Archetype-based solution to tele-monitor patients with chronic diseases

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Abstract— **Health tele-monitoring systems are aimed to improve chronic diseases treatment and reduce cost of care delivery. Behind this innovative and promising philosophy in the care of people with chronic diseases several benefits can be found: hospitalizations may be reduced, patients' quality of life improved and clinical outcomes considered more complete. As tele-monitoring includes measuring and collecting health information about individual patients, the evolving concept of Electronic Health Record (EHR) is crucial. Getting a shareable and universally accessible EHR is a challenge whose importance is contemplated by organizations that establish and manage standards. In the context of the CHIRON project[1], Congestive Heart Failure (CHF) patients are enrolled in an observational study to be tele-monitored by experienced doctors. Technical solutions have been designed to deal with EHR desirable features and visual requirements for remote visualization and study. An EN13606/openEHR-kernel is the core component dealing with multisource patient data making up a complete EHR system assuring semantic interoperability. EN13606 [1] and OpenEHR [2] follow the two-level modelling approach describing specifications of a reference model and archetypes to store, retrieve, exchange and manage health data in EHRs. Dynamic components to access, visualise and insert data into patients' records are shown through a doctor-friendly user interface. It has been called Slim MEST (Medical Expert Support Tool) and combines high flexibility and adaptability as it is built upon the same archetypes defined in openEHR-kernel. Functionality is extended by means of an ECG signal viewer application, which proofs versatility of data collected by sensors used in the tele-monitoring process while offers the clinicians a practical tool for their diagnosis.**

Keywords—**EHR, archetypes, tele-monitoring, parameter, openEHR.**

I. INTRODUCTION

The use of communication technology to monitor patients and their health status is a focal point for improving chronic disease management. Hospitalizations can be reduced, patients' self-care is enhanced and outcomes are meant to be more valuable. Risk identification, particularly short- and very short-term, and multiple interactions among old and newly investigated risk indexes [3] may be an effective tool for patient-centric tele-monitoring [4] with the potential of fostering the continuum of care [5] in patients with chronic diseases.

To detect diseases in an early stage, before symptoms have occurred, the CHIRON project investigates patients with Congestive Heart Failure (CHF) both at home and in ambulatory conditions. Newly envisaged risk functions are applied to go beyond what has been done recently [6].

Provision of Electronic Health Record (EHR), as well as demographic information and data integration, are assessed following openEHR open standard specification **[**1**]**, which relies on archetypes as the standardized methodology to get reusability and scalability. Patient data is obtained from heterogeneous sources can be stored using the openEHR reference model [7].

The project equips the patients with unobtrusive sensors to collect multiple physiological parameters such as ECG, skin temperature, sweating index and activity patterns, as long as means to store other parameters, getting a complete list of 67 parameters which were found relevant for CHF patients, after a survey between cardiologists experts. Raw data collected by the sensors is made available for visualisation purposes by means of the ECG Viewer which access directly to the raw data. Only significant values are incorporated to the EHR, such as periodical averages. The tele-monitoring process generates raw data but only averages are copied to the EHR in order to give the doctors only the relevant CHF parameters. The tool also shows other EHR-based information coming from the Hospital Information System (HIS) such as medications, interventions, etc.. Slim MEST tool has been conceived to take advantage of the openEHR flexible dual model concept which separates out the reference model and the clinical knowledge (archetypes) modelled by doctors [9]. It encapsulates archetypes, data storage and retrieval and offers a doctor oriented interface which gives a complete overview of parameters trends and the health profile of the patient by accessing the EHR. Figure 1 shows components involved in the solution and their communication flows.

