A Software Solution for Ambulatory Healthcare Facilities in the Republic of Serbia

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Abstract — During the last decade, the Ministry of Health of the Republic of Serbia, a developing country, funded several projects aiming to make the public healthcare system more efficient through the use of information technology (IT). This system development experience paper presents the first results of our project that develops software support for public ambulatory healthcare facilities, concentrating efforts on improving the work environment of general practice (GP) doctors. While earlier projects in Serbia centered on organizational and financial aspects of healthcare processes, our project focuses on medical aspects and results in a medical information system (MIS) based on a specially developed electronic health record (EHR). We also present a brief overview of our supporting tools for data modeling and application generation, developed for easier realization of MIS. Another goal of the project is to support interoperability and cooperation of ambulatory and clinical MIS within the University Clinical Center of Niš (there is no similar interoperability in any city in Serbia). The main contribution of this system development experience paper is to show how we have been applying and adapting modern MIS concepts in challenging circumstances of a developing country. These experiences could be relevant for other countries with similar challenges.

Keywords—electronic health record (EHR), medical information system (MIS), code generation, rapid application development

I. INTRODUCTION AND MOTIVATION

The Republic of Serbia is a developing country in Southeast Europe. Public healthcare system in Serbia has been organized under the authority of the Ministry of Health for more than 150 years. During that time, it has been significantly changed several times: from a “two-tier” system before the World War II, via a strictly state-owned but relatively well-funded system during socialist Yugoslavia, through the chaos and underfunding of hyperinflation- and war-ragged 1990s, to the present-day situation with both the public system offering universal healthcare and relatively small and differentiated private practices. The public healthcare system is now organized into several levels, where the most important one is ambulatory — called “primary” by the Serbian Ministry of Health. Within this system, the term “secondary care” is used to denote healthcare provided by hospitals and clinical centers. Hereafter, we use the terms “primary” and “secondary” healthcare in the same way as the Serbian Ministry of Health uses them.

This public healthcare system has a complex organization and numerous operational inefficiencies, so it needs significant information technology (IT) support to perform better. The main problems are the dependence on large amounts of paper documents and the complexity of procedures/processes (often annoying to patients). Members of medical staff spend a lot of time on basic paperwork, such as writing somebody’s name and birth date on a document. As with other countries, Serbian medical institutions are large producers and consumers of various data, so they need medical information systems (MIS), which bring proven improvements to healthcare systems [1].

Since 2001, the Serbian Ministry of Health has been making significant efforts [2], with financial help from the World Bank, to introduce IT in the public healthcare system. At first, the main problem was that almost no medical facility had enough computers, network equipment and Internet connectivity. In 2002, several clinics got computers and first MIS have been developed, but they have not been networked and worked almost without any kind of data interchange. By the end of 2008, the Ministry of Health has finished the first phase of the general reconstruction project and all medical facilities belonging to the government-run healthcare system got appropriate IT equipment and Internet connectivity. In 2008, the Ministry of Health started several projects resulting in first interoperable MIS based on standards. At present, the only MIS software component that works in each medical facility and is truly interoperating is the financial reporting system. It has been developed under the authority of the Ministry of Health and its main purpose is creating lists of used material and medical services provided in a medical facility. Administrative workers collect paper forms from medical staff and make reports on a daily basis. However, no medical data are interchanged electronically. Practically, there is no interoperability and collaboration (exchange of patient medical information) between primary (ambulatory) and secondary (hospital/clinical) healthcare in Serbia.

This paper presents the first results of a project dedicated to developing software supporting healthcare processes in ambulatory healthcare institutions in the Niš region of Serbia. It is a system development experience paper. The project Web site [3] contains information auxiliary to this paper. The project has been supported and funded by both the Ministry of Science and Technological Development and the Ministry of Health of the

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Republic of Serbia. In the completed first phase (reported in this paper), the project focus was on digitalization of medical data and processes. In the recently started second phase, the focus has moved to collaboration between MIS of primary and secondary healthcare. The main users of this software are general purpose (GP) medical doctors, since they have the most paperwork in the actual healthcare organization in Serbia.

