APPLYING ONTOLOGY AND CONTEXT AWARENESS CONCEPTS ON HEALTH MANAGEMENT SYSTEM: A DENGUE CRISIS STUDY CASE

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ABSTRACT

This work presents the prototype of the LARIISA, a context-aware framework that makes use of intelligent mechanisms for helping decision-making on health management system. It allows the implementation of ontologies reflecting different levels of public health (e.g. state-wide, locality-wide, etc.) mirroring LARIISA's Local and Global semantic model. The prototype collects context-aware information about the family health by using LISA - LARIISA Integration System - a highly expansible system that aims at facilitating the inclusion and exclusion of context providers. It uses SISA, a health management application able to perceive the status of emergency epidemiological and adapt itself in real time to a risk situation. This way, the LARIISA prototype can direct the health care worker to verify and troubleshoot an epidemiological problem or detect new outbreaks of dengue, for example. The epidemiological map visualized by the health managers (doctors, secretaries of health, state government, etc.) can contribute to decision-making in a fast and efficient manner.

KEYWORDS

Health Management; Ontology; Context awareness; Dengue; Prototype.

1. INTRODUCTION

The Information and Communication Technology (ICT), as well as the expansion and advancement of the Internet through its ability to remote monitoring and interaction with patients, can significantly help health workers in developing actions more agile. This is possible, for example, with remote monitoring systems installed in homes and can be used to collect and transmit information about the health of family members.
This information would be sent to health professionals, in order to provide improvements to the coordination of actions and effectiveness of the detection/treatment remote of diseases [1]. This scenario fit into the context-aware applications [2] that exploit the dynamic context of its users, by capturing the user's context implicitly, either by sensors or ontological associations [3] based on predetermined rules. A context-aware system is able to adapt dynamically, providing a personalized service to the user.

This work presents a prototype of the LARIISA - Laboratory of Intelligent and Integrated Networks Applied to Health System [1][4][5], a project that makes use of intelligent systems in the public health governance area. It advocates using mobile devices, embedded systems and also the set-top box appliance of the Brazilian System of Digital Television- SBTVD for obtaining context-aware information about the family health [6]. It is also designed to provide health managers with an intelligent governance framework that will support them in making decisions concerning the Basic Attention network from the Brazilian Unified Health System (SUS) [7][8][9].

This prototype allows the implementation of ontologies [10] reflecting different levels of public health governance (e.g. state-wide, locality-wide, etc.) mirroring LARIISA's Local and Global context model and uses GINGA [11], a middleware developed for the Brazilian Digital TV, and Android smartphones as context providers. It uses the LISA (LARIISA Integration System) [4], a highly expansible system that aims at facilitating the inclusion and exclusion of context providers, and it also uses the SISA [12], an application for context-aware health management systems, able to perceive the status of emergency epidemiological and adapt itself in real time to a risk situation.

The prototype uses the dengue epidemiological problem as proof of concept of the LARIISA proposal. This disease can affect a large number of people in a short period of time, whereas its transmission vector, Aedes aegypti, completes its development cycle in 0 or 7 days, depending on the climatic conditions.

From 1980 to 2005, the World Health Organization (WHO) reported approximately four million cases of dengue in Brazil alone. A study by Brandeis University, USA, showed that dengue cost about two billion dollars a year for the Americas [7], divided between spending on treatment (hospital costs) and combating mosquito.

Costs for the treatment of dengue can be minimized with a system of efficient decision making in real time. In this sense, the current studies and international experiences have shown that in an effective care network, 65% to 75% of dengue cases can be solved even in primary care [13].

This paper is organized as follows: Section II describes LARIISA Prototype, the framework, the heath context model and a case study about the Health Agent Scenario. Section III shows the LARIISA´s Dengue application. Section IV presents related work. Finally, Section V concludes the paper and discusses future work.

2. LARISSA PROTOTYPE

The LARIISA defines a basic architecture [4][5]used for the building of context-aware applications for governance decision-making in one of the five intelligence domains: Knowledge Management, Normative, Clinical-Epidemiological, Administrative and Shared Management [14]. It incorporates classical components of ontology-based knowledge management systems, such as ontologies (OWL-DL ontologies), ontology instances, inference and derivation mechanisms, etc. [15].

