A GSM-BASED MOBILE SYSTEM FOR EMERGENCY TELEMEDICINE -“AMBULANCE”

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Abstract - Recent studies conclude that early and specialized prehospital management contributes to emergency case survival. Ambulance personnel, who usually are the first to handle emergency situations, do not have the required theoretical knowledge and experience. Financial and practical reasons do not allow the participation of specialized physicians on ambulance vehicles. We have developed a portable medical device that allows telediagnosis, long distance support and teleconsultation of mobile health care providers by specialized physicians. The device allows the transmission of vital biosignals and still images of the patient from the incident place to the hospital. The transmission is performed through the GSM mobile telecommunication network, standard spread out all over the E.C. countries. The device can telematically “bring” a specialist doctor at the site of a medical emergency, allow him to evaluate patient data and issue directions to the emergency personnel on treatment procedures until the patient is brought to hospital. Due to the need of storing and archiving data being interchanged during the telemedicine sessions, we have equipped the consultation site with a multimedia database able to store and manage the data collected by the “AMBULANCE” system. The performance of the system has been validated in four different countries using a controlled medical protocol.

Keywords: Ambulance, Emergency health care, telemedicine, GSM, medical databases.

I. INTRODUCTION

Recent studies conclude that early and specialized prehospital patient management contributes to emergency case survival [1]. Especially in cases of serious injuries of the head, the spinal cord and internal organs the way of transporting and generally the way of providing care is crucial for the future of the patient. Previous statistics are grim: in 1994, there were 2,070 persons dead and 33,698 injured in car accidents in Greece. The number of deaths is substantially higher since it does not include a 15% of injured that die during hospitalization. Furthermore in the London area, 49% of casualties require at least 2 hours to reach adequate hospital care, 79% of victims of accidents in rural roads die on the scene, another 11% during transportation [2]. At least 8% of these cases had a 50% chance of survival, if adequate pre-hospital care existed. The reduction of this death toll is definitely achievable through measures and strategies which improve access to care, and administration of pre-hospital care.

Cardiac disease is another common killer. Much can be done today to stop a heart attack or resuscitate a victim of sudden cardiac death (SCD). Time is the enemy in the acute treatment of a heart attack or SCD. Many studies worldwide have shown a rapid response time in the pre-hospital setting resulting in treatment of acute cardiac events increases mortality and improves patient outcomes dramatically [3-8]. Studies have also shown that 12-lead ECGs performed in the ambulance increase time to treatment of thrombolytic therapy effectively stopping a heart attack in progress and preserving heart muscle function [9]. This means the patient is more likely to return to a normal lifestyle after a cardiac event.

Unfortunately, ambulance personnel (Emergency Medical Technicians - EMTs, Emergency Medical Paramedics-EMPs or General Practitioners - GPs), who usually are the first to handle such emergency situations, do not have the required advanced theoretical knowledge and experience. On the other hand practical and financial reasons do not allow the participation, routinely on ambulance vehicles of specialized physicians such as neurosurgeons, cardiologists, orthopedics etc. Ambulance personnel can rely on the directions provided to them by experts, with the assumption that information concerning the clinical status such as vital biosignals and a picture of the patient can be available to the experts.

Recent developments in mobile telecommunications and information technology suggest that the development of a real time emergency telemedicine unit is possible. Along this direction, an emergency telemedicine unit has
been developed. This device is able to telematically “bring” the expert to the emergency site by leading the doctor to observe vital biosignals and a still image of the patient from the emergency side; thus have him perform an accurate diagnosis and subsequently direct the emergency paramedic or technician on how to treat the patient, providing him with simple to understand but accurate directions to treat the patient until he gets to the hospital. In order to enhance the effectiveness of the system, we have developed a multimedia database where we can store and manage all data interchanged during the telemedicine session; something crucial for clinical, legal and administrative purposes. Regarding this database system, the features of confidentiality date protection and system security have been taken into serious consideration in accordance to international standards [10-13].

The design and implementation of this device was within the framework of the “AMBULANCE” project that was supported by the E.C. under the TELEMATICS program.

II. METHODS

We have developed a portable medical device, which allows telediagnosis, long distance support, and teleconsultation of mobile health care providers by specialized physicians, located at a hospital or a specialized health center. The complete system (figure 1) consists of two sites: the ambulance site (mobile station) and consultation site (hospital station). To ensure maximum portability, communications are performed via cellular (mobile) networks and particularly using the GSM standard which has a pan European coverage.