The experiences and solutions from MIS in the developed countries are only partially relevant for Serbia, due to the differences in the organizational structure of the public healthcare system, the level of availability of computers and the Internet, the level of computing literacy among medical professionals, and many other socio-technical issues [4]. We were not able to find an existing MIS (offered as a product or described in the literature) that sufficiently addressed the needs and challenges our project faces. On the other hand, many post-socialist and, to a degree, some other developing countries in the world have somewhat similar (albeit not identical) challenges [5]. Thus, we believe that our experiences and solutions can be of interest to a broader audience, particularly from developing countries.

The following section discusses some of the requirements and challenges (constraints) relevant for our project. In Section III we give an overview of the overall system architecture. The basis of our system is the electronic health record, elaborated in Section IV. The software support is presented in Section V. The final section summarizes conclusions and future work.

II. SOME REQUIREMENTS AND CHALLENGES

Our main goal has been to create a software system that uses modern MIS-related technologies to satisfy the needs of the Serbian public healthcare system. The main requirement for our work was to remain compatible with the existing organization of this healthcare system and its current computing infrastructure (mostly based on Microsoft Windows, with not always satisfactory Internet connection). Our software solution for ambulatory healthcare facilities in Serbia is currently used by medical facilities within the Niš region. This region is relatively large (21080 km²) and by European standards poorly inhabited (1.35 million people, population density 63.6 inhabitants/km²). Due to the difficult terrain and relatively long distances between major towns, the public healthcare system is based on medical facilities in administrative districts. The region contains 7 administrative districts, each containing several municipalities. Each municipality has its own ambulatory and emergency healthcare center. The ambulatory center is usually organized around several departments concentrated in the administrative centre of the municipality. In most cases, the departments are: a general practice, several specialist departments (commonly: gynecology, pediatrics, cardiology, and dental service), a laboratory, and a basic diagnosis department (usually providing X-ray, electrocardiography – ECG, and ultrasound examinations). Additionally, most villages have their own general practitioner office. For example, the ambulatory center in Niš has, apart from the main building in central Niš, 43 satellite objects in suburbs and rural area. Further, there is at least one general hospital, as well as specialized clinics, in each administrative district. The biggest and the most important medical facility in the Niš region is the University Clinical Center Niš (UCCN), a conglomerate of 23 different clinics connected with the Medical Faculty of the University of Niš.

Another crucial requirement for our software was that the MIS interface should resemble the actual paper documents as much as possible. The main users of our software are doctors and nurses, who have to make the transition from paper-based to electronic health records as easily as possible. Usually, doctors and nurses (especially older nurses) in Serbia do not have good computer user skills, so any MIS that is different from the existing administrative forms and procedures will become their nightmare and will not be used in practice. (We know about MIS that did not gain practical acceptance in Serbia for this reason.) Therefore, we have tried not to change user’s methodology of work and habits, but only to adapt them. For example, we will illustrate later in the paper how our software customizes forms to look like the paper documents used for years.

A further requirement was to minimize (to the extent possible) direct entry (typing) of medical data by medical staff, to reduce mistakes and increase work efficiency. One aspect was to minimize typing of personal, demographic and insurance-related data about patients and doctors. In 2007, Serbian Ministry of Health has introduced a new personal health booklet with the bar code containing patient’s id number. Thus, our software now downloads all patient-related data from the Ministry of Health, with scanned barcode being the sole input. The only situation when a nurse has to enter patient’s data is when the patient cannot be found in the database, but has a valid medical booklet. Another aspect was to allow medical staff to select medical institutions, doctors, diagnoses, medicines, prices of services, and other common information from lists of valid options, downloaded from the Ministry of Health.

The Serbian public healthcare system is significantly different from the healthcare systems in the developed countries, so many solutions from MIS developed for these countries did not meet our requirements. However, the Serbian healthcare system is similar to the systems in the countries of former Yugoslavia and East Europe, so we also wanted to enable that our solutions can be easily localized and applied outside Serbia.

