Web-Based Tool for Management of CAD Patients after Coronary Bypass Surgery

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Abstract

The purpose was to create a flexible system for biomedical data acquisition, analysis and archiving. Web-based tool includes centralized storage of data of coronary artery disease (CAD) patients after coronary artery bypass surgery (CABS) at different stages of treatment. The implemented web based tool is based on client-server architecture and international open source technologies including Apache web server, PHP scripts and MySQL database. The system implemented in client server architecture. The server stores the data and controls basic system functionalities. The client is used by users in order to access data from the server. The system should assure strict secure measures, that is why system is available only for authorized users. Web-based tool enable to monitor patient's functional state, to evaluate the effectiveness of treatment using novel methods of data visualization as well as to establish teleconsultations among doctor-doctor and patient-doctor- patient.

1. Introduction

Many teams of health professionals are involved in medical care of coronary artery disease (CAD) patients: general physicians, cardiologists, cardio surgeons, kinesiologists, physiotherapists, social workers etc. After cardiac surgery patients undergo in-patient rehabilitation program which continues at home under supervision of family doctor. In this way a patient is treated in different health care institutions. A huge medical data are collected and a rapid exchange of information of patient's data between different specialists should be provided quickly. Teleconsultations play crucial role in this process.

The aim of this work was to create a web-based tool for biomedical data acquisition, analysis and archiving, allowing continuously monitor the status of CAD patients after coronary artery bypass surgery (CABS) during long-term rehabilitation program and to evaluate the effectiveness of the treatment.

2. Structure of web-based tool

The structure of the Web-based tool is shown in Figure 1. Technologies used in the Web system include Apache web server, PHP scripts, MySQL database server. Data mining tool included into the system for visualization of various psychological tests and feature extraction from biomedical database for further analysis. The client can use any web browser to contact server. Apache web server is used to run PHP programs that perform communication between user and web based tool via user interface.

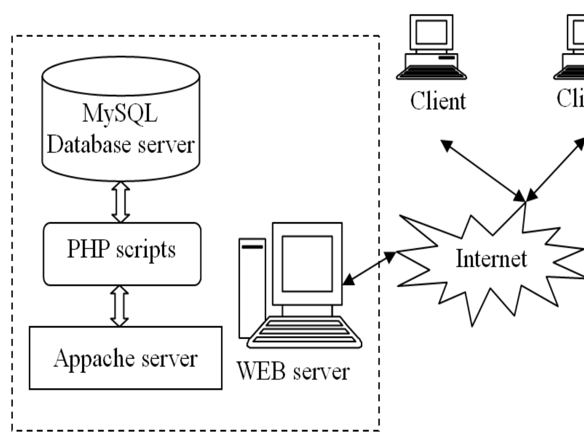

Figure 1. Web-based tool for management of CAD patients after coronary artery bypass surgery structure.

A Web-based tool is easy to maintain and guarantees user access to the latest, most recent versions. The clients connect to the Web server using Web browser. For user interface interaction and data flow organization the Web server uses PHP, Java and other programming techniques.

The data depending on the security level and user role are accessible in different treatment levels only to physicians and specialists of strongly defined field and group. System recognizes four user roles:

1) Information system administrator;
2) Patient's data manager;

3) Reviewer;
4) Patient.

Each role has a particular set of transaction capabilities. Information system administrator's capabilities are: input, update, delete, review system users and patient's administrative and biomedical data. User, having manager role of patient's data, can upload, modify and delete data. User with prescribed reviewer role can review data and generate reports. Individual patient can review his own data of different treatment stages.

Components of Web-based tool are shown in Figure 2. Biomedical database can be separated into three main components:

1) Patient's complaints and clinical signs;
2) Psychoemotional state;
3) Functional investigations.

Each of them has a number of data which is obtained in different health care institutions.

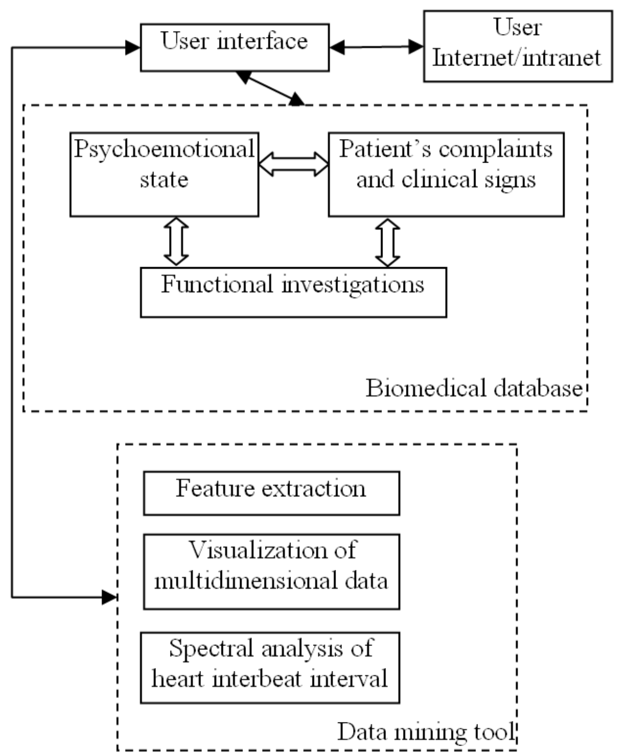

Figure 2. Web-based tool components.

