A Quality of Context Evaluating Approach in an Ambient Assisted Living e-Health System

Débora Cabral Nazário[1,2], José Leomar Todesco[1], Mário Antônio Ribeiro Dantas[3], Igor Tromel[3], Augusto Neto[4]
[1]Department of Knowledge Engineering, Federal University of Santa Catarina, Brazil
[2]Department of Computer Science, Santa Catarina State University, Brazil
[3]Department of Informatics and Statistics, Federal University of Santa Catarina, Brazil
[4]Department of Informatics and Applied Mathematics, Federal University of Rio Grande do Norte, Brazil
debora.nazario@udesc.br, tite@egc.ufsc.br, mario.dantas@ufsc.br, igorvbt@grad.ufsc.br, augusto@dimap.ufrn.br

Abstract— **This paper provides an approach to evaluating Quality of Context (QoC) parameters in a ubiquitous Ambient Assisted Living (AAL) environment. Lack of quality can lead assisted systems to respond inappropriately, resulting in errors related to assistance or support, or putting the user at risk. QoC assessments can improve these systems and set them to perform specific actions whenever lapses in quality occur. Initially, the study presents a literature review of QoC, then it introduces the context management architecture used. The proposal is verified with the Siafu simulator in an AAL scenario where the user's health is monitored with information about blood pressure, heart rate and body temperature. Considering some parameters, the proposed QoC assessment allows verifying the extent to which the context information is up-to-date, valid, accurate, complete and significant. The implementation of this proposal might mean a big social impact and a technological innovation applied to AAL, at the disposal and support of a significant number of individuals such as elderly or sick people, and with a more precise technology.**

Index Terms— **Context, Quality of Context, Ambient Assisted Living, Ubiquitous Computing, Health.**

I. Introduction

Ubiquitous computing has increasingly been part of people's daily activities through the use of mobile and portable devices. These devices have diverse features and interfaces such as GPS (Global Positioning System), radio and TV, audio players, digital cameras etc. This type of computing has strong links with the characteristics of the physical world and its users' profiles [1].

Such information is called context, and represents the input element for context-aware computing. Context is any information that can be used to characterize the situation of entities such as person, place or object that is considered relevant to the interaction between a user and an application [2].

According to [3], context has four dimensions: computational context refers to the technical aspects related to capacities and computing resources; physical context is accessed by sensors with features encompassing, for example, location, traffic condition, speed, temperature, lighting, etc.; time context captures information such as time of a day, week, month, season, year, etc.; user context is related to the social dimension of the user, such as the user's profile, people nearby, current social situation, preferences, health.

A system can thus use such significant context information and then provide more optimized and personalized services, increasing user satisfaction. Through the use of context, it is also possible to minimize the consumption of resources such as energy, processing and communication, providing more accurate and dynamic services [1].

In ubiquitous environments, one of the many important factors is the context-aware. But the context information may not be reliable or useful, becoming a problem in terms of quality of the context information. Consequently, an important point about the context-aware is that the context information must be reliable; quality must be ensured [4].

Quality of Context (QoC) is any information that describes the quality of information that is used as context information. So QoC refers to the information itself, not the process or the hardware component that provides the information [5]. QoC does not require perfect context information with the highest possible accuracy and up-to-dateness, but it needs a correct estimation of the data quality [6].

This study initially conducts a review of the literature concerning QoC, and then demonstrates the use of QoC in an Ambient Assisted Living (AAL) environment, evaluating some QoC parameters.

Assisted Living is the term given to the provision of care to people either in their own homes or in supported housing, underpinned by technology. The provision of care, augmented by assisted living technologies, is growing because of the increasing demand and also due to the maturing of many of the underlying technologies that make assisted living possible [7].

The paper is organized as follows: Section 2 presents a literature review of QoC. Section 3 describes the context management architecture adopted and presents the Ambient Assisted Living scenario selected. Section 4 presents the case study implemented and the results. Section 5 describes the further research, section 6 mentions some related works, and section 7 presents our conclusions. Finally, the references used are listed.

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II. Quality of Context

At the outset, this study realized a literature review of Quality of Context. Data were collected from the databases *Web of Science*, *Scopus* and *Google Scholar* resulting in the selection of 108 papers. Subsequently, the papers were classified in categories or topics, generating a taxonomy. The highlighted topics in this QoC taxonomy were [8]:

- Definitions and proposals of QoC parameters;
- Alternatives for quantification of QoC parameters;
- Context representation models with QoC;
- Other topics (resolution of conflicts and inconsistencies, some aspects related to security, distribution of context data, agent and multi-agent approaches);

Application of QoC to a scenario (intelligent environments, health care, disaster);

The proposed QoC assessment will be made through the quantification of some QoC parameters. Many parameters have been proposed and defined in the literature. Based on the study of these parameters, the following parameters are used:

Coverage: defines the set of all possible values for a context attribute [2];

Up-to-dateness: indicates how old the context information is by using a timestamp [5].

