QUALITY RAISED LIFE INTEGRATED SYSTEM BY REMOTE MONITORING AND REAL TIME SIGNAL PROCESSING

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Abstract: The main objective of the project consists in the optimization of medical services for heart disorders introducing a new concept: INTELLIGENT TELE-ECG. This project is designed to facilitate the rapprochement between patients and specialized university clinics through a distributed non-invasive monitoring system which allows, even from family doctor's office, the access to the ECG signal, data transmission in optimal safety conditions and electromagnetic compatibility, signal data processing at specific locations inside the clinics, high level diagnosis and fast transmission of the results back to the patient. The originality of the project consists in the achievement of on-line monitoring with continuous data processing.

Today is inconceivable the existence of high quality medical act without a complex database which allow the possibility to remotely interact with the monitored subject. The proposed method by this project is efficient and has a major impact in optimization assurance of medical services through innovative technology, especially when the costs of such analysis methods are very high world wide and virtually unreachable at national level.

In the last few years, there is a major world wide concern to develop digital Tele-ECG systems. Thus, the general development trend is focused on two directions:

1. Specialized already existing in large medical hospitals and research centers where flexibility in administration primary data, high speed processing and diagnosis are required.
2. Generalized which spread this application to day to day life. In this context digital Tele-ECG systems are welcomed due to un-precedent extension of local wireless networks, mobile technology and satellite communications.

At national level there is now just a specialized department functioning mostly within large hospitals. For example, in the last years attempts were made to pass to generalized frame through implementation a monitoring distributed system useful in traumatology but the results were not applied to large scale, the system quickly becoming specialized. It is noted that some of the current partners of the project have a certain degree of experience resulted from the above attempt. Also in Romania, another attempt to implement a Tele-Medical system was made by WORLD-Care (USA) in some hospitals from Bucharest. The project didn't become operational due to managerial aspects.

The perspective of extending the generalized direction has great interest in Romania, especially due to future integration in EU structures. Selecting new technologies for health as one of the priority themes of the Sixth Framework Program is in line with a major political and strategic choice the Union made recently in meeting the challenges of the new knowledge-based economy. Halting the deteriorating

health situation has become a key condition for a sustainable world, especially in the following fields: combating diabetes, diseases of the nervous system and cardio-vascular diseases and rare diseases.

All around the world Tele-Medical services have larger and larger extent. The most interesting and important monitored signal is considered the ECG Signal. Millions of people die each year from cardiovascular diseases which can be controlled or prevented. According to the World Health Organization's (WTO) annual health report, just over 29% of all disease-related deaths were caused by cardiovascular problems.

As acquisition and processing ECG signal model there are at this moment two methods:

- use monitoring on short time intervals with the possibility of on-line data processing and diagnosis (drawback of the method consist in impossibility to achieve a complete diagnosis);
- use continuous acquisition of ECG signals for 24 hours with further Holter-type diagnosis and data process (drawback of this method is the impossibility to immediate interfere with the patient).

Current world-wide acceptation of Tele-ECG is continuous on-line monitoring of ECG signals from a patient.

The originality of the method proposed in this project consists in achieving monitoring with continuous data processing having the possibility of automate diagnosis using the build-up database. With other words, this method represent an Intelligent Tele-ECG having possibilities to cumulate diagnose from both medical expertise and software analysis.

After full scale implementation of the generalized direction, large parts of the population will benefit of complete diagnosis regardless of distances or patient conditions. The achievement of this goal will decrease the number of patients hospitalized, by ambulatory observations.

If we look all around the world, the Tele-ECG system proved to be very useful and with real possibilities to improve medical services through the decrease of cardiac death rate.

In Poland the Tele ECG system has started since 1996 and now a reduction of hospitalization rate has been noted from 5% to 2%. The system started involving 2000 independent patients and over 12000 patients from family doctors, the ECG signal database having now over 22500 entries.

The efficiency of Tele-ECG data transmission in Osaka-Japan has reduced by 57% the number of patients with cardio respiratory disorders through fast tracking down and intervention.

