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A Quality Model for the Evaluation AAL Systems

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Abstract

The Ambient Assisted Living (AAL) domain aims to support the daily life activities of elders, patients with chronic conditions or disabled people. The need to support these elderly, in difficulty has prompted researchers to focus on the field of home care. Several platforms have been developed over the last two decades, based on several functionalities to the improvement of their quality. Hence, Quality Criteria (QCs) must be identified and well defined to successfully achieve the system purposes. The goal is to obtain a set of data quality characteristics that would be applicable to the context of AAL systems and evaluate them using data coming from multiple sensors. To do this, we based our work on ISO/IEC 25012 and ISO/IEC 25010 standards that establish QCs respectively on system and software product quality and data quality, to extract the most relevant QCs that could be more fitting for AAL systems. We have applied an approach to extract the most important criteria than can be associated with AAL system based on the acquisition, the transmission, and the treatment processes. To convince all stakeholders including both technologies and end users of AAL systems, high quality must be guaranteed, but measuring quality in AAL system is difficult because of the variety of stakeholders. To evaluate the entire data quality model for AAL system, we will apply an evaluation procedure on this model, which consists first make our model hierarchically, then evaluate it using the metrics based on the sensor data and the concept of fuzzy logic.

Keywords: quality models; quality dimension; quality evaluation; metrics;

1. Introduction

Today's society is witnessing a demographic shift towards an increasingly older population[1]. Statistical reports[2]

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show that people aged over 60 represent one-quarter (1/4) of the population in Europe and should increase in the next few years. The need to support these elderly, in difficulty has prompted researchers to focus on the field of home care. Several intelligent environmental systems[3] (AI: Ambient Intelligent) have been developed and a significant result in intelligent home technologies, sensor networks, robot assistance and e-health have actively contributed to the development of the AAL system[4]. Today, emerging applications in the field of assistance and support for the elderly are increasingly using data from sensors. Multiple AAL-related platforms have been developed, including AMIGO[5], SOPRANO[6], OpenAAL[7], PERSONA[8], MPOWER[9], UniversAAL[10], HOMER[11], AmiVital[12] and OpenCare[13]. Many factors make the development of AAL system very complex[14], such as the use of an advanced equipment technology like sensors and actuators, the personalization and adaptation of the system to fit the different cases like the use at home, at work or through mobile support.

Our goal is to obtain a set of criteria that would be applicable to the context of AAL system, based on the ISO/IEC 25012[15] and ISO/IEC 25010[16] standards that establish QCs respectively on system and software product quality and data quality. This approach includes three phases: Analyze and extract impact factors, specify data quality criteria and composition of data quality model. Once the data criteria are defined, we compose our data quality model hierarchically, where each factor is composed of one or several criteria and each criterion is composed of one or more sub-criteria until reaching measurable criteria called leaves criteria. Using this model, we will be able to explore and use the metrics of the standards models using equivalence relations we have used in[17] between these criteria. To evaluate the entire data quality model for AAL system, we will apply an evaluation algorithm we have developed in our precedent paper[18], using two processes. The first process executes the metrics extracted from the sensors data and the second one uses the result of the first process using fuzzy logic[19] approach to evaluate the entire specified data quality model and end up with a final numerical result.

2. Related works

In the domain of data quality evaluation, several methodologies have been made[20]. A significant amount of work has been done in the domain of surveillance and especially in AAL systems where the work was focused on evaluating the performance of motion detection[21], object detection[22], and tracking[23]. Many quality criteria in AAL platforms are presented and were used to evaluate different AAL projects including Alhambra, OpenAAL, UniversAAL, PERSONA, and Hydra[24].

In our precedent papers, we made an evaluation approach based on fuzzy logic[17,25] with an example of a Client/Server architecture. We have adopted an algorithm to instantiate and evaluate data quality model using five type of equivalence relations[18] (Same names-Same meaning, Same names-Different meaning, Same names-Similar meaning, Different names-Same meaning and Different names-Similar meaning) between the different data quality models. In this paper, we describe an approach to building a data quality model based on an Ambient Assisted Living (AAL) system and apply our approach to evaluate and validate our algorithms.

