A Scalable and Secure Telematics Platform for the Hosting of Telemedical Applications. Case Study of a Stress and Fitness Monitoring

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***Abstract*—Mobile telemedical applications are of crucial importance today as they do offer the potential to improve the quality of the health care related services. It has been proven that the leading cause of several illnesses and diseases are stress and the lack of fitness practices. Based on that, a system capable of estimating and monitoring both stress and fitness levels without a physical consultation of a medical specialist is presented in this work. A correlation between physiological parameters and stress or fitness is explored in the developed intelligent expert system. In order to enable the implementation of such a complex system, a flexible Telematics Platform is conceived. This Telematics Platform does guarantee a secure data communication involving encryption and a suitable visualization of the fitness and stress assessment results on both the patient's mobile phone and on a web-based portal. Moreover, the platform is scalable and can therefore be easily extended in order to support different kinds of telemedical applications. The system presented in this paper does enable the efficient and cost-effective stress and fitness monitoring of patients while being at home or practicing their daily jobs with their subsequent eventual mobility.**

Keywords-eHealth; telemedicine; fitness and stress monitoring; telehealth; m-health; telematics platform.

I. INTRODUCTION

The state-of-the-art in healthcare is strongly affected by the exciting convergence between the medical fields and a series of technological developments in IT, the increasing patient's care quality requirements and finally the strongly increasing cost pressure. Telemedical solutions are currently revolutionizing the practice of health care due to a series of benefits; the most important ones are the followings: reducing of hospitalization rates, cost-effectiveness from the patients' point of view, enabling the right care at the right time, increasing and improving patient's monitoring with appropriate management programs and finally enabling the health information organization through a structured gathering of all relevant information at one central place.

The scope of this paper is to present the core features of the developed Telematics Platform as well as the fitness and stress monitoring applications implemented on it. The patient's mobility is guaranteed by the developed system. Patients use their usual mobile phone and wear a belt equipped with appropriate wireless sensors for the acquisition of different physiological parameters such as heart beat, breathing rate, body temperature, etc. The patient is continuously monitored while not being significantly disturbed in his/her every-day-activities. Moreover, with the help of the implemented intelligent modules for stress and fitness modeling, there is no need for a direct involvement of a medical doctor in the real-time decision making process.

II. RELATED WORKS

Mobile telemedical applications have been receiving more and more attentions due to their ability to satisfy today's society demands in health care. Telehealth care has become an important issue for implementing novel medical services and it has become a very promising market for industry. There is no wonder why big player such as Intel, Microsoft and Google have being developing their eHealth platforms and related applications in the last years. Intel health guide is a system for chronic care management and personalized health monitoring at home [1]. But the patient has to acquire the Intel health guide device PHS600 in order to get full benefit of the system. Microsoft Health Vault is a platform for storing and maintaining health and fitness information, but devices for vital signs collection should be compatible with Health Vault [2]. Google Health is a web-based system for organizing health information and sharing it with doctors as explained in [3]. The import of data from vital sign devices is still a future development project for Google Health.

In the last decade, a number of projects have been interested in the conception of platforms for the implementation of telehealth applications. In the year 1998 a telematics platform for patient oriented services was developed; it is presented in [4]. Three years later, a prototype for mobile telemedicine was conceived and presented in [5]; thereby the communication between the mobile phone and telemedical processor was enabled through the standard infrared (IrDA) interface which however does need a direct line of sight.

Newer platforms have been exploiting recent advances in telecommunication networks. In [6] a framework solution for

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information systems which could be expoited for research projects in preventive medicine is described. This consists of a workflow description, a process communication, a process data computation and a data visualization.

The implementation of differents telemedical applications has been introduced in several papers. Promising results of the stress monitoring using distributed wireless intelligent sensor systems have been presented in[7]. In [8] a simple fitness monitoring is presented. In the processing phase of reducing the variance within physiological information data (weight, blood pressure and heart beat) simple algorithms which do not take into account other facts are applied. A large body of literature suggests that Heart-Rate Variability (HRV) analysis can be potentially used for the assessment of stress. However, a practical problem, that is so far not well addressed in literature, is to derive some form of quantitative relations between parameters of ANS activity and stress. The major difficulty in establishing these kind of relations is the difference in behavior among individuals due to different body conditions, gender, age, physical fitness, emotional states, and so on. To handle such problems, the authors in [9] propose a fuzzy filtering based algorithm for the preprocessing of the physiological signal.

III. EHEALTH-MV SYSTEM

A. System Description

Collecting the vital signal measurements from vital sensors, transmitting these measurements the mobile phone and from there to the process database is the first task of this project. These physiological parameters are acquired as described in[10]. Persons to be tested or monitored wear belts equipped with wireless vital sensors. Sensor data are sent via Bluetooth to the mobile phone (acting as gateway) of that test person and from there via UMTS/GPRS to the process database (Fig.1).

