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Intelligent System for Medication Management in Residential Environments

Vandermi J. Silva*. Cláudio. E.M. Gomes*. Suellen. S. Santana*. Vicente F. De Lucena, Jr.*

*Universidade Federal do Amazonas, Amazonas
Brazil (Tel:55-92-3305-1489; e-mail: vandermi@ufam.edu.br, claudioeddy@gmail.com, suellen.eng@gmail.com vicente@ufam.edu.br).

Abstract: This paper presents an intelligent system capable of managing prescriptions and schedules of medications taken in a residential environment. The system has an intelligent medicine cabinet that stores drugs, RFID access cards, prescriptions and all information about the medication. A software architecture that integrates multiple devices, such as tablets, smartphone and Smart TV to be used as interfaces for the patient to interact with schedule making of prescription drugs, reminders for health staff and patients and for real-time adherence monitoring**.**

Keywords: Medication management, medication adherence, intelligent systems, healthcare.

1. INTRODUCTION

One of the biggest problems of medication adherence occurs in elderly patient during treatment. These Patients typically fail to take medication or delayed due to the difficulty of prescription reading or forgetting their scheduled times, (Alexa et al. 2013). However, we believe these problems can be solved with the use of sensor technologies, information-based activities and decision support systems.

Clinical Decision Support Systems (CDSS) is a tool that helps doctors make better decisions. There are many systems which are used for diagnosing diseases. For different types of diseases CDSS uses different algorithmic approaches (K. R. Ravindranath, 2015).

Context-aware systems are systems able to adapt its operations to the current context without user intervention, to increase usability and efficiency considering the environment information, user activity and user location, (Abowd et al. 1997). Context data in healthcare applications is an interesting case study and needs to be studied further, especially where the systems are constantly changing, for example, those involving the concept of Ambient Intelligence AmI and ubiquitous computing.

AmI is an emerging discipline that promises to bring intelligence to everyday environments. It is based on advances in sensor networks, pervasive computing, ubiquitous and artificial intelligence. The technologies resulting from this paradigm promise to revolutionize the way the user interacts with the environment and adapt to it, (Diane et al. 2009).

In the present scenario, the concept of connected things is in full development and many devices are on the market that can be used to directly interact with the World Wide Web. One of these technologies is the Internet of Things (IoT) that facilitates the exchange of data and services between connected devices and proposes an infrastructure of Information Technology (IT) in which objects exchange information on the network in a secure and easy way, (Rolf and Romana 2010). These technological environments allow any electronic device that has an IP address can connect to the Web directly.

It is possible that the connected environments, using the current network technologies for access to public services, such as, medical schedule, medication warnings automatic messages to social networks about taking medicines and text messages (SMS) to allow improve and monitoring medication adherence.

This paper presents a system based on context information to monitor the taking of medicines by collecting sensor data from an intelligent medicine cabinet and patient's activity at home. This study aimed was to improve medication adherence and follow the patient treatment evolution, through electronic prescription data evaluation as a starting point. A residential gateway provides this information to diverse devices such as, smart TV, smartphone and other consumer electronics connected to the residence.

2. PROPOSED ARCHITECTURE

To facilitate the development of the system It was built a scenario in which an intelligent environment communicates with a doctor's office. These technology networks and web services allow a residential gateway receives the data via internet of an electronic prescription system to manage the taking of medicines. In this case, the gateway processes the data and provides the medicine cabinet, smartphone, TV and other devices, prescriptions schedule for taking the medicines, electronic reminders and a web-based return channel, for data exchange between the doctor's office and the patient residence. This scenario helped in visualization and implementation of the system architecture of the modules presented in the next session.

The architecture shown in Fig. 1 is designed to integrate a variety of sensors, mobile devices and appliances. The architecture has four modules that allow them to collect and analyze data from sensors and devices, for example, the patient's interactions with medicine cabinet, smartphone, TVs and tablets, allowing a subsystem based on policies and rules make decisions using the information processed.