Precision: describes exactly how the context information provided reflects reality [5];

Completeness: is the extent to which the context information is available, sufficient and not absent [4];

Significance: indicates the importance of the context information, its value is particularly important in life-threatening situations for humans [9];

III. Context Management Architecture and The AAL Scenario

QoC can be used to improve context management, assisting in decision making as regards its applications. The context management architecture is presented in Figure 1.

The bottom layer shows the context providers, which may be room sensors such as temperature, light; health monitoring sensors such as heart rate, blood pressure; mobile device sensors such as location, time, and preferences; or actuators that can be used in intelligent automation.

The middle layer shows the context processing, where acquisition of context information, processing and distribution of such information will take place. In order to follow these steps, some modules will be used:

1. *Context Collector*: collects the context data from the sensors;
2. *QoC Quantifier*: performs the quantification (calculations) of QoC parameters and QoC overall value considering the context, for instance space, time, user, etc.;
3. *QoC Evaluator*: verifies the QoC associated with the context information by means of ontologies;
4. *Security Policy*: checks the security policies adopted for the distribution of context knowledge and QoC among context consumers.

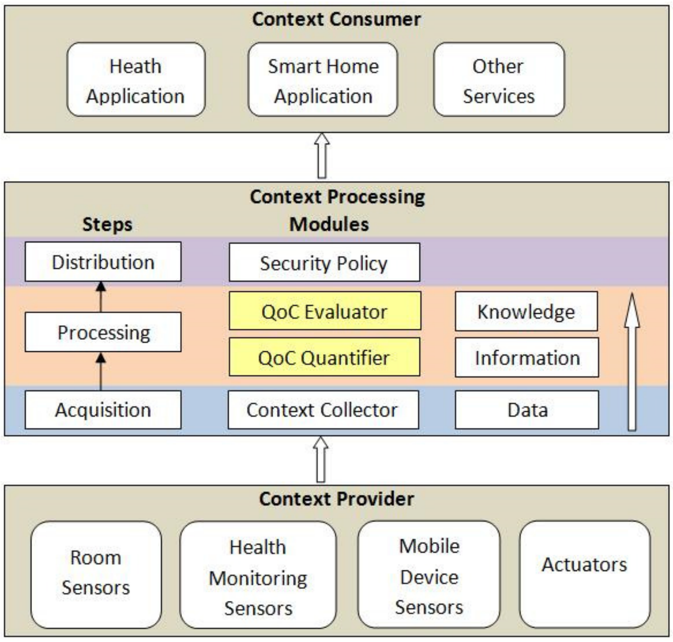

Figure 1. Context Management Architecture

It is in the middle layer that the QoC assessment will be made, comprising the modules *QoC Quantifier* and *QoC Evaluator*. For the case study investigated here, details of the QoC Quantifier module will be provided.

Still in this layer, data is converted into information and then into knowledge. The context collector obtains data (values that have no meaning when isolated). The QoC Quantifier both makes the necessary calculations, as well as develops, relationships with the context involved, hence the information is generated. The Evaluator, in turn, assesses the QoC through inferences in the ontology(s), so this module deals with context knowledge.

Finally, the top layer displays context knowledge and QoC consumers, such as healthcare applications, home or intelligent environments, in addition to other services where the context is considered.

Among many possible scenarios for applying the model, these can be cited: leisure, tourism, traffic, industry, commerce, health, entertainment, smart environments, disasters, and others.

Since the proposed study focuses on the context processing layer, it could be understood that this applies to any type of scenario previously mentioned. For the purpose of verifying this proposal, an Ambient Assisted Living (AAL) scenario was selected.

The proposed AAL scenario is a house consisting of a kitchen, a laundry, a bathroom, a TV room, a bedroom and a studio/office.

An old person (henceforth referred to as resident) occupies the house. The resident takes daily medication for health control. Some of his/her daily activities are: Waking up around 8:00 a.m.; Having breakfast; Walking the dogs; Taking medicines; Doing health monitoring (blood pressure, heart rate, body temperature); Having lunch at home or at a nearby restaurant; Doing some housework and handicraft; Reading; Having dinner; Watching TV; Using the bathroom; Sleeping.