Some firms have started to produce Tele-ECG transmission equipments fitted with acquisition and data processing modules. Most of these achievements are completed in U.S.A., EU countries having light performances. Can be mentioned ADInstruments USA (www.adinstruments.com) with notable hardware and software developments.

The solutions practically implemented started to be tested in special climate, geographic and electromagnetic compatibility conditions. For example, in the Annual Review of Biomedical Engineering (2003, Vol. 5, No. 1: 383), some results over testing Tele-ECG systems are presented. The objective of this study was to determine reliability of vital-signs monitoring systems in extreme environments. Three climbers were monitored 24 hours while climbing through Khumbu Icefall. Data were transmitted to Everest Base Camp (elevation 17,800 feet) and retransmitted to Yale University via telemedicine.

Monitoring systems of different bio-signals acquired from patients are indicated in related references since the '80. The USA 403775/1985 patent (Reinhold, Herbert and Albert, 1985) describe a system for monitoring a plurality of patients including a plurality of patient-worn units and one or more office units.

A patient unit detects a patient's EKG in real time. The analyzed data is sent over a standard voice-grade telephone line or other suitable communication channel to an office which prepares a patient report for a physician. In addition, the office unit provides an interactive scheme by which various alarm and recording criteria are established for a particular patient at the time of hook-up. Also, the office unit automatically communicates with the physician under predetermined emergency circumstances so that a patient can get medical attention.

Technical advances in miniaturization and wireless communications have enabled development of monitoring devices that can be made available for general use by individuals/ patients and caregivers. New methods for short-range wireless communications not encumbered by radio spectrum restrictions (e.g., ultra-wideband) will enable applications of wireless monitoring without interference in ambulatory subjects. (Progress in Electromagnetics Research Symposium 2005, Hangzhou)

Theoretical complex studies start to appear after 2000 in different magazines and conference revues, important contributions being made by researchers from USA, Japan, China or France. Synthesis papers can be mentioned:

- Thomas F. Budinger, Bio-monitoring with Wireless Communications, Annual Review of Biomedical Engineering, Vol. 5: 383-412;

- Jeng-Pang Wang, A Real-Time Wireless Physiological Monitoring System, Progress In Electromagnetics Research Symposium 2005, Hangzhou August 23-26;
- Hung, K., Yuan-Ting Zhang, Implementation of a WAP-based telemedicine system for patient monitoring, IEEE Transactions on Information Technology in Biomedicine, Volume 7, Issue 2, June 2003 p.101 – 107,

but library references is complex also due to interdisciplinary character of studies. One remark is for the existence on the Net of a dedicated magazine: Telemedicine Journal and e-Health.

In Romania, like world-wide, signal processing, automate diagnosis and data transmission are still in fundamental special research field, being not an option which is largely applied. Among the partners of this project, especially the Universities have contributions to ECG data processing through commutative and non-commutative methods, the activities being conducted within several Research Grants. With study directions in bio-engineering and data processing, research platforms have been developed in Master research activities and also PHD research activities, some of the graduates continuing their research work abroad (USA, Greece, Italy, France). It is noted the cooptation of a research team of Mathematics, specialists in signal processing and compression, having a real chance to achieve new quality software instruments.

Other partners have certain degree of expertise in realization of performance data acquisition systems, being among top market leaders with remarkable results in electrical equipment implementation and tele-measurement data transmission systems. The partnership is completed from medical side, with an important hospital, having a fundamental function in orienting medical activities, database implementation solutions, imposing some medical processing protocols. Here is ensured the validation of research results. This applied research project will lead to an experimental system model with two broadcast centers, one at the hospital and the Coordinator.

Based on tests and validations, at the final stage a development solution will be indicated, in which first beneficiaries will be Cardiac Departments from large hospitals, followed then by extension of the system for entire population through family doctors.

