Integrated Model AmI-IoT-DA for Care of Elderly People

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Abstract. Elderly people suffer physical and mental deterioration, which prevent and limit them to control household chores; they loss their independence and autonomy, affecting their quality of life and well-being. In this paper an AmI IoT integrated layered model is introduced. The proposed model combines functionalities of Internet of Things (IoT), Ambient Intelligence (AmI) and Data Analytics (DA), to provide a reference for the monitoring and assistance of elderly people. The model proposes four segments responsible for automating housing, supervising the user, taking reactive actions, supervise events, identify habits, and access to AmI and IoT services and Data Analytics.

Keywords: Internet of Things · Ambient intelligence · Data analytics
Elderly care

1 Introduction

This paper presents a layered model Quysqua for integrating the reference models IoT, AmI and Data Analytics. The model has been designed to be applied in tele-care applications. The reference case used for its validation is the care of elderly people.

A problem that emphasizes our days is the way of life of a person in his home, because due to their natural condition of the process of aging, begins to manifest symptoms of deterioration that affect his quality of life. The main difficulties that elderly people present are: the decrease in physical capacity, cognitive capacity, physiological capacity, loss of their senses among others [1]. Reason why organizations such as "the convention on rights of persons with disabilities" mentions in their agreements that older adults can only carry out simple tasks [2]. Therefore, they want someone in the home to take care of them and help them in whatever they need, but this in reality is not easily fulfilled by the families. This a very relevant problem since, in 2020, it is estimated that, for every 100 adolescents under 15 years, there will be 50 people over 60 years old. In addition, the WHO [3] announces an expectation of life of 75 to 80 years, so it is understood that there will be more elderly people living alone in their home.

Persons of advanced age as well as being alone and sick must assume displacement costs, face traffic problems, insecurity and the risk of contagion of diseases [4], having to attend congested hospital centers for routine checkups and treatments of their diseases. Depending on the degree of severity of the disease, it can be treated on an outpatient

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basis and remote at home [5]. And thus benefit the health of patients, contributing to the management of hospital centers and allowing better use of doctors' time [6].

In order to solve this problem, several useful approximations have been made. different technologies designed for home care such as: sensor networks wireless networks [7], remote monitoring at home via cell phones [8], augmented reality using mobile devices [9], collection of biomedical signal analysis [10], and remote medical devices [11]. Some of these technologies support parametric and remote management [12], satellite communication [13], integration with geographic information systems [14]. Another way that supports the well-being of the elderly is the approach proposed by Hassanalieragh [15] that defines the opportunities and challenges in a solution for monitoring health conditions by implementing Internet of the Things (IoT) as impact technology. Zamora [16] proposes DOMOSEC, which is a given solution for home automation and that could be used for monitoring people, using commercial devices. Mileo [17] raises the use of wireless sensor networks (WSN) in which it supports a system of "Smart House" for the care of the elderly people. Dogali [18] proposes an architecture for tele-care that monitors vital signs such as Electroencephalogram (EEG) and Electrocardiogram (ECG) in real time for timely care of medical applications in patients of the third age. Silva [19] produced Unimeds, a system that relies on ambient intelligence to supply and control of medicines to people who are assisted at home. To guarantee the care of the vulnerable older adult, support systems and methodologies for remote health care in patients have been developed [20], and also systems of transmission, consolidation and signal processing biomedical [21], support systems for medical decision making [22], and systems for generation of alerts [23] had been proposed.

The main objective of this article is centered on the development of a model that integrates some of the models already mentioned. This integration is divided into two dimensions. The first dimension focuses not only on the care and well-being of elderly people, but also on supporting sick older adults who need medical care at home. The second dimension is focused in the computer field, integrating in a common framework different components from the hardware layer until tools for analytics.

This article is organized in three sections as follows: in the first section the general description of the proposed model is introduced, in the second section includes the validation tests and the analysis of the obtained results, in the final section some conclusions and future work are presented.

2 General Description

The Quysqua model is organized in four large stack segments: IoT segment (Internet of Things), AmI segment (ambient intelligence), DA segment (Data Analytics) and ApS segment (Application Segment). Each segment groups functionalities encapsulated in layers, components and sub- components, as shown in Fig. 1.

