A Distributed Clinical Information System for Pediatric Surgery – Basics and Specifics

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Abstract - The basic concepts and specific requirements for design of a distributed clinical information system for pediatric surgery are presented in this paper. The system is based on the Service Oriented Architecture, which ensures its interoperability. Web service adapters are proposed as a means to provide integration of the system with other existing e-health systems. The specific health information (investigations, treatments, diagnoses, etc.) for the patients of a pediatric surgery department is organized and stored in electronic health records. The main part of this information, concerning the undertaken surgical interventions and the treatment's results, is submitted as free text. The system described in the paper is designed to provide support for the physicians and PhD students in the department conducting scientific research in the area by allowing extended, different criteria searches and analysis of stored information for pediatric surgery cases.

I. INTRODUCTION

A Clinical Information System (CIS) is a computer based system that is designed for collecting, storing, manipulating and making available clinical information important to delivery of patient care [1]. CIS constitutes separate information system in clinics and hospital departments and can provide some of the following functions [2]:

- Collection and storage of patients' status and treatment data, organizing them in Electronic Patient Records (EPR) or Electronic Health Records (EHR); management and synchronization of health data exchange with other existing e-health systems such as Hospital Information Systems (HIS), if necessary;

- Management and organization of the activities of the clinic or hospital department which can be cardiology, internal medicine, pediatric surgery, etc;

- Support of training and scientific research in the area, extraction and analysis of stored information, preparation of reports.

The use of a CIS for storing, organizing and manipulating the information flow in a clinics or hospital department allows easy access to patient data. The information is structured and well organized, which makes it easier to maintain and quicker to search through, compared with such manipulations on paper records.

Electronic health record (EHR) is a concept, which defines the way to organize electronic health information about a patient. It is a digital record that is theoretically capable of being shared across different e-healthcare systems. EHR may include a wide range of data, which can vary according the specific area of its application.

The required functionality of a particular clinical information system and its specific area of application have to be considered, when a design of the system is proposed. The designing process also depends on the current status of e-health at national level in the country, where the system will be used. Basic concepts, which are applied to satisfy the data, functional and national requirements of building a clinical information system for pediatric surgery, are presented in the paper. The Service Oriented Architecture (SOA) is chosen to ensure the interoperability of designed system. Web service adapters are proposed as a means to provide its integration with other existing e-health systems. The specific health information (investigations, treatments, diagnoses, etc.) for the patients of the department is organized and stored in electronic health records. The system described in the paper is designed to provide support for the authorized physicians and PhD students conducting scientific research in the area by allowing extended, different criteria searches and analysis of stored information for pediatric surgery cases.

II. RELATED WORK

A large number of researches in the area of E-Health are dedicated to design and development of e-healthcare systems and networks. The challenges of designing suitable architecture for such an information system with key issues flexibility, adaptability, robustness, integration of existing systems and standards, semantic compatibility, security and process orientation are discussed in [3].

Many of the proposed solutions for e-healthcare systems [4, 5, 6, 7 and 8] are based on the Service Oriented Architecture. SOA offers the potential to achieve efficiency in application development, integration of third-party applications and greater agility by minimizing the need for extensive application replacement when seeking standardization or incorporating new technology [9]. This approach is preferred for systems, which provide diverse functionalities in e-healthcare and

can also be applied in telemedicine [4, 5] or as decision-support systems and networks [6, 7].

The distributed e-healthcare system, proposed in [8] uses the service oriented architecture as a basis for designing, implementing, deploying, invoking and managing healthcare services. The e-healthcare system provides support for physicians, nurses, pharmacists and other healthcare professionals, as well as for patients and medical devices used to monitor patients.

In a university research project [4], SOA is used in conjunction with grid computing technology for developing a sensor and actuator framework that allows a remote monitoring of the health status of a patient. The idea for personalized health management system based on SOA and Web Services is also implemented in Healthcare@Home [5]. It is a research project, which uses mobile devices and/or dedicated home-based network servers to 'push' or 'pull' patients data to a data analysis engine and evaluates diabetes risk assessment for a particular individual.

A distributed architecture for clinical decision support called SANDS (Service-oriented Architecture for National Health Information Networks Decision Support), which is based on the principles of a service-oriented architecture is proposed in [7]. The architecture allows disparate clinical information systems and clinical decision support systems to be seamlessly integrated over a network according to a set of interfaces and protocols. SOA is the preferred architecture style for designing Health Research Data Network, proposed in [6].

