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A Web Application for Managing Data of Cardiovascular Risk Patients

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Abstract— **In the last years the development of home based e-health applications, which use information, telecommunication and videoconferencing technologies, is increased because of their characteristics that allow reducing hospitalization costs and managing and monitoring patient health in real time. However, the development of a home based e-health monitoring system requires the contribution of different expertise, from medicine to engineering, and technologies, from Electronics to Medical Informatics and Telemedicine. Here we illustrate a home based e-health project that has been developed with the cooperation of several different research groups of the Bioengineer Department of the "Politecnico di Milano". They provided and integrated all required knowledge and background, including Biomedical Electronics and Biosensors, Biosignal Processing, Medical Informatics and Telemedicine, and Information and Communication Technologies. The aim of the discussed work was to design and implement a Web application that enables different healthcare actors to insert and browse healthcare data, bio-signals, and biomedical images of patients enrolled in a program of cardiovascular risk prevention. Such application is intended to be part of a home monitoring system to be used during the home physical training program of cardiovascular risk patients.**

I. INTRODUCTION

HOME e-health applications represent important instruments for physician to control patient health for diagnostic, rehabilitative and therapeutic purposes, as well as to assess efficacy of treatment. Development of wearable and noninvasive devices and of telecommunication technologies allows improving data acquisition and obtaining more realistic and reliable information of patient conditions than traditional measurements in hospital [1].

From the technological and decisional point of view, a home monitoring system is a complex environment with an updatable knowledge base. Thus, for its development it is fundamental not only to acquire and monitor biomedical signals but also to extract useful parameters in order to immediately synthesize the patient health status in a clear and easy way by considering a minimum amount of data [2].

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It is hence necessary to take into account signal fluctuations and to predispose, with the minimum transmission delay and maximum failure robustness, either alarms or emergency messages in case of abnormal signal patterns or parameter values exceeding predefined thresholds [3]. Moreover a significant interaction with physicians is also recommended in order to establish how many times, in what representation format and to whom the home monitoring information must be sent.

Considering the above requirements, the home monitoring system described in this work has been designed by different research groups. Each of them was in charge of one of the system main components: signal acquisition, local data storage, signal processing, data transmission, and centralized data storage (see Figure 1). This allowed developing a precise, reliable and effective tool for the home monitoring of patients with moderate cardiovascular risk.

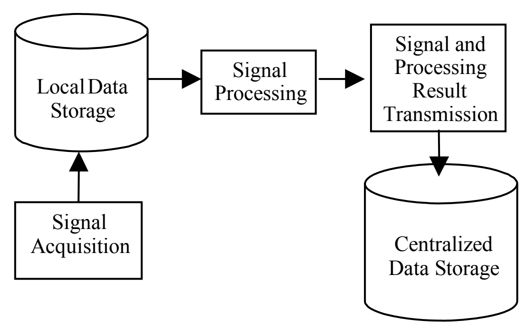

Fig. 1. Building blocks of our home monitoring system. The acquisition of signals, storing of local data, and signal processing occurred at patient home regard a single person. The data stored into the "Centralized Data Storage" block regard all monitored patients and are available for offline advanced processing.

Here we discuss the design and implementation of a Web application we built on the described system. It enables different healthcare actors to insert, browse, and share healthcare data, bio-signals, and biomedical images of patient enrolled in a program of cardiovascular risk prevention.

II. PROJECT OVERVIEW

The considered patients have some risk factors (such as smoke, diabetes, and cholesterol) and had none, one, or more ischemic episodes without suffering permanent heart damage. The treatment of such patients is named "secondary heart prevention”. We hypothesized a secondary heart prevention program composed as it follows. First, a cardiologic visit is performed at patient enrolment. Then, during hospitalization the patient is treated with a daily physical training consisting of using a cycle ergometer while being monitored by healthcare personnel. At the same time some patient vital signs and signals from the cycle ergometer are recorded. After hospital discharge, during some months the patient will practice the training at home.

In order to describe patient health conditions, his/her ECG signal is studied during the daily training program, which is characterized by 30 minutes of cycle ergometer exercise preceded and followed by 5 minutes of rest [4].

