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Kardionet — Web based system to support cardiovascular
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Kardionet - Web based system to support cardiovascular hospital treatment

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Abstract In this paper we describe Kardionet system to support medical treatment of the cardiac patients. Distinguishing feature of the system is use open source software and freely available programs or libraries that allowed for significantly reduce of the cost of producing and maintaining it.

The Kardionet system allows the integration of various systems used in hospitals, such as image datastorage systems, and allows for easy collection of patient data at the all stages. The system speeds up consultation process and supports quick decisionmaking which is crucial for patients with heart disease. Kardionet system works with mobile devices such as tablet PCs and smartphones, allowing a wide, fast and convenient access to the electronic medical records. It also allows for automatic notification of the users about events recorded by the system.

Kardionet system is the result of close collaboration between medical doctors from the Central Clinical Hospital in Warsaw and computer scientists at the Interdisciplinary Centre for Mathematical and Computational Modelling, University of Warsaw.

1 Introduction

Information systems are gaining important role in modern health care system, both hospital and non-hospital. The main task is to support a physician in the diagnosis and treatment of patients. One of the basic tasks of such systems is to collect, storage and process information. In the case of medical application the main data is information about the patients and their treatment.

The history of electronic systems in medicine is long and there are many solutions available, primarily commercial. Unfortunately, most solutions are created as a broad application applicable to various hospital departments and hospitals with different specificities. They are not optimized for a specific usage area which is this case treatment of patients with heart disease. For this reason, it has been necessary to create a dedicated computer system, which will take into account the specificity of the cardiac treatment. The most important is fast collection of the information about the patient - at the time the rescue team reaches patient

and make decision which action is necessary action. This proces should be accomplished by gathering, analysis and sharing of various data about the patient including image data of various type.

Another important motivation to create a modern system for the cardiology are advances of the modern technology, both in terms of software and hardware solutions. The most important is use of mobile devices such as tablet PCs and smartphones as terminals for the system and use of the web technology for creating user interface. Thus it became possible to support the healing process from the moment of arrival of the rescue team to the patient and at all stages of patient stay in hospital. The use of the mobile devices has enabled the staff to convenient access to the data.

In this paper we describe innovative system Kardionet which uses latest software and hardware technologies to create flexible and scalable system to support medical treatment of the cardiac patients. It should be pointed out that system Kardionet allowed for a significant increase in functionality over the existing solutions. It has created a basis for further development and applications in other medical areas. This was achieved through the use of modern information technologies and by working closely with doctors, who determined the shape and functionality of the system.

The computer system Kardionet consists of many elements. The main part is data storage and data sharing, which cooperates with the imaging systems, data collection and communication systems with the rescue teams. Data obtained from the external systems are collected in the Kardionet database and are made available by using a dedicated user interface. The modular system design and the use of standard interfaces based on the web services technology allows to interact with the other systems. At present, Kardionet system includes:

1. system for storing and sharing data
2. tools for processing image data,
3. tools used for data transmission from the ambulances,
4. notification system for medical doctors.

System for storage and retrieval of the data allows to enter and modify the patient's medical history. Using this system, doctors and other authorized personnel can view, update and analyze data about a patient and his hospitalization. The system has powerful user interface that allows easy access to the data. Kardionet allows also to manage users and define access rights to the medical data.

Tools for image processing and storage are designed to facilitate appropriate analysis of the medical images to allow easy and quick diagnosis of the patient. Basic tools to access the image data and perform simple analysis are built-in Web-based user interface. Advanced image analysis is performed using a dedicated application cooperating with the data storage system.

Ambulances are equipped with tools that allow to enter data about the patient and his illness into Kardionet system during the initial contact with the patient. Thanks to this, the doctor on duty can become acquainted with the state of a patient, decide which action to take and properly prepare medical units for

help. The system is also capable of including transmission of ECG signal, which becomes another element in facilitating an appropriate diagnosis of the patient.

The notification system is responsible to quickly inform doctors about events for which it is necessary to react. Example event is an insertion patient's disease to the system by rescue team or reception. The doctor on duty can therefore almost immediately, take the necessary action.

