Evolving an Intelligent Framework for Decision- Making Process in e-Health Systems

Leonardo M. Gardini[1], Carina Oliveira[2], Reinaldo Braga[2], Ronaldo Ramos[2], Luiz O. M. Andrade[3], Mauro Oliveira[2]

[1]*State University of Ceará (UECE) - Fortaleza, Brazil*

[2]*Federal Institute of Ceará (IFCE) - Fortaleza, Brazil*

[3]*Federal University of Ceará (UFC) - Fortaleza, Brazil*

Email: lgardini@gmail.com, odorico@saude.gov.br, {carina.oliveira,reinaldo.braga,ronaldo,mauro}@ifce.edu.br

Abstract **–This paper presents improvements of LARIISA, a framework that makes use of context-aware information to support decision-making and governance in the public health area. More specifically, two relevant e-health applications are presented to illustrate the LARIISA system. The first one uses Bayesian networks in dengue scenarios. The second application uses ontology to manage home care scenarios. In both cases, the contributions related to the LARIISA framework include patient health diagnosis provided remotely, support for decision-making health systems, and context information for context-aware health systems.**

Keywords - framework; context-awareness; ontology; decision-making; health;

I. Introduction

Among the challenges of information management in the health area, we highlight the difficulty faced by a significant part of managers to act efficiently on decision-making processes. To address some of these challenges, a framework called LARIISA [1] [2] was originally conceived to support decision-making processes concerning public health governance. This framework makes use of applicable concepts such as context-awareness, ontology and personal tracking to support health managers to take more knowledgeable decisions.

This paper presents LARIISA, a framework that makes use of context-aware to support decision-making and governance in the public health area. Besides that, two applications are presented to illustrate the applicability of the LARIISA system. The first one uses Bayesian network in scenarios of dengue fever disease. The second application uses ontology to treat home care situation. In both cases, the contributions related to our framework include patient health diagnosis provided remotely, support for decision-making health systems, and context information for context-aware health systems.

This paper is organized as follows: Section II discusses shortly about context-awareness and personal tracking concepts. Section III describes the objectives of the LARIISA framework. Section IV presents the evolution of LARIISA with an intelligent model for enhancing the decision-making on the proposed system. Section V presents the two applications. Finally, Section VI concludes the paper and discusses future work**.**

II. Context-Awareness and Personal tracking concepts

Information could be captured revealing where the user is or what the user is doing, and then this information could be used to offer personalized services and information [3]. Context is this type of information, which characterizes a situation and can be used by decision-making processes. Applications that use this type of information are named context-aware applications [4]. Therefore, a context model defines types, names, properties and attributes of the entities involved in context-aware applications, such as users and static/mobile devices. The model attempts to predict representation, search, exchange and interoperability of context information among applications. A well-designed model is the key to any context-aware system [5].

Aiming in assisting users in their day-to-day tasks, context-aware applications have been using elements of ubiquitous systems to obtain user context information. A simple example is the use of sensors that detect the presence of people and automatically trigger lighting to an environment, according to the people location and time.

We propose the use of context information related to the user location while registering his/her remote health diagnosis. The user location is registered by using the GPS sensor of the device. The GPS coordinates and the description of the patient context are added to the patient health diagnosis, helping the decision-making process of LARIISA. The ability to track, trace and control anything from anywhere on the planet has been humankind's unfulfilled desire [6].

In this context, it can be cited Captain [7], a context-aware system based on personal tracking. The main purpose of Captain is to map the trajectory of a mobile user, adding contextual information related to each user position. The mobile application proposed on the Captain project performs the yacht tracking, associating contextual information with each position.

While registering the trajectory followed by the mobile device, it allows users to create multimedia documents (e.g. photo, audio, video), which are connected to an enriched description of the user context (e.g. weather, location, date). Finally, all this data and documents are combined to produce a new content, which is published on the Web.

III. LARIISA FRAMEWORK

LARIISA defines the basic architecture for building context-aware applications and supporting decision-making in the health care area. LARIISA was specified taking into account specific requirements of five governance fields: Knowledge Management, Systemic Normative, Clinical and Epidemiological, Administrative and Shared Management [1]. LARIISA provides context-aware diagnosis based on geolocation and can be applied in different scenarios of decision-making for local and global contexts [8].

Also, LARIISA framework works with real-time information and comprises inference systems based on ontology models. It is context-oriented, providing adaptability to the decision-making applications existing in the Brazilian healthcare network. The current healthcare network is divided into five levels: Primary Care Network (also known as Family Health); specialized Ambulatory Care Network; Hospital Network; Urgency and Emergency; and Mental Health.

