Proceedings of the 5th WSEAS Int. Conf. on APPLIED INFORMATICS and COMMUNICATIONS, Malta, September 15-17, 2005 (pp27-32)

An Integrated Decision Support Platform for Medical Specialists

K. DIMOPOULOS, G. MANDELLOS, G. KOUTELAKIS, G. TRIANTAFYLLOU, M. KOUKIAS, D. LYMPEROPOULOS
Wire Communication Lab, Electrical & Computer Engineering Dept.,
University of Patras, Rion
GREECE

Abstract: - This paper presents an integrated decision support platform for medical specialists, which use the signals from different points of the human body as a part of the patient examination. This platform is a software application for the acquisition, archiving, presenting and processing of medical signals. Moreover, this application preserves data that concern patient's history and past medical treatment. The coexistence of medical signals and patient history data in a functional interface supports doctors to result in the potentially more accurate diagnosis and treatment for each incident. Application's architecture provides the user with an integrated electronic working domain handling diverse types of information and medical records. The design and the implementation of the platform was a result of a close collaboration between engineers and doctors in order the development of a real efficient tool for the medical specialists to be achieved.

Key-Words: - Electroencephalography, EEG, ECG, Video-EEG, Functional-MRI, WADA-Test, SPECT, Spectroscopy, Vital Signs, Electrocardiography

1 Introduction

The pre-surgical assessment of epileptic patients involves a wide range of tests (EEG, Video EEG – ictal, interictal, PET, brain activity recording with implanted electrodes, anatomic and functional MRI, MEG, WADA test) that are employed for the functional evaluation of epilepsy cases and the exact anatomical localization of the focal point. The recording and the representation of these signals can be significant, since it could be a powerful tool to support and justify the decision of neurologists.

Vital Signs consist another major component of patient care. Evaluating a patient's breathing, acquiring the electrocardiogram, assessing the heart rate, taking his temperature, determining the blood pressure, and obtaining a medical history represent a basic set of actions, which lead to useful medical data. This information is obtained from every patient a medical doctor encounter. In emergency cases (e.g. ambulance transportation[1]), acquisition of the above vital signs is the first care service offered to the patient. Without this information, the doctor may remain unaware of life threatening conditions that require him to provide specific treatment at the scene along with prompt transport to the appropriate treatment facility.

A complete clinical picture of a patient requests specially designed dynamic applications for storing, analysing, and correlating a range of non-homogeneous data providing the medical specialists the capability of making a decision about the pharmacological and/or operational treatment they will follow.

This paper presents an integrated decision support platform, which provides the facility of managing Encephalography, Cardiography and other medical signals that help doctors to make a more accurate diagnosis and treatment of the incidents, they should manage. The platform, described in this paper, is software for archiving, presenting and processing of signals, which are very important for the human health. The development of the application took place in cooperation with the medical stuff of the Cardiology Department of the Olympion Hospital, in Patras, and the Neurosurgery Clinic of Evangelismos General Hospital, in Athens, Greece.

The platform provides an integrated environment for medical signals management that presents in a functional way one or more kind of different signals on doctor's demand. Moreover, this environment keeps and provides all the information of the past patient state that is useful for the full utilization of the signals' data. The acquisition of a large quantity of information offers to the system the ability to operate as an expert system, too. Thus, it has the capability to execute procedures that extract suggestions for the doctors in order to treat medical incidents in a more accurate and effective way.

2 Medical Signals and their meaning on human health

This section deals with the definition and usefulness of medical signals that are concerned in this paper.

A Decision Support System can be useful to doctors, if it is able to provide doctors with all the significant information for a complete patient's medical view. Thus, it should include signals coming from the most important parts of the human body, brain, heart, vessels. These signals, can be acquired in different forms either as waveforms or as independent values. More specific, the presented Decision Support System acquires, stores, and manages data from the next signal categories.

2.1 Encephalography signals

Electroencephalography (EEG)[2] is the most important test for diagnosing epilepsy, because it records the electrical activity of the brain. As epilepsy is characterised the transient but recurrent disturbances of brain function. It may or may not be associated with impairment or loss of consciousness and abnormal movements or behaviour. The EEG shows patterns of normal or abnormal brain electrical activity. For example, certain types of waves may be seen after head trauma, stroke, brain tumor, or seizures. EEG is acquired by electrodes (small, metal, cup-shaped disks) which are attached to the scalp and are connected by wires to a brain wave monitor.

