# An Enhanced Architecture for LARIISA: An Intelligent System for Decision Making and Service Provision for e-Health using the cloud

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***Abstract*—Health care services can be scarce and expensive in some countries and especially in isolated regions. The lack of information can degrade health care services, for example, by ineffective resource allocation or failure in epidemiological prediction. This paper proposes an architecture for system of decision making and service provisioning in the health care context. It encompasses and integrates data produced by environmental sensors installed in the assisted homes, medical data sets, domain-specific and semantic enriched data sets, and all data generated and collected in applications installed on mobile phones, wearable devices, desktops, web servers, and smart television. LARIISA architecture is presented as a platform to manage, provide and launch services that monitor and analyze data to supply relevant information to decision makers and health care actors that participate in the health care supply chain.**

***Index Terms*—context-aware, architecture, decision-making, health care, privacy, cloud computing, service.**

## I. INTRODUCTION

The advance in pervasive computing and network communication has influenced the data collection growth nowadays. Modern devices of the type of smart-phones, smart-home devices, smart-televisions and wearable devices can be connected in public and private networks, increasing the capacity to monitor the environment and those who use these devices. Besides the sensory data, meta-data about these sensors, such as GPS-system accuracy, and contextual information, such as current weather, can be aggregated to the collected data as well. With the advent of portable devices packed with medical sensors (e.g. smart-phones, smart-bracelets) [1], it is possible to make use of the data produced from these devices to support health care assistance.

In this paper, we propose LARIISA, an intelligent system, to support health care services by supporting health care governance and igniting processes, actors, and services involved using data remotely collected from these devices. In LARIISA, sensory data, such as vital signs, GPS-locations, and accelerometers are structured along with their contextual data and meta-data in order to be reasoned and trigger services in response to some context or situation. For instance, falling detection or the wellness determination for elderly that triggers the nursing assistance service in the scenario of unusual behavior detected using accelerometers [2] or smart home devices [3].

LARIISA is an evolving framework that has been developed along five years, aiming to support health care governance by providing relevant information for decision making. In its latest development cycle, LARIISA evolved to support a scenario of a context-aware health care governance, collecting data from several data sources, sensors and interacting with patients through a digital television interface [4]. The results demonstrated the suitability and contribution of this approach to support scenarios involving different assistance actors in the health care supply chain, for instance, by identifying regional dengue fever outbreak and grounding public health care investment in a specific region.

The enhanced architecture for LARIISA hereby proposed aims to extend the benefits of this original project by improving its situation and context-awareness, and providing an extensible platform to subscribe different services and information alerts related to health care assistance. For this reason, we propose an architecture designed to support service subscription and registration, allowing applications to be programmed based on services provided by the platform. In addition, the new LARIISA provides mechanisms to describe health care assistance work flows to respond accordingly to the patient's situation and context. The interactivity using the rich user interface present in the smart-phones, smart-televisions and wearable devices is incorporated as an important aspect into LARIISA architecture. This way, these devices can inform and demand additional information from patients, besides their capacity to collect sensory data.

Intensive data-analytic system, such LARIISA, needs to address some architectural issues, like scalability and complexity in the deployment process. In this context, cloud computing presents advantages for addressing these shortcomings. Cloud computing elasticity allows dynamic configuration and deployment of basic IT services to form complex business processes. This way, cloud computing's elasticity enables businesses to deploy the desired complex process autonomously and dynamically adapt the IT services to deliver requested functions without worrying about the infrastructure's cost and maintenance. Moreover, the cloud's auto scaling mechanisms deliver the exact amount of needed resources while maintaining the Service Level Agreement (SLA) contracted between the Cloud Provider and the Cloud Consumer. These benefits, alongside the Pay-as-You-Go business model, made the cloud an innovative, cost efficient, and flexible delivery model for business processes.

Although pervasive environments have limited computational capabilities, they generate large amounts of sensory data. Therefore, the need for ubiquitous unlimited computational and storage capabilities to aggregate, process and store the large amount of collected data. The complementary characteristics of both, pervasive environments and the cloud computing, allowed them to converge [5], envisioning to deliver sophisticated IT services on demand.

The organization of this paper is presented as follows: Section II describes the system evolution and its information and functional views. Section III introduces the enhanced architecture and its details. Section IV presents the technological view and how cloud computing is being employed in the solution. Finally, in Section V contributions , future works, and results are discussed.