[1] www.chiron-project.eu

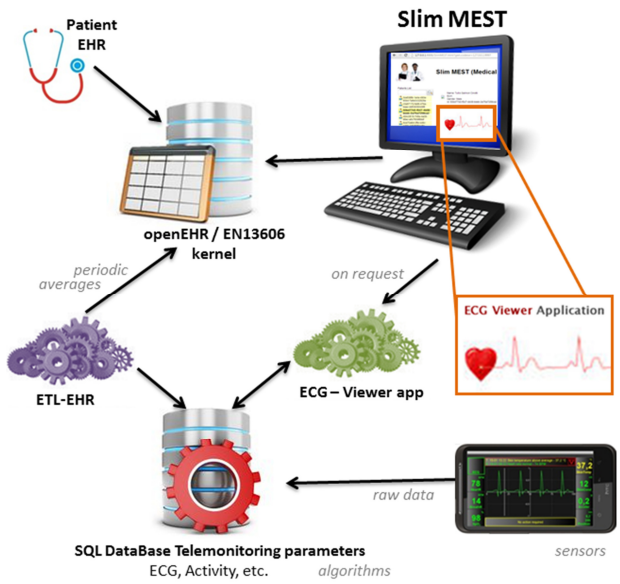

Fig. 1 - Components diagram.

The achievements of the medical objectives are assessed through a six months observational study started at April. Although number of patients and people involved is limited, it attempts to provide a proof of concept and useful conclusions about the potential benefits of this exposed solution.

II. EHR INTEROPERABILITY

A. Archetypes

To store (medical) parameters for the CHIRON project, the reference model EN13606 was used, and more specific the openEHR reference model. The use of EN13606 in eHealth systems is a proven solution for standardization [10]. The key concept of EN13606/openEHR is the so-called archetypes to model the medical knowledge providing interoperability, standardisation and computability regarding electronic health records. For every medical parameter archetypes were searched for in the openEHR clinical knowledge manager [11] which is a repository of archetypes already created and validated by community members are stored and shared. For the project these archetypes were clustered to the specific needs. Concepts were added for, by example, NYHA classification, daily activity, daily weight change and CHF etiology. More generable used parameters already existed in the openEHR knowledge manager, for example archetypes about ECG and lab tests.

After the creation of these archetypes they were approved by the project's cardiologist, which validated the workflow medically.

B. Transforming raw data into EN13606 information

Because of the observational study, the raw sensor data had to be stored correctly in the EHR to be accessible for the doctors. Storing raw data in the archetype model is not useful for medical use in the context of electronic health records. The EHR consists mainly of summaries of observations and evaluations. Therefore a technical translation was done. For example to store the relevant information for an ECG, instead of storing every single point, a calculation was done with an algorithm to extract the useful parameters from the ECG concerning CHF.

III. SLIM MEST

A. openEHR configurator

Clinical concepts modelled as archetypes in openEHR are written in Archetype Definition Language (ADL) [7]. Due to the path/value nature of archetypes, a component to configure the clinical concepts and the corresponding archetypes was found useful and consequently developed.

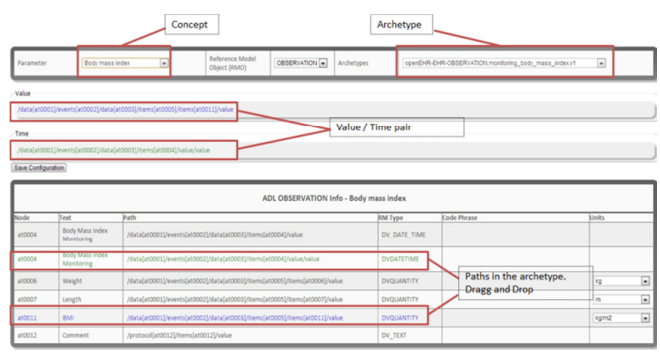

Fig. 2 - openEHR configurator.

This openEHR-configurator simplifies the associations between the parameters needed by the doctors and the archetypes stored in the openEHR kernel. Scalability and flexibility are key factors to allow different archetypes in the future, so the Graphical User Interface for this separate component is built dynamically according the one that is being considered. Figure 2 shows an example of concepts and archetypes.