First database component contains patient's administrative data, his complaints and clinical signs and symptoms for every treatment period.

Second component contains data on assessment of patient's psychoemotional state and the schedule of the individualized program for long-term rehabilitation (defining patient's state, physical capacity, aims and tasks of rehabilitation, aspects of physical rehabilitation, medical treatment, and secondary prevention).

Third component contains data obtained from performed different functional tests such as ECG, echocardiography, angiography, echo stress test, active orthostatic test, bicycle ergometry, polysomnography, etc. Data of psychological testing on sleep quality (Pittsburgh Sleep Quality Index [1]), depression and anxiety (HAD Scale [2,3] are included too. All tests can be performed repetitively during the same follow-up period.

At present time the data collected during different investigation periods of 775 patients (3300 investigations) are stored in the database. Attribute groups and number of attributes in each group are shown in the Table 1.

The elaborated database is in compliance with national (Lithuanian) and EU regulations on safety and data protection. Data are kept confidential. Electronic transfers of data strictly follow data protection guidelines.

Table 1. Attribute groups and number of attributes in biomedical database.

Attribute groups	Number of attributes
Administrative data	30
Clinical data	48
Coronary angiography	26
Active orthostatic test in the morning	25
Active orthostatic test in the evening	25
Active orthostatic test at noon and bycicle ergometry	52
Polysomnography	105
Echocardiography	18
Revascularization and complications	30
Heart rate data during tests including spectral analysis and Poincare plots	62

In biomedical database raw data of physiological signals obtained during functional testing are collected and ready for further processing by means of data mining tool.

3. Data mining tool

Development of new diagnostic methods most frequently is based on frontier knowledge in physiology, genetics, biochemistry, etc. New diagnostics can be also developed combining bio-medical methods with recent achievements in data analysis and information technology. Such a prospective synergy is well represented by a term "medical data mining" [4].

One of the goals of the constructed database described above is to aid development of diagnostic methods of sleep quality based on assessment of sleep stages using information extracted from heart interbeat interval (RR) time sequences. Heart rate sleep pattern depends on modification of autonomic control which changes during the shifts of sleep stages. Because of that there is possible to assess individual sleep stage and evaluate the sleep structure. The latter data can be collected by relatively simple and inexpensive methods. Therefore it is important to extract from this data as much as possible information relevant to the considered patient's functional state and its changes during long-term observation and treatment.

The following standard methods constituting data mining systems are used: data analysis, cauterization, classification and visualization. We emphasize the role of visualization, since involvement of human heuristic abilities to analysis of complicated non-linear phenomena characteristic for biomedical data is of special importance.

3.1. Feature extraction from biomedical database

A problem of feature extraction from heart rate data related to the diagnosis of sleep disorders and diseases is considered. Raw data of heart interbeat interval (RR) and stroke volume (SV) sequences are taken from web-based database. The standard methods for time series analysis, e.g. statistical inference, hypotheses testing, correlation analysis, spectral analysis etc. are included in our tool. Recently methods of nonlinear dynamics have appeared prospective in the analysis of medical time series [5,6]. We have included into our data mining tool frequently used in bioinformatics algorithms of estimating parameters of nonlinear dynamics as well as methods of empirical mode decomposition and progressive detrended fluctuation analysis. The published results in the field of medical data mining concern one dimensional time series, e.g. RR time series. Some additional information can be extracted analyzing vector series, in our case two dimensional (RR, SV) series. Therefore we have included into data mining tool also methods of vector series analysis.

Diagnostic of sleep illnesses and disorders heavily relies on evaluation of sleep structure requesting recognition of sleep stages from estimates of parameters of time series analysis. As mentioned above, different statistical, spectral and non-linear dynamic parameters are taken into account. The choice of a proper classification method from our toolbox should be guaranteed, since the goal of the described data mining tool is to aid the development of a reliable automatic recognition method of sleep stages. The known classification methods like discriminant analysis, artificial neural networks (ANN), support vector machines (SVM) are included as well as comparatively new classification methods based on linear programming; for an original idea we refer to [7].