III. THE OVERALL SYSTEM ARCHITECTURE

Figure 1 shows a general overview of the complete architecture of our software system. All data used by different services and applications are stored within a relational database and external catalogs (Extensible Markup Language – XML files). External catalogs are provided by the Ministry of Health and the Public Medical Insurance Fund. Some of these catalogs are: the list of illnesses (using the International Classification of Illnesses – ICD-10), the list of allowed medicines, the list of all medical staff members at a specific institution, and the list of all registered patients with their demographic data. When requested, the service (module) Medical Catalog Updater connects to the Ministry of Health and then downloads and updates (i.e., synchronizes) all catalogs required by an ambulatory institution. Another synchronization service (Patient Insurance Eligibility Check) connects to the Serbian Public Medical Insurance Fund and synchronizes insurance-related data. The basic action is to download the list containing patient insurance eligibility data and update the local database. Additional data
(lists of services and medicines available within an institution, with related prices and percentage of price covered by the insurance fund), not directly related to the patient but needed for ambulatory facility business, are also downloaded.

All data stored within the database and the catalogs are classified into 3 groups: demographic, medical, and insurance-related. For each of these groups, a separate data-providing service exists. These 3 services, plus the Access Control Module for secure data access, are considered by higher-level services as a single virtual electronic health record (EHR) service, through which all access to data storage has to go (e.g., for security and for easier system updates). The module for supporting GP doctors is the heart of the application layer. It offers full control to each patient’s electronic record. A GP doctor can enter new medical data, use the scheduling service and the prescription service, and interact with a laboratory information system (LIS). On the other hand, specialist doctors have customized applications adjusted to their specific needs. We are working on a knowledge extraction service that will help in detecting rare illnesses and in decision making.

IV. ELECTRONIC HEALTH RECORD – THE SYSTEM BASIS

One of the main goals for developing healthcare/medical information systems is to enable collection and processing of medical data so that the best possible decisions can be made in limited time. Therefore, the first step in the development of our system was defining a data model of an Electronic Health Record (EHR) [6]. An EHR, as the founding block of any MIS, formats medical and other data, and prepares them for processing and/or interchange with other information systems. Another benefit from using EHR and MIS systems is that medical data can be more easily available for further educational and scientific work. With a lot of data stored in an electronic format, different types of search and analysis can be done quickly. For example, EHRs are useful for “rare cases” for which paper data might be lost or forgotten. Researchers, students and other medical staff can access EHRs to improve their work. Our analysis of key capabilities of different MIS systems concluded that the main uses of EHR-based systems were [7]: patient care delivery, patient care management, patient care process support, education and research, improving policy and regulations, public health improvement and patient self-management. However, an important constraint is that data access must be strictly controlled to avoid misuse [8]. This section presents the basic structure of our EHR model. Additional detailed information is posted on our Website [3].
cified in any medical record (i.e., EHR). Classes modeling specific records extend MedicalRecord and bring domain-specific properties required by particular medical domains. Each medical record contains the list of diagnosed chronic illnesses and the list of chosen doctors. By Serbian legislation, each patient can choose up to 4 medical doctors who can sign prescriptions related to the patient’s chronic illnesses. One of the chosen doctors is marked as the “main personal GP”. This doctor signs and verifies all medical documents related to the patient.

The full history of illness is a collection of different medical analyses, reports about medical treatments (e.g., prescribed medications), laboratory analyses, general notes about the patient and other medical documents. It is a part of a medical record. Since a medical record can be seen as a collection of data from different medical procedures, MedicalRecordItem is the base class for such data. Any class defining some medical document extends this class. Thus, all medical treatments, examinations, analyses, procedures, and processes result in a creation of a medical record item (MRI). Each MRI has the list of properties stored as instances of the class MedicalRecordItemElement. For each property, the system stores its name, type and measurement unit. An MRI is also associated with the list of boundaries of normal values and the list of prices for different patients. Such generic modeling (actually, meta-modeling) offers the possibility to perform various extensions (e.g., of the set of medical services) in a uniform and consistent way. It also enables our generator tool (explained briefly in the next section) to automatically create a separate class and a database table for each medical record and MRI type. The defined EHR model is usable in any kind of ambulatory medical institution, but also in the hospital/clinical environment [10] because hospitals also keep their own history of illness for each hospitalization. These can be treated in the same way as MRIs within ambulatory institutions. However, after a hospitalization is finished, the hospitalization report could become a part of the main health record. Therefore, one can define the class HistoryOfDisease as a sub-class of MedicalRecordItem that brings specialization relevant for hospitals.

