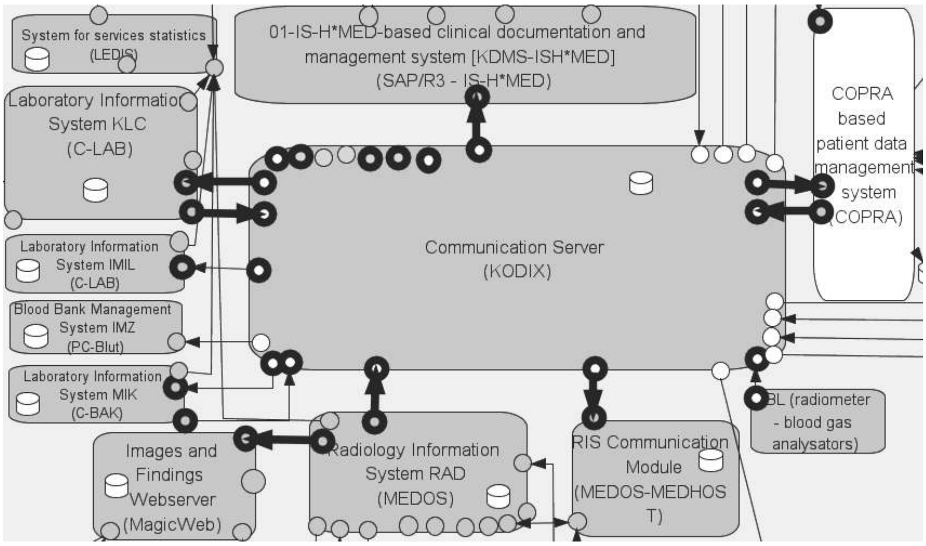

Figure 7. Usage of HL7 in LUH's IS. Bold elements indicate communication links using HL7

d. Within LUH's IS communication standards are widely used. Communication between the most important subsystems of the HIS is supported by HL7 messages (see Fig. 7). CUH's IS has a lot of proprietary interfaces which do not use HL7 or the like. In CUH, HL7 is currently used only for the communication with an external laboratory.

In addition to the revealed architectural differences, which had been unfolded by means of 3LGM², differences concerning information management had been found. Different styles of information management in both universities' medical centres seem to contribute to the particular architectural characteristics.

Ⅳ. Conclusion and discussion

As a small contribution we proposed 3LGM² as an ontology to describe information systems, a reference model to describe the domain of health care information processing, and the 3LGM² tool to create models and plans for information systems in health care. We applied these concepts to systematically compare information systems of two universities' medical centres. We regard this comparison as small but important step towards better cooperation between Asia and Europe in building health care information systems. The confrontation of the information systems of both sites with each other using the same terminology provides new chances for sharing experiences and, thus, for cooperation.

The direct comparison unfolded e. g. differences concerning architectural styles, heterogeneity, redundancy, use of communication standards and organisation of information management between both hospitals. It is worth noting here that the comparison of the two architectural styles does not claim anything about the quality of the IS. In our study, no reason could be found for rating one information system significantly better than the other. For doing this, a more thorough understanding of quality of information systems in health care and respective research is needed.

Although 3LGM² proved to be a suitable means for describing architectures of information systems and comparing them, it does not intend to be the "common language" for describing and comparing organizational aspects of information management. Hence, we need other description languages for this task. The IT Infrastructure Library (ITIL) could be used as such a language. Complementing research on describing, comparing and quality of information systems in health care by research on common description languages for organizational aspects of information management will be an interesting next step to assess the overall quality of information systems and to do more elaborate comparisons.

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