This model aims to be a reference complete model; although, in its implementation not is mandatory to include all the segments, layers, components and subcomponents. In practice, depending on the specific application, only the required elements have to be developed. In the work presented in this paper, the reference case of care of elderly

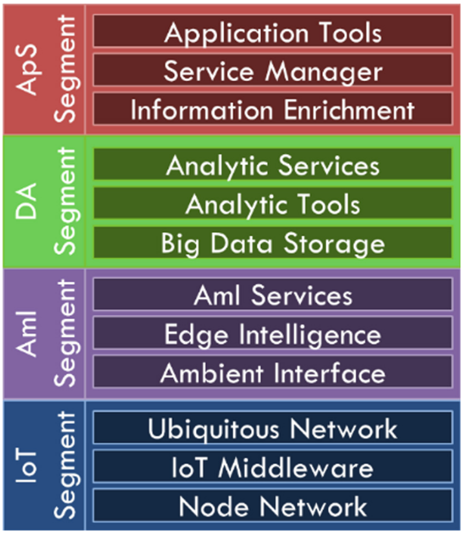

Fig. 1. General scheme of the Quysqua model.

people was used as a basis to create and validate the model; however, most of the elements are general and could be also applicable for other type of contexts.

In the IoT segment, the layers are responsible for the configuration of node networks (sensors and actuators), the integration of heterogeneous low level communication technologies, and basic data management (homogenize, transform and validate) collected from sensors and sent to actuators, seen as ubiquitous services. In this segment, the home automation is done, creating networks of specific nodes to supervise and control the house, and to monitor user state and behavior. Thus, providing one platform that is responsible for the integration and communication with physical devices of the house and the user.

The layers of the AmI segment are responsible for data consumption supplied by the IoT segment, application of edge intelligence for reactive decision-making, and providing services for sending and receiving messages at the AmI communication interface. In this segment, the interpretation of the of the ambient and the user behavior using the information produced by the sensors is performed. Important situations are detected yielding to the generation of events. This events can produce immediate actions on the environment, but also can sent messages to the higher segments alerting about the detected situation.

The objective of the DA segment is to perform long term and more exhaustive analysis of the data recovered from the lower segments. The results generated by this layer can be accessible to the users as support information to take high level decisions. The DA segment is composed of three layers. The lower layer is devoted to the storage, cleaning and organization of the data. The second layer incorporates a set of different tools to perform data analytics, most of them based on machine learning techniques. The higher layer includes a service interface that is used to access to the services delivered by the segments from the higher application layer.

Finally, the segment ApS is in charge of providing a set of services for enriching the information and presentation by using adaptation techniques, allowing personalization and context awareness, and also tools for visualization and presentation of information to the users. The service manager layer is in charge of controlling session creation and assuring correct control access to the services used by the application in all the layers of the system. The last and higher layer includes a set of tools to make easier the development of applications. A more detailed description of components included in each layer of the Quysqua model is out of the scope of this paper.

3 Validation and Analysis of Results

In order to validate that the Quysqua model is coherent and that it can be applied to solve the problem of the care of elderly people that was introduced in Sect. 1, four types of tests were designed and applied.

3.1 Validation of the Reference Case

The Quysqua model is applied in a physical dimension, attending to the care of the rhythm cardiac disease of a person. The idea is analyzing how each layer of the model could contribute to deal with this situation in a coherent and useful way.

The reference case of the heart rhythm starts at the low level in the IoT segment by connecting wereable sensors to measure the patient's heart rate through signals such as systolic blood pressure and oxygen saturation. This information is available using the component that publishes the data produced from these sensors; the layer not only manages the connections to the nodes that provide the data but also monitors their proper operation and also makes low level validations regarding the correctness/coherence of the data. Once the AmI segment obtains the sensors information from the ubiquitous layer, the edge intelligence layer according to reactive rules can for instance informs the elderly person that he should take his medications every day at 5 pm. This layer can also analyse the body signals to detect if there is any thing out of the normal margins, when an anomaly is detected immediate actions can be taken, for instance activate an alarm to sound at home or remind the person to take a medication. In this case, the AmI Services layer sends the information to the upper layers that had subscribed to get it, for instance, sending it to be included in the data analytics storage, or even directly creating an external notification that can be sent to the doctor or emergency services through the ApS segment. In the DA segment, a long term analysis can detect and diagnose a variation or anomaly in the condition of the person, and even compare this result to what is happening with other persons; this kind of high level information can be used by the doctor to decide for instance that the patient should take the medication in different schedule. The access to this information by users as the doctor is done for instance through a web application, using the services of the ApS segment; the doctor can take the decision about what will be the new time frequency with which the older adult should take the medicine and also introduce it in the system to modify the rules that fire actions at the AmI segment.