Care2x [10] is another open-source Web-based university research project that implements hospital information system. It has modules for different functions and departments in a hospital and includes a central data server and a health exchange protocol. PHP and JavaScript are chosen here for scripting languages in contrast with many other solutions, which use Java, the database system is mySQL.

There are also many commercial solutions in the area. Some enterprises in Bulgaria provide e-healthcare Web portals, systems and handsets, but none of them offers all of the specific functionality needed for a pediatric surgery department. Such an e-healthcare information system is developed by Gama Consult [11]. The main purpose of the system is to collect and store patients' status and treatment data in order to generate reports to the National Health Insurance Fund. Its design is not prepared to store huge amount of free text data and to support extended, different criteria searches and analysis of the stored information.

III. REQUIREMENTS OF BUILDING A DISTRIBUTED CLINICAL INFORMATION SYSTEM FOR PEDIATRIC SURGERY

Every medical specialty has its own characteristics and specifics. Surgical specialties focus on manually operative and instrumental techniques to treat disease. So the main part of health information for a patient in a surgery department must consider the undertaken surgical treatment. The need of collection, storage and manipulation of patient's information define some requirements for the design of a clinical information system for a surgery department.

A. Data requirements

The information for a patient in pediatric surgery department can be summarized in two categories: general information and specific medical information. General information is collected and stored for all the patients in a hospital. It includes demographic data and general medical data such as blood type, allergies, health status for the patient. The information, specific for a patient in a surgery department concerns the undertaken surgical intervention and treatment results among with attendant investigations – laboratory tests and medical images.

- Demographic data

When a patient enters a hospital in Bulgaria, his demographic data – name, address, age, etc., are usually stored in the information system, which services the hospital. If there is a separate information system (CIS) in the department, where the patient is treated, his demographic data should be also available there. In order to avoid inputting the data again in the CIS, they can be accessed and retrieved from the hospital information system.

- Laboratory tests and medical images

The results from laboratory tests and medical imaging instruments have to be transmitted digitally from the appropriate device to the CIS to be designed to avoid the need to manually file, retrieve, or transport them. The standards should be followed and the universal formats should be used for storage and transfer of the results and images. The CIS should also provide suitable services for information exchange with the appropriate devices.

- Specific medical information

The part of specific medical information for a patient in a surgery department, concerning the undertaken surgical intervention and treatment results, is mainly descriptive, not pliable for any standardization and is submitted as free text. These characteristics define some requirements when Database Management System (DBMS) is chosen and database of designed CIS is created.

- Security

Security and privacy are particularly important issues for healthcare. Personal health information is confidential, so access to such information must be restricted to authenticated and authorized users. Secure transmission of such information must be completed with secure storage of the data.

B. Functional requirements

Proposed CIS will be designed to satisfy the following basic functional requirements:

- collect and store general and specific medical information for patients in pediatric surgery department;
- maintain EHRs for organizing the patient's data;
- provide extended, different criteria searches, extraction and analysis of stored information for pediatric surgery cases.

C. National requirements

Many countries suffer from a lack of healthcare IT standards creating interoperability barriers for healthcare IT adoption at local and national levels [12]. In Bulgaria, there is a lack of unified national standards for health data formats and EHRs [13]. There are no protocols defined for communication and health data exchange between existing e-health systems [14]. The hospital information systems, which are developed in Bulgaria last years, use local databases to store the whole health information for the patients in a particular hospital. There is no federation of the data, stored locally in different healthcare databases, and those of Ministry of Health (MH) and National Health Insurance Fund (NHIF). So the definitions for health data formats, EHRs and protocols for communication and health data exchange should be properly chosen in the designing process.

All the data, functional and national requirements can be summarized to govern the designing process and to achieve and ensure opportunity for the designed CIS to:

1) exchange patient information with other existing e-health systems such as HIS or NHIF ;

2) retrieve and store results from laboratory tests and medical imaging instruments by digitally transmiting information from the appropraite devices;

3) submit, store and manipulate large amount of free text data;

4) maintain EHRs for organizing the patient's data in secure manner and in accordance with the current status of e-healthcare in Bulgaria;

5) provide extended, different criteria searches, extraction and analysis of stored information for pediatric surgery cases.