The LARIISA Project aims at researching and developing a framework that uses information primarily collected from and sent to the households which. Once processed by knowledge management mechanisms, this information will guide health managers in the decision making process. With this purpose, LARIISA will capture real-time information from digital TV set top boxes and mobile devices that will provide health authorities with further elements to make more knowledgeable decisions.

A LARIISA's proof of concept (PoC) is being implemented that presents the following characteristics:

- Embedded Hardware and software: Specification and implementation of social, economic, environmental and biometrical context providers that will run in mobile and medical devices as well in TV set-top boxes.
- Software Engineering: modeling and development of a SOA-based system that offers some services to support health managers with decision-making at the primary care level.
- Ontology-Based Knowledge Management System (OBKMS): An OBKMS will be created and maintained to provide support to LARIISA´s decision-making applications.
- e-Health applications: Intelligent applications will help the decision-making in areas such as epidemiology and clinics for the maternal-infantile health;
- Socio-economic feasibility analysis of the decision-making process leveraged with real-time and quality information and taking account of the acceptability by the user.
- Interactive Content: Development of interactive content to be conveyed to the user via Digital TV.

LARIISA prototype runs a top the Ceará Digital Belt [16] in addition to other existing communication links, like WiMax, WiFi e GPRS. It is based on inference systems that will reason on ontologies tailored to model context information.

2.1 LARIISA Framework Enhanced with LISA

LISA - LARIISA Integration System – is a highly expansible system that aims at facilitating the inclusion and exclusion of context providers [4] to LARIISA. Therefore, LISA's main objective is to define a way to regulate the access of the context providers, offering them a single interface to LARIISA. Moreover, it proposes context-aware adaptation mechanisms, like the Service Adaptation component, that have an important role for the integration between LARIISA core framework and the health model [5].

Context providers are responsible for collecting raw health related context data from different sources like mobile devices used by health agents, from set top boxes, from environmental sensors (temperature, humidity, pluviometry, etc.), from medical devices (ECG, EEG, pulse, etc.) and so on. Collected data will be sent to the Context Aggregator (CA) module from LARIISA.

LARIISA is designed to be compliant with international e-Health standards, like the ones listed in the Interoperability Decree, issued by the Ministry of Health in Brazil in 2011 [8]. Thus, it will adhere to standards like DICOM [17] (the Digital Imaging and Communications in Medicine standard for distributing and viewing any kind of medical image regardless of the origin - radiology, dermatology, pathology, endoscopy etc.), HL7 [18] (regulates the interoperability among systems), etc. As for the integration platform solution, we decided for the Open e-Health Integration Platform (IPF), which provides comprehensive support for message processing and connecting information systems in the healthcare sector [19].

Context providers connect to the integration bus through specific web services so that applications running on smartphones, set top boxes, medical equipment, etc. need adapters to collect data coded in different protocols, encapsulate the data in HL7 messages and forward them to the final system through appropriate channels (point-to-point or publish-subscribe).

2.2 LARIISA Health Context Model

It is necessary to define a formal health context model in order to facilitate context representation, sharing, and semantic interoperability in the health care governance system. For this purpose, we have defined two OWL-DL ontologies for modeling local and global health context information, respectively.

- *Local health context* [5] describes the situation of any entity interacting with the governance system, such as end-users (patients), health managers, health agents, etc. This information is used for defining local health decision rules and for deriving global health context information.
- *Global health context* [5] describes high-level information derived from local health context that is used for making health governance decision. For example, it describes the number of Dengue cases confirmed in a region (e.g., neighborhood, city, community), during a given period of time (e.g., a day, a week). In fact, such information can be seen as global indicators used for improving governance decisions.

Based on the *Context top Ontology* we proposed in a previous work [20] to classify local and global health context information according to five dimensions [5]:

- *spatial* - any information characterizing the situation from spatial dimension (e.g., location, place, GPS coordinates);
- *temporal* - any information characterizing the situation from time dimension (e.g., timestamp, interval, period of day, month, year, day, season);
- *spatio-temporal* - any information characterizing the situation that is dependent of both spatial and temporal dimensions i.e., weather conditions, temperature, noise, luminosity;
- *social* - any information characterizing the situation from social relationships;
- *computational* - any information describing the situation from the computational characteristics (e.g., user device's capacities).

