Prospects for the Design of an E-health System for Monitoring Patients with Diabetes and Stroke

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Abstract: - The population of Romania is an aged population with high risk of disease and a reduced birth rate. One possible solution to address these issues is the improvement and proliferation of surveillance and prevention systems, in order to manage or rapidly detect the health problems with the lowest costs. In this paper we present the e-health / e-homecare system we propose, that would facilitate and improve the efficiency of the primary medical care, a fundamental component of the medical system.

Key-Words: - E-health, prevention, expert system, monitoring, diabetes, stroke

1 Introduction

The population of Romania is an aged population with high risk of disease and a reduced birth rate. The solution to this problem is very complex and must address many aspects of the life and health, including specific solutions at the social, economic and medical levels. From a medical point of view, the solution must focus on the improvement and proliferation of surveillance and prevention systems, in order to rapidly detect and manage the health problems with low costs.

The monitoring for the prevention of the relapses or the early detection of diseases represents the key element in primary care. The stroke and diabetes have a high incidence in Romania and in the whole world. The stroke represents the third cause of death in the world and in the south east of Europe the rate is a few times higher than in the rest of Europe. In 2006 but even in other years, the cardiovascular diseases represented constantly 70% of the death causes, 25% being stroke related [17]. The endocrine, nutrition and metabolic diseases represented only 1%, but diabetes represented 95% out of this cases.

We intend to design an e-health / e-homecare system [42], i.e. a monitoring and prevention software and hardware medical system that facilitates and makes more efficient the primary medical care, a basic component of the medical system. Consequently, this system is in accordance with the Government’s requirements [10], regarding the health reform (activities in preventive medicine, homecare, including educational activities for family medicine and scientific research activities). In the case of the primary care, the system could be used for continuous and real-time monitoring of children, elderly and chronic patients even at home and for the rapid scanning in any medical facility, including family medicine offices, learning institutions and production units.

This proposal is also included in the current trend at European and international level, to project and implement prevention and monitoring systems [14, 19, 21, 25, 27, 35, 43]. Globally there are a number of attempts to create monitoring systems for glycaemia at the patient’s home [24], but the majority of those are SMBG (Self-Monitoring of Blood Glucose) [22, 23, 31, 38] in the case of diabetes. These systems imply a range of disadvantages like the lack of automatic acquisition and interpretation of the tracked biological markers. Those duties are performed by the patients themselves.

2 Goals

The best way of implementing the prevention is possible by appraising the last discoveries in electronics, devices and sensors, as well as using advanced mathematical models, processing algorithms and signal analysis techniques. Also the proposed medical system will constitute a useful component and will contribute to the development of an integrated informatics system at national level, being compatible with any pre-existing systems that implement the unanimously-accepted HL7 (Health
Level Seven) standard, used for implementing health care systems.

Our main objective is to designing and implement at low cost a hardware and software prototype of a medical monitoring e-health system for primary healthcare and transmission of the acquired data to a processing and analysis point capable to automatically send warnings towards the nearest medical unit. The system will be based on an intelligent application that will process and analyse in real time the health status of the monitored individual. The application will be therefore able to assist and support the objectivity of the medical specialist decisions. The proposed system could be also integrated with other pre-existing systems like intelligent domestic systems.

Other objectives that we envisage are: i) the transfer of specialized medical assistance to the patient’s home; ii) the reduction of the costs of monitoring and prevention; iii) the reduction of collateral costs of chronic disease treatment by quickly identifying those diseases; and iv) the increase of efficiency of the primary medical prevention and care at national level.

The target groups are children under medical surveillance, young people and adults with high risk of disease, elderly with disabilities and chronic disease patients that require continuous surveillance at home. The system will be an extremely useful tool in national projects on prevention and control of un-transmittable diseases, being focused on cardiovascular diseases, diabetes and nutrition disease, and neurological diseases [10]. It will be specialized for monitoring the patients with diabetes and those with high risk of relapse in stroke by real-time automatic processing and analyzing of glycemia, pulse and oxygen concentration in blood. An expert system will be implemented [26], under the form of a complex decisional tree that will permanently analyze the recorded values of the monitored individual. Dependent on those values the system will take the decision to raise an alarm or not to the closest medical unit.