The simulation used sensors of blood pressure, heart rate and body temperature, with emphasis on health monitoring sensors.

IV. Case Study and Results

This study used the context simulator Siafu [10] to simulate both context provider and context processing. This simulator was chosen because it allows the creation of new scenarios, obtaining context information as needed, and it enables inclusion of QoC assessment during simulation.

A. Siafu Simulator

This case study used Siafu – an open-source context simulator developed in Java language at the *NEC European Research Lab* [10]. This simulator is aimed at generating context information in a given scenario. Some of the scenarios developed are available for simulations, for instance: some cities, a university and an office. In addition to graphic visualization and simulation of the context information, the data output is via listener or CSV file.

This tool enables the development of new scenarios in three steps. The first step is defining the environment, the second step is programming the behavior, and the third step is bundling the data [11].

After these steps, the simulation can be performed in the application Siafu, allowing real-time visualization of the agents. It is possible to change the agents' behavior at runtime, or change runtime.

B. Context Provider

A graphic scenario was created with Siafu, with an agent representing the resident. The simulated sensors are those related to the monitoring of the resident's health: blood pressure, heart rate and body temperature, in the bottom layer of the proposed architecture: *Context Provider*.

C. Context Processing

The first step of the context processing is data acquisition. The data is obtained from the sensors through a context collector module implemented in the simulation.

Subsequently, the QoC quantification is done using the *QoC Quantifier* module, as described:

D. QoC Quantifier

At this point, an algorithm will quantify the QoC parameters through the *QoC Quantifier* module. All parameters must have values between 0 and 1, according to the form of use proposed by most of the authors under consideration.

Up-to-dateness **(U)**:

The quantification of this parameter is based on [9], where:

$$age = information\ measured\ time - current\ time;$$

$$U = 1 - \frac{age}{lifetime}, if\ age < lifetime;$$

$$U = 0, otherwise;$$

The variable *lifetime* is set to a value at which the information becomes "old", outdated. The parameter *Up-to-dateness* is calculated for each unit of context information (sensor), so its implementation includes: U (temperature), U (pulse), U (pressure).

Coverage **(C):**

According to the definition of [2], the value range for each sensor (*upper_limit, lower_limit*) is identified and then tested, as follows:

$$C = 1, if\ value\ is\ in\ valid\ range;$$

$$C = 0, otherwise;$$

The parameter *Coverage* is calculated for each unit of context information (sensor): C (temperature), C (pulse), C (pressure). These value ranges may be re-evaluated, if necessary. These are the initial values used for the simulation.

Precision **(P):**

It is the difference between the actual value and the value measured by the sensor, divided by the actual value; the two values (actual and measured) are in the simulation, as shown below:

$$P = 1 - \frac{|actual\_value - measured\_value|}{actual\_value}$$

Each unit of context information (sensor) will have the value of the parameter *Precision* as: P (temperature); P (pulse); P (pressure) – in this case, precision will be the same for diastolic and systolic pressure.

Completeness **(Cm):**

According to [9], this measurement of quality indicates the amount of information provided by a context object. It is the ratio between the number of available attributes and the total attributes of a context object, in this case, a sensor. The calculation takes into account the available attributes and weight of each attribute, as shown below:

$$Cm = \frac{\sum(weight\ available\_attribute)}{\sum(weight\ all\_attributes)}$$

Whereas context attributes (information from a sensor) can have different weights, the parameter *Completeness* is the sum of weights of the available attributes divided by the sum of weights of all attributes of the sensor.

In the literature, it is not clear what an available attribute is. This study considered an attribute as available if a measured value is within the prescribed lifetime in the calculation of the parameter *Up-to-dateness*.

Approach to using the parameter *Significance*

Considering that the present case study deals with health monitoring, the parameter *Significance* is proposed to be used for alerting towards situations that require more attention.

The parameter *Coverage* indicates whether the value is in a valid range. But values can be critical. For instance, if temperature is 39, the patient has a fever. The same happens to unexpected values of pressure and pulse.

Thus, implementation shows:

S=1 when the values are valid, but not expected;

S=0 for other values within the range considered normal;

As in the parameter *Coverage*, these values defined as "out of normal" or "not expected" can be reevaluated/configured.