IV. BASIC CONCEPTS IN DESIGN OF A DISTRIBUTED CLINICAL INFORMATION SYSTEM FOR PEDIATRIC SURGERY

A. SOA and system interoperability

The term service-oriented architecture refers to a style of designing reliable distributed systems that deliver functionality as services [15]. The Service Oriented Architecture reinforces basic software architecture principles such as abstraction, encapsulation, modularization and software reuse. It emphasizes implementation of components as modular services and provides interfaces that can be used by clients. The interfaces are separated from their implementations, so the underlying implementation of the individual service is free to change without affecting how the service is consumed.

Two major levels of integration can be achieved, using the SOA [16] – technical interoperability and syntactic interoperability [17]. According to the European Telecommunication Standards Institute (ETSI), technical interoperability is often centered on communication protocols and the infrastructure needed for those protocols to operate. It ensures the systems to be interconnected in a secure and reliable manner. From a technical point of view, SOA is a design paradigm aimed at creating or enabling applications to interoperate across different technical and operational platforms. This is achieved at a technology level by observing detailed international standards as XML and protocols, in particular those of Web services.

Syntactic interoperability or application integration is usually associated with data formats, which help systems and applications talk to each other in mutually understandable terms. This is achieved by connecting systems at the application level and resolving issues of data consistency.

These two levels of integration, if gained for an e-health system, based on SOA would help the system to interoperate and collaborate at a much higher level and to achieve semantic interoperability. It would enable applications as extraction and analysis of content-based knowledge, decisions support and patient intelligence.

B. Web Services and web service adapters

A Web service is a software system designed to support interoperable machine-to-machine interaction over a network [18]. It has an interface described in a machine-processable format. Other systems interact with the Web service in a manner defined by its description, obeying XML and other Web-related standards. These standards allow developers to implement distributed applications using different tools and different programming languages.

Web service adapters are applied for adopting web services to client needs. They are implemented to maintain the access of functionality in a different architecture. Web service adapters can be useful in two cases:

- when the service behavior of a system requires interactions with external Web services; or
- when a system exposes service behaviors as Web services.

Following some of data and functional requirements, the clinical information system to be designed has to interact and exchange information with existing information systems. Service oriented architecture is an appropriate approach to satisfy the need for interoperability of the system. Web service adapters can be designed to provide the opportunity of integration of the system with other existing e-health systems.

C. Electronic Health Records (EHR) and bottom-up approach

EHR is a repository of information regarding the health status of a subject of care in computer processable form, stored and transmitted securely, and accessible by multiple authorized users [19]. It has a standardized or commonly agreed logical information model which is independent of EHR systems.

From the viewpoint of standardization, the most important characteristic of the EHR is the ability to share EHR information between different authorized users. In technical terms, this requires interoperability of information in the EHR and interoperability of EHR systems which exchange and share this information. In