2 Concept of the Kardionet system

While Kardionet system was designed, the main emphasis was put on the integration of the main parts of the system with the user interface. With such approach the user interface has become a major element in delivering data to users. For this reason, the requirements for the user interface are:

- access from many places - for example, from nurses room, doctors offices, other medical centers through the Internet or dedicated network,
- access from multiple devices such as desktop computers, small mobile devices: tablets, smartphones, PDAs,
- secure access to the data - extended permission system to access patient data c,ombined with the user roles,
- validation of the data entered - validation of user-specified data with the display of the appropriate warning and error messages,
- dynamic user interface providing users with interactive functionality similar to the desktop applications (dynamic validation of data, hints, etc.),
- simultaneous work on the multiple windows - allowing for the simultaneous operations on the different data
- extensions - enabling creation, expansion and addition of new functionalities to the system using modular construction,
- ability to develop system by many people - the modular architecture allows for efficient application development, shortens time to release a stable and functional version of the system and reduces development costs and maintenance.

2.1 Technologies used

In order to meet the objectives, especially those related to the access to the application from various devices, we have selected Web technologies. They allows nowadays to develop single user interface, which can be displayed using web browsers available for the wide range of the devices.

From the variety of the web technologies we have selected the Enterprise Java platform (JEE) [2], which is a standard development tool for the component-based architecture. JEE-based applications, like those written in Java will run on any hardware architecture, and any operating system, where Java Virtual Machine is available. In addition, applications allow for a high level of safety and are very efficient. Moreover, solutions based on the JEE should, without

major modifications, operate on any available application server, and thus the choice of the application server is not essential. In particular case we have selected Apache Tomcat 6.0 [3].

Modern web technologies provide many opportunities for creating software applications. For the construction of the skeleton Spring Application Framework, Version 2.5.6 has been chosen. The database access was implemented as Spring JDBC. One of the objectives of the project was to obtain maximum functionality of the user interface - similar to that presented by the traditional desktop applications, while minimizing the number of used technology and libraries. Therefore, the user interface is written using the following technologies and libraries:

- JavaServer Pages (version 2.1) [4] - the basic operations associated with displaying the user interface
- JavaServer Faces (version 1.2.1913) [5] - creating a user interface using templates,
- Facelets (version 1.1.1915) [6] - library for facilitating user interface, it serves as a support for JavaServer Faces
- Apache MyFaces Trinidad (version 1.2) [7] - a collection of user interface components
- Google Web Toolkit (version 1.7.0) [8] - a collection of easy to build user interfaces using AJAX technology.

It should be emphasized that all the technologies and the libraries used are open, available as open source which reduces the manufacturing costs of the final system.

3 Project Structure

The project structure can be divided into several parts: the hardware infrastructure, the structure of the source code and logical structure.

3.1 Hardware infrastructure

Kardionet system consists of several components forming the hardware infrastructure. We can distinguish the following elements:

- database server for users and patients data
- server for cardiac data transmission from the emergency units
- SMS notification server
- server for image data
- Web server
- clients
- tablet Client
- other client devices (eg smartphones, PDA's, mobile devices)

The arrangement of these components is flexible and depends on hardware capabilities. For example it is not necessary to install a central database and a web server on one computer, the infrastructure components can be installed on different computers.

3.2 Software components

The source code of the Kardionet project is divided into Apache Maven modules, separate parts of the code with their own dependency, which can be developed independently. Among nearly 40 modules there are responsible for different activities such as access to the database or sending SMS notifications. There is number of GWT modules responsible for particular input forms or displays of acquired data. The dedicated module intragates all GWT modules in a single framework.

3.3 User Interface design patterns

The user interface was developed using a series of design patterns and libraries. The two most important design patterns used in the Kardionet system are: MVC pattern and the pattern of MVP.

MVC Pattern MVC (Model-View-Controller) is a design pattern to separate data (model) from the way how it should be presented, (view) and logic (Controller). The main advantages of MVC is possibility to use a single data model in multiple views, possibility to use multiple instances of the same data model in one view, ease implementation, testing and maintenance of the data model, and finally easy way to add new types of components.

