Remote Transmission and Analysis of Signals from Wearable Devices in Sleep Disorders Evaluation

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Abstract

The aim of this work is to propose a new approach to traditional sleep monitoring, in order to simplify the acquisition and the managing of the signals and to reduce the patient's discomfort during data acquisition. Signals are collected by a sensorized garment and transmitted to a central elaboration station. The results of the elaboration are made available to the sleep specialist through a web services organized internet portal. The sleep specialist is able to review the data, to write and store in a database a diagnosis and to suggest a treatment for the patient. The employment of a sensorized garment drops down costs for installation and maintenance of a dedicated sleep monitoring center. Moreover, the internet-based system proposed simplifies and speeds-up the retrieving and consultating of historical evidences.

1. Introduction

Sleep quality has in general a very deep impact on human health and quality of life.

The major diseases that can occur during sleep are breathing problems (apneas, snoring), insomnia, movement disorder and sleep fragmentation.

In particular breathing disturbances are associated with hypertension and are an important risk factor for what regards cardiovascular and cardiorespiratory diseases in populations with and without cardiopathies [1]. In this context breathing pathologies can be considered as a life-threatening condition. An untreated obstructive sleep apnea tends to worse over time and can easily result in an high risk of a cardiac attack or cardiac arrest during sleep or a dangerous accidents due to the loss of attention or to the excessive sleepiness during the daily life.

Polisomnography is the traditional approach to the monitoring of the sleep activity. The patient is required to spend several night in a dedicated structure, the sleep laboratory. Here his body is covered with sensor and wires for the detection of the relevant signals: cerebral and cardiac activity, breathing, body and limbs movements, oxygen saturation, etc

This method provides complete information about sleep, sometimes not necessary for the diagnosis of some sleep pathologies (i.e. apneas) and presents some limitations especially for what regards the impossibility to monitor wide populations due to the high costs of the exams and the sparsity of sleep laboratories.

Another aspect that must be taken into account is the obvious discomfort of the patient during the data acquisition, factor that can lead to relevant alterations of the collected data.

The aim of our work is to propose a portable, easy-to-use and cost-effective system that permits the realization of the polisomnographic exam directly at patient's home. Only a subset of signals is recorded, that, however, are sufficient for the identification of some sleep disorders, or allow a screening in the population, identifying the subjects who really need a complete polysomnographyc evaluation. The employment of a sensorized garment for the data acquisition during sleep grants portability and a low intrusive approach, improving patient's comfort and avoiding him the stress of the registering sessions in the sleep laboratory.

The patient is provided with a personal device, a smart phone, that is able to send the collected data to the server for the elaboration. Thanks to a simple and effective user's interface the patient is able to manage all the aspects of the recording session, without the participation of specialized staff.

From the clinician's point of view, the employment of a distributed architecture and the web-services based web portal is a flexible tool that permits the access and the consultation of the data from wherever is needed: office's workstation, home's PC or through internet connected devices such as Personal Digital Assistants and smart

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phones. The portal allows the clinician to perform a tempestive consultation of the elaborated data and permits him to rapidly access data relative to past registering sessions, improving his ability of rapidly asset the state of the patient and the effectiveness of the therapy. Thus the proposed system can find a very useful application in the follow-up of the sleep therapy after the diagnosis.

2. Methods

From an architectural point of view the system is divided into three major conceptual actors: the patient, the technical station and the clinician/professional.

The patient's station consists of a wearable device, a T-shirt with embedded textile sensors for the survey the signals of interest: ECG, breath and body movement.

Signals are collected from a front-end electronic device inserted in the garment.

The front-end device performs a first pre-processing of the signals (noise reduction, artifact suppression) and then transmits the data via bluetooth connection (in real time or at the end of the recording session) to an external assistive recording mobile device controlled by the patient. This device could be a last-generation smart phone or a Personal Digital Assistant device, provided with a simple and effective graphical user interface user that acts as a virtual assistant for the patient, guiding him through all the phases of personal data insertion, signal registering and communication.

Data are stored in the internal memory of the device along with information relative at the registering session (inserted directly by the patient). At the end of the sleep session the patient sends the data (through a GSM connection) to the technical station where they are processed by an automatic routine and stored in a local database.