LARIISA system is able to perceive the status of an emergency epidemiological situation and then set up itself (in real time) to a risk situation.

Identifying which user is sending health status (enriched data) to the LARIISA Database is crucial for the proposed framework. Without this identification, it is not possible to determine who is sending health vital signs to the system. To overcome this challenge, a unique identification (ID) number needs to be informed by the user at the moment he/she starts a new health diagnosis from his/her mobile device [1]. The unique ID chosen is the SUS ID [9], an identification number assigned to every Brazilian citizen as part of the national registry of users – for the consolidation of the *Sistema Único de Saúde* (SUS) of Brazil [10]. In this context, the unique ID can be used to register a new health diagnosis and also query information from other databases such as SUS database, public hospital databases, etc.

We consider the use of the LifeWatch V phone, a fully featured android-based phone [11] [12]. This device has a variety of health sensors (blood glucose, body fat, stress test, etc). Our proposal is limited to the body temperature, blood pressure and heart rate sensors. It is also important to mention that context-aware systems have some dependencies that may not be satisfied in some situations. The Internet connection, for example, can be limited or even not available at certain moments. In order to minimize these dependencies, we propose some design decisions.

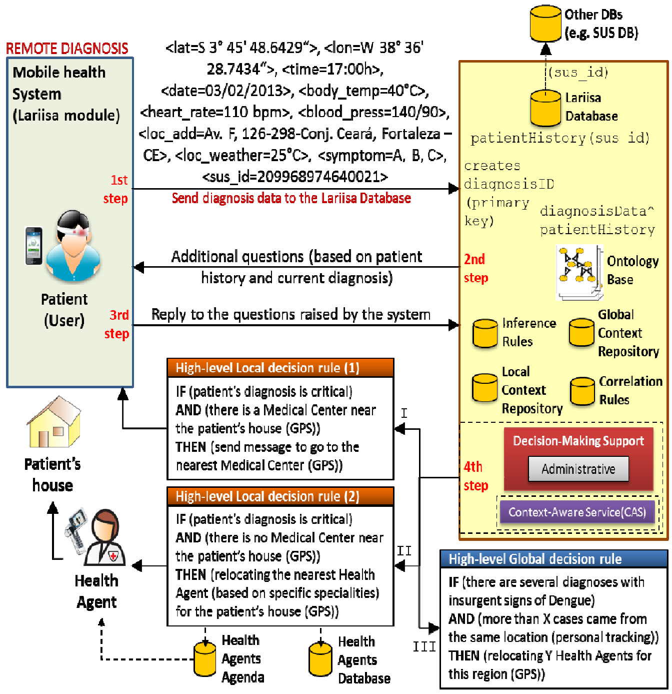

Fig. 1. LARIISA Architecture

A. *Data Acquisition*

The *Data Acquisition* uses sensors available in mobile devices to get information about localization, time, heart rate, blood pressure, body temperature, local weather, etc. In addition, SUS ID and symptoms informed by the user when the application is started are also considered as *Data Acquisition*.

According to Figure 1, the user starts the data acquisition process in the mobile device. After starting the application, the *Data Acquisition* process starts to collect all data needed to send the patient's enriched health data to the Lariisa Database. Before starting the acquisition of location, time and health, the user must inform his/her SUS ID and symptoms to the system. These data (SUS ID and symptoms) are added to the other data acquired, including health data gathered by the sensors and data gathered from the Internet via Web Services. Location name and weather can be obtained from the Internet, both using the position information acquired by the GPS. If Internet connection is not available at the moment diagnosis system is started, all data will be cached and further it will be sent to the Lariisa Database. In order to improve the *Data Acquisition* process, SUS ID information is stored on the system. Therefore, the user does not need to send the ID at the next time he/she uses the system.

In order to improve the data processing step, it is important to organize the acquired data into the metadata. Therefore, the system uses tags to arrange the information in the metadata.

B. *Data Processing*

The *Data Processing* part is responsible to increase the robustness of the system by offering more than a context-aware data collector. It associates and organizes the information in order to provide a comprehensive structure to be published (registered) on the Lariisa Database.