We also take into consideration the possibility to monitor, in parallel, both the audio and the video signals in order to monitor the comportment of the patient, recording the movements and the vocal signal to perform action recognition (e.g. the patient fell on the floor due to fainting, epileptic seizure or any alarming misbehavior) or recognizing the mimic and gestures for the non-verbal communication analysis. These two research directions will constitute novelty elements of a high importance for patients not able to verbally communicate their state of health or to call emergency services.

### The proposed system architecture

The system will gather and analyze in parallel and in real time a multitude of vital signals of the patient that form an image of the general state of health [45] (see Figure 1, where DAQ stands for Data AcQuisition). These will be transmitted to an expert system that will interpret the results and will take the decision regarding any medical alert. The recorded bio-signals from the patient include glycemia, pulse and oxygen blood concentration but the system can be easily extended based on a modular design that will make it more versatile. Specialized modules to record cardiac signals (ECG) [39], respiratory signals, temperature and other biological signals (e.g. albuminuria) could be added to the system. If the recorded signals have abnormal values or an evolution that is indicative of a pathological status, the system will decide to automatically raise an alarm either to the medical specialist or to a medical unit, or even to call the 112 emergency number.

![Fig. 1. The e-health monitoring system in a regular setup.](image)

The system will be non-invasive, capable to perform a fast and safe analysis, to permit the monitoring with normal mobility and high comfort. The transmission of the signals to the computer that will analyze the health status of the patient will be done using wireless technologies for a higher flexibility. The system architecture is depicted in Figure 2. The system is composed of an information acquisition module, whose principal function is to record signals from the patient. These signals are then transmitted to a computer that will run the expert system application [26], to process and analyze the signals. Based on the interpretation of the recorded signals, in the event of a detection of an abnormal health status the system will take the decision to alert the closest medical unit. The communication protocols will be designed and the most efficient technologies will be established for the transmission of the data. Automated dialing can be performed by a mobile phone connected to a serial port of a PC, the software implementing also this communication protocol.
Fig. 2. Proposed system architecture.

The system will be integrated with the domestic systems already existent or in development like video security surveillance systems, closed-circuit television systems or wireless systems for control and monitoring of intelligent buildings, developing an complex intelligent system to monitor the quality of life not only the health status.

4 Implementation of the system

The basic version of the system will use portable intelligent sensors like the portable glycemia analiser DEXCOM 7+ [5] or the portable digital pulse oximeter Mindray PM-50 [30], capable of transmitting to distance the relevant information.

The DEXCOM 7+ sensor (Figure 3a) appears like a platinum thread, very small, flexible and round that is introduced in the derma and attached to the skin with an adhesive plaster. The sensor is the smallest in the market, the most flexible and confers the maximum of comfort to the patient. Additionally, it is the only sensor with the longest utilisation period of 7 days. The miniaturized transmitter is water resistant and integrated with the sensor, forming a compact and small unit, that transmits to a wireless receptor with an LCD screen (Figure 3b). This is capable to display the instantaneous value of the glycemia at intervals up to 3 hours, as well as the time dependant evolution of the glycemia levels (Figure 3c).

(a)  (b)  (c)

Fig. 3. Portable digital glycemia analyser DEXCOM 7+.

The glucoze is the most important monosaccharide in the blood and an extremely important indicative for the diagnosys and monitoring of the diabetes as well as of the hypoglycemia [41]. Usually there can be 3 types of probes: i) seric glucose determined à jeun (or basal); ii) seric glucose determined at 2 hours after eating and iii) random seric glucose determined from a blood sample drawn at any time of the day, non depending from the interval from the last meal. For the diagnosys of the diabetes, ADA (American Diabetes Association) defines the following criteria:
- Suggestive symptoms (polyuria, polydipsia, unexplained weight loss) and a random glucose value ≥ 200 mg/dL or
- Basal glycemia value ≥ 126 mg/dL at two measurements
- Glycemia value ≥ 200 mg/dL at 2 hours after the administration of 75g of glucose (glucose tolerance test)

Depending on the type of diabetes and the value of the glycemia, in [3] is recommended that there must be performed a certain number of measurements during a day, at least 1 to 4 measurements. In [29] are analyzed the supplemental information and the limits of the continuous monitoring of the glycemia in the case of the diabetes type 1 management. The recommendations regarding the management of the diabetes are resumed in several papers [7, 28]

The pulse oximeter PM-50 (see Figure 4) is a portable and easy to use, with a very long operational time, the device entering stand-by mode if not used. The data recorded can be transmitted to a PC for interpretation. The sensor can be used in both adults and children or infants.

