

Context-Oriented Data Processing for Homecare Application

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Abstract—Due to growing numbers of elderly and increase in chronic diseases, many homecare systems have been proposed in order to improve the quality of care and social assistance services. These systems are based on using advanced technologies such as sensors in order to ensure a continual patient's monitoring and support contextual information provided anywhere and at any time. Effectiveness and efficiency of homecare solution depends on the capability of processing the large amount of data acquired through sensors in a continual basis. This paper addresses this issue and proposes an extensible approach aiming to process and filter data in real time in order to distinguish between normal and abnormal situations, detect alarm conditions and store only relevant information. To process data and take into account patient's physiological and environmental changes, a sensors-based context model and context-based rules are defined.

Keywords—Context model; homecare system; rules management; sensors; data filtering; alarm situations.

I. INTRODUCTION

In recent years, face to growing numbers of elderly and increase in chronic diseases, many homecare applications have been proposed in order to improve the quality of care and social assistance services [1][2]. Financially, living in a smart home is preferable to living in a nursing home, which is quite expensive [3]. These applications integrate various advanced information and communication technologies such as sensors [4], wireless communication, ubiquitous computing [5], etc., which support ubiquitous information provided anywhere at home and at any time in order to ensure a continual patient's monitoring. However, effectiveness and efficiency of long-term condition care depends on the capability of processing data gathered in continual basis and proposing adequate services to the patient.

This situation confronts us with various challenges: (1) sensors generate a large amount of data in a continual basis, (2) data are not all necessary for use, (3) data should be analyzed immediately when received in order to detect alarm situations, (4) data should be filtered at home to eliminate irrelevant data before being transferred to health care professionals, and (5) sensors can change according to the development of the patient's situation.

In light of these challenges, we are proposing a home care solution capable of processing data locally at home.

The motivation of this research is to design an approach aiming to filter data according the patient's care needs. It provides an extensible prototype for monitoring and handling sensed data. This approach is based on using sensors in order to collect data on the patient's everyday life. For this, managing the context in which the patient lives becomes a primordial requirement in order to support any changes in the patient's status and environment.

The prototype we develop will be implemented in a local application located in the patient's home for two reasons. Firstly, data have to be filtering locally in order to send only useful information to health professionals. Secondly, critical situations should be taken into account immediately in the form of available services without waiting for the opinion of a health professional.

This work is considered as a first phase of a complete project capable of processing data or external requests (for example, from professional health care) in order to propose and manage personalized services according to the patient's needs and preferences. To release this goal, the prototype we develop should be generic and extensible in order to cover all patients' needs and to adapt to any patients' preferences.

In this research, three processes are identified: alarm, storage and delete processes. Defined context-based rules are used for separating between normal and abnormal data and analyzing normal data in order to make decision to store useful information and reject useless data.

We note that we are not concerned to collect data from sensors. We suppose that data are available to be processed in an exploitable format.

The paper is organized as follows: Section 2 discusses related works. Section 3 presents the architecture of the system. Section 4 discusses about the modeling of context model based on using sensors. Section 5 presents the modeling of different rules useful for filtering data. Section 6 explains the data acquisition process. Section 7 shows the different steps for data processing mechanism. We will end the paper with a conclusion and future works.

II. RELATED WORKS

Nowadays, many researchers have been interested in elderly and dependent people needs, particularly in Europe [6], and proposed homecare systems such as Ambient-assisted Living [7], Remote patient monitoring [8], location

tracking, patient behavior modeling, etc. in order to recommend adequate solutions related to long-term monitoring of patient's activity and homecare assistance [9].

This convergence of homecare systems enables elderly and dependent people to stay at home and receive human care in a much quicker and easier manner [10][11]. These systems have mainly focused on the patient's data acquisition through data monitoring devices such as sensors placed either directly on the patient's body for collecting individual data (temperature, heart rate, oximetry, etc.) or at the patient's environment for detecting distress situations (patient falling, fire, abnormal movement, etc.) [12]. Sensed data are then transferred to a central server via wireless communication technology to be analyzed by medical professionals in order to make decisions in consequence of them.