MVP Pattern MVP (Model-View-Presenter) is a derivative of MVC design pattern. As in the MVC, the model is data to display, and the view is a user interface. Presenter is the mediator between the model and the view. If the action takes place in the view, it is delegated to the presenter who performs the appropriate operations on the model, then view is updated. The view has no direct access to the data. In contrast to the MVC view not only displays the user interface, but also responds to the user interface events (in the MVC, it was the task of the controller).

The advantage of MVP design pattern is possibility to change the data display technology (view) with a small amount of work.

In order to apply the MVP pattern to the GWT module the code is divided into the main class that implements EntryPoint and four additional classes. The first one is called MvpWidget consists of the components displayed on the page, or widgets. The second part is called MvpView. This interface contains the names of all the methods that must implement MvpWidget class. These methods are used to get and set values in the widgets and to add the event handler. The next part is a class MvpPresenter that displays MvpWidget and by using the methods declared in MvpView, adds behavior to the components displayed on the page. It also sends data to be displayed in the components. The last part is a class that implements EntryPoint. Its task is to create objects and classes MvpWidget and MvpPresenter. It also shows various components of the MvpWidget.

The user interface of the Kardionet system is designed primarily in GWT. This technology requires large number of JavaScript code to be loaded to the

client during the first time the module is displayed, than further work is very effective. In the current implementation the transfer speed was acceptable, but optimization of the generated HTML code is necessary.

3.4 The basic functionality of the system Kardionet

The following paragraphs describes the basic functionalities provided by the user interface.

Registration interface is used to set up accounts for the users. New user provides his details such as name, phone number, e-mail, medical center and a branch he is working in. If he is a doctor, he provides medical record number. After registration a new user can not log in until the administrator assigns him to the department, medical facility or the entire system. This process requires verification of the authenticity of the information given by user. If user is involved with several branches, it is sufficient that the administrator's authorized person at least at one branch.

System access is protected by a password that must be at least six characters length, must include small and large letters and numbers or special characters. Thus, knowledge of the user login system does not allow for an easy way to break his password using brute force methods.

Permissions As the main task of the kardionet system is to store electronic patient records, it is important that no one has unauthorized access to data. It is not just about read access to the data, but also access to the functionality which allows to add and modify data.

User can log into the system if the account is authorized in at least one branch, to which the user is enrolled. In addition, correct username and password in the login panel has to be provided. In order to prevent break the password validation is performed by repeatedly calls of the hash function SHA-1. In addition, all-time password hashes are salted, which results in the fact that two identical passwords will be stored in a different way in the database.

After logging into the system, the user sees only menu items he can use. For example, administrators can see links to the member list of the branch, but he cannot register a new patient or a search for a patient.

Each page includes a parameter `canView`, whose task is to transfer to the main page information if the user has sufficient permissions to view this page.

For example, if a user enters module that displays all the users of the system, the system checks if the user is logged on and whether it has sufficient rights. Since kardionet system is heavily using asynchronous communication, there is implemented mechanism that allows to check each asynchronous request. System is capable to verify if the user sending the request is logged, and whether it has adequate rights. If so, the request is processed, and if not, appropriate message is displayed to the user.

If the user is authorized in more than one branch, he can change the currently selected medical unit.