(a)  (b)  (c)

Fig. 4. Portable digital pulse oximeter Mindray PM-50.

In case of stroke it is vital for the patient that a specialized medical care unit to intervene in at most 3 hours after the beginning of the stroke [6], one of the targets of the AHA (American Hear Association) being to increase the percentage of stroke patients that reach a hospital in useful time [37]. In the same paper are specified the recommendations regarding the collecting of data regarding the moment of the stroke to be stored in a database, implicitly to automatically analyze that data. A series of problems regarding the definition of quantified objective indices of the functional recovery after a stroke are presented in [2].

In addition to the basic variant of the monitoring...
system for the patients with diabetes and risk of stroke relapse, the possibility of automated recording and interpretation of the biological indicators and development of a more complex system is investigated. For the ulterior development of the system, the heart signal can be an important source to analyze the health status of the patient, the parameters that are characteristic of the cardiac signal, P-QRS-T, could be analyzed using signal processing and analyzing algorithms [39]. Additionally, the correlation of the information about the blood pressure can be of a vital importance in monitoring diabetes patients [40].

Thermo vision or infrared (IR) imagery is used in a wide range of medical applications [11, 13, 32, 36]. The use of such technology in this project will allow the acquisition in a non-invasive manner of the information about the temperature of the monitored patient (see Figure 5 and 6). The novelty element is represented by the development of processing algorithms of the temperature images in order to determine the general status of comfort of the monitored subject.

The data regarding the temperature can be correlated with the information from the visible spectrum (see Figure 6), for example by deploying the existing algorithms for the human face detection [18, 20, 44] or by designing algorithms specialized for analyzing the temperature information. We mention that the images from Figure 6 are obtained with the informed consent of the parents, according to the medical professional ethics code [12].

Another novelty element regarding the development of the system and identifying new research directions and innovation is represented by the implementation of a dedicated module for the action recognition of the individual [1, 8, 16, 34] to monitor daily activities [33] and detecting emergency situations. Such a module can be very useful to analyze the movements of the monitored patient. As an example, in Figures 7, 8 and 9 from [34] a series of actions are depicted, then the results of the image processing algorithms that can be used and, finally, the mode of representing the actions of an individual with the help of functions that describe the trajectories of the points that define the followed object.

![Fig. 5. Examples of IR images.](image)

![Fig. 6. The correlation of IR images with visible spectrum images.](image)

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![Fig. 7. Images that describe the recognized actions.](image)

![Fig. 8. Example of processing in order to recognize the actions of an individual: (a) visible light original image; (b) distances image; (c) segmented image; (d) morphologic skeleton and definition of centroids and key points for tracking.](image)

![Fig. 9. Trajectories on Ox and Oy of the morphologic skeleton centroids for some of the tracked actions.](image)

![Fig. 10. Images that describe the recognized actions.](image)
5 Conclusion

In this paper we present the proposed architecture of an e-health system that can be used to monitor the health status of patients with diabetes and stroke. The monitoring can be performed even at patient’s house. The system will automatically acquire biological signals from the monitored patient, along with audio-video information, as well as infrared image data. The signals will be interpreted in real time by an expert system, in order to create a general picture of the health status of the patient. In case of a pathological situation or an emergency, the system will automatically dial the number of the closest medical unit or 112. We also describe the currently available devices and sketch up the implementations alternatives we have in order to realize the system, as consequence of the prospection process we’ve gone through. The system would represent a useful tool for the primary care, the fundamental component of any medical system. The main consequences of deploying such a system are the improvement of the efficiency of the primary care and the reduction of costs for the monitoring of the patients with chronic diseases.

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