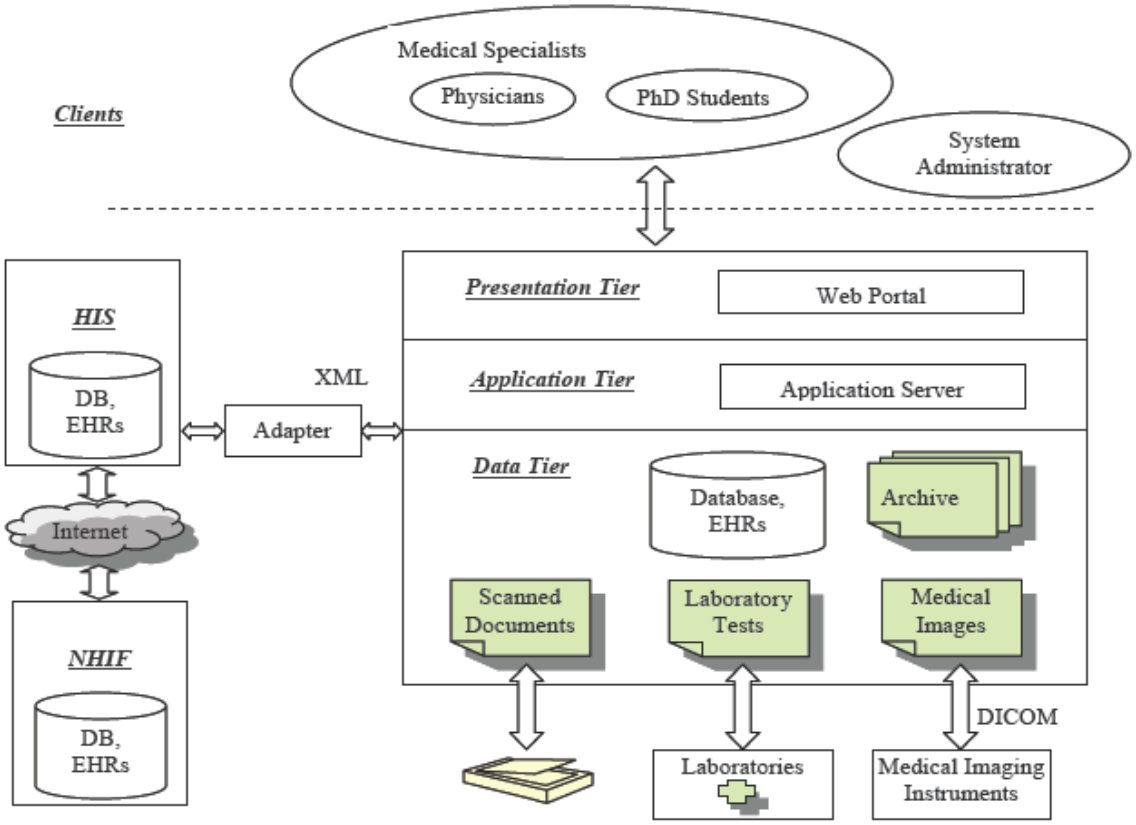

Figure 1. Multitired model of distributed Clinical Information System for Pediatric Surgery Department

order to achieve interoperability a set of standards and protocols are necessary in the area.

In most countries, where such standards are defined and available, a national approach to EHR adoption is the 'top-down' [12]. It is an approach for development of EHRs in clinical information systems, considering them as parts of hospital information system. The lack of unified national standards and protocols for EHRs makes it impossible to adopt this approach in Bulgaria. The 'bottom-up' approach [13] is applied instead; it suggests the development of local databases with EHRs, based on SOA. This approach allows easy integration of such a designed system with other e-health systems – existing or to be designed in the future. The coordination of information exchange between systems is ensured by the open XML format. An advantage of the approach is the opportunity to design the required clinical information system for pediatric surgery department without awaiting the indefinite time delay for development, acceptance and approval of national standards in the area.

V. DESIGN OF A DISTRIBUTED CIS FOR PEDIATRIC SURGERY DEPARTMENT

A. *System architecture*

The system is designed considering the people, who will use it, required functionality to be provided for them and data types and formats to be collected, stored, manipulated and exchanged with other systems.

Basic users of the system are the medical specialists – physicians and PhD students, who work in pediatric surgery department. They can: 1) enter data for the patients in department; 2) make inquiries for patients, treatments, surgical interventions, diagnoses etc.; 3) conduct extended, different criteria searches for pediatric surgery cases to make scientific research in the area.

Based on the requirements previously defined, a distributed architecture is proposed – fig. 1. The model has four tiers:

- Client tier – the clients of the system are resided here. The role of the tier is to allow the user access to the system. This tier can be implemented with Web browser or as desktop application to provide the necessary user interface by means of Web pages or Web services.
- Presentation tier – Web portal or the 'entry point' of the system. The user queries are submitted here and are accepted or rejected, according the rights for access. If accepted, the queries are transmitted to the next tier to be served. Presentation tier communicates with other tiers in two-way manner. When the results from a query are ready, the tier translates them to the client tier for output.
- Application tier (business logic, logic tier or data access tier) – presented with Application server. It controls the application's functionality by performing detailed processing. Two main directions in functionality of the tier can be distinguished: 1) query processing; and 2) control

of data access and transmission. The data are transmitted in XML format. The functions of the tier are realized on the basis of Web services, which ensure the interoperability of the system and allows its easy integration with other systems.

- Data tier – the information is stored and retrieved here. This information is organized as follows: 1) in a database; 2) as files in the file system and 3) in archive.