Magnetoencephalography (MEG)[2] is completely non-invasive, non-hazardous technology for functional brain mapping, providing spatial discrimination of 2 mm and an excellent temporal resolution on the order of 1 ms, localizing and characterizing the electrical activity of the central nervous system by measuring the associated magnetic fields emanating from the brain. Every current generates a magnetic field according to the right hand rule of physics. This same principle is applied in the nervous system whereby the longitudinal neuronal current flow generates an associated magnetic field. MEG measures the intercellular currents of the neurons in the brain giving a direct information on the brains activity, spontaneously or to a given stimulus. Measurement preparation and collection times are relatively short and can be performed by a technician with a minimum of training.

Video EEG monitoring is a more specialized form of an EEG, which the patient is constantly monitored over a video screen. This allows doctors to observe brainwave activity during the time a seizure or spell is occurring. It is used to diagnose episodic events (those which happen from time to time). Such events are epileptic seizures, fainting or black-out spells, spells of unknown origin, confusion, hallucinations or behaviour problems.

2.2 Electrocardiography and other vital signs

Electrocardiography (ECG)[3] is the most important test for non-invasive diagnosis and detection of coronary heart disease. Records the voltage changes transmitted to the body surface produced by electrical events in the heart muscle. ECG is used by doctors, in order to be informed for a direct evidence of cardiac rhythm and conduction, or for an indirect evidence of myocardial anatomy (size, wall thickness, e.t.c). Also, ECG informs about the blood flow between the heart and the body, the functional state of the heart e.t.c. The recording of the voltage changes on the heart muscle is called electrocardiogram (ECG) and is acquired using a set of electrodes called "leads". Each lead has a specific placement on the human body. The data collected are represented as a set of waveforms.

Pulse oximetry offers a relatively inexpensive, simple and reliable means to monitor respiratory function in a wide variety of clinical areas, in hospitals and the community. It is used to monitor patients who have actual or potential respiratory problems. Pulse oximetry measures oxygen saturation levels (SPO2) by monitoring the percentage of hemoglobin (Hb), which is saturated with oxygen as well as measuring heart rate (pulse rate). Oximetry may be used for 'spot checks' or a continuous measurement. Measurements should always be considered, taking into account all clinical data acquired about this person. A 'spot check' or single measurement of hemoglobin saturation might suggest respiratory problems. Therefore a continuous measurement gives more reliable results.

Blood is carried from the heart to all parts of human body in vessels, called arteries. Blood pressure is the force of the blood pushing against the walls of the arteries. Each time the heart beats, it pumps out blood into the arteries. Blood pressure is at its highest when the heart beats, pumping the blood. This is called systolic pressure. On the other side, when the heart is at rest, between beats, blood pressure falls. This is the diastolic pressure. Blood pressure is always given as these two numbers, the systolic (higher) and diastolic (lower) pressures. Both are important. High blood pressure - also called hypertension - is a major health problem in the world today. It is sometimes called "the silent

killer" because it doesn't have any symptoms, yet it can be causing serious damage inside the body. It is a primary cause of stroke, heart disease, heart failure, kidney disease, and blindness. It triples a person's chance of developing heart disease, and boosts the chance of stroke seven times and the chance of congestive heart failure six times. Blood pressure is acquired with both invasive and non-invasive methods. The easier one is the non-invasive measurement (NiBP).

The Body Temperature is a critically important vital sign that often affects patient treatment decisions. The measurement is performed in order to find out whether the patient's temperature is over the normal values. In those cases, the patient has a fever. Most fevers are a sign of infection and occur with other symptoms. Abnormally high or low temperatures can be serious.

3 Application Design Considerations

Our target was the development of an Integrated Decision Support Application in order to provide Medical Specialists with all the significant personal and medical data for each patient. All data manipulated by this application are mentioned in the part 2 of this paper, entitled “Medical Signals and their meaning on human health”.

During the application’s design we had closely cooperated with doctors. The application should implements the following functions:

- a user friendly front end interface, which provides the end user with all necessary information to fulfill the desired tasks.
- a simplified (manual or automated) form for patient and medical data entry
- an intelligent data mining mechanism, responsible for the storage and retrieval.
- a signal handling system for acquisition, visualization and review
- a structured report engine
- terminology familiar to doctors
- minimum user effort in order to complete a task.

The information that is handled is divided into four categories: the patient demographic data, the multimedia data, the encephalography medical data (e.g., raw data, text, and annotations) and the electrocardiography and other vital signs data. Criteria for the data structuring and the quality control are posed separately for each data category.

4 Application’s Analysis

This part of the paper presents the functionality of the application, the tools used for the development and the required system configuration.