During the training with the cycle ergometer, one lead ECG signal is recorded by an ECG handle device mounting a Microchip DSP micro controller. The device permits to define sampling rate (from 250 Hz, to 500 Hz, also up to 1000 Hz), exercise duration, and Real Time Clock (RTC), which keeps track of time in a "real mode", to characterize data file and to define the exercise start. The device can also perform parallel acquisition and communicate with a “Windows Media Center Server” (WMC). The WMC is placed at patient’s home as a local data server, and communicate with the device through either a RS232 serial cable interface, or a Bluetooth wireless serial bridge device as to guarantee data thoroughness and synchronization.

All data acquired are stored and processed in real time by the WMC [5], [6]. Because of patient state of moderate cardiovascular risk, it has been implemented a real-time signal processing library, consisting of both algorithms developed in MathLab 7.0 and technical and clinical specifications, to apply to the ECG signal analysis.

The Communications Specification for Fitness Equipment (CSAFE) protocol was specifically designed to support communications between various types of networked fitness equipment. Although the CSAFE protocol does not include a full network definition, it is a standardized data packaging specification [7]. By using CSAFE protocol, also the cycle ergometer can be monitored. Thus, it can report the Strength of Cycle (W) and the number of Revolutions Per Minute (RPM) of the flywheel as exercise parameters. They can then be related to the analysis results, and permit a feedback to the patient about the training session performance.

All collected data and the processing results are also used by the system to automatically trigger alarms about patient conditions. They are stored in a local repository on the WMC and then are transmitted by an Internet connection to a “Centralized Data Storage” server (see Figure 1), which holds data coming from all patients enrolled into the program. The data stored on the central server are at research and medical personnel disposal to perform further processing (such as QRS detection, RR length series, calculations of Heart Rate Variability (HRV) patterns, along with time domain and frequency domain parameters on the ECG signal). Also all these calculated data are stored into the “Centralized Data Storage” server.

TABLE I
ROLES AND AVAILABLE FUNCTIONS

Role	List of Functions
Administrator	1) Insert/modify the data of new users (Patients, Doctors, Nurses, Technicians, and also other Administrators); 2) Able and disable users to access the system; 3) Perform queries on user data; 4) Insert the components of medical exams (e.g. text and images); 5) Visualization and browsing of log (audit) data.
General Practitioner	1) Registration; 2) Insert anamnestic data of his/her patients enrolled in the training program; 3) Visualization and browsing of patient data, signals, and images; 4) Monitoring the training data; 5) Request of medical examinations for his/her patients.
Nurse	1) Registration; 2) Insert data regarding the reception of patient, such as personal and anamnestic data; 3) Modify/Update patient personal data; 4) Visualization and browsing of patient data (e.g. drug prescription).
Medical Technician	1) Registration; 2) Insert data and upload signal and image files regarding medical examinations; 3) Visualization and browsing of medical examinations.
Patient	1) Registration; 2) Visualization and browsing of own data, organized as medical record; 3) View the list of uploaded training data files; 4) Change personal and contact data.
Medical Specialist	1) Registration; 2) Download signal and image files regarding medical examinations; 3) Visualization and browsing of data regarding his/her patient examinations, which were requested by the General Practitioner and whose data were inserted by a Medical Technician; 4) Download training data files of his/her patients; 5) Insert examination referrals.

III. METHODOLOGY AND IMPLEMENTATION RESULTS

We designed and implemented a Web application - the “Centralized Data Storage” server – that enables the remote organized collection of many different types of patient data (i.e. personal, medical, and training data) into a database and several file system repositories, and allows their querying and maintenance. In the following paragraphs, we will describe the fundamental components of the Web application and its structure, that is the roles for the involved actors, the definition of data, the structure of data storage, and the aspects of data protection.