Some initiatives have already been deployed with full archetype-based development [9-14] demonstrating at a vendor level the lack of dynamicity to constraint the archetype nodes, so the stakeholders continued to use their own software interfaces linking them to the dual model solution. Archetypes are defined as maximum datasets, therefore there is a need of selecting the information to be shown.

OpenEHR-configurator plays an important role in the automation of EHR accesses. It sets the properties which allow the correct communication between the client application and the openEHR-kernel. As a result, heterogeneous medical parameters can be treated uniformly through its API and client applications maintenance gets deeply simplified.

B. Graphical User Interface

Interface for medical experts is provided through Slim MEST. This tool is a web based application that allows ubiquitous secure access to doctors, where they can visualise, update and analyse the data of their patients. The application accesses the EHR, located in openEHR-kernel, remotely and shows up data collected in the observation period plus some data coming from the EHR.

Slim MEST relies on archetypes that are included in the EHR. Following this strategy makes the tool specially robust and flexible to the variations introduced in the openEHR-kernel it accesses to. This allows also a simpler adaptation to another supposed openEHR system in any other context. A communication layer, configured by openEHR-configurator (Section III. A), makes remote calls independent from the tool and relates archetypes in the EHR with concepts that will let the GUI being built dynamically.

The Slim MEST provides the following features:

- *Visualise parameters health status*: the last patient health status (last sensor measurements and heterogeneous EHR values, as medications or previous diagnosis) is shown.

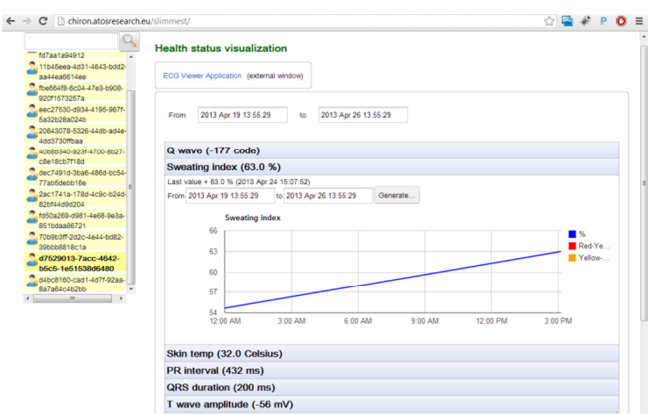

Fig. 3 - Slim MEST: Visualisation.

A self-expandable table is provided showing parameter name beside its last value and allows generating graphs between certain period of time of the numeric parameters illustrating the variation together with the stipulated thresholds. Diseases and medications are displayed indicating start and end of diagnoses and treatment. A printable report is available with this information.

- *Insert parameters health status*: this option brings out a paginated list of all available parameters in the system and allows introducing new measured or calculated values. As a reference, last value stored is shown beside the insertion area, accompanied by the date when the measurement was taken. Doctors guidelines have been widely taken into account in the design of the data update mechanism. As a result, new values are stored with the current date and time. A printable document that summarizes the actions taken can be obtained.

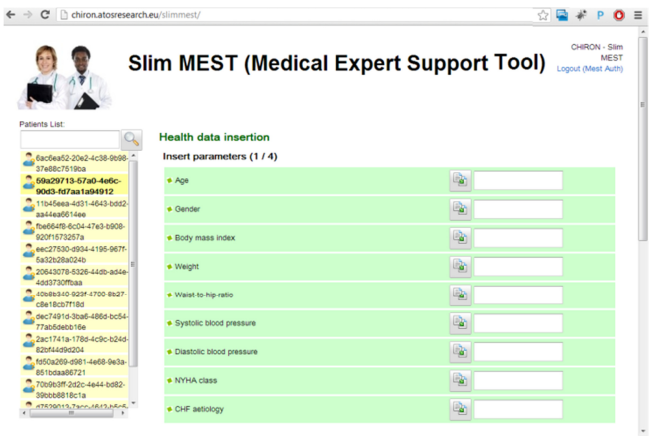

Fig. 4 - Slim MEST: Insertion

IV. ECG VIEWER

As described in the previous section the overall objective of the proposed solution is the effective management of the patient data coming from various sources (demographic, monitored and clinical data) coming from the EHR; but the medical experts need to analyse the raw data collected during the observational study protocol.