4.1 Application’s functionality

The system is designed as a group of separated but closely collaborative sections. The main sections of the corresponding interfaces are:

- **The Personal Data Section**: This section is responsible for the management of the patients’ personal data. It includes tools for the creation, modification, and deletion of these data (Figure 1). It also provides query tools.

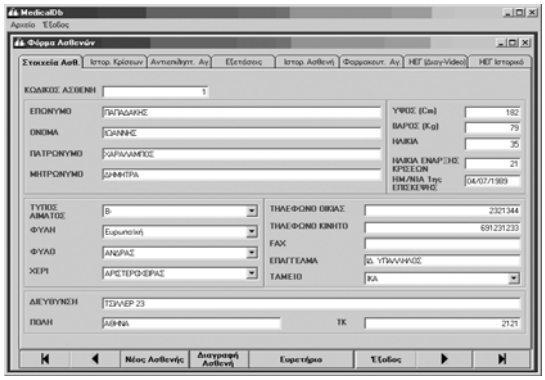

Fig.1 Personal data form

- **The Presurgical Patient’s History Section:** Here, data related with Patient’s history are managed. The data concern presurgical epileptic events and are categorized in type, frequency and age period. Description entries of epileptic seizures are selected by windowed directed options to automatically correlate to other data of the application (Figures 2 and 3).

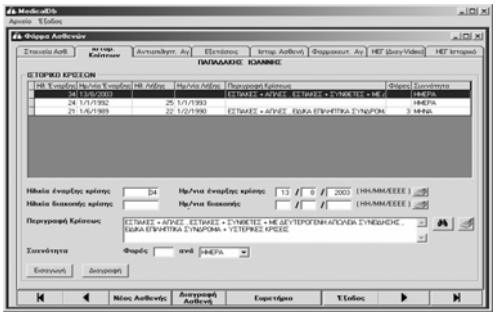

Fig. 2. Clinical examination form.

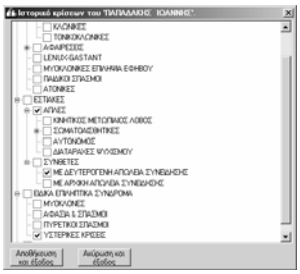

Fig. 3. Seizure's analysis and classification.

- **The Pharmaceutical Treatment Section:** This section provides doctors with the required tools in order to be able to correlate data referring to anticonvulsant therapy and other pharmaceutical treatment evaluation. (Figure 4).

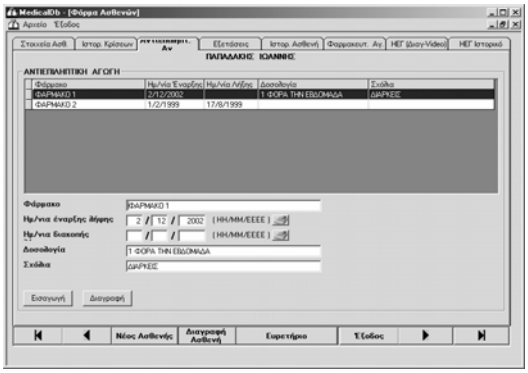

Fig.4 Pharmaceutical treatment evaluation form

- **The Section for Other Examinations:** This group contains the results of biochemical, blood, urine, and lung laboratory examinations that are organized in laboratory-exam modules based on the primitives of the HL7 and CEN/TC 251 WG4 standards.
- **The Section for Blood Oxygen Saturation (SPO_2):** It is another valuable measurement as it shows the percentage of oxygen in blood. It further shows the percentage of cell oxygenization (Figure 5).

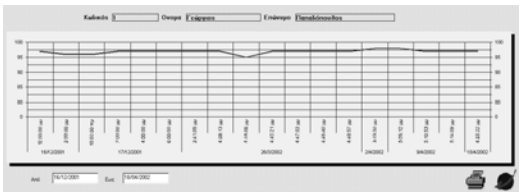

Fig.5 SPO_2 diagram

- **The Section for Electrocardiograms [3][4][5]:** It manages data acquired through electrocardiographs. These data are useful as they show the functional state of the heart, the blood flow to other organs, etc. Data are organized based on the CEN/TC 251 WG4 prEN 1064 standard [4][6][7] (Figure 6).