In recent years, we have noticed that a homecare system providing a patient remote care is closely combined with the notion of context which is more commonly considered in context awareness systems [13][14]. A context is mainly defined as any information that can be used to characterize the situation of entity as the location, the time, the preferences, etc [15]. This concept has been mostly used in ubiquitous computing systems [16] and, more recently, in Ambient-Assisted Living (AAL) domain in order to locate users anywhere and propose services at anytime according to the user's status and environmental conditions [17]. The contextual information acquisition and processing are among the main challenges identified in the AAL systems and performed by a central middleware [18]. Most of the context-based healthcare middleware centralize the data processing transferred from homes and focus on detecting critical situations. Moreover, most of researches in homecare domain are very specific to particular needs such as detecting alarm situations. However, to be more efficient and adaptive, it is more interesting to be able to cover all daily patients' needs by abstracting from the different contextual situations in order to filter data, which specify the context and propose social assistance accordingly. In our opinion, the core of the application should be designed in a contextual independent way, i.e., by defining different contexts in which it will be used. In this paper, we are taking into account this challenge by proposing a data processing mechanism capable of filtering data in order to propose personalized and auto-triggered services in function of patients' needs.

III. ARCHITECTURE OF PROPOSED APPLICATION

The main objective of this research is to design a data processing mechanism responsible for filtering contextual data acquired through sensors according to the patient's care needs. The filtering process consists in analyzing sensed data in real time in order to distinguish between abnormal and normal situations and eliminate irrelevant information. Abnormal status concerns with critical conditions which need to be detected and handled immediately, whereas, normal status designates either the need to store data for a later use or simply to ignore them if no use. As a matter of fact, in normal situations, some gathered data are needed for

specific tasks decided by health professionals (for example, writing a report once a day at 6 p.m on the patient's state).

Thus, the data processing mechanism refers to three steps: 1) alarm process for detecting critique situation, 2) storage process for testing if data need to be stored and 3) delete process for deleting useless data.

Fig. 1 presents a functional description of the mechanism which consists of four modules: 1) acquisition of data, 2) data processing mechanism, 3) context-based rules, and 4) sensors-based context management. The first one describes how collected data are stored in an exploitable text format before being processed.

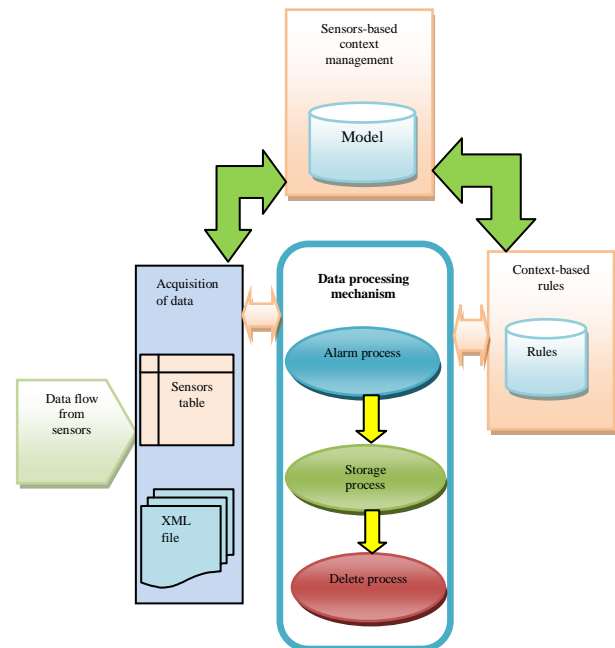


Figure 1. Functional description of the application.

The second one explains the different steps of performing the alarm, storage and delete processes in order to filter contextual data. The third module defines the context-based rules used in the data processing module in order to reason over the contextual information. The latest module creates a sensors-based context model served to represent a generic description of sensors and sensed contextual information. Each of these modules will be presented in detail in the next sections.

IV. SENSORS-BASED CONTEXT MANAGEMENT

In general, a home-based care system relies on using sensors located anywhere at home in order to provide information on patient's daily-live conditions and the home environment. Thus, one of our key requirements is to manage sensors efficiency and easily by identifying their characteristics, their roles and their locations and by providing a description of contextual information collected from sensors. To do this, a generic, reusable and extensible sensors-based context model is proposed in order to facilitate adding new sensors, updating or deleting sensors at any time if needed.

Because the rules definition and the data acquisition modules use the high description of the sensors-based context model, it is important to be able to start with defining the sensors implemented at the patient’s home through the model.

Fig. 2 represents an abstract description of sensors-based context model. A *patient* is characterized by a *context* which is identified by a set of sensors or other categories. Each *category* is composed of sensors or other categories. A *sensor* is described by a set of *sensorInfo* which describe the roles and the characteristics of the sensor. Each sensor is sensed by a set of composite context parameters represented by the entity *complexContextP*.