A. Role Definition

We considered different actors involved in the program, able to manage patient data with different views, and operating at different locations (such as in the Hospital environment, at Patient Home, and in the General Practitioner office). Thus, we identified the following roles: Medical Specialist, General Practitioner, Nurse, Technician, and Patient. In order to manage the Web application, we also defined the Administrator role. Obviously, each role has associated a number of available functions, and data upon which these functions are allowed (see Table I). For example, a General Practitioner can perform the anamneses and/or request medical examinations only for his/her registered patients enrolled in the program, and can access all his/her patient data. A Medical Technician can visualize the list of requested examinations that are waiting for results, and he/she can insert their resulting data, signals, or images. A Medical Specialist can visualize the list of requested examinations waiting for referrals, and can access all patient data regarding the medical tests he/she is referring (for instance past training session recordings).

B. Data Definition

We considered the following patient data: personal data, anamnestic data, data of previous ischemic episodes (such as when and where the episode happened), description and report of past medical exams that generated alphanumeric data (e.g. physical or biochemical examinations, bio-signals (e.g. ECG or EEG recordings), and bio-images (by Computed Tomography or Magnetic Resonance)).

For each training session we consider data from the patient and data from the cycle ergometer. These data are stored in different files. From the patient, single value attributes (such as patient identifier, training session identifier, timestamp at starting instant, timestamp at ending instant, and actual section duration) are recorded. Depending on sample frequency, one lead ECG signal and Training Session Phase (i.e. initial rest, exercise, or final rest) are recorded. Furthermore, similar data from the cycle ergometer are also recorded: patient identifier, training session identifier, timestamp at starting instant, timestamp at ending instant, and actual duration section. Besides, the Strength of Cycle (W), flywheel number of Revolutions Per Minute (RPM), Patient's Beating (bpm), and Training Session Phase are recorded according to the chosen sample frequency.

C. Data Storage and Web Application Structure

The data storage area comprises three structures: a database and two file system repositories (see Figure 2). We designed and implemented a relational database that can contain and manage the data regarding the different actors involved, and the patient personal and several clinical data, as defined in the preceding section. The data coming from medical examinations (such as images) and the data regarding the training sessions are stored into files in a file system repository, even though their descriptive attributes are stored into the database. After a training session, the WMC automatically uploads the files, which are in Comma Separated Value (CSV) format, into an "Upload Area" on the server. Then these files are moved and stored in the file system repository of the corresponding patient (see Figure 2). To achieve this automatically, the files are labeled with the patient identification code.

To remotely access and manage the stored data, we adopted a client-server architecture and designed and implemented a Web application with a user-friendly Graphical User Interface. It has a public area, which shows information about cardiovascular risks, and a reserved area, which permits different registered actors to access the data they are allowed to.