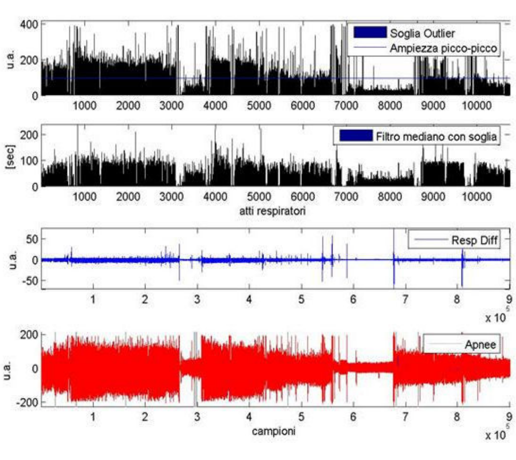

Figure 1: Report form the Automatic Processing Routine

The technical station consists of a server with a MySQL database and a specific dedicated software to the processing and storage of the transmitted data.

The signal processing aimed to the quantification of sleep fragmentation and the identification of sleep apneas. Sleep fragmentation is related to the number of microarausals and/or apneic events. The number of microarausals and apneas during the whole night are expressed as mean per hour, and are clinical indices for the sleep evaluation. Microarausals were detected on the sequence of RR intervals by identifying falls of RR below 10% the mean value of the preceding 10 s, followed by a rise lasting at least four beats. apneic events were detected by applying different criteria at the same time:

- apnea definition on respiration signal;
- presence of microarausals on RR sequence. The identification is more robust if a coherence appears in the range 0-0.04 Hz between HRV and respiration signals.

All the communication workflows between these entities are managed by a distributed architecture.

This platform contains a workflow engine that defines and manage all the possible operation that the actors involved in the process can perform.

Communications between the central platform and the elaboration station (concept server) are realized through web-services technology, using in particular the Apache AXIS framework for the realization and the deployment of the services. Apache Axis is a SOAP engine, a framework for constructing and managing SOAP processors [2].

SOAP stands for “Simple Object Access Protocol” and is a standard protocol from the World Wide Web Consortium [3]. It is an XML-based format for structuring messages to be exchanged between applications. SOAP is platform and language independent and is particularly suitable for communications of structured data on the Internet.

The web portal the professional utilizes for the interaction with the platform is built upon the Cocoon technology. Cocoon, from the Apache Software Foundation [4], is a web developing framework that utilizes the XML technology for the dynamic generation of web pages.

Cocoon includes an advanced framework for building interactive web forms, called “Cform”. Cforms are utilized in the portal for the visualization of data and for the interaction with the platform.

When the specialist performs some request on the portal, the central platform creates and sends a service request, structured as a SOAP HTTP message, to the specific web service, that is located on the technical station's server. The server performs all the required operations described in the web service's code (mainly inquiries to the server's database) and sends back to the central platform another SOAP-structured message with the required information.

These information are structured as an XML file, from which the Cocoon framework builds the portal pages, structured as a Cform, to be shown to the specialist who sent the request.

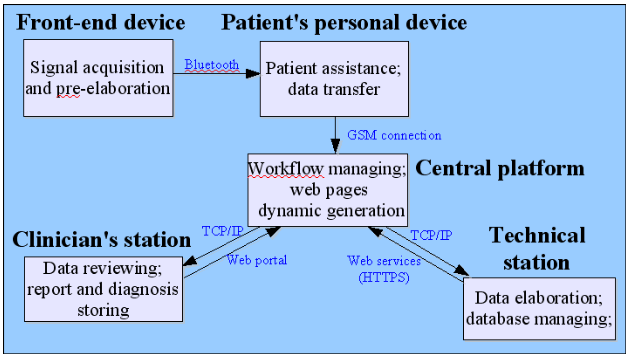

Figure 2: System Architecture

The definition of these uses cases is essential in the implementation of the web interfaces and web services needed for the specialist interaction with the central platform.

- login with the portal: when the clinician want to connect to the portal he has to insert a login and a password for his identification. After the login the initial page is shown. It contains some information about the clinician connected and a list with the active customers/patients followed by the specialist, with information about their current state and with the date of their last sleep registering session.