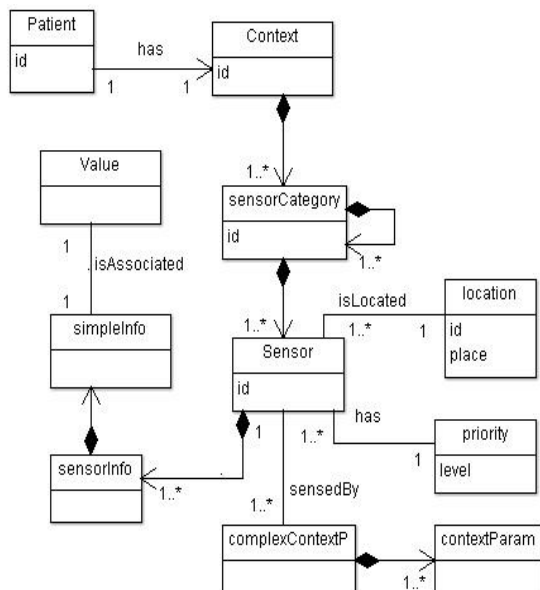


Figure 2. Abstract description of sensors-based context model

These parameters give a high description of data extracted from a given sensor. A *complexContextP* entity is composed of *contextParam* entities which designate simple context parameters. The entity *location* represents where a sensor is located at patient’s home. The entity *priority* represents the priority associated to a sensor. We identify three levels of priority: high (1), middle (2), low (3).

Fig. 3 represents an example of concrete structure of sensors-based context model. This example identifies two categories of sensors: activity and environment sensors. Accelerometer and Temperature are two sensors. Accelerometer and temperature sensors are located at the bedroom. Info designates *sensorInfo* entity. Role is a *simpleInfo* entity which has a value “detect walk”. Accelerometer sensor is sensed by a *contextParam* “action”.

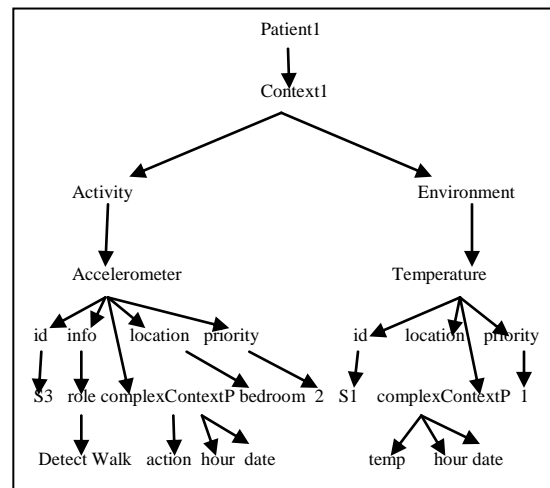


Figure 3. Concrete sensors-based context description

V. DEFINITION OF CONTEXT-BASED RULES

Once the sensors and their characteristics have been defined through the sensors-based context model, the rules useful for the data processing mechanism could be determined. These rules are applied on contextual data extracted from sensors what involves a relationship of dependence between sensors and rules (Fig. 4).

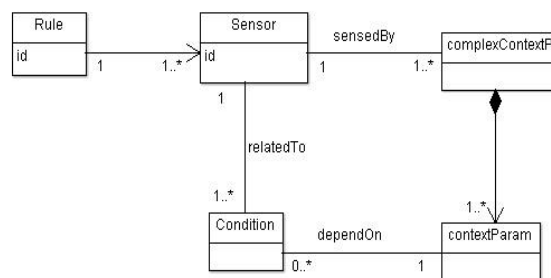


Figure 4. Abstract context-based rules model

A rule is generally defined as a collection of one or several elementary conditions. Each condition depends on a sensor which means that one rule is associated to one or several sensors which regroup one or multiple elementary conditions (Figure 4). If a sensor is related to one condition, the latter is simply represented as a child node of sensor. Otherwise, conditions related to a sensor are interconnected by links named connectivity. We distinguish two forms of connectivity {AND, OR}.

Fig. 5 illustrates an example of a rule with four conditions C1, C2, C3, C4 related to a given sensor, these conditions have to be connected with AND and/or OR. We suppose that C1, C2 and C3 are interconnected by AND and this collection is linked to C4 by OR.

Therefore, we notice that these conditions are structured in three levels (Fig. 5). Level 1 is for OR, level 2 is for

AND or/and elementary conditions and level 3 for representing elementary conditions.