## II. LARIISA

Local and global health context information models for governance decision making were considered in the latest LARIISA development cycle [6], [7]. A basic architecture for building context-aware applications and supporting decision-making in the health care area was defined in this version, considering requirements of five health care governance domains [4]:

- Systemic Normative: area related to the participation of public officials and health care administrators in the development of laws and regulations, and its consequence to the health care system;
- Clinical and Epidemiology: discipline related to the correlation among several determinants and biological conditions, such as social, economic, genetic, lifestyle and health system assistance, to the patient's well-being and health-disease status;
- Administrative: area related to the administrative and management processes related to health care system;
- Shared Management: field related to the social involvement and shared management among federal and agency entities;
- Knowledge Management: area related to the collection and deliver of tactical knowledge and lessons learning from different levels of the other health care domains.

In this paper, we propose several enhancements in the informational, technological, functional and technological viewpoints. In the information viewpoint, we propose to scope

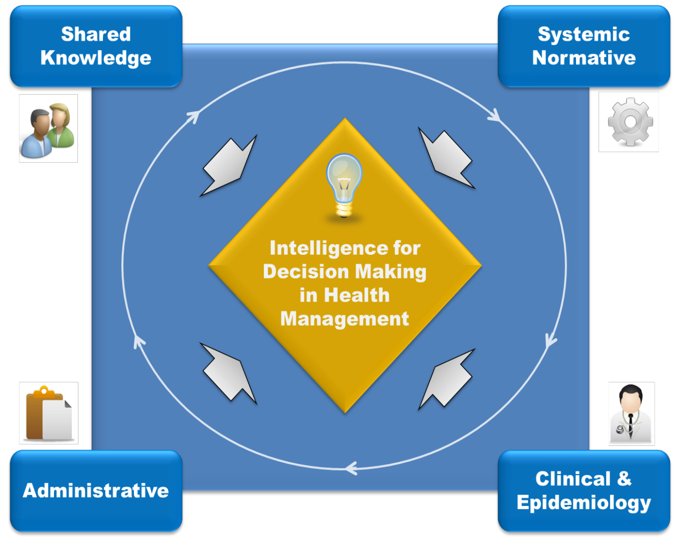



Figure 1. Five health governance domains [4]

LARIISA's health care knowledge domains in four health care governance domains , as depicted in Figure 1:

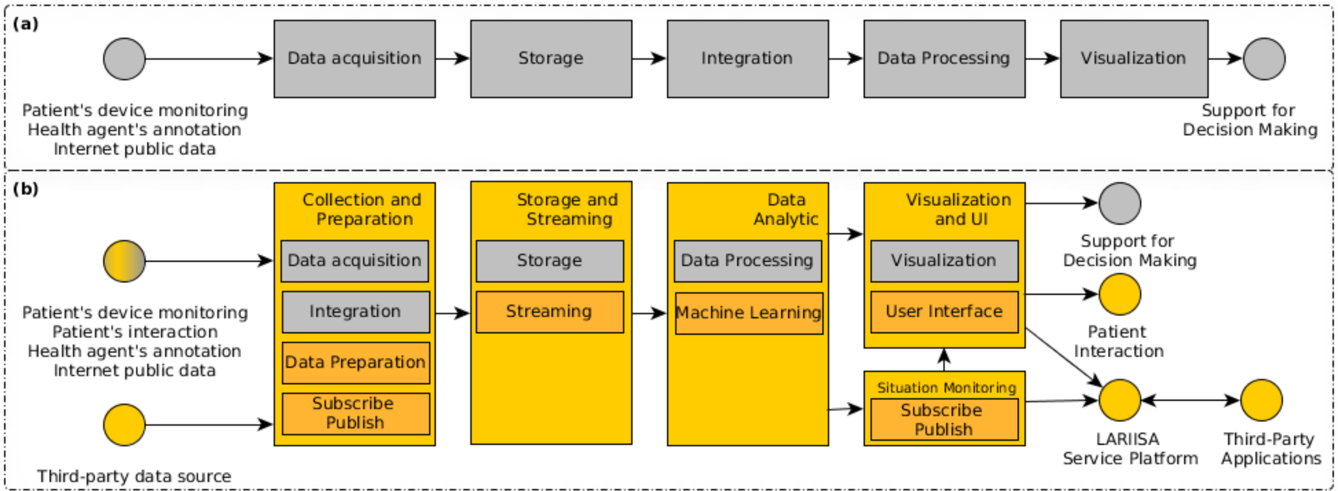
The 'knowledge management' discipline is not removed but rather it is implicit across all other domains. This is implemented by sharing knowledge annotations made by several actors about the information that LARIISA provides.

