Communications in Medical and Care Compunetics

Lodewijk Bos
Denis Carroll
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Future Visions on Biomedicine and Bioinformatics 1

A Liber Amicorum in Memory of Swamy Laxminarayan

ICMCC
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A Tribute to Swamy

Lodewijk Bos

"Thank you so much for your note of invitation. I am very pleased to accept. I think this could be an exciting conference, it seems like a unique model. I look forward to working with you and Andy. I will certainly make it a point to get together with you, if i happen to be in Europe in the next couple of months."

This was the first email I received from Swamy Laxminarayan, 23 November 2003. Andy Marsh had linked us together. A month later he accepted to be scientific chair of the ICMCC Conference in 2004, the conference that led to the ICMCC foundation of which both were co-founders.

Within 2 months after that first message, he had invited quite a number of friends to support the conference. Many of those are still involved in some way with the goals and works of ICMCC.

I was a complete stranger to the area of health technology. I have told the story many times; I wanted to organize a conference looking from the ICT angle towards the fields of medicine and care. As Swamy pointed out, a unique concept. In the only 22 months I had the privilege to know him and even call him a friend he listened to my ideas and supported and massaged them.

He opened doors for me, got ICMCC its membership of the IFMBE. I met him only five times in person; two ICMCC conferences, once at an IFMBE event in Italy, once for a meeting in London and once, in 2004, when I visited him in Idaho. Looking back, it seems unbelievable that someone, in a long-distance friendship (the time difference between Utrecht and Idaho caused him to say that ICMCC never sleeps), could have such an impact. Due to his support and belief in what I wanted to achieve with ICMCC we still exist as a foundation, despite the fact that in the meantime two more members of our board passed away and I suffered from a very aggressive cancer. During my studies in the arts as a young man Iwas taught

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by the best in the world, but none of these great teachers had such an influence as this modest friend from Idaho.

He knew how to bring people together and for our second (and his last) ICMCC Event in 2005 he managed to bring together the president-elect of the IEEE (Prof. Michael Lightner), the president of the IFMBE (Prof. Dr. Joachim Nagel) and the president of the IEEE-SSIT (Prof. Brian O'Connell). And he definitely enjoyed it.Michael Lightner, Joachim Nagel, Jeremy Nettle, Winnie Tang, Lodewijk Bos, Swamy Laxminarayan, Brian O'Connell (ICMCC Event 2005)

This book is a tribute and an archive. Part 1 forms the tribute, where, 5 years after his death, some of his friends and colleagues give an impression of their work to date.

Part 2 is the archive, as we re-publish some of the last papers to which Swamy contributed, trying to show the present reader the width of his horizon. And finally an overview of what Swamy has done during his live, including an almost complete, more than impressive bibliography.

In grateful memory,

Lodewijk Bos
President ICMCC

A Comprehensive View of the Technologies Involved in Pervasive Care

Laura María Roa Romero, Luis Javier Reina Tosina, Miguel Ángel Estudillo Valderrama, Jorge Calvillo Arbizu and Isabel Román Martínez

Abstract It is widely accepted that the application of Information and Communications Technologies (ICT) in the healthcare environment leads to an improvement in medicine and healthcare delivery. The ageing of population, the prevalence of chronic condition, and other societal changes, as well as advancements in science and technology, require an evolution in healthcare delivery from centralized, general and reactive care, towards distributed, personalized and preventive care. The application of ICT can address these new scenarios but it is needed a methodological approach to establish common guidelines so that the developed systems are interoperable, reusable and future-proof. In this chapter, we present a methodology based on Open Distributed Processing (ODP) and standards to address the complexity of design and development of distributed systems in healthcare. This methodology specifies systems according to decomposition in viewpoints, each one focused on particular issues. We test this method by applying it to the general healthcare domain and particularizing it for a specific use case of an ICT application, a pervasive care system. We describe both the technology neutral viewpoints and those dependent on it.

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1 Introduction

Nowadays it is widely accepted that the application of Information and Communications Technologies (ICT) in the healthcare environment lead to the improvement of medicine and healthcare delivery. Thus, among the potential benefits, it can be remarked a more efficient management of health information; the possibility of remotely collecting data from wearable monitoring devices; more sophisticated and accurate techniques and methods for treatment and diagnosis; and so on.