Making use of the acquired data organized by tags, the data processing part is started. It has to organize the data in order to facilitate the content generation for later registering on the Lariisa Database. The key idea is to use the context information of the remote health diagnosis data for decision-making support, considering both local and global contexts. The system provides enriched health diagnosis based on the information acquired by the mobile application. For example, if a user starts a remote health diagnosis, the system will generate a new diagnosis with the coordinates S 3° 45' 48.6429", W 38° 36' 28.7434" at 17:00 on 03/02/2013. Besides that, the mobile application captures health data from medical sensors (body temperature, blood pressure, heart rate, etc.), and the user is requested to add his/her health symptoms and SUS ID [9].

If the mobile device due to an absence of connection does not acquire the information of location name and weather, our system interface has to be able to obtain this information based on context information. The specialized web services provide the weather status for present and future times. To solve this problem, we propose a mechanism to capture this information using a HTML parser in order to get the location name and for the past time. This parser reads the web page *DailyHistory* of the *WeatherUnderground* and obtains the weather status related to the context information provided by the acquired data [1]. When the application generates the content to register all health status data, the third step of the proposed system can be started.

C. Publishing

The last part of the system is responsible for registering the content on the Lariisa Database. An important part of the architecture proposed is the use of Context Aggregator Layer (CA) to receive health status context information from context providers. This layer is also responsible for running context aggregation operations in order to have useful high-level context represented by the Local Health Context Ontology [1]. Moreover, health managers could view the content of diagnoses organized by day, by place, or by patient (e.g. filtering diagnoses results by SUS ID).

IV. Lariisa Evolution

The main characteristic of LARIISA evolution is related to our methodology for modeling the problem of pattern classification, based on patients' diagnosis data. Besides that, we consider some steps to achieve our target, which consists of analyzing the metrics in order to obtain the training set. Therefore, the training step is executed after the capture of feature vectors, which contains some sub steps, such as feature selection and the predictive labeling.

It is important to observe that the proposed pattern building and labeling approaches are independent of the chosen pattern classifiers.

We emphasize that the proposed pattern building and labeling approaches are independent of the chosen pattern classifiers.

The training set, i.e., the set of labeled patterns used for training is obtained through the following steps:

Step 1: Extract raw data from the database, which contains usage information of the beneficiaries;

Step 2: Perform feature selection;

Step 3: Find every patient that did a health diagnosis somewhere in the analyzed period of time;

Step 4: For each patient's diagnosis data found on Step 3, build a pattern considering a procedure window counted from the first time a target diagnosis was done. This is intentioned to capture the moment of transition when the patient passes from low risk to high risk. These patterns are called target patterns;

Step 5: Find each patient that never had a critical disease during the same time period;

Step 6: For each patient found on Step 5, build patterns considering a procedure window counted from each available month. Note that each reference month generates a distinct pattern per patient. These patterns are called non-target patterns;

Step 7: Obtain a training set formed by every target pattern and the same quantity of non-target patterns, randomly sampled.

V. Larissa Applications

In this section, two applications are described as a proof of concept of the LARIISA proposal:

A. LARIISA Bay

LARIISA_Bay is a component based on Bayesian networks that works together with the LARIISA framework [13]. This component is concerned with the treatment of uncertainty in health systems. Here, the representation of context-sensitive information (i.e., data collected) as well as the knowledge of experts are used [13].

As a result, LARIISA_Bay is able to assist team of specialists to better diagnose diseases according to the data collected from different users of the system.

Figure 2 illustrates the proposed phases of LARIISA_Bay. To better illustrate these phases, we describe examples of the dengue fever disease, which corresponds to the case study.

The Input System: it corresponds to an information-gathering interface that allows the interaction of three different decision makers: the patient (i.e. user of the system), the health agent and the specialist. In Figure 2, note that the specialist interface contains the health agent interface, which in turn contains the patient interface. In this initial phase, sensor can also be used, for example, to monitor patients' vital signs. As a result, metadata is created from the gathered information. It is also possible to use external context providers.

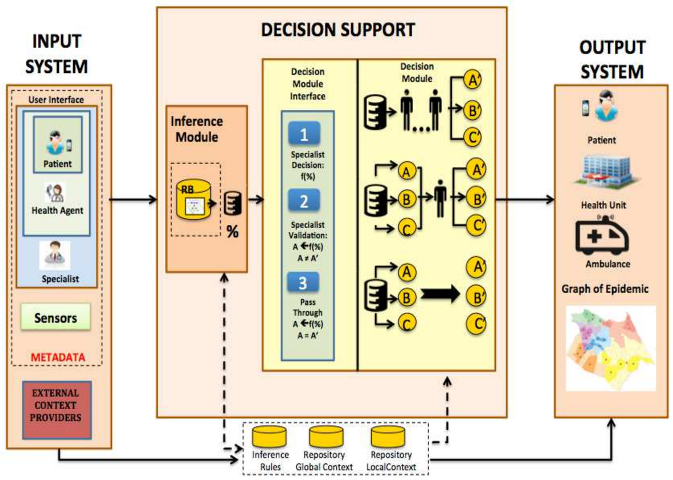

Fig. 2: LARIISA_Bay Application [13]

Decision Support: the Inference Module corresponds to the Bayesian network modeled to support the decision making of medical teams.