Moreover, we have added a new dimension named *health_Element* for classifying context information from the health point of view (e.g., heart rate, pulse, blood_pressure). We defined two subclasses named *Global_Health_Context* and *Local_Health_Context* (i.e. Global_Health_Context ∪ Local_Health_Context ⊆ Context). These concepts capture from the context any information characterizing the situation that is relevant for improving health care governance decisions, i.e. it can be used for defining local and global health decision rules. We use as basis the ECA model (Event-Condition-Action) [21] for describing global

and local decision rules that are translated into SRWL rules. The Event represents the identification of changes on the context, Condition describes a set of valid context constraints, and the Action describes the decision.

Simplified versions of the local and global health context information models for governance decision-making were proposed in a previous work [5]. This platform, characterized by real-time information and inference systems based in an ontology model, will be oriented to the context, giving higher adaptability to the applications on decision-making for the present reality, in that case, the health care network.

2.3 Case Study: Health Agent Scenario

Let us consider the Health Agents that deals daily with users of health care system, visiting family homes and communities (see Figure 1). Without an information system, the visiting schedule of Health Agents follows a linearity and not efficient agenda. The idea in this case study is to improve the quality of health services provided by health agents. It can be achieved, for instance, adapting health agent's agenda to the current situation. Health agents could be recruited for visiting an area where there are insurgent signs of Dengue (i.e., Global Health Context) or people that need health care (i.e., Local Health Context).

We identify two administrative decisions: i) Adaptation of Health Agent's agenda taking into account Global health context (i.e., global decision rule); ii) local adaptation of agenda taking into account only local health context information (i.e., local decision rule).

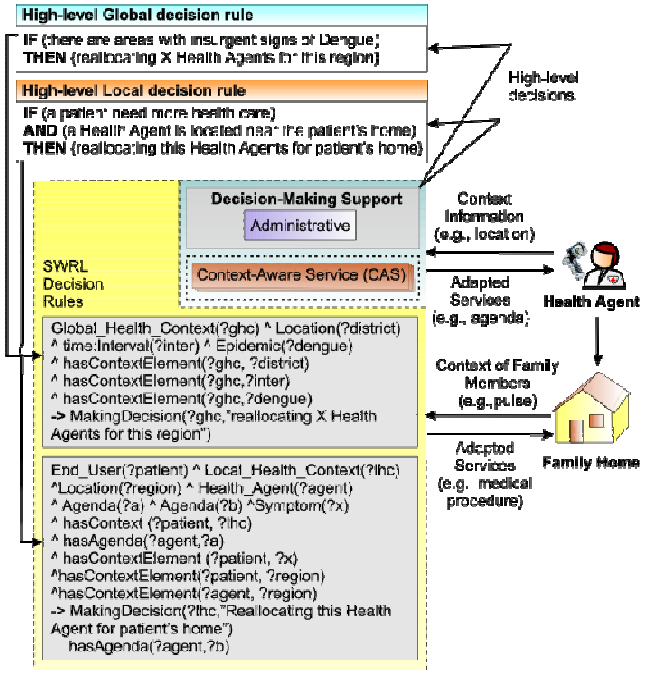

Figure 1. Case Study: Health Agent scheduling

3. SISA, THE LARIISA'S DENGUE APPLICATION

3.1 The SISA Components

SISA [12] is a LARIISA application that supports decision making and focuses on the idea of improving the quality of services provided by health workers in cases of fighting epidemiological crises, especially dengue. To meet the needs of the key players in the system architecture of the SISA is divided into three main modules (Figure 2):

- **Mobile Module**: This module is expected to be the interface used by health workers with the system. It allows, through the use of mobile devices (e.g. mobile phone, PDA, tablet, etc.), consultation schedule of visits to be conducted in the homes; receive notifications of urgency; and act as a context provider because it allows entering data observed in site visits;
- **DTV Module**: This module is a Context Provider used to capture information from families. An interactive application, linked to the campaigns against dengue is showed in [5]. This application enables the filling of information (epidemiological data) which will be used by the Web module;
- **WEB Module**: This module is an interface web for the SISA users.