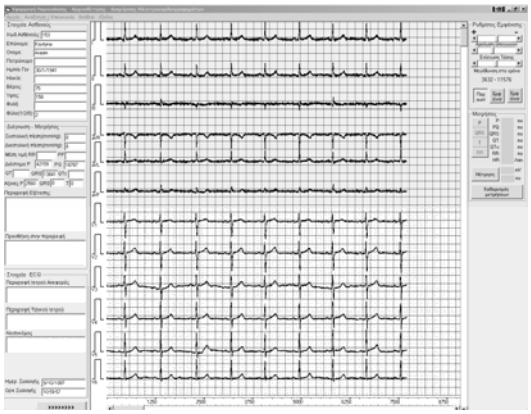

Fig.6 Electrocardiograms Interface

- **The Section for Blood Pressure:** Data for systolic blood pressure, diastolic blood pressure and also heart rate (Figure 7).

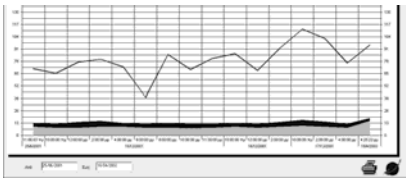

Fig. 7 Blood Pressure Interface

- **The Section for Body Temperature:** As abnormally high or low body temperatures can be serious for human health, this section deal with this data category (Figure 8).

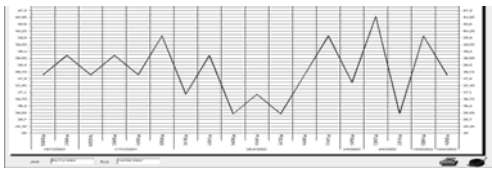

Fig.8 Body Temperature Interface

- **Family History Section.** History data are entered here, using predefined keywords so that automatic link to be established to certain diseases and sections of the application, e.g. pharmaceutical treatment or characteristics of the topology.
- **The Non-Epileptic Pharmaceutical Treatment Section:** This section manages data relative to patient's history of any other

pharmaceutical treatment with the corresponding prescription.

- **The Elementary Presurgical Assessment Section [2]:**
  - Interictal EEG that is the lateralization of characteristically epileptic findings, the localization and seizure's topography.
  - Video EEG that includes 3 seizures, interictal and postictal findings, the lateralization, and the imaging (Figure 9).

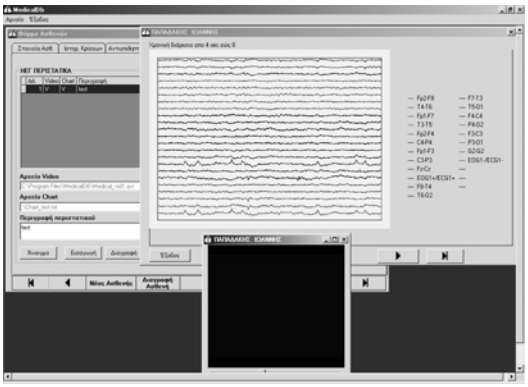

Fig.9 EEG VIDEO

  - MRI shows details fot hippocampal sclerosis, hippocampal volume try, multiple focuses, and fusion.
  - neuropsychological examination.
  - WADA test . This section, accepts digital biosignals produced from encephalographic recordings during WADA test, as presented in figure 10, at pre-surgical control in epilepsy. The particular process consists of the digital acquisition of 21 channels EEG, although the system is able to cover up to 128 different recordings from a corresponding number of channels

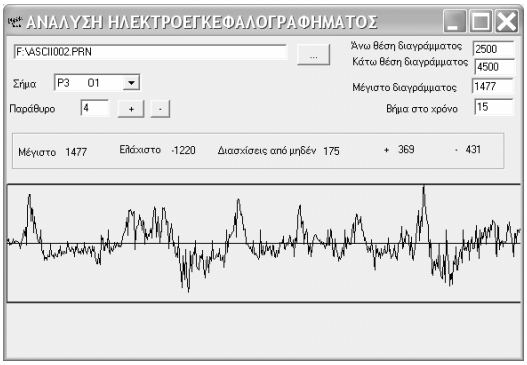

Fig. 10 WADA Test

  - Data acquired from the medical device are saved to a separate memory. There are further capabilities for insertion of extra information and notes. Moreover, the application provides query and retrieve functions. Researcher medical doctor can analyze the EEG waveform as a whole, or as a part from a selected channel and/or time range. Biosignal modeling refers to certain waveform pattern identification (e.g. alpha, theta waves etc) and correlation to known types. Statistical processing refers to biosignal parameters calculation, similar to: frequency, voltage, synchronization and periodicity.
  - An expert medical doctor, conversant with the application, can successfully identify pathological EEG waveforms and use the automatic recognition and analysis in pre-surgical control, epilepsy.
  - functional MRI.
  - SPECT (ictal - interictal).
  - MEG.
  - Post-Operational Monitoring Section: All the corresponding data are saved in the appropriate database.