Proposed calculation of QoC:

In this case study, the calculation of QoC was made for each sensor, and took into account the parameters *Up-to-dateness* (U), *Coverage* (C), *Precision* (P) and *Completeness* (Cm), with equal weights (which can be revised):

$$QoC = \frac{U + C + P + Cm}{4}$$

The parameter *Significance* (S) is available as additional QoC information. If the value is 1, priority is given to evaluating the information, and when it is 0 it can be said that there is no reason for concern, and it will not decrease the QoC value. It serves only to alert to certain situations, when necessary. This is a point where the present study differs from the approach proposed by [12].

Paper [13] gives more detail about the QoC Quantifier.

E. Results

As a result of the implementation, the graphic display (Figure 2) shows the simulation with real-time QoC and context information.

Each unit of context information for Diastolic Pressure, Systolic Pressure, Pulse and Temperature includes: actual values (Ac), read values (R), calculated precision (P) and age (A). Subsequently, QoC information includes: Up-to-dateness (U), Coverage (C), Precision (P), Completeness (Cm), Significance (S) and the overall QoC value (QoC).

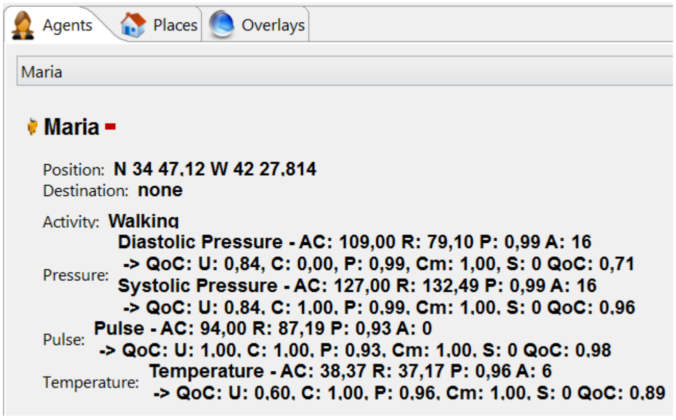

Figure 2. QoC and Context Information during Simulation

In addition to the graphic display, a history of information recorded at every instant of time is shown below in Table 1, for time (T). The column type (TP) includes Temperature (T), Diastolic Pressure (DP), Systolic Pressure (SP) and Pulse (P). The column LR is the last read value, and the remaining columns follow the same nomenclature of Figure 2.

TABLE 1. OUTPUT DATA OF THE SIMULATION

T	Tp	Ac	R	LR	U	C	P	Cm	S	QoC
56	T	37.5	-	34.5	**0**	1	0.93	0	1	**0.48**
57	T	37.6	36.6	36.6	**1**	1	0.97	1	0	**0.99**
101	T	38.7	**37.9**	37,9	1	1	0.98	1	**1**	0.99
105	P	120	104	104	1	1	0.87	1	0	0,97
138	DP	90	86	86	1	1	0.95	1	0	0.99
138	SP	136	129	129	1	1	0.95	1	0	0.99
150	DP	76	48	48	1	**0**	**0.63**	1	0	**0.66**
150	SP	114	72	72	1	**0**	**0.63**	1	0	**0.66**

Several tests can be performed with the output data of the simulation. Table 1 illustrates some situations. The first line shows that at time 56 the temperature has low QoC. There is a big difference between the last reading and the true value, which means that in this case the information is outdated. Afterwards, time 57 shows a good QoC, the reading is updated, the values are valid and accurate, and S equals zero indicates that the values are within the expected range. At time 101, S changed to 1, indicating that the temperature is higher than expected; QoC remained adequate but it is a situation that deserves attention. Time 105 illustrates the pulse reading, with good QoC. The subsequent times concern pressure readings. At time 138, the QoC value is appropriate as well as other parameters, with S equals zero, indicating that the values are in line with the expectations. At time 150, in turn, the QoC value is low, and so is the precision value, and the value of C is zero (outside the expected value range). These values indicate a possible problem with the pressure gauge.

It is worth noting that multiple values described in the QoC assessment can be configured as: information lifetime (in U), upper and lower limits (in C), weights of attributes (in Cm), critical limits (in S), and weights of the parameters in the QoC calculation.

In short, it can be said that the sensor QoC information represents the extent to which the information provided is:

- Up-to-date – as from Up-to-dateness (U);
- Valid – Coverage (C);
- Accurate – Precision (P);
- Complete – Completeness (Cm);
- Significant – Significance (S);
- In addition to its general QoC value, which uses U, C, P and Cm.

F. QoC Evaluator

The overall QoC value quantified should indicate whether the quality of the information obtained is adequate. In this case, context is used, providing a more precise adaptation.