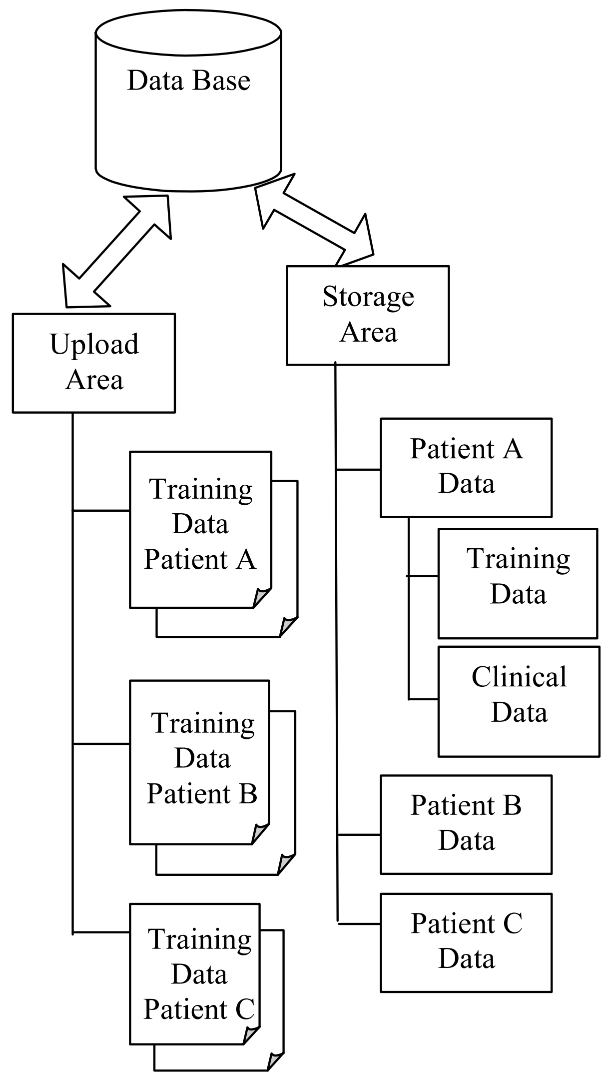

Fig. 2. The data storage structures of the system. While the "Upload Area" folder does not contain any sub folder, the "Storage Area" folder has a tree structure. The first level contains the Patient's folders. Then each of them, i.e. the second level folders, contains "Training Data" and "Clinical Data" folders.

The Web application has been developed using Microsoft Active Server Pages (version 3.0) technology, together with Javascript scripting language, and HyperText Markup Language 4.0 to implement its Web pages. Javascript language has been used to add logical reasoning to Web pages, i.e. to check Web form contents. Active Data Objects technology has been used to retrieve web page content from the database, which has been developed using Microsoft Access 2003. Microsoft Internet Information Server is used to perform connections between clients, which use a Web browser to request files, data, and services, and the Web server, which satisfies the client requests.

D. Data Protection

The data storage structures contain patient's medical data that require ensuring confidentiality and protection against unauthorized access and use. The following security features have been implemented:

1) Only registered (authorized) actors, who have their own login and password, can access and manipulate the data according to their roles and privileges.
2) Only from home of authorized patients, who are enrolled in the prevention program, WMC can upload training data files.
3) Medical specialists can perform operations on data regarding their area of interest and their patients.
4) An audit system is implemented to establish the sender of uploaded data.
5) The files uploaded into the "Upload Area" are checked before moving them to the "Storage Area".

IV. Evaluation Results

At present we have made some preliminary informal assessments of uploading and downloading training session files by using the developed Web application. For these assessments we considered training sessions of 10 minutes, which generated a 20 KBytes file of data from the cycle ergometer and 320 KBytes file of patient data. On our Ethernet LAN network file uploading/downloading took few seconds. We also considered sessions of 40 minute length. In this case data from the cycle ergometer produced a file of about 80Kbytes in size, while data from the patient produced a file of about 1.3Mbytes in size. We hypothesized that, at least, a Asymmetric Digital Subscriber Line (ADSL) connection, with a data upload rate of 256Kbps or 640Kbps, is available at patient home. Patient data file upload took from 1 min and 28 s to 2 min and 36 s using a connection service having 256Kbps upload rate, and from 49 s to 1 min and 23 s using a connection service having 640Kbps upload rate.

V. Discussion

In designing the Web server we considered a series of steps, useful for Web service capacity planning, that are explained in [8]. Each service request uses the site's resources differently. Some services can use large amounts of processing time of the application server (for example by uploading data into file system repositories). Others can concentrate on the database server [8], for example by enquiring the database in order to obtain similar data of different patients. Different actors exhibit different navigational patterns and, as a consequence, invoke services in different ways and with different frequencies. For instance, a nurse visualizes patient drug prescriptions in order to administer them to the patient, while a medical specialist downloads training data in order to analyze them.

Bio-signal databases are created with different goals and requirements. Applicability of a data format specification needs to be judged with respect to such requirements but also to the intended or potential user community of the bio-signal database [9]. In order to define our data format, we considered different available format specifications, such as the European Data Format (EDF). EDF was developed in 1991 and published by European engineers who had their occupation in medical environments [10]. Even though we did not use a standard data format specification within our system, we can produce output data files in EDF format.

VI. Conclusion

We designed and implemented a Web application able to store and manage the data of patient enrolled in a program of cardiovascular risk prevention.

The designed and implemented Web application is pre-arranged not only to manage the home care activities but also to store the patient and training data in order to create a subject database useful to analyze efficacy of treatments or to monitor pathology progress.

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