3. Define a data quality model for AAL system

The AAL system has the ability to track, record, analyze and interpret data coming from sensors that represent the activity of elderly people. We must first enumerate and review the functionalities of the AAL system that will be implemented in our data quality model. In our case, the objective is to develop a complete Quality Model (QM) that defines all common Quality Characteristics QCs for AAL systems. As a starting point, we adopt the ISO/IEC-25012 and ISO-25010 standards that form the generic data quality model. From these set of characteristics, we extract a subset that is well suited for the evaluation of AAL system. This step of definition is composed of three phases: Analyze and extract impact factors, specify data quality criteria and composition of data quality model as shown in Fig. 1.

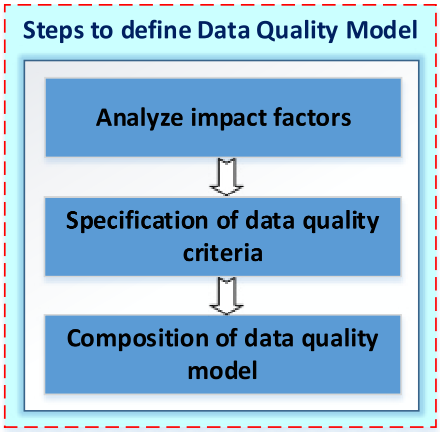

Fig. 1. Steps to define data quality model.

3.1. Analyze impact factors

In this phase, we analyze the impact factors based on acquisition, transmission and treatment processes shown in Fig. 2. Each of these processes is composed of different components that identify their impact factors.

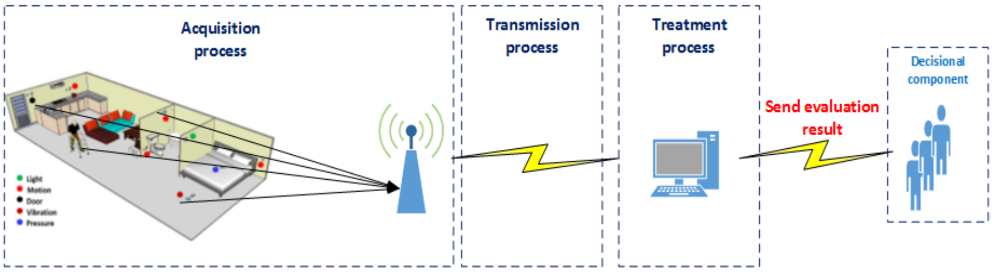

Fig. 2. Steps for selecting quality factors in AAL system.

This operation includes the operations involved in collecting data from different types of sensors, their transmission, and their treatment as shown in Table1. The AAL system requires an efficient acquisition of sensor data for an easy and effective interpretation of the environment around the elderly peoples.

Table 1. Quality impact factors.

Process	Component	Impact factor	Designation
Acquisition	Sensor devices	State of sensors	Defaults may appear due to malfunction. The sensitivity of wearable sensors can be affected by the sweat and sensors require a recalibration
		Sensor resources	Memory capacity, Autonomy, Sensors lifetime and calibration
	Measures	Measurement type	Scale, tolerance, frequency measurement, data update
Transmission	Transmitted data	Data transmission type	Different types of communications (Wi-Fi, Bluetooth Low Energy, Zigbee)
		Data frequency	Periodicity of data transmission
		Secure data	Secure the transmission of data
Treatment	Collected data	Data storage format	Establishing of data backup format
		Data recovery	Possibility to recover data

3.2. Specification of data quality criteria associated with AAL system

Sensors used in AAL systems are exposed to multiple factors that impact the reliability of collected data. Errors in the data may arise from different steps in the monitoring system. In order to define the appropriate criteria for the evaluation of the quality of the sensor data, we perform an analysis which consists in crossing the impact factors components defined in Table 1 with the standardized quality criteria of the ISO/IEC-25012 and ISO/IEC-25010 standards as shown in Table 2 and Table 3.

Table 2. Quality factors of the different processes VS Quality criteria of ISO/IEC 25012.

	Components			
Data quality criteria	Sensor devices	Measures	Collected data	Transmitted data
Accuracy	+	+	+	
Completeness			+	
Recoverability			+	
Confidentiality				+
Efficiency		+	+	
Precision		+		

Table 3. Quality factors of the different processes VS Quality criteria of ISO/IEC 25010.