From a functional perspective, LARIISA was previously defined as intelligent system driven by context to collect, prepare, integrate semantic, analyze, reason, and present information defined by the five health care areas introduced in [4]. In this paper, we increment these functional phases, extending the system capacity to produce information and to monitor situations and contexts. Figure II(b) illustrates the incremental improvement II(b) over the previous LARIISA functional process flow Figure II(a).

In the first phase 'Collection and Preparation', the new process aggregates the previous 'Data Acquisition' and 'Integration' steps. This way, it is not only possible to enrich data with contextual information but also with sensory metadata and patient's feedback. The aspect of 'Data Preparation' included in this new step, as illustrated in Figure II(b), provides techniques to clean, filter, and prepare data to be integrated, stored or streamed. Another important feature of this step is the 'Subscribe Publish' component that allows different third-party data sources to subscribe in LARIISA.

In terms of data delivery for processing, LARIISA now supports data streaming besides the original data storage in the phase 'Storage and Streaming'. This is an important enhancement since patient's situation can be perceived timely to trigger health care assistance through the system.

In order to deliver data analytic capabilities to perceive situations and unusual behaviors, the step 'Data Analytic' aggregates techniques previously included to classify, cluster, and reason, and also machine learning techniques that empower LARIISA to monitor situations based on data models.




(a) Latest functional flow in earlier version of LARIISA. (b) Proposed functional flow for the new LARIISA system

Consequently, the step 'Visualization and UI' provides a library to represent information provided by 'Data Analytics' and 'Situation Monitoring' steps. Similarly to the scenario in Figure II(a), 'Visualization and UI' delivers to the decision makers information about the four health care knowledge domains describe in Figure 1. In this paper, we improve this step by considering the patient and third-party health care actors as information consumers too through LARIISA Service Platform.

Ultimately, LARIISA functional flow is diversified by providing more than just support for decision making, but actionable information to supply a 'Situation Monitoring' step that is responsible to observe stored data or streams, and trigger services and events in the LARIISA Service Platform. The step 'Situation Monitoring' is what makes LARIISA a proactive system, rather than just intelligent, by continuously analyzing data streaming and stored data while making use of all system's capacity to process, reason and identify models. The same module 'Subscribe Publish' permit that LARIISA have different services listening to the same data flows while applying different analytics. LARIISA Service Platform mediates applications and data processing. Its description is detailed in the next Section.

## III. System Architecture

Besides patients and decision makers, several third-party actors participate in the functional scenarios of the new LARIISA system, as depicted in Figure II. Each of them have different information needs and plays different roles in the health care supply chain. Moreover, actors in this proposed version of LARIISA are not just information consumer, but contributors who feedback the system with relevant information both coming from health care assistance and patients.

The architecture proposed in this paper was designed based on services. A Service Oriented Architecture (SOA) models a system in the form of reusable services that deliver applications and business functionality. These reusable services are functions accessed through a well-defined and implemented interface. Multiple services can be combined in order to provide more complex services. Figure2 shows a typical basic scenario of a SOA.

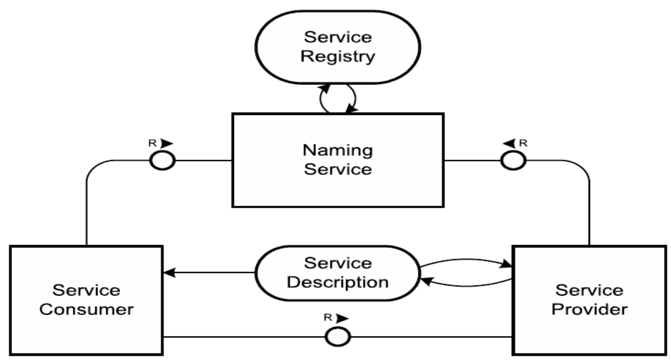



Figure 2. A typical Service-Oriented Architecture [8]

LARIISA's architecture is divided in three layers: Data Service Platform (DSP), Service Platform (SP), and Application Platform (AP), as presented in Figure 3. In the base, the services related to the data collection and transformation processes are disposed organically and highlight the importance to provide each functional step as a service. Data acquisition come from different data sources, including medical data source (that should be safeguarded), linked data (triple stores), traditional transaction databases, data streaming (like social networks), environmental sensors, wearable devices, desktop applications, smart-phones, smart-televisions applications, and devices connected to television set-top-boxes. LARIISA's architecture provides a public publisher/subscriber connector where new data sources can be connected.