Other different cases relative to the care of an elderly and/or sick person have been analysed. The cases not only include physical care situations, but also emotional support requirements, as the need of a person to have communication with his relatives. Similar results are obtained showing that the services of each segment, layer and component are coherent and useful to support the well being of the persons in the reference case.

3.2 Validation in Relation to Well-Known Models of Data Analytics

To prove that the Quysqua Model meets the minimum functionalities required to achieve a good level of data analytics, three papers presenting well-known models of data analytics were chosen and compared to the proposed model. The purpose of this test is to demonstrate that the model covers the most important functionalities proposed by the other analyzed ones.

The selected works to be compared with were chosen under the criteria of having relation with the specific reference case, assisting a mature adult at home; but also of including the implementation of data analytics techniques and using algorithms for the implementation of data analytics. Table 1 shows a description of the models that were used in the comparison.

Table 1. Description of already recognized data analytics models.

Model	Description
Oracle - 2017, Oracle Advanced Analytics' Machine Learning Algorithms sql Functions [24]	Oracle proposes techniques and algorithms that should be used to contemplate an application of data analytics that has its sources in the large amount of information provided by the Internet of the things
CISCO - 2016, reference model IoT/edge computing [25]	Cisco proposes a decentralized reference model focused on Fog computing. The main idea is that the data, the computation, the processing, and storage are distributed between the cloud and a low level fog layer close to the origin of the data, which process the data and store it in the devices of the network that are closest to the user (fog nodes), without needing do it all in the cloud high level
NIST - 2017, Big Data Reference Architecture NBDRA [26]	NIST (National Institute of Standards and Technology of the USA) proposes a Big Data reference architecture called NBDRA. It provides a framework for admitting a variety of business environments industries, including tightly integrated business systems, improving the understanding of how big data complements and differentiates integrating data analysis, business intelligence, databases and existing systems

As a result of this test, it was found that the Quysqua model, encompasses most of the functionalities defined in the prototypes that were compared, below, the final results of the analysis of each model are presented.

- ORACLE: to comply with all the techniques and algorithms proposed by the model Oracle, the Quysqua model has the DA segment and more specifically the Analytic Tools component. Where you incorporate the different techniques (classification, regression, detection of anomalies, importance of attributes, character extraction, associative rules and clustering) and their implementation algorithms.
- CISCO: The Quysqua model complies with all the functionalities of the model of CISCO reference, which are included in the AmI segment. Inside the Edge Intelligence layer are define the mechanisms of analysis, decision making, prediction of events and interaction with the user, providing tools for direct supervision and control of environment.
- NIST: to comply with all the functionalities of the reference architecture NBDRA, the Quysqua model has the DA segments, which has the Big Data Storage, Analytic Tools and Analytic Services. In addition, functions as data visualization is included in the segment ApS within the Application Tools layer.

3.3 Evaluation Test Using a TAM Acceptance Model

An evaluation test of acceptance was carried out in order to prove that the Quysqua model is coherent, complete, modular, relevant and applicable. The proposed model was presented to 5 experts in the areas of data analytics and internet of things. The experts did a model acceptance survey, which was build inspired by TAM methodology. The goal was to measure if the model complies with the requirements of the reference case using IoT, AmI and DA technologies.

The model was evaluated using 6 criteria, with a set of 23 questions. Each question was evaluated on a scale of 1 to 5 (1 totally disagree, 2 disagree, 3 neither agree nor disagree, 4 agree and 5 totally agree). The detailed results of this third validation test are shown in the Table 2.

As can be seen, the evaluation based on experts of the Quysqua Model was positive, most of the valuations are high. The experts made several recommendations from their perspective of experience (industry or academic) in data analytics and internet of

Table 2. Results of the TAM evaluation.