In the near future, ICT will allow transferring to the clinical practice all the advancements in science and technology since the last decade (genomic and proteomic data, molecular images, miniaturization of monitoring devices, implanted sensor units, nanotechnologies…) in order to enhance the prevention, diagnosis, and treatment of diseases. In the meantime, a revolution in medical methods is being carried out towards a more personalized care. There are more and more resources centered on a single subject of care, for example, body sensor networks for real-time monitoring, studies or analysis made over different scales allowing a multilevel diagnostic, models and simulation tools for predicting drugs reactions or diseases evolution, etc. The application of ICT in healthcare will ease the current healthcare delivery evolve from using partial and isolated information to synthesizing all the knowledge available about each person in a cohesive whole.

Advancements and opportunities have led to the public awareness of the need for a new reorientation of health resources, creating a new conscience in the citizen toward healthcare delivery, who claims for the practice of a preventive medicine instead of the prevailing reactive medicine. Patients demand a pervasive care, more information and knowledge for a personalized healthcare, aimed to an improvement in the quality of life. Furthermore, citizens want to be more and more involved in their own healthcare and maintenance of well-being that will ease, for example, behavioral changes in their daily life (eating habits, physical activity routines…) to prevent or treat possible diseases.

Governments have not been unaware of the impact of ICT as a key factor to derive cost-effective solutions in this changing scenario, and have been forced to develop scientific policies to address the new challenges. Examples of these are the Ambient Assisted Living Joint Programme, launched by the European Commission, or the Spanish Law on the promotion of personal autonomy and care for dependent persons (Ley 39/2006, de 14 de diciembre, de Promoción de la Autonomía Personal y Atención a las personas en situación de dependencia; 2006 Dec 14).

This change of scenario is going to be sped up due to a set of additional growing concerns. During the last two decades different institutions and authorities have warned against a collapse of the public health system in the developed world, by the middle of the century, due to the confluence of diverse factors, including the population ageing, the prevalence of the chronic condition in extensive population groups, the change of social models and structure of family, the impact of migration and population movements in the outbreak of infectious diseases, and the corresponding growth in health expenditure. The application of ICT in healthcare in a methodological way will be a cornerstone to address the new scenarios and challenges, reducing the associated cost and enhancing the efficiency of assistance processes.

A clear example of application of ICT is the paradigm of telemedicine defined as the investigation, monitoring, and management of patients and the education of patients and staff using systems that allow ready access to expert advice and patient information, no matter where the patient or relevant information is located [1]. The concept of telemedicine has gradually been widened from the use of videoconferencing for remote consultation, toward collaborative medicine and research through distributing system capabilities over high-speed networks and information infrastructures.

The movement of health resources from a centralized scenario based on a hospital towards a distributed one across organizations boundaries, including also user home as a location where healthcare can be delivered, is acknowledged as a key issue giving responses to the growing healthcare needs [2]. One of the pioneers to envision this paradigm shift was the late Professor Swamy Laxminarayan [3], who predicted in 2002 the shift of the information age towards a knowledge-centric paradigm, through the opening of new frameworks for the integration of all the biophysical, biochemical, and physiological knowledge for prediction purposes. Hence, the telemedicine paradigm, which was first conceived as a feasible solution, in the sense of cost-efficiency ratio, to deploy health services at underserved areas, is progressively being shifted toward the concept of pervasive care systems (PCS). The centralized health model is thus moved to a distributed one, with the patient/citizen acquiring a more active role in the healthcare delivery process.

Under the direction of the cited editorial article, several research groups and projects [4–6] have made important advances in new settings for PCS. Although under the basis of tele-healthcare is the claim that health services can be offered more effectively and with less cost by providing connectivity with ICT [7] the utilization rates for homecare projects are still falling well below expectations. On the basis for such failure is the common practice to yield technological solutions to particular cases.

This problem affects not only to PCS but also to all healthcare scenarios where ICT have been applied. Due to design methodologies centered on particular requirements and use cases, tackling the specific problem isolated from the whole healthcare organization, consequent solutions lack of flexibility, scalability and reusability. They can only be used in the particular context for which they were designed as they have not taken into account other systems and the interoperability with them. This situation results in a healthcare environment with a wide spectrum of devices, systems and solutions; each one focused on one specific problem; implementing heterogeneous, often proprietary, technologies; with few or no possibilities of interoperability between them and reuse of their capabilities; and finally, with large funds invested in solutions that in a few years may become obsolete.