Each phase in the functional flow of LARIISA have functionalities that are provided as services. In the 'Collection and

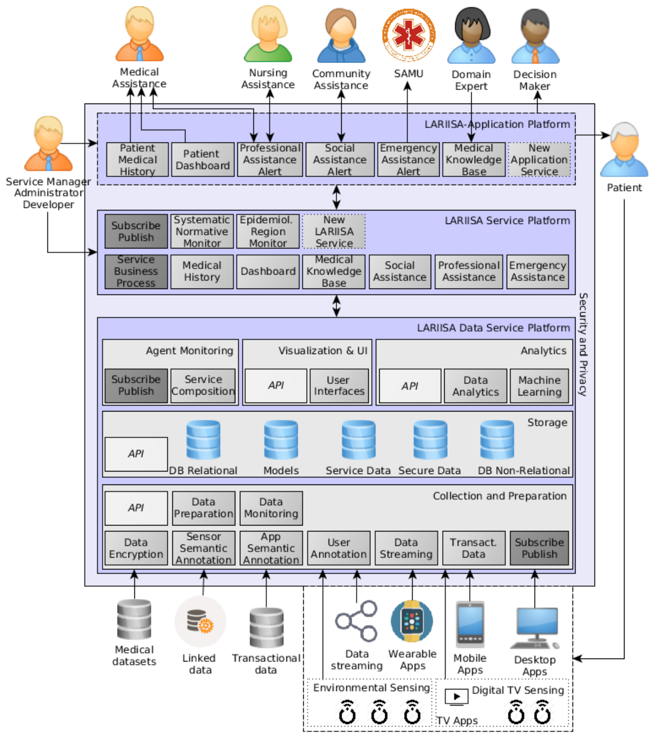



Figure 3. LARIISA architecture

Preparation' module, data encryption, semantic enrichment, stream processing, and functions to prepare data are available. In this case, for instance, data cleaning and context-awareness processing can be done in this module. Since the system is based on its proactive behavior, data monitoring in this module is responsible for triggering agents to analyze the data being stored or streamed. In the 'Storage' module, different services to store and retrieve information are available, considering information safety, integration and structure. 'Analytics' module provide services to cluster, classify, and identify patterns and data models. In 'Visualization and UI', data and information representation API can be accessed in order to format the data differently. These API will provide visual components to show information and to interact with users. The 'Agent Monitoring' module is the core of the pro-activity in the system. This module is normally triggered by 'Collection and Preparation' through its 'Data Monitoring' functionality. The services in this module are driven to perceive data, patterns, and models in order to trigger services in the 'Service Platform'.

These functions can be combined differently to provide different results, such as summary for health care decision makers, health status to doctors, and health care agents. In this sense, we propose an architecture that incorporates the concept of Enterprise Service Bus (ESB) to support the service composition in LARIISA. ESBs are architectures based on open standards, message exchange, and integration of distributed and independent services. They aim to provide routing, invocation and mediation services to facilitate the interactions of different applications and services in a secure and reliable manner [8]. Figure 3 shows a simple ESB scenario.

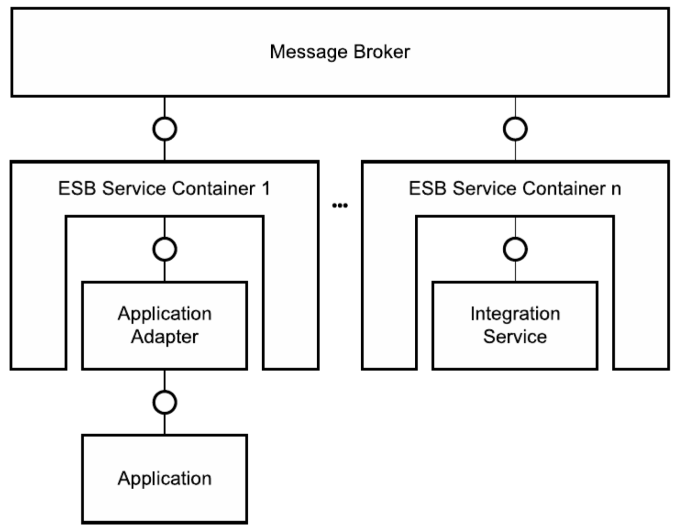



Figure 4. A simple ESB scenario [8]