The system follows the client server model. The mobile site is the client and the consultation site is the server. The software was implemented on Windows 95 platform using windows API and MFC 0.0 class framework, while the TCP-IP protocol was used for the communication. The client is responsible for the collection and transmission of diagnostically important biosignals (3-lead ECG, Blood pressure, Oxygen saturation, Heart rate) as well as collection and transmission of series of still images of the patient. These images can be viewed by the specialists at the hospital site, and concurrently appear on the paramedic’s display. The specialists can annotate on the image, to indicate for example how to extract a victim trapped in car wreckage. The paramedic can observe these annotations on his display as these are drawn by the specialist, in real time. Thus, both sides can look at the same image simultaneously as it changes; this operation is known as “whiteboarding”. The specialist can instruct the technician to position himself in order to capture and transmit more images. During this time signals that are captured by the biosignal monitor are observed by both parties in real time. In order to avoid screen clutter, preference can be given to the signals that are considered more important. Switch between still image mode and biosignals mode is done remotely from the consultation unit.

In the consulting site (hospital station), as shown in Figure 1, the system includes a dedicated workstation where all remote system information are gathered and displayed to the acting expert doctor. If available, the

Figure 1: The Ambulance System Architecture Design.
The system is linked to the Hospital Information System (HIS) and the Picture Archiving and Communication System (PACS).

The need for storing and archiving all data being interchanged during the telemedicine sessions is very crucial for clinical, legal and administrative purposes. Any medical session is probable of creating a legal issue. The full recording of all medical act and decisions can be considered as a legal safeguard. Furthermore, a multimedia database can also be used for clinical purposes such as best treatment assessment, treatment protocol design and training programs. Finally, a database can serve administrative purposes such as statistical analysis and emergency cases management. Considering these, we have developed a multimedia database in order both to manage and archive the cases treated by the emergency telemedicine infrastructure.

A. Mobile Station

The mobile station mainly consists of two components, a Johnson & Johnson - Dinamap plus III biosignal monitor used for biosignals acquisition and a portable PC; the two components communicate using the RS232 interface. The portable PC used is a powerful (Pentium class) PC containing a frame grabber card, a CCD camera (SONY CCB-GC5/P) to capture still images and a Siemens M1 GSM modem for communication with the server.

The mobile station as shown in Figure 2, captures still images of the patient or gets data from the biosignal monitor. The information is stored on the local hard disk displayed on the screen of the PC and transmitted through the GSM modem to the hospital station.

The control of the mobile station is fully automatic. The only thing the paramedic has to do connect the leads on the patient. As soon the PC is turned on, connection is established with the consultation site. Finally the EMT or EMP (when on image mode) has to choose the best image to send to the consultation site.

B. Hospital Station

The hospital station mainly consists of a dedicated workstation named as the Telemedicine Consultation Terminal (see fig.1) which is used as a processing terminal in the hands of the acting expert doctor, called to monitor an emergency case. On that station, the doctor sees the biosignals and still images received from the portable device, online from the emergency scene. Along with this extremely crucial data he has the ability to retrieve additional information on the patient’s past history given that a HIS / PACS system is available. In that case, the system can be customized to exchange data with them. Otherwise, it handles the patient’s medical record by itself. The data received are displayed on the server screen and stored in the Ambulance.

The control program is used by the doctor at the hospital side so as to observe the signals send by the mobile station. The doctor can also send commands concerning the mode of the transmission (Figure 4); still image mode or biosignal mode, GSM network and sends commands concerning the mode of the transmission (Figure 4), still image mode or biosignal mode (Figure 5) to the mobile station. When on biosignal mode doctor can send commands so as to change leads of the biosignal monitor used for data collection at the mobile unit. All data collected by the control program are stored on the hard disk so as to be processed by the database system.
ii. Database

The main functionality of this database is to store and process all information sent by the mobile unit. To enhance even more the doctor’s ability for an accurate diagnosis the system is enriched with a graphical user interface enabling the display of additional clinical information of the patient. This is a friendly interface between the user and the multimedia database specially designed to work and interact with the other modules of the AMBULANCE system. Using this, the doctor has the ability to review previous emergency case related to the specific patient, older laboratory tests and other medical examinations. Having a complete view of the patient’s medical history, the doctor is able to use the system to provide specialized pre-hospital care.

Emphasis in the design was given in the user-friendliness of the system. For this reason, the database, that was designed with the Microsoft Access environment, was equipped with graphical user interface features built using Visual Basic 4.0. All parts of this Ambulance Database System (ADBS) were designed in compatibility with the very common environment of MS-Windows 95. The basic features and data manipulated by the system are depicted in figure 1.

The database is composed of four major tables. In the first, all the patient’s data, both personal and medical (name, address, blood group, allergies, long medication treatments etc.) are stored. The purpose is that the doctor handling an emergency case must have available the patient’s demographic data along with the data sent by the portable device, in order to provide accurate telemedical services. Figure 5 shows the patient’s demographic data form design, containing both personal and clinical data. The second table is an archive of doctors. Each patient has a personal doctor and it is useful for the doctor on duty to be able to contact if possible him/her for a detailed patient’s history.