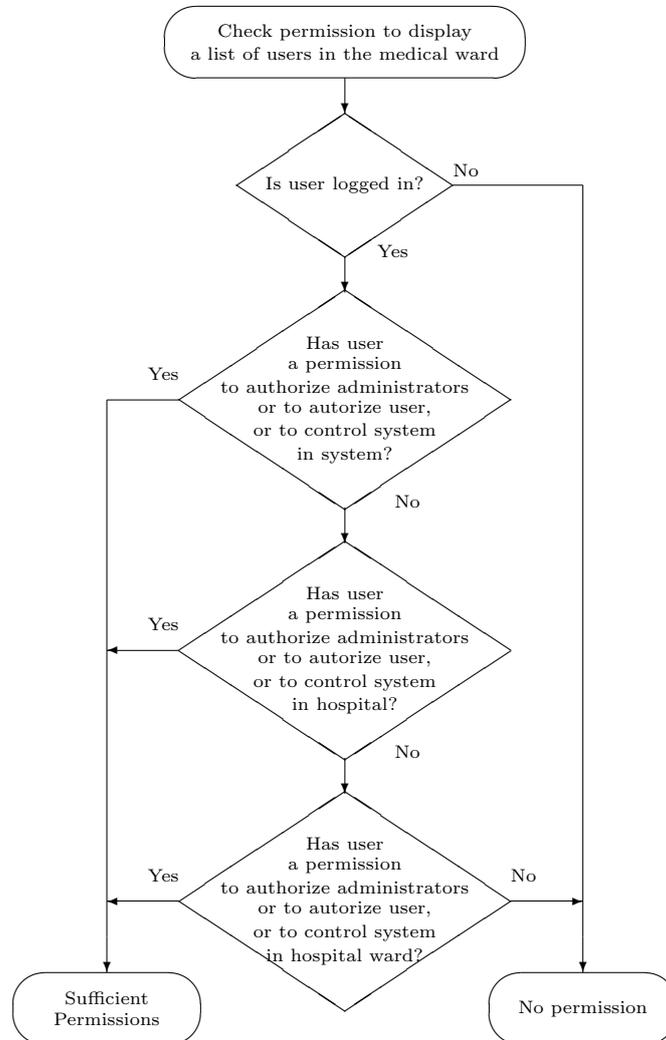


Fig. 1. Schematic representation of process of checking user permission to display the page

User roles The system of roles in the Kardionet system is flexible and expandable. A new role to the system can be easily added, although this requires to add new entry directly into the database and to restart the application. Despite this way to add new roles is simple and does not require any changes in the interference and in the code. Currently defined user roles are as follows:

- superadmin - an administrator who has the right to control the operation of the system and may create new medical centers in the system, and new offices in a medical center and can also authenticate the user and edit the data and transmit and receive roles
- admin - the administrator who has the right to authenticate users and to modify their data,
- doctor, nurse, intern - have the right to enter and modify patient data,
- student, dude - do not have the right to enter or edit data about the patient,
- attending physician - a user with this role will be noted that currently is on duty, so it has more possibilities to use the system, especially he receives notifications about new patients,
- consultant - a user with this role can consult the patient data.

In addition, each role has a range of activities. There are three main ranges assign to the role:

- System - the role is attributed to the whole system, the user has rights to access data from all medical centers,
- Centre - the role is attributed to the whole hospital, the users can access data from the medical center he is allocated,
- Branch - the role is attributed only to the branch.

User Authentication During installation, the system account is created with the superadmin role. This user is no longer an authorized user, his task is the authentication of other users and giving them the appropriate permissions. Due to the architecture of the system root account is assigned to the administrator of the one of the branches of the medical center where she works. Administrator, who can authorize the user in the branch, is:

- administrator of the branch or
- administrator of the medical center, where the branch is located or
- system administrator

Any administrator who can authorize the user, may also revoke its authorization, regardless of which authorized the Administrator user.

Site operation The person entering the Kardionet system after logging into the system will see a window with the basic information:

- name of the user,
- center and medical unit, with a link to allow the change of the currently selected medical facility,
- button to logout
- a link to change user's profile data,
- link to the registration of a new patient,
- link to search the patient's of the current medical center,

- reference to the notification system (if user is doctor on duty),
- reference to the management of the Kardionet system.

Each link directs to a page that is loading GWT module responsible for particular part of the system. Each module is independent, although some modules may require the data set in other modules.

If a user tries to view the content he is not authorized to, he will see the message about insufficient permissions. Similarly, if the user attempts to perform an illegal action he will be informed about insufficient permissions.

3.5 Notification system for cardiac data

One of the main features, in addition to storing and processing of patients' medical history, is data transmission from the emergency units which is especially important for the patients with the heart disease. The system allows to transfer patient data along with the ECG signal from the emergency unit to the hospital. The doctor on duty receives data and based on them helps rescue team to take decision about further patient treatment including decision about transportation to the selected hospital. Early decision results in significant shortening of the time between picking up patient and starting adequate medical treatment. The shortening of this time is critical for the successful treatment.

