Cloud Computing Framework for New Medical Interface Technologies

Maya Dimitrova, Siya Lozanova, Lubomir Lahtchev, and Chavdar Roumenin

Insititute of Systems Engineering and Robotics, Bulgarian Academy of Sciences,
Akad. G. Bonchev Str., Block 2,
1113 Sofia, Bulgaria
{dimitrova, slozanova, lahchev, roumenin}@icsr.bas.bg

Abstract. New interface technologies and devices need to be developed in order to achieve helpful and reliable medical service “in the cloud”. It is proposed to formulate a new development framework for Cloud computing called User Interface as a Service (UIaaS). New multimodal interface technologies for medical instrumentation compatible with web platforms have been recently developed. The paper presents the framework integrating the proposed methods, and some results of the tests of the new interface. The framework is explicitly aiming at supporting seamless and ubiquitous health monitoring based on cloud services for healthcare.

Keywords: Interface technologies, medical instrumentation, cloud services for healthcare, ubiquitous health monitoring.

1 Introduction

Cloud computing for healthcare raises a number of specific issues, such as privacy, data protection, medical record access and update, high performance computation (HPC), etc [1], [2], [3]. Nevertheless, large ICT companies provide services like Google Health and invest in extensive cloud services, explicitly aiming at supporting seamless and ubiquitous health monitoring, starting from portable diagnostic tools via extensive examination record storage to diagnostics “on the move” via immediate ICT contact with medical staff. One of the promises for HaaS and SaaS developers is the recently announced Chromebook, designed by Google, which is announced to appear on the market on 15th June 2011 [4]. To achieve helpful and reliable medical service “in the cloud” new interface technologies and devices need to be developed in addition to the existing approaches. It is proposed to formulate a new development framework for cloud computing called User Interface as a Service (UIaaS).

The paper presents the methods and new interface technologies for medical instrumentation design that we have recently developed within the nationally funded research project “Multimodal user and sensor interface in a computer-aided system for cardiological diagnosis and intervention” No MI-1509 of NSFB (2005-2009). The suitability of the proposed methods for future Cloud computing systems in IT based healthcare is discussed.

The main technological challenge in medical instrumentation design for interventional surgery is twofold – the online visualization of the intervention process (based on improvement of data fusion from the physical level modalities) on the one hand – and reducing the level of radiation emitted by the angiography instrumentation via magnetic tracking of the needles and catheters - on the other [5], [6], [7], [8]. None less challenging is the issue of mobile and seamless medical examination via new interface technologies like portable defibrillators, h'andy sana GSMs [9] and other newly emerging medical peripheries [10]. A framework for future ICT technologies for healthcare is emerging today which is based on the following four pillars of technological advancement (fig.1).

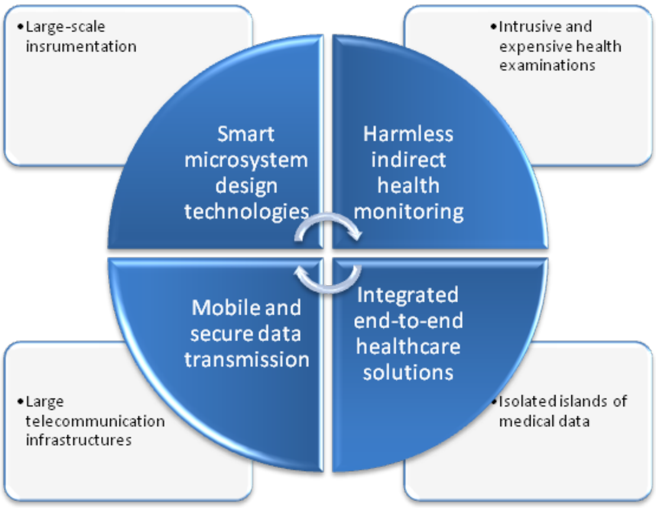

Fig. 1. Framework for future ICT technologies for healthcare (see text)

The first pillar is the transition from design of large-scale medical instrumentation to smart micro-system technologies (HaaS); the second is the transition from large telecommunication infrastructures needed for health record transfer towards mobile and secure data transmission via the appropriate middleware (IaaS); the third is the transition from isolated islands of medical data towards integrated end-to-end healthcare solutions "in the cloud" (SaaS) and the fourth is from intrusive and expensive health examinations towards harmless indirect health monitoring devices – called User Interface as a Service (UIaaS).

We aim at developing a new integrated, smart, mobile and useful technology for doctors and patients to monitor and explore cross-diagnosis conditions and causal relationships among diseases in non-obtrusive, indirect and harmless way. It is suitable for reliable cloud services, explicitly aiming at supporting seamless and ubiquitous health monitoring and online access to medical help.

2 Multimodality of Data Processing, Representation and Visualization in Medical Diagnostic Systems

Multimodality of data processing, representation and visualization in existing medical diagnostic systems is intended to aid the cognitive representations of the medical experts on current symptoms, history of illness and the prognosis of treatment outcome. The complexity of this task, especially in interventional cardiology, is far beyond the capabilities of the current expert systems for medical diagnosis in terms of their speed and precision. Due to the ability of the natural cognitive systems to grab and process vast amounts of visual information, the most developed aiding systems deal with symptom visualization and 3D vessel reconstruction for medical diagnostic support. The main problem encountered in the visualization interface systems is the fusion of data coming from different modalities of sensor information, which is an unsolved issue of current biomedical research yet [5], [10], [12].