An elementary condition is composed of three parts: *contextParam*, predicate and value. *contextParam* designates an entity already defined in the sensors-based context model. As a rule is applied on data extracted from sensor, the use of the entity *contextParam* is highly justified. The predicate designates one of these possibilities {<, <=, >, >=, =, !=} . The value can be a number or a text.

The manner of defining rules facilitates adding new rules for any process and updating existing rules. As the main objective of this application is to test if collected data from sensors is concerned with alarm, storage or delete cases, rules are then classified in two groups: alarm rules responsible for detecting alarm situations and storage rules which test if collected data must be stored for a later use.

We will explain the use of these rules more in detail in the next section.

```

<rule id=1>
  <sensor id=3>
    <OR>
      <condition id='C4'>
        <contextParam>param1</contextParam>
        <predicate> = </predicate>
        <value>45</value>
      </condition>
      <AND>
        <condition id='C1'>
          <contextParam>param2</contextParam>
          <predicate> = </predicate>
          <value>45</value>
        </condition>
        <condition id='C2'>
          <contextParam>param3</contextParam>
          <predicate> = </predicate>
          <value>29</value>
        </condition>
        <condition id='C3'>
          <contextParam>param1</contextParam>
          <predicate> = </predicate>
          <value>48</value>
        </condition>
      </AND>
    </OR>
  </sensor>
</rule>
    
```

Figure 5. An example of a rule

VI. ACQUISITION OF DATA

The data acquisition introduces the way in which contextual data are represented to be exploitable by the data processing mechanism. In this research, we consider that contextual data are received by our application in a final format available to be analyzed. To deal with data, the data processing mechanism requires two basis:

- A table in which active sensors are declared
- XML files used to insert collected contextual data

The table represents the identifications of sensors which are in action and send contextual data. This table is organized according to the sensors emission frequency. Two

cases are possible: at a frequency *f*, we can have either one sensor which send data or several sensors which act together.

Other more important factor which needs to be preprocessed is the priority between sensors. Indeed, each sensor has its own priority level already defined in the sensors-based context model by the priority entity. Therefore, sensors should be ordered and handled in order of priority. Once active sensors are specified in the table, our mechanism verifies their priority level and then classifies them in three levels: high, middle and low. Table1 illustrates an example of the sensors representation. S1 and S2 are two sensors with high priority, S3 a sensor with middle priority, whereas S4 a sensor with low priority.

TABLE I. EXAMPLE OF SENSORS REPRESENTATION

Priority \ Frequency	Low	Middle	High
f1	S4		S1 ; S2
f2		S3	S1
f3	S4		S2

The second facet of the data acquisition part consists in representing contextual data in XML files. This step is not discussed in this research. We work on the assumption that contextual data is organized in XML files and available to be handled in the data processing mechanism. The structure of a XML file is based on the sensors-based context model and more specifically by the entities: sensor, contextParam, complexContextP. Fig. 6 gives an example of a part of xml structure.

```

<sensors>
  <sensor id='S3'>
    <complexContextP>
      <action>walking</action>
      <hour>8.30</hour>
      <date>25/12/2013</date>
    </complexContextP>
  </sensor>
  <sensor id='S1'>
    <complexContextP>
      <temp>37</temp>
      <hour>8.30</hour>
      <date>25/12/2013</date>
    </complexContextP>
  </sensor>
</sensors>
    
```

Figure 6. Example of XML structure

VII. DATA PROCESSING MECHANISM

The mechanism mainly consists in filtering data stored in XML files as described in the data acquisition section. Sensors which generate these data are specified in a sensors table. The filter process is based on using rules defined in the context-based rules module. We have two types of rules: alarm and storage rules. Each rule contains conditions

related to given sensors. Fig. 7 illustrates the different steps of the data processing mechanism. Firstly, we test if data are abnormal or normal. Then, we verify if data should be stored or deleted.

The filter process is performed in various steps:

- 1) For each row of the sensors table, we have to calculate all combinations between sensors. This calculation is made in function of the priority of sensors. We remind that we have three levels of priority: high, middle and low. We start with sensors which have high priority. We pass then to sensors with middle priority. Finally, we terminate with low priority sensors. We illustrate this calculation by an example.