The "marriage" between telecommunication and medicine is not a new concept as many might think. It started at the beginning of the 20th century with the development of the electrocardiogram. First stage of telemedicine from 1901 to 1960: The historical evolution of electrocardiography is closely related to telecommunication in more than one way. In his pioneering work dating back to 1901, Einthoven wrote "Mr. Ader has already built an instrument with a wire stretched between the poles of a magnet. It was a telegraph receiver". This invention of the string galvanometer by Clement Ader, primarily used as a telegraphic communication instrument, was the technical breakthrough that opened the way for Einthoven's basic and extensive studies of human electrocardiography (ECG). Moreover, Einthoven connected his string galvanometer located in the physiology laboratory to the hospital about a mile away by means of telephone lines. He then named his device "Le Telecardiogramme"

Second stage of telemedicine in the late sixties: These first steps in Telephonic ECG recording (Cardiac telemedicine) were prematurely terminated. It was not until the late sixties that the first reports on the clinical use of transtelephonic ECG, primarily for ambulatory surveillance of pacemaker patients, were published.

Third stage of telemedicine in the seventies: A few years later the first pioneering work describing the use of transtelephonic ECG monitoring in arrhythmia detection and ischemia monitoring in high-risk cardiac patients was published. New technology for a revolutionized practice of telemedicine/telehealth and remote home monitoring in the next millennium is in advanced stages of development.

Wireless bio-monitoring now becomes a technology for remote sensing of patients' activity. Technical advances in miniaturization and wireless communications have enabled development of monitoring devices that can be made available for general use by individuals/ patients and caregivers. New methods for short-range wireless communications not encumbered by radio spectrum restrictions (e.g., ultra-wideband) will enable applications of wireless monitoring without interference in ambulatory subjects.

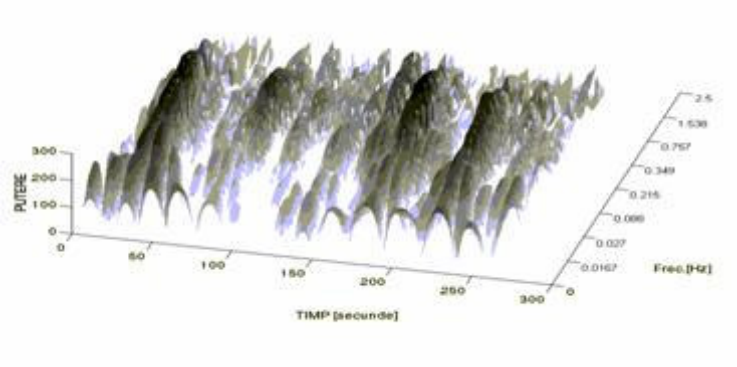
At present the number of people with cardiovascular problems is constantly increasing. This also implies higher costs for the health care systems, including the Romanian one. Actually, the Romanian health care system cannot insure the proper hospitalization for more then one third of the patients requiring heath care assistance. The financial sources are scarce and there is no clear tendency of growing. In these conditions, the polish example is significant for cost efficiency through telemedicine system for cardiovascular illnesses, which also brings a broader access to qualified health care, increasing the general life expectancy.

The system developed in the project achieves two goals by implementing a network for testing and refining the solutions, further to be applied on a larger scale:

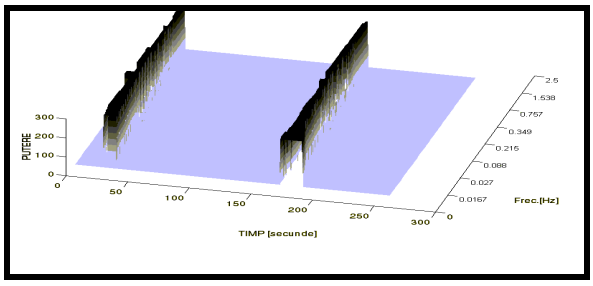
- broadening the patients access to clinics, through direct transmission of ECG recording from the family doctor or even from the patient himself, to a single, specialized centre, avoiding the hospital

