An Enhanced Architecture for LARIISA: An Intelligent System for Decision Making and Service Provision for Health Care

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Abstract **– Health care services can be scarce and expensive in some countries and specially 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 provision 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 in mobile phones, wearable devices, desktops, web servers, and digital television set-top-boxes. Along with the architecture, LARIISA framework 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.**

Keywords - context-aware; architecture; decision-making; health care; privacy; cloud computing; service

I. INTRODUCTION

The advance in pervasive computing and network communication have 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 sensor 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, like 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) [4] [5] [6], 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 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 (using accelerometers [ref]) or refrigerator use frequency can trigger events to the nursing assistance service in the scenario of unusual behavior in senior's health monitoring.

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 digital television interface[3]. 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 smartphones, smart-televisions and wearable devices is incorporated as an important aspect into LARIISA architecture. This way, these devices can inform and demand additional information for patients, besides its previous capacity for sensory data collection.

Distributed and 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 shortcoming. 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 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 data acquired from real world things. Therefore, the need for ubiquitous unlimited computational and storage capabilities were needed 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 31, envisioning to deliver sophisticated IT services on demand.

The organization of this paper is presented as follows: Section 2 describes the first version of the solution. Section 3 introduces the enhanced architecture and the second version of the LARIISA framework. Section 4 presents the health care data analysis process. Section 5 presents the system views. Finally, in Section 5 contributions and 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 **29**. 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 [3].

In this paper, we propose several enhancement in the informational, technological, functional and technological viewpoints. In the information viewpoint, LARIISA is based on the following four knowledge area domains, as depicted in Figure 1:

- 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.

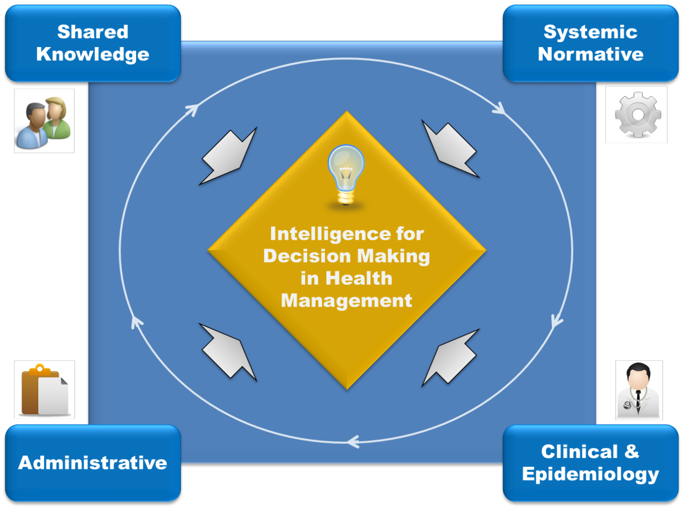

Figure 1: Five health governance domains [3]

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 provided.

From a process 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 defined in [3]. In this paper, we increment these functional phases, extending the system capacity to produce information and to monitor situations and contexts. Figure 2 illustrates the increment improvement Figure 2(b) over or the previous LARIISA functional process flow Figure 2(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 meta-data and patient's feedback. The aspect of 'Data Preparation' is included in this new step, as illustrated in Figure 2.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 LARIISA to subscribe in different third-party data sources.