The second layer, Service Platform (SP), is the bridge between data services and applications based on ESB. In practice, the SP acts as a mediator between the health care assistance business process and the technical implementation details needed to collect, store and analyze data. Besides that, the SP is responsible for orchestrating the business process that decides which application in the AP needs to be triggered and messaged, and what components in the SP needs to be activated to deliver functionalities demanded in the applications available in the AP. This is still a technical layer (higher than DSP) that needs to be operated by administrators, service managers, and developers who want to provide a scenario that involves health care assistance.

The developer needs to interact with the SP and AP in order to know what services in SP he/she will use to ignite applications in the AP, and, if needed, develop new service in the SP using DSP API. Developers are also responsible for developing applications that will make use of the services provided in the SP. The Service Manager is responsible for adjusting parameters of applications in AP and services in SP, while making sure that actors in the health care assistance process have their needs and expectations reflected in the business process defined in the SP. Administrators are responsible for updates and maintenance of the platform in general.

The third layer, Application Platform, is a platform where actors in the health care supply chain have functionalities and interface to interact with LARIISA directly. Some actors will only receive information and their actions will not be counted into the system, such Decision Makers. Other actors will demand and receive information from the system, like doctors and other health carers. In this category, patients can allow specific individuals to have access to their profile based on trust and familiarity, for instance, community or relative assistance can be triggered and monitor patient's situation

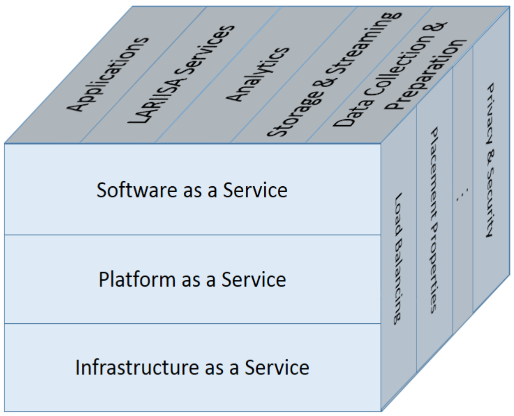



Figure 5. The cube representing the cloud business process of the LARIISA framework

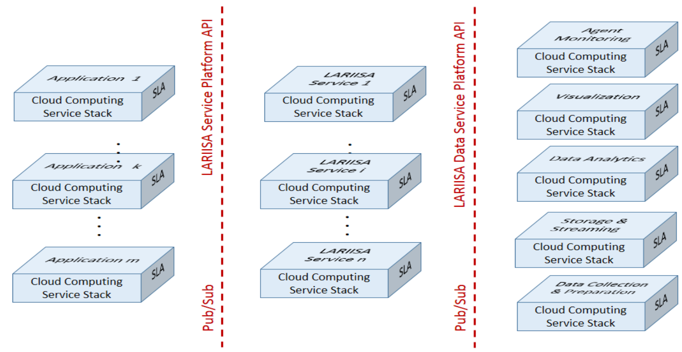



Figure 6. An illustration of service composition of LARIISA framework prior to cloud deployment

based on their granted access. In addition, following a given health care business process defined in SP, messages and information could be triggered for several applications and actors sequentially. A practical example, is an emergency application being triggered after several unsuccessful attempts to reach an elderly patient by phone for two hours since his fall detection event has occurred and sent a message to their relatives through community assistance.

In order to support ESB, services in LARIISA architecture needs to be designed to support modern web service technologies. This will allow services to exchange messages (requests and responses) in the message broker, as illustrated in Figure 4. Another cornerstone in LARIISA architecture is the 'Security and Privacy' aspect that is depicted in FIgure 3 as background for all layers and services. The advantages of designing the new LARIISA as ESB and SOA are the extendability of LARIISA's services, integration of new actors and data sources, and security and privacy verification in each step of the functional process and service access.

