Cyber-Physical Medical Platform for Personal Health Monitoring

O.O. Petrenko¹ and A.I. Petrenko²

1. PhD student, National Technical University of Ukraine “Kiev Polytechnic Institute”, 37 Peremogu Rd., Kiev, Ukraine.
2 Prof., Head of System Design Department, National Technical University of Ukraine “Kiev Polytechnic Institute”, 37 Peremogu Rd., Kiev, Ukraine.

Corresponding author: A.I. Petrenko
E-mail address: petrenko@cad.kiev.ua

Abstract

The new Generation of Advanced Engineering Systems confidently enters into the practice of monitoring and supporting the treatment of chronic patients at home. Hundreds of applications for smartphones with various operating systems have been created by different providers. This paper is a generalization of the author's publications on the possible usage of the service-oriented computing paradigm (SOC) for building a medical services platform which allows unifying the development of applications for patients, doctors and the central server by orchestrating and composing web services from a common cloud repository. Due to this approach the created applications can be adapted to the particular patient, his disease and the plan of his treatment.

Keywords: Wireless Sensor Networks, Health Monitoring, Advanced Engineering Systems for self-care, Personal Health Systems, Cloud services, decision support systems, Web-services


1. INTRODUCTION

During the last few years, significant progress has been made in wearable or on-body wireless biomedical sensors for collecting different physiological parameters of people suffering from various diseases. Together with using smartphones and advanced data stream mining techniques they offer a way for remote monitoring the health of chronically-ill or elderly patients at home, making possible a much higher quality of life.

These telemedicine networks promise to revolutionize health care by allowing inexpensive, non-invasive, continuous, ambulatory health monitoring with almost real-time updates of medical records via the Internet. In the phase before an illness develops patients are provided with medical advice early and they can safely be treated – avoiding hospital treatment. In case of an already existing illness patients are provided with the involvement of the healthcare, where they can get an effective professional treatment, based on the suitable medicine adjustment [1-3].

Treatment of patients becomes personalized and customized because it is possible to build and adjust their treatment plan and workflow by selecting the necessary services for the individual patient, for the doctor and for service management which to be executed on cloud resources. Mobile applications for the patient, physician and service management has a service-oriented architecture [4-5] that accelerates the process of on-demand service creating and making them flexible in adaptation to the tasks of supporting specific patient’s treatment plans.

The Repository of services (web-applications with a unified interface) is established for patient care (care services), for planning and carrying out of treatment (treatment services) and to ensure the functioning of the entire system (management services), from which any individual patient pathway (patient-specific workflows) can be composed. Many of these services may be taken from existing Repositories like the Fi-Ware services for Internet of Things (https://www.fiware.org/developers-entrepreneurs/), External EGI service catalogue for researchers (https://www.egi.eu/services/); Internal service catalogue for EGI Federation members (https://www.egi.eu/internal-services/); INDIGO IAM services (https://github.com/indigo-iam/iam); EUDAT service registry (http://eudat.eu/support-request); GEANT Cloud services (https://clouds.geant.org/), but some of value added services had to be developed: usage of Electronic Health Records, reminder services for patients, supporting remote monitoring over the Internet, early
warning and decision making tools on the base of mathematical prediction of time series, definition and execution of workflows by using capabilities of standardized WS-BPEL engines, social Media and integration into social networking, etc.

The proposed the Cyber-Physical Medical Platform (CPMP) provides the secure, safe and committed healthcare to patients at any point of the country by creating facilities for everybody to check own biomedical vital parameters and data (say, peak flow meter-PFM, blood pressure-BP, blood glucose meters, etc.) at home and to make these data to be evaluable for his doctor in the form of the updating Electronic Health Records (EHR). Ontologies are used not only to integrate different data formats, software tools as a service collection, gathering portable personal devices data and behavioral and environmental data, but to analytic processing of data across the healthcare ecosystem. Solutions had to be expanded across the health continuum, from healthy living, prevention, diagnosis, treatment, recovery and home care, to truly impact patients' health at the individual and population levels and to the most clinically and cost-effective treatments to apply.

2. Solution Description

We are going to achieve interoperability (compatibility) of healthcare services for patients’ groups with different illnesses by using the mentioned Cyber-Physical Medical Platform which consists of:

- Patient’s services and portable diagnostics devices part.
- Cloud platform for storage and processing of PHR data.

Healthcare providers’ services part (Fig. 1).

The basic Platform’s component is a Cloud server with services of transfer, storage and processing data of the status and stage of the patients’ disease. It aggregates the data about the patient’s health parameters, taken by patients at home using portable diagnostics device connected to their smartphones (tablets). Data from the mobile phone to the server are sent via a secured sockets layer (SSL) of web connection, providing a standard industrial level of security inherent in the mobile data network. The server also contains patients’ Electronic Health Records (EHR) with individual treatment recommendations, compiled and constantly corrected by doctors.

A plurality of portable diagnostics device in Patient’s services part depends on the type of disease and may include, in particular, blood glucose meters, blood pressure monitors that measure blood pressure and pulse or peak flowmeter. They also include devices used by patients for home treatment: inhalers, scales, heart rate monitors and insulin pumps. Some patients with complications of their diseases can purchase and use at home portable devices which allow them to take an electrocardiogram, or make ultrasound investigation.

Let’s imagine that every medical sensor (or another data resource) of that Platform has its own URI allowing doctors and patients interact with it via the web browser, and at the same time every sensor can have the software interface – a set of web services allowing intelligent software agents to interact with it (analyze the data etc.) on behalf of doctors and patients. The real-time continuous monitoring is very important for patient at their home treatment, recovery from illness or rehabilitation and even for risky people who want to monitor their activity of cardiac-pulmonary at different positions for early detection of unexpected problem [6-11].