Evaluators criteria	Ev. 1	Ev. 2	Ev. 3	Ev. 4	Ev. 5	Average judgment
Coherence	4.6	4.6	4.3	4.4	4.2	4.42
Modularity	4.5	4.5	3.5	4	4	4
Applicability	4	4.6	4	4.5	4.5	4.32
Completeness	4.3	4	4	4.8	3.6	4.14
Relevance	4.6	4.6	4.3	3.2	4.6	4.26
Compatibility	4.5	4.5	5	4	3.3	4.26
Average evaluator	4.41	4.46	4.18	4.15	4.03	

things. These recommendations will be taken into account in future works to the improve the quality of the proposed model. The most relevant recommendations are:

- For the care of older adults, a very careful use of reactive rules and deliberative rules is mandatory. Safe guard mechanisms should be included to prevent negative effects on the health of the user. The idea of detecting trends and habits is very good, but deeper validation should be done in real field of a hospital under the supervision of medical personnel.
- Ratings below 4, of the criteria of modularity, relevance and compatibility were investigated with the experts. They consider that the model is structured conceptually very well, but they expect more evidence of practical application in the hospital and real-world situations.
- The low qualification in the criterion of modularity occurred because the evaluators expected a complete functional prototype where they would be able to use more techniques and analytics tools.

3.4 Multi-agent System Prototype

A multi-agent systems (MAS) model was designed in order to build the software prototype allowing to evaluate the practical application of the Quysqua model. A partial implementation including some relevant cases of the reference problem was constructed.

To carry out the design of the multi-agent system, the AOPOA methodology [27] was used. First, external actors are identified that become the basis of the analysis of the environment where the system operates. Then an analysis and decomposition of the goals of the system, based on the requirements of the elderly people previously described in this paper, was carried out. Next, the roles and interactions were defined to obtain the architecture of the MAS. Finally, a detailed model of the agents that integrate the defined roles was designed; this model includes the description of the behavior that should have the agent in response to the possible incoming events identified in the interaction model and also determines if any special intelligent mechanism is required to take decisions.

Figure 2 shows the interaction diagram of the designed multi agent system. This diagram is organized according to the segments and layers of the model Quysqua (Fig. 1).

In the figure, the ovals represent the agents, the white arrows interactions, the text on the white arrows indicate the interaction protocols used (request/response and publish/subscribe), and the yellow triangles the adapters to support components (physical sensors/actuators, databases and user interface devices). Table 3 briefly describes the functionalities of each agent.

For the implementation of the IoT segment, there were 2 data sources. The first is a postgress database that was build with real data in a previous DA project; it contains information of biomedical signals from elderly patients of the hospital San Ignacio who received medical care at home for more than 6 months. The second is the data, including different physical and affective variables, generated by the simulator developed in the master's thesis of Agreda [28], which reproduce the typical behavior and

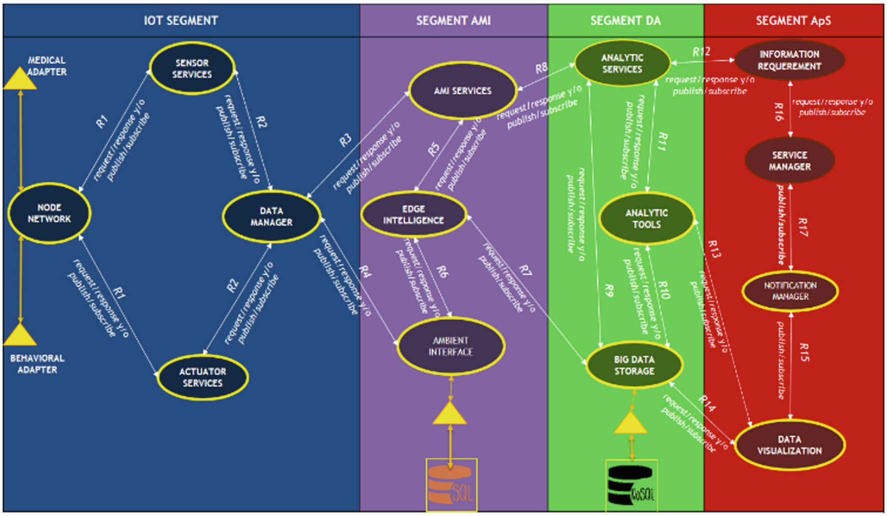

Fig. 2. Multi-agent systems model (SMA).

Table 3. Results of the TAM evaluation.