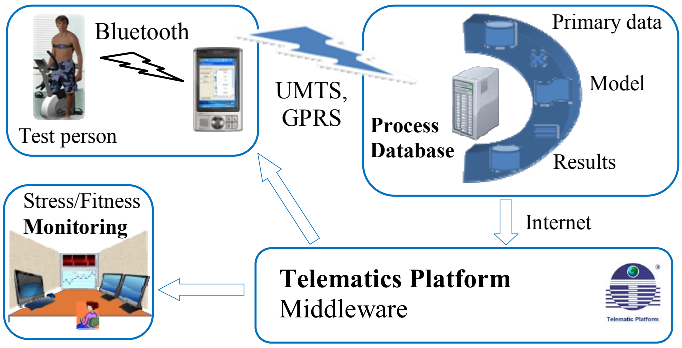

Fig.1. eHealth-MV System

The Process database is connected to the fitness and stress modules and produces assessment results from primary data. These results are sent through HTTP-protocols to the Telematics Platform. The Telematics Platform ensures in its turn a secure data transport, a data storage and controls the access to the data from different user categories. The process information management within the process database block and both interfaces to the Telematics Platform and to the mobile data acquisition system are realized as described in[11]. In [12] it is demonstrated how artificial intelligent can be applied for the interpretation of medical data. Further explanations to the developed vital signs acquisition system, stress and fitness modeling are explained in sub-sections B, C and D respectively.

B. Vital Signs Data Acquisition

The data acquisition is mostly related to a noninvasive measurement of physiological parameters (i.e. HR, HRV, breath frequency, skin temperature ....) and indirect load parameters by accelerometer sensors. This acquisition system is a distributed system containing one or more sensor elements connected wireless to a data concentrator PDA. In addition to this subjective information can be provided by the patients by PDA communication. The PDA sends the data by wireless communication (WiFi, 3G) to a communication server and a central data base for in-time or later calculation of complex secondary information (Stress, fitness,...) from the primary multiparametric raw data [10].

C. Fitness Modeling Principle

Peak oxygen consumption, the accepted measure of cardiorespiratory fitness, is most commonly assessed in the laboratory by indirect calorimetry during standardized treadmill or bicycle test. Because this testing procedure is strenuous, costly and time- and staff-consuming, substantial efforts have been directed to other methods for cardiorespiratory fitness estimation. Thus there exists a greater amount of exercise and non-exercise-models for the estimation of maximum oxygen consumption [eg.[13-15]]. After a literature screening and an internal validation study an exercise- and a non-exercise-model have been implemented in a PDA-application/Server-Application. The exercise model bases on a regression model [16] and includes a one-mile walk-test. While the application guides the user through the testing procedure, data like walking time and average heart rate during the test are automatically analyzed and calculated to estimate maximum oxygen consumption. The non-exercise regression model uses gender, body-mass index and subjective ratings of perceived functional ability and physical activity as input variables[17], [18]. Both models reached correlation coefficients with directly measured oxygen consumption (r=0.85 and above) with low standard error of estimate (4.3 $ml/min*kg^{-1}$ and below). Thus model`s accuracies are supposed to be sufficient for cardiorespiratory fitness classification in a general population.

For an immediate user feedback a graphical and verbal classification of the calculated value can be presented on the PDA-screen and the web-based portal [19].

D. Stress Modeling Principle

A novel fuzzy modeling based HRV analysis method for stress assessment was proposed in[20]. The method of [20] extracts the features of HRV in time-frequency domain and fuzzy techniques are exploited to render robustness in HRV analysis against uncertainties arising from individual variations. The state-of-art is extended with a new study whose aim is to develop a fuzzy expert system that gives a highly accurate description of the biomedical signals under the different stress conditions. An integrated approach that combines fuzzy modeling with the stochastic methods has much to offer in developing the reliable physiological models and in predicting the stress of the patient. One possible way to do this is as follows:

1. A history dependent probability distribution can be considered for the stochastic modeling of the five minutes long series of R-R intervals recorded under a given stress level.
2. The parameters of the distribution (e.g. mean, variance, etc.) can be further assumed as random variables and can be modeled using a stochastic fuzzy model.
3. The stochastic model of heartbeat intervals is individual specific and corresponds to a particular stress level. Once the different heartbeat intervals models are available for an individual, an analysis of the given R-R interval series generated under an unknown stress level is performed as follows:
   a. The given signal is assumed to be generated by a stochastic mixture of a finite number of stress state specific models such that each model tries to fit a part of the signal.
   b. The parameters of the stochastic mixture are inferred under Bayesian framework. The probability that the given R-R interval data belong to a particular stress level specific model can be calculated. The stress levels specified to different models are weighted by the respective probabilities to provide an estimate of the unknown stress level.

The results presented in [21] suggest that intelligent fuzzy computing based biomedical signal analysis is a promising method. The algorithms for predicting patient's stress state from a real-time analysis of physiological data are to be optimized in terms of computational complexity to facilitate the real-time applications. Intelligent fuzzy computing based stochastic analysis of biomedical signals with potential e-health applications is the novelty of this research.

