Archetype-Based Solution to Tele-Monitor Patients with Chronic Diseases

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Abstract— **Health tele-monitoring systems can be applied 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, improvement in the patients' quality of life and clinical evaluations more precise. The tele-monitoring includes measuring and collecting health information about individual patients, thus the evolving concept of Electronic Health Record (EHR) is crucial. Getting a shareable and universally accessible EHR is a challenge whose importance is considered 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 compliant kernel is the core component dealing with multisource patient data making up a complete EHR system assuring semantic interoperability. EN13606 [1] and more concretely openEHR [2] follows 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 called Slim MEST (light-weight 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 providing the clinicians with a practical tool for their diagnosis.**

Keywords—**EHR, archetypes, tele-monitoring, EN13606, 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 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 processed to obtain relevant statistics, which are incorporated to the EHR. The system also includes other EHR-based information coming from the Hospital Information System (HIS) such as medications or interventions. Furthermore, raw data are made available for visualisation purposes, in the case of ECG, using the ECG Viewer tool. This division of tasks creates a conceptually coherent and functional model, taking into account not only medical standards compliance but actual professionals needs. 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 parameter trends and the health profile of the patient by accessing the EHR. Figure 1 shows the components involved in the solution and their communication flows.

[1] www.chiron-project.eu

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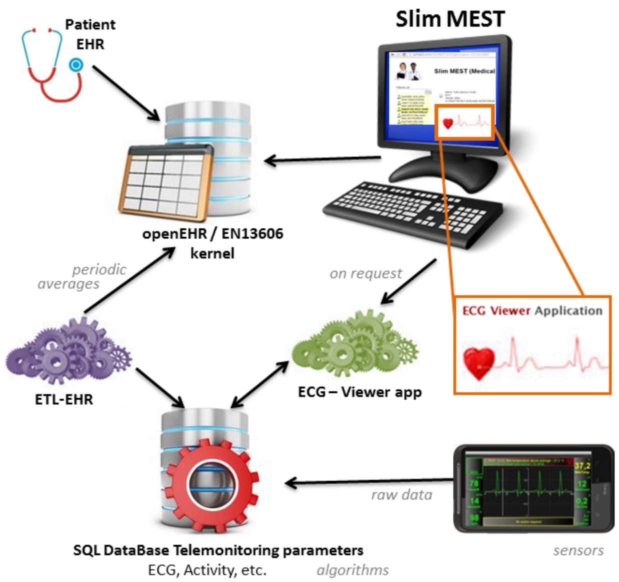

Fig. 1 Components diagram.

The achievements of the medical objectives are assessed through a six months observational study started in May. 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 the exposed solution.

II. EHR INTEROPERABILITY

A. Archetypes

The use of EN13606 in eHealth systems is a proven solution for standardization [10]. To store (medical) parameters for the CHIRON project, the EN13606 standard has been used, and more specific the openEHR reference model. As the EN13606 is a subset of openEHR classes only shareable elements has been used (compositions and observations) to be compliant with both reference models. The key concept of EN13606/openEHR is the so-called archetypes to model the medical knowledge providing interoperability, standardisation and computability of EHR between systems. Each medical concept has been modelled by means of archetypes created ad-hoc or searched for in the openEHR clinical knowledge manager [11] which is a repository of archetypes already stored, validated and shared by community members. For the project these archetypes were designed and clustered following the cardiologists' suggestions. Concepts like NYHA classification, daily activity, daily weight change and CHF aetiology were covered, but also other archetypes already available in the openEHR knowledge manager about blood pressure, ECG and lab tests.

Finally the archetypes selected were approved by the cardiologists, which also validated the medical workflow.

B. Transforming and Storing Raw Data into Archetypes

Heterogeneous medical information comes from multiple systems. The openEHR kernel and middleware permits the connection with the data contained in the patients' EHRs transparently in a standardized way. The openEHR kernel complies with the EU standard for medical data transport using the approved and authorized CKM archetypes. Postgres database is used to store and retrieve the information to / from the archetypes via the openEHR kernel middleware REST-based API (https + JSON) using the ADL path/value approach. Further research is being done to use XML database (eXist-db) using XQuery as the query language.

The raw sensor data are stored in a MySQL database and has to be available in the EHR to provide the doctors a general overview of the patient's health. Therefore during night the daily averages of the parameters are extracted out and calculated from the MySQL database and published to the kernel using the archetypes EN13606 compliant included in the configuration provided in the openEHR configurator (summaries of compositions / entries). For instance, to store the relevant ECG information, 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.