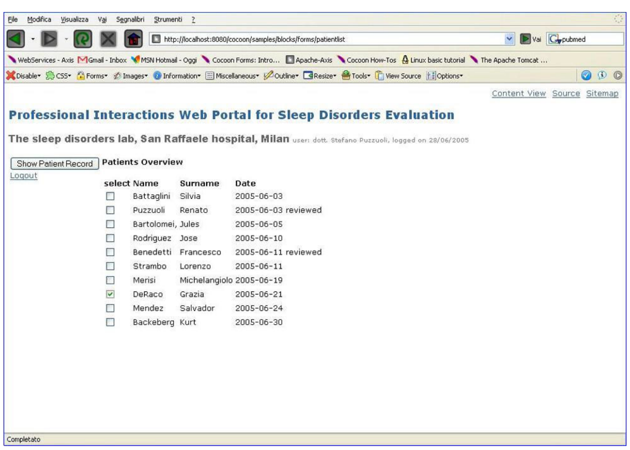

Figure 3: Web Portal Main Page

- From the initial page the specialist can choose to evaluate the data about a specific patient. A new page is shown where are displayed patient's personal data and the results of the automatic elaboration of the registered data performed by the concept server. Is also available a space where the clinician can write and store in the database some notes or a complete diagnosis and prescriptions for that case. It is also possible to generate an electronic report of the whole session, an HL7-CDA (Clinical Document Architecture), Release 2 compliant document in order to integrate the platform with a centralized electronic health record system.

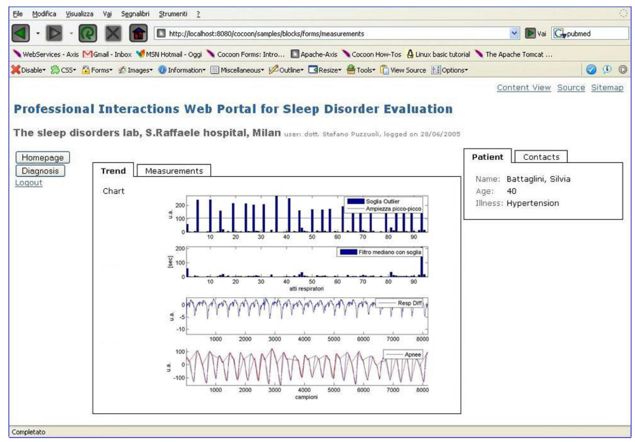

Figure 4: Report Visualization

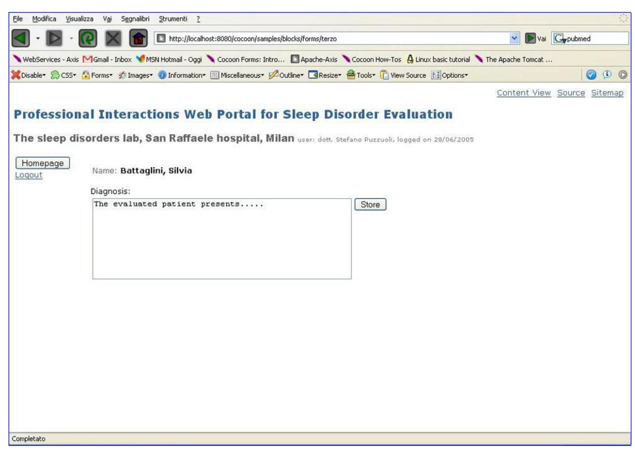

Figure 5: Diagnosis Storing

- In the last section the clinician can perform some researches among his patients, display the report of a particular session or access to a summary of the past patient's sleep reports for an evolutionary perspective of the case. Here the professional is provided with a graphical representation of the evolution of several parameters along the different sleep sessions performed by the patient.

3. Discussion and conclusions

The major improvement this system brings is the possibility of a continuous and cost-effective monitoring of the sleep activity for several nights at home without need of hospitalization. In this perspective, it is possible to monitor the patient for a longer period of time, improving the precision of the diagnosis and the assessment of the therapy.

This can be a particularly useful method for monitoring the quality of sleep in all that patient with some degree of cardiovascular diseases, for whom the presence of sleep disorder can be a serious source of risk.

Moreover this new approach, due both to his relative simplicity and cheapness, can be employed in all that cases where the traditional polysomnography would be unsuitable, for example for monitoring the quality of sleep of night workers or for people with hazardous activities that need a continuous level of attention during work, or for evaluating sleep quality in healthy people that could take advantage from an improved sleep period (elderly people, students).

A serious problem this method presents is the great amount (about 150 Mb) of data generated in every recording session. In particular the transmission of this bulk of data through the bluetooth and the GSM connection is a problem that must be completely solved yet.

Another aspect to be improved deals with the generation of the web portal's pages. Even if the Cocoon framework is a powerful and flexible web pages generator it is quite complicate to manage and requires experienced developers and long periods for code implementation and testing.

Acknowledgements

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