B. The Billing and Payment Model

The UML class diagram of the billing and payment model is shown in Figure 3. This model partly covers financial and business aspects of an ambulatory institution. It is used in combination with medical data to create bills for medical services, analyses and procedures conducted by the institution. The central class here is Payment, which models a bill for a medical service. (This bill could be a credit with a grace period and an interest rate.) Every instance of Payment is associated with a clinical staff member that verifies this bill. Each instance of Payment contains 1 or more instances of PaymentItem. A payment item represents price for 1 specific medical procedure done by a clinical staff member in the institution. Since some medical procedures are covered by insurance and some are not, for each payment item the list of payment modes (direct payment, payment by insurance) with related values must be defined. 1 patient can have 1 or more insurance policies that cover different medical procedures with different percentages. For each instance of the class Insurance, the list of insurance scopes is defined, where an insurance scope represents which percentage of the medical treatment price the insurance company covers. Based on these payment item coverage percentages, payment modes for a payment item are defined. For example, assume that a bronchoscope procedure costs 1000 Serbian dinars and is covered 75% by insurance. The payment item for this procedure will have 2 instances of PaymentMode sub-classes: 1 PaymentByInsurance instance with the value of 750 Serbian dinars and 1 DirectPayment instance with the value of 250 Serbian dinars. After a bill creation, the financial department will take care of the payment realization, using existing information systems. We are developing support for interoperability between our MIS and these financial information systems.

C. Actors and Contact Information

This part of our EHR is used for modeling all actors of MIS and for keeping track of their active and inactive contact information (e.g., postal address, telephone, e-mail). The UML class diagram for actors and contact information is posted on our Web site [3]. The base class is Actor, storing data of any entity taking part in our MIS. All actors have a unique id, a type, a current status within the MIS and a relevant qualified name. The list of contacts is also associated with the class Actor. Further specialization is brought through derived classes of Actor. There are two main branches, starting with sub-classes Person and Organization. The class Person is further inherited by the sub-classes Patient, ClinicalStaffMember, and MedicalStaffMember – these actors are the most important ones in healthcare delivery. Beside general demographic data, some additional information is kept about persons: the list of relationships between persons, the list of occupations and work places, and the list of general notes.

D. Users and Privileges

Since medical data are considered as very sensitive, precise and reliable system of access rights and privileges should be defined. In MIS (and similar systems), users must be divided into different groups by access levels to some sets of data [11, 8]. The UML class diagram for users and privileges is posted on our Web site [3]. Any Person object within our MIS is a
potential user. The separate class *ApplicationUser* is used for user profile modeling. It keeps track of user’s credentials and the actual status within the system. Each application user can be a member of one or more groups. Each group of users contains the list of application roles that will be assigned to any member. Each application role contains the list of application actions defined for different entities within the system. Using this scheme, generally, specific rights can be assigned to any user, but usually administrators can predefine the most common groups in order to assign these rights to users faster.

V. Software Support

Implementation of our software system support of ambulatory healthcare in Serbia (with the initial emphasis on the Niš region) started in mid 2008 and the first results are the database modeling tool, the database administration tool and the MIS for ambulatory healthcare support. Since Microsoft Windows platform is installed on almost all computers in the relevant medical facilities and since our team members are experienced Microsoft .NET programmers, we decided to use Microsoft’s technologies for software implementation: SQL Server for the database, .NET 3.5 as the implementation technology, Entity Framework for the data object model, and Team Foundation Server as the development environment source control system. Before we present our application supporting GP doctors and ambulatory healthcare, we will briefly summarize 2 auxiliary tools (the data modeling tool and the generator tool) we used to make the development process faster and more effective. There are also other auxiliary tools (e.g., XML2SQL is a custom-made converter that downloads XML structured data from the Ministry of Health and stores them in the database). Note that screenshot figures in this paper have text in Serbian (Cyrillic and/or Latin script), so we briefly describe their content and provide some screenshot annotations. Further information and examples are posted on our project’s Web site [3].