The seek for new methodological approaches is thus justified. Proper methodologies are necessary to design general architectures that can be suited to every particular case in the healthcare environment. The vision of this environment as a cohesive whole will allow future solutions and systems to cooperate between them in order to reuse capabilities and achieve more complex goals, easing a more efficient and personalized healthcare delivery integrating all the knowledge related to one single person from diagnosis and treatments to daily life, genomics and monitored data. Thus, each particular solution and system will be a building block of a bigger system (the healthcare environment) that is evolvable and more and more complex, sophisticated and efficient.

In this book chapter, we face the application of ICT within the healthcare environment from a comprehensive vision of the whole complexity and potential solutions and technologies to apply. We present a methodological approach based on the Open Distributed Processing Reference Model (ODP-RM) (ISO 10746-1, 2, 3, 4: Information technology—open distributed processing—reference model, 1996) to develop open architectures of health, well-being and social care services. We address the requirements of interoperability, reusability and scalability by conforming international standards and recommendations in the whole development process. This methodology is technology neutral and widely enough to cover all the current and future requirements of scenarios and domains within the healthcare environment from healthcare delivery in hospitals to well-being outdoors services or remote monitoring in homecare.

As a proof-of-concept, we apply the proposed methodology to the development and deployment of a pervasive care platform. We present a general architecture for homecare, developed by our group, which stems from the concept of a personalized care through knowledge generation and we particularize on the underlying technologies. By following the ODP methodology, we start with the analysis of particular requirements of homecare delivery in relation to the subjects of care. As the methodology is technology neutral, it can be applied to current and future technologies and, in particular, we focus on the different solutions with today's available technologies and short-term evolution, and paying special attention to the use of industry standards to benefit from interoperability between heterogeneous systems.

2 Materials and Methods

As it has been pointed out above, the healthcare environment is (and will continue) evolving from centralized scenarios to span across boundaries and domains becoming a complex distributed environment with several heterogeneous devices, systems and capabilities. Distributed systems can grant several benefits to healthcare delivery, but they present a set of issues to be addressed, mainly due to the complexity of their development and management.

The design, development, deployment, maintenance and evolution of a distributed system are highly complex tasks, involving an interdisciplinary, numerous and usually dynamic team. Consequently, the design could represent a substantial body of specifications needed to manage successfully the structure. The formalization of this structure is what we call system architecture. As a single engineering solution might not meet all requirements, this architecture must be flexible. Furthermore, since a single vendor may not have all of the answers, it is essential that the architecture, and any functions necessary to implement it, are defined through a set of standards, so that multiple vendors can collaborate in the provision of distributed systems. Such standards will enable to build open, integrated, flexible, modular, secure and easily manageable systems. Hence, taking into account all previous arguments, it is easy to understand that a coordinating framework for the standardization of the architecture is needed.

In a very simplified way we could say that such framework fundamentally consists of: a precise concepts language; a set of rules for the consistent structuring of system specifications; usually a set of fundamental or widely applicable functions for the construction of these systems; and several transparency prescriptions showing how to use these functions to hide users from the complexity of distribution. An efficient framework should allow different parts of the design to be developed separately if they are independent, but it should clearly identify those points where different aspects of the design constrain each other.

Different standards provide such framework for the formalization of distributed systems architectures. Two samples are the Reference Model of Open Distributed Processing (RM-ODP) and Model Driven Architecture (MDA) [8]. Although these standards differ in several aspects (like the use of viewpoints in ODP against a model approach in MDA), they have a similar philosophy; separating specifications targeting a technology-neutral viewpoint of the system, from those including details that specify how a particular underlying technology is used in the system. As a technology independent specification is suitable for a number of different platforms of similar type, this approach improves the interoperability between components designed by following the same specification although they were developed using different technologies.

One of the characteristics that makes more suitable RM-ODP over other standards is that it provides a coordinating framework for the standardization of open distributed processing that supports distribution, interoperation, platform and technology independence, and portability, together with an enterprise architecture framework for the specification of ODP systems. The framework for system specification provided by the RM-ODP has four fundamental elements: an object modeling approach for system specification; the specification of a system in terms of separate but interrelated viewpoint specifications; the definition of a system infrastructure providing distribution transparencies for system applications; and a framework for assessing system conformance.