  The database is designed to store the main part of patient data and all the other information needed for the system to work properly – users of the system, rights, etc;

  The demographic data for the patients have to be retrieved from the information system [10], which services the hospital, the department belongs to. Web service adapter is proposed as a means to provide the access and data exchange between the designed system and the hospital information system. It can be used to access and retrieve data with NHIF too, if needed. The adapter also allows conversions, if there are any differences between corresponding structures and data formats of EHRs in both systems. The data are exchanged in XML format.

  Results from laboratory tests and medical imaging instruments are transmitted digitally from the appropriate devices to the CIS and stored as files. Standards are followed for handling, storing and transmitting the information. DICOM is adopted as a standard in medical imaging. Scanned documents can also be used as a source of information in order to make the transition easier from paper to electronic records keeping.

  The archive contains backup of information in the database and files.

  This tier keeps data independent from application servers or business logic. Separating data from logic and services improves scalability and performance of designed system.

B. Electronic Health Records

The definition for EHR, presented in table 1, is proposed to organize the information of a patient in pediatric surgery department. It is partitioned into 'core' and 'specific' information.

The core EHR sections hold basic information, which can be stored for a patient in any department in a hospital such as general data and description of patient's disease. The problem list, case history and diagnosis are followed by the clinical notes and medications, taken in the course of treatment and completed with epicrisis and final prescriptions – all submitted as free text.

The information, specific for a patient in a surgery department concerns the undertaken surgical intervention and attendant check up of patient status and results from laboratory tests and medical imaging instruments. The patient status consists of comprehensive, mainly free text description of his tissues, organs and systems. This information together with the results from laboratory tests, medical images and evaluation of anesthesiological risk is needed in a surgical treatment. The surgical intervention itself is described with a surgical protocol, where the surgical progress is given in details, the cultures, taken for analysis are recorded and complications are noted, if any.

A lot of information, included in core and specific EHR, is mainly descriptive, not pliable for any standardization and have to be submitted as free text. On the other hand this information is very important in order to conduct scientific research in the area of pediatric surgery, because it concerns some of the main criteria of searches as diagnosis, patient status and problem list and surgery description. So the opportunities for fast searches in large amount of free text data have to be considered and investigated as a future work at the stage of system implementation.

TABLE I. EHR FOR PEDIATRIC SURGERY DEPARTMENT

Core EHR	
Section	***Description***
Patient demographics	Information, retrieved mainly from the HIS
General medical data	Blood type, Rh, allergies, overall health status of the patinet
Problem list	The patient problem list, submitted as free text
Diagnosis	Code of disease and additional free text
Case (medical) histiory	Free text
Clinical notes and medications list	Free text
Epicrisis, prescriptions	Free text
Specific EHR	
Section	***Description***
Patient status	Comprehensive description of the status of patient's tissues, organs and systems. Submitted mainly as free text.
Anestesiological risk	Presented with class, marked with a digit, according ASA physical status classification system + "E" for emergency.
Laboratory tests – common and specific	Laboratory tests, specific for surgery department such as histology, haemostasis, tumor markers, etc. are included in the patient's record in addition to common laboratory tests. Stored as files.
Medical images	Transmitted digitally from the appropriate devices to the CIS and stored as files.
Surgical protocol: - surgical team; - anaesthesia; - surgery time; - surgery progress; - culture, taken for analisys; - complications	The members of surgical team are presentes with their physician's ID. The anaesthesia is submitted with itd code. The other part of the protocol (except surgery time) is submitted as free text.

VI. CONCLUSION

Design of a distributed clinical information system for pediatric surgery department is described in the paper. The data, functional and national requirements when building such a system are defined. The basic concepts, applied to satisfy the requirements are discussed. The system is based on the Service Oriented Architecture, which ensures its interoperability. Web service adapters are proposed as a means to provide integration of the system with other existing e-health systems. The specific health information for the patients of a pediatric surgery department is organized and stored in electronic health records. The system is designed to provide support for the physicians and PhD students in the department conducting scientific research in the area by allowing extended, different criteria searches and analysis of stored information for pediatric surgery cases. The main part of this information, concerning the undertaken surgical interventions and the treatment's results, is submitted as free text. So the opportunities for fast searches in large amount of data have to be considered and investigated as a future work at the stage of system implementation.

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