A. The Data Modelling Tool

The data modeling tool is the application used for defining the previously-discussed EHR medical data model shown in Figure 2. It generates database tables and prepares input for the generator tool that generates related classes and forms used in the further development process. The model created by the data modeling tool can be saved as an XML file and updated later. Currently, the tool only supports the Microsoft SQL Server database, but it can be easily adapted for use with any database supporting Object Linking and Embedding (OLE). Before the table generation process starts, the user has to enter a few necessary parameters (e.g., OLE connection settings) and to select tables that are related to the base medical record (the *MedicalRecord* class) and the base MRI (the *MedicalRecordItem* class). After this, the user can start specifying the structure of the new medical records and MRIs, including the corresponding MRI elements/fields and data ranges. When this definition process is finished, the user can run the table generation process. This process generates new tables in the database and saves the model in an XML file. Once the data model is mapped into the database, it can be used by our MIS. The created model can be updated later and the related tables will be re-constructed. An additional feature of the data modeling tool is creation of a model from a specific database. When the user specifies OLE connection settings, the medical record base table and the MRI base table, our tool examines the database structure and automatically creates the corresponding EHR model. The tool can automatically resolve situations when changes are detected only on one side (in the database or in the model), but when changes are found on both sides, the tool will prompt the list of changes to the user and offer her to merge the two versions. The user can choose to use the model version, to use the database version, or decide item by item what changes should be accepted.

B. The Generator Tool

During the implementation of our MIS, we decided to develop a software package (named *DatabaseStructure*) used to examine and verify the structure of any database accessible through a Microsoft OLE DB provider. This package was developed as a .NET dynamic link library (DLL) and can be integrated into any .NET application. In addition to reading tables, columns and relations of a database, the package also checks for anomalies in the database, such as the existence of circular relations, the absence of a primary key, and similar anomalies. This package is used to build a specific piece of software – the generator tool. The purpose of the generator tool is to enable automatic generation of some parts of an information system application (some classes and forms) from information in the specified database. Before the generation process starts, the user can choose a programming language for the generated .NET project, among the programming languages supported by the Microsoft’s CodeDom library. The generator tool connects to the database using an OLE DB provider, examines and verifies its structure, and then generates the new application as a .NET project along with executable files. The generated project can be further customized and improved, but all basic functionalities are created through the generation process. The created project contains a simple table editing form for each table. The resulting tables are further customized and transferred to the target application. Figure 4 shows an example table editing form and the resulting target application form in our MIS. In case of any change in the database, the generator tool can be
simply restarted and the forms will be re-created. In this way, we reduced the time needed for the development of applications for ambulatory healthcare support.

Figure 5. An Example of the Scheduling Tool

Figure 6. An Example of Doctor’s Overview of Patients

C. The Application Supporting Ambulatory Healthcare

Based on the described data model and code generation approach, we developed our software application to support ambulatory healthcare and address the specifics of Serbian public healthcare. The main task was to achieve direct mappings between all existing healthcare processes and our MIS. This makes our MIS easier to use by medical staff, since they do not have to change anything in their work procedures/processes, except use our MIS instead of filling paper documents.

The beginning of any medical treatment within the public ambulatory healthcare system in Serbia is the patient’s visit to a GP doctor. The GP doctor performs the initial medical examination and decides what to do next. For example, she can decide to send the patient to a specialist within the same medical facility or to the nearest general hospital. An important step here is searching for a patient in the database. The GP doctor or a nurse can enter (fully or partially) the following search criteria: the first name, the last name, the citizen personal number (unique across Serbia), the unique social security number, or the unique number on the insurance policy card. If the patient brings the insurance card, the doctor can scan the card number using a bar code scanner and instantly find the patient in the database maintained by the Ministry of Health. After the patient is located, other actions are possible. For example, Figure 5 shows the interface for scheduling visits to GP doctors or further medical examinations and treatments. The same interface is on the desktop application in the medical facility and in the Web application that patients can use from home. On the left side, the user chooses a specific doctor. Then, the grid on the right displays possible examination times: the occupied times are in red, while the free ones are in white. To schedule a medical procedure, the user only needs to click on a white field and verify this action in the prompted message box.