The Inference Module has two main purposes in the context of the presented application:

(1) To support the diagnosis of the medical staff, filtering probable cases of dengue in three levels of classification, which are:

i) Normal, for patients without dengue fever;

ii) Grave, for patients with dengue fever disease;

iii) Emergency, for patients with dengue hemorrhagic fever.

(2) To support the diagnosis of dengue fever outbreaks/epidemics in specific regions (i.e., risk areas).

Next, we have the Decision Module Interface, which offers three different application scenarios:

(1) Specialist Decision: it considers the existence of a team of experts able to better diagnose the dengue fever disease according to the received information. Based on the result of the Inference Module, the team of experts can take the most appropriate decision in relation to a particular patient;

(2) Specialist Validation: in this scenario, the result of the Inference Module is filtered/validated by an specialist, instead of analyzed, as in the Specialist Decision scenario;

(3) "Pass Through": in this scenario, one of the following decisions can be made: to leave the decision making to the system or to wait for a health specialist to take the decision.

The Output System: it corresponds to the procedures that can be made after the Decision Support phase to optimize the public health system as a whole. We can mention the following procedures as examples: send guiding procedures to the patient; send a health agent or emergency health team to the patient's home; identify risk areas (graph of the epidemic) in order to adopt proactive preventions.

B. LARIISA_HC

LARIISA_HC is the LARIISA's home care application. It aims to support the easy deployment of e-health applications such as services to monitoring vital signs of elderly and people with specific diseases that require medical supervision at their own home.

By allowing the usage of already deployed home devices such as the television, the system not only reduces the cost of deployment of such solutions but also facilitates the acceptability of such systems.

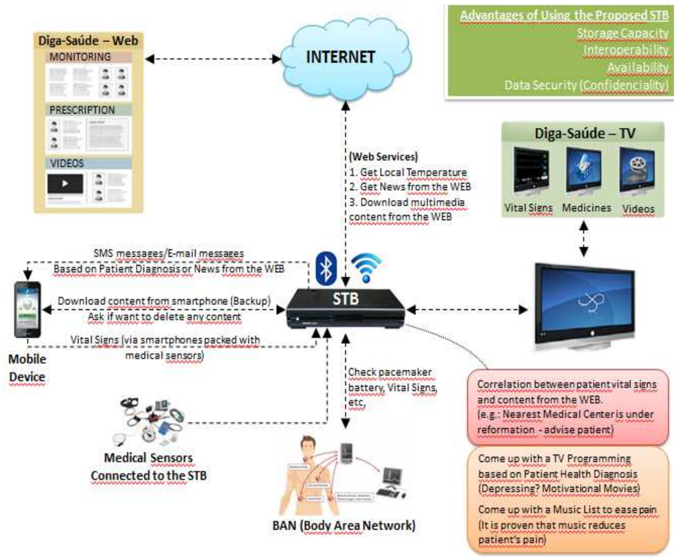

Fig. 3: LARIISA_HC Application

As shown in Figure 3, we can notice vital signs monitoring service, the physical status of patients such as temperature, heart rate, pulse, respiratory rate and also blood pressure can be displayed on the screen of the TV so that the inhabitant can easily notice any anomaly.

In addition, the LARIISA_HC provides access to communication services such as short message messaging to inform relatives of any emergency situation, programming announcements on TV reminding inhabitants of the medication time, facilitating the daily lives of elderly by reminding them important events related to their wellbeing (e.g., doctors' visits, etc).

VI. CONCLUSIONS

Choosing the best mechanism to provide an accurate health diagnosis has demonstrated as being one of the main challenges to improve the whole capacity of the LARIISA framework.

We believe that an approach to overcome this challenge is to implement classifiers that choose suitable intelligent mechanism for providing the appropriate health diagnosis based on patterns and tests. Also, for some diseases the best intelligent system is the use of ontology, and for others, the best approach is the use of Bayesian networks.

As future work, we will continue to focus on improving the LARIISA framework. We plan to study the content combination of different users in order to create reference among their trajectories, personal data and contextual information.

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