By following principles as encapsulation and abstraction, RM-ODP allows the description of system functionality to be separated from details of system implementation, allowing the hiding of heterogeneity, the location of failure, the implementation of security and the hiding of the mechanisms of service provision from the service user. Moreover, the basic characteristics of heterogeneity and evolution imply that different parts of a distributed system can be purchased separately, from different vendors.

The concept of RM-ODP viewpoints framework, therefore, is to provide separate viewpoints into the specification of a given complex system. Each of these viewpoints satisfies an audience with interest in a particular set of aspects of the system. Associated with a single viewpoint is a viewpoint language that optimizes the vocabulary and presentation for the audience of that viewpoint. RM-ODP defines five viewpoints: enterprise, information, computational, engineering, and technology. A viewpoint (on a system) is an abstraction that yields a specification of the whole system related to a particular set of concerns. The five viewpoints defined by RM-ODP have been chosen to be both simple and complete, covering all the domains of architectural design.

The RM-ODP is a general-purpose framework to design and develop standards architectures in any domain. Within the healthcare environment, the ISO/CEN 12967 standard (Health Informatics Service Architecture, HISA, ISO 12967-1, 2, 3, 2009) describes an architecture for the integration of healthcare information services whose base is the ODP methodology. It is pointed out that HISA does not aim to represent a final complete set of specifications. On the contrary, it only formalizes fundamental features that are common and currently essential in any advanced healthcare system, as well as relevant for any healthcare sector and usable by any application also for facilitating the mutual interworking. Therefore, the HISA is an open framework that can be extended during time according to the evolution of the healthcare organization. The specifications are formalized avoiding any dependency on specific technological products and/or solutions.

By using the RM-ODP and fulfilling the HISA requirements, open distributed systems can be developed to support the procedures of healthcare organizations assuring that different vendors will be able to provide interoperable hardware and software components, and even the interoperability between components from different organizations, whenever they follow this standard. As a result social, health care and well-being services for the comprehensive assistance to citizens could be provided by combining capabilities from different vendors and organizations.

3 Results

As it has been shown above, one of the keys of success of open and interoperable solutions is the adoption of standards and recommendations in both general and healthcare domains. Due to this, our methodological approach tries to be conformed to all the relevant standardization efforts in the implied issues.

We separate the results in two differentiated points. The first one is focused on the methodology covering the whole healthcare environment and how it can be adapted to different scenarios in order to develop interoperable systems and solutions, which are reusable and with a long-term life based on technology neutrality. The second point presents a proof-of-concept by applying the methodology to a specific scenario, a pervasive care system. This solution benefits from all the advantages of distributed systems from the very initial design step and it results in a fully interoperable system with other current and future developments, scalable, open and reusable.

3.1 Description of a Particular Use Case of ICT Application

In this section, a description of a Pervasive Care System (PCS) is shown by following the methodology stated. The classical architecture for PCS spanned around three geographically located scenarios—the home, the hospital and the information, data and service provider center—has progressively moved to a distributed network, in which the information sources are heterogeneous in nature, and the frontiers among the scenarios are diffuse. This poses the challenge of moving to the concept of domain, which can span different scenarios depending on the user context. Three domains (involving three or more scenarios) are common in all cases: the point of care (PoC) domain and the professional user (PU) domain; and both supported by an infrastructure domain granting distribution transparency and information exchange capabilities. A viewgraph showing the relationships within such domains is depicted in Fig. 1.

In the PoC domain the subject of care and his/her carers (either professionals or not) interact with devices and systems. Thus, it is required a seamless integration of technologies supporting both in-door and out-door operation, and distributed