Doctor’s overview of patients is shown in Figure 6. In the upper-left corner there is a list of doctors. (When many patients are waiting, availability for various doctors can be examined.) In the center of the upper part of the form is the name of the patient, along with some basic data. On the right side is the calendar. The doctor or the scheduling nurse can switch the date to see schedules for some other day. In the bottom part of the form there are 3 lists of patients: on the left are patients scheduled for the selected day, in the center are patients that arrived into the medical facility and wait to be examined, while on the right are patients that have already been examined. The doctor can choose to examine a patient from the central list. By double-clicking on the patient’s name, the form showing the main page of our electronic medical record will appear. An example of this form and its comparison with the official paper medical record are shown in Figure 7. All patient’s medical data are organized into several tab controls analogous to the existing paper-based documents. The first tab displays patient’s general demographic and insurance data, and a note about important allergies. The other 4 tabs display the list of active histories of illnesses, the lists of other essential medical data (immunizations, hospitalizations, and important illnesses), data
about annual general medical examinations, and data about closed histories of illnesses. When a patient visits a doctor for a regular medical examination, the doctor will open the second tab (illustrated in Figure 8) and will start entering data for the current visit. On the left side there are 2 big text fields – the upper is for medical history and the lower is for medical advice. On the right side, 4 lists can be used for entering other specific data: diagnoses, recommended therapies (e.g., medicines), referrals to specialist medical examinations, and sick leaves.

Figure 8. An Example of GP Doctor’s Report after a Medical Examination

To ensure appropriateness of our MIS for healthcare professionals in Serbia, several senior doctors, nurses, administrators, and IT professionals from the central ambulatory facility in Niš took active part in its development. They also verified and validated the initial prototypes of our MIS software. The initial input and subsequent feedback received from these medical professionals was invaluable, because of their diverse perspectives, knowledge, and practical experiences with the complex procedures/processes in the ambulatory healthcare in Serbia. Based on their feedback, we did several modifications and improvements of our MIS. We conducted this thorough testing and improvement of functionality and usefulness of the initial prototypes of our MIS in computer laboratories, outside of healthcare facilities. It resulted in very high satisfaction by the involved medical professionals with our MIS software. After securing the buy-in from these medical professionals, we gave several presentations and demonstrations to medical department heads and IT professionals from the central ambulatory facility in Niš. First demonstrations were group presentations, but then we held separate meetings with each of these people key for installation of our MIS. During the latter meetings, we collected comments and some additional specific requirements, resulting in further improvements of our MIS. Subsequently, our MIS was installed in the current pilot use in several departments of the central ambulatory facility in Niš. We also trained current and potential future users of our MIS in that facility. When this pilot use is finished in late 2009, we will collect feedback and requests for further improvements. We aim to receive strong recommendations from the medical professionals involved in the pilot, so that we can proceed with the installation of an improved version of our MIS in all public ambulatory healthcare facilities in the Niš region. This multiple stage roll-out of our MIS is necessary to overcome resistance to change by medical staff members and to convince both medical professionals and patients into the benefits our MIS brings.

D. Connection with Data Analysis and Reporting Tools

We built into our ambulatory MIS interfaces for connection with various tools for data analysis and reporting, e.g., powerful tools using the On-Line Analytical Processing (OLAP) or relatively simple tools like our ReportER [7]. ReportER is a small reporting tool that can display fields from a database and allows doctors to use the common logical operators and brackets to easily get data they need, without writing Structured Query Language (SQL) statements. Figure 9 gives an example of OLAP results that doctors and medical researchers can use – it shows distribution of diagnosed neurologic illnesses across by marital status and sex. This example is related to our previous research, in which we developed MIS for pediatric, cardiology, and neurology clinics in Niš [12, 13]. We developed these MIS in 2002 and after 7 years of operation their databases contain relevant volumes of data and after many different data analyses and reports. Additional examples, including examples of OLAP results that management of ambulatory and hospital/clinical medical institutions can use (e.g., in performance evaluation of medical staff members), are posted on our project’s Web site [3]. As soon as the databases from our ambulatory MIS are filled in with relevant volumes of data, similar data analysis and reporting tools can be applied on this data.