4.2 Tools used for the development

The tools that have been used in the development of this application are:

- Microsoft Visual Basic v. 6.0 for the application design
- Microsoft Access for the data storage and manipulation
- Seagate Crystal Reports for the reports

4.3 System configuration

The required system characteristics in order to have a functional decision support tool and also the characteristics of the development workstation are:

- Intel Pentium IV 3.2MHz
- 1GB RAM
- 250GB hard disk space
- Microsoft Windows 2000/XP
- Dual monitor system with 1280 x 1024 resolution on each monitor

5 Discussion

Epilepsy is a brain disorder. It occurs, when then electrical signals in the brain are disrupted. This change in the brain, leads to a seizure. Seizures can cause brief changes in a person's:

- body movements,
- awareness,
- emotions,
- senses, as taste, smell, vision, or hearing.

Heart and Pulmonary diseases are also critical situations for the human life. In many cases, the diagnosis and the treatment of such situations requires immediately data acquisition from different body parts. Sometimes, the above diseases have interaction with brain during a seizure.

These and other data (history, medication, etc.), leading to assessments define a complicated path of procedures, where a lot of information is collected and decisions are taken. The decision support platform, presented in this paper, has been designed to follow up this path from the early stages of a seizure to even then post-surgical evaluation and further research analysis. Appropriately designed parts of the application help medical doctors to:

- record all kind of personal and medical data
- execute decision support procedures

A significant function of the system is the ability to act as a knowledge database and as an expert system. Therefore, the system improves its decision capabilities as the number of incidents registered in the system increases.

6 Conclusion

The large amount and the heterogeneous type of the collected information, during the evaluation of the medical incident, is the main problem in the extraction of a correct diagnosis and treatment. The proper management of this information is the requirement of the medical stuff to be facilitated in providing high quality treatment to the patients. The application, described in this paper, has been designed to overcome the above problem and to support doctors in their mission. The functional representation of a range of medical signals and, moreover, of extensive information about the patient's medical state and history provides an ideal environment for the incident information evaluation and the medical findings extraction.

Data organization, decision making criteria and result extraction mechanisms are under an optimization procedure for even more accurate results. As the application can be used as an expert system, its extensive use and enrichment will prove its value and usefulness. More modules can be added in a further development, such as telemedicine facilities, teleconference, viewer for medical images etc.

7 Acknowledgments

The authors wish to acknowledge the help and support of Mrs E. Scorila and Mr. C. Baltogiannis doctors of the Neurosurgery Clinic of Evangelismos General Hospital, Athens, Greece. They offered significant help on the functionality and usability of the first version of the application for neurosurgery specialists, called "DESSA"[2]. That application was the ancestor of the medical signals platform, presented in this paper.

References:

[1] G. J. Mandellos, D. K. Lymperopoulos, M. N. Koukias, A. Tzes, N. Lazarou, and C. Vagianos, "A Novel Mobile Telemedicine System for Ambulance Transport. Design and Evaluation", *26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, September 1-5, 2004, San Fransisco, California

[2] K. G. Dimopoulos, C. Baltogiannis, E. Scorila, D. K. Lymperopoulos, "DESSA: A New Decision Support System for Neurosurgery", *26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, September 1-5, 2004, San Fransisco, California

[3] G. Mandellos, G. Koutelakis, G. Triantafyllou, M. Koukias, D. Lymperopoulos, "A Medical Network Using the Enhanced SCP-ECG Protocol for multi vital-sign Manipulation", WSEAS TRANSACTIONS ON IN*FORMATION SCIENCE AND APPLICATIONS, July 2005, Vol 3, Iss. 7, pp. 925-933 (9)*

[4] Health Informatics – Standard Communication Protocol – Computer assisted electrocardiography, CEN/TC251, prEN 1064:2002.

[5] G. Mandellos, M. Koukias, G. Anastassopoulos, D. Lymperopoulos, "A new SCP-ECG module for telemedicine services", *WSEAS TRANSACTIONS ON COMPUTERS, November 2004, vol. 3, Iss. 5, pp. 1258-1263 (6)*

[6] OpenECG Portal, Internet address www.OpenECG.net

[7] N. Long, Open ECG data standard, Philips Medical systems perspective, *Journal of Electrocardiology*, Vol. 36 suppl., 2003, pp. 167.