The experiments perform a 24 hour monitoring of 50 subjects in e-health setting. The developed e-health system permits the acquisition of not only physiological data but also the subjective data using the mobile handheld where the software version of modified NASA Task Load Index (TLX) was implemented. The subjects were asked at different times of the day during monitoring to input at the mobile handheld the subjective rating score of stress felt by them during last 5 minutes. The subjects were required to provide a rating on the scale from 0 to 100 for each of the 6 components of stress (mental demands, physical demands, temporal demands, own performance, effort, and frustration). The overall stress score based on the average of ratings on six subscales is of interest for prediction. The aim is to predict the overall stress score based on the analysis of 5 minutes long heartbeat intervals.

IV. A Description of the Telematics Platform

A. *eHealth-MV System Architecture*

The layered architecture of the eHealth-MV is illustrated in Fig. 2. The Telematics Platform serves as a middleware and connects users to the implemented services while providing a secure data transmission. Different user categories such as patients, test persons, medical doctors, coaches, center/hospital administrators and the system administrators are the possible users of the system as illustrated in Fig. 3. Fitness and stress modules are made available to the process layer block in the form of web services.

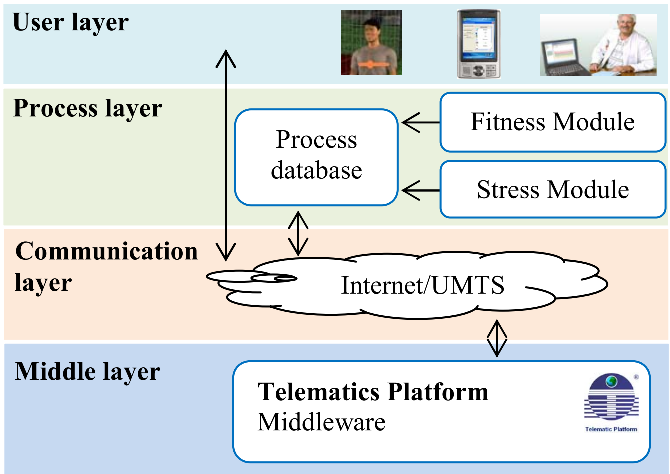

Fig. 2. Layers of the eHealth-MV Architecture

B. *User Rights Management in eHealth-MV*

In the developed eHealth-MV system, a web-based portal structure as shown in Fig. 3 has been implemented.

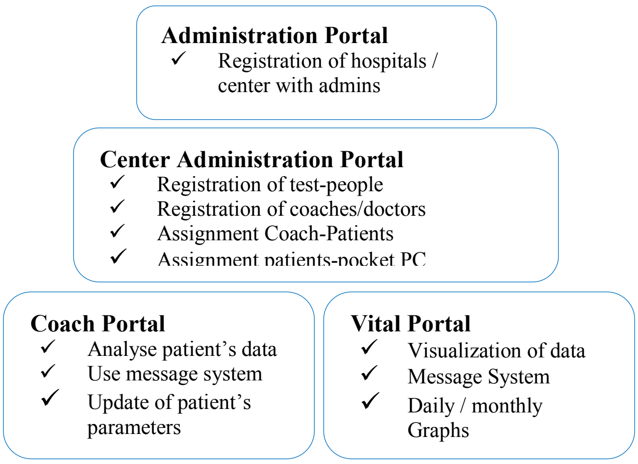

Fig. 3. Portal Structure in the eHealth-MV System

The users of the system can perform the tasks as illustrated on Fig.3.The Vital Portal is the web-based portal where test people can access to their data.

C. *Features of the Telematics Platform*

The Telematics Platform is conceived as client-server architecture. Data security and confidentiality are fundamental for telematics platforms used for patients oriented services. Therefore, such features as authentication, data-encryption, separation of personal and medical data during storage, anonymity of data during transfer have been implemented into the Telematics Platform in order to address these concerns.

Any information stored or transferred through the system is encrypted using appropriate methods involving different key sizes. The life time of the key is the session duration. The encryption engine is built up in a modular way which allows expansion to other methods.

V. CONCLUSION

The preliminary results of the ongoing eHealth-MV project appear to be promising. Fitness modeling has been developed and successfully tested with 110 test persons. Fitness levels could be classified in several levels, from an extremely bad to an excellent fitness level. A new fuzzy computing based stochastic method was proposed for modeling the stress state of the patient. The initial results have indicated a good accuracy and reliability of the analysis method in predicting the stress level from the measured physiological data. However, the optimizations regarding the computational complexities and accuracy are still under development.

The mobile real-time data acquisition of the vital signals has been developed and tested for the purpose of the project. This enables data collection at any time independently of the location and the ongoing activity by the test person or patient.

The scalable Telematics Platform has been developed and it is ready to support different telemedical applications.

Such a system could stop the cost explosion caused by long term hospitalization or frequent physical consultations by medical doctors.

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