When a quality problem is detected, that is, when the QoC value is not appropriate, it is expected that the set of parameters used will enable an analysis towards identification of the problem by means of the *QoC Evaluator* module.

It is expected that the ontology in the *QoC Evaluator* module can help identify QoC problems by means of context information values, QoC parameters, and rules created in the ontology, in addition to integration with other ontologies such as those related to health.

G. Security Policy

After the QoC assessment, when the step of context processing is completed, the security policies adopted are verified prior to the context and QoC distribution to context consumers. This study will not cover this topic, which will be saved for future work.

V. Further Research

After conducting the case study described, with the Siafu simulator, the research will proceed with the use of the e-Health Sensor Platform [14]. The application will thus use a real-world scenario with data collected from users through the e-Health Sensor platform.

The e-Health Sensor Shield V2.0 allows Arduino and Raspberry Pi users to perform biometric and medical applications where body monitoring is needed by using 10 different sensors (Figure 3): pulse, oxygen in blood (SPO2), airflow (breathing), body temperature, electrocardiogram (ECG), glucometer, galvanic skin response (GSR - sweating), blood pressure (sphygmomanometer), patient position (accelerometer) and muscle/electromyography sensor (EMG) [14].

Figure 3. e-Health Sensor Platform

This information can be used to monitor in real time the state of a patient or to get sensitive data in order to be subsequently analyzed for medical diagnosis. If real time image diagnosis is needed, a camera can be attached to the 3G module in order to send photos and videos of the patient to a medical diagnosis center.

The e-Health Sensor Platform has been designed by Cooking Hacks (the open hardware division of Libelium) in order to help researchers, developers and artists to measure biometric sensor data for experimentation, fun and test purposes. Cooking Hacks provides a cheap and open alternative compared with the proprietary and price prohibitive medical market solutions.

Initially, the experiment will use the same simulated sensors (body temperature, blood pressure and heart rate). So the same QoC parameters will be calculated (Up-to-dateness, Completeness, Coverage, Precision, Significance) as well as the QoC value. The calculation of the Precision parameter will consider the sensor specification.

VI. Related Works

Some studies found in the literature are cited in Table 2, involving scenarios related to Health and QoC use.

TABLE 2: RELATED WORKS

	Description	Note
[15]	Introduces the application scenario Medical Advice and Emergency System, focusing on challenges;	Suggests QoC as further research;
[16]	Develops a QoC algebraic model with dimensions of freshness, availability and cost, and illustrates with a mobile healthcare service;	This model does not use ontology, and offers no details on its implementation;
[17]	Describes the quantification of some QoC parameters and proposes a framework with privacy policies based on QoC applied to a health tele monitoring scenario;	Does not use ontology;
[18]	Describes the use of ontology techniques and semantic cache for a mobile emergency medical assistance system;	Does not use QoC;
[7]	Develops a conceptual model of AAL system layers and an example of AAL system architecture, discussing the importance of QoC in this domain;	It is only a conceptual model;
[19]	Presents a framework to support ambiguous context based on dynamic Bayesian networks; uses the QoC parameter accuracy, and addresses health care;	Uses sunspot sensors;

The assessment proposed by the present study is different from the studies cited in what concerns the set of QoC parameters used and how some of the parameters were quantified, for instance: Coverage, Precision and Significance, as well as the calculation of the overall QoC value of the context source.

The implementation of this proposal in an Ambient Assisted Living (AAL) scenario with health monitoring through sensors of heartbeat, blood pressure and body temperature demonstrates how this approach can support situations involving risk of life for sick or elderly people or with some disability.

VII. Conclusions

This study stands out for its approach to evaluating QoC information in a ubiquitous assisted environment, supporting the care of people with special needs (elderly or with health problems), thus improving their quality of life.

In order to conduct the proposed case study, the simulator Siafu was used, since it provides tools for obtaining the necessary context information, and allows the implementation of the proposed QoC assessment in an AAL scenario.

By studying QoC, it is intended to achieve the following objectives: detect anomalies or inconsistencies in sensors, generate alerts, activate backup sensors, discard data with insufficient QoC, choose appropriate providers, and other actions.

Whereas life expectancy has been increasing, the world population has been aging. For that reason, AAL systems can provide not only a more effective adaptation by increasing user satisfaction, but also support and care for elderly or disabled people improving their well-being and quality of life. Thus, it is believed that the implementation of this proposal might mean a big social impact and a technological innovation applied to AAL, at the disposal and support of a significant number of individuals such as elderly or sick people, and with a more precise technology.

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