3.2. Visualization of multidimensional data

One of the most important data mining tools is visualization of the available information. Visualization helps to involve heuristic human abilities in analysis, classification and decision making. It is especially difficult to extend human intuition to multidimensional space, since physical imagination is restricted with three dimensions. For visualization of multidimensional data we use methods of multidimensional scaling (MDS) [8,9]. Let us briefly introduce the idea of MDS. The goal is to present a two dimensional picture to represent a population of patients who are described by multidimensional vectors. The components of vectors are numerical expression of different objective symptoms and/or subjective self-assessment. Data on i-th patients constitutes vector X_i, and patients are indexed as $i=1,\dots,k$. The set of two-dimensional vectors X_I , $i=1,\dots,k$ is constructed using the idea of MDS to map a set of n dimensional vectors to a two dimensional plane preserving as much as possible the mutual distances between vectors. Mathematically this problem can be formulated as minimization of

$$stress = \sum_{i=1}^{k} \sum_{j=i+1}^{k} (d_{ij}(Z) - \delta_{ij}(X))^2 ,$$

with respect to $Z=(Z_1,\dots,Z_k)$, where $d_{ij}(Z)=\|Z_i - Z_j\|$, $\delta_{ij}(X)=\|X_i - X_j\|$, and $\|\cdot\|$ denotes a norm in the n dimensional space and in the two dimensional space correspondingly. The minimization of *stress* is a difficult problem because of multimodality, high dimensionality and possible non differentiability. Possibly because of these difficulties MDS methods are not popular in data mining. However, hybrid methods based on combination of evolutionary global search and local descent [10] appeared sufficiently efficient to visualize multidimensional bio medical data related to sleep problems.

To illustrate the application of MDS based visualization of multidimensional data let us consider a data of 80 patients of the Rehabilitation hospital of the Institute of Psychophysiology and Rehabilitation in Palanga, Lithuania. Data on each patient is represented by fourteenth dimensional vector whose components are scores according to answers to the questionnaire of Hospital Anxiety and Depression Scale [2,3]. The two dimensional image of the data is presented in Figure 3.

The clustering of patients into groups is well shown. Four groups are indicated: (1) no anxiety and no depression, (2) depression and no anxiety, (3) anxiety and no depression, and (4) depression and anxiety. On the computer screen the picture can be shown in colors, making visualization more impressive. The data on a new patient can be shown in the picture by a special marker enabling a physician to make a preliminary assessment of a patient very fast.

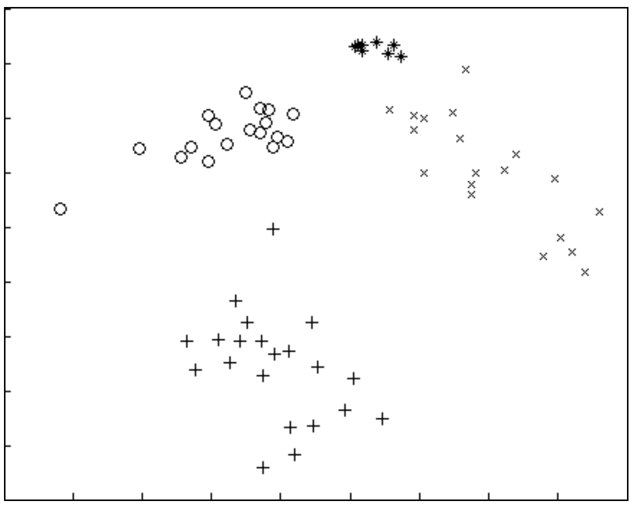

Figure 3. Visualization of data on psychoemotional status assessment using Hospital and Anxiety Scale. Note that the points representing patients appear as follows: *, no anxiety and no depression; x, depression and no anxiety; o, anxiety and no depression; +, depression and anxiety.

4. Discussion and conclusions

The elaborated web-based tool based on new Internet techniques includes data storage and analysis, decision support system, visualization of data and teleconsultations for health care service. The advantages of web-based tool are: ease of use and access for the user, ease of storage of testing data, centralized information storage and management. Such systems are easy to maintain as they only present one common application for every user and guarantee user access to the latest, most recent versions.

Data mining results can be used for sleep apnea detection, visualization of assessment of psychoemotional state.

Feature extraction from biomedical database and performed spectral analysis of heart interbeat intervals (RR) can be used with well known classification methods such as artificial neural networks (ANN), support vector machines (SVM) for sleep stages classification and sleep apnea detection in future.

The visualization of biomedical multidimensional data using MDS methods aids the discovery of structural properties of data; inasmuch such two-dimensional visualization extends human heuristic capabilities to analyze multidimensional objects.

Web-based tool enable to monitor patient's functional state, to evaluate the effectiveness of treatment using novel methods of data visualization as well as to establish teleconsultations among doctor-doctor and patient-doctor-patient. It improves diagnostics and increase effectiveness medical information exchange and provides urgent medical teleconsultations.

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