Figure 9. An Example of OLAP Reporting

VI. CONCLUSIONS AND FUTURE WORK

The Ministry of Health of the Republic of Serbia, as a national ambulatory healthcare provider, is facing growing expectations about the quality of medical care. They have to invest significant time and resources to support development of new MIS for public healthcare facilities in Serbia. The presented MIS for ambulatory healthcare support has been created to simplify all steps in the complex system of ambulatory healthcare in Serbia (with the initial emphasis on the Niš region). Its target users are medical practitioners, particularly GP doctors, who have massive paperwork after each medical examination.

We have addressed the main requirement of remaining compatible with the existing organization of the Serbian public healthcare system by following the existing division of work between different facilities and departments and by following the existing procedures/processes. To address the related requirement that the MIS interface should closely resemble paper
documents, we used the existing document formats and the existing terminology in our EHR model and the interface forms. Only in a few cases we had to make minor adjustments (e.g., in visual layout). The medical professionals who participated in the development and/or evaluation of our MIS verified that these differences are no impediment for practical acceptance of our MIS. This approach also accommodates the low computer skills of many target users, because methodology of work and habits are not changed drastically. With this, we have also alleviated the significant challenge of resistance to change and the danger that our MIS will not be used in practice. To satisfy the requirement of minimizing typing of medical data, we use scanning of the patient’s personal health booklet bar-code to obtain all patient-related data stored by the Ministry of Health and health insurance. We also allow medical staff to select common information from the lists of valid options.

Similar requirements and challenges exist in many other countries. Additionally, some developing countries, particularly the countries of former Yugoslavia and East Europe, have somewhat similar healthcare characteristics (e.g., types and forms of medical documents across former Yugoslavia have similarities). We have been developing our MIS in a way that enables easy adaptation and localization to other countries. Its architecture has several layers (tiers) and services/modules are relatively independent from each other. For example, we provided interfaces to various data analysis and reporting tools. For security, but also to enable easier changes, access to data from application-level services/modules can go only through the virtual EHR service. Application-level services (e.g., for scheduling) can have a Web interface, but can also be run as desktop software (this is necessary in situations when Internet connectivity is not satisfactory). Our EHR model not only captures information from paper documents in the Serbian public healthcare system, but is also extensible and adaptable for other countries, because it applies generic modeling. The supported data modeling and code generation approach and the software tools we developed for it enable rapid implementation of new versions and variations (e.g., for other countries) of our MIS.

The MIS presented in this paper is the result of the first phase of our project. We have already started the second phase, in which our main focus is on providing interoperability and collaboration between the electronic medical record (EHR) and the clinical MIS within the University Clinical Center of Niš (UCCN). Since Niš is a regional medical center, patients from smaller towns often come to Niš for specialist medical analyses or examinations in the central ambulatory facility or the clinical center. Many of these visits have to be scheduled, sometimes several months in advance. Currently, doctors in hospitals and doctors in ambulatory healthcare facilities conduct little data exchange. The only exchanged data is the history of the illness – in most cases, this is a 1-page paper document containing only data about 1 specific illness. Thus, doctors in hospitals usually do not have any record of how and why the patient was treated prior to coming to them. Acquiring full patient history takes long time in hospitals and the data are often incomplete or incorrect (e.g., some patients deliberately hide parts of their medical history). Conversely, when the hospital treatment is completed, the doctor in the ambulatory healthcare facility receives only a brief report about the patient’s current physical condition. Therefore, integration and collaboration between the EHR and the clinical MIS in the primary (ambulatory) and the secondary (hospital) healthcare in Serbia is a must. To achieve it, we are currently testing software that we wrote for connecting our MIS with biochemistry analyzers, which produce data about blood and urine analyses and store the data in a specific local format that differs from one manufacturer to another. This task will be finished in 2009. We are also working on a notification service informing doctors and patients about significant events and information (e.g., analysis results) via short message service (SMS) or e-mail. We also plan support for personal digital assistant (PDA) devices. Further, particular attention is given to enriching our MIS with a business intelligence (BI) module and a special search engine for data retrieval. At the end of the project, our software will: provide support for both ambulatory and clinical healthcare and their collaboration, be fully appropriate for Serbian circumstances, have features of modern MIS from developed countries, and enable interoperability of our MIS with other information systems in Serbia and abroad.

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