Under this concept the present research also includes an ECG (Electrocardiogram) Viewer application aiming at real electrocardiogram signal visualization. The ECG Viewer allows the doctors to visualise a specific part of the real ECG signal when such a demand rises. This means that when medical experts receive a critical alarm for a specific patient from the MEST they are able to have access in the original ECG signal, in an appropriately visualized depiction, for that specific patient. The ECG Viewer has been set to provide a 30-secs, 60-secs or 90-secs ECG signal after the time of interest has been selected, at which the critical situation has been observed in the Slim MEST. The expert is able then to move back and forth in time, observing the ECG signal and make up his conclusions based on his

knowledge. The ECG Viewer provides a user-friendly, easy and responsive environment with unlimited time-axis zoom capabilities, signal coordinates tracking and even exportation of the ECG signal in various formats.

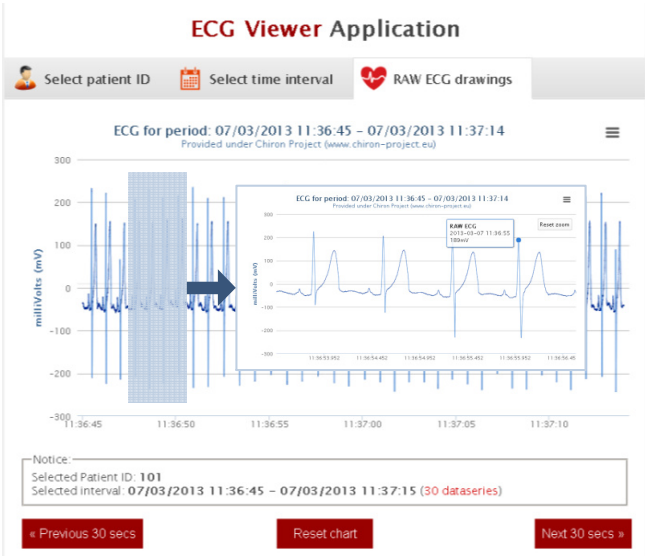

Fig. 5 - ECG Viewer and zoom feature demonstration.

ECG Viewer application has been developed to be presented within an Internet browser environment. Since the ECG signal is being sampled with a 500Hz frequency, the viewer has been set to provide a maximum of 90-secs visualisation. As the ECG signal length increases, it becomes more demanding to be visualised within a browser, due to the significant large amount of data that the both modules have to parse. The visualisation engine is based on jQuery framework and its extensions, thus providing maximum compatibility.

V. CONCLUSIONS

Health is a topic that concerns everybody. The conjunction between health care and technology has always been a source of hope to improve quality of life. This paper studies in depth an EHR-based tele-monitoring implantation for CHF patients and presents the satisfactory solution that has been reached through a collaborative work. EN13606 / openEHR model provides many benefits as an EHR standard and creates an effective synergy with tools designed to ease the doctor participation and intervention in the care of the patients with chronic diseases converting the archetypes in the basis of the overall system. What makes this approach especially significant is that the tele-monitored patients and doctors get benefit from this progress due to its dynamicity and simplicity. Additional parameters do not require new releases; just archetype modelling and concepts assignment.

Future success in eHealth, tele-monitoring and standardisation resides in collaboration, intercommunication and investigation that becomes exciting when day by day idealistic forecasts become closer.

ACKNOWLEDGMENT

This research was carried out in the CHIRON project (Cyclic and person-centric Health management: Integrated appRoach for hOme, mobile and clinical eNvironments) co-funded by the ARTEMIS Joint Undertaking (grant agreement #2009-1-100228) and by national authorities.

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