	Components			
Data quality criteria	Sensor devices	Measures	Collected data	Transmitted data
Reliability	+	+	+	
Security			+	+

Even if a generic model is difficult to conceive, we propose a vision of data quality providing important genericity and enabling us to include this model to be applied to the evaluation of sensor data in AAL system, we will focus on the definition of quality criteria necessary to be associated with the real-time operation of sensor data. To define these criteria, we rely on the analysis shown in Table 2 and Table3 and end up with the following criteria result: Accuracy, Completeness, Efficiency, Precision from the ISO/IEC-25012 standard and Reliability, Security from the ISO/IEC-25010 standard. In Table 4, as a result, we define the set of factors and criteria taken into account in our approach. These criteria compose the data quality model for AAL system, where each criterion can be composed by one or several sub-criteria as shown in Fig. 3.

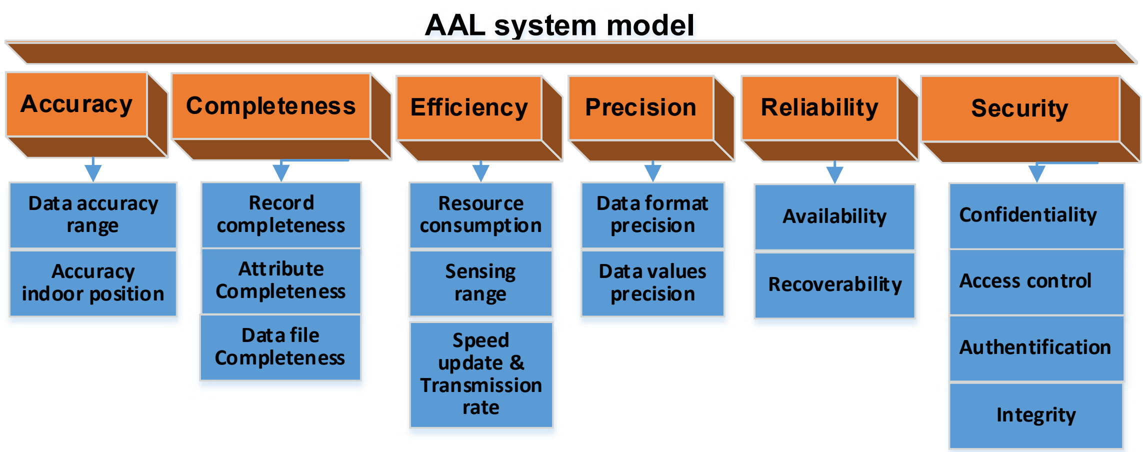

Fig. 3. AAL system model.

Table 4. Criteria definitions related to AAL system.

Data quality factors	Definition
Accuracy	Accuracy refers to the degree of how the observed information conforms to the reality. For example, in the AAL system, the accuracy of event detection is the ratio of the number of correctly detected events to the total number of events that occurred.
Completeness	comparison between an estimated quantity of produced data for a given time and rate and the current values.
Efficiency	Represent a number of resources of the platform (e.g. memory, CPU) used under stated conditions.
Precision	comparison between an initial or current spatial reference with an estimated value regarding the precision factor of the indoor positional system.
Reliability	estimated value considering a set of possible random sources over a data source and a probability of reliability.
Security	keeps the individual health information confidential, restrict the access to the patient data and give privileges associated with a user profile, information related to the patients' sensitive health must be ensured to be viewed by the authorized persons, ensure that the received data has not been altered by an intruder and the systems must be resistant to security attacks.

3.3. Representation of AAL system

We have built a knowledge base to represent the environment of the AAL system using ontology concepts described in[26]. We use a universal concept "Thing", which generalized all root concepts and described the set of data related to the AAL domain[27]. The information collected refers to the user and the environment. This ontology proposes a hierarchy of Entity, Sensors, and Actuators as shown in Fig.4. To represent our ontology, we use OWL[28] (Web Ontology Language) to define the different classes of concepts, the relations between these concepts and the instances for each element. An object Property links a class instance with another class instance, while a Data Property links a class instance with data values. Each class can be further extended as shown in Fig.4, where the sub-classes of the Entity concept are Location, Object, and Person. The Object sub-class is composed of several objects as doors, chairs, etc... . The sensors and actuator classes are also defined hierarchically. Data captured from sensors is associated with the metrics of our data quality model we want to evaluate. Using these values, we quantify the different leaves criteria representing the lowest level of the data quality model.