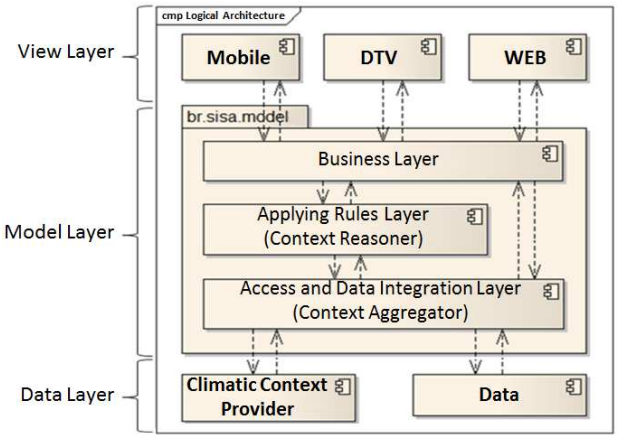

Figure 2. Logical Architecture SISA

The SISA technology uses through an interactive application that enables citizens to indicate symptoms of family members; these symptoms can characterize cases of suspected dengue. The data captured by the interactive application is sent to the remote module SISA, which will be aggregated, enriched with knowledge captured and saved in a database. In addition, these data will be exported following a semantic representation that is based on ontologies for application of inference rules associated.

The resulting decisions are forwarded to the levels of performance, being the primary Agent Community Health - ACH, since it maintains direct contact with the community. At the governance level of health, the SISA adds on an epidemiological map observed of the region suspected dengue. In case of a negative finding (i.e. after a visit from a health worker), the system removes the epidemiological map marking, and a positive case confirmed by the ACH, the system dials confirmation of dengue cases and their respective classification levels of care.

If there are many cases identified in a given region, the system is able to generate alerts decision-making to combat on-site (i.e. sending health workers to the site), for the acquisition of drugs, among other management operations (i.e. creation of an emergency unit to combat the epidemic).

3.2 Implementation Aspects

The **TV module** consists of an application of Interactive Digital TV, created in GINGA-NCL, which will be transmitted via data carousel, along with audio and video campaign to combat dengue

The **Web Module** uses current web development technologies: Java, Java Server Faces (JSF), Rich Faces, Jfree Chart, Entities, Hibernate / JPA, database PostGreSQL. To implement the inference engine was used with JBoss Drools rules written in the format DRL. Below is shown the business rule that assesses the climate context to aid decision making of "Citizen" in this context and based SISA can direct the agent to the nearest health site

The **Mobile Module** provides context responsible for data collection informed by health workers, this module has two basic components implemented with WAP and JAVA ME (JME). The access to WAP-based component occurs via HTTP, through the use of any mobile device (mobile phone, PDA, tablet etc.). The component JAVA ME is used to enable the receipt of notifications of urgency, it also depends on the Internet to facilitate the integration, via *Remote Method Invocation* (RMI), the web module. Below the Figure 3 and 4 illustrates the initial results of the respective modules.

Figure 3. TV module capturing context of citizen

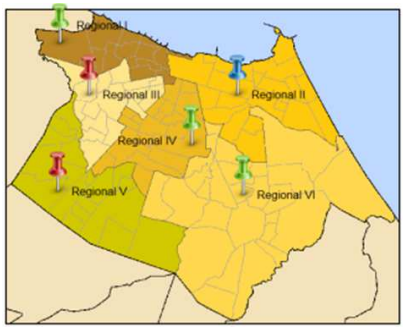

Figure 4. Web module displaying epidemiological map of Fortaleza / CE for managers

SISA uses DTV technology, through an interactive application that enables citizens to indicate symptoms of the members of your family that can characterize cases of suspected dengue. Considering the communication infrastructure of Digital Belt, the data captured by the interactive application is sent to the remote module of SISA, which will be aggregated, enriched and saved to a conventional database, and are exported following a semantic representation based on ontologies for the application of inference rules associated. The resulting decisions are then forwarded to the performance levels, and the Community Health Agent - ACH acts as the primary actor, since the health agent maintains direct contact with the community.

At the governance level of health, the SISA adds an epidemiological map of the region observed with suspected dengue identified. In case of a negative finding (e.g. after a visit from a health worker), the system draws the map marker and epidemiological in a positive case, this is confirmed by ACH, the system dials the case of confirmation dengue and its corresponding risk rating. If there are many cases identified in a given region, the system is able to generate alerts decision-making to combat on-site (e.g. sending health workers to the site), for the purchase of medicines, among other operations management (e.g. creation of an emergency unit to combat the epidemic).