Agent	Descriptión
Node network	Interacts with the environment both in the reception and acting through the adapters
Sensor service	Sensor handler to manage data reading, in synchronous sensors for which reading is requested
Actuator service	Converts into signals the signals of each one of the sensors or actuators that have in charge
Data manager	Receives messages from sensors and actuators and perform a process of homogenization and transformation of data to generate messages that include cleaned data
Edge intelligence	Makes decisions about the environment and the user, the generation of knowledge AmI services and interaction with the user and a first level of data analytics
AmI service	Sends the actions towards the IoT segment and notifications to agents of DA segment of Aps
Ambient interface	Stores reactive rules and data in the database associated to the AmI segment
Analytic services	Generates the DA segment notifications to the AmI segment and the ApS segment
Analytic tools	Performs the modeling of user habits, create suggestion rules and interpretation of results executed by the Analytical Events Supervisor
Big data storage	Stores the deliberative rules and data in the database associated to the DA segment
Notification manager	Gets the notifications from the different agents and generates messages to external users or entities
Data visualization	Manages a presentation layer through a GUI graphical interface so that user can accesses the information using graphics and tables
Service manager	Provides security to the multi agent system through an access control service
Informatión requirement	Performs tasks related to the adaptation of information and contents of the messages received from the AmI or DA segments

the environment of an older adult who lives alone. A web application with JavaEE-JSF technology, which implements the EclipseLink library JPA2.1 was developed in order to handle persistence to a PostgreSQL database. A SOAP WebService was created for the publication of sensor data. And also a middelware was constructed to collect data from the agents of the simulator subsystem, as well for the data collected by wearable devices.

For the implementation of the AmI segment, 3 important agents had to be built; one for the edge intelligence management, one that handles the reactive rules and AmI notifications, and another that manages the persistence in the database. The prototype developed by Agreda was modified and complemented to provide the information required in the cases of the reference problem. The implementation was made by developing a standalone application with Java- SE, which implements the libraries: the BESA3 agent framework [29] and the library Jfuzzy for the management of fuzzy logic in the edge intelligence agent. MySQL-JDBC was used to handle the communication with a MySQL database associated to the ambient agent interface. A SOAP WebService client connector was to create for the agent in charge of notifications in order to consume the services offered by the IoT segment.

A functionality that uses a DB Scan algorithm was built to demonstrate a case of the implementation of the DA segment services. This clustering technique is used to detect anomalies in the behavior and habits of an elderly person. In the visualization service the segments generated by the algorithm are marked and labeled with different colors for each detected habit. For greater ease in the analysis, the detail of the alerts is presented in the lower part of the user screen. This functionality allows the specialist to filter information for each of the monitored patients, and to make combinations of signals for the more complex analyzes. The implemented system also includes the development of a web application with JavaEE-JSF technology, which implements the EclipseLink JPA2.1 library to manage the persistence to a MySQL database associated to the DA segment data and notifications. The data produced by the AmI segment is consumed through of a SOAP WebService client.

For the implementation of the ApS segment, the free software chart of Primefaces and JFreeChart was used for the visualization of the data. These bookstores offer data visualization functionalities that can facilitate the monitoring of patients and the process of making decisions, through line graphs that represent the behavior or trend of a given signal, combined graphs to represent trends between minimum and maximum values, and point clouds to identify the trends detected by DB Scan algorithm.

4 Conclusions and Future Work

The model resulting from the integration process was a broad and robust model, which covers the components and functionalities of AmI, IoT and data analytics. The model was designed to be flexible and modular.

The Quysqua Model, proposes a reference model that can be applied to the case reference, which focuses on the care and welfare of an elderly person living alone in a housing unit with an automated environment. The implementations of this model would have defined an architect base, to which only the rules of environmental intelligence should be configured to guarantee the care and welfare.

In the process of evaluating the proposed model, a methodology was proposed that it consists in carrying out four tests that demonstrated that the model is complete and applicable in telecare. The more detailed and practical test was the development of a functional and partial prototype of the proposed model. This prototype was used to verify that the model can be implemented for the reference case.

It can be concluded that all topics related to data analytics oriented towards adult health care constitute a growing theme. HE observes a strong tendency towards the creation of global DA architectures and givings by which all the assistance services can be provided to any type of health condition. The correct operation of the implemented system using previously stored real data and a simulated environment demonstrates the feasibility of the proposed model as it includes its main components. In the near future, a more complete implementation must be constructed in order to operate in a real environment.

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