We approach the problem of designing a useful interface for interventional cardiology from a cognitive perspective and distinguish two levels of modalities in a user-computer medical-aid interface – abstract level modality and physical level modalities. On the abstract level knowledge discovery takes place, which requires abstract visualization and semantic translation of symptoms and health conditions. On the physical level fusion of data takes place to obtain real visual image of a specific health condition.

2.1 An instrumental method for robust registration of functional heart signals from peripheral areas of the body

Figure 3 illustrates how cardiologists read an electrocardiogram – in terms of the spatial position of the heart and its physical deformation. In abstract terms, they use the ECG record as a measuring instrument for geometric distance and infer the actual geometry of a hidden object (the heart) [11].

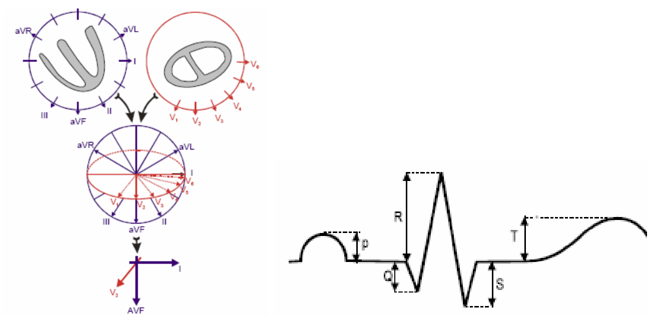

Fig. 2. Mental reconstruction of the heart geometry by a medical expert from reading 12 channel ECG record [1]

[1] The picture is adapted with the permission of Dr. S. Marchev from (Marchev, 2007) [11]

Despite modern advancement of diagnostic and interventional instrumentation - the 12 channel electrocardiograph is still the most reliable diagnostic tool in cardiology. Profiles of record patterns signify, first of all, deformations of heart tissue structure (spatial relations) and, based on this, causal relations between different organ malfunctions, and the respective heart deformation. We have tested a hypothesis that heart-relevant patterns of electrical activity can be obtained from peripheral areas of the body, which can be monitored by appropriate interfaces to medical diagnostic systems.

2.2 Experimental results and application

The aim of the current study was to test a hypothesis that large blood vessels near the surface of the human body reflect the main pattern of the PQ RST complex in an ECG record. This was reliably confirmed in signals taken either from the neck artery, or from the shoulder artery by applying Holter microelectrodes to these areas (fig. 3). Moreover – strong correlation between the neck and the shoulder was obtained – which makes the shoulder the most appropriate place since the neck artery has to be protected from contact.

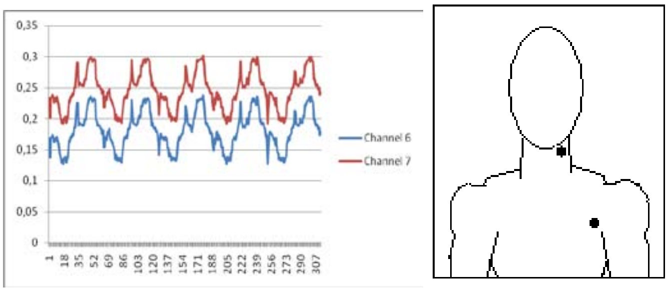

Fig. 3. Patterns resembling PQ RST complexes, taken from the shoulder areas of the body

The second aim was to test the Holter mini-electrodes used for response to ultrasound. This showed full insensitivity to sound, which confirmed the assumption that the received signal is pure electrical (but not vibration) signal.

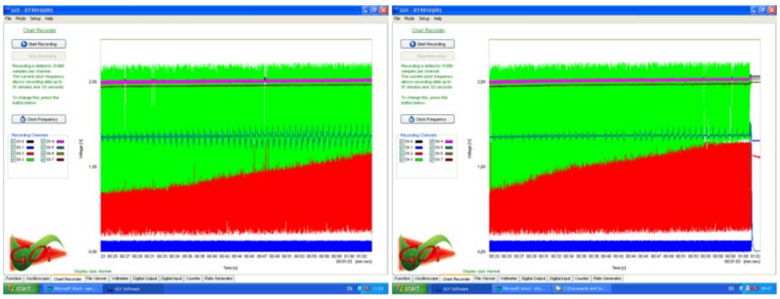

Fig. 4. Patterns of artery vibrations for high BP (left) or arrhythmia (right)

We have investigated other sensor modalities (speed of blood flow and vibration of the artery wall) in order to receive correlates of these electrical signals for nonelectrical diagnosis of heart condition (fig. 4). The multimodal interface is compatible with web platforms that have been recently developed for health monitoring and medical data processing via high performance computation [3]. The proposed methods and some results of the tests of the new interface will be presented aimed at supporting seamless and ubiquitous health monitoring based on Cloud computing.