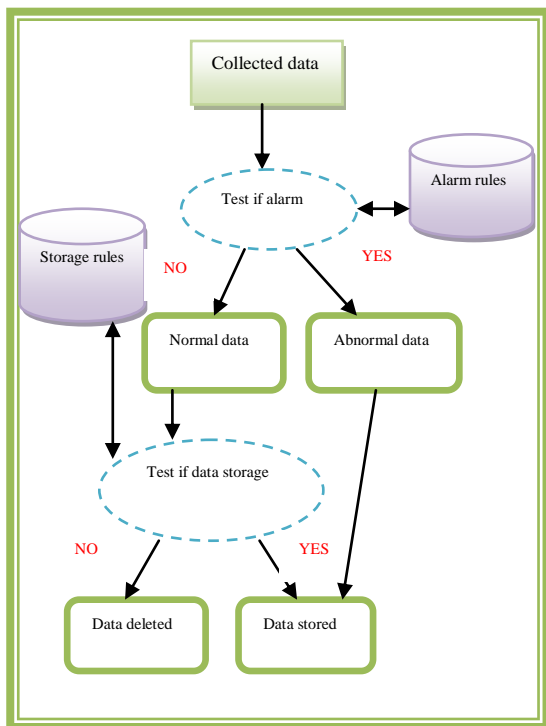


Figure 7. Data processing mechanism

In row1, there are three sensors

- S1-S2 with high priority
 - S4 with low priority
- Firstly, we start by calculating combinations between high priority sensors S1 and S2 which has as result: S1, S2, S1-S2.
 - Secondly, as we do not have middle priority sensors, we pass to low priority sensors. We have one sensor S4. Then one combination is calculated = S4.
 - Finally, we calculate combinations between sensors S1, S2 and S4. We have as result: S1-S4, S2-S4, S1-S2-S4.

The calculation of combinations has as result $C = \{S1, S2, S1-S2, S4, S1-S4, S2-S4, S1-S2-S4\}$

- 2) Once combinations are found, the second step consists in looking for rules which correspond to

sensors designated in each combination. As we have alarm and storage rules, we start by alarm rules because alarm process is more priority to take into account.

For each combination c of C , we have two possibilities:

- Rules corresponding to sensors of c are not found => next combination
- Otherwise, conditions contained in each rule are extracted in order to form a XML query

The formed query will be executed on the contextual data stored in the xml file. The execution of the query returns either 1 or 0.

- 1 => data are abnormal
- 0 => data are normal

The first case triggers an alarm situation and data storage

The second case triggers the storage process

- 3) For normal data, we have to test if data need to be stored or deleted. Similar to alarm process, the same steps are applied on the combinations of C . We research if there are storage rules which correspond to sensors contained in each combination. If it is the case, a query is formed which will be executed on the xml file. We can have two responses:

- 1 => data storage is needed
- 0 => data can be deleted

Once these different tasks are ended up, we can delete xml file which contains data under process and pass to next row of the sensor table.

The next step in this research consists of triggering services in function of patient's needs. In this paper, we do not develop this point, but we can give an idea on which our next research will include. In principle, each rule is associated to one or many services as described in Figure 8. Once a rule is found and its formed query returns 1 as a result, services related to this rule is triggered to execute tasks defined for selected services.

rule	trigger	service
id	1	1,* id

Figure 8. Relationship between rule and service

Thus, we have described the different steps needed to process and filter data generated through sensors and stored temporarily in xml files.

VIII. CONCLUSION AND FUTURE WORK

In the paper, we have presented an approach capable to process and filter data acquired through sensors locally in order to classify them in three categories: alarm data to detect alarm situations, relevant data to be stored for a later use and irrelevant data to be eliminated. We remind that the

main objective of this application is not to trigger alarm situations, but only to indicate there are abnormal data which need to be taken into account immediately or normal data.

This work is the first step in a project, which consists of assisting any patient at home whatever the situation, needs and preferences he has. To achieve this goal, a generic and personalized view is proposed in order to consider any new adding or change in the daily patient's context. For this, a sensors-based context model has been designed for characterizing sensors and contextual data. Context-based rules have been defined for reasoning over contextual data. This application has for advantage to eliminate irrelevant data at patient's home and transfer only useful data. Extensibility and configurability of the context-oriented data processing mechanism behavior may be achieved by extending the context-based sensor model with new concepts or specializations of existing ones and by adding/modifying reasoning context-based rules. This application can be easily extended with using specified services in order to satisfy patient's needs and provide personalized access to patient's data.

Presently, we are planning to implement the approach in java to evaluate and test the success of the prototype from a scenario. The second step is about using and managing services in order to improve alarm management and real-time monitoring. We are also thinking about managing profiles needed for defining all patients' characteristics such as pathologies, disabilities, preferences and personal data in order to propose to the patient personalized services. Finally, we will also consider actors involved in a different extent in the care of a patient such as patient's relatives, doctors, nurses, the care center, etc.

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