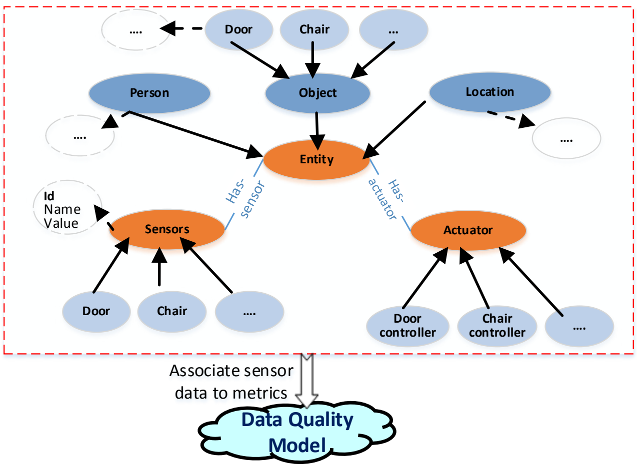

Fig. 4. Representation of AAL system model.

4. Data quality evaluation approach

Our objective illustrated in the adopted modelization and evaluation approach (see Fig. 5) is to evaluate the extracted data quality model for AAL system. Data are extracted from multiple sensors, parsed and saved in an XML file. These data are used to associate the sensors resources to the data quality model metrics. This model represents the specified data quality model (Specific DQM) instantiated from the generic data quality model (Generic DQM) composed of the ISO/IEC-25012 and ISO/IEC-25010 standards. To extract our model, we have used the equivalence relations adopted in the instantiated algorithm we have developed in our previous work[18].

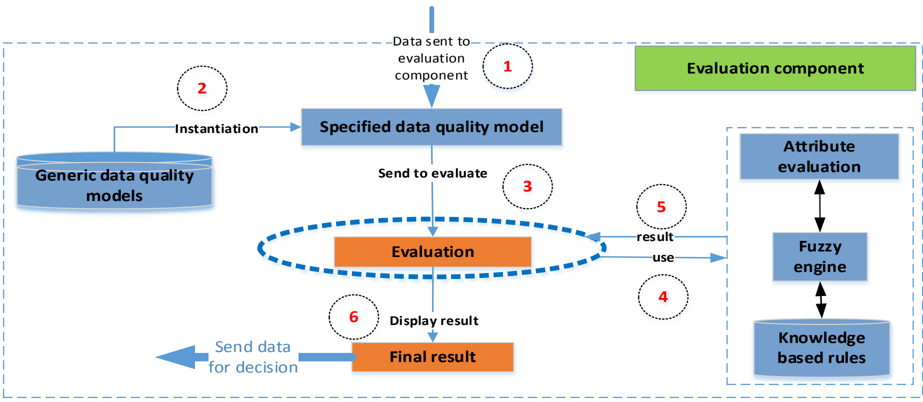

Fig. 5. Adopted modelization and evaluation approach

To quantify the criteria of the example shown in Fig. 6, we [2]use two processes; the first one executes metrics related to sensors data and the second one uses these data to evaluate the data quality model, using the concept of fuzzy logic. We have presented an algorithm named Global_Evaluation as shown in Fig. 7. This procedure starts the evaluation of criteria from the bottom of the hierarchical model to define the leaves criteria list. From this list, we define the node segments with a chronological order where each node has a main criterion, its sub-criteria and a number order. For each node name, we quantify first the sub-criteria that represent the leaves criteria using the metrics. Metrics are calculated with formulas composed of metrics variables that represent the sensors data values extracted from the AAL system. In the second step we use the fuzzy logic concept to calculate the value of the main criterion. We use the same steps to evaluate all criteria until reaching the different factors that compose the data quality model.