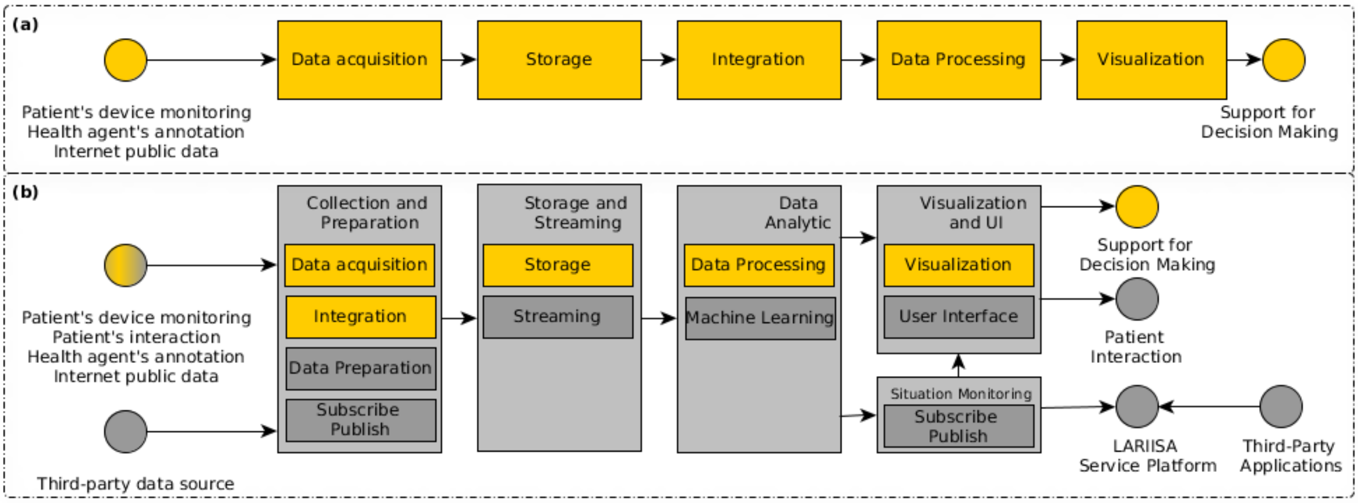

Figure 2: (a) Latest functional flow in earlier version of LARIISA. (b) Proposed functional flow for the new LARIISA system

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

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

Ultimately, LARIISA functional result 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 systems 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. The description of this platform is detailed in Section 3.

Consequently, the step 'Visualization and UI' provide a library to represent information provided by 'Data Analytic' and 'Situation Monitoring' steps. Similarly to the scenario in Figure 2.a, 'Visualization and UI' deliver 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.

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 2. Each of them have different information needs and plays different roles in the health care supply chain. Moreover, actors in the new 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 which access is done through a well-defined and implemented interface. Multiple services can be combine in order to provide more complex services. Figure 3 shows a typical basic scenario of a SOA.

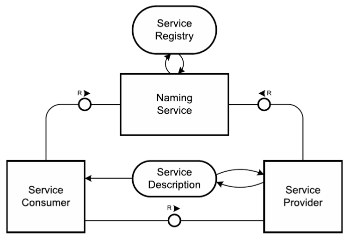

Figure 3: A typical Service-Oriented Architecture 32

LARIISA's architecture is divided in three layers: Data Service Platform (DSP), Service Platform (SP), and Application Store (AS), as presented in Figure 4. 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 transactional 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 public publisher/subscriber connector where new data sources can be connected.

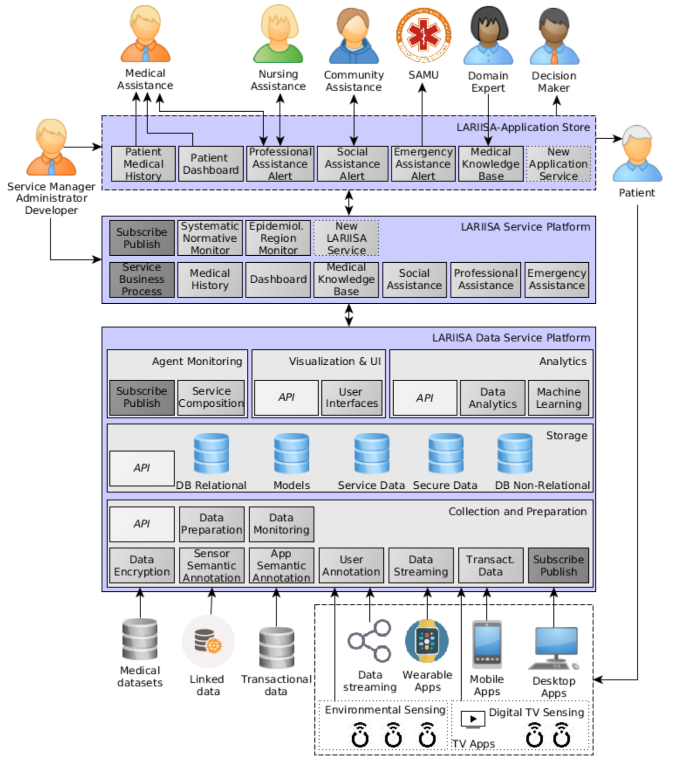

Figure 4: LARIISA architecture

Each phase in the functional flow in LARIISA have functionalities that are provided as services. In the 'Collection and 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 & 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, models in order to trigger services in the 'Service Platform'.