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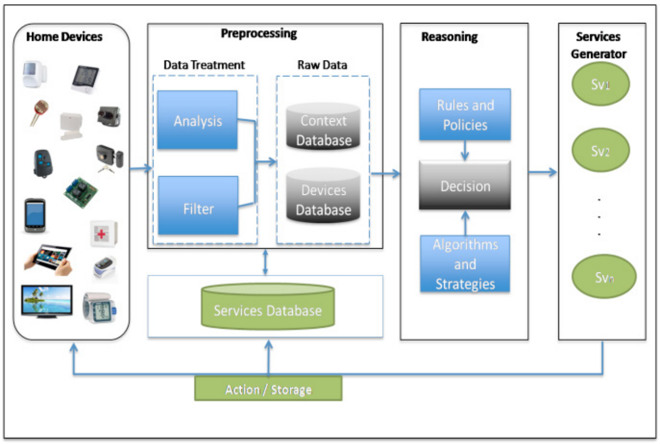

Fig.1. Proposed Architecture for the system development presented in modules.

2.1 Home Devices Module

The Home Devices Module is composed of several sensors represented by cameras, motion sensors, light sensor, door sensor, temperature sensor, and home devices such as computers, tablets, TV, phone and intelligent cabinet, which have the task of collecting environmental data and user.

Sensor data samples that can be collected in the environment are entry and exit of a user through a door opening sensor and a micro camera. This data are captured and stored in the database.

The medicine cabinet has embedded sensors and actuators themselves, it is considered in the system as a residential device such as TV and other appliances. Examples of data collected from the medicine cabinet are medical prescriptions and alarms made available by it. After collecting data from sensors and devices, they are analyzed and filtered to build the contextual databases and devices.

2.2 Preprocessing Module

The preprocessing module has two sub-modules which are analysis and filters responsible for checking the raw data received from sensors and devices and separate them into data context and data devices. The context base is composed respectively by user activity and by data acquired by sensors. This data is collected through the smartphone, tablet or TV and processed by the residential gateway.

The device database stores the information of the living environment through sensors, such as motion sensors, door opening sensors and windows, ambient temperature and cameras, location information in addition to the result of the built-in facial recognition in intelligent medicine cabinet. The service database stores messages, services, alerts, return channel and any other service provided to the patient through the gateway.

2.3 Reasoning Module

This module is the system intelligence and is divided into three subsystems Rules/Policies, Algorithms/Strategies and Decision.

Rules and policies subsystem are responsible for helping the Decision System, for example incompatibilities with active ingredients, allergies, medicine validity and recall.

Strategies contains inferences and algorithms to help the decision subsystem to compose the attributes.

Decision subsystem uses decision tree algorithms and chaining rules to select the best attributes to build services on Services Generator Module.

The algorithm chosen for the experiments using the concept of entropy to measure the gain information and determining which attributes are more likely to be used in the classifier. Equation (1) shows the overall calculation of entropy given by the sum of the probabilities of attributes.

$$H(A) = -\sum_i p_i * log_2 p_i \qquad (1)$$

Assuming that the probability of observing each value is $p_1, p_2, \ldots, p_n$ whose domain is $(a_1, a_2, \ldots, a_n)$, the entropy is calculated in order to use to enhance the best attributes information gain and consequently avoid memory and processing waste in the treatment of a great mass of data, in addition to reducing noise in the base.

2.4 Services Module

The Service Generate Module is the layer responsible for the composition of new services based on device data and the context, for example, the evaluation of decision tree algorithms can identify whether the patient took the medicine, if he has taken, if he has not taken or if he has taken it late. This data can be transferred to a physician through a recommendation system or electronic messages available in the cloud.

The result of processing in the reason module is the services provided in the generation service module. They may be a short message to the healthcare team, or to a caregiver, or a return channel to the doctor with visual feedback provided on the Web about the adherence status of the prescribed medication.

An example of a warning message is displayed in Fig. 2. All tags are extracted from the document data users and data collected from devices and sensors. After the presentation of the services in the service layer, they are stored in the service base for future use, no need to be processed again.


```
<?xml version="1.0" encoding="UTF-8"?>
        <prescription_message>
                <message_data>
                        <patient>Suellen</patient>
                        <doctor_phone>+5592992547005</doctor_phone>
                        <medicine>Dipirona</medicine>
                        <dosage>01 comprimido</dosage>
                        <taken_data>03/05/2016</taken_data>
                        <taken_time>20:45</taken_data>
                        <local>home</local>
                        <status>OK</status>
                <message_data>
        </prescription_message>
```


Fig. 2. Content of a messaging service based on data collected from the system.