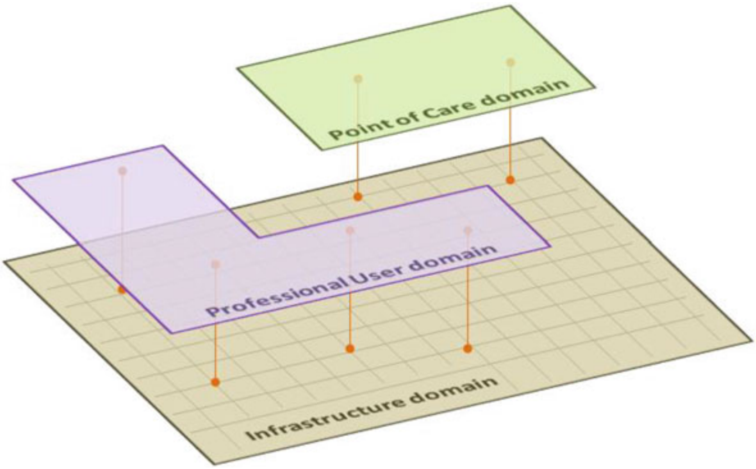

Fig. 1 Relation between domains of a Pervasive Care System

processing. In the PU domain, a global view of the health state of the subject of care must be provided to the professional user. This domain will be spanned across boundaries connecting heterogeneous systems and services from healthcare organizations and third-parties, e.g., EHR, PHR, clinical support systems, models and simulation tools, etc. All of them will be information sinks by using data generated in the PoC domain and by generating knowledge about the health state of the subject of care. Both domains will be supported by an ICT infrastructure domain, allowing the real-time processing of the data acquired from the subject of care, the efficient supervision and control of alarms, etc. In addition, security, confidentiality, privacy and protection for all data managed must be guaranteed.

In the next sections we apply the ODP methodology to the healthcare domain and this particular scenario, and we describe the ODP viewpoints.

3.2 Technology-Neutral Viewpoints

Due to the growing need of a complete architecture supporting the heterogeneity and complexity of healthcare services, our methodology is based on the RM-ODP and its particularization for the healthcare environment, the HISA standard. We have chosen ODP because of its maturity and complete methodology of distributed system specification. Moreover, it has been used to define HISA, a standard architecture applied in the healthcare environment, by following the same goals which we try to achieve.

As it has been described above, the key concept of the ODP framework is the viewpoint: an abstraction that yields a specification of the whole system related to a particular set of concerns. The five viewpoints (enterprise, information, computational, engineering and technology) cover all the domains of architectural design and they are not completely independent; key items in each one are identified as related to items in other viewpoints, allowing achieving a complete and cohesive specification of the whole healthcare environment.

Our methodology describes the healthcare environment from a general vision including all potential services, systems and scenarios related to well-being, health, and social care of end-users. Due to the complexity and heterogeneity of such domain, in this book chapter we only present an overview of the possibilities of RM-ODP as a formalization tool allowing the establishment of common guidelines and directives to a wide spectrum of services and systems.

In this section we analyze the three upper viewpoints of the healthcare environment—enterprise, information and computational—and we particularize them for the PCS. The viewpoints are going to be described by paying special attention to the internationally accepted standards suitable to be applied in health domain and by considering the casualty of current and future services. Thus, we propose a general-purpose technology-neutral future-proof methodology to develop and deploy open, scalable and interoperable systems in the healthcare domain. Because of the technological neutrality of the methodology, the two lower viewpoints (engineering and technology) are not tackled in this section, but they do in the following one where a specific PCS scenario is described.

It is unfeasible to make an exhaustive specification of the healthcare environment due to its complexity and heterogeneity between countries, organizations and even application scenarios. With this viewpoint (and the following two) we aim to state a set of directives to apply ICT in health domain in a proper and consistent manner.

In order to design and develop systems oriented to particular use cases and scenarios, the following results can be used and extended to address specific requirements. This process is tested and illustrated with the proof of concept of the PCS.

In an enterprise specification, an ODP system and the environment in which it operates are represented as a community. Thus, in our approach the complete healthcare domain is a community (which will include several sub-communities) and whose main objective is the prevention and treatment of citizens' illnesses and well-being by means of social and health care services; investigation and control of health public risks; and other methods and tools.

The processes performed in this community to achieve its objective are carried by entities fulfilling roles within the community. A rich set of potential entities and roles in health domain are presented in Table 1. The classification of roles in structural and functional ones conforms to ISO/TS 21298 (Health

Table 1 List of entities and corresponding roles in the healthcare environment

Entities			Roles
		Examples	
People	Professional	Any person	Structural (e.g., medical doctor, pharmacist, child-care worker…) Functional (e.g., responsible healthcare professional, administrator…)
	Non-professional	Any person	Functional (e.g., subject of Care, carer, guardian, parent…)
Organizations	Healthcare	Hospital Pharmacy Clinic	Healthcare deliver
	Others	Gym Dietary center Insurance company	Information source
Systems	Devices	Fall detection monitor Pulsometer	Information sink
	Data repositories	EHR PHR	Knowledge generator
	Other resources	Decision support system Models and simulation tools	