These functions can be combined differently to provide different results, such summary for health care decision makers, and health status to doctors and health care agents. In this sense, we propose an architecture that incorporate 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 32. Figure 4 shows a simple ESB scenario.

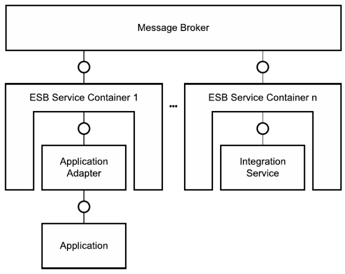

Figure 5: A simple ESB scenario

The second layer, Service Platform, is the bridge between data services and applications based on ESB. In practice, the SP acts mediating 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 AS 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 AS. 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 AS in order to know what services in SP he/she will use to ignite applications in the AS, and, if needed, develop new service in the SP using DSP service calls. 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 applications parameters in AS and in 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 in the platform in general.

The third layer, Application Store, 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 based on their granted access. In addition, following a given health care business process defined in SP, messages and information could be trigger for several applications and actors sequentially. A practical example is an emergency application being triggered after several unsuccessful attempts to reach a elderly patient by phone pasted two hours since the fall detection event has 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 5. The advantages of designing the new LARIISA as ESB and SOA are the extendibility 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

The functional module of the LARIISA architecture is illustrated in Figure 4. 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 added to the latter functional model to define a cloud business process. Therefore, LARIISA can be viewed as a 3 dimensional cube topped with an application layer as shown in Figure 5. The cube consists of:

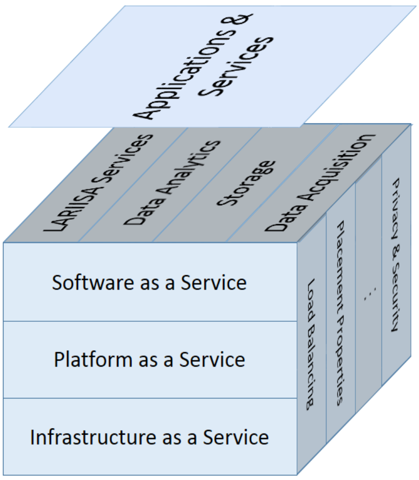

Figure 5: The cube representing the cloud business process of the LARIISA framework

- The business process (LARIISA functional model): It describes the information flow throughout the system. It is divided into sub processes blocks which deliver the required IT service. A sub process block hides the underlying computational model (interconnected basic IT services) needed to deliver the requested task.

- The cloud computing service stack: It represents the underlying virtual network on which the business process runs. It contains the specifications of virtual machines (physical requirements, operating system, etc.), virtual links (bandwidth, etc.), and VMs' post-configuration requirements.

- The service level agreement: It describes the provisioning parameters of the business process, the post provisioning initial configuration, and finally the KPIs and SLOs (Service Level Objets) in order to enforce contracted violation penalties and the requested QoS level during run time.

This cube represents the entire LARIISA business process. However, each business process is the work flow of many sub processes. Therefore, 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. The architecture of the IT service is affected by the SLA description and parameters. 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.

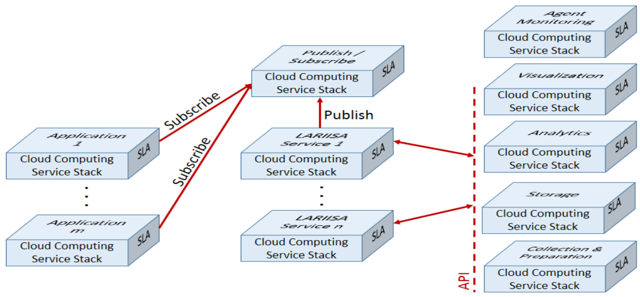

Figure 6: An illustration of service composition of LARIISA framework prior to cloud deployment

Finally, The application layer on top of the cube represent any third party software designed to use the deployed business process in order to deliver services for the end-user.

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 (Funda/'c/ ao Cearense de Apoio ao Desenvolvimento Cient/'ifico e Tecnol/'ogico).

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 [28] 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.

LARIISA [3] is an intelligent system for decision-making in a public health management environment. In [22] 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.

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 [24], a non-profit, open industry organization of healthcare and technology companies.

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