The *Context of Global Health* describes the information at a high level, from local health context which is used for making decisions about health governance. The information in the context of the family is collected by the health agent, through the registration of the “Ficha A” in LISA-MCP. The data is sent by LISA to LARIISA, which evaluates a few parameters, like the number of occurrences of dengue fever, the geographical location and the period of study of dengue cases. Considering the information, LARIISA could, for example, advise concerned health managers to create emergency room in the region for the treatment of dengue. Figure 5 shows the decision-making process specified in both ECA (Event-Condition-Action) [21] and SWRL [22] rules.

Dengue fever outbreak decision-making process specified with the *ECA model*:

IF ((numberOfDengueRecurrenceCases(region Y, period Z) > X) THEN {Alert: to create an ER in the region Y}

The equivalent *SWRL Rule*:

Global_Health_Context(?ghc) ^ Location(?Y) ^ time:Interval(?Z)
^ hasContextElement(?ghc, ?Y)
^ hasContextElement(?ghc,?Z)
^ NumberOfRecurrenceCases(?W) ^ hasContextElement(?ghc,?W)
^ swrlb:greaterThan(?W,X)
MakingDecision(?ghc,”Alert: to create an ER in the region Y”)

Figure 5. Creation of Emergency Room for dengue control

4. RELATED WORK

Context-aware services have been developed based detection technologies and adaptation to the context, with the goal of improving the quality of health care public systems. While it is clear that there are solutions that propose the use of context-aware technologies to the health care system (e.g. Healthcare Systems)

[23][24][25], to our knowledge is still incipient existence of approaches to support decision-making context-aware to the governance of public health systems.

In [23], the authors present a Context-Aware Integrating System Services (CASIS) that allows building applications capable of high-level decision-making adaptation based on information collected by the system. In [25], the authors propose a system for context management based on ontologies (Context Management System - CMS), which enables you to define contextual terms of use in medical areas. In turn, in [24] the authors describe an architecture for context-aware health systems focused on the ability to monitor patients remotely. However, the prototype described in this article is based on semantic mechanisms of knowledge management and inference based on OWL-DL and SWRL rules, which seek to provide mechanisms to aid decision making at local and global levels.

The main difference of this prototype compared to existing work is that it considers specific requirements for decision-making context-aware systems in health governance. Furthermore, this prototype was specified using the model as a basis KTA [26] (see [5] the framework LARIISA), reducing the gap between the processes of creation / transfer of knowledge and actions of maintenance of public health. Another innovative aspect of this prototype compared to existing platforms is that its architecture is designed on the Brazilian Digital TV model [6] and middleware GINGA, with the communication infrastructure of the Digital Belt base [16].

5. CONCLUSION

We presented in this paper the LARIISA prototype, a pilot project in the state of Ceará (Brazil), whose purpose is to enable the intelligence governance in decision making in healthcare environments, subsidized by the information captured in the context of families. It uses the model of Brazilian Digital TV and Digital Belt Ceará State, serving as proof of concept to the field of epidemiological project LARIISA.

The prototype obtains context-aware information about the family health in order to provide support for decision makers. It can direct the health care worker to verify and troubleshoot an epidemiological problem or detect new outbreaks of dengue disease. So, the suggested environment attends the requirements needed for the interconnection of the context providers to the database of LARIISA and their subsequent use in the context of a system of decision-making in public health.

It is also designed to provide health managers with an intelligent governance framework that will support them in making decisions concerning the Basic Attention network from the Brazilian Unified Health System (SUS). The implemented prototype improves the “Ficha A” by adding information about geographic (e.g. GPS coordinates of dwellings) and social (e.g. photos of people and of relevant health conditions, etc) that can be of use to healthcare decision-makers. For that it uses simple devices for interfacing (DTV set top boxes and cell smartphone, etc.). The use of DTV technology, exploring the most of its features, such as ubiquity, maximizes its use aggregating new services to the society. The developments of context-aware applications are typically challenging and apply them to DTV technology becomes an even greater challenge.

The LARIISA prototype demonstrated its viability and relevance in combating dengue, and may contribute in national policies such as the National Plan to Combat Dengue (PNCD) [11]. Furthermore, we expect the use of SISA on a much larger scope for diseases like dengue, considering that the activities to combat dengue are similar to those used to combat other epidemics.

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