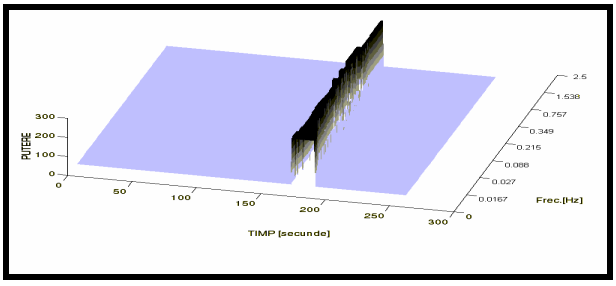
call and stay, thus making important savings both for the patients, as well for the health care system,
- using specialized software for detection of new parameters, which can show the cardiac risk of people, who apparently don't present any symptoms. Early detection of cardiovascular disorders increases the possibility of preventing and stopping the illnesses.

The technological researches have evolved in the past years due to the developments of electronics and information technology. New equipments were produced and tested in various conditions, in order to obtain the highest precision in detection, transmission and evaluation of ECG signals. A Tele ECG system is defined by its complexity. Creating and implementing it is the result of cooperation amid specialists from different scientific fields: engineers, doctors, mathematicians, information technology specialists. That is way the scientific team of the present project involves specialists from all these fields, who demonstrated through their works that they can achieve the project objectives at scientific and academic standards.



The server data base will assign the following to each ECG signal:
- time processing, frequency, time/ frequency
- diagnostic regarding the risk of cardio-vascular events.





The role and responsibilities of each partner where described, we only wish now to underline the importance of created partnership, in size as well as in scientific and technical abilities. We note the involvement in the research team's project of young graduates, who carry on there studies of Master and PhD on themes related to the activities proposed in the project.

The benefits brought by the usage of this new equipment are relevant in the following aspects:
- Intelligent Tele-ECG brings a significant technical leap in the biomedical equipments field through constant monitorization of ECG signal, regardless the distance;
- the application will increase the life quality:
  a) for the patients with cardio-vascular diseases, witch can be monitored at home without the need of going to a specialized clinic
  b) it can be a method of preventing diseases aggravation by monitoring the healthy patients with high risk of developing cardio-vascular disease
- the possibility of extending the intervention at the of family doctor, or even the patient, increasing the diagnosis quality and reducing the time for getting the results
- the possibility of creating a national level data base
- the possibility of connecting with similar systems from other countries thus enlarging the data base, with favorable repercussion in increasing life quality of EU citizens.

The benefits apply to all partners, thus being able to use the research and development possibilities for creating new, modern research methods in a field that allows the expansion of evolved technical solutions implementation.

The staff technical abilities will evolve through advances knowledge assimilation regarding informational measure systems.

An important problem is tie to the benefit for the bio-security field: the patients are no longer force to be in contact with hospital environment and therefore minimizing the risk of unwanted contamination. The economics elements regarding the profit are not relevant because at the end of the research project the partners will create an experimental model and they do not claim any property rights over the results.

The system rentability, if the research will lead to the possibility of future development of the experimental model, can be evaluated by correlating the results already obtained in other countries. The costs for hospitalization and the number of hospitalization day have significantly decreased, easing the budget, and the quality of medical services rose.

I. DATA ACQUISITION:

1. Mobile acquisition unit:
   a. Notebook
   b. System for ECG signals acquisition and conditioning:
      - ECG biosensors
      - Bio amplifier
      - 12 channels data acquisition board

2. Optimization of the data acquisition process.

II. DATA TRANSMISSION:

1. Selection of the optimal solution for transmission via Internet through:
   - Optic fiber
   - 3G telephony
   - Wireless 2,4 & 3,5 GHz

2. Validation of the optimal solution depending to the transmission safety, reliability and efficiency

3. Realization of the transmission system.

III. DATA PROCESSING:

1. Processing:
   a. Time analysis software
   b. Frequency analysis software
   c. Time-frequency analysis software
   d. Automatic diagnose software

2. Database:
   a. Data server
   b. Internet server internet – portal
   c. ECG signal database

3. Software for on-line databases comparing

IV. SYSTEM IMPLEMENTATION:
INTELLIGENT TELE-ECG

REFERENCE

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