In order to quick and automatic information of the doctors about new patient data notification system has been developed. It consists of the retrieval system which stores newly communicated data in the kardionet database. This event is followed by sending an SMS message to the defined cell phones of doctors on duty. Once doctor is notified he can read uploaded data about the patient and his condition and then he can quickly decide on further treatment. If the patient's hospitalization is needed, patient's medical history is automatically created. A detailed diagram of the flow of information during the transmission of the cardiac data is shown in the Fig. 3.5

3.6 Image data in the Kardionet system

One of the important functionality of the system is the integration of the health record with the systems for collecting and sharing of imaging data. Usually a dedicated database for storing medical images and data describing it is created. Kardionet system allows to include image data to the patient's health record. It allows also to interoperate with the existing image servers and databases, data acquisition and imaging systems based on the existing PACS systems.

Kardionet system provides administrators with tools to configure data sources such as DICOM Servers. While viewing an individual patient's disease history Kardionet system queries the registered image data storage systems for the availability of the image data. If such data is present it is downloaded and stored in the Kardionet database. From this moment image data is viewed as part of the patient's health record, however the Kardionet system is capable to check if updated images are available.

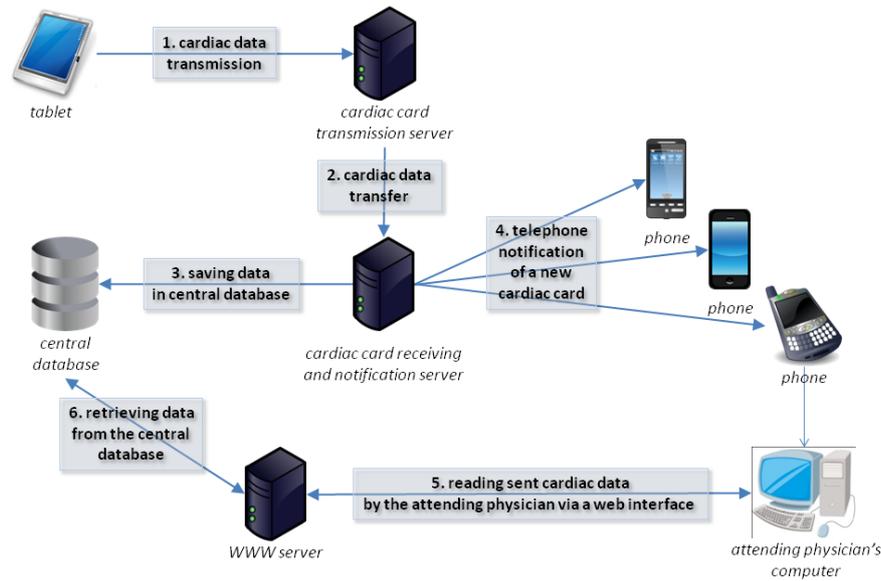


Fig. 2. Notification schema of the cardiac card transmission. [Source: own]

4 Summary

The described here Kardionet system is the result of close collaboration between medical doctors from the Central Clinical Hospital in Warsaw and computer scientists at the Interdisciplinary Centre for Mathematical and Computational Modelling, University of Warsaw. Such close cooperation, allowed us to create modern computer system to support treatment of the cardiac patients. Distinguishing feature of the system is use open source software and freely available programs or libraries that allowed for significantly reduce of the cost of producing and maintaining the system.

The computer system allows the integration of various systems used in hospitals, such as image data storage systems, and allows for easy collection of patient data at the all stages. The system speeds up consultation process and supports quick decision-making which is crucial for patients with heart disease. Kardionet system works with mobile devices such as tablet PCs and smartphones, allowing a wide, fast and convenient access to the electronic medical records. It also allows for automatic notification of the users about events recorded by the system.

Kardionet system is currently being tested at the Central Clinical Hospital in Warsaw.

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