The third table has all information related to previous emergency cases for each patient. This is very helpful for the doctor in case the ongoing emergency case is similar to a previous one. Finally the fourth table consists of information related to previous examinations and laboratory tests of the patient. This part of the application is strongly linked to the availability of a HIS and a PACS of the hospital as presented earlier.

The ADBS system enhances the doctor’s possibilities for a more accurate and prompt diagnosis. It allows detailed queries on patients, doctors, previous emergency cases and patient laboratory examinations. Figure 6 illustrates the form used to record the emergency cases. For each emergency case, important information is recorded like the incident’s code number, the date, the time, the initial and final diagnosis, the ambulance number and personnel and the incident’s type, etc. This information is compliant to the directive “Standard Guide for View of Emergency Medical Care in the Computerised Patient Record” (designation E-1744-95) of the American Society for Testing and Materials (ASTM).

a. The ECG and image viewer

One of the components of this application allows the display not only of textual information but also ECG’s, xray, CT, MRI and other medical images, in an efficient way. More specifically, this application allows the
display of 12-lead ECG and/or 3-lead ECG recordings. For the purposes of the pilot application, ADBS can handle data sent from a Kriticon biosignal monitor and a CardioPerfect 12-lead device. The ECG reader is easily customizable to any type of device or file type, thus enhancing interoperability. The doctor has increased capabilities to handle ECG recordings, like zoom-in and out, time and amplitude measurements, lead selection, and scroll into the recording to view the complete ECG. Especially for the recordings that were transmitted during previous emergency incidents, the expert doctor has also the ability to view the basic vital signs of the patient that were recorded along with the ECG. Those biosignals are the non invasive blood pressure, (systolic and diastolic), the oxygen blood saturation, the temperature and the heart rate. All vital signs are fully synchronized with the ECG recording.

The ADBS application is also able to display and process medical images in a variety of formats. The images are related to previous medical examinations and can be retrieved from anywhere in the hospital or other network, provided that they are stored in a digital form. When the image is loaded into the viewer, the medical expert handling the emergency case can analyze the image for better visualization. He can zoom-in and out on a specific area, flip horizontally and vertically, and rotate the image. Further image processing functions are available for increased functionality and can easily be added upon request.

b. The database administration

Security and confidentiality of stored information are very critical issues to medical archiving systems. The application database is fully protected from unauthorized access. The database itself is password protected and fully encrypted. The whole application is password protected with a three level access (administrator, doctor, data entry). Access to the database’s information is possible only within the application’s environment. The database is administrated by a single person, (Administrator) who has access to all the features of the database. He is the only one with the permission to concede or deny access to the database’s records. He can create new accounts to the database by creating user-names and a passwords unique to new users and he can modify user information data upon request. Both user-names and passwords are encrypted when stored with a key encapsulated into the application’s code, making it almost impossible to forge. The Administrator as a database manager has the authority and responsibility to change the database’s encryption, compact the databases, keep backup copies and remove trash from the records.

All other user, with doctor or data entry permission, are not allowed to delete or modify any record from the database. The users with data entry access are also restricted from processing medical data such as ECG recordings or medical images.

For all users, the database is fully searchable with multiple query capabilities for patients, doctors, medical examinations and previous emergency incidents. The application is interacting with the other modules of the “AMBULANCE” system, and all data transmitted for the emergency cases is automatically stored and classified without any user’s intervention. The user only inserts textual data like comments, type of incident, first diagnosis, etc. Figure 7 shows one of the query forms, that the application is presenting to the expert.

III. RESULTS-DISCUSSION

Implementation of the software modules has been completed on prototype hardware. The system has been demonstrated. All functions were tested, including biosignal, image transfer whiteboarding, and data storage and retrieval. Further work is being carried out in integrating the system to hospital HIS/PACS networks. Four pilot sites in Greece, Italy, Sweden and Cyprus are participating in the demonstration phase. Particularly the demonstration phase is currently being performed at the facilities of the Athens Medical Center (Greece), the Malmo Ambulance Services (Sweden), the Azienda Ospedaliera Pisa (Italy) and Cyprus Ambulance Services (Cyprus). System verification has been successfully completed & system demonstration is in progress.

IV. CONCLUSIONS

We have developed a portable medical device to be used for emergency telemedicine applications. The device uses GSM mobile telephony links and allows the collection and transmission of vital biosignals, still images of the patient and bi-directional telepointing capability. The advance man-machine interface enhances the system functionality by allowing the paramedics to operate in hands-free mode while receiving data and communicating with specialists in a hospital, where all relevant data are stored in the ambulance database system. The system was implemented as a part of the AMBULANCE project, and is being demonstrated with promising results in four European pilot sites.
REFERENCES