## IV. Service Architecture

In a cloud environment, the cloud service stack (Software as a Service, Platform as a Service, and Software as a Service) and the service level agreement can be used alongside the functional model described in Section III, in order to deliver LARIISA's services via the Cloud. Therefore, LARIISA can be viewed as a 3 dimensional cube as shown in Figure 5. The cube consists of:

- LARIISA functional model: It describes the information flow throughout the system. We can distinguish several main components in the functional model: (a) data collection and preparation, (b) storage and streaming, (c) analytics, (d) services platform, and (e) applications. In a cloud view point, each of these component can be treated as a sub process block delivering its required IT service. Each sub process block hides the underlying computational model (interconnected basic IT services) needed to deliver the requested task.
- The computational model: It represents the cloud computing service stack. This model describes the underlying virtual network on which the functional model runs. It contains the specifications of virtual machines (physical requirements, operating system, etc.), virtual links (bandwidth, etc.), and virtual machines (VMs) post-configuration requirements.
- The service level agreement (or non functional requirements) model: It describes the provisioning parameters of the functional model, the post provisioning initial configuration, and finally the Key Performance Indicators (KPIs) and Service Level Objets (SLOs) to take into account when enforcing the contracted violation penalties and the requested Quality of Service (QoS) level during run time. This model defines the architecture of within each component and its evolution during run time.

It is possible to dismantle the cube into smaller interconnected cubes as illustrated in Figure 6. In this case, each cube will represent a sub process block. As mentioned before, each of the following blocks can be a single virtual machine or a complex architecture. However, it is worth noting that both approaches should deliver the same defined sub process IT service in the functional model. The architecture of the IT service is affected by the SLA description and parameters in the non functional requirements model. For example, if a LARIISA sub process block represents an elder fall detection service, and the service provider requests privacy enforcement on this block, two privacy agents monitoring results will be added to the block thus changing its internal architecture. Moreover, if the deployment of "storage and streaming" component requires auto scaling mechanisms for example, the service provisioning process will add a load balancer module to the latter component. This way, the "storage and streaming" component can be duplicated as needed.

## V. Conclusion

The evolutionary process of LARIISA since its beginning in 2010, shows that all research conducted brings innovation for the society. This can be proven with two projects that were started in late 2014 - one sponsored by Finep (Financiadora de Estudos e Projetos) and the other by Funcap (Fundacão Cearense de Apoio ao Desenvolvimento Científico e Tecnológico).

With the inclusion of the concept of meta-data in LARIISA framework and deepening of geolocation studies and their correlations, it was possible to move the platform to a standardized model of collecting and entering data into LARIISA databases. These components also enhanced the decision-making power of applications through contextual information.

Furthermore, with the spread of pervasive and portable technology use in different social classes and age groups make this enhancement to LARIISA system is a candidate to democratize health care assistance for low-income population and seniors monitoring.

GISSA architecture [9] was built taking into account the architecture proposed in Figure 3. Within the LARIISA the ripening process, we observed that the creation and evolution scenarios favors the visualization of new applications that add functionality to the studied platform.

The previous version of LARIISA [4] delivered an intelligent system for decision-making in a public health management environment. In [10] the authors propose a data integration platform for the LARIISA. The aim of this proposed platform is to enable the integration of a large variety of health information databases with different governance issues involved, enabling interoperability among these multiple sources of data. Making use of this platform, the framework on this paper will be able to correlate information stored in different databases of private or public companies. It would permit the system to find additional information of a specific patient (e.g. via SUS ID) to collect more health information related to a specific patient, thereafter taking a decision more accurately.

The new proposed LARIISA aims to extend its functional scenarios by delivering a service and application platform what allows different actors in the health care supply chain to interact with the system and gather different information according to their need. By applying modern concepts of data mining, SOA and ESB, this proposed platform aims to reach scenarios as social assistance or emergency alerts based on the patient's wellness perception which are conceived by data interpretation and situation awareness.

As future work, we will focus on implemented the proposed architecture. The framework presented on this paper has the purpose of joining Continua Health Alliance [11], a non-profit, open industry organization of health care and technology companies.

## Acknowledgment

We gratefully acknowledge Brazilian research groups ARACATI DIGITAL and LAR-A, at the Federal Institute of Cearaá, and MPCOMP, at the State University of Ceará, where this work started. This work is part of NextSAUDE and GISSA Projects, a research project on health area approved and sponsored by DataSUS, the information technology department of Brazil's Ministry of Health (*Ministério da Saúde do Brasil*).

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