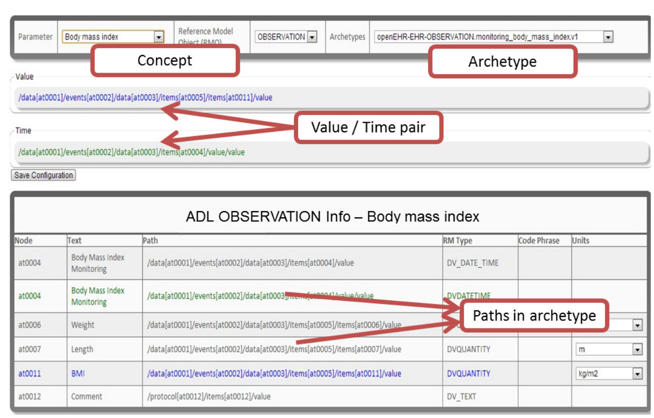

Fig. 2 openEHR configurator.

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 easily include new concepts and archetypes in the future, so the Graphical User Interface is dynamically built. Figure 2 shows an example of concepts and archetypes configuration.

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 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.

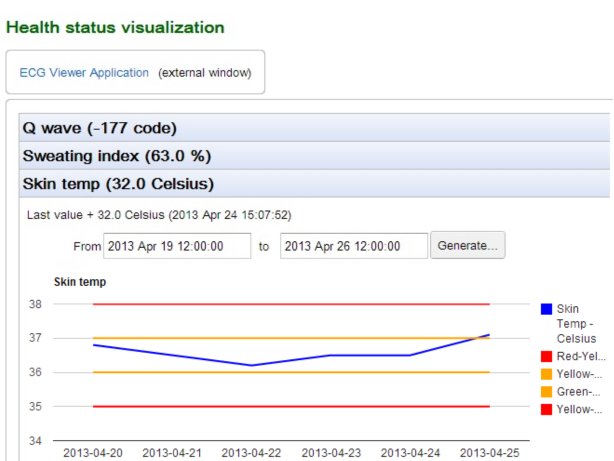

Fig. 3 Slim MEST: Visualisation.

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.

  A self-expandable table is provided showing parameter name beside its last value and allows generating graphs between certain periods 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.

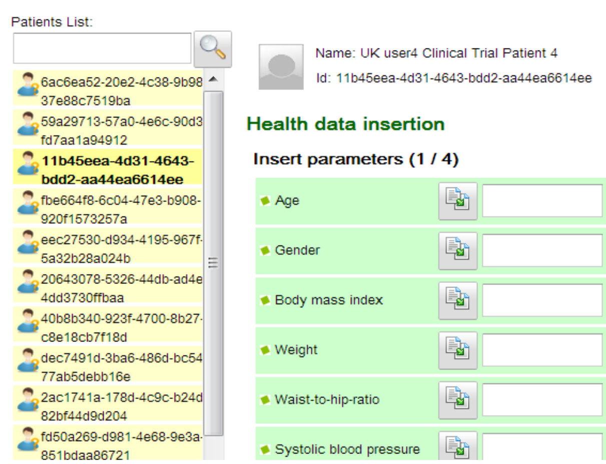

Fig. 4 Slim MEST: Insertion

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 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 Slim 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.

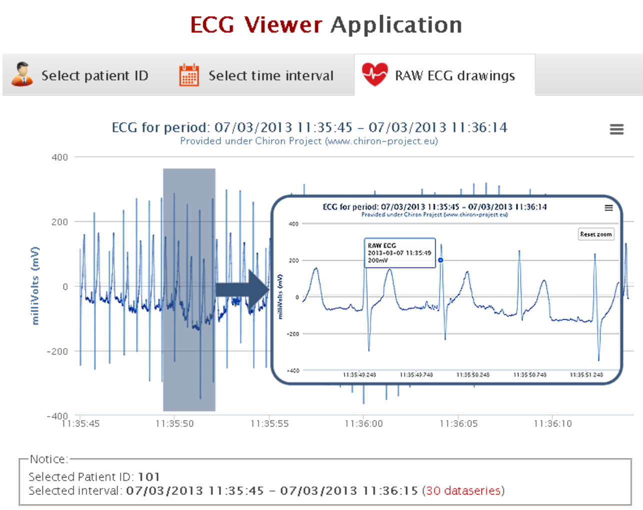

Fig. 5 ECG Viewer and zoom feature demonstration.

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 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.

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