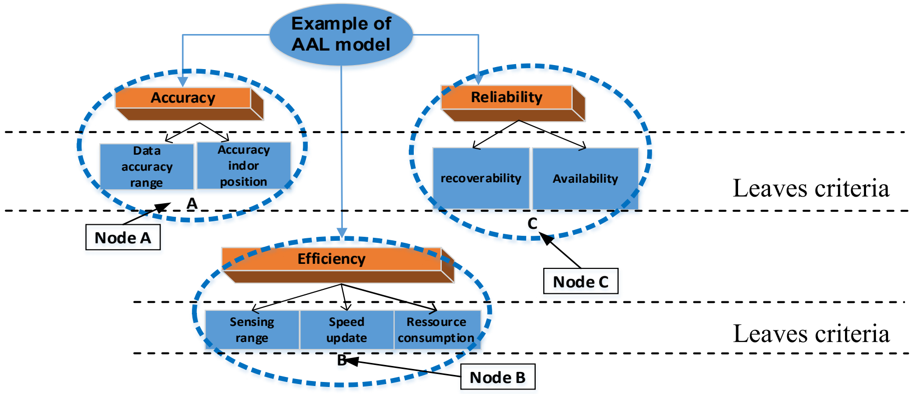

Fig. 6. Part of AAL model criteria

We have presented a case study in our previous paper[17], where we explained the different followed steps to apply the fuzzy logic concept to reach the final values of each criterion.

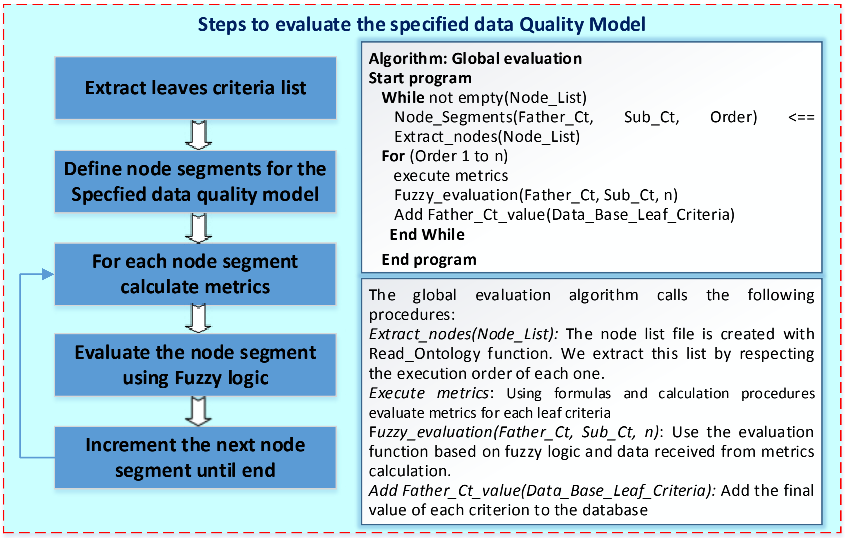

Fig. 7. Adopted modelization and evaluation approach

In our case, we apply this algorithm to evaluate each of the Accuracy, Reliability, and Efficiency factors. Fig. 8 shows the final result of efficiency factor (Efficiency=25%), using Matlab TOOLBOX fuzzy logic tool and the gravity center method for the deffuzification step. The same principle will be applied to get numerical values for each factor, these values help us to make decisions to improve data quality.

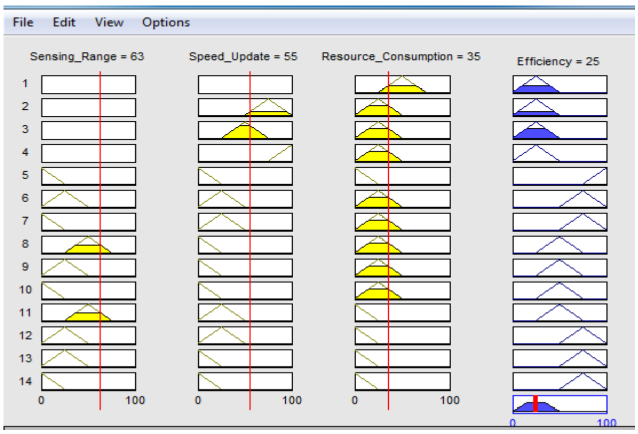

Fig. 8. Defuzzification step for Efficiency factor

5. Conclusion and future works

In this paper, we underline the need to define a data quality model used in the evaluation of an AAL system. We have shown the different criteria that may impact the quality of data received from sensors. Furthermore, we have used this model in our global evaluation approach, using the concepts of fuzzy logic. This procedure represents a generic way that can be applied also to any surveillance system. The result of the evaluation represented by the quality indicators helps the user to take the right decisions in real-time. As our research work shows the possible factors that may impact the quality of sensor data and thus impact the users' decision making.

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