3 Cloud Computing Framework for Healthcare Systems

For an ubiquitously available patient-health record new micro-system and multi-sensor technologies for representation of medical symptoms are needed. They are based on health indicators for early and prospective diagnosis, implementing smart solutions for inclusion of relatively low-cost devices with higher fidelity than the existing ones [11], [12]. Our system is closest to the one, presented in [2], including close collaboration with medical staff. Our new approach includes adaptation via design of new interfaces based on user needs that can also be used on subscription, rather than by purchasing numerous peripheries – that is – in a Cloud computing framework for healthcare.

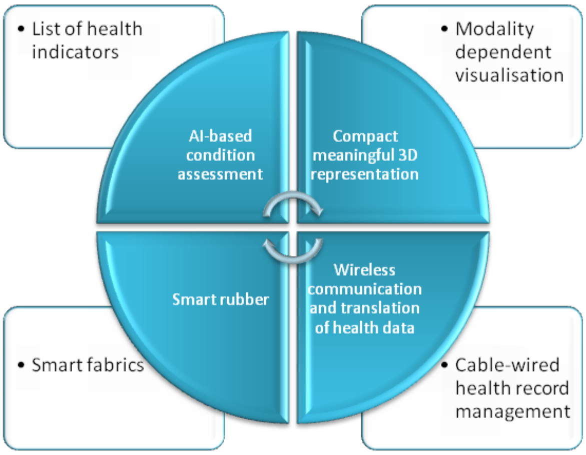

Fig. 5. Cloud computing implementation of the developed interface (see text)

We are developing a device to collect, analyze and transmit data, obtained from registration of peripheral vibrations of the arteries of the human body symptomatic for a number of diseases, which can be revealed by investigating heart problems, rather than focusing on the heart disease per se. It is an attempt to overcome the electrical wiring of patients, including wearing smart fabrics for diagnostics and alerting on health issues. Instead, we propose the development of smart rubber implementing novel health monitoring functionalities – since rubber is the most skin-and-touch friendly material. Smart rubber has large future potential especially for implementing in novel devices to be used as User Interface as a Service (UIaaS) technologies for healthcare (fig. 5).

4 Conclusions and Future Work

The aim of the proposed framework is the implementation of new interface technologies providing the doctors and patients with useful tools to explore conditions and perform monitoring across diagnoses – in an indirect, safe, secure and harmless way - operating as new UIaaS. The device will be integrated in a sophisticated and intelligent backend environment enabling productive end-to-end usage as a step towards modern and ubiquitous healthcare in a Cloud computing framework.

Acknowledgments. This work was supported in part by the National Science Fund of Bulgaria under the Research Project MI - 1509/2005 ”Multimodal User and Sensor Interface in a Computer-aided System for Cardiological Diagnosis and Intervention”.

References

1. Shimrat, O.: Cloud Computing and Healthcare. (2009) http://www.docstoc.com/docs/69086716/ Cloud-Computing-and-Healthcare
2. Cloud Security Alliance[SM]: Domain 12: Guidance for Identity & Access Management V2.1. (2010) http://www.cloudsecurityalliance.org/guidance/scaguide-dom12.pdf
3. Hemsoth, N.: Opening Sequences for HPC on Demand. (2010) http://www.hpcinthecloud.com/hpccloud/2011-05-11/opening_sequences_for_hpc_on_demand.html
4. http://www.google.com/chromebook/
5. Freudenthal, A., Studeli, T., Lamata P., Samset, E.: Collaborative Co-design of Emerging Multi-technologies for Surgery. Journal of Biomedical Informatics, 44 (2011) 198-215
6. Hacim, J.: Interventional Cardiology: Present & Future. Associated Meeting of the ACC, (2004) http://www.tctmd.com/meeting-news/one.html?news_item_id=3784&
7. Keith, N.: A Magnet with a View: Exploring New Frontiers in MRI. Berkeley Science Review, 15 http://sciencereview.berkeley.edu/articles.php?issue=14&article=features01_MRI (2008)
8. Roumenin, Ch.: Microsensors for Magnetic Field. In: Korvink, J. Paul, O. (eds.): MEMS Handbook, Chapter 11, William Andrew Publishing, USA (2003)
9. H’andy sana 210 http://www.independent.co.uk/life-style/health-and-families/health-news/smartphone-may-keep-the-cardiologist-away-1916652.html (2011)
10. Dimitrova, M., Ch. Roumenin, D. Nikolov, D. Rotger, P. Radeva Multimodal Data Fusion for Intelligent Cardiovascular Diagnosis and Treatment in ActiveVessel Medical Workstation. Journal of Intelligent Systems, Freund Publishing House Ltd. ISSN: 0334-1860 18(1-2) (2009) 32-47
11. Marchev, S.: How to Read an Electrocardiogram. Sofia: TEVA (2007) (In Bulgarian)
12. Nafis, C., Jensen, V., von Jako R. Method for Evaluating Compatibility of Commercial Electromagnetic (EM) Micro Sensor Tracking Systems with Surgical and Imaging tables. (2008) www.ascension-tech.com