The proposed the Cyber-Physical Medical Platform for supporting the patient and the physician in the treatment and monitoring differs from many available mobile applications of the similar appointment in the following important features [4,6,12]:
1) Mobile applications for the patient, physician and service management have a service-oriented architecture and can be built in on-demand forms by discovering and using reusable services with transparently described interfaces, available on the network, to perform a certain task.

2) The Repository of services (web-applications with a unified interface) is proposed for patient care (care services), for planning and carrying out of treatment (treatment services) and to ensure the functioning the entire system (services management). Some of these services (so called *Generic Enablers*) can be taken from existing service Repositories, but many of value added services (so called *Specific Enablers*) had to be developed. Functionalties of Specific Enablers for patients, physicians, services management were specified taking into account the recommendations of medical institutions [12, 13].

3) Development of mathematical models and algorithms based on Bayesian approach to data analysis, multivariate conditional distributions, regression models and stochastic volatility models for predicting the dates of potential crisis of a patient (say, asthma attacks) and warning doctor about this.

Depending on particular requirements the Cyber-Physical Medical system can be scaled from the corporate (national) scale of patients care to the scale of supporting profile patients in a particular region.

### 3. IMPLEMENTATION

Treatment of chronically ill patients is personalized and customized by establishing Repository of services (web-applications with a unified interface) for patient care (care services), for planning and carrying out of treatment (treatment services) and to ensure the functioning of the entire system (services management) [6].

Due to such ecosystem, healthcare is migrating from episodic and fragmented illness response to a patient-centric model of care delivery. We are going to develop distributed repositories of services related to processes of data collection and storing from all data sources (and developing the ontology of these services). These repositories will include:

- Ontology-based services for gathering the various portable wearable devices output data.
- Ontology-based services for managing the EHR data, clinical notes, claims, medical imaging data, etc.
- Ontology-based services for capturing the information of patients’ behaviour.
- Services for identifying patients at risk of becoming ill or developing a serious condition by constant patients’ monitoring and personalizing healthcare.
- Services for insights synthesis and information of patients, health professionals, health payers and insurers, and life science companies’ actions.
- Services for aggregating individual patients’ data across a community into a broader, meaningful view of health and healthcare in a particular region to support healthcare migrating from episodic and fragmented illness response to a patient-centric model of public healthcare.

The mechanism of customer-driven medical applied software development will be provided by compositing and orchestrating dynamically discovered services from developed repositories to form the individual patient pathway (patient-specific workflows) of monitoring and treatment, taking into account different existing rules, regulations and standards. We propose also to establish connection between data sources, patients, doctors and healthcare organizations by developing a healthcare ecosystem in the Cloud for data sharing across the entire ecosystem, using SaaS and IaaS technologies. The combined SOA (synchronous one-to-one approach) and EDA (asynchronous many-to-many approach) architecture is characterized by the following [18, 21]:

- Functionality is distributed across the ecosystem of both web services and events (enabling utilization of events resources);
- It is compatible with adopted standards and protocols;
- It supports customers’ analysis scenario development and execution;
- It provides flexible and intelligent configuration and translation of continuous data streams from sensors into patients’ EHRs, which are monitored using specific services and events.
- It hides the complexity of web-service interaction from user with abstract workflow concept and simple graphical workflow editor.
We have got for 2017-2019 years the grant of the Ministry of Science and Education of Ukraine for the project “Development of mobile medical service systems for residents of Front-line areas” (state registration number 0117U002435). It will provide dynamic infrastructure by developing the repository of semantically described interoperable services from which any individual patient pathway (patient-specific workflows) can be composed. From this point of view, the material of the previous sections is a description of our intention in implementing the project in hand.

Today, developing and testing individual experimental functional services are conducted by graduated students of the System Design Department. These services were used by them for prototyping some medical multiplatform applications such as the self-management Mobile Spirometry for Asthma Care, using a smartphone’s Microphone to Measure Lung Function, and the Anti-Asthma Mobile Application, using a peak flow meter. The Mobile application for diabetics was developed also which serves as the diary of glucose in the blood by storing measured results and building interactive graphics intervals (fig. 2)

![Home screen of developed mobile application](image)

It is based on Apache Cordova for the Apple iOS platform and uses the Align BG1 mobile glucometer of the company iHealth been connected to a smartphone through the developed module SDK. Parameters and capabilities of this application is not inferior to the best known today mobile application developed for Apple’s iPhone, Google’s Android, BlackBerry, Microsoft Windows Phone and Nokia Symbian and available today for people with diabetes [14].

4. CONCLUSION AND FUTURE WORK

This paper focuses on developing ontology-based services for gathering outputs from the various data sources (portable wearable devices, the EHR data, clinical notes, claims, medical imaging data, etc.), that are used in various applied fields of mHealth, and on creating management technology for provision of interconnected healthcare-related data sources and processing procedures. The developed services are the main ‘building blocks’ for more complex applications that use some medical data processing scenarios.

The proposed CPM Platform allows easily developing interoperable Cyber-Physical Systems with a wide range of self-care services for chronic patients and which differs from existing holistic solutions in many important features (invention) by using service systems approach. Such more personalized patient-focused healthcare platform is more targeted, effective and efficient and supports the self-control of health.

5. REFERENCES


[19] Petrenko O.O. Comparing the types of service architectures, System Research and Information Technologies- Kyiv, №3, 2016 (in Ukrainian)

